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# Dynamic General Equilibrium Analysis of Stock Market Behaviour in a Growing Economy

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Doctoral Thesis

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Thesis submitted for the degree of Doctor of Philosophy in Economics

July 2016

## Declaration

I, Agnirup Sarkar, hereby confirm that the materials contained in this thesis have not been previously submitted for a degree in this or any other university. I further declare that this thesis is solely based on my own research. All sources are fully acknowledged and referenced.

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# Dedication

To my parents...

# Abstract

The link between stock market activities and economic growth is a contentious topic in macro finance. A branch of the theoretical literature identifies stock markets as the main determinant of growth, while another branch links stock markets with the level or growth of per capita income of a nation. The second strand of literature, which mainly evolves from the Lucas (1978) asset pricing framework, models only the consumption side of the economy and establishes causality flowing from output or its growth to stock prices. A third strand of literature, based on the pioneering work of Cochrane (1991) models only the production side but not the consumption side of the economy, which leads to a bi-directional flow of causality between stock prices and output growth. In reality, however, stock prices might not directly affect growth and vice versa and both can be simultaneously influenced by different exogenous factors. Brock (1982) looks into this issue by merging the partial equilibrium frameworks of the consumption and production based asset pricing approaches into a general equilibrium set-up.

However, there exists a distinct research gap in terms of exploring how stock market activities and growth are simultaneously influenced by various aggregate macroeconomic shocks. In my thesis, I address this research gap by investigating the simultaneous short run behaviour of stock market and growth due to different aggregate technology shocks within a Dynamic Stochastic General Equilibrium framework. In the theoretical frameworks that I use, growth occurs due to accumulation of a reproducible input which is physical capital and hence I essentially deal with endogenous growth models.

In Chapter 1 of my thesis, I first establish some stylized facts about the contemporaneous and lead-lag relationship between market capitalization ratio and growth. To investigate this, I look into annual data of 25 years on market capitalization as a ratio of GDP (as an indicator of stock market development) and growth of per capita GDP (as an indicator of economic growth) for 35 countries and 5 country groups. Majority of the countries (27 out of 35) and country groups (2 out of 3) depict positive and significant correlation coefficient between market capitalization

ratio and growth, thereby establishing that both market capitalization ratio and growth move in the same direction in the short run. In order to test whether there exists a lead-lag relationship between market capitalization ratio and growth, I perform a Granger Causality exercise, a Variance Decomposition analysis and a panel VAR analysis. The results of the Granger Causality test suggest that for most countries and country groups, causality flows from stock market capitalization to growth and not the other way round. The Variance Decomposition analysis suggest that for majority of the countries and country groups, the percentage of fluctuations in per capita growth, as explained by a one time shock to market capitalization ratio is much greater than the fluctuations in market capitalization ratio which can be explained by a one time shock to per capita growth, in periods following the realization of the shock. Finally, the panel VAR analysis indicates that for all countries and country groups, per capita growth is significantly influenced by past values of market capitalization ratio, although the reverse is not true. Thus the key stylized facts are (i) a contemporaneous positive and significant relationship between market capitalization ratio and growth and (ii) a lead-lag relationship between the two in the sense that the effect of a one time shock to market capitalization gets translated to per capita growth to influence the latter's behaviour in future time periods.

In Chapter 2, I develop a Lucas asset pricing framework with production and investment, which can support only the lead-lag relationship but not the contemporaneous relationship between market capitalization ratio and growth. However, if a friction in the form of a borrowing constraint is introduced in this framework, it is able to reproduce both the contemporaneous and the lead-lag aspects of the market capitalization-growth relationship.

In Chapter 3, I first develop a model with imperfectly competitive market structure but fully flexible prices. This framework supports the contemporaneous positive relationship between market capitalization ratio and growth. But the correlation reproduced by this model is not quantitatively close to the correlations observed for most developed and developing countries. However, in the existing imperfect market structure, if nominal frictions in the form of price rigidity and imperfect inflation indexation are introduced, then the model is able to support the positive significant correlation between market capitalization ratio and growth for a wide range of values of the nominal rigidity parameters. But, in this model with nominal rigidities, which is essentially a New-Keynesian model with capital accumulation and endogenous growth, although a positive and significant market capitalization-growth correlation is reproduced for



plausible nominal rigidity parameter values, this correlation starts falling gradually with increase in nominal rigidity and becomes negative for a very high degree of price rigidity. On the whole, it is established that within a general equilibrium framework of asset pricing, the addition of different economic frictions can help in supporting the contemporaneous relationship between market capitalization ratio and growth.

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# Chapter1: Preliminaries

## I. Introduction

One of the most enduring debates in economics is whether financial development leads to economic growth, or whether it is the result of increased economic activity. Schumpeter (1912) argued that technological innovation is the chief determinant of long run economic growth and the cause of innovation is the financial sector's ability to access credit to the entrepreneur. Walter Bagehot (1873) and John Hicks (1969) also opine that financial intermediation played a critical role in igniting industrialization in England by facilitating the mobilization of capital which ultimately contributed towards increasing productivity. On the other hand, economists like Joan Robinson opine that economic growth creates a demand for various types of financial services to which the financial system responds, so that "where enterprise leads finance follows" (1952, p. 86). In other words, economic development creates demands for particular types of financial arrangements, and the financial system responds automatically to these demands. Moreover, some economists are of the opinion that the finance-growth relationship is not very important. For example Lucas (1988, p. 6) asserts that economists "badly over-stress" the role of financial factors in determining economic growth.

Also development economists are sometimes quite sceptic about the role of the financial system and often end up ignoring it completely (Anand Chandavarkar 1992). Furthermore, a collection of essays by the "pioneers of development economics," including three Nobel Laureates, does not mention finance (Gerald Meir and Dudley Seers 1984), while Nicholas Stern's (1989) review of development economics also completely ignores the financial system, even in a section that lists omitted topics. Thus the extant literature on financial intermediation and growth is filled with conflicting views on the relationship between economic growth and financial development. The intersection between financial markets and the real economy is studied comprehensively in Cochrane (2005). However, a huge literature (which I discuss in the literature

review section) on this topic have prompted even the most skeptics to view the development of financial markets and institutions as an inextricable part of the growth process having direct consequences for economic growth and industrialization. According to the dominant economic view on monetary operations, the stock market acts as an important medium of financial intermediation. There are other financial institutions as well, which include banks, mutual savings banks, savings banks, building societies, credit unions, financial advisors or brokers, insurance companies, collective investment schemes, pension funds and cooperative societies. However, for the purpose of the present research, I focus solely on stock market as a medium of financial intermediation.

Throughout the world perceptions about the stock market are often extreme. A section of the media treats booms or busts in the stock market as major indicators of growth or recession of the economy. This is done in spite of the fact that stock market participation of the average citizen in any country is still not very significant. On the other hand, there are sceptics who would like to view the stock market as a world-wide casino where agents participate to speculate and gamble. This latter group would like to deny any positive role the stock market could play in the development of the general economy. The truth probably lies somewhere in between. While it is certainly true that a large part of the activities of the stock market is speculative in nature, historically the stock market has indeed played an important role in mobilizing funds for industrial growth in countries which are now considered to be developed. It is therefore necessary to understand and analyze the role that the stock market has played and can play in the growth process and also the general nature of financial intermediation throughout the major economies of the world. The basic purpose of the present research is to contribute to this understanding.

The nexus between growth and financial intermediation has been the subject of a growing empirical and theoretical literature and I discuss both kinds of literature in detail in the current chapter. However, since my thesis mainly deals with understanding the behaviour of growth and stock markets in a theoretical context, the current chapter will focus more on the theoretical rather than the empirical implications of the subject. I wish to look into the existing theoretical literature in some detail, identify a research gap and then contribute to the literature by addressing the research gap. Thus my approach to answering the emerging research question would be by developing a theoretical framework which will be the content of the next couple

of chapters. But before going into that it is worthwhile to first point out a few relevant stylized facts on the stock market-growth relationship in the present chapter. There is a vast theoretical as well as empirical literature relating GDP or its growth to the levels of stock market activities of a country. It is possible to divide the theoretical literature into two broad groups; one that views economic growth as a result of vibrant stock market activities and the other that views stock market development to be a consequence of rapid economic growth.<sup>1</sup>

The first group identifies stock markets as one of the most important determinants of growth. In this strand of literature, stock markets are viewed as major financial intermediaries that channel savings into investments, thereby facilitating capital formation and production. A more developed stock market, therefore, is supposed to support a higher level of economic activity, per capita income and growth. Along with some of the already mentioned relatively older works, more recent papers by Bencivenga and Smith (1991), Levine (1991), Bencivenga, Smith and Starr (1995), Japelli and Pagano (1994), Jacklin (1987) and Gorton and Penacchi (1990) to name a few, highlight the crucial role played by financial intermediaries in general and stock markets in particular in acting as an efficient bridge between savers and investors, thereby paving the way for capital accumulation and growth.

The second group of literature looks at the stock market-growth relationship from the opposite side and envisages the stream of per capita income or its growth as the determinant of stock market activity. In this second strand of literature, the asset pricing model of Lucas (1978) is a pivotal work. A number of papers are based on the first order condition of this paper and implicitly look into the role of output growth in determining stock prices in an economy. Among these, the contribution by Abel (1988), Mehra and Prescott (1985), LeRoy and LaCivita (1981) deserve special mention. This branch of literature is known as the consumption based approach to asset pricing as it models only the consumption side, but not the production side of the economy.

However, there also exists another strand of the theoretical literature, which focus only on the production and investment, but not the consumption side of the economy. This branch of literature deal with production based asset pricing models and establish a bi-directional causality between stock prices and economic growth. The most notable contribution in this area is by

---

<sup>1</sup>References to journals and articles that belong to these two groups are mentioned in detail in section 2 of this chapter where I discuss the theoretical review of literature.

Cochrane (1991). However, in the real world, it might happen that stock market and growth do not influence each other directly. Rather, it is likely that both are determined simultaneously by exogenous factors. Brock (1982) highlights this aspect when he merges the partial equilibrium frameworks of consumption and production based models of asset pricing and develops a general equilibrium framework. Within this general equilibrium set up, both stock prices and output growth are determined simultaneously by different exogenous factors.

Most of the theoretical literature in this area explores the contemporaneous relationship between stock market and growth and implicitly assumes causality to flow from one of these variables to the other. Nevertheless, the stock market-growth relationship captured here is far from being simple and straightforward. In fact, the relationship portrayed by the extant literature is dependent on a number of factors and is therefore quite complex. However, except for Brock (1982), there has not been substantial work to explore the *simultaneous* behaviour of asset prices and GDP (or its growth) due to the effect of different exogenous factors. In fact, when it comes to investigating how stock market activities and growth are simultaneously influenced by different aggregate macroeconomic shocks, there exists a distinct research gap. In my thesis, I intend to address this research gap by developing a Dynamic Stochastic General Equilibrium (DSGE) model to analyze how different aggregate macroeconomic shocks influence the short run dynamics of stock market behaviour and economic growth. Thus my entire thesis deals with the short run stock market-growth relationship, rather than the long run relationship between the two. Most of the extant literature highlights the issue of whether stock market influences growth and vice versa or how a possible bi-directional causality might exist between them. But in reality, both stock market and output growth are likely to be simultaneously influenced by different aggregate shocks. Also, in the short run, a possible lead-lag relationship can exist between stock market behaviour and growth in the sense that the variance in short run fluctuations of one of these variables due to a shock in a given time period might influence that of the other in the next period. This kind of simultaneous and lead-lag behaviour of stock market and growth can be studied in the context of the short run only. Since the effect of different shocks is investigated, the main focus here lies on the short run dynamics of these variables, generated by these shocks, around a long run steady state. Also most of the studies that have looked into this issue, in particular the strand of literature analyzing stock market influences on growth, have focused mainly on the long run relationship between the two. I find the short run dynamics

of stock market and growth to be relevant and interesting in order to properly understand the behavioural pattern of stock markets in the context of a growing economy. In addition to this, since most policy decisions are based on the short run, the present study provides potential to contribute towards necessary policy implementations as well. However, before proceeding with the formal modelling, it is important to identify a few stylized facts on the short run relationship between stock market and growth.

Empirical studies about the link between financial development in general and stock markets in particular and growth have been relatively limited. Goldsmith (1969) puts forward a significant association between the level of financial development, defined as financial intermediary assets divided by GDP, and economic growth. He recognized, however, that in his framework there was “no possibility of establishing with confidence the direction of the causal mechanisms (p. 48).” Subsequent studies have adopted the growth regression framework in which the average growth rate in per capita output across countries is regressed on a set of variables controlling for initial conditions and country specific characteristics as well as measures of financial development (King and Levine (1993a), Atje and Jovanovic (1993), Levine and Zervos (1996), Harris (1997) and Levine and Zervos (1998) among others). However, all these studies contain issues related to causality and unmeasured cross country heterogeneity in factors such as savings rates that may cause both higher growth rates and greater financial development (as pointed out by Caselli et al (1996)). Over the years, a number of techniques have been adopted to deal with these issues including (a) using only initial values of financial variables (King and Levine (1993)), (b) using instrumental variables (Harris (1997)) and (c) examining cross-industry variations in growth that should be immune to country specific factors (Demirguc-Kunt and Maksimovic (1996) and Rajan and Zingales (1998)).

From most of the empirical literature, however, no conclusive pattern is found to emerge about the direction of causality between stock market development on the one hand and economic growth on the other. Nor does it throw much light on the possibility of a *lead-lag* relationship between the two. In short, although the existing empirical research suggests a connection between stock market development and economic growth for sure, the stock market-growth relationship that is highlighted here, is not very concrete to say the least. This chapter establishes some clear stylized facts about stock market development and growth, focussing mainly on the nature of (a) the *contemporaneous* relationship and (b) the *lead-lag* relationship between the



two. As a measure of stock market development, I choose market capitalization, defined by the price of a share times number of outstanding shares. Since this value varies from country to country, I divide it by GDP to make it comparable across countries. But before going into the empirics, I establish a simple theoretical relationship between the short run cyclical fluctuations of stock market capitalization as a proportion of output and output growth, based on the first order condition of the Lucas tree (1978) model. This theoretical relationship provides a sound base to perform the empirical analysis, for the purpose of which, I look into annual data of 25 years on market capitalization as a ratio of GDP as an indicator of stock market activities and growth of per capita GDP as a measure of economic growth for 35 countries and 4 country groups. Data on market capitalization as well as GDP are in real terms. Since I look into data on stock market, my data set comprises of mostly developing and developed countries.

Firstly, since no definite pattern emerges from the existing literature about a possible *lead-lag* relationship between stock market activities and growth, I address this issue by first running a Granger causality test, using time series data from different countries and country groups. This is done in spite of the fact that no clear causality might actually exist between stock market activities on the one hand and economic growth on the other and both can be influenced by independent exogenous factors. The sole purpose of this exercise is to develop some understanding about whether stock market activities precede economic growth, or whether it happens the other way round. However, a more difficult question arises with respect to whether the forward-looking nature of stock prices could be driving apparent causality between stock markets and growth. Current stock market prices should represent the present discounted value of future profits. In an efficient equity market, future growth rates will, therefore, be reflected in initial prices. This argues for using turnover (sales over market capitalization) as the primary measure of development, thereby purging the spurious causality effect because higher prices in anticipation of greater growth would affect both the numerator and the denominator of the ratio. In the present chapter, I address issues of causality in the framework introduced by Granger (1969). Granger causality tests have been widely used in studies of financial markets as well as several studies of the determinants of economic growth including savings (Carroll and Weil, 1994); exports (Rahman and Mustafa, 1997, Jin and Yu, 1995); government expenditures (Conte and Darrat, 1988); money supply (Hess and Porter, 1993); and price stability (Darrat and Lopez,

1989).<sup>2</sup> A limited number of previous studies have used Granger causality to examine the link between financial markets and growth. Thornton (1995) analyzes 22 developing economies with mixed results although for some countries there was evidence that financial deepening promoted growth. Spears (1991) reports that in the early stages of development, financial intermediation induced economic growth in Sub-Saharan Africa, while Ahmed and Ansari (1998) report similar results for three major South-Asian economies. Also Neusser and Kugler (1998) report that financial sector GDP Granger-caused manufacturing sector GDP in a sample of thirteen OECD countries. In reality, the relationship between stock market and growth might not be of a cause - effect nature and might actually be driven simultaneously by different exogenous factors, although most of the theoretical literature on asset pricing implicitly assume flow of causality either from stock prices to growth or from growth to stock prices. I think it relevant to empirically investigate this issue, not necessarily to establish a cause-effect relationship between stock market developments and growth, but to form some understanding about which one of these preceeds the other.

Also, in the real world, even if a macroeconomic shock can influence both stock market and growth at the same time, the change in behaviour of any one of these variables as a result of the shock can take some time to get translated to the other in order to affect the latter's behaviour in the short run. The present literature does not throw much light on the *lead-lag* relationship from this particular angle. In order to figure out whether present market capitalization ratio depends upon the lagged values of growth, or whether in fact it is the determinant of current growth, I run a panel vector autoregression (VAR) taking into consideration all countries and country groups in the data set. In addition to this, within a VAR structure, I perform a variance decomposition analysis of stock market capitalization as a ratio of GDP and per capita growth, in order to compare the percentage of short run fluctuations in future market capitalization driven by GDP growth with the percentage fluctuations of GDP growth driven by market capitalization. By performing this variance decomposition analysis, my ultimate objective is to understand whether market capitalization is the chief determinant of growth during later time periods, or whether the opposite is true. In other words, this is to understand whether there exists a *lead-lag* relationship between market capitalization ratio and growth and also the nature of this *lead-lag* relationship,

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<sup>2</sup>The studies cited are illustrative of many others looking at each potential determinant of growth. Others have used the Granger causality framework to examine the link between factors such as privatization, literacy and defense spending and growth.

if there exists any.

Secondly, from the existing literature, the *contemporaneous* relationship between stock market capitalization and growth is totally ambiguous. As it is quite likely that both market capitalization and growth are simultaneously determined by aggregate shocks within a general equilibrium economic framework, it is interesting to empirically observe the nature of contemporaneous behaviour between the two in the short run. In the present chapter, this is done by evaluating the correlation between market capitalization ratio and growth for different countries in order to clearly understand whether there actually exists a short run significant contemporaneous relationship between market capitalization ratio and growth and also if it is positive or negative. The idea is to figure out whether cyclical fluctuations in stock market capitalization and growth move in the same direction or not in the short run.

Thus the connection between stock market development and economic growth as suggested by the extant empirical literature, is far from definitive. Although the relationship postulated is a causal one, most empirical studies have addressed this issue rather obliquely, if at all. In my empirical analysis, in order to understand the contemporaneous short run behaviour of market capitalization ratio and growth, I compute the correlation coefficient between market capitalization as a ratio of output and per capita growth. I find that correlation coefficient is positive and significant for 27 out of 35 countries and 3 of the 4 country groups. From this, it is clear that for majority of the countries market capitalization ratio and per capita growth move in the same direction in the short run.

Next, in order to explore the possibility of a *lead-lag* relationship between stock market capitalization and growth, I look into the results of the Granger causality test, the variance decomposition analysis and the panel VAR analysis. The result of the Granger causality exercise on thirty five countries and four country groups establish that causality mostly flows from market capitalization towards growth. Also from the variance decomposition analysis, it is established that for most of the countries and country groups, percentage of fluctuations in future period per capita growth as explained by a one time shock to market capitalization ratio is much greater than the percentage of fluctuations of future market capitalization ratio, as explained by a shock to per capita growth. Finally, by means of a panel VAR, it is found that per capita growth in a certain time period depends significantly on lagged values of market capitalization ratio, although the opposite is not necessarily true. This lends strong support to the fact that the effect

of a shock on stock market capitalization gets translated to growth with a certain lag, although growth does not in any way affect future stock market capitalization behaviour. All these results lend support to the possibility of a *lead-lag* relationship between market capitalization ratio and growth in the sense that the former precedes the latter. Once I identify these stylized facts, my next goal is to construct theoretical models with different economic environments which can help in providing support to the empirical findings. This is done in the next two chapters, where I explain the short run market capitalization-growth behaviour in two different DSGE frameworks.

The present chapter is organized as follows: In Section II, I review the theoretical literature on the relationship between stock price and growth. In Section III, I present a survey of the empirical literature. In Section IV, I develop a theoretical framework based on the Lucas (1978) asset pricing framework to study the empirical relationship between growth and the stock market. In Section V I carry out my empirical analysis to identify the short run market capitalization ratio-growth relationship. In Section VI, I conclude by formulating the research question and briefly explaining how I intend to address it.

## **II. Theoretical Literature: stock price-GDP relationship**

As pointed out earlier, I divide the main theoretical literature into two broad categories – (1) literature where the theory depicts causality to flow from stock market developments towards growth and (2) literature where the theory depicts causality to flow from growth towards stock market developments. I now discuss the relevant works under each category.

### **A. Is stock market a leading indicator of growth?**

The literature relating financial development to economic growth is very old. Writers as old as Bagehot emphasized the strong role played by the development of the financial sector in fuelling the engine of growth during the industrial revolution in England. This was mentioned in Bagehot's very famous book *Lombard Street: A Description of Money Market* (1873). Later, Schumpeter in his *Theory of Economic Development* (1912) had put a lot of stress on the requirement of well-functioning banks that could play a pivotal role in financing product and process innovations and make economic progress possible. Hicks (1969), while giving a detailed account of how development of financial institutions mattered in the process of industrialization

in the eighteenth and nineteenth-century England, went to the extent of asserting that capital market development was among the primary causes of the industrial revolution.

There are opposite views as well. According to Robinson (1952), financial development is not the cause of economic development but merely its effect. In the next sub-section I am going to discuss in more details theoretical papers which deal with this kind of reverse causality. Again, traditional accounts of economic development, building upon the work of Lewis (1954), identified the scarcity of physical capital as the main constraining factor to growth for a less developed country. The prescription, therefore, was to increase the rate of savings which would fuel capital accumulation and growth. The need for financial development was never mentioned.

The emphasis on physical capital accumulation shifted to human capital accumulation from the mid-1980s with the pioneering work of Romer (1986, 1990) and the emergence of endogenous growth models. In particular, Lucas (1988) used the insight of an endogenous growth model in the context of economic development and argued that investment in education and human capital formation crucially determines the long-term growth and development of an economy. According to Lucas, the huge difference in per capita incomes of nations could be explained by differences in human capital formation. The emphasis on financial development was not only absent in these initial endogenous growth models, but authors like Lucas actually expressed the opinion that economists have a tendency to ‘badly over-stress’ the role of financial institutions in economic growth. A firm ground, however, for sustained research on the relationship between economic growth and financial development was being prepared through a parallel stream of thought. The pioneering work of Goldsmith (1969) revealed a systematic relationship between economic growth and financial development which gave impetus to new theoretical work in the 1990s. Several alternative channels through which financial intermediaries can affect growth, were investigated.

What are the possible channels through which financial intermediation in general and stock markets in particular can affect economic growth? To answer this question, we have to understand first the forces behind economic growth. Economic growth can be generated from two alternative sources: physical capital accumulation and technical progress. In reality, however, the two factors often reinforce each other - new innovations are embedded in new physical capital and the requirement of building up new physical capital gives an impetus to innovate. Be that as it may, both physical capital accumulation and innovation require financial capital.

A machine installed now yields a cash flow for several years in future but requires a substantial monetary investment at present. This means that a considerable sum of money has to be locked in for a long period if this investment is to be undertaken. Apart from the problem of being locked in for a long period, an element of uncertainty is also involved with the investment. This uncertainty arises out of uncertainties in future cash flows which in turn are due to uncertainties in future market conditions. Similarly, technical progress requires innovation and innovation requires substantial monetary investment in R&D. Again, the R&D process could go on for a long time before any success is attained, and the outcome of the R&D process itself is uncertain. Therefore, like investment in physical capital, investment in R&D also involves locking in of funds as well as substantial uncertainty.

Now, the agents who are investing the funds in physical capital or R&D are usually different from the agents who are providing the funds. The former set of agents consists of investors and the latter set consists of savers. For a number of reasons, the savers might be reluctant to provide funds for investment.

First, the savers might be reluctant to lock in their funds for a long period. They might need the whole or a part of their savings at some intermediate future date due to an emergency which can occur with some positive probability at any point in time in future. The phenomenon is called liquidity risk. If this risk is not mitigated, it is likely to affect the flow of savings available for investment which in turn would affect long term growth.

Second, the savers are likely to be risk averse and are prone to dislike the uncertainty associated with long term investment in physical capital and R&D. So if they have to bear the risk of investment, they would be willing to lend less than is socially optimal. This is the problem of investment risk which if borne by the savers would reduce growth.

Third, apart from the problems of liquidity risk and investment risk, there is a problem of information leading to moral hazard. The success of a project, be it R&D or one involving investment in physical capital, depends not only on the amount of financial capital invested but also on the amount of effort put in by the investor. Generally, for the savers, who are providing the financial capital, it is extremely costly to observe the effort put in by the investor in the project. This is called costly state verification. On the other hand, if work effort involves a disutility for the investor, as is likely to be the case, the investors would tend to expect less work effort than is optimal under full information when work efforts can be observed and contracted

upon. The suboptimal effort would reduce the expected return from the project which in turn would diminish the savers' incentives to provide funds. As a result of all this, the growth process would be thwarted.

How can well-functioning financial institutions mitigate these problems? First, I talk about the problem of liquidity risk. In a seminal contribution, Diamond and Dybvig (1983) constructed a model of financial intermediation where banks can invest in two alternative projects: one illiquid (with higher lock in period) high return project and one liquid (with lower lock in period) low return project. A fraction of savers receive a liquidity shock which compels them to withdraw money from the bank at an early date. Savers can observe only their own shocks and not the shocks of others. In a good equilibrium, where everyone expects that there will be no bank run and that expectation is fulfilled, banks can invest only a fraction of their deposits in liquid projects and the rest in high yielding illiquid projects. This increases the return on savings compared to the situation where there are no banks. This happens because risk averse individuals tend to invest more in liquid, low yielding projects than risk neutral banks in a good equilibrium. This reduction of liquidity risk can have a direct effect on growth. As shown by Bencivenga and Smith (1991), the elimination of liquidity risk by banks will increase investment in high return illiquid projects and enhance the rate of growth.

Levine (1991) allows agents to observe one another's shock. He considers a primary and a secondary stock market. In the primary stock market firms raise capital. A shareholder who contributes to the capital of firm in the primary market is subjected to a liquidity shock. When there is a secondary market, a shareholder receiving a liquidity shock can sell his share and get the required liquidity keeping the capital of the firm unchanged. Therefore, existence of secondary markets can mitigate liquidity risks without affecting the stock of capital. Furthermore, if liquidity risks are mitigated by the secondary market, savers will have the incentives to buy more shares in the primary market contributing to higher capital formation. In this sense, the primary market and the secondary market are complimentary.

Implication of the mitigation of liquidity risk by the secondary market on growth is immediate. The thread is picked up by Bencivenga, Smith and Starr (1995) in an endogenous growth model. The authors show that projects with high return but long gestation lags will be undertaken provided costs of trading in the secondary market are low. This in turn will increase the rate of growth. It should be pointed out that if the rate of growth is linked to the rate of savings,

in some models (like Jappelli and Pagano (1994)) the effect of stock market development on the rate of growth is ambiguous. This is so because a reduction of risk and improvement of return have an ambiguous effect on savings due to income and substitution effects working in opposite direction. If income effects are weaker than substitution effects, an increase in the expected rate of return in the stock market increases savings and the rate of growth. But if income effects are strong, the opposite will happen and in this case financial development might reduce the rate of growth.

Again, as Jacklin (1987) and Gorton and Pennacchi (1990) point out, if agents can freely trade in secondary equity markets, no one will go to the banks and banks will exist only if trading in liquid equity markets is sufficiently costly. This implies that vibrant stock markets are likely to crowd out banking activities.

Besides mitigating liquidity risks, financial institutions can also substantially reduce investment risks by diversifying the portfolio. In general, savers are risk averse, high return projects involve higher risks and investments are lumpy. Therefore, if savers have to invest on their own, because of the lumpiness of investment they cannot diversify their portfolio and is inclined to invest in low risk low return projects. On the other hand, if financial intermediaries like banks or the stock market are in place, they can pool together the savings of all individuals and invest them in a diversified portfolio yielding a higher rate of return. This should enhance the rate of growth. This particular growth-finance nexus working through portfolio diversification has been discussed by Saint-Paul (1992), Devereux and Smith (1994) and Obstfeld (1994) among others. On a similar vein, King and Levine (1993c) have argued that financial intermediaries, by reducing risks through portfolio diversification, encourages investment in high risk high return innovations which leads to higher technical progress on an average and hence a higher rate of growth.

If there is an information asymmetry between savers and investors, the investors having private information about the quality and quantity of inputs, especially the work effort, that is going into the production process, the savers can solve the problem by acquiring information about the investors. However, information acquisition is costly and more importantly this cost is lumpy. For an individual saver it is never worthwhile to acquire this information because his total saving is small in comparison with the lumpy cost of acquiring information. But if a financial institution like a stock market regulatory body pools together the savings of a large number



of savers, expenditure on acquiring information becomes worthwhile. A number of researchers, e.g. Diamond (1984) or Boyd and Prescott (1986), have stressed the role of lumpy information acquisition costs behind the emergence of financial intermediation. Again, growth implications of information acquisition by financial intermediaries have been explored by Greenwood and Jovanovic (1990). Therefore, the literature linking efficient information acquisition by financial intermediaries with growth stresses yet another channel of growth-intermediation nexus.

To conclude, we find three major ways in which financial intermediation can enhance savings and growth: it can mitigate liquidity risk, it can reduce investment risk through diversification and it can help acquire information which leads to efficient allocation of investable funds. On the other hand, if income effects are strong, increased rates of return on savings can actually reduce savings and growth.

## **B. Is growth a leading indicator of stock market?**

There is a second strand of literature which links stock markets with growth or levels of per capita income through a reverse causation. This second strand of literature, the origin of which can be traced back to the efficient market hypothesis of Fama (1965) and was first fully developed by Lucas (1978), visualizes per capita income determining stock prices. The pioneering work of Lucas (1978) led to subsequent theoretical work by LeRoy and LaCivita (1981), Mehra and Prescott (1985), Abel (1988), Cochrane (2001) and others. In these theoretical models, stocks are viewed as one of the major instruments which attract savings. With intertemporal utility maximizing agents, an increase in current income is likely to affect savings and therefore the stock market. However, the direction of the effect of an increase in income on stock market activities is not clear from the theory.

Due to a rise in income in the current period, consumers being risk averse and hence eager to smooth out their consumption over time, would tend to save more. The increase in savings, caused purely as a result of a rise in income, is likely to increase the demand for stocks and hence their prices. Consequently, following a rise in per capita income, stock prices and market capitalization, defined as the value of total stocks in the market, is likely to go up. If stock prices increase at a rate greater than the rate of increase in GDP, an increase in the market capitalization to GDP ratio is observed. On the other hand, if a rise in income in the current period sends out a signal of higher income in the following period as well, then in order to smooth

out consumption, current consumption will increase and current savings will fall, leading to a fall in market capitalization ratio. Thus the net effect of a rise in income on the market capitalization ratio is ambiguous.

Thus, there are two separate effects. The first effect is the intertemporal substitution effect which should induce the agent to save more in the present period by substituting present consumption by future consumption in the act of smoothing out consumption if future income is uncertain. But there is also the second effect, which can be viewed as the ‘information’ effect. If higher income now signals still higher income in the future, there is little requirement for intertemporal substitution, in which case, an increase in current income may actually reduce current savings reducing current demand for stocks and stock prices. If it is the other way round, i.e., if current high income signals lower income in future, then due to intertemporal substitution, demand for stocks should go up now, leading to an increase in stock prices. A strong income effect in the current period can occur purely because of a high income signal in the future period; which in turn might lead to a rise in current consumption to such an extent that present savings might actually fall. Similarly, a weak income effect occurs in the current period because of a low income signal in the future period, leading to a fall in current consumption and rise in current savings.

If the strong income effect outweighs the intertemporal substitution effect, a rise in current income will lead to a fall in stock prices and hence market capitalization ratio. On the other hand, a weaker income effect can be outweighed by the intertemporal substitution effect, thereby leading to a rise in stock prices and market capitalization ratio. Thus, in the second stream of literature, per capita income determines the market capitalization ratio, that is, the direction of causality flows from per capita income to market capitalization. But it is not clear whether one can get an unambiguous signal about the current state of the economy from the stock market.

## **B.1 Lucas Tree model and its Variants**

In Lucas (1978) the model is too general to obtain explicit solutions of asset prices. In fact, Lucas himself recognizes that the relationship between stock prices (which can be translated to market capitalization for the present context) and current income is complicated and can very well be non-monotonic. Abel (1988), however, assumes a special (log normal) distribution for dividends (income) and comes up not only with an explicit solution for asset prices but this

solution actually implies a positive relationship between the market capitalization ratio and per capita income. The theoretical structure of this chapter discussed in Section IV is based on Lucas (1978) and Abel (1988). Since the theoretical framework in this chapter as well as the ones in the next two chapters are directly based on Lucas (1978), I next describe in some detail the basic framework of the Lucas asset pricing model.

The Lucas (1978) asset pricing framework considers an economy populated by infinitely many identical individual consumers, where the only assets are some identical infinitely lived trees. Aggregate output is derived from fruits falling from trees, which cannot be stored. As marginal utility from consumption is assumed to be positive, all fruits are eaten in a given time period. Considering  $c_t$  to be the consumption of fruit per person,  $L_t$  to be the population,  $d_t > 0$  to be the exogenous supply of fruits dropping from each tree and  $K_t$  to be stock of trees,

$$c_t L_t = d_t K_t \quad (1)$$

Also it is assumed that in a given period of time, each tree produces exactly the same amount of fruit as every other tree, although  $d_t$  varies from one period to another. This kind of an economy, where output arrives without any deliberate attempt on part of the residents, is called an endowment economy or an exchange economy.

In equilibrium, the price of trees is determined in such a way that each period a consumer does not want either to increase or to decrease his holding of trees. If  $p_t$  denotes the equilibrium price,  $k_t^i$  the stock of trees held by the  $i$ th consumer and also assuming that if the tree is sold, the sale occurs after the owner receives all the fruits for that particular period, the total resources available to the  $i$ th consumer in time period  $t$  are sum of the total fruits received from ownership of the trees, i.e.  $d_t k_t^i$ , plus the potential proceeds in case the consumer were to sell his stock of trees, i.e.  $p_t k_t^i$ . Total resources are split into two uses: current consumption  $c_t^i$  and purchase of trees i.e.  $k_{t+1}^i$  for the next period at price  $p_t$ . The representative consumer's resource constraint is given by

$$k_{t+1}^i p_t + c_t^i = d_t k_t^i + p_t k_t^i \quad (2)$$

The  $i$ th consumer maximizes discounted stream of his expected utilities subject to the budget constraint given by (2), so that his objective function is

$$\begin{aligned}
& \text{Max } E_t^i \sum_{n=0}^{\infty} \beta^n u(c_{t+n}^i) & (3) \\
& \text{s.t. } : k_{t+1}^i = \left(1 + \frac{d_t}{p_t}\right) k_t^i - \frac{c_t^i}{p_t}
\end{aligned}$$

Assuming all consumers to be identical, such that  $c_t^i = c_t^j = c_t$ , the First Order Condition which follows from the above objective function is given by

$$p_t u'(c_t) = \beta E_t^i ((p_{t+1} + d_{t+1}) u'(c_{t+1})) \quad (4)$$

The Lucas model is a very general model that takes into account both income and information effects on stock prices.

I now discuss some papers that have evolved from the Lucas Tree Model and have been built up on the above First Order Condition in (4).

Assuming a logarithmic utility function i.e.  $u(c_t) = \ln c_t$  and also taking into consideration the fact that the entire dividend is consumed by the representative consumer in a given time period, the time period  $t$  equilibrium price of an asset or in this case tree can be expressed as a function of the dividend in time period  $t$  as follows:

$$p_t = \left(\frac{\beta}{1-\beta}\right) d_t \quad (5)$$

Abel's (1988) paper, written a decade after Lucas's benchmark work, uses the same framework of an endowment economy without storage as a starting point, but relaxes the assumption of a logarithmic utility function. Even with a much more general utility function i.e. one with isoelastic marginal utility of the form  $u(c_t) = \frac{c_t^{1-\alpha}-1}{1-\alpha}$ , he is able to derive an analytical solution of the stock price as a function of dividend, by assigning a conditional lognormal distribution to the dividend process. With the abovementioned CRRA utility function, the consumer's First Order Condition in equilibrium is evaluated as:

$$p_t y_t^\alpha = \beta E_t [(p_{t+1} + y_{t+1}) y_{t+1}^\alpha] \quad (6)$$

where  $y_t$  denotes current dividend, while as before stock price is given by  $p_t$ .

Abel derives an explicit solution for the price function depending on the distributional assumptions of the dividend process. The price function thus obtained expresses the equilibrium stock price  $p_t$  as a function of current dividend  $y_t$  as well as other state variables relevant for calculating the conditional expectation in (6).

The dividend process is assumed to be conditionally lognormal with a serially correlated conditional mean and a serially correlated conditional coefficient of variation, i.e. conditional on the information set available in period  $t$ ,  $\ln(y_{t+1})$  is  $N(m_t, s_t^2)$ . If  $\mu_t$  and  $v_t$  are the conditional mean and the conditional coefficient of variation respectively of  $y_{t+1}$ , then :

$$\mu_t = E_t(y_{t+1}) = \exp(m_t + \frac{1}{2}s_t^2) > 0 \quad (7)$$

$$v_t^2 = \frac{Var_t(y_{t+1})}{\mu_t^2} = \exp(s_t^2) - 1 \geq 0 \quad (8)$$

where  $\mu_t$  and  $v_t$  vary over time.

They are in the information set at time  $t$  and are relevant state variables for the determination of the equilibrium stock price in period  $t$  because consumers who are making saving decisions in period  $t$  must forecast the dividend and stock price in period  $t + 1$ . Also  $\omega_t$  and  $\theta_t$  are defined in such a way that :

$$\omega_t = \mu_t^{1-\alpha} \quad (9)$$

and

$$\theta_t = [1 + v_t^2]^{\alpha(\alpha-1)/2} \quad (10)$$

to get an useful relation in

$$E_t(y_{t+1}^{1-\alpha}) = \omega_t \theta_t \quad (11)$$

Using the lognormal conditional distribution in future dividends, Abel obtains an exact relationship between asset prices and current dividend (income). Among other things, this exact relationship implies that the market capitalization to GDP ratio is increasing in current dividend or income, provided the relative risk aversion parameter  $\alpha$  is greater than unity. The exact relationship derived in the paper is of the form:

$$p_t = p(y_t, \omega_t, \theta_t) = [a + b\omega_t\theta_t + d\omega_t + e\theta_t]y_t^\alpha \quad (12)$$

where  $a$ ,  $b$ ,  $d$  and  $e$  are constants. Taking  $\psi_t = [a + b\omega_t\theta_t + d\omega_t + e\theta_t]$  it can be written that

$$p_t/y_t = \psi_t y_t^{\alpha-1} \quad (13)$$

It is to be noted that in the above equation, although strictly speaking  $p_t/y_t$  is stock price divided by GDP, I denote this as market capitalization - GDP ratio, taking  $p_t$  as the entire stock index, i.e. assuming that the consumers hold ownership to one tree (100% stocks) in equilibrium, so that total market capitalization equals  $p_t$ .

Thus in this paper, by restricting the specification of consumer's preferences and the stochastic specification of dividends, it is possible to obtain an exact solution for the price of the aggregate stock. In particular, given  $\psi_t$ , the market capitalization ratio increases or decreases with per capita income according as the risk aversion parameter  $\alpha$  is greater than or less than unity.

LeRoy and LaCivita (1981) observe that within the conventional pure exchange asset pricing models similar to the one in Lucas (1978), risk neutrality or near risk neutrality cannot explain the high asset price volatility as observed empirically. In this kind of an exchange setting, it is only by bringing in risk aversion that one is able to reproduce greater dispersion in asset prices. The authors develop the recursive equilibrium representation of stock prices by assuming that all individuals have identical endowments and identical additively separable utilities. They assume a stationary distribution of endowments with Markov transition between two states and demonstrate that a higher risk aversion leads to greater dispersion of stock prices.

The model used by LeRoy and LaCivita is a special case of the Lucas (1978) recursive equilibrium model, where instead of assuming a continuum of possible states like Lucas, they specify only two possible states, good or bad, occurring at each date. As in Lucas, utilities are assumed to be additively separable and probabilities are assumed to follow a Markov process. Under these assumptions, for given probabilities, contingent endowments and discount factors, stock price is expressed as a function of the particular state occurring in that date as well as a measure of the degree of risk aversion; this characterization making it particularly easy to investigate the connection between risk aversion and share price volatility. The authors show

that in a good state, stock price is an increasing linear function of the risk aversion parameter, whereas in the bad state, it takes the shape of a hyperbola, decreasing toward a lower asymptote with increase in risk aversion. Subject to the proviso that stock price is higher in a good state than in a bad state (this might not hold true with low risk aversion), it follows that stock price volatility unambiguously increases with risk aversion. It is also shown in the paper that for any endowment and probabilities, the coefficient of dispersion of stock prices is less (greater) than that of the endowment if the Arrow - Pratt measure of relative risk aversion is less (greater than) one.

Mehra and Prescott (1985) provide a variation of Lucas (1978) pure exchange model. They assume that the growth rate of endowment (instead of level) follows a stationary Markov process. This assumption, which requires an extension of competitive equilibrium theory captures the non stationarity in consumption series associated with the large increase in per capita consumption that occurred in the 1889-1978 period. The economy has a single representative stand in household and is judicially selected so that the joint process governing the growth rates in aggregate per capita consumption and asset prices would be stationary and easily determined. It is assumed that there is one productive unit producing the perishable consumption good and there is one equity share that is competitively traded. The firm's output is constrained to be less than or equal to  $y_t$ . The growth rate in  $y_t$  is subject to a Markov Chain i.e.

$$y_{t+1} = x_{t+1}y_t$$

where  $x_{t+1} \in \{\lambda_1, \lambda_2, \dots, \lambda_n\}$  is the growth rate and  $Pr\{x_{t+1} = \lambda_j; x_t = \lambda_i\} = \phi_{ij}$ . It is assumed that the Markov Chain is ergodic.  $\lambda_i$  are all positive and  $y_0 > 0$ .

The authors consider a class of competitive pure exchange economies as in Lucas (1978) for which the equilibrium growth rate process on consumption and equilibrium asset returns are stationary, with their focus restricted to economies for which the elasticity of substitution for the composite consumption good between two consecutive years is consistent with micro, macro and international economics. The economies are constructed to display equilibrium consumption growth rates with same mean, variance and serial correlation as those observed for the U.S. economy during the period from 1889 to 1978. It is found that for such economies the average real annual yield on equity is a maximum of four - tenths of a percent higher than on short term debt. This is in sharp contrast to the six percent premium observed from historical data

on S&P returns and treasury bill returns. The results that the authors find, are robust to non stationarities in the means and variances of the economies' growth processes.

For a high equity premium, as observed empirically, either non risk neutral (or risk averse) consumers or highly volatile consumption stream is required in order to be consistent with the model. But the observed consumption series is too smooth, meaning it does not show too much variation., with standard deviation in the growth rates of consumption over the period 1890 to 1979 being a mere 3.6 percentage point. Given the observed series for consumption, it is necessary to have an inordinately high degree of risk aversion (the relative risk aversion parameter  $\theta$  has to be approximately twenty - five) to replicate the observed high equity premium.

Hence, the observed high equity premium is not consistent with the consumption CAPM model. Since real per capita consumption is growing at an yearly average of two percent, the elasticity of substitution between the consumption good across two consecutive time periods, which is sufficiently small to yield the six percent average equity premium, also give rise to real rates of return which exceeds those observed empirically by a huge margin. The authors conclude that most likely an equilibrium model which is not an Arrow-Debreau economy i.e. where markets are incomplete, can simultaneously rationalize both historically observed large average equity return and the small average risk free return.

### **C. Bi-directional causality between stock price and GDP: Production Based Models of Asset Pricing**

In subsection B.1 of section II, I discussed the consumption based asset pricing models in order to explain the phenomenon of growth being a leading indicator of the stock market. I now highlight the production based approach to asset pricing that captures a contemporaneous relationship between stock returns and economic fluctuations. While the consumption based model links stock returns to marginal rates of substitution inferred from consumption data through a utility function, the production based approach ties asset returns to marginal rates of transformation, which are inferred from data on investment (or output and other variables related to production) through a production function. While consumption based models are derived from consumer's first order conditions from optimal intertemporal consumption demand, production based models emphasize a producer's first order conditions for optimal intertemporal investment demand.

The testable content in the consumption based asset pricing models is a restriction on the



joint stochastic process of consumption and returns. If the return process is modelled and predictions are made about the consumption behaviour, it is a theory on consumption as in the permanent income hypothesis. If, however, the consumption process is fixed or modelled and predictions are made about returns, it becomes a consumption based asset pricing model. On the other hand, the testable content in a production based asset pricing model is the restriction on the joint stochastic process of investment, or other production variables and asset returns. As in the consumption based approach, in the production based approach also this restriction can be interpreted in two ways. If the return process is fixed, it is a version of the  $q$  theory of investment, but if the investment process is modelled, it gives rise to a production based asset pricing model.

The central concept of the production based asset pricing approach is the investment return or the stochastic intertemporal marginal rate of transformation. Considering a firm that employs labour and capital to produce a consumption good, if the firm reduces sales of the consumption good at date  $t$  by one unit and increases investment, it can sell extra units of the consumption good in period  $t + 1$ , while leaving its capital stock and sales plan unchanged for the periods thereafter. The investment return is defined as the rate of conversion of one period consumption good into that in the next period. This return on investment is not risk free since the additional sales at date  $t + 1$  can depend on events specific to that particular date and not known at date  $t$ , which include changes in productivity, investment decisions and labour decisions as response to events at date  $t + 1$  only.

While the consumption based asset pricing models mainly point out macroeconomic variables as the chief determinant of asset returns, thus indicating an across time relationship or asynchronous relationship between the two, production based models capture a more contemporaneous relationship between asset returns on the one hand and investment returns on the other. This may seem contradictory to the results of Fama (1981), Fama and French (1999), Fama and Gibbons (1982) and Barro (1990), which document ex - post stock returns to be associated with subsequent changes in GNP or cash flows. However, these papers do not necessarily contradict the production based model, as investment is a leading indicator. If investors find earnings and output to be higher in the future, this leads to increase in stock prices, leading to higher ex - post return from last period to the present period, which in turn forecast a rise in income. But, a rise in stock prices in the current period induces investors to raise their investment immediately in

response to increased price relative to cost of capital. So a rise in investment growth and hence rise in investment return from last period to present period is observed, along with a simultaneous rise in stock return. In case of lags within the investment process, there is rise in investment for a few periods, although investment plans increase immediately. If production function takes into consideration the lags, investment and stock returns should still move at the same time. Thus production based models of asset pricing capture bi - directional causality between stock prices on the one hand and different macroeconomic indicators like GDP and investment on the other.

Cochrane (1991) investigates the link between stock returns and economic fluctuations in a production based asset pricing framework. This particular approach, in which a production based model is used to explain the two links between stock returns and economic fluctuations, has also been the focus of a lot of other empirical research in finance; the two links being (a) a number of variables forecast stock returns, including the term premium, the default premium, lagged returns, dividend - price ratios on the one hand and investment on the other and (b) many of the same variables, and stock returns in particular, forecast measures of economic activity such as investment and GNP growth. This paper uses the producer's first order conditions to relate investment returns with asset returns in an environment where firm managers have access to complete financial markets. The paper revolves round the idea that firm managers trade portfolio of assets whose payoff across different states of nature in the next date mimic exactly those of the investment return. When price of this mimicking portfolio exceeds one, managers short the portfolio, invest one unit of the proceeds, pay off the mimicking portfolio with the investment return and are able to make a sure profit in the process. Firms continue to adjust their investment and production plans until investment return equals portfolio return. In this way firms remove possible arbitrage opportunities between investment returns and asset returns.

A crucial assumption here is that markets are complete, because of which there exist portfolios with ex - post payments proportional to any function of the state variables. Because of this, the producer's first order conditions imply ex - post that in every state of nature the investment return and the mimicking portfolio return should be equal. This is a novelty of Cochrane (1991) as most of the investment literature only looks into a comparatively weaker relationship of expected investment return equating the expected return on a certain asset. But the result of equal investment and portfolio return in Cochrane (1991) crucially hinges on the complete

market assumption. Cochrane constructs investment returns from investment data, using a production function featuring adjustment costs of investment. Since the production function uses the mimicking portfolio return as the return on the firm's own stock, the model predicts the investment return to be equal to the stock return. Regressions are run to test whether forecasts on stock return and investment return are equal and also whether stock return forecasts and investment return forecasts of future activity are equal, thereby giving rise to a partial equilibrium explanation of the relations between stock returns and economic fluctuations.

The simple implementation of a production-based asset pricing model in this paper predicts that stock returns and investment returns should be equal. Forecasts of investment returns and stock returns appear to be the same for most of the forecasting variables. Conversely, forecasts of future investment to capital ratios and GNP growth from investment returns and stock returns also appear to be the same. Other important findings include that ex post investment returns and stock returns are highly correlated and that the projection of investment and stock returns on investment to capital ratios matches in many respects. However, investment returns do not explain the component of stock returns forecastable by dividend-price ratios. Dividend to price ratios seem to forecast a long horizon component in stock returns not present in investment returns. This component of stock returns might reflect a long-term movement in productivity, which is assumed to be constant here.

Although the consumption based asset pricing model is the conventional approach to understanding a link between real activity and expected stock returns, there are several reasons to believe that a production based model proves more useful for this purpose, as the latter ties stock returns directly to production variables such as output and investment, whose relatively large movements characterize economic fluctuations, rather than to the relatively smooth non-durable and services consumption series. Also firms being larger than consumers, transactions and information costs, lumpiness of goods that may contribute to some of the problems in the consumption based models may not apply to a production based model of asset pricing. Having said that, it must be pointed out that one of the two types of models does not have to be completely wrong in order to prove soundness and credibility of the other. The production based approach will provide an interesting complement to the consumption based models, even if a specification of the latter is found to work perfectly.

## D. Stock price and GDP determined simultaneously: General equilibrium models of asset pricing

Both consumption based and production based models are partial equilibrium in nature. However, partial equilibrium consumption based models are often called general equilibrium by treating the consumption stream as an endowment following Lucas (1978). Since provisions for storage and production are found in real economies, empirical applications of these models in fact only portray a partial equilibrium relation between consumption and asset returns. But in order to properly investigate the link between stock returns and economic fluctuations taking the economy as a whole, general equilibrium models with nontrivial production sectors seem more appropriate. Some examples of these include Balvers, Cosimano and McDonald (1990), Sharatchandra (1992) and Rouwenhorst (1995). Brock (1982) provides another important example of a general equilibrium set-up. General equilibrium models make more powerful predictions, although these predictions can be more sensitive to misspecifications. Incorporating a production sector within the Lucas tree framework present a more realistic picture of the world where firms produce with the help of labor and capital, and undertake physical investment which in turn makes the trees in the economy grow. Households consume, work for the firms, and save in the form of buying shares issued by the firms. The dividend ( $D_t$ ) is thus given by:

$$D_t = Y_t - I_t - w_t L_t^d \quad (14)$$

where  $Y_t$  is output (or GDP),  $I_t$  is firm's investment in the form of retained earnings, and  $w_t L_t^d$  is the wage bill for employing  $L_t^d$  workers, where  $L_t^d$  stands for labor demand. It is assumed that  $Y_t$  and  $I_t$  are driven by the production and investment technologies as:

$$Y_t = K_t^\alpha (A_t L_t)^{1-\alpha} \quad (15)$$

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (16)$$

The household's sequential budget constraint is:

$$C_t + P_t(Z_{t+1} - Z_t) = D_t Z_t + w_t L_t^s \quad (17)$$

where  $L_t^s$  stands for labor supply.

In this framework, there are three markets under consideration now: goods, asset and labor. There is no rental market for capital because we assume that the firm owns all the capital stock. In equilibrium, these three markets clear. If two of these markets clear, the third market also clears automatically by Walras' Law.

In consumption CAPM models, physical investment  $I_t$  was ignored, as was production. That is why the goods market equilibrium condition was  $C_t = Y_t = D_t$ , i.e. each period, the total amount produced was taken as dividend by the representative household and was entirely consumed by him. Thus consumption based asset pricing models alone divorce production from asset pricing, while production based models in themselves divorce consumption from asset pricing. A synthesis of production and consumption CAPM, as proposed by Brock (1982) presents a more general case. Brock develops an intertemporal general equilibrium theory of capital asset pricing in an attempt to assimilate ideas from the finance literature and the literature on stochastic growth models. In this way, the author has obtained a theory capable of addressing several general equilibrium questions such as the impact of an increase in corporate income tax upon the relative prices of risky stocks, the impact of an increase in progressivity of the personal income tax upon the relative price structure of risky assets, etc.. Brock (1982) modifies the stochastic growth model proposed by Brock and Mirman (1972) in order to incorporate a non trivial investment decision into the asset pricing model of Lucas (1978). This is done in such a way so as to preserve the empirical tractability of the Merton (1973) formulation of intertemporal capital asset pricing models and at the same time determine the risk prices derived by Ross (1976) in his arbitrage theory of asset pricing. Brock (1982) provides a context in which specific conditions are established on tastes and technology which are sufficient for equilibrium returns to be linear functions of the uncertainty prevalent within the economy. Basu (1987) provides a similar general equilibrium framework to link the financial sector of the economy to the adjustment cost arising out of the technological side of the economy.

### **III. The Empirical Literature**

As I have already pointed out, traditionally, the stock market is viewed as one of the financial institutions that channelizes savings into investments and thereby gives impetus to growth. There is a vast empirical literature that looks into the relationship between financial intermedi-

ation and economic growth. The pioneering work of Goldsmith (1969) gave impetus to further empirical and theoretical work.

Several alternative channels through which financial intermediaries can affect growth, were investigated. More recently Levine and Zervos (1996) undertook an elaborate study to explore the growth–finance nexus empirically. This empirical literature on financial intermediation and long-run growth consisted of both cross-country studies as well as case studies of specific countries.

Jayaratne and Strahan (1996) found that for the U.S. the regulation in financial markets influenced post-war economic growth directly. They examined the impact of less rigid bank branch regulation in the United States on regional economic growth in individual states. They found a positive effect on per capita growth through improvement in the quality of bank loans. Jayaratne and Strahan emphasize in their examination that the states do not deregulate state banks to encourage future growth. Nevertheless, they found weak evidence that bank loans increased after the banking reform. However, according to their analysis, there were no signals that capital investment increased after the regulatory measures. This result implies that the improvement in the quality of bank loans is the main channel through which economic growth is influenced, indicating causality from financial development to economic growth.

Demirguc-Kunt and Levine(1996a. and 1996b.) offer empirical evidence for the importance of stock market development for output growth. Stock market development is measured by the ratio of market capitalization and GNP. They find that in different countries the extent of stock market development highly correlates with the development of banks, nonbank financial institutions, pension funds and insurance companies. Japan, the United States, and the United Kingdom have the most developed stock markets. Colombia, Venezuela, Nigeria, and Zimbabwe have the less developed stock markets and, according to these authors, the growth rates of the countries considered reflect this differences significantly.

Rajan and Zingales (1998) emphasize in their study that the initial level of financial development is a leading indicator, rather than a causal factor, for financial markets to anticipate faster economic growth. One way to solve the causality problem is to find an indicator or instrumental variable which is independent of economic growth. Rajan and Zingales assume as a benchmark that financial markets in the Unites States are frictionless. This benchmark country further explains for every branch of industry the demand for external finance. Consequently,

they analyse the branches of industry over a great number of countries and test if the branches depending on external finance grew relatively faster in countries where from the beginning of the test period the financial systems were better developed. They found that industries which heavily depend on external finance grow faster in countries with well-developed intermediaries and stock markets than in countries with less developed financial systems. They emphasize that financial development lowers the costs of external financing and therefore foster economic growth. This suggests that causality runs from financial development to economic growth.

Beck, Demirgüç-Kunt and Levine (2000) also studied the relationship between financial structure and economic growth. Their focus is on the degree the financial system is market or banking oriented and what the relation is to economic growth. Two methodologies of these authors are interesting and worth to review here. The first is their cross-country approach that determines if economies grow faster in market or banking oriented systems. They find no clues that either market or banking oriented systems have more or less influence on economic growth. What comes forward is that the level of financial development and the surroundings in which financial intermediaries and markets operate influence economic growth. The second methodology is a branch of industry approach to analyse whether different branches, which heavily depend on external finance, grow faster in market or bank based financial systems. They conclude that economies that heavily depend on external finance grow faster.

The article by Fase (2001) searches for an answer to the question as to whether an increase in financial development can be associated with long-term economic growth in The Netherlands between 1900 and 2000. One conclusion of this analysis is that financial intermediaries, and thus the level of financial development, have a positive influence on economic growth in The Netherlands during the first decenniums of the 20th century. However, in the post-World War Two period financial intermediation has, according to Fase, less influence on economic growth. Causality tests show that in The Netherlands during the first decenniums of the 20th century causality ran from financial intermediation to economic growth. After World War II this causality vanished completely. An important conclusion from this analysis is that before World War II financial intermediation plays an important role for economic growth, but disappears after this war. Fase assumes that this may reflect the growing maturity and internationalization of the Dutch economy since the Second World War.

Now I discuss some of the more recent empirical papers that have looked into the causality

between financial intermediation and economic growth. I go through the methodologies used in each of these papers in some detail.

Caporale, Howells and Soliman (2004) examine the causal linkage between stock market development, financial development and economic growth. They argue that any inference that financial liberalisation causes savings, investment and growth, or that financial intermediation causes growth, drawn from bivariate causality tests may be invalid, as invalid causality inferences can result from omitting an important variable. The empirical part of this study exploits recent techniques developed by Toda and Yamamoto (1995) to test for causality in VARs, and emphasises the possibility of omitted variable bias. The selected countries are Argentina, Chile, Greece, Korea, Malaysia, Philippines and Portugal. The sample under investigation covers the period 1977:1-1998:4. For stock market development, the authors use two standard indicators: 1) the market capitalisation ratio, which equals the value of listed shares divided by GDP. 2) the value traded ratio, which equals the total value of shares traded on the stock exchange divided by GDP. Bank deposit liabilities to nominal GDP and the ratio of bank claims on the private sector to nominal GDP are used as a proxy for bank development. Also, GDP in levels is used as a measure for economic development. The evidence obtained from the sample of seven countries suggests that a well-developed stock market can foster economic growth in the long run. It also provides support to theories according to which well-functioning stock markets can promote economic development by fuelling the engine of growth through faster capital accumulation, and by tuning it through better resource allocation.

Fase and Abma (2003) examine the empirical relationship between financial development and economic growth in nine emerging economies in South-East Asia. The sample period varies across countries but covers at least 25 years. The countries under consideration are Bangladesh, India, Malaysia, Pakistan, Philippines, Singapore, South Korea, Sri Lanka and Thailand. Growth rate of GDP is an indicator of economic growth whereas capital investment and aggregate financial assets are indicators of financial environment. A Granger-Sims method of causality is used to test the direction of causality between financial intermediation and economic growth. The main finding is that financial development matters for economic growth and that causality runs from financial structure to economic development. This result indicates that in developing countries a policy of financial reform is likely to improve economic growth.

Abu-Bader, Ben-Gurion and Abu-Qarn (2006) look into the causal relationship between fi-



nancial development and economic growth in five Middle Eastern and North African (MENA) countries for different periods ranging from 1960 to 2004, within a trivariate vector autoregressive (VAR) framework. The authors employ four different measures of financial development and apply Granger causality tests using the cointegration and vector error-correction (VEC) methodology. These four different measures of financial development are ratio of money stock to nominal GDP, the ratio of money stock minus currency to GDP, the ratio of bank credit to the private sector to nominal GDP and the ratio of credit issued to nonfinancial private firms to total domestic credit (excluding credit to banks). Real GDP per capita is used as a measure for economic development. The empirical results show weak support for a long-run relationship between financial development and economic growth, and for the hypothesis that finance leads growth. In cases where cointegration was detected, Granger causality was either bidirectional or it ran from output to financial development.

Guha Deb and Mukherjee (2008) have studied the causal relationship between stock market development and economic growth for the Indian economy over the last decade or so. By applying the techniques of unit-root tests and the long-run Granger non-causality test proposed by Toda and Yamamoto (1995), the authors test the causal relationships between the real GDP growth rate and three stock market development proxies. Their results are in line with the supply leading hypothesis in the sense that there is strong causal flow from the stock market development to economic growth. A bi directional causal relationship is also observed between real market capitalization ratio and economic growth.

Ahmed, Ali and Shahbaz (2008) investigate whether there is a relationship between stock market development and economic growth in case of developing economy such as Pakistan. The data set covers annual times series data from 1971 to 2006. The authors employed two new tests, i.e., DF-GLS, and Ng-Perron to find integrating order of the said variables of the study. To test long-run robustness, J-J Co-integration and ARDL bounds testing techniques are applied. To investigate long-run causal linkages and short-run dynamics, Engle-Granger causality and ARDL tests are applied respectively. GNP per capita and market capitalisation as a share of GDP are taken to be indicators of economic growth and stock market development respectively. After finding order of integration, their findings suggested that there exist a very strong relationship between stock market development and economic growth. Engle- Granger-Causality estimation confirms in the long-run, there is bi-directional causality between stock market development and

economic growth. However, for short-run, there exist only one-way causality, i.e., from stock market development to economic growth.

Arestis, Dimitriades and Luintel (2001) utilize time series methods on data from five developed economies and examine the relationship between stock market development and economic growth, controlling for the effects of the banking system and stock market volatility. The authors employ quarterly data on output and indicators of banking system development, stock market development and stock market volatility for Germany during 1973:1-1997:4, the United States for 1972:2-1998:1, Japan for 1974:2-1998:1, the United Kingdom for 1968:2-1997:4, and France for 1974:1-1998:1.4. Output is measured by the logarithm of real GDP; stock market development by the logarithm of the stock market capitalization ratio, defined as the ratio of stock market value to GDP; banking system development by the logarithm of the ratio of domestic bank credit to nominal GDP; stock market volatility is measured by an eight-quarter moving standard deviation of the end-of-quarter change of stock market prices. The results support the view that, although both banks and stock markets may be able to promote economic growth, the effects of the former are more powerful. They also suggest that the contribution of stock markets on economic growth may have been exaggerated by studies that utilize cross-country growth regressions.

#### **IV. A theoretical framework to study the empirical relationship between growth and the stock market**

The theoretical models discussed so far are not particularly suitable to verify empirically the short run relationship between market capitalization ratio and growth. The Lucas (1978) asset pricing model is too general to establish a specific relationship between the two variables. Therefore, immediate empirical implications do not easily follow from this general model. Abel's (1988) model, on the other hand, comes up with a specific solution of asset prices. In particular, it expresses the current market capitalization ratio as a linear function of the current per capita income, the nature of the relationship being dependent upon the value of the risk aversion parameter. The relationship between market capitalization - GDP ratio and per capita GDP growth is expressed by equation (13). From this equation it follows that the market capitalization - growth relationship depends on  $\psi_t$  and can be tested empirically only if the series  $\psi_t$  is guaran-

teed to be stationary. But nothing in the assumptions of the model guarantee this. As for the other two models which follow from the first order condition of the Lucas tree asset pricing model, the focuses were different. While Mehra and Prescott focused on returns to equity, LeRoy and LaCivita looks primarily at the volatility of stock prices. Neither the production based models, nor the general equilibrium ones which combine consumption and production based approaches, establish a straight forward analytical relationship between market capitalization and per capita income which can be empirically tested. The parallel branch of literature, that focuses on the role of financial intermediation on growth, also fails to establish a clear analytical relationship between stock market capitalization on the one hand and economic growth on the other, that can be verified empirically.

The purpose of the present section is to first develop a framework inspired by the Lucas tree model (1978) to understand the short run relationship between market capitalization - GDP ratio and GDP growth. My objective here is to extend the first order condition of the Lucas asset pricing framework and establish a compact and concise relationship between the short run fluctuation patterns of market capitalization ratio and per capita growth which can be used as a starting point for some short run empirical analysis. For this purpose I assume that the economy is on a balanced growth path from which deviations occur in the short run. These short run deviations from balanced growth can be viewed as business cycle fluctutaions around a long run trend growth path. Such cyclical relationship between market capitalization ratio and growth can be directly tested against appropriately filtered data. Thus by means of a simple extension of the Lucas asset pricing setup, I intend to establish a foundation based on which the contemporaneous (in the same time period) and intertemporal (across two different time periods) short run relationship between market capitalization ratio and growth can be tested empirically.

Before going into details of my theoretical construct, let me briefly discuss the nature of the two variables, between which I intend to establish a short run relationship. The variables, as mentioned earlier, are GDP growth and market capitalization as a ratio of GDP. Market capitalization is measured by price of a share multiplied by the number of outstanding shares. Now, this number varies from economy to economy, i.e. it may be large for a rich country, but small for a comparatively poorer country. For this reason, it is necessary to normalize market capitalization of a given economy by dividing it by the value of GDP for that particular economy, so that it is reasonable to compare the value of market capitalization between various economies.

I have taken this market capitalization ratio as an indicator of share market activities. Now, there are other indicators of financial intermediation as well, like bank deposit and bank credit which I ignore. This is not because I think they are unimportant, but because I intend to settle the issue of short run relationship between market capitalization ratio and growth in a more focused manner.

In some countries, including the United States, banks are small and the bulk of investment financing and growth rests on the stock market. On the other hand, there are countries like Germany and Japan, where banks are big and take a large part of the burden of investment financing. The difference between stock financed investment and bank financed investment is that while in the latter case risk taking is institutionalized (being borne by banks), in the former case risks are taken by individuals. Which of the two would emerge as the dominant practice depends, to a large extent, on the history of the concerned country. But even when banks play important roles in investment financing and growth, usually there is a minimum requirement of an equity-debt ratio which needs to be fulfilled by a company, before any bank would consider giving it a loan. Therefore, the importance of equity remains in place even for countries where banks are big financiers. This again justifies my stance of focusing solely on the stock market.

### **A. Simple extension of Lucas Tree Model to establish short run relationship between market capitalization ratio and growth**

I consider an endowment economy similar to the one in Lucas (1978), where each period's dividend is equal to output produced in that particular period and the entire dividend is consumed in equilibrium. Denoting time period  $t$  output by  $y_t$ , stock price by  $p_t$  and consumption by  $c_t$ , and also assuming a power utility function of the form  $u(c_t) = \frac{c_t^{1-\alpha}-1}{1-\alpha}$ , the general First Order Condition can be written in the form used by Abel (1988), which is given by equation (6).

Assuming each household to own same number of shares in different firms and also the total number of shares in each firm to be unity,  $p_t$  can be taken as the total value of market capitalization and  $\frac{p_t}{y_t}$  as the market capitalization to output ratio. In equilibrium,

$$\frac{p_t}{y_t} = \beta E_t \left[ \left( \frac{p_{t+1}}{y_{t+1}} + 1 \right) \left( \frac{y_{t+1}}{y_t} \right)^{1-\alpha} \right] \quad (18)$$

Assuming that the growth of output follows a loglinear AR(1) process, I have:

$$\frac{\widehat{y_{t+1}}}{y_t} = \rho \frac{\widehat{y_t}}{y_{t-1}} + \varepsilon_{t+1} \quad (19)$$

In the above equation,  $\frac{y_t}{y_{t-1}}$  represents output growth at time period  $t$  and  $\frac{y_{t+1}}{y_t}$  represents output growth at time period  $t + 1$ . A hat ( $\widehat{\phantom{x}}$ ) over a certain variable represents a proportional change or log difference from its steady state value. In other words, the variable ( $x$ ) with a hat represents a proportional deviation of the magnitude  $(x_t - \bar{x})/\bar{x}$  from its steady state value  $\bar{x}$ .

In this model, output growth is assumed to be a stationary process, but output level is non-stationary. I denote the steady state gross growth rate by  $(1 + \gamma)$  and the steady state market capitalization ratio by  $\frac{\bar{p}}{y}$ .

Loglinearising (18) around the balanced growth path  $(\frac{\bar{p}}{y})$  and  $(1 + \gamma)$  I have

$$\frac{\widehat{p_t}}{y_t} = \pi_1 E_t \left( \frac{\widehat{p_{t+1}}}{y_{t+1}} \right) + \pi_2 E_t \left( \frac{\widehat{y_{t+1}}}{y_t} \right) \quad (20)$$

where the coefficients  $\pi_1$  and  $\pi_2$  depend on all structural parameters and are given by

$$\pi_1 = \{\beta(1 + \gamma)^{(1-\alpha)}\} \quad (21)$$

and

$$\pi_2 = (1 - \alpha) \quad (22)$$

The rational expectations equilibrium solution to (20) is

$$\frac{\widehat{p_t}}{y_t} = \lambda \frac{\widehat{y_t}}{y_{t-1}} \quad (23)$$

where

$$\lambda = \left( \frac{(1 - \alpha)\rho}{1 - \rho\beta(1 + \gamma)^{1-\alpha}} \right) \quad (24)$$

Equation (23) represents the contemporaneous relationship between the short run cyclical fluctuations in market capitalization ratio and the short run cyclical fluctuations in growth.

Derivation of (20) and (23) is shown in the appendix. This brings me to my first proposition.

**Proposition 1** *If the growth rate of output follows an autoregressive process given by (19) and  $0 < \rho < 1$ , the rational expectations equilibrium solution to (21) is  $\frac{\widehat{p_t}}{y_t} = \lambda \frac{\widehat{y_t}}{y_{t-1}}$ , where  $\lambda$  is a constant.*

Now, along a balanced growth path,

$$\frac{\bar{p}}{y} = \frac{\beta(1+\gamma)^{1-\alpha}}{1-\beta(1+\gamma)^{1-\alpha}} \quad (25)$$

In order to ensure that this steady state market capitalization ratio is positive, I must have

$$\beta(1+\gamma)^{1-\alpha} < 1 \quad (26)$$

which automatically holds for  $\alpha > 1$  (since  $\beta$  is a fraction). For  $\alpha < 1$ , however, additional restrictions on  $\beta$  is necessary to make this condition hold such that  $\beta < \frac{1}{(1+\gamma)^{1-\alpha}}$ . (26) is a fundamental condition without which the steady state (along which loglinearization occurs) does not exist.

Now, from equation (23), the relationship between the short run fluctuations in market capitalization ratio and growth depend upon the value of  $\lambda$ . From (24) it is clear that the value of  $\lambda$  is ambiguous and depends upon the values of the parameters  $\beta$ ,  $\gamma$  and  $\alpha$ . Since  $\beta$  represents the household's discount factor and  $\gamma$  represents the net growth rate, both these parameters are  $< 1$  and the value of the constant  $\lambda$  effectively depends upon the value of  $\alpha$ , which represents the coefficient of relative risk aversion.

When  $\alpha > 1$ , the steady state value of market capitalization ratio is always positive. Also  $\lambda$  is unambiguously negative.

On the other hand, when  $\alpha < 1$ , considering positive steady state market capitalization ratio,  $\lambda$  becomes unambiguously positive. This is because with  $\alpha < 1$ , a positive steady state value of market capitalization ratio is ensured by  $\beta(1+\gamma)^{1-\alpha} < 1$ , which automatically implies  $\rho\beta(1+\gamma)^{1-\alpha} < 1$ , i.e. a positive value of  $\lambda$ .

I now put forward my second proposition as:

**Proposition 2** *For a considerably high value of relative risk aversion, i.e. the coefficient of relative risk aversion exceeding one, market capitalization-output ratio and growth move in opposite directions, whereas for lower values of relative risk aversion, i.e. the coefficient of relative risk aversion less than one, market capitalization-output ratio and growth move in the same direction in the short run.*

Thus a tight equilibrium relationship between the short run fluctuations of market capital-

ization ratio and growth can be obtained from this simple model, the implication of which is summarized by the above proposition.  $\alpha > 1$  implies a negative value of  $\lambda$ . This means that when the individual is highly risk averse, he wishes to smooth out his consumption. Here, the information effect dominates the income effect as a result of which the individual saves less in the current period as a high growth in this period indicates that growth will be higher in the following period as well. A fall in savings is associated with a fall in the market capitalization ratio. Hence in the short run, income growth rate and market capitalization ratio of a highly risk averse individual will move in opposite directions.

## V. Empirical analysis

### A. Motivation

The compact relationship between the short run fluctuations of market capitalization ratio and growth, captured by equation (23) creates an environment suitable to empirically investigate the short run contemporaneous behavioural patterns of these two variables. However, since this theory is derived from the first order condition of the Lucas asset pricing framework, the final result is based on the fact that growth is exogenous in this particular set-up, which might not be a reasonable assumption, as put forward by some of the other relevant work on this area. In fact, direction of causality between stock market and growth is very much dependent on the particular theoretical approach, as is evident from the literature survey. Also, most of the research on this area deals with the contemporaneous relationship between market capitalization ratio and growth, but not necessarily any lead-lag relation, although in reality, it is quite likely that the behaviour of one of these variables might have a delayed effect on the other, rather than an immediate effect. Even then, the relationship between stock market and growth, as established by the different theories, is not at all straightforward, but extremely complex and dependent on a number of factors. In fact, both stock market behaviour and growth can be independently influenced by several exogenous shocks to the economy.

The lesson from the Lucas tree model is that any exogenous stream of endowments (GDP) can be priced in the stock market. The Lucas model, thus, assumes that the GDP process is exogenous and precludes any possibility of a reverse feedback from stock price to GDP. However, a section of the literature surveyed earlier also suggests that stock market fluctuations could

precede business cycles fluctuations in a way that stock market could be a leading indicator of the macroeconomic performances of a nation as well. The Lucas tree framework models only the consumption side, but not the production side and thus gives rise to the consumption based branch of asset pricing models, which envisages causality flowing from growth to stock market capitalization. The production based asset pricing approach, on the other hand, models only the production side of the economy and establishes bi-directional causality between stock market and growth as in Cochrane (1991). In the real world, it is quite likely that neither market capitalization, nor growth directly determines one another and the short run dynamics of both these variables are driven by other exogenous factors which can be treated as aggregate shocks to the economy. A general equilibrium framework in the form of a Lucas tree model but with investment and production, which assimilates the production and consumption based approaches as in Brock (1982) is more suitable to capture the kind of short run dynamics of market capitalization ratio and growth which is triggered by different macroeconomic shocks. I intend to investigate this in the next chapter, but before going into that, it is worth establishing some stylized facts regarding the short run relationship between market capitalization ratio and growth.

Thus, from the extant literature, the contemporaneous relation between stock market capitalization and growth is quite complicated and ambiguous. As it is likely that both stock market and growth are simultaneously determined by aggregate shocks within the economy, it will be interesting to empirically observe the nature of the contemporaneous relationship between the two. Hence, in the next section, I look into the correlation between market capitalization ratio and growth for different countries using time series data for each country in order to understand whether there actually exists a short run significant contemporaneous relationship between market capitalization ratio and growth i.e. whether they follow the same time path or not in the short run.

Also, the present literature does not throw much light on the lead-lag nature of the relationship between stock market and growth. In the real world, a macroeconomic shock can influence both stock market and growth, but the change in behaviour of any one of the variables due to the shock can take some time to get translated to the other in order to affect its behaviour in the short run. Since no clear conclusion can be drawn from the existing literature about the direction of causality between stock market capitalization and growth, in order to figure out whether



present stock market activities depend upon the lpast values of growth, or whether the past values of stock market capitalization determine current growth, I empirically investigate this first by running a Granger causality test, using time series data on market capitalization - GDP ratio and growth of per capita GDP from different countries and country groups. This is done despite the fact that no clear causality might actually exist between stock market activities on the one hand and economic growth on the other and both can be influenced by independent exogenous factors. The sole purpose of the Granger causality exercise is to develop an understanding about the nature of lead-lag relationship between market capitalization ratio and growth, if there exists any such relationship. Next, within a VAR structure, I perform a variance decomposition analysis of stock market capitalization and growth in order to compare the percentage of short run fluctuations in future market capitalization driven by GDP growth with the percentage fluctuations of GDP growth driven by market capitalization. In other words, a variance decomposition helps understand whether market capitalization is the chief determinant of growth during later time periods, or whether the opposite is true. Finally I run a panel vector autoregression (VAR) taking into consideration all the countries and country groups in order to figure out if market capitalization ratio depends significantly on the past values of per capita growth, or whether per capita growth is significantly dependent on the past market capitalization ratio values.

## **B. Data**

In the previous section, I mention that as an indicator of the stock market activities, I use market capitalization as a proportion of output. To understand the relationship between market capitalization as a proportion of output and growth of output over time, I look at annual data on these two variables for 35 countries and 4 country groups for the time period covering 1988 to 2012. The 35 countries are Australia, Austria, Bangladesh, Belgium, Brazil, Canada, China, Columbia, Denmark, Egypt, Finland, France, Germany, Greece, India, Italy, Malaysia, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Philippines, Portugal, Russia, Singapore, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad and Tobago, United Kingdom and USA. The 4 country groups are Euro Area, South Asia, High Income non OECD countries and High Income OECD countries. Since I deal with data on market capitalization, it is understandable that the countries in question are mostly high income and middle income.

The data used for my analysis is secondary<sup>3</sup>. The time period and the choice of countries have been dictated by the availability of data.

In order to find a measure of output growth, I have first collected data on GDP per capita, which is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2005 U.S. dollars. From this series, I have constructed a gross growth of per capita GDP series for each country for the given time span of 25 years.

As a measure of financial health, I have used data on market capitalization as a percentage of GDP for each country for 25 years, where market capitalization (also known as market value) is the share price times the number of shares outstanding. Listed domestic companies are the domestically incorporated companies listed on the country's stock exchanges at the end of the year. Listed companies do not include investment companies, mutual funds, or other collective investment vehicles.

In the tables summarizing the empirical results, I use **MK** to denote market capitalization as a percentage of GDP and **PCG** to denote growth of per capita GDP over time. To ensure linearity, natural logs of both series are taken while performing empirical operations.

### **C. Cross country evidence of contemporaneous market capitalization ratio-growth relationship**

The contemporaneous stock market - growth relationship, as portrayed by the extant literature, is extremely complicated and dependent on a number of factors. In the previous section, the theory developed from the simple extension of the Lucas (1978) first order condition gives rise to a result, in which the contemporaneous relationship between market capitalization ratio and growth depends upon the value of the risk aversion parameter. Thus, before fully understanding the theoretical implication of this contemporaneous relationship, it is quite important to identify any specific stylized pattern emerging from the short run time path followed by market capitalization ratio and growth. In order to investigate this, I calculate the correlation coefficient between market capitalization as a percentage of GDP and growth of per capita GDP for each

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<sup>3</sup>Data Source: World Development Indicators ([www.data.worldbank.org](http://www.data.worldbank.org))

of the countries and country groups during the given time span of 25 years. Table 1 presents the correlation coefficient between market capitalization ratio and growth for each of the different countries and country groups.<sup>4</sup>

Out of the 35 countries under consideration, 27 depict a positive and significant correlation coefficient between market capitalization ratio and growth. These countries are highlighted in bold in Table 1, with the correlation coefficient being significant at 99% level of significance for 9 (Bangladesh, Brazil, Greece, India, Russia, South Africa, Sri Lanka, Sweden and Trinidad and Tobago) out of these 27 countries, significant at 95% level of significance for 9 (China, Columbia, Egypt, Finland, Italy, New Zealand, Nigeria, Pakistan and United Kingdom) out of these 27 countries and significant at 90% level of significance for the remaining 9 (Belgium, Canada, Malaysia, Netherlands, Philippines, Singapore, Switzerland, Thailand and USA) out of these 27 countries. Also 3 out of the 4 country groups depict a positive and significant correlation coefficient between market capitalization ratio and growth. The correlation coefficient is significant at 99% level of significance for 2 (South Asia and High income non OECD) out of these 3 countries, while it is significant at 95% for 1 (Euro Area) out of these 3 countries.<sup>5</sup> From this analysis, it is evident that for most of the developing and developed countries and country groups, market capitalization and growth are positively and significantly correlated, i.e. they move in the same direction in the short run. Figure 1 shows a bar diagrammatic representation of the correlation coefficients of different countries and country groups.

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<sup>4</sup>Table 1 can be found in the appendix.

<sup>5</sup>In Table, 99% level of significance is denoted by \*\*\*, 95% level of significance by \*\* and 90% level of significance by \*.

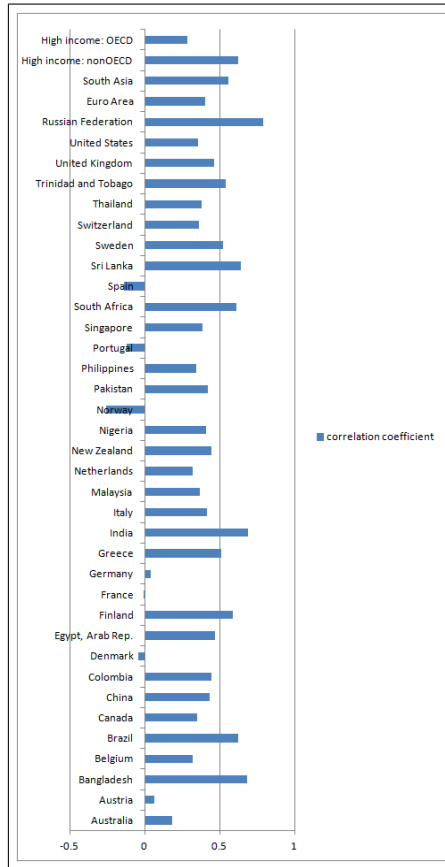


Figure 1: Correlation coefficients of different countries and country groups

Taking all countries and country groups, if I look into a quartile distribution of their respective correlation - coefficients, it is found that the correlation coefficient value corresponding to the first quartile is 0.320, the second quartile is 0.412 and the third quartile is 0.527. This implies that for 75% of all countries/ country groups in the data set, the market capitalization - growth correlation coefficient is greater than 0.320, for 50% of the countries/ country groups, the correlation coefficient between market capitalization and growth is greater than 0.412 and for 25% it is greater than 0.527. These results establish that in the short run, majority of the countries depict a positive significant correlation between market capitalization ratio and growth.

## **D. Cross country evidence of lead-lag relationship between market capitalization ratio and growth**

### **D.1 Granger Causality**

The existing theoretical literature discussed so far mostly looks at the contemporaneous relationship between market capitalization ratio and growth. A section of this literature envisages market capitalization to be the main determinant of growth, while another section, emerging out of the first order condition of the Lucas tree model, looks into GDP or its growth as the main determinant of stock prices. Yet another branch of literature that looks into production based models of asset pricing, come up with a bi-directional causality between stock market capitalization and growth. Brock (1982) merges the partial equilibrium frameworks of the production and consumption based asset pricing approaches and establishes a general equilibrium framework where both stock prices and growth are determined simultaneously, although his work does not focus particularly on the direction of causality between stock prices on the one hand and growth on the other. More realistically, in a certain time period, neither market capitalization ratio, nor growth might affect one another, although both can be driven simultaneously by a third exogenous factor. Also, instead of direct causality, there might exist a lead-lag relationship between the two variables in the sense that the change in one of them due to a shock might get transmitted to the other not immediately, but after a period or two. In this empirical section, I explore the lead-lag issue as well, but for the time being I focus on the direction of causality between stock market and growth. Since a large section of the literature is based on contemporaneous unidirectional and bidirectional causality between the two variables, I find it worthwhile to first check the direction of causality between market capitalization ratio and growth for each of the countries under consideration, in an attempt to understand whether market capitalization ratio is the main driving force towards growth or growth is the main driving force towards market capitalization ratio. Thus the purpose of this exercise is not necessarily to establish a direct causal relationship between the two variables, but to form some idea about which one of these variables precedes the other.

For this, I perform a Granger causality exercise for market capitalization ratio and growth for all the 35 countries and 4 country groups. For each of the different countries and country groups, data for each of the 2 variables is available for 25 years. Denoting market capitalization ratio

by  $MK_t$  and per capita growth by  $PCG_t$  and after ensuring that the two series are stationary, I conduct a joint granger causality exercise. To test the null hypothesis that  $MK_t$  does not granger cause  $PCG_t$ , consider the following autoregression

$$PCG_t = a_0 + a_1PCG_{t-1} + a_2PCG_{t-2} + \dots + PCG_{t-m} + b_1MK_{t-1} + b_2MK_{t-2} + \dots + b_nMK_{t-n} + \epsilon_{pcg\ t} \quad (27)$$

In this regression in (27) all lagged values of  $MK_t$  that are individually significant provided that collectively they add explanatory power to the regression according to an F test whose null hypothesis is no explanatory power jointly added by the different lagged values of  $MK_t$ . The null hypothesis that  $MK_t$  does not granger cause  $PCG_t$  is not rejected if and only if no lagged values of  $MK_t$  are retained in the regression.

Similarly, to test the null hypothesis that  $PCG_t$  does not granger cause  $MK_t$ , in the following autoregression

$$MK_t = \alpha_0 + \alpha_1MK_{t-1} + \alpha_2MK_{t-2} + \dots + \alpha_pMK_{t-p} + \beta_1PCG_{t-1} + \beta_2PCG_{t-2} + \dots + \beta_qPCG_{t-q} + \epsilon_{mk\ t} \quad (28)$$

if and only if no lagged values of  $PCG_t$  are retained in the regression, the null hypothesis cannot be rejected and it is established that  $PCG_t$  does not, indeed, granger cause  $MK_t$ .

In my analysis, I reject the null hypothesis in favour of the alternative hypothesis only if the p value falls below 0.05, in which case causality is established at 5% level of significance. The optimal lag length for each country is chosen by the Akaike Information Criterion. Table 2 summarises the direction of causality between  $MK_t$  and  $PCG_t$  for each country.<sup>6</sup>

From Table 2, it is evident that for 23 (Austria, Belgium, Brazil, Columbia, Denmark, Egypt, Finland, France, Germany, Greece, India, Italy, Malaysia, Netherlands, Norway, Pakistan, Philippines, Portugal, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad and Tobago, United Kingdom and USA) out of 35 countries, market capitalization granger causes per capita growth. For the remaining 12 (Australia, Bangladesh, Canada, China, Columbia, Greece, India, New Zealand, Nigeria, Russia, Singapore and South Africa) countries, none of the null hypothesis can be rejected, ie. for these 12 countries, neither market capitalization

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<sup>6</sup>Table 2 can be found in the appendix.

granger causes growth, nor growth granger causes market capitalization. For 3 (Euro Area, High income non OECD and High income OECD) of the 4 country groups, direction of causality runs from market capitalization to growth, while only for South Asia, no causality is found to exist either from market capitalization to growth or the other way round. For none of the countries and country groups, causality is observed to run from growth to market capitalization ratio. From these findings, it can be inferred that for majority of the country and country groups, direction of causality is found to exist from market capitalization ratio to growth and not the other way round.

## D.2 Variance decomposition analysis

Most of the theoretical literature on asset pricing look into the contemporaneous relationship between stock prices and growth. However, in reality the short run relationship between market capitalization and growth can be of a lead-lag nature, i.e. due to a one time shock, the change in behaviour of one of the variables in a certain time period can also have an influence on the other's behavioural pattern during later time periods. The relationship between the short run fluctuations in market capitalization ratio and growth, as represented by equation (23) provides a suitable foundation to test empirically the existence of a lead-lag relationship between market capitalization ratio and growth. In order to empirically test whether there exists a lead-lag relationship between market capitalization ratio and growth, I first conduct a variance decomposition exercise with all the countries within a VAR set up. In this way I compare the relative influence of market capitalization in determining future fluctuations of per capita growth with the role played by per capita growth in driving the future fluctuations of market capitalization ratio. Next I set up a panel VAR model to explore the influence of past values of one variable on the current value of the other, thereby investigating whether present market capitalization ratio depends significantly on past values of per capita growth or whether it is the past values of market capitalization ratio that significantly determinate per capita growth in the current period.

In order to understand whether there exists a lead-lag relationship between market capitalization ratio and growth, I first propose a vector autoregression (VAR) setting inspired by the literature that I surveyed so far from which with the help of a variance decomposition analysis, I find the influence of a one time shock to market capitalization on the short run fluctuations

of growth and also how much a one time shock to growth accounts for a change in short run fluctuations of market capitalization. The present study intends to contribute to the existing literature by undertaking the time series analysis for 35 countries and 4 country groups.

When it is unclear whether a variable is actually exogenous or not, a natural extension of transfer function analysis is to treat each variable symmetrically. A VAR framework helps us to understand how each variable depends on its lagged (past) values as well as the lagged values of the other variables. Denoting market capitalization as a ratio of GDP at time  $t$  by  $MK_t$  and per capita growth at time  $t$  by  $PCG_t$ , the time path of  $MK_t$  can be allowed to be affected by current and past realizations of the sequence of  $PCG_t$  and likewise the  $PCG_t$  sequence can be affected by current and past realizations of the  $MK_t$  sequence in the following  $p$ th order VAR setup:

$$\begin{aligned}
MK_t = & c_{mk} - a_{mk\ pcg}^0 PCG_t + a_{mk\ mk}^1 MK_{t-1} + a_{mk\ pcg}^1 PCG_{t-1} + a_{mk\ mk}^2 MK_{t-2} + \\
& a_{mk\ pcg}^2 PCG_{t-2} + \dots + a_{mk\ mk}^p MK_{t-p} + a_{mk\ pcg}^p PCG_{t-p} + \epsilon_{mk\ t} \quad (29)
\end{aligned}$$

$$\begin{aligned}
PCG_t = & c_{pcg} - a_{pcg\ mk}^0 MK_t + a_{pcg\ mk}^1 MK_{t-1} + a_{pcg\ pcg}^1 PCG_{t-1} + a_{pcg\ mk}^2 MK_{t-2} + \\
& a_{pcg\ pcg}^2 PCG_{t-2} + \dots + a_{pcg\ mk}^p MK_{t-p} + a_{pcg\ pcg}^p PCG_{t-p} + \epsilon_{pcg\ t} \quad (30)
\end{aligned}$$

The first model in equation (29) describes how market capitalization as a ratio of GDP at time  $t$  ( $MK_t$ ) depends on its own past values upto  $p$  lags as well as the past values of per capita growth  $PCG$  also upto  $p$  lags.  $MK_{t-p}$  denotes the value of market capitalization as a ratio of GDP  $p$  periods before time period  $t$ . Similarly,  $PCG_{t-p}$  denotes per capita growth  $p$  periods before time period  $t$ . In a similar manner, the second model describes how per capita growth at time period  $t$  ( $PCG_t$ ) depends on its own past values upto  $p$  lags as well as the past values of market capitalization ratio  $MK$  also upto  $p$  lags.

$c_{mk}$  and  $c_{pcg}$  denote the constant terms and the coefficient  $a_{i,j}^k$  denotes the measure of the dependence of  $i$  on  $j$ , where  $i = mk, pcg$  and  $j = mk, pcg$ .

It is assumed that both  $MK_t$  and  $PCG_t$  are stationary,  $\epsilon_{mk\ t}$  and  $\epsilon_{pcg\ t}$  are white noise disturbances with standard deviations  $\sigma_{mk}$  and  $\sigma_{pcg}$  respectively and  $\{\epsilon_{mk\ t}\}$  and  $\{\epsilon_{pcg\ t}\}$  are uncorrelated white noise disturbances.



The structure of the system represented by equations (29) and (30) incorporates feedback because  $MK_t$  and  $PCG_t$  are allowed to affect each other. For example,  $a_{mk\ pcg}^0$  is the contemporaneous effect of a unit change of  $PCG_t$  on  $MK_t$  and  $a_{mk\ pcg}^1$  is the effect of a unit change in  $PCG_{t-1}$  on  $MK_t$ . The terms  $\epsilon_{mk\ t}$  and  $\epsilon_{pcg\ t}$  are pure innovations or shocks in  $MK_t$  and  $PCG_t$  respectively. Thus, assuming coefficients  $a_{i,j}^k \neq 0$ , a shock to market capitalization ratio (per capita growth) in time period  $t$  will indirectly affect per capita growth (market capitalization ratio) contemporaneously in time period  $t$  as well as in future time periods.

Now, in order to investigate whether a lead-lag relationship exists between market capitalization ratio and growth, I have to figure out how market capitalization in a certain time period affects growth in later time periods and also how growth affects market capitalization in the future, both in the short run and in the long run. For this, I examine the forecast error variance decompositions, which indicate the percentage of the variance in one variable that is due to errors in forecasting itself as well as the other variable. In other words, the forecast error variance decomposition is used to understand the proportion of movements in a sequence due to its own shocks versus shocks to the other variable. If  $\epsilon_{pcg\ t}$  shocks explain none of the forecast error variance of  $MK_t$  at all forecast horizons, it can be inferred that the  $\{MK_t\}$  sequence is exogenous. In this case  $MK_t$  evolves independently of the  $\epsilon_{pcg\ t}$  shocks and of the  $\{PCG_t\}$  sequence. At the other extreme,  $\epsilon_{pcg\ t}$  could explain all the forecast error variance in the  $\{MK_t\}$  sequence at all forecast horizons, making  $MK_t$  entirely endogenous.

However, a variance decomposition analysis of market capitalization as a ratio of GDP i.e.  $MK_t$  and growth of per capita GDP i.e.  $PCG_t$  establish that for all 35 countries and 4 country groups, neither  $MK_t$  nor  $PCG_t$  is entirely exogenous or endogenous, i.e. forecast error variance in each of these variables is influenced partly due to its own shock and partly as a result of shock to the other variable. Although in each period, short run fluctuations of  $MK_t$  and  $PCG_t$  are caused due to shocks in both these variables, in order to clearly understand which of the variables has a greater impact on the other's behaviour during the future time periods, I focus only on the shock impact of a particular variable in explaining the fluctuations of the other variable. In other words, as a result of the variance decomposition analysis, I compare the influence of a one time shock to  $MK_t$  in explaining short run movements of  $PCG_t$  during the later periods with the effect of a one time shock to  $PCG_t$  in explaining the future short run fluctuations in  $MK_t$ .

For my analysis, I choose the number of time periods as 10, but report my findings only for

period 2 and period 10, with period 2 taken as the short run and period 10 as the comparatively longer run. For all the countries and country groups, the percentage of the total change in fluctuations of  $PCG_t$  brought about due to a one time shock on  $MK_t$ , is reported both for period 2 and for period 10. Similarly, the percentage of the variance in fluctuations in  $MK_t$  explained by a one time shock to  $PCG_t$  is also reported for both long run and short run scenarios. I calculate the business cycle fluctuations using the Christiano Fitzgerald filter, separating out the cyclical component from the trend component of a series. In this way, for each of the thirty-three countries, I obtain the short run fluctuations in  $MK_t$  as well as  $PCG_t$ . These short run business cycle fluctuations represent a deviation from trend for each variable. Since I am interested to investigate which variable is the main driving force towards a change in short run behaviour of the other variable, I choose to carry out a variance decomposition analysis of the short run fluctuations of  $MK_t$  and  $PCG_t$  for each of the countries and country groups. The optimal lag length for this analysis is selected according to the Akaike Information Criteria. Tables 3 and 4 report the influence of  $MK_t$  on  $PCG_t$  and vice versa for the 2nd period and the 10th period respectively, treating  $MK_t$  as the exogenous variable in the Cholesky ordering for VAR. The countries for which  $MK_t$  is the main determinant of the short run behaviour of  $PCG_t$  during the later periods are highlighted in each of the following tables.<sup>7</sup>

From Table 3 it follows that, for all countries except Russia, the variance in fluctuations of per capita growth in the 2nd period due to a one time shock to market capitalization ratio is far more than the short run variance in fluctuations of market capitalization due to a one time shock to per capita growth when market capitalization ratio is treated as the exogenous variable in the Cholesky ordering of the VAR set-up.

From Table 4 it follows that in the 10th period also market capitalization ratio plays a much more dominant role in determining the fluctuations of per capita growth, compared to the role played by per capita growth in determining the cyclical behaviour of market capitalization ratio, when market capitalization ratio is treated as the exogenous variable in the Cholesky ordering. However, in the 10th period, there is increase in the number of countries for which per capita growth plays a much more dominant role in determining the short run fluctuations of market capitalization ratio. This number increased from 1 in the 2nd period to 6 in the 10th period; the 6 countries being Australia, Austria, Malaysia, Nigeria, Portugal and Russia. From

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<sup>7</sup>Tables 3 and 4 can be found in the appendix.

Tables 4 and 5, it is clear that Russia is the only country for which per capita growth as a driving force behind the cyclical fluctuations of market capitalization ratio dominates market capitalization ratio both in the short run and in the comparatively long run. Australia, Austria, Malaysia, Nigeria and Portugal were the countries for which the percentage of fluctuations in per capita growth as determined by market capitalization ratio is found to dominate those in market capitalization ratio determined by per capita growth only for the shorter run, but not for the comparatively longer run.

However, throughout the above analysis of variance decomposition, market capitalization ratio has been treated as the exogenous variable in the Cholesky ordering. It will be interesting to figure out the extent of forecast error decomposition of market capitalization ratio as explained by per capita growth and that of per capita growth as explained by market capitalization ratio when the Cholesky ordering is reversed i.e. per capita growth is treated as the exogenous variable and market capitalization ratio is treated as the endogenous variable. Table 5 depicts the short run effect of a one time shock to per capita growth on the fluctuations in market capitalization ratio and vice versa in the 2nd period and Table 6 depicts the effect of market capitalization on the cyclical behaviour of per capita growth in the 10th period when per capita growth instead of market capitalization ratio is treated as the exogenous variable in the Cholesky ordering.<sup>8</sup>

From Table 5 it is clear that even when per capita growth is treated as the exogenous variable, a one time shock to market capitalization ratio has more influence on the short run fluctuations of per capita growth than the impact of a one time shock to per capita growth on the cyclical behaviour of market capitalization ratio in the 2nd period for majority of countries and country groups. For 26 out of 35 countries and 2 out of 4 country groups, the percentage of fluctuations of per capita growth as explained by market capitalization ratio is greater than the fluctuations of market capitalization ratio explained by per capita growth. The 9 countries for which per capita growth is the main driving force towards the cyclical behaviour of market capitalization ratio during the later time periods are Australia, Greece, India, Netherlands, New Zealand, Norway, Pakistan, Russia and Spain, while among the country groups, this holds true for the 2 country groups of South Asia and High Income non OECD.

From Table 6 it is evident that when per capita growth is treated as the exogenous variable in the Cholesky ordering, still for 26 of the 35 countries and 3 out of the 4 country groups, market

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<sup>8</sup>Tables 5 and 6 can be found in the appendix.

capitalization ratio can explain more of the short run fluctuations of per capita growth than the corresponding impact of per capita growth on the cyclical behaviour of market capitalization ratio in the 10th time period. The 9 countries for which per capita growth is the main driving force towards the cyclical behaviour of market capitalization ratio during the later time periods are Australia, Greece, India, Netherlands, New Zealand, Norway, Pakistan, Russia and Spain, while among the country groups, this holds true only for South Asia.

From Table 5 and Table 6 it follows that for Greece, India, Netherlands, New Zealand, Norway, Russia, Spain and South Asia, market capitalization is not the chief determinant of fluctuations in per capita growth throughout the initial and later time periods, when per capita growth is treated as the exogenous variable in the Cholesky ordering. For Australia, Pakistan and the High Income non OECD country group, only for the tenth period and not for the second period, the percentage of fluctuations in per capita growth determined by market capitalization is found to be larger than the percentage of fluctuations in market capitalization ratio determined by per capita growth. On the other hand, for Nigeria and Portugal, the percentage of fluctuations in per capita growth as determined by market capitalization ratio is found to dominate those in market capitalization ratio determined by per capita growth for the second period, but not for the tenth period.

Thus for 8 countries, market capitalization ratio determines per capita growth fluctuations neither in the short run, nor in the long run when per capita growth is treated as the exogenous variable in the Cholesky ordering; these 8 countries being Greece, India, Netherlands, New Zealand, Norway, Russia, Spain and South Asia. However, this number is only one (Russia) when market capitalization ratio is treated as exogenous in the ordering.

On the whole, irrespective of the nature of Cholesky ordering, the variance decomposition analysis establishes that for most countries market capitalization is the main determinant of future fluctuations of per capita growth both in the short run and in the comparatively long run. This further establishes the lead-lag relationship between market capitalization ratio and per capita growth.

### **D.3 Panel VAR analysis**

Since I have 25 years data on market capitalization ratio and per capita growth for each of 35 countries and 4 country groups, it is worthwhile to perform a panel VAR taking into account

the entire data set by creating a balanced panel. In this set-up, by running a test for joint causality, my ultimate goal is to figure out whether market capitalization ratio depends on the lagged (past) values of per capita growth, or whether per capita growth depends on the past values of market capitalization ratio, even when I do not assume any particular variable to be exogenous. This enables me to understand whether a lead-lag relationship exists in the first place between market capitalization and growth and if such a relationship exists, what is its nature, i.e. whether market capitalization ratio significantly influences future growth or whether growth significantly determines future market capitalization ratio.

After ensuring both the market capitalization ratio and per capita growth series are stationary for all 35 countries and 4 country groups, a panel cointegration test is performed using the Kao residual cointegration test, first by treating market capitalization ratio as exogenous and next by treating per capita growth as exogenous. On both occasions, the null hypothesis of no cointegration cannot be rejected, thus ensuring that the absence of cointegration between market capitalization ratio and growth. As a result, I can perform the panel VAR exercise.

First, I take market capitalization as the dependent variable. From the Akaike information Criteria, the optimal number of lags for each of these variables is found to be 4. Denoting market capitalization ratio by  $MK_t$  and per capita growth by  $PCG_t$ , equation (31) describes how market capitalization depends on its own past values (upto 4 lags) as well as the past values (upto 4 lags) of per capita growth.

$$\begin{aligned}
 MK_t = & C_1 + C_2MK_{t-1} + C_3MK_{t-2} + C_4MK_{t-3} + C_5MK_{t-4} + C_6PCG_{t-1} \quad (31) \\
 & + C_7PCG_{t-2} + C_8PCG_{t-3} + C_9PCG_{t-4}
 \end{aligned}$$

There is no error correction term in the above equation as no cointegration exists between market capitalization ratio and per capita growth in the panel data set. A Hausman Test rejects the null hypothesis of a random effect model being the most appropriate for the panel data set in favour of a fixed effect model. Hence, within the framework of a fixed effect model, I check whether or not market capitalization at time period  $t$  i.e.  $MK_t$  depends jointly and significantly on the past four period values of per capita growth i.e.  $PCG_{t-1}$ ,  $PCG_{t-2}$ ,  $PCG_{t-3}$  and  $PCG_{t-4}$ . For this purpose, a null hypothesis of  $C_6 = C_7 = C_8 = C_9 = 0$  is set up. A  $p$ -value of 0.09(> 0.05) indicates that I must accept the null hypothesis that current market

capitalization ratio does not depend on the values of per capita growth upto the past 4 periods.

Next, I perform the panel VAR exercise with per capita growth as the dependent variable. Equation (32) describes how per capita growth depends on its own past values (4 lags) as well as the past values (4 lags) of market capitalization (MK) i.e.

$$PCG_t = C_1 + C_2PCG_{t-1} + C_3PCG_{t-2} + C_4PCG_{t-3} + C_5PCG_{t-4} + C_6MK_{t-1} \quad (32) \\ + C_7MK_{t-2} + C_8MK_{t-3} + C_9MK_{t-4}$$

As no cointegration is found to exist between market capitalization and growth from the panel data set, equation (32) is also devoid of any error correction term. In this case also a Houseman Test rejects the null hypothesis of a random effect model being the most appropriate for the data set in favour of a fixed effect model. Hence, with the help of a fixed effect model, I check whether or not per capita growth at time period  $t$  i.e.  $PCG_t$  depends significantly and jointly on  $MK_{t-1}$ ,  $MK_{t-2}$ ,  $MK_{t-3}$  and  $MK_{t-4}$ , i.e. the past four period values of market capitalization ratio, by setting up the null hypothesis of  $C_6 = C_7 = C_8 = C_9 = 0$ . A p-value of  $0.001 (< 0.05)$  indicates rejection of the null hypothesis that per capita growth today does not depend on the values of market capitalization upto the past four periods and acceptance of the alternative hypothesis that per capita growth at time period  $t$  depends upon past four period values of market capitalization i.e.  $MK_{t-1}$ ,  $MK_{t-2}$ ,  $MK_{t-3}$  and  $MK_{t-4}$ .

Thus the panel VAR analysis establishes that in a given time period although market capitalization ratio does not depend significantly on the past values of per capita growth, per capita growth significantly depends on the past market capitalization ratio values.

## VI. Emerging Research Questions

The link between stock markets and economic growth has been an important issue in Economics for quite some time now. The existing literature, both empirical and theoretical, suggests a connection, though not very definitive, between stock market development on the one hand and economic growth on the other. Although the empirical research postulate a causal relationship, most of the empirical studies on this area have addressed the issue of causality rather obliquely. Also, the stock market - growth relationship, as portrayed by the theoretical literature, is far from simple, to say the least. A relatively older section of the theoretical literature envisages stock

market developments as the leading determinant of growth. Another section of the theoretical literature, following from the first order condition of Lucas (1978), implicitly look into the role of output growth in determining stock prices in an economy. This branch of literature, known as the consumption based approach to asset pricing, model only the consumption side, but not the production side of the economy. A third section of the theoretical literature focus only on the production side and investment, but not the consumption side of the economy. This branch of literature deal with production based asset pricing models and establish a bi-directional causality between stock prices and economic growth, as put forward by Cochrane (1991). However, in the real world, both stock market and growth might not affect each other directly and both are likely to be determined simultaneously by exogenous factors. This is captured by Brock (1982) where the partial equilibrium frameworks of consumption and production based models of asset pricing is merged to form a Lucas tree model with investment and production. Within this general equilibrium structure, both stock prices and output growth can be determined simultaneously by different exogenous factors. In my thesis, I focus on the theoretical side of the stock market - growth literature and wish to work along the lines of a general equilibrium model similar to the one developed by Brock (1982) in order to understand the short run dynamics of stock market capitalization and growth as a result of the realization of different aggregate shocks within the economy. However, before I formally proceed with the modelling, it is important to establish a few stylized facts regarding the short run behaviour of stock market and growth, which can be tested by the theory.

For this I look into data on market capitalization as a ratio of GDP and per capita growth for 35 countries and 4 country groups. Firstly, I observe that the contemporaneous relationship between market capitalization and growth, as established by the literature (both empirical and theoretical), is quite complex. It is very likely that both stock market activities and growth are influenced by aggregate shocks within the economy, which is not explored throughout the bulk of the literature. In order to understand the contemporaneous short run behaviour of market capitalization ratio and growth, I compare the correlation coefficient between market capitalization as a ratio of output and per capita growth and find that correlation coefficient is positive and significant for 27 out of 35 countries and 3 of the 4 country groups. From this, it is clear that market capitalization ratio and per capita growth move in the same direction in the short run. Also, in reality, the effect of a macroeconomic shock on one of the variables might

get translated to the other not immediately, but with a lag. The extant literature does not capture a possible lead-lag relationship between stock market capitalization and growth which can occur in this way. Since nothing definite can be inferred from the theoretical as well as the empirical literature about the existence of a lead-lag relationship between market capitalization ratio and growth, I perform a Granger causality analysis, a variance decomposition analysis and a panel VAR analysis in order to develop some understanding about the nature of this lead-lag relationship, if there exists any. The Granger causality exercise on 35 countries and 4 country groups establish that causality mostly flows from market capitalization towards growth. Next, I perform a variance decomposition analysis within a VAR structure to establish that for most of the countries and country groups, the percentage of fluctuations in future per capita growth that can be explained by a one time shock to market capitalization ratio is much greater than the percentage of fluctuations of future period market capitalization ratio, as explained by a shock to per capita growth. Finally, by means of a panel VAR, I establish that per capita growth in a certain time period depends significantly on lagged values of market capitalization ratio, although the opposite is not necessarily true, thereby establishing the fact that the influence of stock market capitalization gets translated to growth not immediately, but with a lag.

Thus two main short run patterns emerge as a result of the empirical analysis. They are:

(1) In the short run, market capitalization - output ratio and output growth are positively correlated, i.e. due to different macroeconomic shocks, both follow the same short run time path. Hence, a positive and significant contemporaneous relationship is found to exist between market capitalization ratio and growth.

(2) In the short run, due to macroeconomic shocks, the change in behaviour of market capitalization ratio gets transmitted into per capita growth to affect fluctuations of the latter during subsequent time periods. In comparison, the change in behaviour of per capita growth does not translate into market capitalization ratio to significantly affect the latter's short run fluctuations in subsequent periods. This shows that there exists a lead-lag relationship between market capitalization ratio and growth in the sense that due to different aggregate shocks, the change in behaviour of the former takes some time to get translated to the latter. The variance decomposition analysis shows that market capitalization ratio explains a considerable percentage of the fluctuations of per capita growth during later time periods, thereby establishing that the former is the chief determinant of the latter's future behaviour, although in reality, both can be



driven by different macroeconomic shocks.

My next step is to identify the fundamental that drives the two main stylized facts as stated above. These fundamentals can be Total Factor Productivity (TFP) shocks, Investment Specific Technology (IST) shocks, Capital Quality (CQ) shocks ie positive or negative changes in capital stock through appreciation or depreciation of capital, preference shocks or a financial shocks and can be captured within a Dynamic Stochastic General Equilibrium (DSGE) model.

Therefore, I pose two main research questions:

- (a) Why is there a positive correlation between market capitalization ratio and growth? and
- (b) Why is there a lead-lag relationship between the two?

In the following chapters I develop DSGE models with different economic frameworks, where I explore the relative role of different aggregate shocks in explaining the contemporaneous and the lead -lag short run behaviour of market capitalization ratio and growth, as established empirically in the present chapter. My aim is to come up with sound theoretical models, which can explain both kind of patterns in the short run dynamics of stock market and economic growth that have emerged from the present empirical analysis.

## Appendix

### Derivation of equation (20) and equation (23)

Going back to the Lucas Tree Model in equation (18), ignoring the expectations sign and taking log on both sides, I get:

$$\ln\left(\frac{p_t}{y_t}\right) = \ln\beta + \ln\left(\frac{p_{t+1}}{y_{t+1}} + 1\right) + (1 - \alpha)\ln\left(\frac{y_{t+1}}{y_t}\right) \quad (33)$$

Taking ln deviations from steady state values I get:

$$\ln\left(\frac{p_t}{y_t}\right) - \ln\left(\frac{\bar{p}}{\bar{y}}\right) = \left\{\ln\left(\frac{p_{t+1}}{y_{t+1}} + 1\right) - \ln\left(\frac{\bar{p}}{\bar{y}} + 1\right)\right\} + (1 - \alpha)\left\{\ln\left(\frac{y_{t+1}}{y_t}\right) - \ln(1 + \gamma)\right\}$$

=>

$$\widehat{\left(\frac{p_t}{y_t}\right)} = E_t\left(\widehat{\left(\frac{p_{t+1}}{y_{t+1}} + 1\right)}\right) + (1 - \alpha)E_t\left(\widehat{\left(\frac{y_{t+1}}{y_t}\right)}\right) \quad (34)$$

Now,

$$\begin{aligned} \widehat{\left(\frac{p_{t+1}}{y_{t+1}} + 1\right)} &= \frac{\frac{p_{t+1}}{y_{t+1}} + 1 - \frac{\bar{p}}{\bar{y}} - 1}{\frac{\bar{p}}{\bar{y}} + 1} \\ &= \left[\frac{\frac{p_{t+1}}{y_{t+1}} - \frac{\bar{p}}{\bar{y}}}{\frac{\bar{p}}{\bar{y}} + 1}\right] \left[\frac{\bar{p}}{\bar{y}} + 1\right] \\ &= \frac{\widehat{\left(\frac{p_{t+1}}{y_{t+1}}\right)}}{\frac{\bar{p}}{\bar{y}} + 1} \end{aligned} \quad (35)$$

Substituting (35) in (34) I get:

$$\begin{aligned} \widehat{\left(\frac{p_t}{y_t}\right)} &= \left[\frac{\frac{\bar{p}}{\bar{y}}}{\frac{\bar{p}}{\bar{y}} + 1}\right] E_t\left(\widehat{\left(\frac{p_{t+1}}{y_{t+1}}\right)}\right) + (1 - \alpha)E_t\left(\widehat{\left(\frac{y_{t+1}}{y_t}\right)}\right) \\ &= \pi_1 E_t\left(\widehat{\left(\frac{p_{t+1}}{y_{t+1}}\right)}\right) + \pi_2 E_t\left(\widehat{\left(\frac{y_{t+1}}{y_t}\right)}\right) \end{aligned} \quad (36)$$

$$\left(\text{where } \left[\frac{\frac{\bar{p}}{\bar{y}}}{\frac{\bar{p}}{\bar{y}} + 1}\right] = \pi_1 \text{ and } (1 - \alpha) = \pi_2\right)$$

Equation (36) is the same as equation (20).

Along the Steady State, I have:

$$\frac{\bar{p}}{y} = \frac{\beta(1+\gamma)^{1-\alpha}}{1-\beta(1+\gamma)^{1-\alpha}}$$

Substituting this in (36) we get:

$$\widehat{\left(\frac{p_t}{y_t}\right)} = \{\beta(1+\gamma)^{(1-\alpha)}\}E_t\left(\frac{\widehat{p_{t+1}}}{y_{t+1}}\right) + (1-\alpha)E_t\left(\frac{\widehat{y_{t+1}}}{y_t}\right)$$

Now, I have:

$$\frac{\widehat{y_{t+1}}}{y_t} = \rho \frac{\widehat{y_t}}{y_{t-1}} + \varepsilon_{t+1}$$

=>

$$E_t \frac{\widehat{y_{t+1}}}{y_t} = \rho \frac{\widehat{y_t}}{y_{t-1}}$$

Therefore,

$$\widehat{\left(\frac{p_t}{y_t}\right)} = \{\beta(1+\gamma)^{(1-\alpha)}\}E_t\left(\frac{\widehat{p_{t+1}}}{y_{t+1}}\right) + (1-\alpha)\rho \frac{\widehat{y_t}}{y_{t-1}} \quad (37)$$

Let  $\widehat{\left(\frac{p_t}{y_t}\right)} = z_t$  and  $\widehat{\left(\frac{y_t}{y_{t-1}}\right)} = x_t$ , which makes equation (37)

$$z_t = \{\beta(1+\gamma)^{(1-\alpha)}\}E_t z_{t+1} + (1-\alpha)\rho x_t \quad (38)$$

Let  $z_t = \lambda x_t$ .

=>

$$\lambda x_t = \{\lambda\beta(1+\gamma)^{(1-\alpha)}\}E_t(x_{t+1}) + (1-\alpha)\rho x_t \quad (39)$$

Now,

$$x_{t+1} = \rho x_t + \varepsilon_{t+1}$$

=>

$$E_t(x_{t+1}) = \rho x_t \quad (40)$$

Plugging (40) in (39), we get:

$$\lambda = \frac{(1 - \alpha)\rho}{1 - \rho\beta(1 + \gamma)^{1-\alpha}}$$

=>

$$\frac{\widehat{p}_t}{y_t} = \left( \frac{(1 - \alpha)\rho}{1 - \rho\beta(1 + \gamma)^{1-\alpha}} \right) \frac{\widehat{y}_t}{y_{t-1}} \quad (41)$$

Equation (41) is the same as equation (23).

Table 1: market capitalization - growth correlation coefficient values for different countries and country groups

Country/Country Groups	MK-PCG correlation coefficient
Australia	0.1842
Austria	0.0625
<b>Bangladesh</b>	0.6829***
<b>Belgium</b>	0.3187*
<b>Brazil</b>	0.6236***
<b>Canada</b>	0.3498*
<b>China</b>	0.4351**
<b>Columbia</b>	0.4462**
Denmark	-0.0407
<b>Egypt</b>	0.4669**
<b>Finland</b>	0.5896**
France	-0.0017
Germany	0.0405
<b>Greece</b>	0.5090***
<b>India</b>	0.6870***
<b>Italy</b>	0.4125**
<b>Malaysia</b>	0.3704*
<b>Netherlands</b>	0.3206*
<b>New Zealand</b>	0.4437**
<b>Nigeria</b>	0.4115**
Norway	-0.2570
<b>Pakistan</b>	0.4185**
<b>Philippines</b>	0.3463*
Portugal	-0.1209
<b>Russia</b>	0.7926***
<b>Singapore</b>	0.3833*
<b>South Africa</b>	0.6087***
Spain	-0.1400
<b>Sri Lanka</b>	0.6424***
<b>Sweden</b>	0.5233***
<b>Switzerland</b>	0.3602*
<b>Thailand</b>	0.3767*
<b>Trinidad and Tobago</b>	0.5390***
<b>United Kingdom</b>	0.4644**
<b>USA</b>	0.3580*
<b>Euro Area</b>	0.4002**
<b>South Asia</b>	0.5553***
<b>High income non OECD</b>	0.6203***
High income OECD	0.2855

Table 2: Granger causality analysis for different countries and country groups

Country/Country Groups	Direction of Causality between MK and PCG
Australia	No Causality
<b>Austria</b>	<b>MK→PCG</b>
Bangladesh	No Causality
<b>Belgium</b>	<b>MK→PCG</b>
<b>Brazil</b>	<b>MK→PCG</b>
Canada	No Causality
China	No Causality
Columbia	No Causality
<b>Denmark</b>	<b>MK→PCG</b>
<b>Egypt</b>	<b>MK→PCG</b>
<b>Finland</b>	<b>MK→PCG</b>
<b>France</b>	<b>MK→PCG</b>
<b>Germany</b>	<b>MK→PCG</b>
Greece	No Causality
India	No Causality
<b>Italy</b>	<b>MK→PCG</b>
<b>Malaysia</b>	<b>MK→PCG</b>
<b>Netherlands</b>	<b>MK→PCG</b>
New Zealand	No Causality
Nigeria	No Causality
<b>Norway</b>	<b>MK→PCG</b>
<b>Pakistan</b>	<b>MK→PCG</b>
<b>Philippines</b>	<b>MK→PCG</b>
<b>Portugal</b>	<b>MK→PCG</b>
Russia	No Causality
Singapore	No Causality
South Africa	No Causality
<b>Spain</b>	<b>MK→PCG</b>
<b>Sri Lanka</b>	<b>MK→PCG</b>
<b>Sweden</b>	<b>MK→PCG</b>
<b>Switzerland</b>	<b>MK→PCG</b>
<b>Thailand</b>	<b>MK→PCG</b>
<b>Trinidad and Tobago</b>	<b>MK→PCG</b>
<b>United Kingdom</b>	<b>MK→PCG</b>
<b>USA</b>	<b>MK→PCG</b>
<b>Euro Area</b>	<b>MK→PCG</b>
South Asia	No Causality
<b>High income non OECD</b>	<b>MK→PCG</b>
<b>High income OECD</b>	<b>MK→PCG</b>

Table 3: Short run (p=2) forecast error decomposition of MK as explained by PCG and that of PCG explained by MK (Cholesky ordering: MK,PCG)

Country/Groups	% MK variance explained by PCG	% PCG variance explained by MK
<b>Australia</b>	<b>5.29%</b>	<b>6.33%</b>
<b>Austria</b>	<b>13.21%</b>	<b>14.36%</b>
<b>Bangladesh</b>	<b>2.13%</b>	<b>46.26%</b>
<b>Belgium</b>	<b>9.48%</b>	<b>46.40%</b>
<b>Brazil</b>	<b>7.14%</b>	<b>77.22%</b>
<b>Canada</b>	<b>4.27%</b>	<b>49.45%</b>
<b>China</b>	<b>8.08%</b>	<b>41.94%</b>
<b>Columbia</b>	<b>6.44%</b>	<b>31.32%</b>
<b>Denmark</b>	<b>0.44%</b>	<b>79.06%</b>
<b>Egypt</b>	<b>0.51%</b>	<b>51.84%</b>
<b>Finland</b>	<b>3.81%</b>	<b>63.85%</b>
<b>France</b>	<b>3.38%</b>	<b>60.03%</b>
<b>Germany</b>	<b>4.45%</b>	<b>67.26%</b>
<b>Greece</b>	<b>3.63%</b>	<b>64.16%</b>
<b>India</b>	<b>2.88%</b>	<b>37.17%</b>
<b>Italy</b>	<b>0.25%</b>	<b>31.80%</b>
<b>Malaysia</b>	<b>0.28%</b>	<b>52.64%</b>
<b>Netherlands</b>	<b>1.82%</b>	<b>72.65%</b>
<b>New Zealand</b>	<b>1.83%</b>	<b>30.18%</b>
<b>Nigeria</b>	<b>2.16%</b>	<b>2.18%</b>
<b>Norway</b>	<b>1.14%</b>	<b>39.10%</b>
<b>Pakistan</b>	<b>7.46%</b>	<b>40.25%</b>
<b>Philippines</b>	<b>2.87%</b>	<b>30.98%</b>
<b>Portugal</b>	<b>2.04%</b>	<b>69.26%</b>
Russia	25.47%	15.82%
<b>Singapore</b>	<b>2.86%</b>	<b>67.92%</b>
<b>South Africa</b>	<b>4.49%</b>	<b>48.32%</b>
<b>Spain</b>	<b>47.29%</b>	<b>65.52%</b>
<b>Sri Lanka</b>	<b>3.26%</b>	<b>48.49%</b>
<b>Sweden</b>	<b>1.42%</b>	<b>72.17%</b>
<b>Switzerland</b>	<b>1.50%</b>	<b>68.48%</b>
<b>Thailand</b>	<b>2.82%</b>	<b>56.25%</b>
<b>Trinidad and Tobago</b>	<b>4.04%</b>	<b>20.22%</b>
<b>UK</b>	<b>1.30%</b>	<b>51.51%</b>
<b>USA</b>	<b>1.44%</b>	<b>66.47%</b>
<b>Euro Area</b>	<b>1.11%</b>	<b>87.95%</b>
<b>South Asia</b>	<b>0.06%</b>	<b>34.87%</b>
<b>High Income non OECD</b>	<b>0.50%</b>	<b>83.57%</b>
<b>High Income OECD</b>	<b>0.11%</b>	<b>91.45%</b>

Table 4: Short run (p=10) forecast error decomposition of MK as explained by PCG and that of PCG explained by MK (Cholesky ordering: MK,PCG)

Country/Groups	% MK variance explained by PCG	% PCG variance explained by MK
Australia	9.22%	7.57%
Austria	49.17%	14.69%
<b>Bangladesh</b>	<b>15.43%</b>	<b>45.33%</b>
<b>Belgium</b>	<b>20.35%</b>	<b>58.41%</b>
<b>Brazil</b>	<b>22.67%</b>	<b>75.67%</b>
<b>Canada</b>	<b>5.86%</b>	<b>66.31%</b>
<b>China</b>	<b>34.04%</b>	<b>42.20%</b>
<b>Columbia</b>	<b>6.43%</b>	<b>41.38%</b>
<b>Denmark</b>	<b>6.89%</b>	<b>82.41%</b>
<b>Egypt</b>	<b>7.80%</b>	<b>70.99%</b>
<b>Finland</b>	<b>21.34%</b>	<b>65.34%</b>
<b>France</b>	<b>12.86%</b>	<b>70.04%</b>
<b>Germany</b>	<b>14.39%</b>	<b>67.92%</b>
<b>Greece</b>	<b>27.20%</b>	<b>36.83%</b>
<b>India</b>	<b>6.81%</b>	<b>61.20%</b>
<b>Italy</b>	<b>0.43%</b>	<b>36.59%</b>
Malaysia	44.44%	39.19%
<b>Netherlands</b>	<b>14.45%</b>	<b>69.41%</b>
<b>New Zealand</b>	<b>3.16%</b>	<b>28.95%</b>
Nigeria	32.50%	8.70%
<b>Norway</b>	<b>10.13%</b>	<b>50.85%</b>
<b>Pakistan</b>	<b>13.42%</b>	<b>40.99%</b>
<b>Philippines</b>	<b>4.23%</b>	<b>30.64%</b>
Portugal	51.78%	41.87%
Russia	36.97%	22.48%
<b>Singapore</b>	<b>22.09%</b>	<b>59.45%</b>
<b>South Africa</b>	<b>6.58%</b>	<b>66.76%</b>
<b>Spain</b>	<b>62.64%</b>	<b>46.32%</b>
<b>Sri Lanka</b>	<b>3.58%</b>	<b>51.09%</b>
<b>Sweden</b>	<b>3.21%</b>	<b>80.62%</b>
<b>Switzerland</b>	<b>4.45%</b>	<b>72.34%</b>
<b>Thailand</b>	<b>4.09%</b>	<b>57.84%</b>
<b>Trinidad and Tobago</b>	<b>6.50%</b>	<b>24.59%</b>
<b>UK</b>	<b>1.64%</b>	<b>66.97%</b>
<b>USA</b>	<b>2.88%</b>	<b>77.93%</b>
<b>Euro Area</b>	<b>7.82%</b>	<b>89.19%</b>
<b>South Asia</b>	<b>6.92%</b>	<b>34.01%</b>
<b>High Income non OECD</b>	<b>3.29%</b>	<b>91.14%</b>
<b>High Income OECD</b>	<b>3.14%</b>	<b>93.75%</b>



Table 5: Short run (p=2) forecast error decomposition of MK as explained by PCG and that of PCG explained by MK (Cholesky ordering: PCG,MK)

Country/Groups	% MK variance explained by PCG	% PCG variance explained by MK
Australia	6.92%	0.83%
<b>Austria</b>	<b>0.34%</b>	<b>10.22%</b>
<b>Bangladesh</b>	<b>0.15%</b>	<b>1.05%</b>
<b>Belgium</b>	<b>21.13%</b>	<b>45.69%</b>
<b>Brazil</b>	<b>33.40%</b>	<b>48.01%</b>
<b>Canada</b>	<b>12.38%</b>	<b>32.23%</b>
<b>China</b>	<b>4.89%</b>	<b>55.88%</b>
<b>Columbia</b>	<b>7.45%</b>	<b>30.71%</b>
<b>Denmark</b>	<b>1.88%</b>	<b>75.41%</b>
<b>Egypt</b>	<b>13.57%</b>	<b>54.15%</b>
<b>Finland</b>	<b>4.65%</b>	<b>32.54%</b>
<b>France</b>	<b>8.67%</b>	<b>53.18%</b>
<b>Germany</b>	<b>2.94%</b>	<b>71.62%</b>
Greece	15.27%	8.70%
India	40.11%	1.58%
<b>Italy</b>	<b>6.44%</b>	<b>36.28%</b>
<b>Malaysia</b>	<b>8.15%</b>	<b>59.60%</b>
Netherlands	62.95%	1.53%
New Zealand	31.65%	2.01%
<b>Nigeria</b>	<b>0.68%</b>	<b>1.78%</b>
Norway	25.25%	8.11%
Pakistan	20.35%	6.68%
<b>Philippines</b>	<b>3.76%</b>	<b>28.98%</b>
<b>Portugal</b>	<b>31.09%</b>	<b>42.13%</b>
Russia	23.36%	14.02%
<b>Singapore</b>	<b>15.62%</b>	<b>19.68%</b>
<b>South Africa</b>	<b>17.16%</b>	<b>29.34%</b>
Spain	63.17%	13.08%
<b>Sri Lanka</b>	<b>0.49%</b>	<b>50.44%</b>
<b>Sweden</b>	<b>20.81%</b>	<b>51.09%</b>
<b>Switzerland</b>	<b>25.10%</b>	<b>52.20%</b>
<b>Thailand</b>	<b>10.54%</b>	<b>42.05%</b>
<b>Trinidad and Tobago</b>	<b>3.69%</b>	<b>20.09%</b>
<b>UK</b>	<b>15.49%</b>	<b>27.88%</b>
<b>USA</b>	<b>14.67%</b>	<b>51.97%</b>
<b>Euro Area</b>	<b>11.30%</b>	<b>49.69%</b>
South Asia	34.69%	1.42%
High Income non OECD	18.96	5.92
<b>High Income OECD</b>	<b>18.21%</b>	<b>44.35%</b>

Table 6: Short run (p=10) forecast error decomposition of MK as explained by PCG and that of PCG explained by MK (Cholesky ordering: PCG,MK)

Country/Groups	% MK variance explained by PCG	% PCG variance explained by MK
<b>Australia</b>	<b>11.19%</b>	<b>12.76%</b>
<b>Austria</b>	<b>0.32%</b>	<b>16.61%</b>
<b>Bangladesh</b>	<b>0.33%</b>	<b>1.25%</b>
<b>Belgium</b>	<b>24.59%</b>	<b>53.01%</b>
<b>Brazil</b>	<b>32.48%</b>	<b>58.95%</b>
<b>Canada</b>	<b>13.57%</b>	<b>50.79%</b>
<b>China</b>	<b>7.65%</b>	<b>57.56%</b>
<b>Columbia</b>	<b>20.07%</b>	<b>39.83%</b>
<b>Denmark</b>	<b>6.76%</b>	<b>83.60%</b>
<b>Egypt</b>	<b>13.12%</b>	<b>60.67%</b>
<b>Finland</b>	<b>5.86%</b>	<b>53.78%</b>
<b>France</b>	<b>17.08%</b>	<b>66.27%</b>
<b>Germany</b>	<b>16.06%</b>	<b>67.03%</b>
Greece	20.35%	10.94%
India	40.33%	4.75%
<b>Italy</b>	<b>7.14%</b>	<b>42.68%</b>
<b>Malaysia</b>	<b>8.21%</b>	<b>64.04%</b>
Netherlands	39.96%	6.86%
New Zealand	32.19%	15.40%
Nigeria	4.06%	2.21%
Norway	26.58%	24.20%
<b>Pakistan</b>	<b>20.05%</b>	<b>23.57%</b>
<b>Philippines</b>	<b>5.13%</b>	<b>28.67%</b>
Portugal	51.78%	41.87%
Russia	39.95%	24.45%
<b>Singapore</b>	<b>0.48%</b>	<b>23.28%</b>
<b>South Africa</b>	<b>17.25%</b>	<b>57.55%</b>
Spain	51.29%	25.88%
<b>Sri Lanka</b>	<b>3.27%</b>	<b>53.02%</b>
<b>Sweden</b>	<b>20.76%</b>	<b>62.19%</b>
<b>Switzerland</b>	<b>26.49%</b>	<b>66.25%</b>
<b>Thailand</b>	<b>12.82%</b>	<b>47.78%</b>
<b>Trinidad and Tobago</b>	<b>6.17%</b>	<b>24.58%</b>
<b>UK</b>	<b>16.87%</b>	<b>41.54%</b>
<b>USA</b>	<b>16.03%</b>	<b>64.28%</b>
<b>Euro Area</b>	<b>14.17%</b>	<b>60.01%</b>
South Asia	34.41%	1.54%
<b>High Income non OECD</b>	<b>21.54%</b>	<b>26.58%</b>
<b>High Income OECD</b>	<b>18.86%</b>	<b>60.70%</b>

# Chapter 2: Market capitalization and growth in a general equilibrium framework with borrowing constraint

## I. Motivation

To motivate this chapter, I begin with a quick summary of the key empirical results that followed from the previous chapter. In the previous chapter I look into yearly data on market capitalization as a ratio of GDP and yearly data on per capita GDP growth for 35 countries and 4 country groups for a time period spanning twenty five years and established important contemporaneous and intertemporal short run relations between the two variables. A panel VAR analysis established that per capita growth depends significantly on lagged values of market capitalization ratio, although market capitalization ratio does not depend significantly on the past values of per capita growth. Also within a VAR set-up, I established with the help of a variance decomposition analysis, that for almost all countries and country groups, the effect of a change in market capitalization on the later period short run fluctuations of growth is far greater than the effect of a change in growth on short run fluctuations of market capitalization during later periods. In other words, as a result of a one time shock, the cyclical fluctuations in market capitalization ratio have a considerable influence on future period cyclical fluctuations of per capita growth. In comparison, the cyclical fluctuations in per capita growth have much less influence on the fluctuations of market capitalization ratio throughout the future periods. These two findings, along with a Granger causality test that showed causality to flow from market capitalization ratio to growth for most countries, established an intertemporal or across time period relationship between market capitalization and growth. From this it followed that there exists a lead-lag relationship between market capitalization ratio and growth in the sense that the former's behaviour in a particular time period has a much greater impact on the latter's

behaviour during the periods to follow, than it is true for the other way round.

Next, in order to investigate the short run movement pattern in market capitalization ratio and growth within the same time period, I calculated the correlation coefficient between market capitalization ratio and per capita growth for each of the countries and country groups. It is found that for majority of countries and groups of countries, this correlation coefficient is positive and significant. This contemporaneous finding established the fact that in the short run, both market capitalization ratio and per capita growth moved in same directions. Therefore from the short run empirical findings, two basic stylized patterns emerge: (1) In the short run, for most countries, there exists a lead-lag relationship between market capitalization ratio and per capita growth in the sense that the impact of market capitalization on per capita growth's behaviour in future periods is much greater compared to the influence of per capita growth on future market capitalization behaviour and (2) For majority of the countries, market capitalization and output growth move in the same direction in the short run.

A section of the existing literature identifies stock market to be the leading indicator of growth, while another section ties stock market activities to the level or growth of economywide GDP. The second strand of literature, mostly evolving from the Lucas (1978) asset pricing framework, investigate the relationship between stock - market and economic activities, in the light of partial equilibrium consumption based capital asset pricing models. There is yet a third group pioneered by Cochrane (1991) who study this relationship using a production and investment based partial equilibrium asset pricing approach and emphasize on the bi-directional causality between stock market health on the one hand and macroeconomic activities on the other. Both consumption and production based asset pricing approaches give rise to partial equilibrium models as the former divorces production and investment, while the latter completely ignores consumption.<sup>1</sup> Brock (1982) merges the production and consumption based approaches and comes up with a general equilibrium model of capital asset pricing in order to study the impact of certain macroeconomic factors like corporate and personal income taxes on stock market activities within a stochastic growth framework. However, to the best of my knowledge, no major work has been done in this area to highlight the contribution of different exogenous factor(s) on the short run movements in market capitalization and growth. For example, within

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<sup>1</sup>However, since in the Lucas (1978) asset pricing model, total output or endowments are treated as dividends and these are exogenously given in each period, the production sector does not need to be modelled formally and the whole framework can be treated as a general equilibrium one.

a general equilibrium structure, the simultaneous effect of different exogenous macroeconomic shocks on stock market capitalization and growth has not been investigated in the existing literature and the present research intends to fill up this research gap by addressing the issue in an endogenous growth framework. In fact, in the previous chapter, while investigating the short run intertemporal and contemporaneous relationships between market capitalization ratio and growth, the reason for the emergence of these specific short run patterns was left unexplored.

In this chapter I put forward a general equilibrium model based on Brock (1982) in which short run movement patterns in market capitalization and growth are driven by exogenous aggregate macroeconomic shocks, as a result of which the two variables are determined simultaneously. Thus in this model, both the short run contemporaneous and intertemporal relations between market capitalization ratio and growth are determined due to exogenous shocks. Instead of a cause - effect relationship flowing from one variable to the other, I focus on the direction in which market capitalization and growth move in the short run i.e. the simultaneous behaviour of these two variables as a result of the realization of different aggregate shocks. Once the short run patterns in market capitalization ratio and growth are established, I match these with the empirical findings; my chief objective being the theory to be in line with the two main stylized patterns of contemporaneous and lead-lag relationship emerging out of the empirical analysis. Once the model is able to support the basic empirical patterns, inference can also be drawn regarding the relative influence of the different shocks towards explaining the short run fluctuations of stock market capitalization and per capita growth.

In the previous chapter, I went through the Lucas (1978) asset pricing framework in some detail, while discussing the strand of literature that envisages per capita income as the main determinant of stock market development. This kind of framework deals with a pure exchange economy, in which dividends from stocks are assumed to be fruits falling from trees, which cannot be stored and are hence all consumed. In such a framework, the equilibrium price of trees, as determined through the representative consumer's utility maximization exercise subject to his budget constraint, is such that every period, each identical consumer wants neither to increase, nor to decrease his holding of assets (trees). However, in the economy described in Lucas (1978) output arrives without any deliberate actions on part of the residents and the theoretical framework does not take into account investment and production. The theoretical structure which I introduce in the present chapter is based on the Lucas tree framework, but also allows

for investment and production. In this particular framework, the economy consists of infinitely many identical firms, owned by households, with the representative household owning shares in all the firms. During each period, with the help of a linear production function, a firm produces output using capital as the only source of input. The firm invests a part of its total output, while distributing the remaining as dividends to its owner, i.e. the representative household. Dividend is endogenous and determined by the firm's optimisation problem similar to Brock (1982). Dividend income is the only source of income for the representative household. The latter uses a part of it to consume and the rest to buy new assets of the firm. I incorporate three aggregate macroeconomic shocks within the system in the form of a Total Factor Productivity (TFP) shock, an Investment Specific Technology (IST) shock and a Capital Quality (CQ) shock and investigate the short run dynamics followed by market capitalization ratio and per capita growth as a result of realization of each of these shocks in a Dynamic Stochastic General Equilibrium (DSGE) framework. Although in the previous chapter, it is shown that there exists a positive relationship between market capitalization-output ratio and growth in the short run for a low degree of relative risk aversion, no concrete inference was drawn about the simultaneous behaviour of these two variables in response to different aggregate shocks. This is investigated in the present chapter within a general equilibrium theoretical framework.

However, without the interference of any frictions, this kind of a basic Lucas tree asset pricing model with investment and production in itself cannot support the short run contemporaneous relationship between market capitalization and growth. It is observed from the model that both market capitalization and growth follow opposite time paths in the short run due to realization of a TFP and an IST shock. It is only due to the effect of a CQ shock that the two variables move in the same direction. Since TFP and IST are the main determinants of market capitalization and growth and CQ plays very little role in determining the short run dynamics of these two variables, a negative short run market capitalization - growth correlation coefficient is obtained from the model, thereby negating the short run contemporaneous stylized pattern. Since a complete market asset pricing structure provides insufficient support to the data, I incorporate a friction within the existing asset pricing framework in the form of a borrowing constraint à la Kiyotaki and Moore (1997). The new feature of this model is that at any time period, the firm can borrow from an international bank or financial intermediary at a fixed rate of interest. The firm being a price taker in the international market takes the international rate of interest as

given. Also, only firms and not households have access to the international financial market.

Now, the bank who is lending to the firm faces a problem of repayment from the firm in the sense that the firm can borrow a certain amount of money today and not repay the loan tomorrow. Hence the maximum amount of loan that the firm will be granted in a certain time period should be equal to the amount that the bank will be able to recover from it in the next period, which is the firm's stock of capital in that particular time period. Hence, in the new scenario, the firm will face a borrowing constraint, where it will not be allowed to borrow any amount greater than its next period's discounted capital stock. Under an equilibrium where the borrowing constraint binds fully, the model reproduces a positive significant correlation coefficient between market capitalization and growth, one that is quantitatively close to the data, thereby supporting the contemporaneous empirical finding. In this framework, the short run time paths of market capitalization ratio and per capita growth follow the same direction due to realization of both TFP and CQ shocks. An IST shock, however induces the two variables to move in opposite directions. But since TFP now becomes the main driving force behind both market capitalization ratio and growth, the short run correlation coefficient between the two variables as obtained from the model turns out to be positive. Thus by incorporating a borrowing constraint friction into the complete market baseline model, it is possible to explain the contemporaneous positive significant correlation between market capitalization ratio and growth.

Both theoretical frameworks support the short run lead-lag relationship between market capitalization ratio and growth in the sense that per capita growth is dependent on previous period market capitalization ratio, whereas the opposite is not true.

There has been a very long tradition of looking into financial factors as crucial indicators of business cycles, starting with Fisher's (1933) debt-deflation explanation of the Great Depression. In this line of thought, deteriorating credit market conditions like growing debt burdens and falling asset prices are not just passive reflections of a declining economy, but major factors stagnating economic activities. Although a substantial literature exists supporting this particular view, most theoretical work on this topic had been partial equilibrium in nature until the late 1980s when Bernanke and Gertler (1989) formalized these ideas in a general equilibrium framework. Following their work, various others have come up with dynamic models in which financing frictions on the firm side amplify or propagate output fluctuations as a response to

aggregate shocks. Some examples include the real models of Kiyotaki and Moore (1997) and Carlstrom and Fuerst (1997) and the sticky price model of Bernanke et al (1999). A comprehensive review of the various empirical studies, which have shown that the firm's investment decisions are sensitive to various measures of the firm net worth, can be found in Hubbard (1998). At the household level, evidence of financing constraints has been widely documented by Zeldes (1989), Japelli and Pagano (1989), Campbell and Mankiw (1989) and Carroll and Dunn (1997).

Although from a modelling point of view, my starting point is the Lucas (1978), the idea of borrowing constraint is inspired by the concept of collateral constraints tied to real estate values for firms, as in Kiyotaki and Moore (1997) and also used later on by Iacoviello (2005). Regarding the concept of incorporating borrowing constraint as a financial friction within an asset pricing framework, there exists a rich literature that has actually investigated this issue. He and Pages (1993) use the concept of borrowing constraint to study an individual's optimal consumption and portfolio policy when an individual has limited opportunity to borrow against future labour income and cannot totally insure against the risk of income fluctuations. He and Modest (1995) show that incorporating a combination of short sale, borrowing, solvency and trading cost frictions within a consumption based asset pricing model can help explain the empirically observed comovements of consumption and asset return which fail to satisfy the restrictions imposed by the equilibration of the intertemporal marginal rate of substitution. Guiso, Japelli and Terlizzese (1996) establish that in presence of transaction costs, the expectation of future borrowing constraints should induce individuals to keep a lower proportion of their wealth in the form of illiquid and risky assets. Luttmer (1996) examines how financial frictions in the form of proportional transaction costs and short sale borrowing constraints affect asset returns. Zhang (1997) develops ways to endogenize borrowing constraints used in a class of computable incomplete market models, by allowing the constraints to depend on an investor's characteristics such as time preference, risk aversion and income streams. Vila and Zariphopoulou (1997) uses the concept of borrowing constraint in order to study intertemporal consumption and portfolio choice of an infinitely lived agent facing a constant opportunity set. The concept of borrowing constraint as a maximum limit to borrowing, which I use in the present chapter, is loosely based on the idea used in this paper, where the proposed constraint is interpreted as a borrowing limit within which an investor has no incentive to default. Yao and Zhang (2005) investigate how



borrowing constraints influence optimal consumption and portfolio decisions when housing risk is involved.

While these studies have highlighted the importance of financial factors to explain several macroeconomic and financial issues, till date there exists no systematic evaluation of the extent to which a general equilibrium model with borrowing constraint frictions can explain the short run relationship between health of the stock market on the one hand and macroeconomic growth on the other. In an attempt to address this research gap, in the present chapter, I investigate the importance of a borrowing constraint friction in determining the empirically observed short run cyclical fluctuations of market capitalization and growth within a DSGE framework with capital accumulation and endogenous growth. The chapter is organized in the following way:

In section II I introduce the main theoretical framework that I follow in this chapter, which is a Lucas type asset pricing model with production and investment. Within a general equilibrium framework, I analyze the short run behaviour of market capitalization ratio and per capita growth due to the effect of a TFP, IST and CQ shock. Assuming each shock to follow an AR(1) process, I discuss the impulse response of market capitalization ratio and per capita growth along with a few relevant macroeconomic variables. Due to the simultaneous realization of all three shocks, the short run correlation coefficient between market capitalization and growth is found to be negative. Again, assuming the presence of only one shock, i.e. an i.i.d. TFP shock, I obtain an expression of the market capitalization - growth covariance when the TFP shock follows a lognormal distribution. With plausible parametric values, this covariance expression turns out to be negative. Taking into consideration all shocks, I am able to obtain close form solutions for both market capitalization ratio and growth in this framework and from this it follows that growth in a certain period depends on the value of market capitalization in the previous period, but the opposite is not true. Hence although present period shocks influence market capitalization immediately, they have a lagged effect on growth. Thus the asset pricing framework in section II supports the short run lead-lag relationship between market capitalization ratio and growth, but not the contemporaneous relationship between the two.

In section III, I introduce a financial friction in the form of a borrowing constraint within the asset pricing framework discussed in section 2. Considering TFP as the only shock in action, I first derive conditions under which the borrowing constraint will bind fully in equilibrium. Assuming the TFP shock to be following a lognormal distribution, a covariance expression be-

tween market capitalization and growth is obtained, which for a range of plausible distributional parameter values, is found to be positive. Also with three different shocks, each following an AR(1) process and also starting with an equilibrium where the borrowing constraint binds fully, the short run correlation coefficient, as obtained from the model, turns out to be positive and significant. The economic implication of the short run dynamics of market capitalization ratio, growth as well as a few other relevant variables due to each of the underlying shocks, is analysed in detail in this section. The lead-lag relationship between market capitalization ratio and growth is also supported when the borrowing constraint binds fully in equilibrium, thereby establishing that this incomplete market scenario is in line with both the contemporaneous and lead-lag stylized patterns obtained from the previous chapter.

In section IV, I end this chapter with a few concluding remarks.

## II. Asset pricing framework with production and investment

I consider an economy consisting of infinitely many identical competitive firms and infinitely many identical households. Each firm produces a homogenous output using capital and a linear production function. A firm invests a part of its output, thereby augmenting next period's capital stock and distributes the remaining as dividends to the households who are owners of the firm. For the representative household, dividend income is the only source of income, a part of which goes into consumption and the rest into buying new stocks.

Without any loss of generality, I assume that the total number of shares of a firm is unity and this remains unchanged over time. Also let me assume that the total number of shares of a given firm is equally distributed among all households, i.e. all households own the same amount of shares of this particular firm in their portfolio. If the representative firm is indexed by  $i \in (0, 1)$  and the representative household is indexed by  $j \in (0, 1)$ , this means that for all  $j$ , I have  $z_t(j) = z_t$ . Since this is true for all firms and since the total number of households is fixed at unity, this implies that each household owns the same amount of shares of all firms in its portfolio so that  $z_t(i) = z_t$  for all  $i$ <sup>2</sup>. Since households and firms are identical, from here on I do not use the subscript  $i$  while referring to the representative household or the subscript  $j$  while referring to the representative firm, anywhere within the theoretical set up.

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<sup>2</sup>This is not unreasonable given that share prices and dividends are same across all firms.

## A. Market capitalization ratio and growth

The representative household maximizes its expected utility over an infinite horizon. Time is discrete. The household's utility  $u(c_t)$  is a function of its consumption  $c_t$  alone. Taking  $\beta$  as the household's discount factor, the household's objective function can be formally written as

$$Max : E_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \quad (1)$$

$$s.t. : p_t^z [z_{t+1} - z_t] + c_t = d_t z_t \quad (2)$$

Equation (2) represents the household's resource constraint, where  $p_t^z$  and  $d_t$  are the price and dividend of the stock of the representative firm at period  $t$  and  $z_t$  is the proportion of shares of the representative firm held by the representative household at period  $t$ . Consequently, the right hand side of equation (2) represents total income of the representative household, which is entirely from dividends. On the left hand side of equation (2) the first term represents the intended expenditure of the household at period  $t$  in order to acquire additional assets. This, added with the consumption  $c_t$  exhausts the household's total income.

The representative household maximizes (1) subject to (2) by choosing  $c_t$  and  $z_{t+1}$ . The first order condition with respect to these choice variables establish the following Euler equation:

$$u'(c_t) p_t^z = \beta E_t u'(c_{t+1}) (d_{t+1} + p_{t+1}^z) \quad (3)$$

Now since total number of shares of a firm is unity, integrating shares over all households, it follows that  $z_t = 1$ . Hence the right hand side of (2) becomes  $d_t$ . Again since total stocks of each firm remains unchanged over time, in equilibrium,  $z_t = z_{t+1}$ , so that the left hand side of (2) boils down to  $c_t$ . The two taken together imply

$$c_t = d_t$$

This is in line with Lucas (1978). In the Lucas asset pricing framework dividends are assumed to be fruits falling from a certain tree and have to be consumed entirely in equilibrium since no storage is possible within the economy. However, in the present theoretical framework, there is

provision for production and storage (by investment of a part of the output produced by firms), which does not enter the representative household's problem.

Taking into account this assumption as well as the assumption of a logarithmic utility function, i.e.  $u(c_t) = \ln c_t$ , the stock Euler equation in (3) becomes

$$\begin{aligned}
\frac{p_t^z}{c_t} &= \beta E_t \left( \frac{c_{t+1} + p_{t+1}^z}{c_{t+1}} \right) & (4) \\
&= \beta \left[ 1 + E_t \left( \frac{p_{t+1}^z}{c_{t+1}} \right) \right] \\
&= \beta \left[ 1 + \beta \left\{ 1 + E_t \left( \frac{p_{t+2}^z}{c_{t+2}} \right) \right\} \right] \\
&= \beta \left[ 1 + \beta + \beta^2 + \dots + E_t \left\{ \lim_{n \rightarrow \infty} \beta^{n-1} \left( \frac{p_{t+n}^z}{c_{t+n}} \right) \right\} \right] \\
&= \frac{\beta}{1 - \beta} + \beta E_t \left\{ \lim_{n \rightarrow \infty} \beta^{n-1} \left( \frac{p_{t+n}^z}{c_{t+n}} \right) \right\} & (5)
\end{aligned}$$

If the asset price is bounded (it cannot go to a value such that it would cost more than the household's total income to buy a single asset), it is possible to show that the limit term in equation (5) goes to zero. This means that the equilibrium asset price becomes

$$p_t^z = \frac{\beta}{1 - \beta} c_t \quad (6)$$

This price is determined in such a way that in equilibrium, each period, the representative household would not want either to increase or to decrease his holding of assets. The equilibrium asset price in (6) is in line with the one in Lucas (1978), where equilibrium price of stocks today does not depend on the expected level of dividend in the future. Although higher expected future dividends increase the worthiness of a stock today, it is counterbalanced by the fact that since future consumption equals future dividends, higher expected dividends imply lower marginal utility of consumption in the future, thereby reducing the attractiveness of a stock. These two forces are purely due to income and substitution effects, which in the special case of a logarithmic utility as considered here, are of the same magnitude, but opposite signs and hence offset each other.

In an economy described in Lucas (1978), dividend (described as fruit falling from trees in the Lucas asset pricing framework) arrives without any deliberate effort on the part of the consumers and is referred to as an endowment economy or exchange economy. There is no provision

of storage and production in this kind of an economy. However, in the present theoretical framework, I allow for investment in physical capital and output production in each period by the identical firms owned by the representative household.

The representative firm manufactures its product ( $y_t$ ) using capital ( $k_t$ ) as its only source of input, with the help of a linear production technology given by

$$y_t = \epsilon_t k_t \quad (7)$$

where  $\epsilon_t$  denotes the Total Factor Productivity (TFP) shock which influenced output production in time period  $t$ . In time period  $t$  the firm invests a part of its produce and distributes the rest as dividend to the household. The firm invests an amount  $i_t$  which gives rise to new accumulated capital for period  $t + 1$ , given by  $k_{t+1}$ . The investment process for the firm is represented by the following equation.

$$k_{t+1} = (1 - \delta_t)k_t + i_t \psi_t \quad (8)$$

where  $(1 - \delta_t)k_t$  stands for undepreciated capital stock at time period  $t$ .  $\delta_t$  represents the rate of capital depreciation, which is stochastic and hence signifies a Capital Quality (CQ) shock. A rise in  $\delta_t$  implies higher capital depreciation and hence a bad CQ shock, whereas a good CQ shock is brought about by a fall in  $\delta_t$ .  $\psi_t$  represents an Investment Specific Technology Shock (IST). A rise in  $\psi_t$  augments accumulated capital  $k_{t+1}$ , while a fall in  $\psi_t$  reduces it. Each of the shocks is assumed to be stochastic. The firm maximizes discounted stream of future dividends, where dividend at time period  $t$  is given by

$$d_t = y_t - i_t \quad (9)$$

Thus the time  $t$  objective function of the firm is given by

$$Max : E_t \sum_{s=0}^{\infty} m_{t,t+s} d_{t+s} = E_t \sum_{s=0}^{\infty} m_{t,t+s} \left[ \epsilon_{t+s} k_{t+s} - \frac{1}{\psi_t} \{k_{t+s+1} - (1 - \delta_t)k_{t+s}\} \right] \quad (10)$$

with  $k_{t+1}$  as the firm's choice variable.  $m_{t,t+s}$  denotes the representative household's stochastic discount factor

$$m_{t,t+s} = \frac{\beta u'(c_{t+s})}{u'(c_t)} \quad (11)$$

As the firm maximizes its dividends on behalf of the household, it uses the latter's marginal rate of substitution or stochastic discount factor  $m_{t+s}$  in its dividend maximization problem.

Since in equilibrium the household does not increase or decrease its holding of assets, the equilibrium resource constraint can be written as

$$c_t = \epsilon_t k_t - \frac{1}{\psi_t} [k_{t+1} - (1 - \delta_t)k_t] \quad (12)$$

The left-hand-side of equation (12) represents the representative household's dividend income which is entirely consumed in equilibrium. Taking the first order condition of the firm's maximization problem w.r.t.  $k_{t+1}$  and combining it with the equilibrium resource constraint, I can derive equilibrium consumption ( $c_t$ ) and capital accumulation ( $k_{t+1}$ ) expressions as

$$c_t = (1 - \beta) \left( \frac{\epsilon_t \psi_t + 1 - \delta_t}{\psi_t} \right) k_t \quad (13)$$

and

$$k_{t+1} = \beta (\epsilon_t \psi_t + 1 - \delta_t) k_t \quad (14)$$

Utilizing the equilibrium consumption and capital accumulation expressions from the above equations in (13) and (14) along with the equilibrium asset price in (6), I next derive equilibrium expressions for market capitalization as a ratio of output ( $mk_t$ ) and output growth ( $yg_t$ ).

Total value of stocks for the representative household is given by  $p_t^z z_t = p_t^z$ . Since there exists infinite households in a continuum, integrating over all households, the total economywide value of stock market capitalization is also given by  $p_t^z$ , which means that market capitalization to output ratio  $mk_t$  is defined as

$$mk_t = \frac{p_t^z}{y_t} \quad (15)$$

Also I define growth at time period  $t$  as

$$yg_t = \frac{y_t}{y_{t-1}} \quad (16)$$

Going by the above definitions, equilibrium market capitalization ratio and growth are solved as

$$mk_t = \beta \left[ 1 + \frac{(1 - \delta_t)}{\epsilon_t \psi_t} \right] \quad (17)$$

and

$$yg_t = \beta \epsilon_t \left[ \psi_{t-1} + \frac{(1 - \delta_{t-1})}{\epsilon_{t-1}} \right] \quad (18)$$

Detailed derivations of (13), (14), (17) and (18) are relegated to the appendix.

## B. A special case

In a similar framework, I consider a special case with only the TFP shock in action and this shock is assumed to be independently and identically distributed (i.i.d.). This specification makes it possible to obtain a close form solution for the covariance between market capitalization ratio and growth, if the TFP shock follows a lognormal distribution. The sign of the covariance, in turn, indicates whether the market capitalization - growth correlation is positive or negative. Due to absence of the CQ shock, the depreciation rate of capital is fixed at  $\delta$ . In this set up expressions for market capitalization ratio and growth change as

$$mk_t = \beta \left[ 1 + \frac{(1 - \delta)}{\epsilon_t} \right] \quad (19)$$

and

$$yg_t = \beta \epsilon_t \left[ 1 + \frac{(1 - \delta)}{\epsilon_{t-1}} \right] \quad (20)$$

This can be checked by plugging  $\psi_t = 1$  and  $\delta_t = \delta$  in the expressions of market capitalization ratio and growth in (19) and (20).

In the framework with only TFP shock, it is evident that market capitalization and growth move in opposite directions due to the realization of a TFP shock. A TFP shock augments growth but diminishes market capitalization. Assuming  $\epsilon$  follows a lognormal distribution with mean 0 and variance  $\sigma^2$ , the expression for the unconditional covariance between market capitalization ratio and growth can be calculated as:

$$Cov(mk_t, yg_t) = \beta (1 - \delta) \left( 1 - e^{\sigma^2} \right) \left( 1 + (1 - \delta) e^{\sigma^2/2} \right) \quad (21)$$

which is unambiguously negative assuming  $0 < \beta < 1$ ,  $0 < \delta < 1$  and  $0 < \sigma < 1$ .

This result can be formally presented by the following proposition.

**Proposition 1** *In an asset pricing model with production and investment, in the presence of only one shock, which is a lognormally distributed TFP shock, the covariance between market*

capitalization ratio and growth is given by equation (21) and the value of this covariance is unambiguously negative.

The correlation coefficient between market capitalization ratio and growth is  $Cov(mk_t, yg_t)$  divided by the product of the variances of market capitalization ratio and growth. As the denominator is always unambiguously positive, a negative covariance value also implies a negative value for the correlation coefficient between market capitalization ratio and growth. Detailed derivation of  $Cov(mk_t, yg_t)$  is relegated to the appendix.

### C. Short run quantitative analysis

Generalizing the scenario with three different stochastic shocks, assuming each of the shocks to follow an AR(1) process, I next analyze the effect of each of these shocks on market capitalization and growth. Figures 1, 2 and 3 represent the impulse response behaviours of market capitalization and growth along with a few other macroeconomic variables due to the realization of a TFP shock, an IST shock and a CQ shock respectively. These figures capture the short run dynamics of growth (denoted by  $yg$ ), market capitalization (denoted by  $mk$ ), consumption to capital ratio (denoted by  $ck$ ), dividend to capital ratio (denoted by  $dk$ ), dividend to output ratio (denoted by  $dy$ ), investment to capital ratio (denoted by  $ik$ ), investment to output ratio (denoted by  $iy$ ) and expected capital growth (denoted by  $kg$ ). The shock processes are described below.

TFP shock:

$$\epsilon_t - \bar{\epsilon} = \rho_\epsilon(\epsilon_{t-1} - \bar{\epsilon}) + \zeta_t^\epsilon \quad (22)$$

The steady state value of  $\epsilon_t$  is  $\bar{\epsilon}$ .  $\zeta_t^\epsilon$  is the disturbance term.

IST shock:

$$\psi_t - \bar{\psi} = \rho_\psi(\psi_{t-1} - \bar{\psi}) + \zeta_t^\psi \quad (23)$$

The steady state value of  $\psi_t$  is  $\bar{\psi}$ .  $\zeta_t^\psi$  represents the disturbance term.

CQ shock:

$$\delta_t - \bar{\delta} = \rho_\delta(\delta_{t-1} - \bar{\delta}) + \zeta_t^\delta \quad (24)$$

$\bar{\delta}$  represents the steady state value of  $\delta_t$ .  $\zeta_t^\delta$  is the disturbance term.

In order to carry out the necessary simulations, the relevant baseline parametric values are



reported in Tables 1 and 2.<sup>3</sup>

The household discount factor  $\beta$  is fixed at 0.99 and the depreciation parameter  $\bar{\delta}$  at 0.025 i.e. at the conventional levels consistent with quarterly calibration. In order to find an estimate of the productivity parameter  $\bar{\epsilon}$  for developed countries, the long run per capita quarterly real GDP growth rate for USA at 0.49% i.e. an annualized growth rate of 1.97% for the sample period 1947-2014 is targeted to set the productivity parameter at 0.048.<sup>4</sup> Without any loss of generality, I fix the standard deviation of the exogenous component of all the shocks, i.e.  $\sigma_\epsilon^2$ ,  $\sigma_\xi^2$  and  $\sigma_\delta^2$  at unit levels in order to normalize the impulse responses.

Figure 1 represents the effect of a TFP shock on the relevant macroeconomic variables.

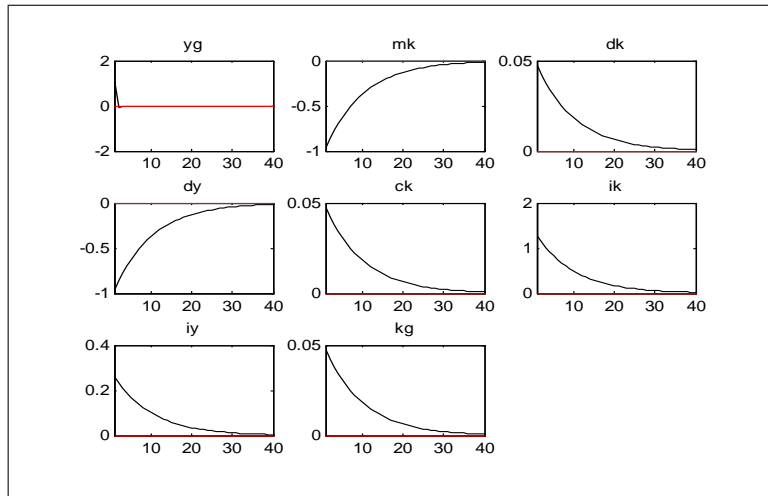


Figure 1: Impulse response to TFP

A positive TFP shock at time period  $t$  augments output, because of which there is an increase in  $yg$ , i.e. growth at time  $t$ . An increase in current production leads to increase in current investment by the firms, which is reflected in an increase in investment - capital ratio  $ik$ . Since the TFP shock follows an  $AR(1)$  process, its persistence effect on output is reflected in future production as well, due to which firms find it worthwhile to increase their investments. In fact, investment in physical capital increases more than proportionately compared to the increase in output, due to which a rise in investment - output ratio  $iy$  is observed. A considerable rise in investment in physical capital is reflected in a rise in next period's expected capital growth  $kg$ . Also, since a positive TFP shock increases current output, an increase in firm dividends is also observed due to pure income effect, which is represented in Figure 1 by a rise in dividend to capital ratio  $dk$ . As dividend is entirely consumed in equilibrium, the rise in  $dk$  is exactly

<sup>3</sup>Tables 1 and 2 can be found in the appendix.

<sup>4</sup>Data for annual per capita real GDP in chained 2009 US dollars is taken from Bureau of Economic Analysis.

proportional to the rise in consumption - capital ratio  $ck$ . However, a fall in dividend - output ratio  $dy$  signifies that dividends increase at a rate which is lower than the corresponding rise in output, which in effect implies that the relative rise in firm's dividend is less than that of firms' investment. As the increase in households' dividend income is slower than that of output, the increase in their demand for stocks is less than that of output, which gets manifested in a fall in the market capitalization to output ratio. Thus due to a positive TFP shock market capitalization ratio and growth move in opposite directions in the short run.

Figure 2 represents the short run behaviour of market capitalization and growth along with those of other relevant variables due to realization of an IST shock.

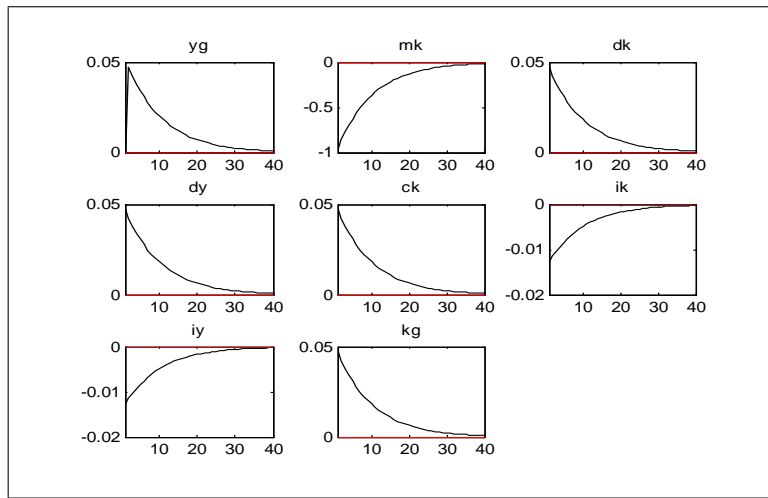


Figure 2: Impulse response to IST

A positive IST shock at time period  $t$  augments capital stock at time period  $t + 1$ , which leads to a rise in expected capital growth  $kg$  in time period  $t$ . A rise in time  $t + 1$  capital stock also leads to a rise in output and hence growth  $yg$  in time  $t + 1$ . Due to improvement in investment specific technology, less investment is now required to produce the same output on part of the firms, due to which a fall in investment - capital ratio  $ik$  and investment-output ratio  $iy$  is observed in time period  $t$ . Although this implies a relative rise in dividend income for consumers, as reflected by a rise in the dividend to capital ratio  $dk$  and dividend to output ratio  $dy$ , its effect does not subsequently get translated into a rise in market capitalization ratio  $mk$ . This happens because a good IST shock sends a signal of increased capital stock and hence increased production in the next period to the consumers. The latter being risk averse and hence in favour of consumption smoothing across periods, increase their present consumption to such an extent which leads to a drop in their relative investment in financial assets, thereby leading

to a fall in current market capitalization. Also the IST shock does not have any effect on present output, as a result of which market capitalization ratio cannot rise through increased demand for stocks due to the income effect of a rise in output. Thus a positive IST shock induces market capitalization ratio and growth to move in opposite directions in the short run.

Figure 3 describes the short run dynamics of the key macroeconomic variables due to realization of a good CQ shock.

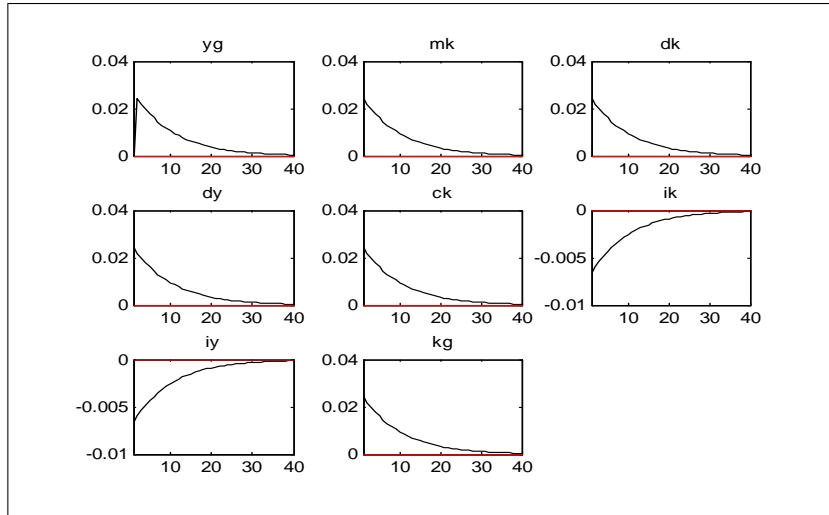


Figure 3: Impulse response to CQ

A good CQ shock at time period  $t$  implies lesser depreciation of current capital stock, which implies increased capital stock in time period  $t+1$ . As a result of this expected capital growth  $kg$  in time  $t$  is observed to go up. As less investment is now necessary to produce the same quantity of output, a fall in investment to capital and investment to output ratios  $ik$  and  $iy$  in Figure 3 is observed. As dividend income is entirely consumed in equilibrium, an increase in consumption - capital ratio  $ck$  in Figure 3 implies a proportional rise in dividend to capital ratio as a result of a positive CQ shock. In fact, dividends rise at a rate greater than the corresponding rise in output, as a result of which there is a rise in dividend to output ratio  $dy$ . A rise in dividend income boosts up demand for stocks for the household on the whole. Apart from that, since a good CQ shock increases capital stock and hence output in the next period, there is anticipation of higher dividends in the next period, which also contributes towards driving up the households' demand for assets. Thus on both counts, there is an increase in the market capitalization ratio  $mk$ .

On the other hand, since a good CQ shock in the current period leads to augmented capital stock in the next period, output growth  $yg$  is observed to increase in the next period. Thus due

to a positive CQ shock, market capitalization ratio and growth move in the same direction in the short run.

The impact effect of each of the three shocks on the above mentioned variables is summarized in Table 3, where a positive sign indicates an increase and a negative sign a decrease in a certain variable in response to a given shock.<sup>5</sup> In the present analysis, an IST and a CQ shock affects output growth not immediately, but after a one-period lag. Although in the literature, impact effect describes the behaviour of a variable in the period of realization of a particular shock, in the present analysis, I use this term to refer to the effect (positive or negative) of a shock on a particular variable, irrespective of whether the variable gets affected in the period of realization of the shock or not. Thus in Table 3, the positive effect of an IST and a CQ shock on output growth  $yg$  implicitly refers to a one-period lagged effect, while the shock effects on all the remaining variables describe immediate responses.

From Table 3 it follows that a good TFP shock as well as a good IST shock increase output growth but decrease market capitalization ratio. Both TFP and IST shocks negatively impact the market capitalization ratio despite having positive impact effects on dividend to capital ratio. The dividend - output ratio decreases due to a TFP shock and increases as a result of an IST shock. The investment to capital ratio, on the other hand, is increased by a TFP shock but diminished by an IST shock. Both market capitalization and growth, however, are augmented by a positive CQ shock, which also increases the dividend to capital ratio and dividend to output ratio while decreasing the investment to capital ratio.

Table 4 reports the variance decomposition of the relative importance of different shocks towards explaining the short run movements of each of the above mentioned variables, i.e. the percentage of variance of the variables attributable to each of the shocks.<sup>6</sup> Ideally, in order to simulate the model, the variance of the three shocks should have been calibrated from actual data. But due to lack of empirical evidence, the standard error of the exogenous component of each shock has been fixed at unit level in the course of simulating. This is done in an attempt to assign equal quantitative importance to each shock, such that absence of authentic data does not lead to bias in favour of a particular shock. However, this particular drawback about the variance decomposition analysis must be clearly understood before looking into the relative quantitative importance of shocks in explaining the variance of a given variable in Table 4.

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<sup>5</sup>Table 3 can be found in the appendix.

<sup>6</sup>Table 4 can be found in the appendix.

From Table 4 it is clear that TFP shock performs best in explaining the short run movements of each of the macroeconomic variables under consideration. In case of market capitalization ratio  $mk$  and consumption to capital ratio  $ck$ , however, both TFP and IST shocks play equally important roles in determining their short run dynamics. From the impulse response figures it is clear that a positive TFP shock augments growth, but diminishes market capitalization and a positive IST shock does the same. A good CQ shock, however, augments both market capitalization ratio and growth. Since TFP and IST (and not CQ) are the main drivers of market capitalization ratio and growth and both these shocks induce the two variables to move in opposite directions, a negative short run market capitalization-growth correlation coefficient ( $-0.20$ ) is obtained from simulating the model. It must be pointed out that this short run correlation between market capitalization and growth obtained from the model refers to the correlation induced between these variables over a time horizon extending up to 40 periods after the period of realization of the shocks. The negative correlation does not, however, support my empirical findings, in which market capitalization and growth are found to be positively and significantly correlated for most developing and developed countries.

#### **D. Lead-lag relationship between market capitalization and growth**

Having established that this kind of theoretical framework does not support a positive and significant contemporaneous relationship between market capitalization and growth, I now shift my focus on trying to figure out how this model performs in terms of explaining the lead-lag relationship between market capitalization and growth, as observed empirically in the previous chapter. In the previous chapter it had been established with the help of a panel VAR structure, taking into consideration all countries, that in a certain time period, growth depends on lagged values of market capitalization, although market capitalization does not depend on the lagged growth values.

From the equilibrium asset price, consumption and capital accumulation expressions in equations (6), (13) and (14), I have

$$p_t^z = \frac{k_{t+1}}{\psi_t} \quad (25)$$

Equation (25) shows that capital stock at time  $t + 1$  is directly dependent on time period  $t$  stock price, from which it follows that stock price in a certain time period determines capital stock and hence output in the next period.

This is further supported by the fact that from equations (17) and (18), growth in time period  $t$  can be expressed in terms of market capitalization ratio in time  $t - 1$  as

$$yg_t = \epsilon_t \psi_{t-1} m k_{t-1} \quad (26)$$

although time  $t$  market capitalization cannot be expressed in terms of previous period growth in a similar manner, which is in line with the empirical finding that in a certain time period, growth depends on lagged values of market capitalization, although market capitalization does not depend on the lagged values of growth.

Now, from the equilibrium asset price and consumption expressions in equations (6) and (13), I have

$$p_t^z = \beta \left[ \epsilon_t + \frac{(1 - \delta_t)}{\psi_t} \right] k_t \quad (27)$$

From equation (27) it follows that a TFP, CQ or IST shock in time period  $t$  will influence the stock price at time period  $t$ . This effect on the stock price in time period  $t$  immediately gets translated to capital stock in time  $t + 1$  via equation (25). An effect on the time  $t$  capital stock  $k_{t+1}$  also has an effect on output at time  $t + 1$ , i.e.  $y_{t+1}$ . Thus a shock in time period  $t$  influences asset prices  $p_t^z$  (and hence market capitalization  $\frac{p_t^z}{y_t}$ ) in that particular period and production  $y_{t+1}$  (and hence output growth  $\frac{y_{t+1}}{y_t}$ ) in the next period solely through the asset price channel. Since a shock, by way of its effect on stock price and hence market capitalization in time period  $t$  immediately influences growth in time period  $t + 1$ , this gives rise to a lead-lag relationship between market capitalization ratio and growth in the sense that the former precedes the latter. The result can be put forward by the following proposition.

**Proposition 2** *In an asset price model with production and investment, within a dynamic stochastic general equilibrium environment, the effect of different shocks in a given period on stock price immediately translates into next period's capital stock, giving rise to a lead-lag relationship between market capitalization to output ratio and growth in the sense that the former precedes the latter.*

Thus I find that in the asset pricing framework with production and investment, which is discussed in this section, market capitalization is a leading determinant of next period's growth, which supports my empirical finding from the VAR analysis in the previous chapter. This means

that in a given time period, an effect of all three shocks on stock price, which also signifies an effect on market capitalization, will get immediately translated into next period's output growth. However, a TFP shock effect on current growth will not get translated to market capitalization in a similar manner in order to affect the latter's behaviour in future periods. From Figures 1, 2 and 3 it follows that market capitalization is influenced by all three shocks immediately in the period of realization of these shocks. But for output growth, this is true only for the TFP shock and not for the IST and CQ shocks, i.e. a TFP shock influences growth in the period of its realization, although the IST and CQ shocks do not have any immediate effect on growth in the period in which they are realized. On the other hand, in the current period, all three shocks influence market capitalization, through which their effect gets translated into next period's growth. This explains the empirically observed lead-lag relationship between market capitalization and growth in the sense that the former's behaviour in the current period affects that of the latter in future periods. It must be pointed out here that this lead-lag effect is not the direct causal effect of one variable on the other. Rather it is driven by different aggregate technology shocks within the economy.

### **E. Main findings from a frictionless general equilibrium model of asset pricing**

Thus in this section, I have incorporated investment and production into a Lucas (1978) asset pricing framework. There are three shocks in this particular set up: a TFP shock, an IST shock and a CQ shock and when these three shocks are simultaneously in action, I am able to derive close form solutions for market capitalization ratio and growth. Next, in order to derive a close form solution for the covariance between market capitalization ratio and growth, I take into account the effect of the TFP shock only and assume it to follow a lognormal distribution. For plausible parameter values, the sign of this covariance is unambiguously negative. Even when the three shocks follow an AR(1) process, it is found that market capitalization and growth move in opposite directions in the short run due to two of their most dominant shocks, i.e. TFP and IST. Also the effect of TFP on growth does not have a persistent effect. Although due to a positive CQ shock market capitalization ratio and growth both increase in the short run, the influence of this shock on either of these variables is negligible. The short run fluctuations of market capitalization ratio and growth are predominantly determined by the TFP and IST shocks.

Since market capitalization ratio and growth are driven in opposite directions by either of these shocks, a negative short run correlation between market capitalization ratio and growth follows. This framework, however, supports the lead-lag relationship between market capitalization ratio and growth in the sense that due to a shock, the former immediately impacts the latter in the period following the shock. In order that both these variables follow the same direction in course of their short run time paths, ie. to reproduce a positive and significant contemporaneous relationship between the two, I introduce a financial friction in the form of borrowing constraint in the next section.

### III. Asset pricing framework with borrowing constraint friction

In this section I introduce a borrowing constraint friction, inspired by Kiyotaki and Moore (1997), within the existing theoretical framework. I consider a firm producing output with capital as the only input as in the previous framework. However, in the present framework, the firm is entitled to borrow an amount  $b_t$  from an international bank or financial intermediary at a fixed gross rate of interest  $r'$ , or net rate of interest  $r$  where

$$r' = 1 + r \tag{28}$$

The firm being a price taker in the international market takes the international rate of interest as given. Also, only firms and not households have access to the international financial market. The firm's resource constraint can be written as

$$d_t + i_t + r'b_{t-1} = \epsilon_t k_t + b_t \tag{29}$$

with  $i_t$  being represented by the same investment equation as in the previous framework, which is equation (8).

The right-hand-side of the firm's resource constraint represents total resources of the firm i.e. the total output produced at time period  $t$  given by  $\epsilon_t k_t$  plus the amount borrowed by the firm, which is  $b_t$ . The left-hand-side of the resource constraint equation shows that a part of the firm's total income goes into investment  $i_t$ , a part  $r'b_{t-1}$  is utilized to repay the amount borrowed at time period  $t-1$  and the remainder  $d_t$  is distributed to the household as dividends.



Now, the bank who is lending to the firm, faces a problem of moral hazard from the firm in the sense that the firm can borrow a certain amount of money at time period  $t$  and not repay the loan in the next period. Hence the maximum amount of loan the firm will be granted at period  $t$  should equal the net worth of the firm at period  $t + 1$ , which is  $k_{t+1}$  i.e. the firm's capital stock at period  $t + 1$ .

If  $b_t$  is the amount of loan taken by the firm at period  $t$  at rate of interest  $r'$ , then at time period  $t + 1$  the firm is supposed to repay  $r'b_t$ . But since the maximum amount that the lender can recover is  $k_{t+1}$ , the firm will face a borrowing constraint given by

$$r'b_t \leq k_{t+1} \quad (30)$$

## A. Market capitalization and growth in a borrowing constrained equilibrium

### A.1 Conditions under which borrowing constraint binds fully in equilibrium

Since firms are owned by households, the firm, on behalf of the representative household, will maximize discounted stream of future dividends subject to the borrowing constraint represented by equation (30). The maximization problem of the firm can be expressed more formally as:

$$Max : E_t \sum_{s=0}^{\infty} m_{t,t+s} [\epsilon_{t+s} k_{t+s} + b_{t+s} + \frac{1}{\psi_t} ((1 - \delta_t) k_{t+s} - k_{t+s+1}) - r' b_{t+s-1}] \quad (31)$$

$$s.t. : b_{t+s} \leq \frac{k_{t+s+1}}{r'}, s = 0, \dots, \infty \quad (32)$$

where  $m_{t,t+s}$  denotes the stochastic discount factor for the households as in the previous section and is given by equation (11). Since firms are owned by households and optimize dividends on behalf of the households, the latter's marginal rate of substitution enters the firm's maximization problem.

In order to solve the maximization problem given by (31), I set up the Lagrange function as:

$$L_t = E_t \sum_{s=0}^{\infty} m_{t,t+s} \left[ \epsilon_{t+s} k_{t+s} + b_{t+s} + \frac{1}{\psi_t} ((1 - \delta_t) k_{t+s} - k_{t+s+1}) - r' b_{t+s-1} \right] + \sum_{s=0}^{\infty} \lambda_{t+s} \left( \frac{k_{t+s+1}}{r'} - b_{t+s} \right) \quad (33)$$

For the above problem in (33),  $\lambda_{t+s}$  denotes the Lagrange multiplier at time period  $t$ . At time  $t$ , the choice variables of the firm are its investment  $k_{t+1}$  and the amount it decides to borrow i.e.  $b_t$ .

The first order conditions to the Lagrangian problem in (33) with respect to  $k_{t+1}$  and  $b_t$  implies

$$\begin{aligned}\frac{\partial L_t}{\partial k_{t+1}} &= 0 \\ &= > \quad \frac{\lambda_t}{r'} - \frac{1}{\psi_t} + E_t m_{t,t+1} \left[ \epsilon_{t+1} + \frac{1}{\psi_{t+1}} (1 - \delta_{t+1}) \right] = 0\end{aligned}\quad (34)$$

and

$$\begin{aligned}\frac{\partial L_t}{\partial b_t} &= 0 \\ &= > \quad 1 - \lambda_t - E_t m_{t,t+1} r' = 0\end{aligned}\quad (35)$$

Combining the first order conditions to the Lagrangian problem in (34) and (35) and assuming that  $\lambda_t > 0$ , I have

$$\frac{1}{c_t} \left[ \frac{1}{\psi_t} - \frac{1}{r'} \right] = \beta E_t \frac{1}{c_{t+1}} \left[ \frac{\epsilon_{t+1} \psi_{t+1} - \delta_{t+1} - \psi_{t+1} + 1}{\psi_{t+1}} \right]\quad (36)$$

Now, in order to arrive at equation (36), I need  $\lambda_t > 0$ . From the Kuhn-Tucker condition,

$$\frac{\partial L_t}{\partial \lambda_t} \geq 0, \lambda_t \geq 0, \lambda_t \frac{\partial L_t}{\partial \lambda_t} = 0\quad (37)$$

Hence from (37)  $\lambda_t > 0$  implies  $\frac{\partial L_t}{\partial \lambda_t} = 0$  which means

$$\frac{k_{t+1}}{r'} = b_t\quad (38)$$

Equation (38) implies full binding of the borrowing constraint. Intuitively, for  $\lambda_t > 0$ , the marginal benefit from borrowing is greater than the marginal cost from borrowing and hence it is beneficial for firms to borrow and hit the credit ceiling when there is a positive value of  $\lambda_t$ .

To see this more clearly, note that from equation (35)  $\lambda_t$  is given by

$$\begin{aligned}\lambda_t &= 1 - E_t m_{t,t+1} r' \\ &= 1 - \beta E_t \frac{u'(c_{t+1})}{u'(c_t)} r'\end{aligned}\tag{39}$$

On the right hand side of equation (39) the first term i.e. 1 denotes marginal benefit from borrowing, because an additional unit of borrowing increases current output by 1 unit while the second term i.e.  $\beta E_t \frac{u'(c_{t+1})}{u'(c_t)} r'$  stands for marginal cost from borrowing. The second term in equation (39) effectively represents the discounted value of the output loss that the firm has to incur in the next period as a result of its repayment of the loan, due to one extra unit of borrowing in the current period.  $\lambda_t$  is thus the difference between the marginal benefit and marginal cost resulting from one additional unit of borrowing. As long as  $\lambda_t > 0$ ,  $1 > \beta E_t \frac{u'(c_{t+1})}{u'(c_t)} r'$ , signifying that the marginal benefit exceeds the marginal cost from borrowing. Under these circumstances, the firm will always be eager to borrow more and hit the borrowing limit. When  $\lambda_t = 0$ ,  $1 = \beta E_t \frac{u'(c_{t+s})}{u'(c_t)} r'$ , making the marginal benefit from borrowing equal to the marginal cost. In this situation, the firm becomes indifferent to borrowing. The graph in Figure 4 depicts a borrowing constrained equilibrium, i.e. an equilibrium situation in which the firm will borrow upto the full limit allowed by the financial intermediary.

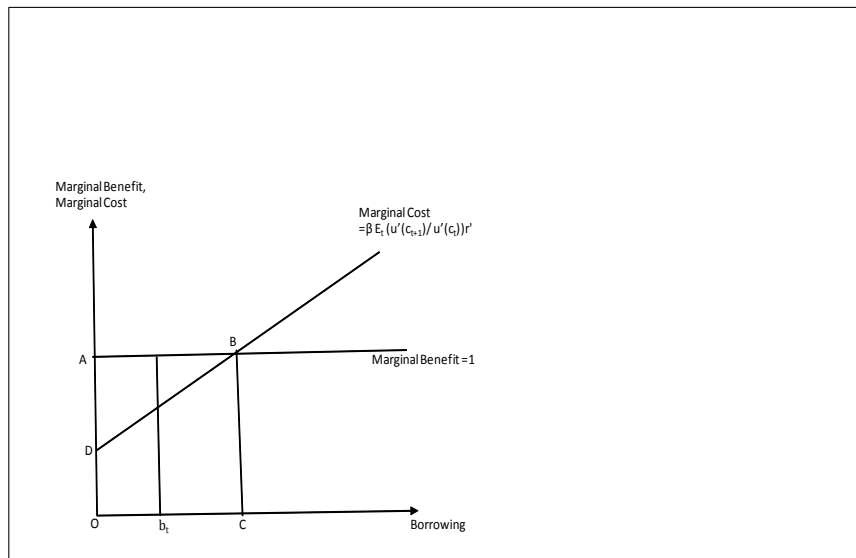


Figure 4: Borrowing constrained equilibrium

In Figure 4 the horizontal line represents the marginal benefit and the upward rising line

represents the marginal cost from one additional unit of borrowing.<sup>7</sup> These lines intersect at the point  $B$ , making marginal benefit equal to marginal cost and hence  $\lambda_t = 0$ . The amount of borrowing which corresponds to this intersection point is denoted in Figure 4 by  $C$ . Note that  $\lambda_t > 0$  throughout the positive range of borrowing represented by the segment  $OC$  in the borrowing axis. The point  $b_t$  on the borrowing axis represents the borrowing limit (i.e. the maximum amount that the firm is allowed to borrow from the international financial intermediary). Thus, assuming that marginal benefit equals marginal cost for a positive level of borrowing and also that the borrowing limit imposed by the financial intermediary is always positive, so long as the point  $b_t$  lies to the left of the point  $C$  (the firm is allowed to borrow less than a level at which marginal benefit equals marginal cost) the firm will always borrow upto the full amount. In other words, the borrowing constraint will bind fully. This is because, for levels of borrowing which are less than that at point  $C$ , marginal benefit from borrowing uniformly exceeds marginal cost, making  $\lambda_t > 0$ . If the borrowing limit lies in the range  $OC$ , as demonstrated in Figure 4, the firm will always be hungry to borrow at the maximum limit imposed by the financial intermediary and hence the constraint will fully bind. In the present theoretical framework, I assume that the borrowing constraint always binds to the full extent in equilibrium.<sup>8</sup>

From equation (39), in order that  $\lambda_t > 0$ , I must have  $1 > \beta E_t \frac{u'(c_{t+s})}{u'(c_t)} r'$ , which imposes the following restriction on the exogenous world interest rate  $r'$  as

$$r' < \frac{u'(c_t)}{\beta E_t u'(c_{t+1})} \quad (40)$$

If the borrowing limit imposed on the firm is positive and the restriction on  $r'$  given by (40) always holds at this limit, then borrowing constraint binds fully in equilibrium. For the present analysis I only consider the range of the gross interest rate  $r'$  for which the above condition holds.

This leads to the next proposition.

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<sup>7</sup>With increase in current borrowing, future consumption goes down and marginal utility from future consumption goes up. Similarly, increased borrowing leads to fall in marginal utility of current consumption. Hence the marginal cost line is increasing in levels of borrowing.

<sup>8</sup>In other words, I only consider the range of borrowing limits for which  $\lambda_t = \max\left(0, 1 - \beta E_t \frac{u'(c_{t+s})}{u'(c_t)} r'\right)$ , such that in equilibrium the firm borrows upto the full possible limit. There can be other possible equilibria as well. These can include negative borrowing (i.e. lending), or unconstrained borrowing. However, in the present section, I only consider the equilibrium situation where the firm borrows upto the full limit, i.e. the borrowing constraint binds entirely in equilibrium.

**Proposition 3** *A borrowing constrained equilibrium holds for a restriction on  $r'$  represented by (40) for a positive borrowing limit.*

I now derive the optimal consumption and investment decisions in an equilibrium for an example economy where the borrowing constraint fully binds. Since in equilibrium, consumption equals dividend, in a borrowing constrained equilibrium, the economywide resource constraint for time period  $t$  can be written as

$$\epsilon_t k_t + \frac{k_{t+1}}{r'} = c_t + k_{t+1} - (1 - \delta)k_t + k_t \quad (41)$$

Refer to equation (36) which combined the first order conditions to the firm's profit maximization problem with respect to  $b_t$  and  $k_{t+1}$ . Using this equation and the equilibrium resource constraint in equation (41), the borrowing constrained equilibrium consumption  $c_t$  and capital accumulation  $k_{t+1}$  can be solved as

$$c_t = (1 - \beta) \left( \frac{\epsilon_t \psi_t - \psi_t - \delta_t + 1}{\psi_t} \right) k_t \quad (42)$$

$$k_{t+1} = \beta \left( \frac{r'}{r' - \psi_t} \right) (\epsilon_t \psi_t - \psi_t - \delta_t + 1) k_t \quad (43)$$

Detailed derivation of equations (36), (42) and (43) is relegated to the appendix.

Using the equilibrium values of consumption and capital accumulation from (42) and (43) in (40), and assuming  $u(c_t) = \ln c_t$ , I can derive a borrowing constraint binding restriction on gross international interest rate as

$$r' < \psi_t \left[ 1 + \frac{1}{E_t \left( \frac{\psi_{t+1}}{\epsilon_{t+1} \psi_{t+1} - \psi_{t+1} - \delta_{t+1} + 1} \right)} \right] \quad (44)$$

While investigating the short run dynamics of market capitalization and growth along with other relevant variables in Section III E, I assume that the borrowing constrained equilibrium holds in every period. Since I deal with serially correlated shocks while exploring the short run dynamics, this means that I consider only admissible ranges of the values of TFP shock  $\epsilon$ , the IST shock  $\psi$  and the CQ shock  $\delta$  for which the restriction on the world interest rate captured by (44) holds true in each period. In other words, I consider the set  $(\epsilon, \psi, \delta)$  for which the firm

remains a net borrower throughout and borrows the full amount it is allowed to.

As a simple case, I assume  $\epsilon_t$  is i.i.d. and no IST and CQ shocks, i.e.  $\psi_t = 1$  and  $\delta_t =$  a constant. With this assumption, I derive a restriction on  $r'$ . The derivation and implications of this restriction are relegated to the appendix.

## A.2 Market capitalization and growth expressions

As in equilibrium, representative household consumes entire dividend earnings, with a logarithmic utility function, the equilibrium asset price, which follows from the household's utility maximization exercise, is given by equation (6) as

$$p_t^z = \left( \frac{\beta}{1 - \beta} \right) c_t$$

Using the full borrowing equilibrium values of consumption and capital accumulation from (42) and (43) in the above asset pricing equation, I derive an expression for market capitalization-output ratio and output growth as

$$mk_t = \frac{p_t^z}{y_t} = \beta \left( \frac{\epsilon_t \psi_t - \psi_t - \delta_t + 1}{\epsilon_t \psi_t} \right) \quad (45)$$

and

$$yg_t = \frac{y_t}{y_{t-1}} = \beta \left( \frac{\epsilon_t}{\epsilon_{t-1}} \right) \left( \frac{r'}{r' - \psi_{t-1}} \right) (\epsilon_{t-1} \psi_{t-1} - \psi_{t-1} - \delta_{t-1} + 1) \quad (46)$$

Derivation of (45) and (46) is relegated to the appendix.

## B. A special case

I now look into the entire set up, but with only one shock, i.e. a TFP shock which follows an i.i.d. distribution. As in the previous section, here also the sole purpose of doing this is to derive closed form solutions of the covariance between market capitalization ratio and output growth, assuming that the TFP shock follows a lognormal distribution.

It is already established in the previous section that in equilibrium representative household consumes his entire dividend earnings. With a logarithmic utility function, the equilibrium asset price, i.e. price at which representative household will wish to neither increase nor decrease his

holding of assets, is given by equation (6) as

$$p_t^z = \left( \frac{\beta}{1 - \beta} \right) c_t$$

From equation (42) and (43) it follows that with only TFP shock in action, the borrowing constrained equilibrium values of consumption and capital accumulation is given by

$$c_t = (1 - \beta) (\epsilon_t - \delta) k_t \quad (47)$$

$$k_{t+1} = \beta \left( \frac{r'}{r' - 1} \right) (\epsilon_t - \delta) k_t \quad (48)$$

Using the equilibrium consumption and capital accumulation values from equations (47) and (48) along with the value of the equilibrium asset price from equation (6), I derive expressions for market capitalization - output ratio and output growth as

$$mk_t = \frac{p_t^z}{y_t} = \beta \left( 1 - \frac{\delta}{\epsilon_t} \right) \quad (49)$$

and

$$ygt = \frac{y_t}{y_{t-1}} = \beta \epsilon_t \left( \frac{r'}{r' - 1} \right) \left( 1 - \frac{\delta}{\epsilon_{t-1}} \right) \quad (50)$$

From the market capitalization ratio and the growth expressions in (49) and (50), it is evident that a good TFP shock (rise in  $\epsilon_t$ ) is going to increase both market capitalization ratio and growth, from which I expect to find a positive market capitalization - growth correlation.

Also from the above expressions, it is clear that in order to ensure a positive value of market capitalization and growth,  $\epsilon$  should be greater than  $\delta$  for all different time periods. This is possible only if  $(\epsilon - \delta)$  follows a lognormal distribution, because in that case,  $E(\epsilon - \delta) > 0$ . Hence I assume that  $(\epsilon - \delta)$  follows a lognormal distribution with mean 0 and variance  $\sigma^2$ , which means  $\epsilon$  follows a shifted lognormal distribution.

Hence,  $E(\epsilon - \delta) = e^{0.5\sigma^2}$  and  $E(\epsilon) = e^{0.5\sigma^2} + \delta$ .

Also,  $E(\epsilon^{-1}) \simeq e^{0.5\sigma^2} - \delta e^{2\sigma^2} - \delta^2 e^{4.5\sigma^2}$ , detailed derivation of which is shown in the appendix.

Thus the unconditional covariance between short run fluctuations in market capitalization

ratio and growth can be calculated as:

$$Cov(mk_t, yg_t) = - \left( \frac{r'}{r' - 1} \right) \beta^2 \delta \left[ 1 - \left( e^{0.5\sigma^2} - \delta e^{2\sigma^2} - \delta^2 e^{4.5\sigma^2} \right) \left( e^{0.5\sigma^2} + \delta \right) \right] \left[ 1 - \delta \left( e^{0.5\sigma^2} - \delta e^{2\sigma^2} - \delta^2 e^{4.5\sigma^2} \right) \right] \quad (51)$$

Detailed derivation of this is done in the appendix. Equation (51) gives rise to the following proposition.

**Proposition 4** *In the presence of only one shock, i.e. a TFP shock, following a shifted log-normal distribution, a borrowing constrained equilibrium within an asset pricing framework with production and investment, gives rise to a market capitalization ratio - growth covariance represented by equation (51) which is positive for plausible parameter values.*

Now, assuming  $r' > 1$  and also  $0 < \beta < 1$ ,  $0 < \delta < 1$  and  $0 < \sigma < 1$ , the sign of the covariance becomes ambiguous.

Fixing values of the parameters  $r'$ ,  $\beta$  and  $\delta$  at  $r' = 1.01$ ,  $\beta = 0.96$  (standard discount factor value for annual data) and  $\delta = 0.1$  (standard depreciation rate value for annual data) and varying the value of  $\sigma$  i.e. the standard deviation of the  $(\epsilon - \delta)$  distribution from 0.25 to 0.9, I get a plot for  $Cov(mk_t, yg_t)$ , which is shown in Figure 5.

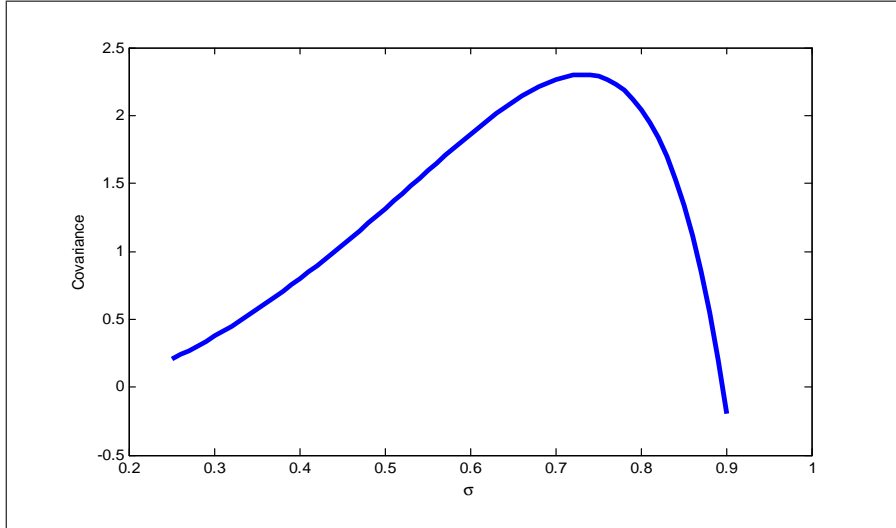


Figure 5: Market capitalization - growth covariance for different values of standard deviation of lognormally distributed  $(\epsilon - \delta)$

In Figure 5, as  $\sigma$  increases from 0.25,  $Cov(mk_t, yg_t)$  steadily rises till  $\sigma = 0.75$ , after which it starts falling but still retains mostly positive values.  $Cov(mk_t, yg_t)$  reaches negative values



only when  $\sigma$  is very close to 0.9. Thus the above plot shows very few values of covariance which are negative and this is in line with the stylized fact that majority of countries depict a positive and significant short run correlation between market capitalization ratio and growth.<sup>9</sup>

Alternatively, fixing values of the parameters  $r'$ ,  $\beta$  and  $\sigma$  at  $r' = 1.01$ ,  $\beta = 0.96$  and  $\sigma = 0.25$  and varying the value of depreciation  $\delta$  from 0.025 to 0.1, I get a plot for  $Cov(mk_t, yg_t)$ , which is shown in Figure 6.

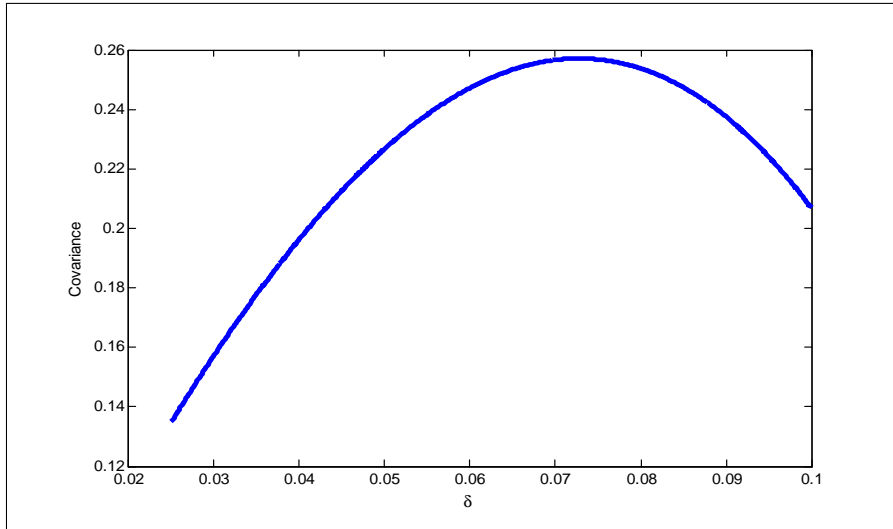


Figure 6: Market capitalization - growth covariance for different values of capital depreciation parameter  $\delta$

From Figure 6, it is evident that the range of different values of covariance remains uniformly positive for all reasonable values of  $\delta$ , thus once again supporting the contemporaneous positive significant short run correlation between market capitalization and growth, as was empirically established for most countries.

### C. Comparing constrained and unconstrained equilibrium scenarios when firms have the opportunity to borrow

So far I have been working in a theoretical framework where firms have the provision to borrow, but their borrowing is subject to a constraint being imposed by the financial intermediary. Under these circumstances, I only look into the equilibrium scenario, where firms borrow the full amount they are allowed to, which is the discounted value of their next period capital stock. In this borrowing constrained equilibrium, a positive correlation between market capitalization

<sup>9</sup>A reasonably high positive value of covariance is in line with a positive significant value of correlation coefficient.

ratio and output growth is found to exist, which supports the empirical findings. However, the present chapter does not investigate in detail the market capitalization-growth behaviour in a situation where firms have the opportunity to borrow, but without facing any constraint from the financial intermediary.<sup>10</sup>

If firms are allowed unconstrained borrowing, they will end up borrowing upto the point where their marginal benefit from borrowing equals marginal cost in equilibrium. In this scenario, if a good TFP shock hits the economy, this will not have an effect on borrowing, since firms are already indifferent to borrowing in equilibrium. A good TFP shock will augment current output, which will only lead to an increase in investment, as households look to smooth out consumption across time periods.

On the other hand, when the intermediary imposes a constraint on the firms, the latter's marginal benefit from borrowing exceeds marginal cost at the point of full borrowing, such that in equilibrium, firms would be eager to borrow more. Since a good TFP shock signals increased investment (due to increased output), in this situation firms will be allowed to borrow more in equilibrium, as their borrowing limit would increase as a result of increased accumulated capital. Firms, being hungry to borrow in equilibrium, will borrow to the full extent. Thus in a borrowing constrained equilibrium, a TFP shock augments the level of borrowing, which does not happen under an unconstrained equilibrium situation. Further, in a constrained equilibrium, as firms end up borrowing more, households will be interested to insure against next period's income, which is expected to go down as a result of future loan repayment. This implies an increased demand for stocks, eventually leading to a rise in market capitalization, which, in turn, drives the positive correlation between market capitalization ratio and growth.

Since in an unconstrained equilibrium, an aggregate shock does not affect borrowing and, through this channel, the demand for assets, I do not find this particular equilibrium situation very relevant in the context of investigating the short run market capitalization-growth relationship.

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<sup>10</sup>If firms are not imposed a constraint, then several possibilities can arise (depending upon the nature of the shock) which is beyond the scope of this chapter. In this subsection I discuss one possible consequence of an unconstrained equilibrium.

#### D. Productivity shock augments borrowing

In an equilibrium where borrowing constraint fully binds i.e.  $b_t = \frac{k_{t+1}}{r'}$ , with only TFP shock in action, the borrowing to capital ratio can be calculated as

$$\frac{b_t}{k_t} = \frac{\beta}{r' - 1}(\epsilon_t - \delta) \quad (52)$$

This means that a positive TFP shock will be associated with a rise in borrowing to capital ratio. In order to test this finding I look into average TFP and average borrowing to capital ratio for thirty three countries, which is illustrated in Table 5.<sup>11</sup> For this purpose, I gather yearly data for GDP, capital stock and external private debt stock (all adjusted at constant 2005 US\$) from 1987 to 2013 for 33 mostly developing countries<sup>12</sup>. For each country TFP for a given year is calculated by dividing that year's output by the capital stock. This measure of TFP is consistent with the linear technology production function I use in my theory. I take an average of the TFP calculated across 27 years for each of these countries. Similarly, I have calculated the average borrowing to capital for each country using data on external private debt stock and capital stock.

The cross country correlation coefficient between average productivity and average borrowing to capital ratio for all 33 countries comes out as 0.233, which is significant at 10% level of significance.

Figure 7 depicts the cross country average productivity and average borrowing to capital ratio graphs.

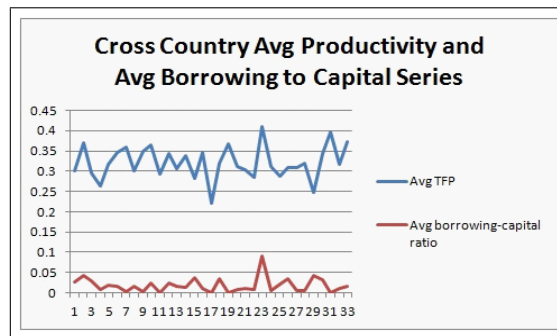


Figure 7

It is clear from Figure 7 that the basic pattern of movements for average productivity and

<sup>11</sup>Table 5 can be found in the appendix.

<sup>12</sup>The source of my data set is the World Development Indicators (<http://data.worldbank.org/data-catalog/world-development-indicators>).

average borrowing is very similar across different developing countries.

Next I plot a scatter diagram with avg productivity in the x-axis and average borrowing to capital in the y axis for all the different countries which is shown in Figure 8.

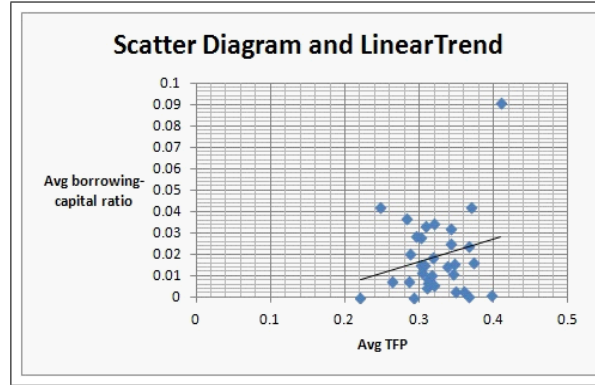


Figure 8

The linear trend that fits through the scatter diagram is upward rising, indicating positive correlation between average productivity and average borrowing to capital ratio across different developing countries.

From the theory I have established that if the borrowing constraint binds, ie, if a country is borrowing the entire amount it is allowed to (which in this case is its next period's discounted capital stock), a higher productivity should indicate a higher borrowing to capital ratio as well. From the data for 33 developing countries, I find a positive correlation (significant at 10% level of significance) between the average TFP and average borrowing to capital ratio across all countries. The underlying assumption is that for all these countries borrowing constraint fully binds in equilibrium. These results support my theoretical finding that more borrowing is associated with higher productivity if the borrowing constraint fully binds. This is because a positive TFP shock signals higher capital stock in next period through equation (48), thereby increasing the borrowing limit of the firm, which in turn also increases the borrowing to capital ratio.

### E. Short run quantitative analysis

Coming back to the generalized framework with three different technology shocks, I now focus on the contemporaneous market capitalization - growth relationship in this framework. In order to understand this, I look into the short run dynamics of market capitalization and growth along with those of a few other relevant macroeconomic variables in response to a TFP shock, an IST

shock and a CQ shock. <sup>13</sup>Each of the shocks is assumed to follow an AR(1) process, as in the previous section; the TFP shock represented by equation (22), the IST shock by equation (23) and the CQ shock by equation (24).

Figures 8, 9 and 10 represent the short run behaviours of market capitalization and growth along with a few other macroeconomic variables due to the realization of a TFP shock, an IST shock and a CQ shock respectively. In these impulse response figures, growth of output is denoted by  $yg$ , market capitalization as a ratio of GDP is denoted by  $mk$ , consumption to capital ratio is denoted by  $ck$ , dividend to capital ratio is denoted by  $dk$ , dividend to output ratio is denoted by  $dy$ , investment to capital ratio is denoted by  $ik$ , investment to output ratio is denoted by  $iy$ , borrowing to capital ratio is denoted by  $bk$  and expected capital growth is denoted by  $kg$ .

In order to carry out the necessary simulations, the household discount factor  $\beta$  is fixed at 0.99 and the depreciation parameter  $\bar{\delta}$  at 0.025 which are the conventional levels consistent with quarterly calibration. In order to find an estimate of the productivity parameter  $\bar{\epsilon}$ , the long run per capita quarterly real GDP growth rate for USA is taken as a baseline measure. For the sample period 1947 – 2014 the US quarterly long run per capita growth rate is found to be 0.49% (an annualized growth rate value of 1.97%) which is targeted to set the productivity parameter at 0.048. As in the previous section, without any loss of generality, I fix the standard deviation of the exogenous component of all the shocks, i.e.  $\sigma_\epsilon^2$ ,  $\sigma_\xi^2$  and  $\sigma_\delta^2$  at unit levels in order to normalize the impulse responses. The international borrowing rate is fixed at 1% such that  $r' = 1.01$ .

The correlation coefficient reproduced by the simulated model is positive and significant at 0.48 for the baseline parametric values. Table 6 represents a sensitivity analysis of the market capitalization - growth correlation coefficient for different values of long run capital depreciation parameter  $\bar{\delta}$  and gross interest rate parameter  $R$ .<sup>14</sup>

With increase in the value of  $R$  from 1.01 to 1.09, the market capitalization - growth correlation coefficient does not change. But this correlation coefficient is a little sensitive to  $\bar{\delta}$ . With

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<sup>13</sup>Although I deal with serially correlated shocks while investigating the short run dynamics, I assume that each period the borrowing constraint binding restriction on the world interest rate must be valid, such that the firm remains a net borrower in each period. For this reason, as mentioned earlier, I consider only admissible ranges of the values of TFP shock  $\epsilon$ , the IST shock  $\psi$  and the CQ shock  $\delta$  for which the restriction on the world interest rate captured by (44) holds true in each period, i.e. I consider the set  $(\epsilon, \psi, \delta)$  for which the borrowing constrained equilibrium is valid throughout the entire short run time path of the firm.

<sup>14</sup>Table 6 can be found in the appendix.

increase in  $\bar{\delta}$  from 0.01 to 0.09, the value of the correlation coefficient falls slightly from 0.483 to 0.432. It should be noted that like in the previous theoretical set-up, this short run correlation refers to the correlation of market capitalization ratio and growth for a time horizon extending upto 40 periods after the period of realization of the shocks.

Figure 9 demonstrates the effect of a TFP shock on the chief macroeconomic variables.

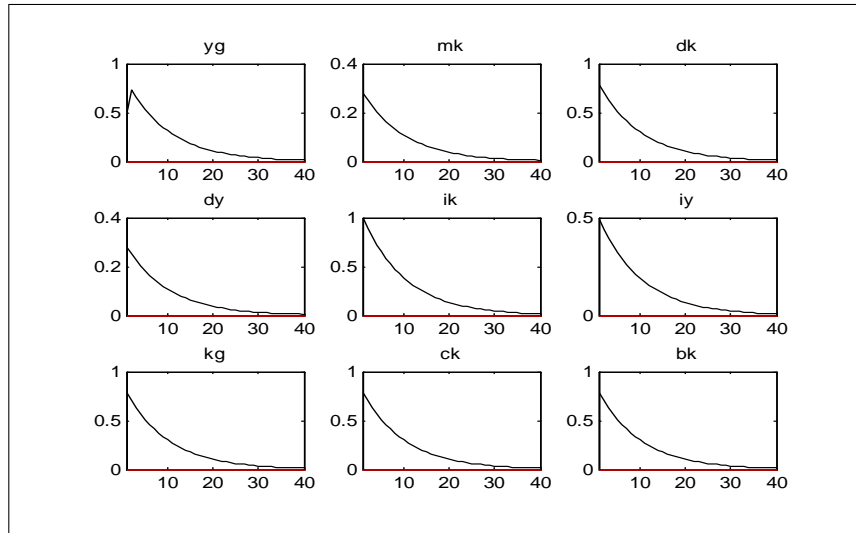


Figure 9: TFP impulse response in borrowing constrained model

A positive TFP shock induces market capitalization ratio and growth to move in the same direction in the short run. A good TFP shock in time period  $t$  increases production and hence growth  $yg$  at time period  $t$ . Also, an increase in total output augments total investment by the firm, which is evident from an increase in  $ik$  i.e. the investment to capital ratio. In fact, investment increases at a rate greater than the rise in output, due to which an increase in the investment - output ratio  $iy$  is observed. A rise in the total investments in physical capital lead to an increase in the total capital stock in the next period, which explains the rise in expected capital growth  $kg$ . This is why a spike in output growth is observed in time  $t + 1$ , implying a further rise in growth from the current to the next period. A rise in next period capital stock increases the firms' borrowing limit. Also since TFP shock follows an AR(1) process, an anticipated rise in next period's production increases the firm's ability to repay loans in the next period, which is why firms can afford to increase their optimal borrowing to capital ratio  $bk$  in the current period. Now, although investment rises considerably, total dividends in time period  $t$  also rise and that too at a rate higher than the rise in output, as is evident from a rise in  $dy$ . Thus both investments and dividends of firms increase at a rate higher than the increase in

output, which is possible as a result of an increase in current borrowing by the firm.

Although the rise in dividend to capital ratio  $dk$  is a bit lower than the rise in investment to capital ratio  $ik$ , as is evident from Figure 9, an increase in  $dy$  signifies that on the whole dividends increase at a rate higher than the increase in output. As dividend income of the households increase at a rate greater than the increase in output, their rise in asset demand also exceeds the corresponding rise in output, subsequently leading to a rise in the ratio of market capitalization to output. Since in equilibrium, household's consumption equals total dividends, a rise in consumption to capital ratio  $ck$  in Figure 9 is reflected in a proportional rise in  $dk$ . In fact, in this case, a rise in total dividends increases households' total demand for assets on both counts; firstly because of the pure income effect of an increase in output getting translated into increased dividend income and secondly due to an increase in anticipated dividends as a result of a rise in expected production in the next period. An increased asset demand, in turn, contribute towards increase in the market capitalization ratio  $mk$ .

Figure 10 represents the short run dynamics of some of the key macroeconomic variables in response to an IST shock.

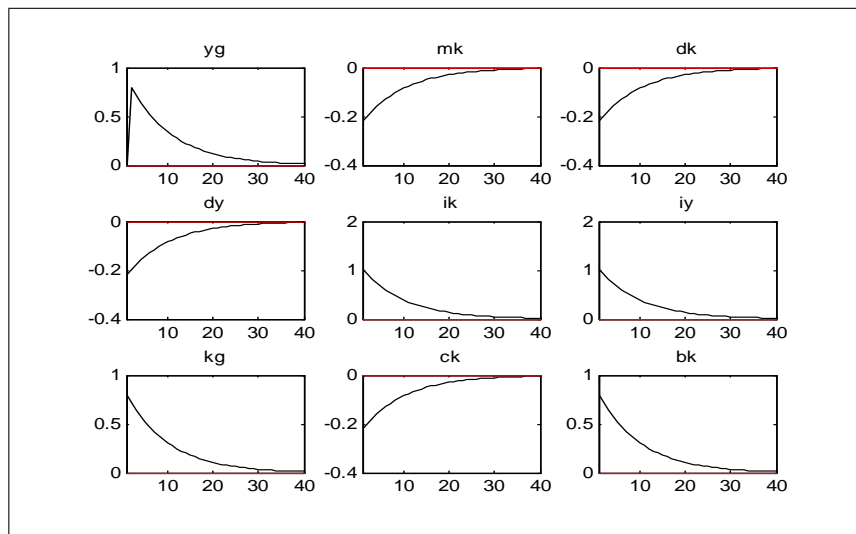


Figure 10: IST impulse response in borrowing constrained model

Market capitalization ratio and growth move in opposite directions in the short run due to a positive IST shock. In response to a good IST shock, total investments in time period  $t$  increase, which augments total capital stock in time period  $t + 1$ , thereby also increasing the expected capital growth  $kg$ . This leads to increased output growth, which is manifested by a spike in  $yg$  in the period immediately after the realization of the shock. Due to the investment-friendly

environment created by the positive IST shock, a rise in total investments occur in time  $t$ , reflected by a considerable increase in investment to capital ratio  $ik$  and investment to output ratio  $iy$ . Also, as firms are able to borrow in the current period, they can afford to increase their current investments, as opposed to the scenario where there was no provision for borrowing which led to a fall in  $ik$ . In the present scenario the considerable rise in investments by the firms is achieved at the cost of a fall in their current dividends. This fall in dividends at time period  $t$  is reflected in a fall in dividend to capital ratio  $dk$  and dividend to output ratio  $dy$ .

A fall in households' dividend income leads to a fall in the total demand for assets, which in turn is manifested in a drop in the market capitalization ratio  $mk$ . Also, since an IST shock augments next period output, the risk averse household, in an attempt to smooth consumption across periods, increases its current consumption, as a result of which there is fall in relative asset demand and hence market capitalization ratio. Moreover, since the IST shock does not have any direct positive influence on current output, there is no question of the pure income effect of an output rise getting translated into increased demand for stocks and increased market capitalization. A good IST shock also leads to an increase in borrowing to capital ratio  $bk$ . This is because, greater investment in physical capital implies a boost in next period's total capital stock, thereby raising the firm's borrowing limit and allowing it to borrow more in the current period.

Figure 11 summarises the impulse response of the relevant variables due to a CQ shock.

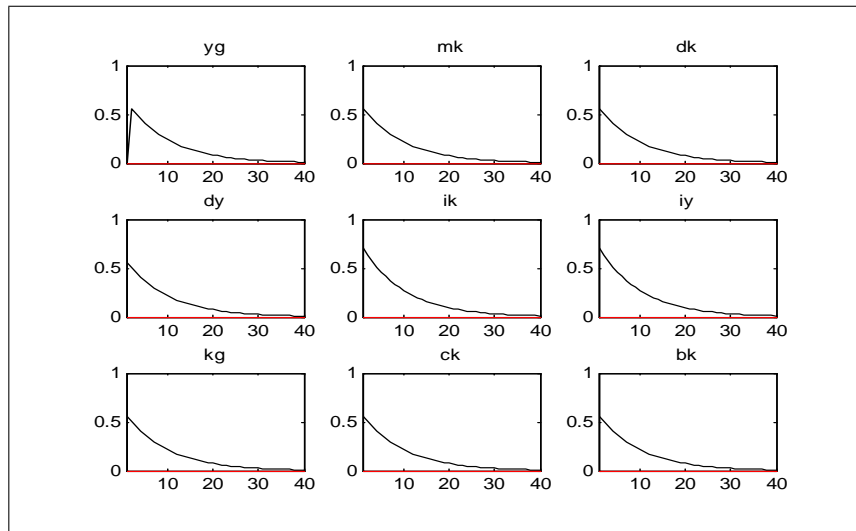


Figure 11: CQ impulse response in borrowing constrained model

In response to a good CQ shock, i.e. with a fall in the depreciation rate of capital, market



capitalization and growth follow the same direction in their short run time paths. A good CQ shock reduces depreciation of existing capital, thereby boosting up total accumulated capital for the next period. This implies an increase in next period's capital growth  $kg$  and output growth  $yg$ . In this case, lesser depreciation of capital encourages firms to invest more in physical capital, leading to a rise in investment - capital ratio  $ik$  and investment - output ratio  $iy$ , as opposed to a fall in  $iy$  when no borrowing was allowed. Although firms' investments rise considerably, this does not hamper a corresponding increase in their total dividends, as is evident from a rise in dividend to capital ratio  $dk$  and dividend to output ratio  $dy$ . This happens because a fall in capital depreciation leads to a rise in next period output through higher capital accumulation. A rise in next period capital stock increases firms' borrowing limit in the current period, due to which there is an increase in current borrowing to capital ratio  $bk$ . As firms can borrow more in the current period, they can afford to increase both their dividends and their investments.

A rise in households' total dividend income leads to increase their demand for assets, which results in a rise in asset price and hence market capitalization ratio. A fall in the depreciation rate guarantees higher capital accumulation and hence higher output in the next period, leading to an increase in current optimal borrowing, thereby increasing total leverage of the household, and this also contributes towards increasing its demand for assets. Another reason for market capitalization to increase through the channel of higher asset demand is due to the fact that a current CQ shock causes anticipated rise in next period's output and hence dividends, making investment in stocks more attractive.

The impact effect of the three shocks on each of the variables is summarized in Table 7, with a (+) sign indicating an increase and a (-) sign a decrease of a variable in response to a particular shock. Much like Table 3 in the previous theoretical framework without borrowing constraint, Table 7 also represents the effect of the shocks on each variable, irrespective of whether these variables get affected immediately, or with a lag.<sup>15</sup>

It is clear from the above table that a good TFP shock and a good CQ shock have a positive effect on all variables under consideration. This, however, is not true in case of a positive IST shock due to the effect of which there is a one shot fall in dividend to capital ratio and market capitalization ratio.

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<sup>15</sup>Table 7 can be found in the appendix.

Table 8 represents the relative importance of each of the different shocks in terms of explaining the short run dynamics of the variables under consideration.<sup>16</sup>

From Table 8 it is clear that the TFP shock and the IST shock play the most important role in explaining the short run fluctuations of each of the variables discussed just now. The influence of an IST shock is dominated by that of a TFP shock for all variables except investment - output ratio. A TFP shock increases both market capitalization ratio and growth, whereas an IST shock increases output growth but decreases market capitalization ratio. Market capitalization ratio is driven much more dominantly by a TFP shock than an IST shock; the relative importance of the former being at a massive 76.30%, while that of the latter being at only 23.68%. For growth, however, the relative importance of a TFP and an IST shock in explaining its short run fluctuations is much more uniform, with a TFP shock determining 58.67% and an IST shock 41.28% of the short run growth dynamics. A capital quality shock explains very little of the short run movements of any of the variables under consideration. Since TFP is identified as the main driving force behind the short run dynamics of both market capitalization ratio as well as growth and also since both these variables are augmented due to the impact effect of a good TFP shock and follow similar short run time paths in the periods following the shock, the correlation coefficient obtained from simulating the model comes out to be positive and significant at 0.48 for the baseline parametric values, which supports the contemporaneous market capitalization - growth empirical findings, in which the two are found to be positively and significantly correlated for most developing and developed countries.

## **F. Lead-lag relationship between market capitalization and growth**

The borrowing constrained model performs much better than the model without borrowing in supporting the positive and significant contemporaneous relationship between market capitalization and growth, as established empirically. Having established this, I now check whether the current framework also supports the lead-lag relationship between the two variables, which followed from the empirical analysis.

Like in the previous framework without any frictions, in present set up also, it is established that the effect of each of the shocks on market capitalization get translated into next period's output growth, although TFP is the only shock that directly influences growth in the current

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<sup>16</sup>Table 8 can be found in the appendix.

period. As a result, from Figures 10 and 11 the intertemporal relationship between market capitalization ratio and growth presents itself in a lead-lag form most conspicuously due to IST and CQ shocks, because these shocks influence growth only in the second period through the indirect channel of market capitalization. Due to a TFP shock, however, growth first undergoes a one time increase in the current period and then spikes up once again in the second period, firstly as a result of the first period persistence effect of TFP on itself and secondly due to the first period TFP effect on market capitalization, which gets translated into growth in the second period.

Going back to equations (45) and (46), the borrowing constrained equilibrium values of market capitalization ( $mk_t$ ) and growth ( $yg_t$ ) are given by

$$mk_t = \frac{p_t^z}{y_t} = \beta \left( \frac{\epsilon_t \psi_t - \psi_t - \delta_t + 1}{\epsilon_t \psi_t} \right)$$

and

$$yg_t = \frac{y_t}{y_{t-1}} = \beta \left( \frac{\epsilon_t}{\epsilon_{t-1}} \right) \left( \frac{r'}{r' - \psi_{t-1}} \right) (\epsilon_{t-1} \psi_{t-1} - \psi_{t-1} - \delta_{t-1} + 1)$$

from which it follows that

$$yg_t = \epsilon_t \left( \frac{r'}{r' - \psi_{t-1}} \right) \psi_{t-1} mk_{t-1} \quad (53)$$

From (53) it is clear that the time  $t$  value of growth can be expressed as a function of the time  $t - 1$  value of market capitalization ratio. However, the market capitalization ratio at time  $t$  cannot be expressed as a function of growth at time  $t - 1$  in a similar way. Hence in a framework with borrowing constrained equilibrium and three different stochastic shocks acting simultaneously, at any given time period, market capitalization as a ratio of GDP is not influenced by previous period's growth, although growth is very much dependent on previous period's market capitalization ratio. This is in line with the empirical findings, where with the help of a panel VAR approach, it has been established that growth is dependent on the lagged values of market capitalization ratio, although the opposite is not true.

Also using the equilibrium asset price in (6) and equilibrium consumption (42) I have

$$p_t^z = \beta \left( \frac{\epsilon_t \psi_t - \psi_t - \delta_t + 1}{\psi_t} \right) k_t \quad (54)$$

and combining the equilibrium capital accumulation in (43) with the equilibrium consumption and asset price, I have

$$p_t^z = \frac{(r' - \psi_t)}{\psi_t r'} k_{t+1} \quad (55)$$

From (54) it follows that a TFP, IST or CQ shock in time period  $t$  affects stock price and hence market capitalization in time period  $t$ . This effect of a shock on time  $t$  market capitalization gets immediately translated to  $k_{t+1}$  i.e. capital stock in time period  $t + 1$  through equation (55). An effect on time  $t + 1$  capital stock implies a subsequent effect on output and hence growth in time period  $t + 1$ . This explains the lead-lag relationship between market capitalization and growth in the sense that the former precedes the latter in terms of response to stochastic shocks. This result can be explained with the help of the following proposition.

**Proposition 5** *In an asset price model with production and investment, in case of a borrowing constrained equilibrium, the effect of different shocks in a given period on stock price immediately translates into next period's capital stock, giving rise to a lead-lag relationship between market capitalization to output ratio and growth in the sense that the former precedes the latter.*

Thus the borrowing constrained model is able to explain both the contemporaneous as well as the lead-lagged relationship between market capitalization ratio and growth.

## **G. Why borrowing constrained model explains contemporaneous market capitalization - growth relationship**

While the model without borrowing can explain only the lead-lag relationship but not the contemporaneous relationship between market capitalization ratio and growth, both these aspects about the market capitalization - growth relationship can be explained by incorporating a friction, in the form of a borrowing constraint, into the model. In the framework with borrowing constraint friction, the persistence effect of the TFP shock on growth is much more prominent compared to the previous set - up which did not allow for borrowing. Also in the present framework, the TFP shock has a positive influence on market capitalization, whereas in the previous framework, it led to a fall in the market capitalization ratio. This is due to the fact that in the present scenario, since investment and hence future accumulated capital stocks increase in the event of a positive TFP shock, there is increase in the borrowing limit of the firms as set by the international financial intermediary. As a result of the increased current period leverage,

firms can afford to increase both their current investments as well as their current dividends. In fact, dividend increases at a rate greater than the increase in present output, which drives an increased asset demand (due to a rise in dividends, which constitute household income) on part of the household and eventually an increase in the ratio of market capitalization to output. In the previous framework, since firms do not have the provision to borrow, in the event of a positive TFP shock, they cannot afford to increase both physical investments as well as dividends to the extent they are able to in the present scenario with a borrowing constrained equilibrium. In fact, in the no borrowing framework, as a result of a good TFP shock, investments increase at a rate greater than the rise in output, leading to a fall in the dividend to output ratio. The net result is a decrease in market capitalization to output ratio, due to diminished asset demands.

In both theoretical frameworks, the CQ shock cannot explain much of the short run fluctuations in market capitalization ratio and growth and the TFP and IST shocks prove to be the chief determinants of the short run dynamics in these two variables. In the previous framework without borrowing, both TFP and IST shocks caused market capitalization and growth to move in opposite directions. In the present framework with borrowing constraint friction, although the IST shock effect on these variables remains unchanged, a TFP shock induces both market capitalization and growth to move in the same direction in the short run. Since in the model with borrowing constraint friction, TFP plays a much more dominant role compared to IST, in determining the short run dynamics of market capitalization, a contemporaneous positive and significant correlation between the market capitalization ratio and growth can be reproduced from this model.

#### **IV. Summary and concluding remarks**

The extant literature on stock market and the macroeconomy highlights mainly the causal relationship between the two. In the present chapter I investigate the short run contemporaneous and intertemporal relationship between market capitalization ratio as a proportion of GDP and GDP growth, as established empirically, in the context of a stochastic general equilibrium framework where short run dynamics of each of the variables is driven by aggregate macroeconomic shocks. The theoretical framework used for this purpose is a Lucas (1978) type asset pricing framework with production and investment, i.e. a combination of production based and consumption based capital asset pricing models as in Brock (1982).

In a complete market environment, i.e. without the existence of any frictions, this kind of framework in itself cannot support the contemporaneous short run relationship i.e. the positive and significant market capitalization - growth correlation. However, within the existing set-up, once a borrowing constraint friction is introduced giving rise to a scenario in which firms are allowed to borrow from an international financial intermediary up to a finite amount, which equals their next period discounted capital stock, the positive significant short run correlation between market capitalization ratio and growth can be reproduced within an equilibrium situation in which the borrowing constraint binds fully. In both frameworks, the TFP and IST shocks are the main determinants of market capitalization, growth and relevant macroeconomic variables. Due to a positive IST shock, market capitalization ratio and growth move in opposite directions in the short run in both set-ups. A good TFP shock, however, makes short run market capitalization and growth to move in opposite directions in the complete market framework, whereas incorporating a borrowing constraint friction induces the two to follow the same directions in their short run time path. This is possible through increased leverage of the firms in a full borrowing equilibrium, due to which there is increase in the dividend to output ratio, leading eventually to a rise in the market capitalization ratio, through increased asset demand.

In the borrowing constrained equilibrium scenario, it is also found that a positive productivity shock augments the end of period capital stock, which in turn increases the firm's equilibrium level of borrowing. In both theoretical frameworks with and without borrowing constraint frictions, a lead-lag relationship between market capitalization ratio and growth is observed, in the sense that growth in a certain period depends upon market capitalization in the previous period, although the opposite is not true. Each of the shocks is found to influence market capitalization ratio in the period of their realization and these shock effects on market capitalization get subsequently translated into next period's growth.

Thus in this chapter I have investigated how a financial friction helps explain the short run stock market-growth relationship. However, the theoretical framework used in the present chapter does not have market imperfections and price distortions, as one would expect in the real world. In the next chapter I intend to explore the economic implications of the presence of real and nominal rigidities on the short run stock market capitalization and growth behaviour within a New-Keynesian set-up.

## Appendix

### A. Derivations of (13), (14), (17) and (18)

The objective function of the firm is given by

$$Max : E_t \sum_{s=0}^{\infty} m_{t,t+s} d_{t+s} = E_t \sum_{s=0}^{\infty} m_{t,t+s} \left[ \epsilon_{t+s} k_{t+s} - \frac{1}{\psi_t} \{k_{t+s+1} - (1 - \delta_t) k_{t+s}\} \right]$$

This can be written as

$$Max : \left[ \epsilon_t k_t - \frac{1}{\psi_t} \{k_{t+1} - (1 - \delta_t) k_t\} \right] + m_{t,t+1} \left[ \epsilon_{t+1} k_{t+1} - \frac{1}{\psi_{t+1}} \{k_{t+2} - (1 - \delta_t) k_{t+1}\} \right] + \dots$$

$$\frac{\partial L_t}{\partial k_{t+1}} = 0$$

=>

$$\frac{1}{\psi_t} = m_{t,t+1} \left[ \epsilon_{t+1} + \frac{1}{\psi_{t+1}} (1 - \delta_{t+1}) \right] \quad (56)$$

From the equilibrium resource constraint,

$$\epsilon_t k_t = c_t + \frac{1}{\psi_t} [k_{t+1} - (1 - \delta_t) k_t]$$

=>

$$\epsilon_t + \frac{1}{\psi_t} (1 - \delta_t) = \frac{c_t}{k_t} + \frac{1}{\psi_t} \left( \frac{k_{t+1}}{k_t} \right)$$

=>

$$\epsilon_{t+1} + \frac{1}{\psi_{t+1}} (1 - \delta_{t+1}) = \frac{c_{t+1}}{k_{t+1}} + \frac{1}{\psi_{t+1}} \left( \frac{k_{t+2}}{k_{t+1}} \right) \quad (57)$$

Using (57) in (56),

$$\frac{1}{\psi_t} = m_{t,t+1} \left[ \frac{c_{t+1}}{k_{t+1}} + \frac{1}{\psi_{t+1}} \left( \frac{k_{t+2}}{k_{t+1}} \right) \right]$$

=>

$$\frac{k_{t+1}}{c_t} = \beta \psi_t \left( 1 + \frac{1}{\psi_{t+1}} \left( \frac{k_{t+2}}{c_{t+1}} \right) \right)$$

=>

$$\frac{k_{t+1}}{c_t} = \beta \psi_t \left( 1 + \frac{1}{\psi_{t+1}} \left( \frac{k_{t+2}}{c_{t+1}} \right) + \frac{1}{\psi_{t+2}} \left( \frac{k_{t+3}}{c_{t+2}} \right) + \dots \right)$$

=>

$$\frac{k_{t+1}}{c_t} = \frac{\beta\psi_t}{1-\beta} \quad (58)$$

Using (58) in the equilibrium resource constraint in (57), I have:

$$\epsilon_t k_t = c_t + \frac{1}{\psi_t} \left[ \left( \frac{\beta\psi_t}{1-\beta} \right) c_t - (1-\delta_t)k_t \right]$$

=>

$$c_t = (1-\beta) \left( \frac{\epsilon_t\psi_t + 1 - \delta_t}{\psi_t} \right) k_t$$

which is equation (13)

and

$$k_{t+1} = \beta (\epsilon_t\psi_t + 1 - \delta_t) k_t$$

which represents equation (14).

The equilibrium asset price is given by

$$p_t^z = \frac{\beta}{1-\beta} c_t$$

Plugging in the equilibrium consumption, I have

$$p_t^z = \beta \left( \frac{\epsilon_t\psi_t + 1 - \delta_t}{\psi_t} \right) k_t$$

Market capitalization ratio is given by

$$\begin{aligned} mk_t &= \frac{p_t^z}{y_t} \\ &= \frac{\frac{\beta}{1-\beta} c_t}{y_t} \\ &= \beta \left( \frac{\epsilon_t\psi_t + 1 - \delta_t}{\epsilon_t\psi_t} \right) \end{aligned}$$

which is given by (17).



Growth is given by

$$\begin{aligned}
yg_t &= \frac{y_t}{y_{t-1}} \\
&= \frac{\epsilon_t k_t}{\epsilon_{t-1} k_{t-1}} \\
&= \beta \frac{\epsilon_t}{\epsilon_{t-1}} (\epsilon_{t-1} \psi_{t-1} + 1 - \delta_{t-1}) \\
&= \beta \epsilon_t \left[ \psi_{t-1} + \frac{(1 - \delta_{t-1})}{\epsilon_{t-1}} \right]
\end{aligned}$$

which is (18)

## B. Derivation of covariance between market capitalization and growth in a model without borrowing and only TFP shock:

Unconditional Covariance between Market Capitalisation and growth is given by:

$$cov\left(\frac{p_t}{y_t}, \frac{y_t}{y_{t-1}}\right) = cov\left(\beta + \frac{(1 - \delta)}{A\epsilon_t}, \frac{\epsilon_t}{\epsilon_{t-1}} \beta (A\epsilon_{t-1} + 1 - \delta)\right)$$

(assuming  $A = 1$ )

$$cov\left(\frac{p_t}{y_t}, \frac{y_t}{y_{t-1}}\right) = (1 - \delta)\beta cov\left(\frac{1}{\epsilon_t}, \epsilon_t\right) + (1 - \delta)^2 \beta cov\left(\frac{\epsilon_t}{\epsilon_{t-1}}, \frac{1}{\epsilon_t}\right)$$

The First Term:

$$\begin{aligned}
(1 - \delta)\beta cov\left(\frac{1}{\epsilon_t}, \epsilon_t\right) &= (1 - \delta)\beta (E(1) - E(\epsilon_t^{-1})E(\epsilon_t)) \\
&= (1 - \delta)\beta (1 - e^{-5\sigma^2} e^{.5\sigma^2}) \\
&= (1 - \delta)\beta (1 - e^{\sigma^2})
\end{aligned}$$

(assuming  $\epsilon$  follows a lognormal distribution with mean 0 and variance  $\sigma^2$ )

The Second Term:

$$\begin{aligned}
(1 - \delta)^2 \beta cov\left(\frac{\epsilon_t}{\epsilon_{t-1}}, \frac{1}{\epsilon_t}\right) &= (1 - \delta)^2 \beta (E(\epsilon_{t-1}^{-1}) - E(\epsilon_t \epsilon_{t-1}^{-1})E(\epsilon_t^{-1})) \\
&= (1 - \delta)^2 \beta (E(\epsilon_{t-1}^{-1}) - E(\epsilon_t)E(\epsilon_{t-1}^{-1})E(\epsilon_t^{-1}))
\end{aligned}$$

(assuming  $\epsilon_t$  and  $\epsilon_{t-1}$  are independently and identically distributed)

$$\begin{aligned}
(1 - \delta)^2 \beta \text{cov}\left(\frac{\epsilon_t}{\epsilon_{t-1}}, \frac{1}{\epsilon_t}\right) &= (1 - \delta)^2 \beta (E(\epsilon_{t-1}^{-1})(1 - E(\epsilon_t)E(\epsilon_t^{-1}))) \\
&= (1 - \delta)^2 \beta e^{.5\sigma^2} (1 - e^{.5\sigma^2} e^{.5\sigma^2}) \\
&= (1 - \delta)^2 \beta e^{.5\sigma^2} (1 - e^{\sigma^2})
\end{aligned}$$

Adding up the first and second terms,

$$\begin{aligned}
\text{cov}\left(\frac{p_t}{y_t}, \frac{y_t}{y_{t-1}}\right) &= (1 - \delta)\beta(1 - e^{\sigma^2}) + (1 - \delta)^2 \beta e^{.5\sigma^2} (1 - e^{\sigma^2}) \\
&= \beta(1 - \delta)(1 - e^{\sigma^2})(1 + (1 - \delta)e^{.5\sigma^2})
\end{aligned}$$

which is equation (21).

### C. Derivations of (36), (42), (43), (45) and (46)

In the borrowing constrained model, the maximization problem of the firm can be expressed formally as:

$$\begin{aligned}
\text{Max} \quad & E_t \sum_{s=0}^{\infty} m_{t,t+s} [\epsilon_{t+s} k_{t+s} + b_{t+s} + \frac{1}{\psi_t} ((1 - \delta_t) k_{t+s} - k_{t+s+1}) - r' b_{t+s-1}] \\
\text{s.t.} \quad & b_{t+s} \leq \frac{k_{t+s+1}}{r'}, s = 0, \dots, \infty
\end{aligned}$$

In order to solve the above maximization problem, I set up the Lagrange function as:

$$L_t = E_t \sum_{s=0}^{\infty} m_{t,t+s} \left[ \epsilon_{t+s} k_{t+s} + b_{t+s} + \frac{1}{\psi_t} ((1 - \delta_t) k_{t+s} - k_{t+s+1}) - r' b_{t+s-1} \right] + \sum_{s=0}^{\infty} \lambda_{t+s} \left( \frac{k_{t+s+1}}{r'} - b_{t+s} \right)$$

At time  $t$ , the choice variables of the firm are its investment  $k_{t+1}$  and the amount it decides to borrow i.e.  $b_t$ .

The first order conditions to the Lagrangian problem with respect to  $k_{t+1}$  and  $b_t$  implies

$$\frac{\lambda_t}{r'} - \frac{1}{\psi_t} + m_{t,t+1} \left[ \epsilon_{t+1} + \frac{1}{\psi_{t+1}} (1 - \delta_{t+1}) \right] = 0$$

and

$$1 - \lambda_t - E_t m_{t,t+1} r' = 0$$

respectively.

Combining these first order conditions by equating  $\lambda_t$ , I have

$$E_t m_{t,t+1} \left[ \frac{\epsilon_{t+1} \psi_{t+1} - \delta_{t+1} - \psi_{t+1} + 1}{\psi_{t+1}} \right] = \left[ \frac{1}{\psi_t} - \frac{1}{r'} \right]$$

$$\frac{1}{c_t} \left[ \frac{1}{\psi_t} - \frac{1}{r'} \right] = \beta E_t \frac{1}{c_{t+1}} \left[ \frac{\epsilon_{t+1} \psi_{t+1} - \delta_{t+1} - \psi_{t+1} + 1}{\psi_{t+1}} \right]$$

From the equilibrium resource constraint

$$\epsilon_t k_t + b_t = c_t + \frac{1}{\psi_t} [k_{t+1} - (1 - \delta_t)k_t] + r' b_{t-1} \quad (59)$$

In the borrowing constrained equilibrium, where  $b_t = \frac{k_{t+1}}{r'}$ , this resource constraint becomes

$$\epsilon_t k_t + \frac{k_{t+1}}{r'} = c_t + \frac{1}{\psi_t} [k_{t+1} - (1 - \delta_t)k_t] + k_t$$

$\Rightarrow$

$$c_t + k_{t+1} \left[ \frac{1}{\psi_t} - \frac{1}{r'} \right] = k_t \left[ \frac{\epsilon_t \psi_t + 1 - \delta_t - \psi_t}{\psi_t} \right]$$

$\Rightarrow$

$$1 + \frac{k_{t+1}}{c_t} \left[ \frac{1}{\psi_t} - \frac{1}{r'} \right] = \frac{k_t}{c_t} \left[ \frac{\epsilon_t \psi_t + 1 - \delta_t - \psi_t}{\psi_t} \right]$$

$\Rightarrow$

$$\frac{\epsilon_t \psi_t + 1 - \delta_t - \psi_t}{\psi_t} = \frac{c_t + k_{t+1} \left[ \frac{1}{\psi_t} - \frac{1}{r'} \right]}{k_t}$$

$\Rightarrow$

$$\frac{\epsilon_{t+1} \psi_{t+1} + 1 - \delta_{t+1} - \psi_{t+1}}{\psi_{t+1}} = \frac{c_{t+1} + k_{t+2} \left[ \frac{1}{\psi_{t+1}} - \frac{1}{r'} \right]}{k_t} \quad (60)$$

Using the above relationship from (60) in the equilibrium resource constraint in (59), I have

$$\frac{k_{t+1}}{c_t} \left( \frac{1}{\psi_t} - \frac{1}{r'} \right) = \beta E_t \left( 1 + \frac{k_{t+2}}{c_{t+1}} \left( \frac{1}{\psi_{t+1}} - \frac{1}{r'} \right) \right)$$

$\Rightarrow$

$$\frac{k_{t+1}}{c_t} = \frac{\beta}{1-\beta} \left( \frac{\psi_t}{r' - \psi_t} \right) \quad (61)$$

Plugging in the relation from (61) in the equilibrium resource constraint in (59),

$$\epsilon_t k_t + \frac{\beta}{1-\beta} \left( \frac{\psi_t}{r' - \psi_t} \right) \frac{c_t}{r'} = c_t + \frac{1}{\psi_t} \left[ \frac{\beta}{1-\beta} \left( \frac{\psi_t}{r' - \psi_t} \right) c_t - (1 - \delta_t) k_t \right] + k_t$$

the borrowing constrained equilibrium consumption  $c_t$  and capital accumulation  $k_{t+1}$  can be solved as

$$c_t = (1 - \beta) \left( \frac{\epsilon_t \psi_t - \psi_t - \delta_t + 1}{\psi_t} \right) k_t$$

which is (42) and

$$k_{t+1} = \beta \left( \frac{r'}{r' - \psi_t} \right) (\epsilon_t \psi_t - \psi_t - \delta_t + 1) k_t$$

which is (43).

The equilibrium market capitalization ratio is given by

$$mk_t = \frac{p_t^z}{y_t} = \left( \frac{\beta}{1-\beta} \right) \frac{c_t}{y_t} = \beta \left( \frac{\epsilon_t \psi_t - \psi_t - \delta_t + 1}{\epsilon_t \psi_t} \right)$$

which is (45)

and the equilibrium output growth is given by

$$ygt = \frac{\epsilon_t k_t}{\epsilon_{t-1} k_{t-1}} = \frac{\epsilon_t}{\epsilon_{t-1}} \beta \left( \frac{r'}{r' - \psi_{t-1}} \right) (\epsilon_{t-1} \psi_{t-1} - \psi_{t-1} - \delta_{t-1} + 1)$$

which is (46).

#### D. Derivation of restriction on world interest rate with only i.i.d. TFP shock

$\epsilon_t$  is i.i.d.,  $\psi_t = 1$  and  $\delta_t = \delta$ , a constant. Hence in equation (44)

$$r' < 1 + \left[ \frac{1}{E_t \left( \frac{1}{\epsilon_{t+1} - \delta} \right)} \right]$$

which means a restriction on net international interest rate as

$$r < \left[ \frac{1}{E_t \left( \frac{1}{\epsilon_{t+1} - \delta} \right)} \right] \quad (62)$$

If  $\epsilon$  is iid, I have  $r < \left[ \frac{1}{E \left( \frac{1}{\epsilon - \delta} \right)} \right]$  where  $E \left( \frac{1}{\epsilon - \delta} \right)$  is a constant. In that case a higher  $\epsilon$  (good TFP shock) implies that in equation (62) the right - hand - side becomes larger. Thus, a positive TFP shock increases the chance of the borrowing constraint to bind fully because the home borrower's expected net marginal benefit is higher. With  $(\epsilon - \delta)^{-1}$  being lognormal, with mean 0 and variance  $\sigma^2$ , I have  $E \left( \frac{1}{\epsilon - \delta} \right) = e^{0.5\sigma^2}$ . In that case for borrowing constraint to bind fully, I must have  $r < e^{-0.5\sigma^2}$ , in which case a fall in  $\sigma$  will increase the chances of a fully binding borrowing constraint.

### **E. Derivation of covariance between market capitalization and growth in the borrowing constrained model with only TFP shock:**

I had explained earlier that if  $(\epsilon - \delta)$  follows a lognormal distribution with mean 0 and variance  $\sigma^2$ , I have

$$E(\epsilon - \delta) = e^{.5\sigma^2}$$

and

$$E(\epsilon) = e^{.5\sigma^2} + \delta$$

Now, I will derive an expression for  $E(\epsilon^{-1})$ .

I have

$$\begin{aligned} \epsilon^k &= [(\epsilon - \delta) + \delta]^k \\ &= (\epsilon - \delta)^k + kC_1(\epsilon - \delta)^{k-1}\delta + kC_2(\epsilon - \delta)^{k-2}\delta^2 \end{aligned}$$

(following upto 2 orders of Taylor Approximation),

Hence,

$$\epsilon^k = (\epsilon - \delta)^k + k(\epsilon - \delta)^{k-1}\delta + \frac{k(k-1)}{2}(\epsilon - \delta)^{k-2}\delta^2$$

Applying the above formula, I get:

$$\epsilon^{-1} = (\epsilon - \delta)^{-1} - (\epsilon - \delta)^{-2}\delta - (\epsilon - \delta)^{-3}\delta^2$$

=>

$$\begin{aligned} E(\epsilon^{-1}) &= E[(\epsilon - \delta)^{-1}] - \delta E[(\epsilon - \delta)^{-2}] - \delta^2 E[(\epsilon - \delta)^{-3}] \\ &= e^{0.5\sigma^2} - \delta e^{2\sigma^2} - \delta^2 e^{4.5\sigma^2} \end{aligned}$$

Unconditional Covariance between market capitalization and growth is given by:

$$\begin{aligned} cov\left(\frac{p_t}{y_t}, \frac{y_t}{y_{t-1}}\right) &= cov\left[\beta\left(1 - \frac{\delta}{\epsilon_t}\right), \frac{\epsilon_t}{\epsilon_{t-1}}\left(\frac{R}{R-1}\right)\beta(\epsilon_{t-1} - \delta)\right] \\ &= cov\left[\left(\beta - \frac{\beta\delta}{\epsilon_t}\right), \left(\frac{R}{R-1}\right)(\beta\epsilon_t - \delta\beta\frac{\epsilon_t}{\epsilon_{t-1}})\right] \\ &= \left(\frac{R}{R-1}\right)(-\beta^2\delta)cov\left(\epsilon_t, \frac{1}{\epsilon_t}\right) + \delta^2\beta^2cov\left(\frac{\epsilon_t}{\epsilon_{t-1}}, \frac{1}{\epsilon_t}\right) \\ &= -\left(\frac{R}{R-1}\right)\beta^2\delta[E(1) - E(\epsilon^{-1})E(\epsilon)] + \left(\frac{R}{R-1}\right)\beta^2\delta^2[E(\epsilon^{-1}) - E(\epsilon^{-1})E(\epsilon)E(\epsilon^{-1})] \end{aligned}$$

(since  $\epsilon$  is iid,  $E(\epsilon_t\epsilon_{t-1}^{-1}) = E(\epsilon_t)E(\epsilon_{t-1}^{-1}) = E(\epsilon)E(\epsilon^{-1})$ )

If I plug in the values of  $E(\epsilon)$  and  $E(\epsilon^{-1})$  in the above expression, I get the value of unconditional covariance between market capitalization and growth as:

$$cov\left(\frac{p_t}{y_t}, \frac{y_t}{y_{t-1}}\right) = -\left(\frac{R}{R-1}\right)\beta^2\delta[1 - (e^{0.5\sigma^2} - \delta e^{2\sigma^2} - \delta^2 e^{4.5\sigma^2})(e^{0.5\sigma^2} + \delta)][1 - \delta(e^{0.5\sigma^2} - \delta e^{2\sigma^2} - \delta^2 e^{4.5\sigma^2})]$$

which represents equation (51).

Table 1: Parameter Values

$\beta$	$\delta$	$\bar{\epsilon}$	$\psi$
0.99	0.025	0.048	1

Table 2: Second Moment Parameter Values of Forcing Processes

$\rho_\epsilon$	$\rho_\xi$	$\rho_\delta$	$\sigma_\epsilon^2$	$\sigma_\xi^2$	$\sigma_\delta^2$
0.6	0.6	0.6	1	1	1

Table 3: Shock impact effect

	<i>TFP</i>	<i>IST</i>	<i>CQ</i>
<i>yg</i>	+	+	+
<i>mk</i>	-	-	+
<i>dy</i>	-	+	+
<i>dk</i>	+	+	+
<i>ik</i>	+	-	-
<i>iy</i>	+	-	-
<i>kg</i>	+	+	+
<i>ck</i>	+	+	+

Table 4: Shock variance decomposition

	<i>TFP</i>	<i>IST</i>	<i>CQ</i>
<i>yg</i>	99.73	0.21	0.06
<i>mk</i>	49.98	49.98	0.03
<i>dy</i>	99.69	0.07	0.24
<i>dk</i>	44.03	44.03	11.94
<i>ck</i>	44.03	44.03	11.94
<i>ik</i>	99.99	0.01	0.00
<i>iy</i>	99.69	0.07	0.24
<i>kg</i>	52.99	14.38	32.63

Table 5: Average TFP and borrowing to capital

Country	Avg Productivity	Avg Borrowing to Capital
Argentina	0.302	0.028
Bolivia	0.370	0.042
Brazil	0.296	0.029
Cameroon	0.263	0.008
Colombia	0.318	0.019
Costa Rica	0.347	0.016
Dominican Republic	0.359	0.003
Ecuador	0.302	0.015
Egypt, Arab Rep.	0.349	0.003
El Salvador	0.366	0.024
Gabon	0.292	0.000007
Guatemala	0.343	0.025
Honduras	0.306	0.015
India	0.338	0.014
Indonesia	0.282	0.037
Kenya	0.345	0.011
Lesotho	0.221	0.0002
Malaysia	0.320	0.035
Mali	0.367	0.001
Mauritius	0.312	0.009
Mexico	0.304	0.012
Morocco	0.286	0.008
Mozambique	0.409	0.091
Pakistan	0.311	0.007
Peru	0.288	0.020
Philippines	0.309	0.033
Senegal	0.309	0.004
Sri Lanka	0.319	0.006
Thailand	0.248	0.042
Turkey	0.342	0.032
Uganda	0.397	0.001
Venezuela	0.316	0.010
Zambia	0.373	0.016



Table 6: Sensitivity analysis of market capitalization - growth correlation for different depreciation rates and gross interest rates

	$R = 1.01$	$R = 1.03$	$R = 1.05$	$R = 1.07$	$R = 1.09$
$\bar{\delta} = 0.01$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$
$\bar{\delta} = 0.03$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$	$r_{mk,yg}=0.483$
$\bar{\delta} = 0.05$	$r_{mk,yg}=0.452$	$r_{mk,yg}=0.452$	$r_{mk,yg}=0.452$	$r_{mk,yg}=0.452$	$r_{mk,yg}=0.452$
$\bar{\delta} = 0.07$	$r_{mk,yg}=0.450$	$r_{mk,yg}=0.450$	$r_{mk,yg}=0.450$	$r_{mk,yg}=0.450$	$r_{mk,yg}=0.450$
$\bar{\delta} = 0.09$	$r_{mk,yg}=0.432$	$r_{mk,yg}=0.432$	$r_{mk,yg}=0.432$	$r_{mk,yg}=0.432$	$r_{mk,yg}=0.432$

Table 7: Shock impact effect with full borrowing

	$TFP$	$IST$	$CQ$
$yg$	+	+	+
$mk$	+	-	+
$dk$	+	-	+
$ik$	+	+	+
$iy$	+	+	+
$kg$	+	+	+
$ck$	+	-	+
$bk$	+	+	+

Table 8: Shock variance decomposition with full borrowing

	$TFP$	$IST$	$CQ$
$yg$	58.67	41.28	0.05
$mk$	76.30	23.68	0.02
$dy$	76.30	23.68	0.02
$dk$	96.11	3.81	0.08
$ik$	65.75	34.23	0.02
$iy$	32.14	67.85	0.01
$kg$	65.32	34.65	0.02
$ck$	96.17	3.81	0.02
$bk$	65.30	34.67	0.02

# Chapter 3: Market capitalization, growth and inflation in a New-Keynesian framework

## I. Introduction

So far I have been working in a set-up where prices are fully flexible, i.e. prices adjust readily in response to outside shocks. In the real world, however, because of a shock, prices and wages do not respond immediately, but take some time to adjust. In fact, considering the economy as a whole, some prices might be very flexible, while others extremely rigid. This leads to the aggregate price level becoming sluggish or sticky as it does not typically respond to macroeconomic shocks in a way it would have if all prices were perfectly flexible. The same idea applies to nominal wages. This phenomenon of price stickiness, which describes a situation in which the nominal price is resistant to change, is known as nominal rigidity and is an important part of macroeconomic theory. Nominal rigidities are a key component of the New Keynesian approach, which assumes a variety of market failures, particularly imperfect competition in price and wage setting, in order to help explain why prices and wages can become sticky, i.e. do not adjust instantaneously to changes in economic conditions. Thus nominal rigidity plays a crucial role in explaining how money can affect the real economy and why the classical dichotomy breaks down and makes monetary policy non-neutral in the short run. If nominal wages and prices were perfectly flexible, they would always adjust so that equilibrium would be restored in the economy. So for monetary shocks to have real effects, some degree of nominal rigidity is required so that prices do not respond immediately. Nominal rigidities are an integral part of Keynesian macroeconomic theory and New Keynesian thought and in the present chapter, I introduce a new Keynesian mechanism in which prices will be sluggish to return to their stationary state, which in turn will increase the temporal persistence of the effect of a shock. Thus in this chapter I investigate the usual short run market capitalization - growth relationship

in a new Keynesian framework; the contemporaneous behaviour of market capitalization and growth being my primary focus. Moreover, since sluggish price behaviour is a key element in the new Keynesian approach, inflation plays a vital role throughout this theoretical framework. Hence I also find it worthwhile to look into the short run inflation - growth relationship.

Just for a quick recapitulation, let me put forward the key stylized facts. In my first chapter, I look into annual data<sup>1</sup> on market capitalization of listed companies (expressed as a percentage of GDP) and growth for 35 countries for the time period 1988 to 2013.<sup>2</sup> Out of the 35 countries for which I am interested to explore the market capitalization - growth short run relationship, 26 countries show a positive and significant correlation coefficient between market capitalization ratio and growth. Out of these 26 countries, 12 are High Income and 14 are Middle Income. I have also looked into annual data on market capitalization and growth for 4 groups of countries for the time period 1988 to 2012, the 4 groups being Euro Area, South Asia, High Income non OECD and High Income OECD. Out of these 4 groups, 3 groups viz. Euro Area, South Asia and High Income non OECD were found to depict a positive significant correlation between market capitalization and growth. Also, taking into consideration all the countries and country groups, it is observed that for 75% of all countries/ country groups in the data set, the market capitalization - growth correlation coefficient is greater than 0.320, for 50% of the countries/ country groups, the correlation coefficient between market capitalization and growth is greater than 0.412 and for 25% it is greater than 0.527. These results, already discussed in Chapter 1, establish that in the short run, majority of the countries (High Income and Middle Income) depict a positive significant correlation between market capitalization ratio and growth.

Next, I investigate the short run relationship between growth and inflation, which has not been explored in the previous chapters. For this I have gathered annual data on per capita GDP growth and inflation from 1970 to 2014 for 68 countries.<sup>3</sup> The 68 countries which have

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<sup>1</sup>Data Source: World Development Indicators

<sup>2</sup>Market capitalization is defined as the share price times the number of shares outstanding. Listed domestic companies are the domestically incorporated companies listed on the country's stock exchanges at the end of the year. Listed companies do not include investment companies, mutual funds, or other collective investment vehicles. Growth is defined as growth of per capita GDP where GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2005 U.S. dollars.

<sup>3</sup>The measure of inflation is GDP deflated and expressed as annual percentage. Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.

made up my data set for the growth-inflation analysis can be differentiated into 28 High Income countries, 35 Middle Income countries and 9 Low Income countries. Median short run growth-inflation correlation is found to be positive (but insignificant) for High Income countries and negative for both Middle Income and Low income countries. Taking into account all countries within the data set, it is observed that only 25% of countries have inflation - growth correlation coefficient greater than 0.08, while 50% have a correlation coefficient greater than -0.07 and 75% have a correlation coefficient greater than -0.21. Thus for majority of the countries, the short run growth - inflation correlation is not found to be significant from the data.

The median and range of the short run growth - market capitalization and growth - inflation correlation coefficient values are summarized in Table 1 and Table 2.<sup>4</sup>

In the previous chapter, it was found that incorporating a friction in the form of borrowing constraint to a Lucas tree type asset pricing model with production could reproduce the positive significant correlation between market capitalization and growth as found empirically. Without this borrowing constraint friction, however, the positive significant correlation could not be found. In the present chapter, the theoretical framework takes into account different kinds of frictions: market imperfections (imperfectly competitive market structure) and nominal rigidities in the form of sticky prices (prices being sluggish to aggregate demand or aggregate supply shocks) being the key features. It is to be noted that the theory that I will be discussing in the present chapter does not deal with labour and hence wages (and market rigidities) are not part of this set up and my objective is to model the goods market as I wish to explore the determinants of inflation (rate of increase in goods prices rather than wages). Thus, the only form of sluggish behaviour is observed to be coming from the prices set by firms, following a model of staggered price setting inspired by Calvo (1983) in which only a randomly chosen fraction of firms are allowed to adjust their prices in a given period. I also look into another form of price rigidity, where firms' price adjustment process is subject to a cost (price adjustment cost) a'la Rotemberg (1982). However, I introduce nominal rigidities in the form of price imperfections not at once, but only after I look into the short run market capitalization and growth implications in a framework with fully flexible prices, where the only source of imperfection comes from imperfectly competitive markets. Adding nominal rigidities to the original flexible price model is done in order to make it richer, more realistic and better able to match the stylized patterns. Thus, I

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<sup>4</sup>Tables 1 and 2 can be found in the appendix.

first work with a model with imperfectly competitive firms (intermediate good producing firm), but where prices adjust freely and change from period to period according to that set by the firm. After this I introduce a framework where the imperfectly competitive market structure prevails, but in which a fraction of the total number of firms within the economy stick to their original prices and the remaining fraction choose to set new prices according to the maximization of their discounted stream of future profits. Also within this imperfectly competitive market structure, I look into a set up where price adjustment cost incurred by the firm is the main source of price rigidity. So the theoretical setup in the present chapter can be broadly classified into two main types of frameworks: (1) model with imperfect competition and full price flexibility and (2) model with an imperfectly competitive market structure where nominal rigidities are present in the form of price imperfections and imperfect inflation indexation<sup>5</sup>. In the second model, real rigidities are also present in the form of investment adjustment cost and external habit formation. As I explore the effect of capital accumulation on stock market capitalization and growth, the second theoretical structure essentially becomes a New Keynesian endogenous growth model with both real and nominal frictions. I look into the effects of various macroeconomic shocks on market capitalization and growth in both the first theoretical framework i.e. the one with market imperfections only, as well as in the second theoretical framework i.e. the one with nominal rigidities. It is found that in the first theoretical framework with only market imperfections, the positive significant correlation between market capitalization and growth can be reproduced, but the value of the correlation coefficient is not quantitatively close to that observed from the data. Also, market capitalization - growth correlation coefficients obtained from this model do not change much with changes in parameters. However, the New - Keynesian frictions present in the second theoretical set - up can successfully reproduce the positive significant market capitalization - growth correlation as observed empirically. Also in the second model, this correlation coefficient is found to be more sensitive to parametric values. In short, like in the previous chapter, here also I find that introducing frictions within the baseline theoretical framework can bring the model much closer to the data. In the previous chapter, a borrowing constraint friction incorporated in a Lucas tree asset pricing framework with production, could nicely reproduce the desired result of positive significant market capitalization - growth correlation, whereas in the present analysis, introducing price rigidity (both staggered price setting a'la Calvo (1983) and

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<sup>5</sup>Imperfect inflation indexation in my theoretical setup refers to the phenomenon where firms which cannot adjust their price stick to their previous period price adjusted by a fraction of the trend inflation.

price adjustment cost a'la Rotemberg (1982)) and relaxing the fully flexible price feature within an existing framework of market imperfection can reproduce the empirically observed positive significant correlation very accurately. In this chapter I focus mainly on the contemporaneous, rather than the intertemporal i.e. lead-lag relationship between market capitalization ratio and growth.

The first wave of New Keynesian models such as Fisher (1977), Phelps and Taylor (1977) and Taylor (1979a,b), used long term nominal contracts to explain how demand shifts lead to real fluctuations even if expectations are rational. The resulting debate between real business cycle and the New Keynesian schools of thought along with the successive extensions of both types of models, gave rise to a second wave of New Keynesian models or monetary business cycle models that aimed to merge key elements of both approaches. Empirical failures of traditional approaches, intellectual challenges such as the Lucas critique, theoretical innovations such as the combination of nominal rigidities with forward looking and optimizing behaviours of economic agents and the invention of new modeling and estimation techniques were some of the main driving factors behind the two strands of New Keynesian literature. Various innovations in the late 1970s and 1980s, which included modeling of menu costs and overlapping wage and price contracts (Fisher (1977), Taylor (1979b), Calvo (1983)), new methods for solving linear and non linear dynamic models with rational expectations and successful estimation of such models using maximum likelihood techniques (Hansen and Sargent (1980), Fair and Taylor (1983)), triggered the first generation of New Keynesian models with rational expectations and nominal rigidities, allowing for interesting interactions between (systematic) monetary policy and real economic activity. A very basic model of monopolistic competition, in which prices of some goods are determined a period in advance, provides optimizing foundations for the New Classical Phillips Curve and was used by Kydland and Prescott (1977) and Barro and Gordon (1983). Kydland and Prescott's (1982) extension of the neoclassical growth model delivered a modeling approach that stringently enforced all the restrictions following from utility maximizations of representative households and the profit maximization of representative firms on the dynamics of macroeconomic variables. At the same time, the real business cycle (RBC) approach put forward technological innovations as the main drivers of business cycles. Putting together the microeconomic foundations practiced in RBC research with Keynesian concepts of nominal rigidities and imperfect competition, Goodfriend and King (1997) and Rotemberg and

Woodford (1997) presented the first monetary business cycle model, thereby paving the way for the New Neoclassical Synthesis model or the New Keynesian DSGE model.

Early examples of microfounded monetary models with monopolistic competition and sticky prices can be found in Akerlof and Yellen (1985), Mankiw (1985), Blanchard and Kiyotaki (1987), and Ball and Romer (1990). An early version and analysis of the baseline New Keynesian model can be found in Yun (1996), where a discrete-time version of the staggered price-setting model originally developed in Calvo (1983) was used. King and Wolman (1996) provide a detailed analysis of the steady state and dynamic properties of that model. King and Watson (1996) compare its predictions regarding the cyclical properties of money, interest rates, and prices with those of flexible price models. Woodford (1996) incorporates a fiscal sector in the model and analyzes its properties under a non-Ricardian fiscal policy regime. Part of the New Keynesian literature, eg. Rotemberg and Woodford (1996) and Gali (1999) was to account for the empirical irregularities of the RBC models. In the recent past, Christiano et al. (2005) developed and estimated a medium sized DSGE model with capital accumulation, utilization and investment, monopoly power in goods and labour markets, price and wage rigidities along with adjustment costs or constraints on household or firm decision making. Smets and Wouters (2003, 2007) showed how parameters can be estimated with Bayesian methods in contrast to Christiano et al (2005) where impulse response function matching techniques were used in order to choose values of the model parameters. The Smets and Wouters (2003) approach was quickly popularized and led to widespread New Keynesian model building at central banks around the world. Levin et al. (2003) and Cogan et al (2011) provide systematic comparisons of these models with early versions of New Keynesian ones and evaluate their implications for monetary policy rules. In the present chapter, the main theoretical framework is influenced by the much used workhorse model following Gali (2008), Gali and Gertler (2007), Walsh (2007) and Woodford (2003a).

An inflation equation identical to the New Keynesian Phillips curve (NKPC) can be derived under the assumption of quadratic costs of price adjustment, as shown in Rotemberg (1982). Hairault and Portier (1993) developed and analyzed an early version of a monetary model with quadratic costs of price adjustment and compared its second-moment predictions with those of the French and U.S. economies. Two main alternatives to the Calvo random price duration model can be found in the literature. The first one is given by staggered price-setting models with a deterministic price duration, originally proposed by Taylor (1980) in the context of a

non-microfounded model. A microfounded version of the Taylor model can be found in Chari, Kehoe, and McGrattan (2000) who analyzed the output effects of exogenous monetary policy shocks. An alternative price-setting structure is given by state dependent models in which the timing of price adjustments is influenced by the state of the economy. A quantitative analysis of a state dependent pricing model can be found in Caplin and Leahy (1991), Dotsey, King, and Wolman (1999) which assume that firms are constantly reevaluating the optimal price and are weighing the expected benefits from a price change against the current "menu cost" of such a change in order to decide whether or not to change their price. More recent works on state dependent pricing models by Golosov and Lucas (2007) and Gertler and Leahy (2006) also deserve mention in this context. Although not the main focus of this chapter, it is still worth mentioning that an early critical assessment of the empirical performance of the NKPC can be found in Fuhrer and Moore (1986). Mankiw and Reis (2002) give a quantitative review of the perceived shortcomings of the NKPC and propose an alternative price-setting structure based on the assumption of sticky information. Galí and Gertler (1999), Sbordone (2002), and Galí, Gertler, and López-Salido (2001) provide favourable evidence of the empirical fit of the equation relating inflation to marginal costs, and discuss the difficulties in estimating or testing the NKPC given the unobservability of the output gap. Rotemberg and Woodford (1999) and Christiano, Eichenbaum, and Evans (2005) provide empirical evidence on the effects of monetary policy shocks, and discuss a number of modifications of the baseline New Keynesian model aimed at improving the model's ability to match the estimated impulse responses. Evidence on the effects of technology shocks and its implications for the relevance of alternative models can be found in Galí (1999) and Basu, Fernald and Kimball (2004), among others. Recent evidence, as well as alternative interpretations are surveyed in Galí and Rabanal (2004). The theoretical framework I use in this chapter connects to a growing literature that highlights the difference between Calvo and Rotemberg price settings. In this regard Ascari and Rossi (2012) focus on the long run NKPC, Damjanovic and Nolan (2010), and Leith and Liu (2014) focus on optimal inflation. However, none of the papers mentioned so far look into the market capitalization - growth relationship using a New Keynesian endogenous growth framework which is the contribution of this chapter.

In each of the theoretical frameworks discussed so far, I assumed that the firm itself invests in physical capital. In the present chapter, however, firms do not accumulate capital themselves;



rather assign this task to the households, who invest in physical capital on behalf of the firms and get paid a fixed rental in return. Also in the present theoretical framework, firms are categorized into two types: firms that produce intermediate goods (of different varieties) and firms that produce the finished product by integrating all intermediate goods together. I call the first category of firms intermediate good producing firms (I firms) and the second category of firms final good producing firms (F firms). Intermediate good producing firms are owned by the households. Since I firms have variety in their production and also some control over price setting, the market for intermediate goods is imperfectly competitive. I assume product differentiation and monopolistic competition among suppliers of intermediate goods as in the New Keynesian literature originated by Rotemberg (1982), Mankew (1985), Svensson (1986) and Blanchard and Kiyotaki (1987).

The I firms have some market power that they can exploit to let them charge prices higher than their marginal costs. Since there is no free entry and exit, these firms make positive profits which are distributed as dividends to households. I firms produce output with capital only which they sell to the F firms. The amount earned by the I firms as revenue can be divided into two parts: one part is the profit which is distributed as dividends to the households and the other part goes into paying rent to the households. F firms, however, are perfectly competitive. They assemble the intermediate goods to produce the final output. Since the F firms are price takers, they sell the final goods at a fixed price to the households. The amount paid by the F firms to the I firms is in terms of the final good and it is further transferred from the I firms to the households in the form of dividend income and rental income. I assume that there are infinite I firms in a continuum and the I firms exhaust all possible varieties that can be produced in the economy. Just like the I firms, there is also a continuum of infinite identical households who accumulate capital each period and supply this to the I firms. In return they get paid a fixed rental income. Households own shares in the I firms, as a result of which dividend income becomes their other source of income apart from rental income. Households spend part of their income on consumption and with the remaining part, they invest in capital (physical investment), shares of the I firms and risk free bonds (financial investment). Consumption and intended investment in physical capital and financial capital are obtained through intertemporal maximization by the households. Since capital is the only input that goes into producing the intermediate good, the intermediate good's cost of production involves only rental cost.

In Section II, I discuss a model with imperfect market structure but full price flexibility. In this setup, I first add only one shock in the form of a Total Factor Productivity (TFP) shock, which is independently and identically distributed. This enables me to obtain closed form solutions of market capitalization and growth from which it is evident that market capitalization falls, but growth increases because of a TFP shock. Now, in addition to the TFP shock, I incorporate two more shocks in the form of an Investment Specific Technology (IST) shock and a Capital Quality (CQ) shock to the existing framework. When working with three shocks, I relax the i.i.d. assumption and assume each of the shocks to be serially correlated. Both TFP and CQ shocks augment market capitalization and growth, while an IST shock brings about an increase in growth but a fall in market capitalization. When all three shocks are simultaneously in action, the correlation between the short run fluctuations of market capitalization and growth as calculated from the stochastic simulations of these two variables is found to be around 0.32, which is positive but not quantitatively close to the observed correlations for most countries. Thus when I work in a framework with market imperfections but fully flexible prices, the effect of an i.i.d. TFP shock alone cannot support the positive significant correlation between market capitalization and growth as was observed empirically. In fact, in such a scenario, I find market capitalization and growth to move in opposite directions, thereby completely contradicting the underlying stylized facts. However, if within the same theoretical framework, three different shocks in the form of TFP, IST and CQ, each following an AR(1) process, are simultaneously in action, I am able to reproduce a positive correlation coefficient from the model. Thus in the second scenario with three different shocks, the sign of the market capitalization - growth correlation coefficient is positive, i.e. the average time paths of the two variables are at least in the same direction, thereby providing some support to the empirical observations. However, with changes in different parametric values, the correlation is not observed to change much. This does not lend support to the wide range of market capitalization - growth correlation coefficients observed for different countries in the data. This prompts me to incorporate nominal rigidities within the already existing framework with market imperfection, so as to bring the model much closer to the data.

In Section III, I introduce a model with price distortions within a theoretical set-up of imperfectly competitive I firms. I discuss two different sources of price rigidities: (1) due to the staggered pricing rule inspired by Calvo (1983) and (2) price adjustment cost as in Rotemberg

(1982). In the first price imperfection set-up, all firms are ex-ante identical. In a given time period, each firm receives a signal with probability  $\theta$ , on the basis of which it changes its price optimally. If the firm does not receive this signal, however, it decides to stick to its previous period price (adjusted by long run gross inflation a’la Kollmann (2002)). So, ex-post, firms get bunched into two distinct categories: *fix price firms*, i.e. firms that stick to their previous period price and *flex price firms*, i.e. firms that change their prices optimally. Since there are a large number of intermediate firms within the economy, by the law of large numbers, at a given time period, the economy will consist of  $\theta$  fraction of fix price firms and  $(1 - \theta)$  fraction of flex price firms. Just like the previous set-up, here also a large number of identical households, within a continuum, are the owners of intermediate firms and also their suppliers of capital for which they charge a fixed rental rate. Households own the I firm’s assets and also trade in risk free bonds. I firms use capital as the only input. In the second theoretical framework inspired by Rotemberg (1982), all firms continuously adjust their nominal prices, but this is subject to a certain price adjustment cost measured in terms of final goods. The quadratic price adjustment cost function, inspired by Ascari and Rossi (2012) and Ireland (2007), can be thought to be accounting for the negative effects of price changes on the customer-firm relationship. Unlike the Calvo type staggered pricing framework, in the Rotemberg model, there is no heterogeneity among firms regarding their price setting behaviour.

Since I work in a new Keynesian framework, I also introduce real rigidities in the form of adjustment cost of investment and external habit persistence in the household utility function following Smets and Wouters (2003). In both Calvo and Rotemberg price setting frameworks, for reasonable values of nominal rigidity, short run cyclical fluctuations of both market capitalization and growth are influenced by a TFP shock and both these variables are augmented by this shock. However, for a very high nominal rigidity value, output growth is influenced by a TFP shock, whereas market capitalization is driven by an IST shock. Also, for very high price imperfection parameter values, growth increases due to the TFP shock, but market capitalization falls due to an IST shock. Thus, I find that for reasonable values of nominal rigidity parameters, the correlation coefficients between short run fluctuations in market capitalization and growth are positive and significant, as found in the data for most developed and developing countries. On the other hand, the correlation coefficient between inflation and growth, as calculated from the model turns out to be negative for all possible values of the nominal rigidity parameter and this

holds true for both the Calvo as well as the Rotemberg price setting frameworks, thereby once again supporting the empirical findings.

Price rigidity amplifies the effect of TFP and other shocks on market capitalization and growth, which can help explain the positive significant market capitalization-growth correlation. In fact, without price stickiness, since all firms adjust prices proportionately in response to a fall in marginal cost (due to positive TFP shock), the average mark-up is a constant . With price stickiness, however, in a similar situation, some firms cannot lower their prices, while others can, which leads to a rise in their average mark up. This, along with an overall output increase due to positive productivity shocks, lead to an overall increase in dividends, thereby making stock markets more attractive and increasing market capitalization. On the other hand, current growth is augmented unambiguously due to a positive TFP shock, due to increase in current output, which explains the positive market capitalization-growth correlation in a framework with staggered pricing. The short run results from the Calvo and Rotemberg price set-ups follow similar patterns and support the positive and significant market capitalization-growth correlations for plausible values of price imperfection parameters. Section IV concludes the chapter.

## **II. A flexible price model with market imperfection as the only source of friction**

### **A. Basic components**

In this section I discuss the basic features of the theoretical framework. There are three main agents: Households, Intermediate good producing firms (I firms) and Final good producing firms (F firms).

#### **A.1 Firms**

There are two types of firms: intermediate good producing firms (I firms) and final good producing firms (F firms). I firms produce (using only capital) differentiated items of intermediate goods i.e. each firm produces an intermediate good that is different from that of the other firms. The I firms thus have some monopoly power. There are a large number of I firms in a continuous interval of  $(0, 1)$ . Thus infinite varieties of intermediate goods in a continuum is produced in

this economy. Since there is no free entry or exit, I firms make positive profits. These profits are distributed as dividends to households who are owners of the I firms. I firms sell their output to the F firms. The amount earned by the I firms as revenue is spent in paying rent and dividends to the households.

F firms, on the other hand, are perfectly competitive. They assemble the intermediate goods to produce the final output. The F firms being price takers sell the final goods at a fixed price to the households. Both I and F firms are owned by the household. The amount paid by the F firms to the I firms is further transferred from the I firms to the households in the form of dividend income and rental income. In the theoretical framework, I will work with a nominal price for the final good and a nominal price for the intermediate good.

## **A.2 Households**

There is also a large number of identical households within a continuum  $(0, 1)$ . The representative household accumulates physical capital each period and supplies this to the I firms. In return it is paid a fixed rental income. Households also own the I firms and by virtue of this, hold shares in the I firms. As a result of this, dividend income becomes their other source of income apart from rental income. Households spend their income on consumption and on investment in capital (physical investment) and shares of the I firms (financial investment) Consumption and intended investment in shares and physical capital are obtained through intertemporal maximization.

## **A.3 Markets**

I firms exchange intermediate goods for final goods with F firms. The value of the final good that they get as revenue is distributed to households as dividends and rent. Marginal Cost on part of the I firms involves rental cost only. There is no market for labour. In equilibrium households addition to the number of stocks is nil and total value of output must equal the sum of representative household's rental income and dividend income.

## B. Household's Problem

The representative household faces a CRRA utility function of the following nature:

$$u(c_t) = \frac{c_t^{1-\rho} - 1}{1-\rho} \quad (1)$$

where  $\rho$  denotes the risk aversion parameter in the utility function. Household's utility depends only on final consumption  $c_t$ . Marginal utility for the household is given by

$$u'(c_t) = c_t^{-\rho} \quad (2)$$

The following represents the physical capital accumulation equation of the representative household, where  $k_{t+1}$  and  $\chi_t$  represent accumulated capital and investment respectively in time  $t$ .  $\xi_t$  represents an Investment Specific Technology Shock (IST) and  $\delta_t$  represents a Capital Quality (CQ) shock.

$$k_{t+1} = (1 - \delta_t)k_t + \xi_t\chi_t \quad (3)$$

A positive IST shock  $\xi_t$  augments next period's accumulated capital  $k_{t+1}$  and is thus considered to be a good shock. A positive CQ shock, however, is a bad shock as it increases capital depreciation rate  $\delta_t$ . A negative CQ shock, on the other hand, can be treated as a good shock as it implies a fall in the depreciation rate  $\delta_t$  and a subsequent rise in next period's capital stock  $k_{t+1}$ .

Objective function of the representative household is given as

$$\text{Max:} \quad E_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \quad (4)$$

$$\begin{aligned} \text{s.t.} \quad & P_t c_t + P_t \frac{1}{\xi_t} (k_{t+1} - (1 - \delta_t)k_t) + \int_0^1 P_t^z (z_{t+1}(i) - z_t(i)) di \\ & = \int_0^1 D_t(i) z_t(i) di + R_t k_t \end{aligned} \quad (5)$$

The representative household maximises expected value of its discounted stream of future utilities,  $\beta$  being the discount rate, subject to an intertemporal budget constraint (nominal) given by (5). On the right hand side of this budget constraint, total nominal income of the household is given by nominal dividend income represented by  $\int_0^1 D_t(i) z_t(i) di$  and nominal rental income

represented by  $R_t k_t$ , where  $D_t(i)$  is the nominal dividend of the  $i$ th I firm and  $z_t(i)$  is the number of stocks of the  $i$ th I firm held by the representative household. The left hand side of the budget constraint represents how the household uses its nominal income,  $P_t c_t$  being the household's nominal consumption,  $P_t \frac{1}{\xi_t} (k_{t+1} - (1 - \delta_t)k_t)$  being its nominal value of physical investment and  $\int_0^1 P_t^z(i)(z_{t+1}(i) - z_t(i))di$  being the nominal value of the net addition to its stock of assets of all I firms.  $P_t^z(i)$  is the nominal asset price of the  $i$ th I firm.

The household's choice variables are  $c_t$ ,  $k_{t+1}$  and  $z_{t+1}(i)$ . After forming the lagrange function with  $\lambda_t$  as the time  $t$  Lagrange multiplier associated with (5), the first order conditions are as follows:

First order condition with respect to  $c_t$  gives

$$\lambda_t P_t = \beta^t c_t^{-\rho} \quad (6)$$

Using the above relation, the Euler equations with respect to  $k_{t+1}$  and  $z_{t+1}(i)$  can be obtained as

$$k_{t+1} : c_t^{-\rho} \left( \frac{1}{\xi_t} \right) = \beta E_t \left[ c_{t+1}^{-\rho} \left( \frac{\xi_{t+1} r_{t+1} + 1 - \delta_{t+1}}{\xi_{t+1}} \right) \right] \quad (7)$$

and

$$z_{t+1}(i) : c_t^{-\rho} p_t^z(i) = \beta E_t \left[ c_{t+1}^{-\rho} (p_{t+1}^z(i) + d_{t+1}(i)) \right] \quad (8)$$

where  $p_t^z(i)$  and  $d_t(i)$  denote the real asset price and real dividend of the  $i$ th I firm's share at time period  $t$ .

Since in equilibrium,  $z_t(i) = z_{t+1}(i) = 1 \forall i$  and sum of rental and dividend income of the representative household equals the total final output, the equilibrium resource constraint is given by

$$c_t + \frac{1}{\xi_t} [k_{t+1} - (1 - \delta_t)k_t] = \epsilon_t k_t \quad (9)$$

### C. F firm's problem

Define:

$x_t(i)$  =  $i$ th intermediate good used to produce the final good.

$y_t$  = final good.

$P_t(i)$  = nominal price of the  $i$ th intermediate good.

$P_t$  = nominal price of the final good.

All the intermediate goods get bundled by the F firm in order to produce the time  $t$  final good  $y_t$ . The final goods production technology follows a constant elasticity of substitution (CES) bundler of the type

$$y_t = \left( \int_0^1 x_t(i)^\varepsilon di \right)^{\frac{1}{\varepsilon}} \quad (10)$$

where  $\left( \frac{1}{1-\varepsilon} \right)$  is the elasticity of substitution between inputs and  $0 < \varepsilon < 1$ .

Let

$$\sigma = \frac{1}{1-\varepsilon} \quad (11)$$

This means that the production technology can be written as

$$y_t = \left( \int_0^1 x_t(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \quad (12)$$

where  $\sigma$  is the elasticity of demand for each input.

A profit maximising final goods firm chooses to maximise profits. So its objective function becomes

$$\begin{aligned} \text{Max} \quad & P_t y_t - \int_0^1 P_t(i) x_t(i) di \\ \text{st} \quad & y_t = \left( \int_0^1 x_t(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \end{aligned} \quad (13)$$

The optimisation problem represented by (13) gives rise to the general form of the demand function of the  $i$ th intermediate good which is given by

$$x_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} y_t \quad (14)$$

and the general price aggregation equation given by

$$P_t = \left( \int_0^1 P_t(i)^{1-\sigma} di \right)^{\frac{1}{1-\sigma}} \quad (15)$$



Derivation of the demand function of the  $i$ th intermediate good represented by equation (14) and the general price aggregation represented by equation (15) is relegated to the appendix.

#### D. I firm's problem

Production function of the  $i$ th I firm is given by

$$x_t(i) = \epsilon_t k_t(i) \quad (16)$$

There are a large number of I firms within the continuous interval  $(0, 1)$  and each firm faces the same Total Factor Productivity (TFP) shock  $\epsilon_t$ . The  $i$ th I firm uses  $k_t(i)$  units of capital to produce its output  $x_t(i)$ . Households supply capital stock  $k_t$  and this entire capital stock is used up by all the I firms in order to produce their output i.e. intermediate goods.

Nominal profit or dividend of the  $i$ th I firm is given by

$$D_t(i) = P_t(i)x_t(i)(P_t(i)) - TC_t(i)(x_t(i)(P_t(i))) \quad (17)$$

On the supply side of the firm,  $TC_t(i)(x_t(i)(P_t(i)))$  represents the nominal total cost of the  $i$ th I firm and is a function of the  $i$ th intermediate good  $x_t(i)$ .

First order condition with respect to  $P_t(i)$  gives

$$P_t(i)x'_t(i)(P_t(i)) \left( 1 + \frac{x_t(i)(P_t(i))}{P_t(i)x'_t(i)(P_t(i))} \right) = MC_t(i)x'_t(i)(P_t(i)) \quad (18)$$

where  $MC_t(i)$  represents the nominal marginal cost of the  $i$ th I firm.

From the demand function of  $x_t(i)$  in equation (14) I get the elasticity of demand of the  $i$ th good as

$$-\frac{x'_t(i)(P_t(i))}{(x_t(i)(P_t(i))/P_t(i))} = \sigma \quad (19)$$

Using this in the firm's first order condition gives rise to

$$P_t(i) = \left( \frac{\sigma}{\sigma - 1} \right) mc_t(i)P_t \quad (20)$$

where  $mc_t(i)$  represents the real marginal cost of the  $i$ th I firm.

Turning now to the supply side of the I firm, total cost of production for the  $i$ th I firm in

real terms  $tc_t(i)$  is given by

$$tc_t(i)(x_t(i)) = r_t k_t(i)$$

$r_t$  is the real rental rate which is the same for all I firms. Thus the real marginal cost is given by

$$mc_t(i) = \frac{r_t}{MP_{k_t(i)}} \quad (21)$$

where  $MP_{k_t(i)}$  represents the marginal product of capital for the  $i$ th I firm.

Using the production function in equation (16), one gets

$$MP_{k_t(i)} = \epsilon_t$$

Therefore

$$mc_t(i) = \frac{r_t}{\epsilon_t} \quad (22)$$

Plugging (21) in equation (20), I have

$$P_t(i) = \left( \frac{\sigma}{\sigma - 1} \right) \frac{r_t}{\epsilon_t} P_t \quad (23)$$

Hence the nominal price of intermediate goods is independent of  $i$  because all I firms face common marginal cost.

Since all firms are symmetric, it follows from the generalized price aggregation equation (15) that in equilibrium,  $P_t(i) = P_t$ . Using this in (23) I have

$$r_t = \left( \frac{\sigma - 1}{\sigma} \right) \epsilon_t \quad (24)$$

The demand function faced by each I firm is the same which implies that marginal revenue is same for each I firm. Also marginal cost is same across all I firms. Hence equilibrium output is the same for all I firms, i.e. for all  $i$

$$x_t(i) = x_t \quad (25)$$

By the same reasoning of symmetry, it follows that in equilibrium,

$$k_t(i) = k_t \quad (26)$$

and

$$d_t(i) = d_t \quad (27)$$

Next check that in equilibrium, real dividend  $d_t$  is given by

$$d_t = \epsilon_t k_t - r_t k_t \quad (28)$$

Using (28) and the value of  $r_t$  from equation (24),

$$d_t = \left(\frac{1}{\sigma}\right) \epsilon_t k_t \quad (29)$$

Now, in equilibrium, total nominal income of the representative household is (nominal dividend income) + (nominal rental income) =  $P_t[(\frac{1}{\sigma}) \epsilon_t k_t + r_t k_t] = P_t \epsilon_t k_t$ , which is the nominal value of the total output.

## E. An example

I now look into the entire set up, but with only one shock, i.e. a TFP shock which is independently and identically distributed. This is done in order to derive closed form solutions of market capitalization ratio and output growth.

There is no IST shock and capital depreciation is fixed at  $\delta$ . Since it has been established that dividends are the same across all I firms, in the representative household's asset Euler equation in (8) I substitute  $d_{t+1}(i)$  by  $d_{t+1}$  and  $p_{t+1}^z(i)$  by  $p_{t+1}^z$ <sup>6</sup> for real dividends and real asset prices respectively to get

$$c_t^{-\rho} = \beta E_t \left( c_{t+1}^{-\rho} \left( \frac{d_{t+1} + p_{t+1}^z}{p_t^z} \right) \right) \quad (30)$$

Also recall the first order condition with respect to  $k_{t+1}$  in equation (7) changes as

$$u'(c_t) = \beta E_t u'(c_{t+1})(r_{t+1} + 1 - \delta) \quad (31)$$

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<sup>6</sup>Since firms are identical, asset prices must be same across all firms.

Similarly, the equilibrium budget constraint in (9) changes as

$$c_t + k_{t+1} - (1 - \delta)k_t = \epsilon_t k_t \quad (32)$$

Equations (30), (31) and (32) are three key equations from which closed form solutions for  $c_t$ ,  $k_{t+1}$  and  $p_t^z$  can be obtained as

$$c_t = \left(1 - (\beta\tilde{u})^{\frac{1}{\rho}}\right) (\epsilon_t + 1 - \delta) k_t \quad (33)$$

$$k_{t+1} = (\beta\tilde{u})^{\frac{1}{\rho}} (\epsilon_t + 1 - \delta) k_t \quad (34)$$

This equilibrium allocation of  $c_t$  and  $k_{t+1}$  can be also obtained by solving a social planning problem, shown in the appendix.<sup>7</sup>

and

$$p_t^z = \frac{\beta\tilde{v}(\beta\tilde{u})^{\frac{1-\rho}{\rho}}}{\left(1 - \beta(\beta\tilde{u})^{\frac{1-\rho}{\rho}}\tilde{w}\right)\sigma} (\epsilon_t + 1 - \delta) k_t \quad (35)$$

where

$$\tilde{u} = E_t \left( \frac{\left(\frac{\sigma-1}{\sigma}\right)\epsilon_{t+1} + 1 - \delta}{(\epsilon_{t+1} + 1 - \delta)^\rho} \right) \quad (36)$$

$$\tilde{v} = E_t \left( \frac{\epsilon_{t+1}}{(\epsilon_{t+1} + 1 - \delta)^\rho} \right) \quad (37)$$

and

$$\tilde{w} = E_t \left( (\epsilon_{t+1} + 1 - \delta)^{1-\rho} \right) \quad (38)$$

From equations (34) and (35) one gets

$$p_t^z = \frac{\tilde{v}}{\tilde{u} \left(1 - \beta(\beta\tilde{u})^{\frac{1-\rho}{\rho}}\tilde{w}\right)\sigma} k_{t+1} \quad (39)$$

Solutions for  $c_t$ ,  $k_{t+1}$  and  $p_t^z$  are obtained by assuming that  $\epsilon$  is an iid shock because of which

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<sup>7</sup>It is shown that the benevolent planner's allocation replicates that of the imperfectly competitive economy if the former uses a modified discount factor.

$\tilde{u}$ ,  $\tilde{v}$  and  $\tilde{w}$  are all constant and hence treated as parameters.

From equation (35) it is clear that a positive TFP shock directly affects  $p_t^z$ , as a result of which, as is evident from equation (39), next period's capital stock  $k_{t+1}$  gets affected immediately. A change in  $k_{t+1}$  implies a change in  $y_{t+1}$  i.e. the next period's output, which also means a change in  $\frac{y_{t+1}}{y_t}$ , which is next period's growth. Thus a positive TFP shock in time period  $t$  affects stock price in time period  $t$ . An effect on stock price in time period  $t$  immediately influences market capitalization in time period  $t$ , but growth in time period  $t+1$ . This explains the lead lag relationship between market capitalization and growth that followed from the empirical analysis using panel VAR, where it was established that although market capitalization does not depend significantly on the lagged values of growth, growth, in fact is significantly dependent on the lagged values of market capitalization.

In this particular set up as firms are symmetric in equilibrium, share price  $p_t^z$  is same across all firms. This, combined with the assumption that total number of stocks in a firm add up to unity, shares of firms are owned by households in fixed proportions and total number of households is fixed at unity (as in the previous chapter), imply that total value of market capitalization is given by  $p_t^z$ . Thus, market capitalization as a ratio of output is defined as

$$mk_t = \frac{p_t^z}{y_t} \quad (40)$$

In the above expression in equation (40),  $p_t^z$  represents the entire stock index.

From equations (33), (35) and (34), I derive closed form solutions of the time  $t$  market capitalization ratio ( $mk_t$ ) and growth ( $yg_t$ ) as:

$$mk_t = \frac{\beta(\beta\tilde{u})^{\frac{1-\rho}{\rho}}\tilde{v}}{[1 - \beta(\beta\tilde{u})^{\frac{1-\rho}{\rho}}\tilde{w}]\sigma} \left( 1 + \frac{(1-\delta)}{\epsilon_t} \right) \quad (41)$$

and

$$yg_t = \epsilon_t(\beta\tilde{u})^{\frac{1}{\rho}} \left( 1 + \frac{(1-\delta)}{\epsilon_{t-1}} \right) \quad (42)$$

Detailed derivations of (33), (35), (34), (41) and (42) are shown in the appendix.

From the equations (41) and (42), it is clear that a positive total factor productivity shock  $\epsilon_t$  implies a fall in market capitalization ratio and a rise in growth in time period  $t$ . A positive

TFP shock augments output. Since a part of the total value of output goes into consumption and the remaining part into physical and financial investment, due to a rise in output, there is increase in consumption, physical investment and financial investment due to pure income effect only. However, the rise in financial investment, which leads to a subsequent rise in market capitalization, is in this case less than the total increase in output as part of this total increase is attributed to increased consumption and increased physical investment as well. Hence, a positive TFP shock leads to a fall in market capitalization ratio. On the other hand, current growth increases as a positive TFP shock gives rise to increased current production. So the contemporaneous positive correlation between market capitalization and growth, which emerged from the empirical analysis, cannot be supported by this particular theoretical framework with market imperfections, but fully flexible prices.

## F. Quantitative short run analysis with serially correlated shocks

The assumption of a single i.i.d. TFP shock enables me to obtain closed form solutions of market capitalization ratio and growth. Now, I return to the original general set up with three different shocks and assume each of these shocks to follow an AR(1) process. In this framework, however, closed form solutions for market capitalization and growth cannot be obtained. Rather, I focus on the short run dynamics of market capitalization and growth along with those of some other relevant variables, as a result of realization of the different shocks in a Dynamic Stochastic General Equilibrium (DSGE) set up.

I define the consumption to capital ratio as

$$ck_t = \frac{c_t}{k_t} \quad (43)$$

the expected growth of capital as

$$kg_t = \frac{k_{t+1}}{k_t} \quad (44)$$

the dividend to capital ratio as

$$dk_t = \frac{d_t}{k_t} \quad (45)$$

and the Tobin's q as

$$q_t = \frac{p_t^z}{k_{t+1}} \quad (46)$$

Tobin's  $q$  is defined as the ratio of the total market value to the total asset value of a firm. Here I use the ratio of the stock price index to total capital accumulation in a certain period to be the Tobin's  $q$  for that particular period. As in the expression for market capitalization ratio (i.e.  $mk_t = \frac{p_t^z}{y_t}$ ), in the expression for Tobin's  $q$  (i.e.  $q_t = \frac{p_t^z}{k_{t+1}}$ ),  $p_t^z$  represents the aggregate stock price index for the economy which is stock price times number of outstanding shares and  $k_{t+1}$  represents the end of period capital stock. Tobin's  $q$  is an important indicator of the health of the stock market in an economy, with  $q_t$  greater than unity implying that the market is overvalued and  $q_t$  less than unity implying that it is undervalued.

It should be noted that in this set up, where closed form expression of market capitalization as a ratio of output cannot be obtained,  $q_t$  helps to pin down  $\frac{p_t^z}{y_t}$ , which is how market capitalization ratio is defined. This will be clear in equation (51), where I derive an expression of market capitalization ratio in terms of Tobin's  $q$ , expected capital growth and the TFP shock. This is one of the main reasons of introducing Tobin's  $q$  in this set up. In addition to this, Tobin's  $q$  also serves as an important determinant of the financial market and hence and it is always useful to observe its short run dynamics in response to the different macroeconomic shocks. In the previous section with the i.i.d. TFP shock, from equation (39) Tobin's  $q$  is obtained as a constant. This happens because of the assumption that the TFP shock is independently and identically distributed. Assuming that this TFP shock follows a lognormal distribution, it is possible to derive a Tobin's  $q$  expression in terms of the different parameters. It is shown in the appendix that for plausible parametric values, the Tobin's  $q$  is greater than one.

Using the definitions in (43), (44), (45) and (46) the household's real discount factor (marginal rate of substitution) becomes

$$m_{t,t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)} = \beta E_t \left[ \left( \frac{ck_{t+1}}{ck_t} \right) kg_t \right]^{-\rho} \quad (47)$$

Also the rental Euler equation in (7) becomes modified as

$$\left( \frac{1}{\psi_t} \right) = m_{t+1} E_t \left( \frac{\xi_{t+1} r_{t+1} + 1 - \delta_{t+1}}{\xi_{t+1}} \right) \quad (48)$$

and the Tobin's  $q$  Euler equation as

$$q_t = m_{t+1} (dk_{t+1} + q_{t+1} kg_{t+1}) \quad (49)$$

The equilibrium resource constraint changes as

$$ck_t + \frac{1}{\xi_t} [k_{t+1} - (1 - \delta_t)k_t] = \epsilon_t \quad (50)$$

Finally, the expression for market capitalization as a ratio of GDP is given by

$$\begin{aligned} mk_t &= \frac{p_t^z}{y_t} \\ &= \left( \frac{p_t^z}{k_{t+1}} \right) \left( \frac{k_{t+1}}{\epsilon_t k_t} \right) \\ &= q_t k g_t \epsilon_t^{-1} \end{aligned} \quad (51)$$

and that of GDP growth is given by

$$\begin{aligned} yg_t &= \frac{y_t}{y_{t-1}} \\ &= \frac{\epsilon_t k_t}{\epsilon_{t-1} k_{t-1}} \\ &= \left( \frac{\epsilon_t}{\epsilon_{t-1}} \right) k g_{t-1} \end{aligned} \quad (52)$$

### F.1 Forcing processes, balanced growth values and loglinearization

There are three forcing processes, namely Total Factor Productivity (TFP) shock given by  $\epsilon_t$ , Investment Specific Technology (IST) shock given by  $\xi_t$  and Capital Quality (CQ) shock given by  $\delta_t$ . Each of these shocks follow an AR(1) process.

TFP shock process:

$$\epsilon_t - \bar{\epsilon} = \rho_\epsilon (\epsilon_{t-1} - \bar{\epsilon}) + \zeta_t^\epsilon \quad (53)$$

$\bar{\epsilon}$  being the steady state value of  $\epsilon_t$ ,  $\rho_\epsilon$  the coefficient term and  $\zeta_t^\epsilon$  representing the disturbance term for the TFP shock.

IST shock process:

$$\xi_t - \bar{\xi} = \rho_\xi (\xi_{t-1} - \bar{\xi}) + \zeta_t^\xi \quad (54)$$

$\bar{\xi}$  being the steady state value of  $\xi_t$ ,  $\rho_\xi$  the coefficient term and  $\zeta_t^\xi$  representing the disturbance term for the IST shock.

CQ shock:

$$\delta_t - \bar{\delta} = \rho_\delta (\delta_{t-1} - \bar{\delta}) - \zeta_t^\delta \quad (55)$$



$\bar{\delta}$  being the steady state value of  $\delta_t$ ,  $\rho_\delta$  the coefficient term and  $\zeta_t^\delta$  denoting the disturbance term for the CQ shock. A rise in the disturbance term  $\zeta_t^\delta$  implies a good capital quality shock as it diminishes capital depreciation.

In sum, this theoretical framework deals with eight endogenous variables and three exogenous variables. The endogenous variables are consumption to capital ratio represented by  $ck_t$ , expected growth of capital represented by  $kg_t$ , Tobin's q represented by  $q_t$ , rental rate represented by  $r_t$ , household's marginal rate of substitution being represented by  $m_{t+1}$ , dividend to capital ratio represented by  $dk_t$ , market capitalization ratio represented by  $mk_t$  and output growth represented by  $yg_t$ . The three exogenous shock processes are represented by  $\zeta_t^\epsilon$  for the TFP shock,  $\zeta_t^\xi$  for the IST shock and  $\zeta_t^\delta$  for the CQ shock.

Balanced growth expressions for  $ck_t$ ,  $kg_t$ ,  $q_t$ ,  $r_t$ ,  $m_{t+1}$  and  $dk_t$  can be solved in terms of all the deep parameters i.e.  $\beta$ ,  $\sigma$ ,  $\bar{\delta}$ ,  $\bar{\epsilon}$ ,  $\bar{\xi}$ ,  $\rho$ ,  $\rho_\epsilon$ ,  $\rho_\xi$  and  $\rho_\delta$  as<sup>8</sup>

$$\bar{r} = \bar{\epsilon} \left( \frac{\sigma - 1}{\sigma} \right) \quad (56)$$

$$\bar{m} = (\bar{\xi} \bar{r} + 1 - \bar{\delta})^{-1} \quad (57)$$

$$\bar{kg} = \left( \frac{\beta}{\bar{m}} \right)^{\frac{1}{\rho}} \quad (58)$$

$$\bar{ck} = \bar{\epsilon} - \left[ \frac{\bar{kg} - (1 - \bar{\delta})}{\bar{\xi}} \right] \quad (59)$$

$$\bar{dk} = \frac{\bar{\epsilon}}{\sigma} \quad (60)$$

$$\bar{q} = \left( \frac{\bar{m} \bar{dk}}{1 - \bar{m} \bar{kg}} \right) \quad (61)$$

It is to be noted that the short run dynamics of all the eight endogenous variables are around the above mentioned six balanced growth values. The balanced growth values of market

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<sup>8</sup>A bar over a variable represents its value along the balanced growth path.

capitalization and growth can be expressed as

$$\overline{mk} = \overline{qkg} (\bar{\epsilon})^{-1} \quad (62)$$

and

$$\overline{yg} = \overline{kg} \quad (63)$$

Although my main focus is to explore the short run dynamics between market capitalisation ratio  $mk_t$  and output growth  $yg_t$ , it should be noted that the short run behaviours of other endogenous variables also carry important implications about this particular theoretical framework. My solution strategy is to loglinearise the non-linear optimal conditions and the resource constraints around the balanced growth values of the respective variables which have been solved in terms of the deep parameters. A hat ( $\hat{\cdot}$ ) over a variable represents proportional change from its balanced growth path value. The loglinearised system of equations is as follows:

(1) Equilibrium resource constraint represented by equation (9)

$$\overline{ck} \widehat{ck}_t + \frac{1}{\bar{\xi}} \left( \widehat{kg}_t + \widehat{\delta}_t \right) - \left[ \frac{\overline{kg} - (1 - \bar{\delta})}{\bar{\xi}} \right] \widehat{\xi} = \widehat{\epsilon}_t \quad (64)$$

(2) Rental Euler equation represented by (48)

$$\widehat{m}_t + \left[ \frac{\bar{\xi} \bar{r} \left( \widehat{r}_{t+1} + \widehat{\xi}_{t+1} \right) - \bar{\delta} \widehat{\delta}_{t+1}}{\bar{\xi} \bar{r} + 1 - \bar{\delta}} \right] - \widehat{\xi}_{t+1} + \widehat{\xi}_t = 0 \quad (65)$$

(3) Asset Euler equation represented by (49)

$$\widehat{q}_t = \widehat{m}_t + \frac{1}{(\overline{dk} + \overline{qkg})} \left[ \overline{dk} \widehat{dk}_{t+1} + \overline{qkg} \left( \widehat{kg}_{t+1} + \widehat{q}_{t+1} \right) \right] \quad (66)$$

(4) Rental rate expression represented by equation (24)

$$\widehat{r}_t = \widehat{\epsilon}_t \quad (67)$$

(5) Dividend to capital ratio expression represented by equation (45)

$$\widehat{dk}_t = \widehat{\epsilon}_t \quad (68)$$

(6) Household's real discount factor expression represented by equation (47)

$$\widehat{m}_{t+1} = -\rho \left( \widehat{ck}_{t+1} - \widehat{ck}_t + \widehat{kg}_t \right) \quad (69)$$

(7) Market capitalization ratio expression represented by equation (51)

$$\widehat{mk}_t = \widehat{q}_t - \widehat{\epsilon}_t + \widehat{kg}_t \quad (70)$$

(8) Output growth expression represented by equation (52)

$$\widehat{yg}_t = \widehat{\epsilon}_t - \widehat{\epsilon}_{t-1} + \widehat{kg}_{t-1} \quad (71)$$

(9) TFP shock represented by equation (53)

$$\widehat{\epsilon}_t = \rho_\epsilon \widehat{\epsilon}_{t-1} + \widehat{\zeta}_t^\epsilon \quad (72)$$

(10) IST shock represented by equation (54)

$$\widehat{\xi}_t = \rho_\xi \widehat{\xi}_{t-1} + \widehat{\zeta}_t^\xi \quad (73)$$

(11) CQ shock represented by equation (55)

$$\widehat{\delta}_t = \rho_\delta \widehat{\delta}_{t-1} - \widehat{\zeta}_t^\delta \quad (74)$$

In the above system of equations I have 11 equations and 11 unknowns which indicates that the model is solvable.<sup>9</sup>

## F.2 Choice of parameter values

In order to simulate the model, I fix the discount factor  $\beta$  at 0.99 and the depreciation parameter  $\bar{\delta}$  at 0.025 i.e. at the conventional levels consistent with quarterly calibration.<sup>10</sup> The demand elasticity parameter  $\sigma$  is fixed at 6.00 as in Kollmann (2002). In order to find an estimate of

<sup>9</sup>The model is numerically solved using Dynare 4.4.3

<sup>10</sup>I start with quarterly calibrated parameters, but in my dynare code each of the variables are annualized. This is done such that in the impulse response figures each of the periods represent an year and the first and second order moments calculated from the model can be compared with those obtained from the annual data.

the productivity parameter  $\bar{\epsilon}$  for developed countries, the long run per capita quarterly real GDP growth rate for USA at 0.49% i.e. an annualized growth rate of 1.97% for the sample period 1947-2014 is targeted to set the productivity parameter at 0.048.<sup>11</sup> I assume a log utility function and set  $\rho = 1$ .<sup>12</sup> Without any loss of generality, I fix the standard deviation of the exogenous component of all the shocks, i.e.  $\sigma_\epsilon^2$ ,  $\sigma_\xi^2$  and  $\sigma_\delta^2$  at unit levels in order to normalize the impulse responses. Baseline parametric values are given in Tables 3 and 4.<sup>13</sup>

### F.3 Short run dynamics

After simulating the model, I find the correlation between the short run fluctuations of market capitalization and growth to be positive but not quantitatively large enough to match the data. The correlation coefficient between market capitalization and growth comes out to be around 0.32 for the baseline parametric values. This cross correlation, as calculated from the model, is a summary of the impulse response time paths of market capitalization and GDP growth driven by the three different shocks.

Table 5 represents a sensitivity analysis of the correlation coefficients with respect to  $\sigma$  and  $\delta$ .<sup>14</sup> In Table 5 the correlation coefficient between market capitalization and growth is denoted by  $r_{mk,yg}$ . It is observed that the correlation coefficient between market capitalization and growth is sensitive to the value of the demand elasticity parameter  $\sigma$ , but not much to the value of the capital depreciation parameter  $\delta$ . As  $\sigma$  increases from 2 to 10,  $r_{mk,yg}$  increases from 0.282 to 0.363. On the other hand, a very slight increase is noticed in  $r_{mk,yg}$  when  $\delta$  increases from 0.01 to 0.09.

Table 6 compares the correlation coefficient between market capitalization and growth as calculated from the model with that obtained from the data.<sup>15</sup> From my data set, I note all the different values of the market capitalization - growth correlation coefficients, but report only the first quartile ( $Q_1$ ), second quartile ( $Q_2$ ) and third quartile ( $Q_3$ ) of these correlation coefficient values in Table 6. This means that 75% of all  $r_{mk,yg}$  values are greater than the value of  $r_{mk,yg}$  corresponding to  $Q_1$ , 50% are greater than the value of  $r_{mk,yg}$  corresponding to  $Q_2$  and 25% are greater than the value of  $r_{mk,yg}$  corresponding to  $Q_3$ . All other baseline parametric values

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<sup>11</sup>Data for annual per capita real GDP in chained 2009 US dollars came from Bureau of Economic Analysis.

<sup>12</sup>Impulse response results remain more or less same for different values of  $\rho$ .

<sup>13</sup>Tables 3 and 4 can be found in the appendix.

<sup>14</sup>Table 5 can be found in the appendix.

<sup>15</sup>Table 6 can be found in the appendix.

remaining the same, for  $\sigma = 6$ , the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_1$  of the value of  $r_{mk,yg}$  as obtained from the data. Similarly, for  $\sigma = 8$ , the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_2$  of the value of  $r_{mk,yg}$  as obtained from the data. The model does not perform very well in matching the third quartile of the correlation - coefficient values of  $r_{mk,yg}$  obtained from the data.

The impulse responses of the relevant variables under consideration due to TFP, IST and CQ shocks are represented in Figures 1, 2 and 3 respectively. A good TFP shock (increase in  $\epsilon_t$ ) and a good CQ shock (fall in  $\delta_t$ ) bring about a rise in both market capitalization ratio and growth. A good IST shock ( $\xi_t$ ), however, leads to a rise in growth, but a fall in market capitalization ratio.

The short run behaviour of Tobin's q as a result of realization of the three shocks is very similar to that of market capitalization ratio, with both good TFP and CQ shocks augmenting Tobin's q and a good IST shock decreasing Tobin's q. In the previous section where the TFP shock followed an independent and identical distribution, the expression for Tobin's q was found to be independent of shock. In this section, when I assume the three shocks to follow an AR(1) process, I can find a short run dynamics for Tobin's q. Since, from the variance decomposition of the three shocks, it is evident that IST shock is the only dominant shock in driving the short run fluctuations of Tobin's q, it can be inferred that even if all three shocks act simultaneously, their combined effect on Tobin's q will be a negative one.

Thus I find that TFP and CQ shocks lead to an increase in market capitalization and Tobin's q, whereas an IST shock leads to a fall in both these variables. A good IST shock induces the representative household to spend more of its total resources on physical investment and a comparatively lesser amount on financial investment, i.e. consuming financial assets or shares. This implies a fall in asset prices, leading to a subsequent decrease in the total market value of assets and market capitalization. Tobin's q is defined as the ratio of market value to replacement value of assets, i.e.  $\frac{p_t^z}{k_{t+1}}$ . A good IST shock leads to a fall in the total market value of all assets i.e.  $p_t^z$  and a rise in next period's capital  $k_{t+1}$ . So on both counts Tobin's q falls as a result of a good IST shock.

A good TFP shock leads to a rise in total income, which boosts up total financial investment. An increased demand for stocks implies a rise in stock prices, which leads to a rise in total market value of stocks and hence Tobin's q. When the TFP shock follows an AR(1) process, the rate

at which market capitalization increases exceeds the rate at which GDP increases due to a TFP shock, leading to a rise in market capitalization ratio. This is because from equation (24) and equation (29), it is clear that at time period  $t + 1$ , rental rate  $r_{t+1} = \left(\frac{\sigma-1}{\sigma}\right) \epsilon_{t+1}$  and dividend to capital ratio  $\frac{d_{t+1}}{k_{t+1}} = \left(\frac{1}{\sigma}\right) \epsilon_{t+1}$  will depend on  $\epsilon_{t+1}$ , which is the TFP shock at time period  $t + 1$ . If TFP follows an AR(1) process, a good TFP shock at time period  $t$  i.e. a rise in  $\epsilon_t$  will also imply a rise in  $\epsilon_{t+1}$  and hence a subsequent rise in the rental as well as dividend to capital ratio at time period  $t$ . This will urge households to increase their investment in physical as well as financial capital at time period  $t$ . Thus due to a positive TFP shock, investments in financial assets at time period  $t$  increase on both counts: once due to the income effect (a positive TFP shock will augment total income) and once again due to the fact that households would ideally like to take advantage of the increased expected dividends in the next period. Because of this, the rise in market capitalization will dominate the rise in output, leading to an increase in the market capitalization - output ratio. If, however, the TFP shock is i.i.d., a good TFP shock will increase investment in financial assets purely due to the income effect and nothing else, because of which the market capitalization - output ratio will fall as the rise in output will then dominate the rise in market capitalization.<sup>16</sup>

A good capital quality shock leads to a fall in the depreciation rate of capital, which will send a good signal to the investors who will invest more in financial capital, boosting up both market capitalization and Tobin's  $q$ . Growth, on the other hand, is augmented by all the three shocks. A positive TFP shock increases present output, thereby augmenting present GDP growth, which is defined as the ratio of present to past values of GDP. The CQ and IST shocks do not have any direct link to current GDP growth. However, good CQ and IST shocks increase future capital growth, which will also have a positive impact on GDP growth in next period.

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<sup>16</sup>In this particular theoretical setup, the assumption that the TFP shock follows an AR(1) process is a crucial assumption because of which market capitalization and growth move in the same direction. Making the TFP shock i.i.d. in the dynare code by putting  $\rho_\epsilon = 0$ , I find market capitalization falling and growth rising because of a positive TFP shock, thus reproducing the result found in section 3.2.

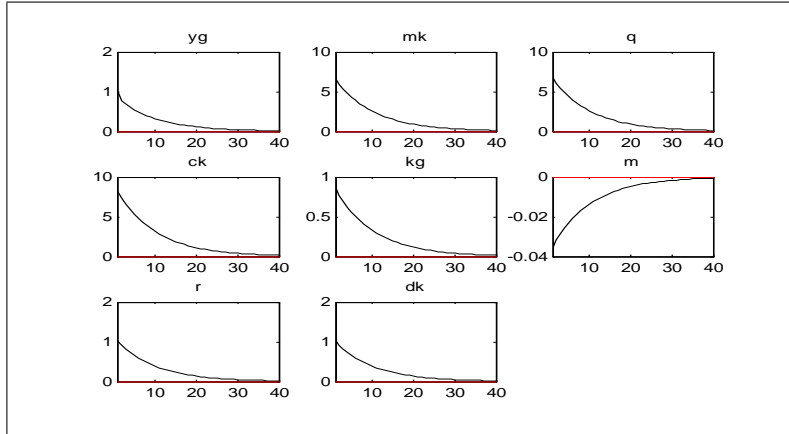


Figure 1: Effect of a TFP shock in flexible price model

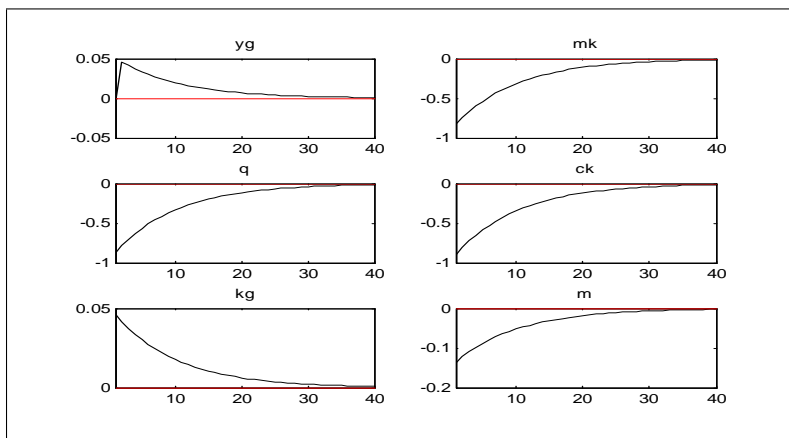


Figure 2: Effect of an IST shock in flexible price model

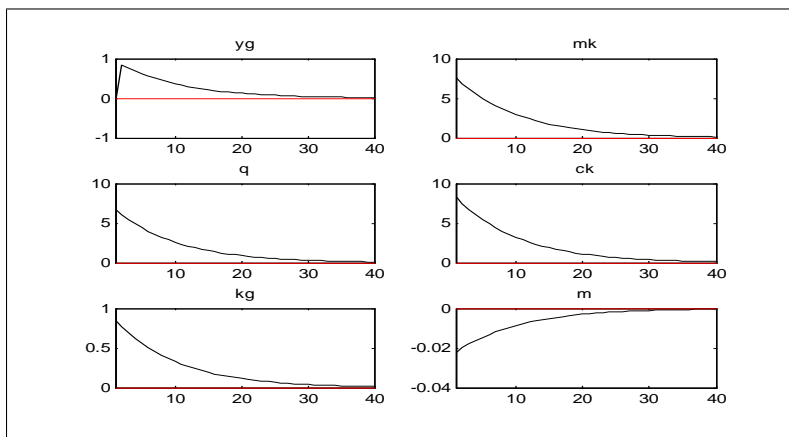


Figure 3: Effect of a CQ shock in flexible price model

From Figures 1, 2 and 3, it is clear that all three shocks have an immediate effect on market capitalization ratio. However, growth is immediately affected only by the TFP shock. The IST and the CQ shocks have a lagged effect on growth, i.e. growth is affected a period after the realization of these shocks. Thus the lead-lag relationship between market capitalization ratio

and growth, as established empirically, is also captured in this model by an IST shock and a CQ shock.

Table 7 summarises the impact effect of the three shocks on market capitalization and growth as depicted by the impulse responses of these shocks in Figures 1, 2 and 3.<sup>17</sup>

These figures capture the short run behaviours of the main macroeconomic variables as a result of realization of good TFP, IST and CQ shocks. Table 8 reports the model variance decomposition of five macroeconomic variables.<sup>18</sup>

While TFP and the CQ shocks are the major determinants of the short run fluctuations of output growth, market capitalization is mainly influenced by the CQ and the IST shocks and to a lesser extent by the TFP shock. The IST shock plays very insignificant role in influencing the short run dynamics of GDP growth. Similarly the TFP shock does not play a major role in determining the short run fluctuations of market capitalization. The capital quality shock, however, plays a very important role in determining the short run behaviours of both market capitalization and growth. 49% of the total fluctuations of GDP growth and 58% of the total fluctuations of market capitalization can be explained by this shock. The capital quality shock also plays prominent roles in determining short run fluctuations of consumption to capital ratio and expected capital growth. The main driving force behind the short run dynamics of Tobin's  $q$  is the IST shock, accounting for 90% of its total fluctuations.

The model correlation coefficient is positive but not highly significant. From the variance decomposition of the different shocks, it is evident that short run behaviour of GDP growth is driven by TFP and CQ shocks, whereas fluctuations in market capitalization ratio is mostly explained by CQ and IST shocks. Although the combined effect of a good TFP shock and a good CQ shock leads to an increase in GDP growth, for market capitalization, the combined effect of CQ and IST shocks is somewhat ambiguous because a good CQ shock augments market capitalization ratio, while a good IST shock decreases it. Since a greater percentage of the fluctuations in market capitalization ratio is explained by the CQ shock, as compared to the IST shock, the net effect of the CQ and the IST shocks will still lead to an increase in market capitalization ratio, but not to the extent of the increase in GDP growth as the positive influence of a CQ shock on market capitalization is checked off, to a certain extent, by the negative influence of an IST shock. This leads to a positive but not very significant market capitalization-

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<sup>17</sup>Table 7 can be found in the appendix.

<sup>18</sup>Table 8 can be found in the appendix.



growth correlation and from Table 5, it is evident that the value of this correlation coefficient is not found to vary a great deal with change in parameter values.

Note that in the existing framework, once I assume each of the shocks to be i.i.d., I get a negative correlation between market capitalization and growth as established in the previous section with only one shock i.e. an independently and identically distributed TFP shock. However, in a framework with market imperfections, but fully flexible prices, if I assume each of the shocks to follow an AR(1) process, I can get market capitalization and growth to move in the same direction, but I cannot reproduce a market capitalization-growth correlation that is quantitatively close to the data.

#### **F.4 Comparing the results with those obtained from the frictionless model of Chapter 2**

Comparing this model with the first model of Chapter 2, i.e. the one without a borrowing constraint friction, I find very similar results, except for the fact that in the present theoretical framework, a serially correlated TFP shock induces market capitalization and growth to move in the same direction. However it must be pointed out that this happens for a very high value of the autocorrelation coefficient parameter ( $\rho_\epsilon = 0.75$ ), as is evident from Table 4. Even then, the value of the correlation coefficient between market capitalization ratio and growth turns out to be 0.32, which makes the existing correlation between the two variables to be weakly significant for baseline parameter values. The correlation coefficient steadily loses significance with decrease in  $\rho_\epsilon$  and becomes negative when  $\rho_\epsilon$  falls beyond 0.35. Still, a higher value of the autocorrelation coefficient parameter for the TFP shock is able to reproduce positive market capitalization-growth correlation in this theoretical framework with fully flexible prices, although this does not happen for a similar higher value of the said parameter in the frictionless model of Chapter 2. The reason is as follows:

While in the present model with market imperfections, a rise in output due to a positive TFP shock leads to a proportional increase in supernormal profits of the firm as well as the return to capital of the households, in a model without market imperfections, an output increase due to a similar shock leads to increase in physical capital accumulation by the firm and increase in households' dividends. However, if the TFP shock is serially correlated, in a framework with market imperfections, this also implies an increase of supernormal profits in future time

periods, thereby boosting up current demand for stocks, so much so that for considerably higher values of the autocorrelation parameter  $\rho_\epsilon$ , this results in an increase in Tobin's  $q$  and market capitalization. On the other hand, in a model without market imperfections, firms do not make supernormal profits. Thus, even if the TFP shock is autocorrelated, this does not in any way boost demand for assets, which is why Tobin's  $q$  is found to be unaffected by the TFP shock. In this particular theoretical framework, although a good TFP shock leads to an increase in dividend income and hence a slight rise in the asset demand, this is much less than the corresponding increase in output, because of which there is a fall in market capitalization to output ratio. But when firms are imperfectly competitive, apart from this rise in asset demand, through the standard income effect channel, there is the added effect of increased demand for stocks and hence stock prices due to the anticipated rise in supernormal profits, which in turn leads to a rise in the market capitalization to output ratio when the TFP shock is strongly autocorrelated.

In both set-ups market capitalization is defined as:

$$\begin{aligned} mk_t &= \frac{p_t^z}{y_t} \\ &= q_t kg_t \epsilon_t^{-1} \end{aligned}$$

where  $q_t$  denotes the Tobin's  $q$ , defined as  $q_t = \frac{p_t^z}{k_{t+1}}$  and  $kg_t$  denotes expected growth of capital. In the first model of Chapter 2, which is essentially a Lucas tree model with investment and production,  $p_t^z = \frac{k_{t+1}}{\psi_t}$ , which means that  $q_t = \frac{1}{\psi_t}$ . Hence, in this model, Tobin's  $q$  only depends on the IST shock and is totally unaffected by a TFP shock (i.i.d. or serially correlated). In the present theoretical framework, although a close form expression for Tobin's  $q$  cannot be derived, it is found to be dependent on a TFP shock through  $p_t^z$ , which in turn depends on the shock through dividend  $d_t$  via the asset Euler equation in (8).<sup>19</sup> An increase in  $q_t$  due to a positive TFP shock is evident from the impulse response diagram in Figure 1, for a fairly high baseline value of the autocorrelation coefficient parameter. In this model with market imperfections and fully flexible prices, for a good TFP shock, the degree of increase in Tobin's  $q$  is observed to diminish with a fall in the value of  $\rho_\epsilon$  and Tobin's  $q$  remains completely unaffected by this shock when  $\rho_\epsilon = 0$  (i.i.d. TFP shock). On the other hand, in both models, a positive

<sup>19</sup>In the current theoretical framework, Tobin's  $q$  is also dependent on an IST and a CQ shock through  $k_{t+1}$  via the capital Euler equation in (7).

TFP shock leads to a small increase in  $kg_t$  i.e. the expected growth of capital stock (recall from Chapter 2,  $kg_t = \beta(\epsilon_t\psi_t + 1 - \delta_t)$  in the model without borrowing constraint friction); the magnitude of increase remaining the same for different values of  $\rho_\epsilon$  and even for an i.i.d. TFP shock i.e.  $\rho_\epsilon = 0$ .

In both models, a positive TFP shock negatively affects market capitalization for a given  $q_t$  and  $kg_t$ , as is evident from the expression of  $mk_t$ . In the first model of Chapter 2, irrespective of the value of  $\rho_\epsilon$ , this negative effect outweighs the positive effect of a TFP shock on  $kg_t$ . As a result, regardless of the degree of autocorrelation, a TFP shock always diminishes market capitalization in this model. In the present theoretical framework with market imperfections, however, an anticipated rise in productivity positively affects Tobin's q, such that  $q_t$  is augmented by a serially correlated TFP shock, the degree of this rise in Tobin's q increasing with increase in  $\rho_\epsilon$ . It is observed that when  $\rho_\epsilon > 0.35$ , the rise in  $q_t$  combined with the rise in  $kg_t$  outweighs the negative effect of the TFP shock on  $mk_t$ , as a result of which a good TFP shock is found to have a positive effect on market capitalization. Since output growth is augmented by the TFP shock in both theoretical set-ups, a negative market capitalization-growth correlation is reproduced in the first model of Chapter 2, whereas in the current scenario, a positive correlation coefficient (although weakly significant) is found to exist between the two variables only for a strongly autocorrelated TFP shock.

## G. Main findings from model with market imperfections

In this section I work with a model with imperfect market structure but full price flexibility, i.e. throughout this section, I have assumed absence of nominal rigidities. Market imperfection is observed on part of the I firms which function within a monopolistically competitive framework. In the existing setup, if I work with only one independently and identically distributed TFP shock, I can obtain closed form solutions of market capitalization and growth, from which it is evident that market capitalization falls, although growth increases because of a TFP shock. Also a closed form expression for Tobin's q can be obtained, if TFP is assumed to be iid. Because of this particular assumption, although the expressions of market capitalization and growth depend on the current period TFP shock, the current period Tobin's q expression is independent of this shock. For plausible ranges of different parametric values, I find Tobin's q to be always greater than one. Next, in addition to the TFP shock, I incorporate two more shocks, an IST shock

and a CQ shock; both these shocks influencing the capital accumulation equation.

While working with three shocks, I relax the i.i.d. assumption and allow each of the shocks to follow an AR(1) process, because of which I cannot obtain closed form solutions of market capitalization and growth as in the case of an i.i.d. TFP shock. Growth is found to be driven by the TFP shock, whereas market capitalization ratio appears to be mainly influenced by the IST and the CQ shocks. A good TFP shock augments growth, while favourable IST and CQ shocks have negative and positive effects respectively on the market capitalization ratio. Since the positive effect on market capitalization due to a CQ shock is checked off to a certain extent by the negative effect of an IST shock, the correlation coefficient between the short run fluctuations of market capitalization and growth is found to be positive but not very significant. The IST and CQ shocks can reproduce a lead-lag relationship between market capitalization ratio and growth, as established empirically. Tobin's  $q$  is mainly influenced by the IST shock and is adversely affected by this shock.

In sum, in the flexible price model with serially correlated shocks, in the scenario with three different shocks, each following an AR(1) process, the sign of the market capitalization - growth correlation coefficient is found to be positive, i.e. the average time paths of the two variables are at least in the same direction, thereby providing some support to the empirical observations. However, with change in parametric values, the correlation coefficient values reproduced by the model are not observed to vary much, which is in contradiction with the data. In order to bring the model closer to the data, i.e. to replicate empirically plausible correlation coefficient between market capitalization and growth, which is observed for most developed and developing countries, I next incorporate nominal rigidity frictions in the form of price rigidities within the existing theoretical framework.

### **III. A New Keynesian model of market capitalization ratio, growth and inflation**

In this section my primary focus is to look into the relationship between the short run fluctuations of market capitalization and growth using a New Keynesian endogenous growth model. Since I deal with staggered pricing, a very important component of the New Keynesian framework, it is also worthwhile to look into the short run relationship between inflation and growth along with

the usual market capitalization-growth relationship. The theoretical framework, which I develop in this section, deals with typical New Keynesian frictions in the form of (1) price distortions, (2) partial inflation indexation, (3) habit persistence in consumers' utility function and (4) investment adjustment cost. Out of these different frictions, the first two i.e. price distortions (price rigidities and price adjustment cost) and partial inflation indexation are sources of *nominal rigidities*, while the latter two i.e. habit formation and adjustment cost of investment can be considered to be real rigidities.

As in the previous framework, here also there are three main agents: Households, Intermediate good producing firms (I firms) and Final good producing firms (F firms). As in the previous set up with flexible prices, here also there are a large number of I firms in the continuous interval  $(0, 1)$  and each I firm exercises some monopoly power by virtue of producing a variety of intermediate goods, different from those manufactured by the other firms. Since there is no free entry or exit, I firms make positive profits, which are distributed as dividends to their owners, the households. Also, as before, I firms produce output with capital only, which they sell to the perfectly competitive F firms. Thus in this framework also there is no labour market and marginal cost on part of the I firms involves rental cost of capital only.

Since this section mainly deals with the short run implications of firms facing nominal frictions, it will be interesting to investigate the effect of two types of nominal rigidities faced by the I firm, which will affect their price setting problems in two different ways. Consequently I analyze two types of price setting behaviour undertaken by the I firm following (i) Calvo (1983) where firms randomly reset prices and (ii) Rotemberg (1982) where all firms continuously set prices subject to a given price adjustment cost.

In the I firm sector, the  $i$ th variety of goods is produced with a linear technology given by equation (16). In this theoretical framework also linear technology ( $AK$  type as in Rebelo, 1991) is the vehicle of endogenous growth. Each variety is produced by a firm with a patent right disallowing the entry of new firms to replicate this variety. Final goods firms transform these intermediate goods into the production of final goods using the CES aggregator in equation (12). The F firm's optimisation problem is exactly the same as the one represented by equation (13) in the previous theoretical framework and it gives rise to the general form of the demand function of the  $i$ th intermediate good, given by equation (14) and the general price aggregation equation given by equation (15).

As in the previous framework, here also there are infinite identical households in a continuum, with the representative household owning all the capital. The households also have ownership to the I firms and rents them capital for the purpose of production. In the theoretical framework, the household's problem is characterized by two new features: (1) external habit formation in consumer's utility function and (2) investment adjustment cost. These will be discussed in more detail when I explain the problem of the representative household.

The price setting problem of the I firm is different from that discussed in the previous section where there was only market imperfection. In this section, the I firm's price setting problem also takes into account nominal frictions in the form of price stickiness, price adjustment cost and imperfect indexation of inflation. In fact, as mentioned earlier, I explore two separate price setting scenarios faced by the I firm, one in a Calvo (1983) set-up and the other in a Rotemberg (1982) set-up; the former dealing with price stickiness and the latter with price adjustment cost as measures of price rigidity.

## A. Representative household's problem

There is a continuum of identical households within an unit interval. The representative household owns the physical capital and rents it to intermediate goods firms. Households also have ownership claims to all these firms. At date  $t$ , the household receives its proceeds from rental income, dividends from the ownership of firms and interest income from holding of a risk-free bond. The household uses its income at date  $t$  by consuming final goods, investing in physical capital and buying new stocks and bonds. There is no aggregate risk in this environment.

The representative home-consumer has the following expected utility function over an infinite horizon.

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t - \gamma_c C_{t-1}) \quad (75)$$

where  $E_0$  denotes the conditional expectation at date  $t$ ,  $\beta$  the subjective discount factor with  $0 < \beta < 1$ .

Note that the household's utility  $u(c_t - \gamma_c C_{t-1})$  is characterized by persistence of aggregate habit. Habit persistence, or 'habit formation' in its most common representation, represents a preference specification, as a result of which the period utility function depends on a quasi-difference of consumption. In the previous section, the utility function without habit formation was given by  $\sum_{t=0}^{\infty} \beta^t u(c_t)$ , where  $c_t$  denotes consumption in period  $t$ ,  $u$  denotes the period

utility function, and  $\beta \in (0, 1)$  denotes the subjective discount factor, while in this framework, the utility function with habit persistence is given by  $\sum_{t=0}^{\infty} \beta^t u(c_t - \gamma_c C_{t-1})$ . The parameter  $\gamma_c \in (0, 1)$ , denotes the intensity of external habit formation and introduces non-separability of preferences over time. Under habit persistence, an increase in current consumption diminishes the marginal utility of consumption in the current period and increases it in the next period. Intuitively, the more the consumer consumes in the current period, the hungrier he wakes up in the next period. The notion of habit formation, as captured by these type of preferences in this particular sense.

In these habit-forming preferences, past consumption represents the consumer's stock of habit in period  $t$ . However, in this particular model, habits are treated as external to the consumer, which means that in the utility function in (75),  $C_{t-1}$  denotes the stock of habit of the consumer which depends on the history of aggregate past consumption as opposed to the consumer's own past consumption. Early formulations of habit formation, eg. Pollak (1970), were cast in the external form. Since the work of Abel (1990), external habit formation has been referred to as 'catching up with the Joneses'. The external form of habit persistence simplifies the consumer's optimization problem since the evolution of the stock of habit is taken as exogenous by the consumer.

Thus, due to aggregate external habit formation, the consumer receives utility from the current consumption,  $c_t$  after adjusting for the history of the aggregate consumption habit,  $c_{t-1}$ . Utility function is logarithmic and is given by

$$u(.) = \ln(c_t - \gamma_c C_{t-1}) \quad (76)$$

The representative household's capital accumulation facing the investment technology is given by the following equation

$$k_{t+1} = (1 - \delta_t)k_t + \left[ 1 - s \left( \frac{\chi_t}{\chi_{t-1}} \right) \right] \chi_t \xi_t \quad (77)$$

where  $\chi_t$  denotes investment undertaken by the household,  $k_{t+1}$  the amount of accumulated capital,  $\delta_t$  the rate of depreciation of the physical capital stock and  $s(.)$  captures the investment adjustment costs as in Christiano et al. (2005). I make the standard assumption that in the long run  $s(.) = s'(.) = 0$  and  $s''(.) > 0$  implying that the adjustment cost disappears in the long

run. There is also an investment specific technology shock (IST) represented by  $\xi_t$ .

The following budget constraint summarises the choice set facing the representative home consumer:

$$P_t c_t + P_t \chi_t + \int_0^1 P_t^z(i)(z_{t+1}(i) - z_t(i))di + B_{t+1} = \int_0^1 D_t(i)z_t(i)di + R_t k_t + B_t(1 + i_t) \quad (78)$$

The right hand side of this constraint represents the total income of the household, which consists of the nominal dividend income given by  $\int_0^1 D_t(i)z_t(i)di$ , nominal rental income given by  $R_t k_t$  and nominal bond income given by  $B_t(1 + i_t)$  where as before  $R_t$  represents the nominal rental rate,  $k_t$  represents the amount of capital supplied by the representative household to the I firms and  $B_t$  represents the number of nominal one period discount bonds the household consumed at time period  $(t - 1)$  where each bond yielded a nominal return of  $(1 + i_t)$ ,  $i_t$  being the nominal interest rate. The usual solvency condition,  $\lim_{T \rightarrow \infty} E_t B_{t+T} \geq 0$  holds for all  $t$ .

The left hand side of the constraint represents the household's nominal consumption given by  $P_t c_t$ , nominal physical investment (accumulation of physical capital) given by  $P_t \chi_t$ , nominal asset investment given by  $\int_0^1 P_t^z(i)(z_{t+1}(i) - z_t(i))di$  and nominal investment on risk free bonds given by  $B_{t+1}$ .  $P_t^z(i)$  represents the nominal price of an asset,  $z_{t+1}(i) - z_t(i)$  represents the household's net addition to its stock of the  $i$ th I firm's asset i.e. number of additional stocks bought by the household at time period  $t$ .

Defining the derivative of the utility function with respect to  $c_t$  as  $u_{c_t}$  and the Lagrangian multipliers associated with the nominal flow budget constraint (78) and the capital accumulation technology (77) by  $\lambda_t$  and  $\mu_t$  respectively, the relevant first order conditions of the household with respect to the time  $t$  consumption ( $c_t$ ), accumulated physical capital ( $k_{t+1}$ ), physical investment ( $\chi_t$ ), accumulated stocks ( $z_{t+1}(i)$ ) and number of one period nominal bonds ( $B_{t+1}$ ) can be written as

$$c_t : \beta^t u_{c_t} - \lambda_t P_t = 0 \quad (79)$$

$$k_{t+1} : \lambda_{t+1} R_{t+1} - \mu_t + \mu_{t+1}(1 - \delta_{t+1}) = 0 \quad (80)$$



$$\chi_t : -\lambda_t P_t + \mu_t \left[ \{1 - s(\cdot)\} \xi_t - \xi_t \left( \frac{\chi_t}{\chi_{t-1}} \right) s'(\cdot) \right] + \mu_{t+1} \left[ \left( \frac{\chi_{t+1}}{\chi_t} \right)^2 \xi_{t+1} s'(\cdot) \right] = 0 \quad (81)$$

$$z_{t+1}(i) : -\lambda_t P_t^z(i) + \lambda_{t+1} (D_{t+1}(i) + P_{t+1}^z(i)) = 0 \quad (82)$$

$$B_{t+1} : -\lambda_t + (1 + i_{t+1}) \lambda_{t+1} = 0 \quad (83)$$

The Tobin's  $q$  (the opportunity cost of investment in terms of foregoing consumption) is defined as:

$$q_t = \frac{\mu_t}{\lambda_t P_t} \quad (84)$$

Using this definition of  $q$  the investment Euler Equation (81) can be rewritten as:

$$q_t [1 - s(\cdot)] \xi_t - \xi_t q_t \left( \frac{\chi k_t}{\chi k_{t-1}} \right) (k g_{t-1}) s'(\cdot) + E_t q_{t+1} m_{t,t+1} \xi_{t+1} k g_t^2 \left( \frac{\chi k_{t+1}}{\chi k_t} \right)^2 s'(\cdot) = 1 \quad (85)$$

where  $k g_{t-1} = \left( \frac{k_t}{k_{t-1}} \right)$  represents the growth of capital at time period  $t$ ,  $\chi k_t$  represents the investment to capital ratio and  $m_{t,t+1}$  is the household's real stochastic discount factor and is expressed as:  $m_{t,t+1} = \beta \frac{u_{c_{t+1}}}{u_{c_t}} = \frac{\lambda_{t+1} P_{t+1}}{\lambda_t P_t}$  (which follows from equation (79)). Using the logarithmic nature of the utility function given by equation (76), the household's stochastic discount factor can be rewritten as

$$m_{t,t+1} = \beta \left( \frac{c_t - \gamma_c C_{t-1}}{c_{t+1} - \gamma_c C_t} \right) \quad (86)$$

In equilibrium,  $c_t = C_t$ .

The capital euler equation represented by equation (80) can be written as:

$$q_t = E_t m_{t,t+1} r_{t+1} + E_t q_{t+1} m_{t,t+1} (1 - \delta_{t+1}) \quad (87)$$

where  $r_{t+1}$  denotes the real rental rate.

The asset euler equation represented by equation (82) can be written as

$$q_t = E_t m_{t,t+1} [dk_{t+1} + q_{t+1} k g_{t+1}] \quad (88)$$

where  $q_t = \frac{p_t^z}{k_{t+1}}$ <sup>20</sup> is an alternate expression for the economywide Tobin's  $q$ , taking into account the fact that it is defined as the ratio of a physical asset's market value and its replacement value,  $p_t^z$  representing the stock price index in real terms and  $dk_t = \frac{d_t}{k_t}$  denotes the economywide dividend to capital ratio,  $d_t$  representing the aggregate dividend in real terms.

The bond euler equation represented by equation (83) boils down to

$$E_t \left( (1 + i_{t+1}) \frac{m_{t,t+1}}{\Pi_{t+1}} \right) = 1 \quad (89)$$

where  $\Pi_t = \frac{P_t}{P_{t-1}}$  denotes inflation at time period  $t$ .

## B. Price setting problem of the I firm

### B.1 Calvo (1983) framework

In Calvo (1983), all I firms facing the same technology are *ex ante* identical. Each period a firm receives a random "price change" signal with a probability  $1 - \theta$ . In the spirit of Yun (1996), if the I firm does not receive a price signal, its price is increased at the steady state rate of inflation ( $\bar{\Pi}$ ) subject to an inflation indexation. The inflation indexation is parameterized by  $\gamma$ , where  $\gamma \in (0, 1)$ , lower  $\gamma$  signifying less indexation. The partial inflation indexation formulation is borrowed from Smets and Wouters (2003). After receiving the price signal, firms can be bunched into two distinct categories: (a) firms which do not choose a new optimized price and stick to their inflation indexed past period price and (b) firms which reset a new optimal price. I call the first category *fix price firms* and the second category *flex price firms*. Since there are a large number of I firms, in each time period,  $\theta$  fraction of the total firms is fix price firms and the remaining  $(1 - \theta)$  fraction consists of flex price firms.

The profit maximization of the F firm yields the conditional input demand function repre-

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<sup>20</sup>I am going to write stock price as  $p_t^z$  (i.e. excluding  $i$  in the subscript) here onwards and also while defining market capitalization ratio, where  $p_t^z$  represents the aggregate stock price index.

sented by equation (14) which is

$$x_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} y_t$$

where  $P_t(i) = \bar{\Pi}^\gamma P_{t-1}(i)$  if  $i \in (0, \theta)$  and  $P_t(i) = P_t^*$  otherwise. As mentioned earlier, the  $i$ th variety fix price firm sticks to its previous period's price ( $P_{t-1}(i)$ ) adjusted by the long run gross inflation  $\bar{\Pi}$ , indexed by  $\gamma$ , where  $\gamma = 1$  and  $\gamma = 0$  imply full indexation and no indexation of inflation respectively. A fraction value of  $\gamma$  indicates partial inflation indexation.

Following Grohe-Schmitt and Uribe (2011), I define a price dispersion term:

$$s_t = \int_0^1 \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} di \quad (90)$$

Categorising two different sets of prices for fix price firms and flex price firms, I can rewrite equation (90) in a recursive form as

$$s_t = \theta \bar{\Pi}^{-\gamma\sigma} \Pi_t^\sigma s_{t-1} + (1 - \theta) \left( \frac{P_t^*}{P_t} \right)^{-\sigma} \quad (91)$$

Derivation of equation (91) from equation (90) is shown in the appendix.

**Characterizing aggregate resource constraint** Price dispersion results in an inefficiency loss in aggregate production as

$$y_t = s_t^{-1} \epsilon_t k_t \quad (92)$$

This follows from the capital aggregation of all firms as:

$$k_t = \int_0^1 k_t(i) di = \int_0^1 \frac{x_t(i)}{\epsilon_t} di = \frac{y_t}{\epsilon_t} \int_0^1 \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} di = \frac{s_t y_t}{\epsilon_t} \quad (93)$$

Schmitt-Grohe and Uribe (2007) show  $s_t$  is bounded below at 1, so that  $s_t$  represents the resource costs due to relative price dispersion under the Calvo mechanism. In fact, the higher is  $s_t$ , the more capital is needed to produce a given level of output. Hence  $s_t$  can be thought of as a tax on TFP. Also, price dispersion being a backward looking variable introduces an inertial component to the model in a Calvo framework. The inefficiency is minimized in the scenario where there is no price dispersion by the firms. In the long run this happens in a zero inflation

steady state, or when there is full price flexibility ( $\theta = 0$ ) or full inflation indexation ( $\gamma = 1$ ). This can be easily verified from equation (94), which represents a long run expression for price dispersion. In this equation,  $\bar{s} = 1$  with  $\gamma = 1$ ,  $\theta = 0$ , or  $\bar{\Pi} = 1$ .

$$\bar{s} = \frac{\left(1 - \theta \bar{\Pi}^{(1-\gamma)(\sigma-1)}\right)^{\sigma/(\sigma-1)}}{\left(1 - \theta \bar{\Pi}^{\sigma(1-\gamma)}\right) (1 - \theta)^{1/(\sigma-1)}} \quad (94)$$

The time  $t$  equilibrium resource constraint takes into account the price dispersion i.e.

$$c_t + \chi_t = \frac{\epsilon_t k_t}{s_t} \quad (95)$$

where  $c_t$  represents the aggregate household consumption and  $\chi_t$  represents the aggregate household investment in physical capital. Net holding of bonds and net addition to stocks is nil in equilibrium.

**Demand functions for fix and flex price firms** Aggregate demand for intermediate goods produced by fix price firms is given by

$$\begin{aligned} x_t^{d(1)} &= \int_0^\theta \left( \frac{\bar{\Pi}^\gamma P_{t-1}(i)}{P_t} \right)^{-\sigma} y_t di \\ &= \theta \bar{\Pi}^{-\gamma\sigma} \Pi_t^\sigma s_{t-1} y_t \end{aligned} \quad (96)$$

where

$$\Pi_t = \frac{P_t}{P_{t-1}} \quad (97)$$

denotes overall inflation at time period  $t$ .

Aggregate demand for intermediate goods produced by flex price firms is given by

$$\begin{aligned} x_t^{d(2)} &= \int_\theta^1 \left( \frac{P_t^*}{P_t} \right)^{-\sigma} y_t di \\ &= (1 - \theta) \left( \frac{P_t^*}{P_t} \right)^{-\sigma} y_t \end{aligned} \quad (98)$$

Relative demand of fix price firms w.r.t. flex price firms

$$\frac{x_t^d(1)}{x_t^d(2)} = \left( \bar{\Pi}^{-\gamma} \Pi_t \left( \frac{P_t^*}{P_t} \right) \right)^\sigma s_{t-1} \left( \frac{\theta}{1-\theta} \right) \quad (99)$$

Now I come to the ex - ante price setting problem for the *ith* flex price firm which sets its price at  $P_t^*$  in time period  $t$ , subject to the fact that this price will stay intact  $k$  periods after this i.e. the time period  $(t+k)$  with probability  $\theta^k$ .

Maximizing at time period  $t$  with respect to  $P_t^*$ , the expected profit at time period  $t+k$ , which is the sum of inflation adjusted discounted stream of profits for this firm, I can obtain an expression for  $P_t^*$ . The firm's profit maximization problem can be written more formally as:

$$Max E_t \sum_{k=0}^{\infty} \theta^k M_{t,t+k} \left( \bar{\Pi}^{\gamma k} P_t^* x_{t+k|t} - TC_{t+k|t}(x_{t+k|t}) \right) \quad (100)$$

subject to the demand functions,

$$x_{t+k|t} = \left( \frac{\bar{\Pi}^{\gamma k} P_t^*}{P_{t+k}} \right)^{-\sigma} y_{t+k} \quad (101)$$

where

$$M_{t,t+k} = \beta^k \left( \frac{P_t}{P_{t+k}} \right) \left( \frac{u'(c_{t+k})}{u'(c_t)} \right) \quad (102)$$

is the firm's nominal stochastic discount factor and  $TC_{t+k|t}$  is the price setter's date  $t$  forecast of the nominal total cost at time  $t+k$ .

From equation (102) and using the logarithmic nature of the production function from equation (76) the firm's nominal discount factor can be written as

$$M_{t,t+1} = \beta \left( \frac{c_t - \gamma_c C_{t-1}}{c_{t+1} - \gamma_c C_t} \right) \left( \frac{P_t}{P_{t+1}} \right) \quad (103)$$

Thus I have

$$M_{t,t+1} = \frac{m_{t,t+1}}{\Pi_{t+1}} \quad (104)$$

where  $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$  is a measure of inflation at time period  $t$ .

The law of motion of the general price level which follows from the price aggregation in

equation (15) is given by:

$$P_t = [\theta(\bar{\Pi}^\gamma P_{t-1})^{1-\sigma} + (1-\theta)P_t^{*1-\sigma}]^{\frac{1}{1-\sigma}} \quad (105)$$

The optimal price ( $P_t^*$ ) obtained from the First Order Condition to the representative flex price firm's price setting problem is nonstationary and thus it is normalized by the general price level  $P_t$  to get:

$$\frac{P_t^*}{P_t} = \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{E_t \sum_{k=0}^{\infty} (\theta \bar{\Pi}^{-\sigma\gamma})^k M_{t,t+k} \Pi_{t,t+k}^{\sigma+1} mc_{t,t+k} \left( \frac{y_{t+k}}{y_t} \right)}{E_t \sum_{k=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^k M_{t,t+k} \Pi_{t,t+k}^\sigma \left( \frac{y_{t+k}}{y_t} \right)} \right) \quad (106)$$

where  $mc_{t,t+k}$  is the  $k$  period ahead forecast of the real marginal cost.<sup>21</sup> Given the linear production function (16),

$$mc_{t,t+k} = r_{t,t+k}/\epsilon_{t+k} \quad (107)$$

$r_{t,t+k}$  being the  $k$  period ahead forecast of the real rental price of capital, which is same across flex price firms as well as fix price firms because both face the same aggregate shocks.

Also  $\Pi_{t,t+k}$  represents the  $k$  period ahead forecast of inflation where  $\Pi_{t,t+k} = \frac{P_{t+k}}{P_t}$ .

Equation (106) can be written in a recursive form as follows

$$\frac{P_t^*}{P_t} = w_t^{-1} \left( \frac{\sigma}{\sigma-1} \right) mc_t + (1-w_t^{-1})\bar{\Pi}^{-\gamma} \left( \Pi_{t,t+1} \left( \frac{P_{t+1}^*}{P_{t+1}} \right) \right) \quad (108)$$

where

$$w_t = E_t \sum_{k=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^k M_{t,t+k} \Pi_{t,t+k}^\sigma \left( \frac{y_{t+k}}{y_t} \right) \quad (109)$$

A recursive form of  $w_t$  from (109) can be obtained as follows

$$w_t = 1 + (\theta \bar{\Pi}^{\gamma(1-\sigma)}) E_t M_{t,t+1} \Pi_{t,t+1}^\sigma \left( \frac{y_{t+1}}{y_t} \right) w_{t+1} \quad (110)$$

Also from (105) it can be shown that

$$\frac{P_t^*}{P_t} = \left( \frac{1 - \theta \left( \frac{\bar{\Pi}^\gamma}{\Pi_t} \right)^{1-\sigma}}{1 - \theta} \right)^{\frac{1}{1-\sigma}} \quad (111)$$

<sup>21</sup>The real marginal cost ( $mc_t$ ) is the same for all firms facing the same technology.

Detailed derivations of equations (106) and (108) and (110) are relegated to the appendix.

Now, I focus once again on the intermediate goods market, where the relative aggregate demand of fix price firms w.r.t. flex price firms has already been established by equation (99)

**Aggregation and symmetric equilibrium** For equilibrium in the intermediate goods market, the relative total supply of fix price firms w.r.t. flex price firms should be figured out. Since fix price firms are heterogeneous in terms of the price they charge for their product, the amount of capital demanded by them should also vary from one firm to another. On the other hand, all flex price firms are identical regarding the price they charge and hence their capital demands are identical.

However, given the conjecture that  $k_t(1)$  is average capital demanded by the fix price firms and  $k_t(2)$  is that demanded by the flex price firms, both  $k_t(1)$  and  $k_t(2)$  can be solved in terms of the current state variables in a symmetric equilibrium<sup>22</sup>.

From the production function of the I firms, it follows that total supply of goods produced by fix price firms is given by

$$x_t^s(1) = \epsilon_t \int_0^\theta k_t(i) di \quad (112)$$

where total capital demanded by the fix price firms is  $\int_0^\theta k_t(i) di$  which is equal to  $\theta k_t(1)$  by the assumption of symmetric equilibrium, where each  $k_t(i)$  is approximated by  $k_t(1)$ , the average capital stock for fix price firms. Thus total supply of fix price goods can be written as

$$x_t^s(1) = \epsilon_t (\theta k_t(1)) \quad (113)$$

Total supply of flex price goods, on the other hand, is given by

$$x_t^s(2) = \epsilon_t \int_\theta^1 k_t(i) di \quad (114)$$

The same price i.e.  $P_t^*$  is charged by each of the flex price firms and same amount of capital (which I denote by  $k_t(2)$ ) is demanded by each of these flex price firms. Thus total supply of

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<sup>22</sup>This is a natural extension of the symmetric equilibrium in the friction free flexible price state.

flex price goods can be written as

$$x_t^s(2) = \epsilon_t ((1 - \theta)k_t(2)) \quad (115)$$

Hence, for equilibrium in the intermediate goods market,

$$\frac{x_t^d(1)}{x_t^d(2)} = \frac{x_t^s(1)}{x_t^s(2)}$$

which implies using (99)

$$\frac{\theta k_t(1)}{(1 - \theta)k_t(2)} = \left( \frac{\theta}{1 - \theta} \right) \left( \bar{\Pi}^{-\gamma} \Pi_t \left( \frac{P_t^*}{P_t} \right) \right)^\sigma s_{t-1} \quad (116)$$

The above equation represents the relative total demand for capital by the fix price firms w.r.t. the flex price firms. This relative demand for capital coming from the I firms is a derived demand and will be generated through the demand for intermediate goods coming from the F firms.

In the capital market total capital supplied by households is  $k_t$  and it is distributed among the two households as

$$\begin{aligned} k_t &= \int_0^1 k_t(i) di \\ &= \int_0^\theta k_t(i) di + \int_\theta^1 k_t(i) di \\ &= \theta k_t(1) + (1 - \theta)k_t(2) \end{aligned} \quad (117)$$

Defining  $\psi_t = \frac{k_t(1)}{k_t(2)} = \left( \bar{\Pi}^{-\gamma} \Pi_t \left( \frac{P_t^*}{P_t} \right) \right)^\sigma s_{t-1}$ , the average capital demanded by fix price firms can be solved as

$$k_t(1) = \left( \frac{\psi_t}{\theta\psi_t + 1 - \theta} \right) k_t \quad (118)$$

and the average capital demanded by flex price firms can be solved in terms of current state variables as

$$k_t(2) = \left( \frac{1}{\theta\psi_t + 1 - \theta} \right) k_t \quad (119)$$

Once the price signal is received at time period  $t$ , the price charged by the  $i$ th fix price firm



will be  $\bar{\Pi}^\gamma P_{t-1}(i)$ , which is its previous period's inflation indexed nominal price. Each of the flex price firms, on the other hand, will be charging the newly set optimal price  $P_t^*$ . However, the total price charged by all the fix price firms taken together will be  $\theta(\bar{\Pi}^\gamma P_{t-1})^{1-\sigma}$  and the total price charged by all the flex price firms taken together will be  $(1-\theta)P_t^{*1-\sigma}$ . This is reflected in the law of motion of the general price level  $P_t$  represented by equation (105).

Let  $D_{1t}$  represent the total nominal dividend of the fix price firms if the measure of fix price firms were unity, i.e. if all firms within the economy were fix price firms. Let  $D_{2t}$  represent the total nominal dividend of the flex price firms if the measure of flex price firms were unity, i.e. if all firms within the economy were flex price firms. Let  $d_{1t}$  and  $d_{2t}$  represent the total real dividends of the fix price firms and the flex price firms respectively and  $R_t$  and  $r_t$  represent the nominal rental price and real rental price of capital respectively, which are same for both fix price firms and flex price firms (due to the fact that both face the same aggregate shock) as mentioned earlier.

Then for fix price firms

$$D_t(1) = \bar{\Pi}^\gamma P_{t-1} \epsilon_t k_t(1) - R_t k_t(1)$$

which implies

$$d_t(1) = \left( \left( \frac{\bar{\Pi}^\gamma}{\bar{\Pi}_t} \right) \epsilon_t - r_t \right) a_t k_t \quad (120)$$

where

$$a_t = \left( \frac{\psi_t}{\theta \psi_t + 1 - \theta} \right) \quad (121)$$

and for flex price firms

$$D_t(2) = P_t^* \epsilon_t k_t(2) - R_t k_t(2)$$

which implies

$$d_t(2) = \left( \left( \frac{P_t^*}{P_t} \right) \epsilon_t - r_t \right) b_t k_t \quad (122)$$

where

$$b_t = \left( \frac{1}{\theta \psi_t + 1 - \theta} \right) \quad (123)$$

However,  $\theta$  fraction of all firms are fix price firms and the remaining  $(1-\theta)$  fraction comprise of flex price firms.

Thus total real dividend of all fix price firms is given by  $\theta d_t(1)$  and total real dividend of all flex price firms is given by  $(1 - \theta)d_t(2)$  and total dividend in the economy is given by

$$d_t = \theta d_t(1) + (1 - \theta)d_t(2) \quad (124)$$

## B.2 Rotemberg (1982) framework

In Rotemberg (1982) all firms continuously adjust their nominal prices but all of them are subject to a quadratic price adjustment cost measured in terms of final goods. We follow Ascari and Rossi (2012) and Ireland (2007) in specifying the price adjustment cost function subject to imperfect inflation indexation as follows:

$$\frac{\varphi}{2} \left( \frac{P_t(i)}{\bar{\Pi}^\gamma P_{t-1}(i)} - 1 \right)^2 y_t \quad (125)$$

where  $\varphi > 0$  is the degree of nominal rigidity,  $\bar{\Pi}^\gamma$  represents the indexation of the last period price level based on the trend inflation,  $\bar{\Pi}$  and  $\gamma$  is the degree of price indexation as before. As stressed in Rotemberg, the price adjustment cost accounts for the negative effects of price changes on the customer-firm relationship. These negative effects increase in magnitude with the size of the price change and with the overall scale of economic activity,  $y_t$ .

The optimal price fixing problem of each I firm in nominal terms is given by:

$$Max : E_t \sum_{k=0}^{\infty} M_{t,t+k} \left[ P_{t+k}(i)x_{t+k}(i) - MC_{t+k}x_{t+k}(i) - \frac{\varphi}{2} P_{t+k} \left( \frac{P_{t+k}(i)}{\bar{\Pi}^\gamma P_{t+k-1}(i)} - 1 \right)^2 y_{t+k} \right] \quad (126)$$

subject to the demand function of the  $i$ th intermediate good given by

$$x_{t+k}(i) = \left( \frac{P_{t+k}(i)}{P_{t+k}} \right)^{-\sigma} y_{t+k} \quad (127)$$

All firms face the same technology and the same price adjustment costs, so there is no heterogeneity in price fixing behaviour as in Calvo. In the firm's price setting problem in (126),  $MC_{t+k}$  denotes the nominal marginal cost of capital faced by each firm and is same across all firms.

The first order condition to the above price fixing problem of the I firm w.r.t.  $P_t(i)$  yields:

$$(1 - \sigma) \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} y_t + \frac{r_t}{\epsilon_t} \sigma \left( \frac{P_t(i)}{P_t} \right)^{-\sigma-1} y_t - \varphi P_t \left( \frac{P_t(i)}{\bar{\Pi}^\gamma P_{t-1}(i)} - 1 \right) \frac{y_t}{\bar{\Pi}^\gamma P_{t-1}(i)} + \beta \frac{u'(c_{t+1})}{u'(c_t)} \varphi P_t \left( \frac{\bar{\Pi}^{-\gamma} P_{t+1}(i)}{P_t(i)} - 1 \right) \bar{\Pi}^{-\gamma} P_{t+1}(i) P_t^{-2}(i) y_{t+1} = 0 \quad (128)$$

where  $r_t$  stands for the real marginal cost of capital faced by each firm.

Now, since all firms face the same technology and the same price adjustment costs, there is no heterogeneity in price fixing behaviour as in Calvo. Hence the same price is charged by each firm, which is equal to the price of the final good, i.e.  $P_t(i) = P_t$ . This follows from the price aggregator in equation (15). Note that in this case a symmetric equilibrium in prices across all firms automatically follows, as a result of these firms being identical. However, in the Calvo price setting framework, although the fix price firms are not identical in terms of the price they charge in the intermediate goods market, a symmetric equilibrium is assumed to hold for these firms in the capital market. Thus the symmetric equilibrium in the Calvo framework is assumed to be valid only for sticky price category of firms whereas in the Rotemberg framework it applies to all I firms in the economy.

Hence the above first order condition in (128) reduces to:

$$(1 - \sigma) + \frac{r_t}{\epsilon_t} \sigma - \frac{\varphi \bar{\Pi}_t}{\bar{\Pi}^\gamma} \left( \frac{\bar{\Pi}_t}{\bar{\Pi}^\gamma} - 1 \right) + \beta \frac{u'(c_{t+1})}{u'(c_t)} \varphi \bar{\Pi}^{-\gamma} \bar{\Pi}_t \left( \bar{\Pi}^{-\gamma} \bar{\Pi}_t - 1 \right) \frac{y_{t+1}}{y_t} = 0 \quad (129)$$

Since each I firm's output is produced by the same linear technology as before and since all firms employ same amount of capital, the aggregate production function is same as each individual I firm's production function and is given by

$$y_t = \epsilon_t k_t \quad (130)$$

The equilibrium resource constraint at time  $t$  takes the adjustment cost into account, i.e.

$$y_t = c_t + \chi_t + \frac{\varphi}{2} \left( \frac{P_t(i)}{\bar{\Pi}^\gamma P_{t-1}(i)} - 1 \right)^2 y_t \quad (131)$$

where  $c_t$  represents the aggregate household consumption and  $\chi_t$  represents the aggregate household investment and net holding of bonds and addition to stocks are nil in equilibrium.

This implies

$$c_t + \chi_t = \left( 1 - \frac{\varphi}{2} \left( \frac{P_t(i)}{\bar{\Pi}^\gamma P_{t-1}(i)} - 1 \right)^2 \right) y_t \quad (132)$$

Thus the Rotemberg price adjustment cost model creates an inefficiency wedge between output on the one hand and consumption and investment on the other.

In the long run, the adjustment cost expression becomes  $\frac{\varphi}{2} (\bar{\Pi}^{1-\gamma} - 1)^2$ ,  $\bar{\Pi}$  representing the long run trend inflation. The inefficiency is minimised in a situation where there is no price change by the firms i.e. in a zero inflation steady state when  $\bar{\Pi} = 1$ . Also the inefficiency vanishes in case of full indexation of inflation, i.e. when  $\gamma = 1$ . Thus, like in the Calvo price setting framework, in the Rotemberg framework also imperfect inflation indexation  $\gamma$  acts as a source of nominal friction and its complete absence i.e. full inflation indexation ensures no loss of efficiency.

Nominal dividend of each I firm is given by:

$$\begin{aligned} D_t &= P_t \epsilon_t k_t - R_t k_t - \frac{\varphi}{2} P_t \left( \frac{P_t}{\bar{\Pi}^\gamma P_{t-1}} - 1 \right)^2 \epsilon_t k_t \\ &= P_t \epsilon_t k_t - R_t k_t - \frac{\varphi}{2} P_t \left( \frac{\Pi_t}{\bar{\Pi}^\gamma} - 1 \right)^2 \epsilon_t k_t \end{aligned} \quad (133)$$

which implies each I firm's real dividend is given by

$$d_t = (\nu_t \epsilon_t - r_t) k_t \quad (134)$$

where

$$\nu_t = 1 - \frac{\varphi}{2} \left( \frac{P_t}{\bar{\Pi}^\gamma P_{t-1}} - 1 \right)^2 \quad (135)$$

Since all firms are identical, the economywide real dividend is given by equation (134).

### C. Market Capitalization ratio and Growth with price distortions in both frameworks

As in the previous chapter, here also the two main variables of interest in the short run are market capitalization as a ratio of output and output growth; my main focus being that of investigating the short run behaviour of these two variables as a result of realization of different aggregate shocks. In addition to that, the present chapter also deals with the short run dynamics

of inflation and growth, although that is not the primary focus. The expression for short run inflation is given by

$$\Pi_t = \frac{P_t}{P_{t-1}}$$

as in eqn (97). While defining market capitalization as a ratio of output and output growth for both Calvo and Rotemberg frameworks, output is taken net of distortion caused by nominal frictions. In the Calvo price setting framework, this distortion is caused by price dispersion resulting from heterogeneity regarding the price charged by fix price firms. In the Rotemberg framework, on the other hand, the distortion is a result of the price adjustment cost.

### C.1 Calvo Framework

In the Calvo set up, from equation (93) final output can be written as

$$y_t = \frac{\epsilon_t k_t}{s_t} \tag{136}$$

Hence output growth can be expressed as

$$ygt = \frac{y_t}{y_{t-1}} = \frac{\epsilon_t k_t s_t^{-1}}{\epsilon_{t-1} k_{t-1} s_{t-1}^{-1}} = \epsilon_t k g_{t-1} s_{t-1} (\epsilon_{t-1} s_t)^{-1} \tag{137}$$

where, as in the previous flexible price framework,  $k g_{t-1} = \frac{k_t}{k_{t-1}}$  stands for the growth of capital at time period  $t$  and price dispersion  $s_t$  is a source of inefficiency as it distorts output by acting as a tax on the productivity parameter  $\epsilon_t$ .

In the annual data set, value of market capitalization is defined as share price times the number of shares outstanding. Without any loss of generality, it is assumed that the total number of shares of a firm is unity which remains unchanged over time and all households own same number of shares of this particular firm in their portfolio. If the representative firm is indexed by  $i \in (0, 1)$  and the representative household is indexed by  $j \in (0, 1)$ , then according to this assumption, for all  $j$ , I have  $z_t(j) = z_t$ . Since this is true for all firms and since the total number of households is fixed at unity, this means that each household holds the same amount of shares of all firms in its portfolio so that  $z_t(i) = z_t$  for all  $i$ . But since total number of shares of a firm is unity, integrating over all households, I have  $\int_0^1 z_t(j) dj = 1$ , which implies  $z_t \int_0^1 dj = 1$ , i.e.  $z_t = 1$ .

Now, assuming  $p_t^z$  stands for the average share price for all fix price and flex price firms in the economy, total value of stocks for the representative household is given by  $\int_0^1 p_t^z(i) z_t(i) di = p_t^z z_t \int_0^1 di = p_t^z$ . Integrating over all households in the economy, the total value of stock market capitalization is given by  $p_t^z \int_0^1 dj = p_t^z$ . This means that  $p_t^z$  stands for the entire economywide stock index and market capitalization to output ratio  $mk_t$  is defined as

$$mk_t = \frac{p_t^z}{y_t} \quad (138)$$

The above expression defines market capitalization as the ratio of the real price of a firm's asset to the final output, where  $p_t^z$  represents the aggregate stock index and  $y_t$  represents total output which takes into account distortion due to price dispersion.

The expression for market capitalization ratio can be also expressed as

$$mk_t = \left( \frac{p_t^z}{k_{t+1}} \right) \cdot \left( \frac{k_{t+1}}{k_t} \right) \cdot \left( \frac{k_t}{y_t} \right) \quad (139)$$

where the first term on the right hand side expression denotes Tobin's q and the second term denotes expected growth of capital. The third term,  $\left( \frac{k_t}{y_t} \right) = \left( \frac{s_t}{\epsilon_t} \right)$ , follows from the definition of final output in equation (136).

Defining Tobin's q as  $q_t$  and expected growth of capital as  $kg_t$ , I can rewrite the expression of market capitalization as

$$mk_t = q_t \cdot kg_t \cdot s_t \cdot \epsilon_t^{-1} \quad (140)$$

## C.2 Rotemberg Framework

In the Rotemberg set up, the inefficiency is captured through a wedge between final output on the one hand and consumption and investment on the other. Since the sum of consumption and investment takes into account this distortion, it affects the total output in the expression of market capitalization ratio. The distortionary effect of price adjustment cost should be taken into consideration while defining market capitalization ratio in order to form a better understanding of how the latter's short run dynamics get influenced by the presence of nominal frictions within the economy. Here, unlike the Calvo set up, final good produced is not affected by any form of

distortion and the full efficient amount is produced through aggregation of intermediate goods (which are produced through a linear technology). But this efficient amount is taxed by the price adjustment cost before it enters the household as income.

The expression for final good, as already established by equation (130) is

$$y_t = \epsilon_t k_t$$

In equilibrium, however, the amount consumed and invested by the representative household is the part of this total efficient output  $y_t$ , net of the price adjustment cost  $\frac{\varphi}{2} \left( \frac{P_t}{\Pi^\gamma P_{t-1}} - 1 \right)^2$  and is given by

$$\begin{aligned} y_{-d_t} &= \left[ 1 - \frac{\varphi}{2} \left( \frac{P_t}{\Pi^\gamma P_{t-1}} - 1 \right)^2 \right] y_t \\ &= \left[ 1 - \frac{\varphi}{2} \left( \frac{\Pi_t}{\Pi^\gamma} - 1 \right)^2 \right] \epsilon_t k_t \end{aligned} \quad (141)$$

$y_{-d_t}$  represents the distorted total output that is consumed and invested by the household. This  $y_{-d_t}$  is the same as the household's income (sum of dividend and rental incomes) net of price adjustment cost. Thus in the Rotemberg framework, distortion is captured in the form of a tax on total income, rather than as a tax on TFP as in the Calvo price setting framework.

Taking this into account, I can find an expression for growth as

$$y g_t = \frac{y_{-d_t}}{y_{-d_{t-1}}} = \frac{\nu_t \epsilon_t k_t}{\nu_{t-1} \epsilon_{t-1} k_{t-1}} = \nu_t k g_{t-1} \epsilon_t (\epsilon_{t-1} \nu_{t-1})^{-1} \quad (142)$$

where from (135)

$$\nu_t = \left[ 1 - \frac{\varphi}{2} \left( \frac{\Pi_t}{\Pi^\gamma} - 1 \right)^2 \right]$$

captures the distortion on income as a result of the price adjustment cost tax.

In the Rotemberg framework, since firms are identical, share price  $p_t^z$  is same across all firms. This, combined with the fact that total number of stocks in a firm add up to unity, imply that total value of market capitalization is given by  $p_t^z$ . Thus, the expression for market capitalization ratio is given by

$$m k_t = \frac{p_t^z}{y_{-d_t}} \quad (143)$$

which is the ratio of the real stock price index to the total distorted income (net of the tax

imposed due to price adjustment cost).

The expression for market capitalization can be expressed in a slightly different way as

$$mk_t = \left( \frac{p_t^z}{k_{t+1}} \right) \cdot \left( \frac{k_{t+1}}{k_t} \right) \cdot \left( \frac{k_t}{y_t - d_t} \right) \quad (144)$$

As in the Calvo framework, here also the first term on the right hand side expression denotes Tobin's  $q$   $q_t$  and the second term denotes expected growth of capital, given by  $kg_t$ . From equation (141) it follows that the third term is given by

$$\frac{k_t}{y_t - d_t} = \frac{1}{\epsilon_t \nu_t} \quad (145)$$

Hence, the entire expression of market capitalization can be rewritten as

$$mk_t = q_t \cdot kg_t \cdot (\epsilon_t \nu_t)^{-1} \quad (146)$$

## D. Equilibrium

In equilibrium, the household's net holding of bonds and addition to stocks is nil. So total household income equals the sum of consumption ( $c_t$ ) and investment ( $\chi_t$ ). In other words, the sum of total consumption and total investment must equal total dividend and rental income, which implies that the aggregate equilibrium resource constraint facing the household is given by :

$$c_t + k_{t+1} - (1 - \delta)k_t = r_t k_t + d_t \quad (147)$$

In both Calvo and Rotemberg price setting frameworks, household income is affected by a distortion caused due to nominal frictions and hence is not equal to the fully efficient output. The distortionary effect on the fully efficient output is brought about by the price adjustment cost in the Rotemberg framework and by the inter firm price dispersion in the Calvo framework.

### D.1 Calvo framework

In the Calvo framework, from equation (136)

$$y_t = \frac{\epsilon_t k_t}{s_t} \quad (148)$$



i.e. the full potential  $\epsilon_t k_t$  cannot be produced because of the existence of price dispersion  $s_t$ , which acts as a tax on TFP.

Also from the F firm's aggregation of intermediate goods it can be shown that

$$y_t = \Omega_t \epsilon_t k_t \quad (149)$$

where

$$\Omega_t = \left[ \theta \left( \frac{\psi_t}{1 - \theta + \theta \psi_t} \right)^{\frac{\sigma-1}{\sigma}} + (1 - \theta) \left( \frac{1}{1 - \theta + \theta \psi_t} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad (150)$$

Derivation of (150) is shown in the appendix. It is to be noted that equation (148) and (149) are equivalent.<sup>23</sup>

Thus in the Calvo framework, in equilibrium the sum of investment ( $\chi_t$ ) and consumption ( $c_t$ ) equals the distorted output  $y_t$ , i.e.

$$c_t + \chi_t = y_t \quad (151)$$

## D.2 Rotemberg framework

In the Rotemberg framework, the full potential  $\epsilon_t k_t$  is produced but the price adjustment cost acts as a wedge between consumption ( $c_t$ ) and investment ( $\chi_t$ ) on the one hand and total output ( $y_t$ ) on the other. The equilibrium budget constraint in the Rotemberg framework is

$$c_t + \chi_t + \frac{\varphi}{2} \left( \frac{P_t}{\bar{\Pi}^\gamma P_{t-1}} - 1 \right)^2 y_t = y_t \quad (152)$$

with

$$y_t = \epsilon_t k_t \quad (153)$$

## E. Forcing Processes

There are four endogenous variables, namely Total Factor Productivity (TFP) shock given by  $\epsilon_t$ , Investment Specific Technology (IST) shock given by  $\xi_t$ , Monetary Policy (MP) shock given by  $i_t$  and Capital Quality (CQ) shock given by  $\delta_t$ . Each of these shocks follow an AR(1) process.

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<sup>23</sup>It is verified that the short run dynamics of  $y_t/k_t = \Omega_t \epsilon_t$  and the short run dynamics of  $y_t/k_t = \frac{\epsilon_t}{s_t}$  are identical.

TFP shock:

$$\epsilon_t - \bar{\epsilon} = \rho_\epsilon(\epsilon_{t-1} - \bar{\epsilon}) + \zeta_t^\epsilon \quad (154)$$

The steady state value of  $\epsilon_t$  is  $\bar{\epsilon}$ .  $\zeta_t^\epsilon$  is the disturbance term.

IST shock:

$$\xi_t - \bar{\xi} = \rho_\xi(\xi_{t-1} - \bar{\xi}) + \zeta_t^\xi \quad (155)$$

The steady state value of  $\xi_t$  is  $\bar{\xi}$ .  $\zeta_t^\xi$  represents the disturbance term.

MP shock:

$$i_t - \bar{i} = \rho_m(i_{t-1} - \bar{i}) + (1 - \rho_m)(\phi_\Pi(\Pi_t - \bar{\Pi}) + \phi_y(yg_t - \bar{y}g)) + \zeta_t^i \quad (156)$$

The interest rate sequence follows a standard Taylor rule in the short run and is specified by equation (156). The monetary authority responds by raising interest rate if it anticipates a higher inflation rate or experiences a higher output growth gap.  $\bar{i}$  is the steady state interest rate and  $\bar{y}g$  is the steady state growth.  $\zeta_t^i$  denotes the disturbance term.

CQ shock:

$$\delta_t - \bar{\delta} = \rho_\delta(\delta_{t-1} - \bar{\delta}) + \zeta_t^\delta \quad (157)$$

A capital quality shock is represented by the depreciation  $\delta_t$  of capital. A positive capital quality shock means higher depreciation whereas a negative capital quality shock implies lower depreciation of capital. Capital depreciation is measured as a difference from its steady state value  $\bar{\delta}$ .  $\zeta_t^\delta$  denotes the disturbance term.

## F. A summary of endogenous variables and their corresponding Balanced Growth values

### F.1 Calvo price setting

In this theoretical framework, I will deal with endogenous variables which are all stationary in the long run. Most of these variables are either expressed in growth or are normalised by capital in order to make them stationary. The long run balanced growth (BG) values of all these variables can be solved in terms of the deep parameters  $\gamma, \theta, \sigma, \beta, \bar{\Pi}, \bar{\epsilon}, \bar{\xi}$  and  $\bar{\delta}$ . There are other deep parameters apart from these which will determine short run fluctuations of endogenous

variables and I am going to discuss more about them in the section on quantitative analysis.<sup>24</sup>

The relevant endogenous variables that I am going to work with are:

- (1)  $\frac{P_t^*}{P_t}$  which is optimal price  $P_t^*$  normalized by the general price level  $P_t$ .

From equation (111), the BG value of this variable can be expressed as

$$\frac{\overline{P^*}}{P} = \left( \frac{1 - \theta \Pi^{(1-\gamma)(\sigma-1)}}{1 - \theta} \right)^{\frac{1}{1-\sigma}} \quad (158)$$

- (2)  $mc_t$  which is real marginal cost.

From equation (106), the BG value of real marginal cost can be expressed as

$$\overline{mc} = \left( \frac{\sigma - 1}{\sigma} \right) \left( \frac{1 - \theta \beta \Pi^{(1-\gamma)\sigma}}{1 - \theta \beta \Pi^{(1-\gamma)(\sigma-1)}} \right) \left( \frac{\overline{P^*}}{P} \right) \quad (159)$$

Derivation of (159) is shown in the appendix.

- (3)  $\epsilon_t$  which is the TFP shock and its BG value is  $\bar{\epsilon}$ .

- (4)  $r_t$  which is the rental rate.

From equation (107), the BG value of rental can be expressed as

$$\bar{r} = \bar{\epsilon} \overline{mc} \quad (160)$$

- (5)  $\xi_t$  which is the IST shock and its BG value is  $\bar{\xi}$ .

(6)  $q_t$  which is Tobin's q. In equation (85), imposing the long run assumptions of  $s(\cdot) = 0$  and  $s'(\cdot) = 0$  the BG value of Tobin's q can be expressed as

$$\bar{q} = \frac{1}{\bar{\xi}} \quad (161)$$

(7)  $m_{t,t+1}$  which is the household's real marginal rate of substitution. From equation (86) its BG value is given by

$$\bar{m} = \frac{\beta}{\overline{kg}} \quad (162)$$

where  $\overline{kg}$  is the BG value of capital growth and is derived next.

- (8)  $\delta_t$  which is the Capital quality shock and its BG value is  $\bar{\delta}$

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<sup>24</sup>As an offshoot of this study, the consequence of long run inflation targetting in a growing economy is explored in a separate paper (See Basu and Sarkar (2016)).

(9)  $kg_t$  which is growth of capital. Using the values of  $\bar{q}$  and  $\bar{m}$  in the euler equation (87), its BG value is calculated as

$$\bar{kg} = \beta (\bar{\xi}\bar{r} + 1 - \bar{\delta}) \quad (163)$$

(10)  $\Pi_t = \frac{P_t}{P_{t-1}}$  which is inflation rate and its BG value is  $\bar{\Pi}$ .

(11)  $M_{t,t+1}$  which is the nominal marginal rate of substitution used by the firm. From equation (103) its BG value is given by

$$\bar{M} = \frac{\bar{m}}{\bar{\Pi}} \quad (164)$$

(12)  $w_t = E_t \sum_{k=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^k M_{t,t+k} \Pi_{t,t+k}^{\sigma} \left( \frac{y_{t+k}}{y_t} \right)$  given by equation (109) and its BG value can be solved as

$$\bar{w} = \frac{1}{1 - \theta \beta \bar{\Pi}^{(1-\gamma)(\sigma-1)}} \quad (165)$$

(13)  $s_t$  which is price dispersion. From equation (91) the BG value of price dispersion can be solved as

$$\bar{s} = \frac{(1 - \theta) \left( \frac{P^*}{P} \right)^{-\sigma}}{\left( 1 - \theta \bar{\Pi}^{\sigma(1-\gamma)} \right)} \quad (166)$$

(14)  $yk_t = \frac{y_t}{k_t}$  which is output to capital ratio. From equation (92) BG value of output to capital ratio can be solved as

$$\bar{yk} = \frac{\bar{\epsilon}}{\bar{s}} \quad (167)$$

(15)  $\chi k_t = \frac{\chi_t}{k_t}$  which is investment to capital ratio. From the capital accumulation equation in equation (77) the BG value of investment to capital ratio can be solved as

$$\bar{\chi k} = \frac{\bar{kg} - (1 - \bar{\delta})}{\bar{\xi}} \quad (168)$$

(16)  $ck_t = \frac{c_t}{k_t}$  which is consumption to capital ratio. From the equilibrium budget constraint in equation (95) I can solve the BG value of consumption to capital ratio as

$$\bar{ck} = \bar{yk} - \bar{\chi k} \quad (169)$$

(17)  $\psi_t = \frac{k_t(1)}{k_t(2)}$  which is relative capital share of the fix and flex price firms. From equation

(116) BG value of this variable can be solved as:

$$\bar{\psi} = \left( \bar{\Pi}^{1-\gamma} \left( \frac{\bar{P}^*}{\bar{P}} \right) \right)^\sigma \bar{s} \quad (170)$$

(18)  $a_t = \frac{\psi_t}{1-\theta+\theta\psi_t}$  and at BG it is given by

$$\bar{a} = \frac{\bar{\psi}}{1-\theta+\theta\bar{\psi}} \quad (171)$$

(19)  $b_t = \frac{1}{1-\theta+\theta\psi_t}$  and at BG it is given by

$$\bar{b} = \frac{1}{1-\theta+\theta\bar{\psi}} \quad (172)$$

(20)  $dk_t(1)$  which is dividend to capital ratio of fix price firms. From equation (120) the BG value of this is given by

$$\overline{dk}(1) = \left( \bar{\Pi}^{\gamma-1} \bar{\epsilon} - \bar{r} \right) \bar{a} \quad (173)$$

(21)  $dk_t(2)$  which is dividend to capital ratio of flex price firms. From equation (122) the BG value of this is given by

$$\overline{dk}(2) = \left( \left( \frac{\bar{P}^*}{\bar{P}} \right) \bar{\epsilon} - \bar{r} \right) \bar{b} \quad (174)$$

(22)  $dk_t$  which is total dividend to capital ratio. From equation (124) its BG value is given by

$$\overline{dk} = \theta \overline{dk}_1 + (1-\theta) \overline{dk}_2 \quad (175)$$

(23)  $\Omega_t = \left[ \theta \left( \frac{\psi_t}{1-\theta+\theta\psi_t} \right)^{\frac{\sigma-1}{\sigma}} + (1-\theta) \left( \frac{1}{1-\theta+\theta\psi_t} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$  and at BG it is given by

$$\bar{\Omega} = \left[ \theta \bar{a}^{\frac{\sigma-1}{\sigma}} + (1-\theta) \bar{b}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad (176)$$

(24)  $i_t$  which is nominal interest rate on the riskless bond. From the Euler equation (89) this is given by

$$\bar{i} = \frac{\bar{\Pi}}{\bar{m}} - 1 \quad (177)$$

(25)  $mk_t$  which represents market capitalization to GDP ratio. From equation (140) BG

value of market capitalization ratio is given by

$$\overline{mk} = \overline{q} \cdot \overline{kg} \cdot \overline{s} \cdot \overline{\epsilon}^{-1} \quad (178)$$

(26)  $yg_t$  which represents GDP growth. From equation (137) BG value of output growth is given by

$$\overline{yg} = \overline{kg} \quad (179)$$

In order to find the short run dynamics of all the twenty six endogenous variables, I need the BG values of the first twenty four variables. The BG values of market capitalization and growth do not influence the short run behaviour of any of the remaining variables. The disturbance terms of the four forcing processes are the four exogenous variables. These are  $\zeta_t^\epsilon$ , i.e. the disturbance term of the TFP shock,  $\zeta_t^\xi$ , i.e. the disturbance term of the IST shock,  $\zeta_t^\delta$ , i.e. the disturbance term of the CQ shock and  $\zeta_t^i$ , i.e. the disturbance term of the MP shock.

## F.2 Rotemberg price setting

In this theoretical framework, I will deal with the following endogenous variables which are all stationary in the long run and can be solved in terms of the deep parameters  $\gamma, \varphi, \sigma, \beta, \overline{\Pi}, \overline{\epsilon}, \overline{\xi}$  and  $\overline{\delta}$ . The relevant endogenous variables are:

- (1)  $mc_t$  which is real marginal cost.

From equation (129), the BG value of real marginal cost can be expressed as

$$\overline{mc} = \left( \frac{\varphi(1-\beta)\Pi^{1-\gamma}(\Pi^{1-\gamma}-1)}{\sigma} + \frac{\sigma-1}{\sigma} \right) \quad (180)$$

Derivation of (180) is shown in the appendix.

- (2)  $\epsilon_t$  which is the TFP shock and its BG value is  $\overline{\epsilon}$ .
- (3)  $r_t$  which is the rental rate and in the BG it is represented by eqn (160).
- (4)  $\xi_t$  which is the IST shock and its BG value is  $\overline{\xi}$ .
- (5)  $q_t$  which is Tobin's q and in the BG it is represented by equation (161).
- (6)  $m_{t,t+1}$  which is the household's real marginal rate of substitution and its BG value is represented by equation (162)
- (7)  $\delta_t$  which is the Capital quality shock and its BG value is  $\overline{\delta}$

(8)  $kg_t$  which is growth of capital and its BG value is represented by equation (163).

(9)  $\Pi_t = \frac{P_t}{P_{t-1}}$  which is inflation rate and its BG value is  $\bar{\Pi}$ .

(10)  $M_{t,t+1}$  which is the nominal marginal rate of substitution used by the firm and its BG value is represented by (164).

(11)  $\nu_t$  which is the price adjustment cost term.

From equation (135) its BG value can be expressed as

$$\bar{\nu} = \left[ 1 - \frac{\varphi}{2} \left( \bar{\Pi}^{1-\gamma} - 1 \right)^2 \right] \quad (181)$$

(12)  $\chi k_t = \frac{\lambda_t}{k_t}$  which is investment to capital ratio and in the BG it is represented by equation (168).

(13)  $ck_t = \frac{c_t}{k_t}$  which is consumption to capital ratio. From the equilibrium resource constraint in equation (131) it is expressed as

$$\bar{ck} = \bar{\nu}\bar{\epsilon} - \bar{\chi}\bar{k} \quad (182)$$

(14)  $dk_t$  which is total dividend to capital ratio.

From equation (134) the BG value of the dividend to capital ratio is expressed as

$$\bar{dk} = \bar{\epsilon} - \bar{r} - \frac{\varphi}{2} \left( \bar{\Pi}^{1-\gamma} - 1 \right)^2 \bar{\epsilon} \quad (183)$$

(15)  $i_t$  which is nominal interest rate on the riskless bond and in the BG it is given by (177).

(16)  $mk_t$  which is market capitalization as a ratio of output and in the BG it is given by

$$\bar{mk} = \bar{q} \cdot \bar{kg} \cdot (\bar{\epsilon} \cdot \bar{\nu})^{-1} \quad (184)$$

(17)  $yg_t$  which is output growth rate and in the BG it is represented by

$$\bar{yg} = \bar{\nu} \cdot \bar{kg} \cdot \bar{\epsilon} \cdot (\bar{\epsilon} \cdot \bar{\nu})^{-1} \quad (185)$$

In the Rotemberg price setting framework also,  $\zeta_t^\epsilon$ ,  $\zeta_t^\xi$ ,  $\zeta_t^\delta$  and  $\zeta_t^i$  i.e. the disturbance terms of the four shocks act as the exogenous variables.

## G. A summary of the key equations

### G.1 Calvo price setting

The relevant equations are given by:

- (1) Production function  $y_t$  represented by equation (149).<sup>25</sup>
- (2)  $\Omega_t$  defined by equation (150).
- (3) Price dispersion recursion represented by equation (91).
- (4) Price aggregation equation given by equation (111).
- (5) Price optimization recursion equation given by equation (108).
- (6) Rental equation represented by equation (107).
- (7) Recursion for  $w_t$  represented by equation (110).
- (8) Firm's discount factor in nominal terms given by eqn (103).
- (9) Capital allocation ratio of fix price firms to flex price firms given by  $\psi_t$  in equation (116).
- (10) Dividend to capital for fix price firms which follows from equation (120).
- (11) Dividend to capital for flex price firms which follows from equation (122).
- (12) Total dividend to capital in the economy represented by equation (124).
- (13)  $a_t$  represented by equation (121).
- (14)  $b_t$  equation (123).
- (15) Equilibrium budget constraint represented by equation (151).
- (16) Investment equation with Investment adjustment cost represented by equation (77).
- (17) A combination of the Euler equations with respect to  $\chi_t$  (represented by equation (85)) and  $k_{t+1}$  (represented by equation (87)).
- (18) Asset Euler equation given by equation (88).
- (19) Bond Euler Equation given by equation (89).
- (20) Relation between Firm and Household discount factor given by equation (104).
- (21) Market capitalization given by equation (140).
- (22) Growth of output given by equation (137).
- (23) MP shock represented by equation (156).
- (24) TFP shock represented by equation (154).
- (25) IST shock represented by equation (155).

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<sup>25</sup>Production function can also be defined by equation (149). It is checked that short run results remain same irrespective of whether production function is defined by equation (148) or equation (149).



(26) CQ shock represented by equation (157).

In the above system, there are 26 equations corresponding to 26 endogenous variables (as pointed out in section (F.1)) which indicates that the model is solvable.

## G.2 Rotemberg price setting

The relevant equations are given by:

(1) Equilibrium resource constraint represented by equation (152).

(2) Capital accumulation equation and is represented by equation (77).

(3) First order condition of firm's profit maximization problem in equation (129).

(4) Dividend to capital ratio of the firm in equation (134).

(5) Nominal marginal rate of substitution of firm represented by equation (103).

(6) Real marginal rate of substitution of household in terms of the nominal discount factor represented by equation (104).

(7) Arbitrage condition equating the Euler equation with respect to  $\chi_t$  i.e. equation (85) and that with respect to  $k_{t+1}$  i.e. equation (87) and represented by equation (233).

(8) Asset Euler equation represented by equation (88).

(9) Bond Euler equation represented by equation (89).

(10) Market capitalization given by equation (146).

(11) Growth given by (142) which is defined by taking into consideration the distortion imposed on full potential output in equation (141).

(12) Rental equation represented by equation (107).

(13) The term  $\nu_t$  which represents the distortionary effect of price adjustment cost on the efficient level of output and is given by equation (135).

(14) MP shock represented by equation (156).

(15) TFP shock represented by equation (154).

(16) IST shock represented by equation (155).

(17) CQ shock represented by equation (157).

In the above system I have 17 equations and 17 endogenous variables (as pointed out in section (F.2)) which indicates that the model is solvable.

## H. Solution strategy

I am primarily interested to explore the short run dynamics between market capitalization ratio  $mk_t$  and output growth  $yg_t$ . However, the short run behaviours of other endogenous variables also carry important implications for this particular theoretical framework. For this I loglinearise the non-linear optimal conditions and the resource constraints around the BG values of the respective variables which have been solved in terms of the deep parameters. A hat ( $\hat{\cdot}$ ) over a variable represents proportional change from its balanced growth path value. The loglinearised system of equations in the Calvo and the Rotemberg price setting frameworks is presented in the appendix.<sup>26</sup>

## I. Quantitative short run analysis

As the purpose of the quantitative analysis is predominantly illustrative, I do not formally estimate the structural parameters. I have relied mostly on existing studies to estimate the structural parameters except the TFP parameter. I start with quarterly calibrated parameter values following the standard New Keynesian DSGE literature (where nominal rigidities in the form of price stickiness have been taken into account).

### I.1 Baseline parameterization

I fix the discount factor  $\beta$  at 0.99 and the depreciation parameter  $\bar{\delta}$  at 0.025 i.e. at the conventional levels consistent with quarterly calibration.<sup>27</sup> The demand elasticity parameter  $\sigma$  is fixed at 6.00 as in Kollmann (2002).

There is considerable disagreement in the literature about the range of values for the price stickiness parameter,  $\theta$ . Kollmann (2002) uses 0.75 as the baseline value while Smets and Wouters (2003) estimate a higher value of  $\theta$  which is around 0.91. These values basically imply that the average duration of prices to remain sticky is 4 quarters to 10 quarters. For the present simulative purposes, I choose a baseline value of  $\theta = 0.85$ , which is an average of the values chosen by Kollmann (2002) and Smets and Wouters (2003).

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<sup>26</sup>In the equation systems of both price setting frameworks, number of exogenous variables match the number of loglinearized equations indicating that the models are solvable. The models are solved using Dynare.

<sup>27</sup>Although I start with quarterly calibrated parameters, in my dynare code each of the variables are annualized, so that the impulse response figures and the first and second order moments calculated from the model replicate annual behaviours of the variables and in this way, comparisons can be made with stylized facts emerging from the annual data.

A similar ambiguity arises about the size of the inflation indexation parameter  $\gamma$ . For Euro regions, Smets and Wouters (2003) estimate a value of this parameter to be around 0.52. Using GMM approach Sahuc (2004) comes up with an estimate of around 0.41 for Euro regions and 0.64 for the US. However, in both these analysis, estimates of the indexation parameter were made on the basis of indexing last period's inflation (i.e. the period prior to which price was set), whereas in the present analysis I have indexed the long run trend inflation. To the best of my knowledge there is no published estimate of the degree of long run inflation indexation. One can interpret  $\gamma$  as a weighted average of short run and long run indexation parameters. To see this clearly, in a similar spirit as in Ascari and Rossi (2012) the indexation rule (say  $\Theta_t$ ) can be based on the past and long run inflation as follows.

$$\Theta_t = (\Pi_{t-1}^{\omega_1})^\mu (\Pi^{\omega_2})^{1-\mu} \quad (186)$$

where the past period inflation  $\Pi_{t-1}$  is indexed by a fraction  $\omega_1$ , trend inflation  $\Pi$  is indexed by the fraction  $\omega_2$ ;  $\mu$  and  $(1 - \mu)$  are the relative weights assigned to  $\Pi_{t-1}^{\omega_1}$  and  $\Pi^{\omega_2}$  respectively. The indexation parameters  $\omega_1$  and  $\omega_2$  are the respective degrees of short run and long run inflation indexation. Ascari and Rossi (2012) assume that  $\omega_1 = \omega_2$  which presupposes that the agent attaches same indexation to both past and trend inflation. The indexation rule (186) can be made more general by allowing the short run indexation ( $\omega_1$ ) to differ from the long run indexation ( $\omega_2$ )<sup>28</sup>. In the long run, (where  $\Pi = \Pi_{t-1} \forall t$ ), the indexation formula (186) then reduces to

$$\Theta = \Pi^\gamma \quad (187)$$

where  $\gamma = \mu\omega_1 + (1 - \mu)\omega_2$ . Viewed from this perspective,  $\gamma$  can be interpreted as a weighted average of short run and long run indexation rules. For the purpose of the present simulation, as a baseline I start off with a conservative estimate,  $\gamma = 0.52$  which is close to Smets and Wouters (2003) estimate or an average of the Euro and US estimates of Sahuc (2004).

Since no definite inference about an accurate estimate of the nominal rigidity parameters  $\theta$  and  $\gamma$  can be drawn from the extant literature, I carry out a sensitivity analysis to check how the short run market capitalization - growth and the growth - inflation correlations depend on

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<sup>28</sup>Such an indexation formulation encompasses other formulations in the extant literature as special cases. For example, if  $\mu = 1$ , it reduces to Smets and Wouters (2003). If  $\mu = 0$  and  $\omega_2 = 1$ , we get Yun (1996) full indexation.

the size of these parameters.

Regarding the price adjustment cost parameter,  $\varphi$ , it is hard to find an estimate that is consistent with our growth model. Keen and Wang (2005) calibrate this by matching the slopes of the New Keynesian Phillips curves from Calvo and Rotemberg models. In context of the present chapter, balanced growth rate is a crucial link between Calvo and Rotemberg models. In a similar vein, I calibrate  $\varphi$  by matching the balanced growth rates,  $G^C$  and  $G^R$ , which yields an analytical expression for  $\varphi$  as follows:

$$\varphi = \left[ \frac{(\sigma - 1) \left( \left( \frac{\overline{P^*}}{\overline{P}} \right) \mu_n^{-1} - 1 \right)}{(1 - \beta) \overline{\Pi}^{1-\gamma} (\overline{\Pi}^{1-\gamma} - 1)} \right] \quad (188)$$

where  $\mu_n$  stands for the long run value of the price mark - up in the Calvo model and is given by

$$\mu_n = \frac{\sigma}{\sigma - 1} \left( \frac{1 - \theta \beta \overline{\Pi}^{(1-\gamma)(\sigma-1)}}{1 - \theta \beta \overline{\Pi}^{(1-\gamma)\sigma}} \right) \quad (189)$$

and  $\frac{\overline{P^*}}{\overline{P}}$  denotes the long run value of  $\frac{P_t^*}{P_t}$  and is given by equation (158).

From (188) the price adjustment cost parameter depends nonlinearly on the trend inflation  $\overline{\Pi}$ . As a baseline we evaluate  $\varphi$  at a zero inflation level which yields (see the appendix for proof):

$$\varphi = \left( \frac{\sigma - 1}{1 - \beta} \right) \left( \frac{\theta}{1 - \theta} - \frac{\theta \beta}{1 - \theta \beta} \right) \quad (190)$$

It is to be noted that  $\varphi$  is increasing in  $\theta$  and not surprisingly at zero inflation steady state, inflation indexation parameter,  $\gamma$  plays no role in determining  $\varphi$ . For the above mentioned quarterly calibrated parameter values of  $\beta$  and  $\sigma$ , Table 9 demonstrates values of  $\varphi$  corresponding to a range of different values of  $\theta$ .<sup>29</sup>

The values of  $\varphi$  corresponding to different  $\theta$  values depicted in Table 9 are consistent with Keen and Wang (2005). The values of  $\varphi$  keep on increasing with increase in the value of  $\theta$ . For the baseline value of  $\theta = 0.85$ , the corresponding  $\varphi$  is fixed at  $\varphi = 178.76$ .

The estimate of the productivity parameter  $\bar{\epsilon}$  (the average value of the TFP shock) differs across countries. For high income countries, I target the long run per capita quarterly real GDP growth rate for USA at 0.49% which means an annualized growth rate of 1.97% for the sample period 1947-2014. In order to estimate  $\bar{\epsilon}$  for middle income countries, I target the long run per

<sup>29</sup>Table 9 can be found in the appendix.

capita quarterly real GDP growth rate of 1.5% i.e. an annualized growth rate of 6% which is an average growth rate for all the developing countries in the data set for the sample period 1970-2014.

In both Calvo and Rotemberg frameworks, I first set the productivity parameter  $\bar{\epsilon}$  at 0.048, which can be taken as the productivity parameter for high income countries as it is calculated by targeting a quarterly growth rate of 1.97%. Similarly, when I target the long run per capita quarterly real GDP growth rate of 1.5%, I calibrate  $\bar{\epsilon}$  at 0.067 for middle income countries. It is observed that due to realization of the exogenous shocks, the short run behaviour of market capitalization and growth (along with other relevant variables) remains almost unchanged for  $\bar{\epsilon} = 0.048$  and  $\bar{\epsilon} = 0.067$ .

The long run inflation rate is usually set at the popular 2% target inflation rate for major high income industrial countries. As a proxy for middle income developing countries, I look into the inflation targeting scenario in India, where the inflation target is set at 4% by the recent Patel commission report.<sup>30</sup> For the present calibrations, I fix the long run trend inflation at 3% which is an average of the trend inflation rate observed for high income and middle income countries.

The adjustment cost parameter  $s''(\cdot)$  is fixed at 2.5 as in Christiano et al. (2005). The habit persistence parameter  $\gamma_c$  is fixed at 0.6 following Basu and Thoenissen (2011). The Taylor parameters  $\phi_\pi$  and  $\phi_y$  are fixed at 1.64 and 0.5 respectively following Gabriel et al. (2011).

Baseline values of deep parameters are given in Table 10 and Table 11.<sup>31</sup>

## I.2 Key results from short run simulations

I look into short run behaviour of market capitalization and growth along with that of other relevant variables in an environment characterized by staggered pricing as in Calvo (1983) and price adjustment cost as in Rotemberg (1982). I will focus on twelve endogenous variables: output growth, market capitalization, inflation, price dispersion, expected capital growth, Tobin's  $q$ , real marginal cost, rental rate, optimal price normalised by general price level, dividend to capital ratio of fix price firms, dividend to capital ratio of flex price firms and total economywide dividend to capital ratio. I will analyse the short run behaviour of each of these variables due

<sup>30</sup>According to the latest Patel commission report, the inflation rate is targeted to be brought down to 4% from the current 10% gradually over in approximately three years.

<sup>31</sup>Tables 10 and 11 can be found in the appendix. Without any loss of generality, the standard deviations are fixed at unit levels to normalize the impulse responses.

to realization of each of the above mentioned shocks.

In each of the tables and figures of this section, for the purpose of short run analysis, market capitalization is denoted by  $mk$ , output growth by  $yg$ , inflation by  $infl$ , price dispersion by  $s$ , expected capital growth by  $kg$ , Tobin's  $q$  by  $q$ , real marginal cost by  $mc$ , rental rate by  $r$ , optimal price normalized by general price level by  $pstar$ , consumption to capital ratio by  $ck$ , investment to capital ratio by  $chik$ , dividend to capital ratio of fix price firms by  $dk1$ , dividend to capital ratio of flex price firms by  $dk2$  and economywide dividend to capital ratio by  $dk$ .

From the short run simulations, the correlation coefficient between market capitalization ratio and growth and the correlation coefficient between growth and inflation are obtained.

The values of these correlation coefficients are observed to vary across different values of the nominal rigidity parameters of price stickiness ( $\theta$ ) and imperfect inflation indexation ( $\gamma$ ). Table 12 reports a sensitivity analysis of the market capitalization - growth correlation and Table 13 reports a sensitivity analysis of the growth - inflation correlation for varying  $\theta$  and  $\gamma$  respectively.<sup>32</sup> In both these tables, the range of the price stickiness parameter is taken from  $\theta = 0.25$  ( $\varphi = 2.21$ ) to  $\theta = 0.80$  ( $\varphi = 96.15$ ) and the range of the inflation indexation parameter is taken from  $\gamma = 0.40$  to  $\gamma = 0.90$ . Values of correlation coefficients are not observed to change much beyond the upper and lower bounds of these nominal rigidity parameters. In other words, variations in values of neither market capitalization - growth correlation coefficients, nor growth - inflation correlation coefficients occur for  $\theta < 0.25$ ,  $\gamma < 0.40$  and  $\theta > 0.80$ ,  $\gamma > 0.90$ .

From Table 12 it follows that in both Calvo and Rotemberg price setting frameworks, the market capitalization - growth correlation coefficient is more sensitive to the value of the price stickiness parameter  $\theta$  or the price adjustment cost parameter  $\varphi$  than the inflation indexation parameter  $\gamma$ , with the correlation coefficient falling with an increase in  $\theta$  and rising with an increase in  $\gamma$ .

In both Calvo and Rotemberg models, throughout the entire range of  $\gamma$ , the value of the correlation coefficient remains positive and highly significant for the price stickiness parameter  $\theta \in (0.25, 0.70)$  i.e. price adjustment cost parameter  $\varphi \in (2.21, 38)$ . For  $\theta = 0.75$  or  $\varphi = 58.25$ , the value of this correlation coefficient still remains positive, although less significant. For  $\theta > 0.75$  i.e.  $\varphi > 58.25$ , however, the market capitalization - growth correlation coefficient starts falling considerably and reaches a negative value at  $\theta = 0.80$ , i.e.  $\varphi = 96.15$ .

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<sup>32</sup>Tables 12 and 13 can be found in the appendix.

In both models, irrespective of the value of  $\theta$ , the market capitalization - growth correlation coefficient increases steadily but not drastically with a rise in  $\gamma$ . Only exception to this happens in the Rotemberg setting, when  $\theta = 0.75$  i.e.  $\varphi = 58.25$ . For this particular value of price distortion, the market capitalization - growth correlation coefficient increases by a considerable margin ( $-0.49$  to  $0.33$ ) when  $\gamma$  increases from  $0.50$  to  $0.60$ .

Thus the positive and significant correlation coefficient between market capitalization and growth, as found empirically, can be reproduced for reasonable range of values of the nominal rigidity parameters. However, with increase in nominal rigidity, i.e. with rise in price stickiness parameter  $\theta$  and fall in inflation indexation parameter  $\gamma$ , the value of the market capitalization - growth correlation coefficient is found to fall.

From Table 13 it is clear that just like the market capitalization - growth correlation coefficient, the growth - inflation correlation coefficient, too, is more sensitive to the value of the price stickiness parameter  $\theta$  than the inflation indexation parameter  $\gamma$  and this is true for both Calvo and Rotemberg price setting frameworks. In the Calvo model, a rise in  $\theta$  leads to a fall in the growth - inflation correlation coefficient and a rise in  $\gamma$  leads to an increase in this correlation coefficient. In the Rotemberg model, however, a rise in  $\theta$  or corresponding  $\varphi$  leads to an increase in the growth - inflation correlation coefficient, whereas a rise in  $\gamma$  implies a fall in this correlation coefficient.

In the Calvo model, a positive growth - inflation correlation coefficient occurs for  $\theta \in (0.25, 0.70)$ . But if  $\theta$  is increased beyond  $0.70$ , this correlation coefficient falls to a negative range of values. In the Rotemberg model, the growth - inflation correlation coefficient takes mostly negative values for the range  $\theta \in (0.25, 0.70)$  i.e.  $\varphi \in (2.21, 38)$  and assumes positive values only when  $\theta$  exceeds  $0.70$  i.e.  $\varphi$  exceeds  $38$ . Throughout the given range of values of  $\theta$  and  $\gamma$ , the growth - inflation correlation coefficient is found to be mostly insignificant.

Thus, in a sticky price framework, for a reasonable range of values of the price stickiness parameter, I find a positive significant correlation between market capitalization and growth, as observed empirically. In the framework with monopolistic competition and fully flexible prices, I found the correlation between market capitalization and growth to be positive but not very significant and not varying much with change in parameter values. In this kind of framework, introducing frictions in the form of price distortions (price stickiness or price adjustment cost) and imperfect inflation indexation can help in reproducing the positive significant correlation.

In both flexible and sticky price frameworks, the rental market of capital is competitive. So all firms, irrespective of being flex or sticky, face the same rental rate. However, in a sticky price scenario, although the consumers cannot differentiate between sticky price firms and flexible price firms in the physical capital market, they can certainly differentiate between the two in the financial capital market. Since flex price firms can set their prices optimally in response to a shock, their dividends can be thought to be more attractive to the consumers in a given time period compared to the fix price firms who have been unable to set their prices optimally. So being able to differentiate between the two types of firms can create consumer bias in favour of the stock market as opposed to the capital market.

Actually, for a given rental, a positive TFP shock leads to a fall in marginal cost. In a fully flexible price scenario, all firms would have uniformly lowered their price, leading to an increase in demand for their products from final goods firms and hence a subsequent increase in the demand for capital coming from all intermediate firms. In a sticky price environment a'la Calvo, a fraction of the firms, who are fix price firms, will be unable to reduce their prices in response to a fall in marginal cost. These fix price firms would not be facing higher demands from final good producing firms and hence would not be demanding more capital, compared to their flex price counterparts. In the presence of a price adjustment cost as in the Rotemberg price setting framework, the optimal price set by the firms will be more than that chosen in the absence of any price adjustment cost. This in turn will reduce the demand for their product coming from the final good producing firms and hence will diminish their capital demand as well. Thus, in a framework with nominal rigidities, the rental rate would be lower than in a framework without nominal rigidities, because the effect of lower demand for capital on part of fix price firms will then influence the market rental rate. Although consumers will be unable to hedge against the fix price firms in the capital market and will face the same rental rate, they will be able to differentiate between the fix and flex categories of firms in the financial market and hence would be able to hedge against the fix price firms by buying less of their shares and more shares of the flex price firms. This will positively affect consumer's tendency to invest in the stock market, eventually boosting up market capitalization.

Also, staggered price movement amplifies the effect of TFP and other shocks on market capitalization and growth, which can help explain positive significant market capitalization-growth correlation for reasonable values of the price stickiness parameter. In fact, without



price stickiness, average mark-up is a constant, i.e. all firms adjust prices proportionately in response to a fall in marginal cost (as a result of positive TFP shock). With price stickiness, however, a fraction of firms cannot lower their prices due to fall in their marginal cost, which leads to a rise in their average mark up. In a Rotemberg price setting framework, a higher value of the nominal rigidity parameter  $\varphi$  implies higher price adjustment cost. This means that as a response to a fall in marginal cost caused by a good TFP shock, firms will not be able to lower their prices proportionately to the full extent they would have been able to in the absence of price adjustment cost. As a result, there is increase in the average mark up. This, along with overall output increase due to positive TFP shocks lead to an overall increase in dividends, thereby making stock markets more attractive and increasing market capitalization. Also growth is augmented due to a positive TFP shock, which explains the positive market capitalization-growth correlation in a framework with staggered pricing.

With increase in the nominal rigidity parameter, the market capitalization-growth correlation is observed to fall. In a Calvo price setting framework, this means a rise in the stickiness parameter  $\theta$ , i.e. a decrease in the percentage of firms who cannot set prices optimally. In such a scenario, the consumer observes that proportion of so-called inefficient firms which cannot reoptimize prices is going up and since these firms cannot set optimal prices for their products each period, it is likely that they are going to face lower demands from the final goods producing firms, which is going to adversely affect their dividends. This, in turn, reduces demand for their shares and hence the market capitalization ratio. Similarly, in the Rotemberg price setting scenario, a rise in the price adjustment cost parameter  $\varphi$  directly reduces firm dividends, thereby lowering demand for stocks and hence market capitalization ratio. With rise in  $\varphi$ , the market capitalization - growth correlation will be observed to fall. In both price setting frameworks, it is observed that when the nominal rigidity parameter crosses a certain threshold value, a positive TFP shock causes market capitalization to fall to such an extent that the resulting market capitalization - growth correlation becomes negative. In the Calvo price setting framework, this threshold value of price stickiness parameter  $\theta$  is 0.80, which corresponds to a value of 96.15 for the price adjustment cost parameter in the Rotemberg framework. Hence rise in nominal rigidity leads to lowering of consumers' stock market bias and hence market capitalization, due to which a fall in the correlation between market capitalization ratio and growth is observed with a steady increase in price stickiness or price adjustment cost.

### I.3 Relative importance of real vs nominal rigidities in explaining market capitalization - growth correlation

In this section my primary aim is to understand the short run behaviour of market capitalization and growth using a New Keynesian endogenous growth model. The theoretical framework developed in this section looks into four different sources of frictions viz. (1) price distortions, (2) partial inflation indexation, (3) habit formation in consumers' utility function and (4) investment adjustment cost.

Out of these, the first two i.e. price distortion and partial inflation indexation constitute nominal rigidities. Price distortion can take different forms depending upon the nature of the price setting framework. In the Calvo price setting framework, this distortion takes the form of price rigidity or price stickiness, captured by the parameter  $\theta$ , while in the Rotemberg framework, it is the price adjustment cost, captured by the parameter  $\varphi$ , which contributes to price distortion. Inflation indexation measured by the parameter  $\gamma$  is another key component of nominal rigidity. With full inflation, i.e. with  $\gamma = 1$  it can be easily checked that the nominal part of the long run price markup vanishes in (159) in the Calvo framework and (180) in the Rotemberg framework. Thus in the long run for either price setting framework, price distortions have real effects on the economy only in presence of imperfect or partial indexation of inflation i.e. with  $\gamma < 1$ . It will be interesting to figure out the relative importance of these two nominal rigidity sources in terms of determining the short run. The latter two frictions i.e. habit persistence in utility function and adjustment cost of investment constitute real frictions. Habit formation is captured by the parameter  $\gamma_c$  while investment adjustment cost influences the short run dynamics through the parameter  $s''(\cdot)$ .

For the price stickiness parameter, a baseline value of  $\theta = 0.85$  is chosen, which is an average of the values chosen by Kollmann (2002) and Smets and Wouters (2003). This corresponds to a value of  $\varphi = 178.76$  for the price adjustment cost parameter. For the inflation indexation parameter,  $\gamma = 0.52$  is chosen as the baseline value. This is close to Smets and Wouters (2003) estimate or an average of the Euro and US estimates of Sahuc (2004). The adjustment cost parameter  $s''(\cdot)$  is fixed at 2.5 as in Christiano et al. (2005) and the habit persistence parameter  $\gamma_c$  is fixed at 0.6 following Basu and Thoenissen (2011). The price distortion friction can be shut down by imposing  $\theta = 0$ , which also implies  $\varphi = 0$  from equation (190). This means that a lack of price rigidity implies absence of price adjustment cost as well. Frictions caused by

imperfect indexation can be eliminated by imposing  $\gamma = 1$ . Similarly, real frictions caused by habit persistence and investment adjustment cost can be shut off by setting  $\gamma_c = 0$  and  $s''(.) = 0$  respectively.

Tables 14 and 15 demonstrate how much impact absence of real rigidities has on the market capitalization ratio - growth correlation coefficient.<sup>33</sup> Table 14 shows a sensitivity analysis of the market capitalization - growth correlation coefficient with respect to different values of  $\theta$  and  $\gamma$ , in the absence of the real friction caused by habit persistence in utility function, i.e. with  $\gamma_c = 0$ .

All other parameters remaining at baseline values, an absence of habit persistence regarding consumption in utility function of the representative household's utility function, leads to a slight fall in the correlation coefficient of market capitalization and growth in both Calvo and Rotemberg price setting frameworks. This is observed by comparing Table 14 with Table 12, (where all real and nominal frictions were taken into consideration). This correlation coefficient keeps on decreasing with increase in  $\theta$ . The correlation coefficient is not very sensitive to the value of  $\gamma$ .

Table 15 shows a sensitivity analysis of the market capitalization - growth correlation coefficient with respect to different values of  $\theta$  and  $\gamma$ , in the absence of the real friction caused by investment adjustment cost, i.e. with  $s''(.) = 0$ .

All other parameters remaining at their baseline values, an absence of investment adjustment cost leads to a considerable fall in the correlation coefficient between market capitalization and growth and this is true for both price setting frameworks of Calvo and Rotemberg. This becomes evident by comparing Table 15 with Table 12, (where all real and nominal frictions were taken into consideration). In this case also correlation coefficient keeps on decreasing with increase in  $\theta$ . The correlation coefficient is not very sensitive to the value of  $\gamma$  and only shows slight increase with increase in  $\gamma$ . However, in the absence of investment adjustment cost, the market capitalization - growth correlation coefficient loses significance throughout the range of different values of  $\theta$  and  $\gamma$ .

Tables 16 and 17 demonstrate the effect of the absence of nominal rigidities on the market capitalization - growth correlation coefficient.<sup>34</sup> Table 16 presents a sensitivity analysis of the market capitalization - growth correlation coefficient with respect to different values of  $\gamma$  when

<sup>33</sup>Tables 14 and 15 can be found in the appendix.

<sup>34</sup>Table 16 and 17 can be found in the appendix.

$\theta = 0$  ( $\varphi = 0$ ) i.e. in absence of the distortions caused due to price stickiness or price adjustment cost.

From Table 16 it is clear that all other parameters remaining at their baseline values, an absence of nominal distortions caused due to price rigidities in the Calvo framework and price adjustment cost in the Rotemberg framework leads to a considerable fall in the correlation coefficient. The correlation is not observed to change much with a change in  $\gamma$ . In both price setting frameworks, only a small increase is noticed in the correlation coefficient as  $\gamma$  increases from 0.4 to 0.9.

Table 17 reports a sensitivity analysis of the market capitalization - growth correlation coefficient with respect to different values of  $\theta$  when  $\gamma = 1$  i.e. in absence of the nominal friction caused by imperfect inflation indexation.

From Table 17 it is clear that other parameters remaining at baseline values, a full indexation of inflation ( $\gamma = 1$ ) does not lead to much change in the value of the correlation coefficient between market capitalization and growth compared to when  $\gamma$  remains at the baseline value of 0.52. This is observed by comparing Table 17 with Table 12. A rise in  $\theta$  from 0.25 to 0.80 leads to a gradual decrease in the market capitalization - growth correlation coefficient.

From Tables 14, 15, 16 and 17 it can be concluded that both real and nominal rigidities play crucial roles in reproducing a positive and significant correlation between market capitalization ratio and growth. Investment adjustment cost emerges as the most important source of real rigidity. Among the nominal rigidity frictions (price distortion and imperfect inflation indexation), distortion caused by price stickiness and price adjustment cost is key in reproducing the short run positive and significant market capitalization - growth correlation coefficient. The short run correlation between market capitalization and growth appears to be dependent to a lesser extent on the real friction caused by consumption habit persistence in representative household's utility function and the nominal friction due to partial indexation of inflation.

#### **I.4 Impulse response in Calvo model**

For the Calvo price setting framework, I first report the impulse response figures of the fourteen endogenous variables viz. market capitalization (denoted by  $mk$ ), output growth (denoted by  $yg$ ), inflation (denoted by  $infl$ ), price dispersion (denoted by  $s$ ), expected capital growth (de-

noted by  $kg$ ), Tobin's  $q$  (denoted by  $q$ ), real marginal cost (denoted by  $mc$ ), rental rate (denoted by  $r$ ), optimal price normalized by general price level (denoted by  $pstar$ ), consumption to capital ratio (denoted by  $ck$ ), ratio of physical investment to capital (denoted by  $chik$ ), dividend to capital ratio of fix price firms (denoted by  $dk1$ ), dividend to capital ratio of flex price firms (denoted by  $dk2$ ) and economywide dividend to capital ratio (denoted by  $dk$ ) due to each of the underlying shocks i.e. TFP (Total Factor Productivity), IST (Investment Specific Technology), MP (Monitary Policy) and CQ (Capital Quality) for baseline parametric values reported in Tables 8 and 9. It should be noted that the following impulse responses are the result of a considerably high baseline value of the price stickiness parameter ( $\theta = 0.85$ ).

Figures 4 and 5 represent the impulse response path of each of the above mentioned variables to a TFP shock.

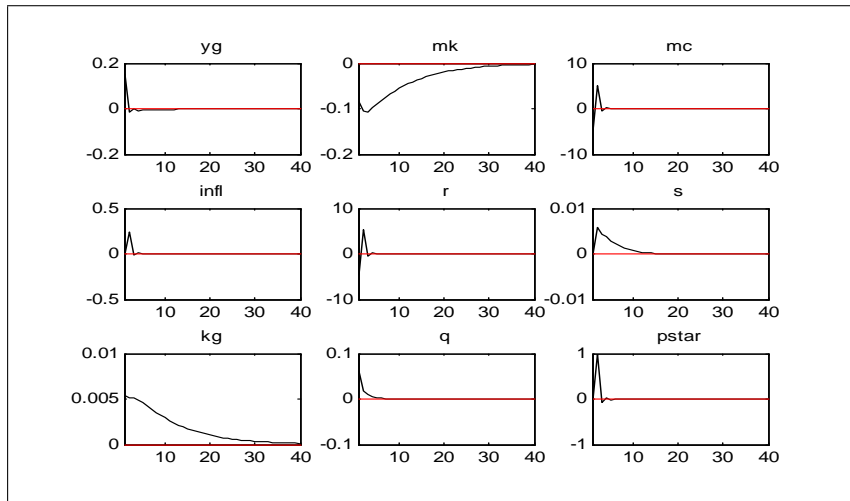


Figure 4: TFP impulse response for baseline parameters in Calvo framework

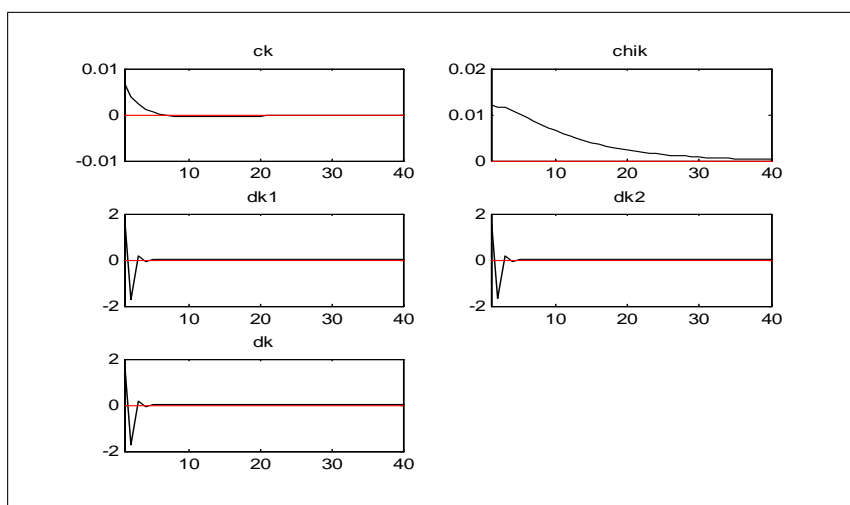


Figure 5: TFP impulse response for baseline parameters in Calvo framework

From Figures 4 and 5 it is clear that a positive TFP shock increases output growth  $yg$ , inflation  $infl$ , price dispersion  $s$ , expected capital growth  $kg$ , Tobin's  $q$   $q$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , investment to capital ratio  $chik$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$ . On the other hand, due to a positive TFP shock, there is a fall in market capitalization  $mk$ , real marginal cost  $mc$  and rental rate  $r$ .

Thus, in a Calvo model, for a high baseline value of the price stickiness parameter  $\theta$ , a positive TFP shock induces market capitalization ratio and growth to move in opposite directions in the short run. However, the short run time paths followed by growth and inflation, as a result of a good TFP shock, are in the same direction. A positive TFP shock augments current output. A fall in the real marginal cost increases the average mark up, which, along with an increase in output, increases the total economywide dividends as well as that of both sticky price and flex price firms. The presence of a large number of staggered price firms lowers total demand for intermediate goods, which leads to a fall in the demand for capital and hence the rental rate of capital.

Since the TFP shock follows an autoregressive process of the first order, a positive TFP shock in the current period signifies a rise in output in the next period as well, which leads to an increase present investment in physical capital. Also, since consumers are risk averse and hence willing to smooth out consumption over time, an anticipated rise in future output and future consumption leads to a rise in present consumption as well due to the information effect. The considerable increase in both consumption and physical investment by the household leads to a fall in total demand for stocks, which in turn signifies a fall in the market capitalization. This, along with a rise in present output as a result of a positive productivity shock, leads to a fall in the market capitalization to output ratio.

Figures 6 and 7 represent the impulse responses of each of the above mentioned variables due to an IST shock.

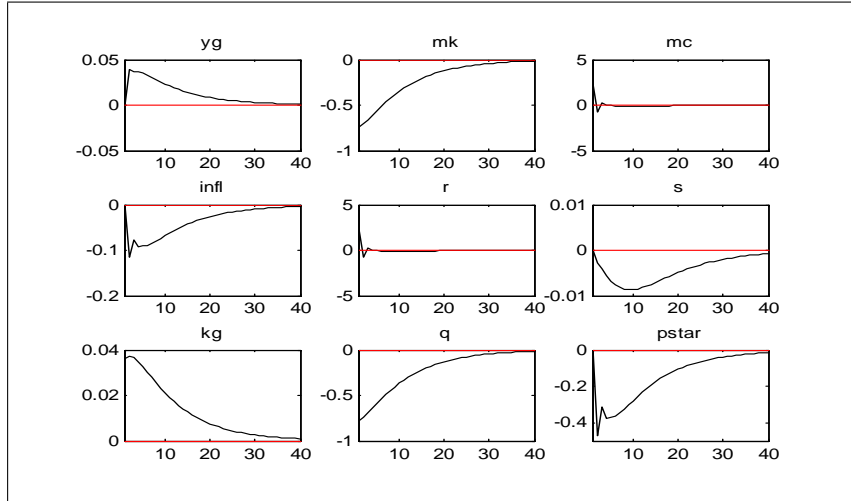


Figure 6: IST impulse response for baseline parameters in Calvo framework

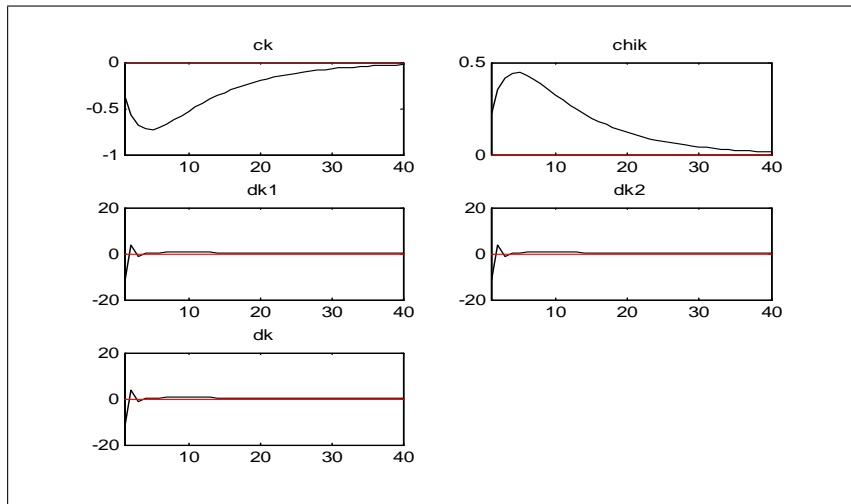


Figure 7: IST impulse response for baseline parameters in Calvo framework

From Figures 6 and 7 it is clear that a positive IST shock increases output growth  $yg$ , real marginal cost  $mc$ , expected capital growth  $kg$  and investment to capital ratio  $chik$ . On the other hand, a positive IST shock leads to a fall in market capitalization  $mk$ , rental rate  $r$ , inflation  $infl$ , price dispersion  $s$ , Tobin's  $q$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$ .

Hence for a high baseline value of the price stickiness parameter, a positive IST shock induces market capitalization ratio and growth to move in opposite directions in the short run. Market capitalization ratio is affected in the period of realization of the shock, while growth is affected in the next period. Also, due to a good IST shock, the short run time paths followed by growth and inflation are in opposite directions as well. A good IST shock augments future

capital stock, which leads to a rise in capital growth in the next period. This augments output growth in the next period as well. An IST shock also increases the rental rate of capital which leads to a fall in the total dividends. Technological innovations specific to investment create an environment where it is more attractive to invest in physical capital, thereby considerably boosting current physical investment. Since an IST shock increases next period's output and consumption, the opportunity cost of consumption goes up in the present period, driving down current consumption and current demand for stocks and boosting current investment on physical capital. A fall in the demand for financial assets contributes to the eventual decline in market capitalization ratio.

Figures 8 and 9 represent the impulse response figures of each of the above mentioned variables as a result of a MP shock.

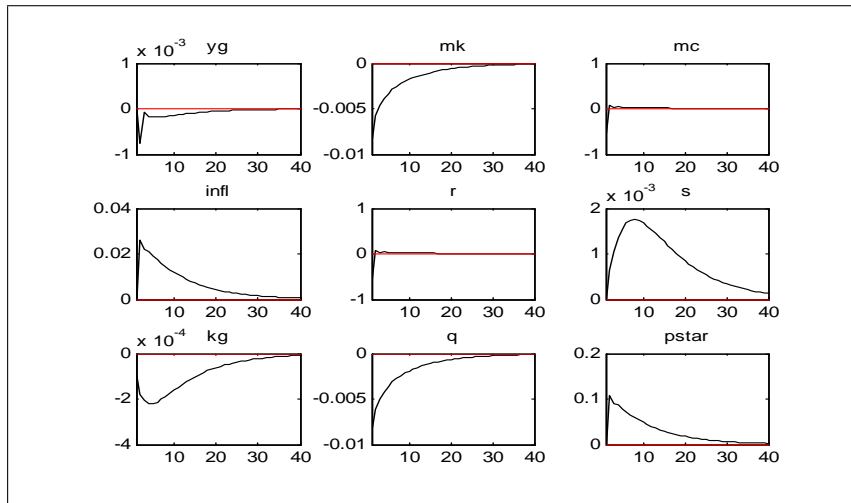


Figure 8: MP impulse response for baseline parameters in Calvo framework

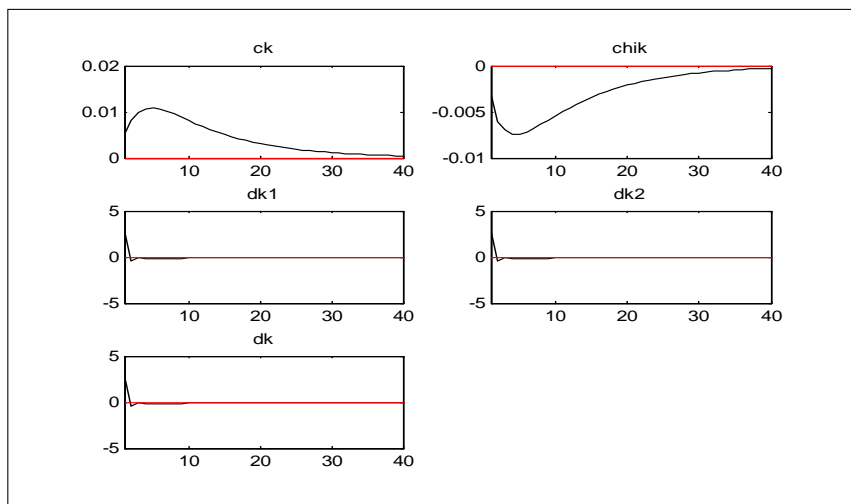


Figure 9: MP impulse response for baseline parameters in Calvo framework



From Figures 8 and 9 it is clear that a positive interest rate shock increases inflation  $infl$ , price dispersion  $s$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$  and decreases output growth  $yg$ , market capitalization  $mk$ , real marginal cost  $mc$ , expected capital growth  $kg$ , Tobin's  $q$ , rental rate  $r$  and investment to capital ratio  $chik$ .

Therefore, for a high baseline value of the price stickiness parameter, a positive MP shock induces market capitalization ratio and growth to move in same directions in the short run. However, growth and inflation follow opposite time paths as a result of a positive interest rate shock. Market capitalization ratio is affected in the period of realization of the shock, while growth is affected in the next period. An increase in nominal interest rates slows down the economy, reducing current growth. There is rise in economywide dividends as a result of a fall in the rental rate of capital. A rise in the nominal interest rate leads to increased demand for risk free bonds, as a result of which there is reduction in investments in physical capital and also a reduction in the demand for stocks. Demand for stocks also diminish along with the value of the Tobin's  $q$ , because of a fall in the market price of capital, which is brought about by a fall in the rental rate. A fall in stock demand eventually diminishes the market capitalization ratio.

Figures 10 and 11 represent the impulse responses of each of the above mentioned variables as a result of a CQ shock.

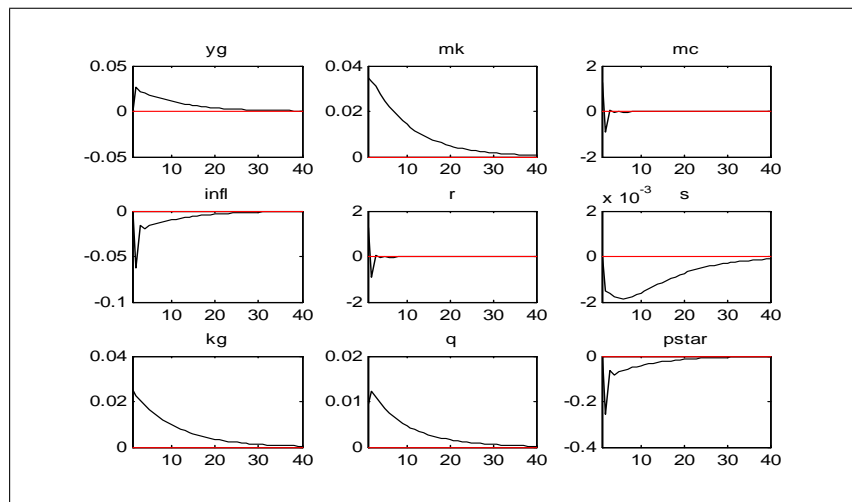


Figure 10: CQ impulse response for baseline parameters in Calvo framework

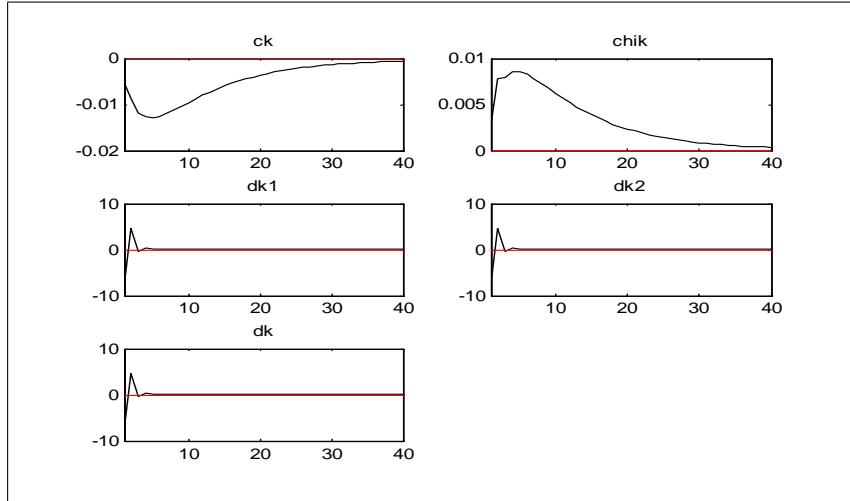


Figure 11: CQ impulse response for baseline parameters in Calvo framework

From Figures 10 and 11 it is clear that a good CQ shock increases output growth  $yg$ , market capitalization  $mk$ , real marginal cost  $mc$ , rental rate  $r$  expected capital growth  $kg$ , Tobin's  $q$  and investment to capital ratio  $chik$ . On the other hand, a positive CQ shock leads to a fall in inflation  $infl$ , price dispersion  $s$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$ .

A fall in the depreciation of capital causes market capitalization ratio and growth to move in the same direction, but growth and inflation to move in opposite directions in the short run. Due to a fall in the depreciation rate, there is an increase in future accumulated capital, which augments capital growth and output growth in the next period. A good CQ shock also rises the rental rate by improving the quality of capital. A rise in real marginal cost and rental contributes towards diminishing the total dividends of the firm. A fall in the depreciation rate of physical capital creates an environment where it is more attractive to invest in physical capital. This increases the total economywide investments. Also a rise in future capital sends out a signal of increased output and dividends in the next period to the consumers, who find it profitable to increase their investments in stocks. An increased demand for investment in financial assets also occurs due to an increase in the present market value of capital. This, in turn, boosts up the market capitalization ratio.

The above impulse response analysis has been conducted with a reasonably high baseline value of  $\theta$ . It will be interesting to compare these impulse responses with the ones obtained for a low value of  $\theta$ . Since the market capitalization - growth and growth - inflation correlations

are quite sensitive to  $\theta$  and not so much to  $\gamma$ , as found from the sensitivity analysis in Tables 12 and 13, I focus solely on the change in short run dynamics for each of the variables as  $\theta$  changes from a low value to a high value. As a highly significant correlation coefficient between market capitalization ratio and growth is observed at a low value of  $\theta$  ( $\theta = 0.25$ ) from Table 12, it is worthwhile to also check the impulse responses of the different variables for a low value of  $\theta$ . From this a comparison can be made between the short run behaviours of the variables for high and low values of the price rigidity parameter. I now present the impulse response analysis for  $\theta = 0.25$ .

Figures 12 and 13 represents the impulse responses to a TFP shock when there is a low level of price rigidity in the economy.

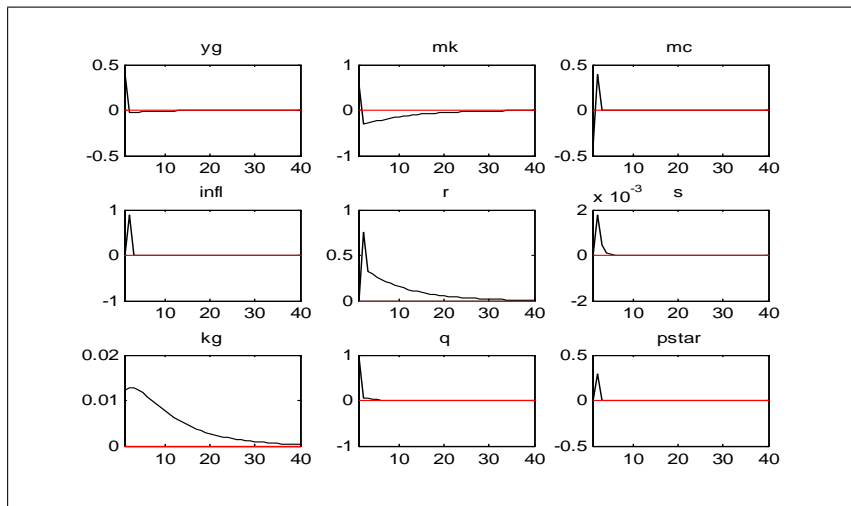


Figure 12: TFP impulse response for low level of price stickiness in Calvo framework

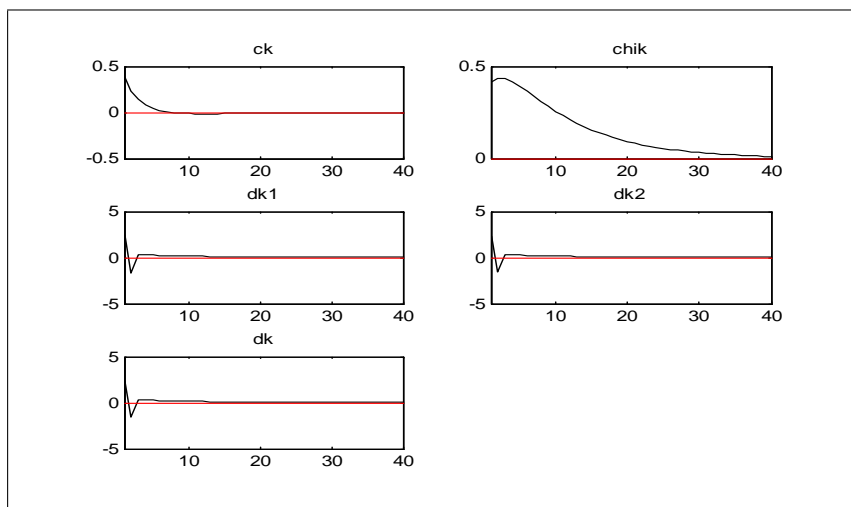


Figure 13: TFP impulse response for low level of price stickiness in Calvo framework

From Figures 12 and 13 it is clear that a positive TFP shock increases output growth  $yg$ ,

market capitalization  $mk$ , inflation  $infl$ , rental rate  $r$ , price dispersion  $s$ , expected capital growth  $kg$ , Tobin's  $q$   $q$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , investment to capital ratio  $chik$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$ . On the other hand, due to a positive TFP shock, there is a fall in only real marginal cost  $mc$ .

Thus, for a low level of price stickiness, a positive TFP shock induces market capitalization ratio and growth to move in the same direction in the short run. Also, as a result of a good TFP shock, the short run time paths followed by growth and inflation are in the same direction. A positive TFP shock augments current output and dividends of both sticky price as well as flex price firms. There is a fall in the economywide real marginal cost of the firms, which, along with a rise in current output, contributes to an increase in total dividends. As there is increase in the proportion of firms setting their price optimally, there is increase in demand for intermediate goods coming from the final good producing firms. This, in turn, leads to increased demand for capital and ultimately drives up the rental rate.

Since the TFP shock follows an autoregressive process of the first order, a positive TFP shock signals a rise in output in the next period as well, which leads to a rise in present investment in physical capital. Since consumers are risk averse and willing to smooth consumption over time, an anticipated rise in future output and future consumption also leads to a rise in present consumption. However, in this case, although there is increase in both consumption as well as investment in physical capital, this does not imply a fall in asset demand. In this case, a rise in the rental rate signifies an increase in the market value of capital, which contributes to an increase in Tobin's  $q$  and an increase in asset demand. Asset demands also increase on account of a present increase in dividends, which, due to the autoregressive nature of the shock, signifies an increase in future dividends as well. Thus when there is lower price rigidity, the positive income effect brought about by a good TFP shock gets translated into an increase in the households' demand for shares. This does not happen when the level of price stickiness is considerably higher. The increase in demand for assets ultimately leads to an increase in the market capitalization ratio.

Figures 14 and 15 represent the impulse responses to an IST shock for a low level of price rigidity in the economy.

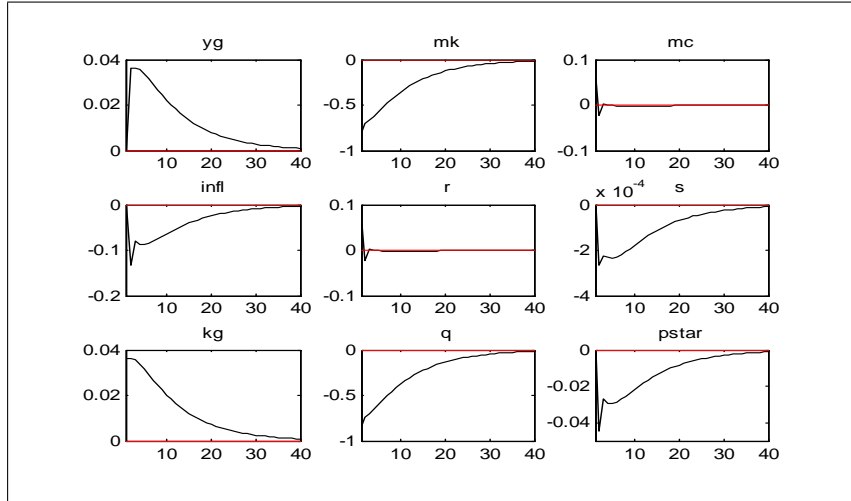


Figure 14: IST impulse response for low level of price stickiness in Calvo framework

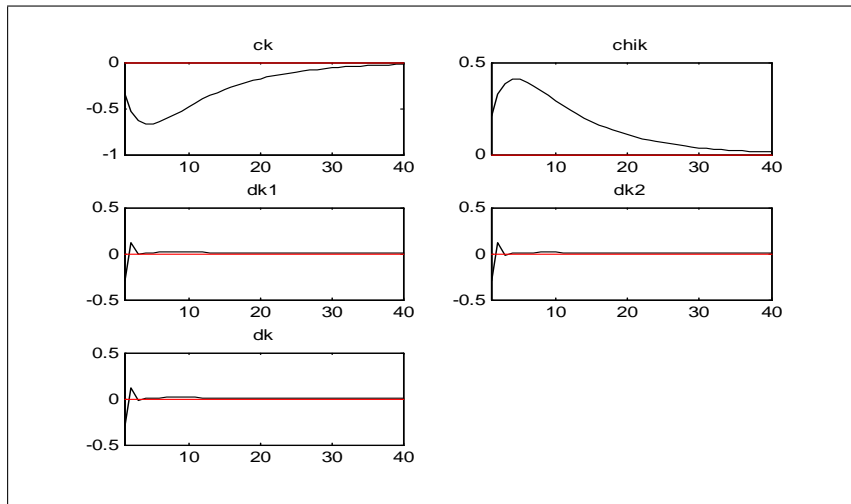


Figure 15: IST impulse response for low level of price stickiness in Calvo framework

From Figure 14 and 15 it is clear that a positive IST shock increases output growth  $yg$ , real marginal cost  $mc$ , rental rate  $r$ , expected capital growth  $kg$  and investment to capital ratio  $chik$ . On the other hand, a positive IST shock leads to a fall in market capitalization  $mk$ , , inflation  $infl$ , price dispersion  $s$ , Tobin's  $q$   $q$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$ .

Hence for a low level of price rigidity, a positive IST shock induces market capitalization ratio and growth as well as growth and inflation to move in opposite directions in the short run. Market capitalization ratio is affected in the period of realization of the shock, while growth is affected a period later. A good IST shock augments future capital stock, leading to a rise in capital growth and output growth in the next period. An IST shock also augments capital stock,

thereby increasing the rental rate of capital which leads to a fall in the total dividends. Just as with high price rigidities, with low levels of price rigidities, also, it is observed that an IST shock lowers consumption and augments investment. This is because technological innovations specific to physical investment create an environment where it is more tempting for investors to invest in physical capital, thereby considerably boosting current physical investment. As an investment shock increases next period's output and anticipated consumption, the present opportunity cost of consumption goes up, decreasing current consumption and current demand for stocks and increasing current investment in physical capital. As demand for financial assets decline, a fall in market capitalization ratio is observed.

Figures 16 and 17 represents the impulse response to an MP shock for a low level of price rigidity.

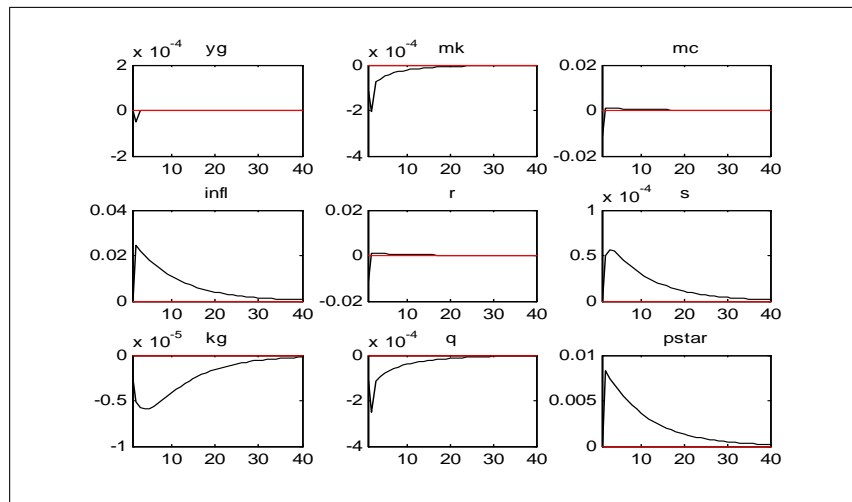


Figure 16: MP impulse response for low level of price stickiness in Calvo framework

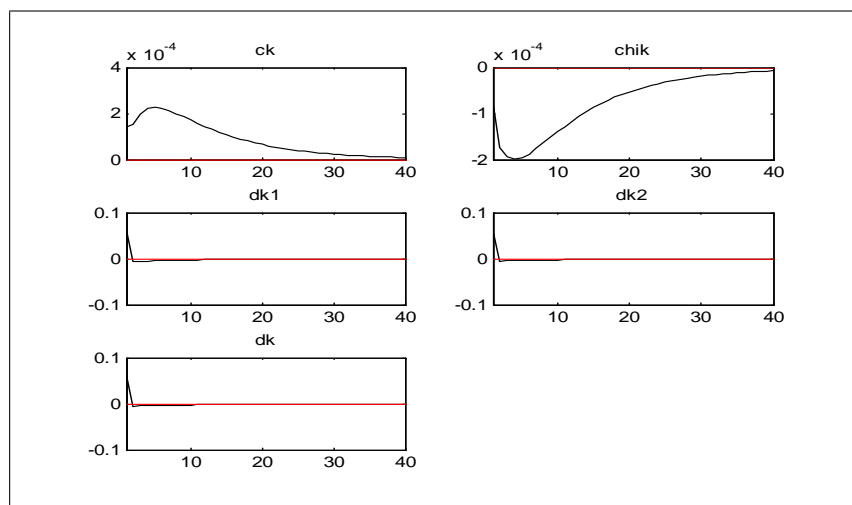


Figure 17: MP impulse response for low level of price stickiness in Calvo framework

From Figures 16 and 17 it is clear that just as in case of high price rigidity, for low levels of price rigidity also, a positive MP shock i.e. a rise in interest rate increases inflation  $infl$ , price dispersion  $s$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$ . However, due to a positive MP shock, there is a fall in output growth  $yg$ , market capitalization ratio  $mk$ , real marginal cost  $mc$ , expected capital growth  $kg$ , Tobin's  $q$ , rental rate  $r$  and investment to capital ratio  $chik$ .

Therefore, for a low value of the price stickiness parameter, a positive interest rate shock causes market capitalization ratio and growth to move in the same direction, but growth and inflation to follow opposite time paths in the short run. In this case also, an increase in nominal interest rates stagnates the economy, reducing current growth. A decreased demand for capital from firms results in a fall in the rental rate of capital. Also rise in the nominal interest rates implies more investment in the risk free bonds, which reduces investments in physical capital and also the demand for stocks. A fall in stock demand along with a fall in the market value of capital, diminishes the market capitalization ratio.

Figures 18 and 19 represents the impulse responses to a CQ shock for a low level of price rigidity.

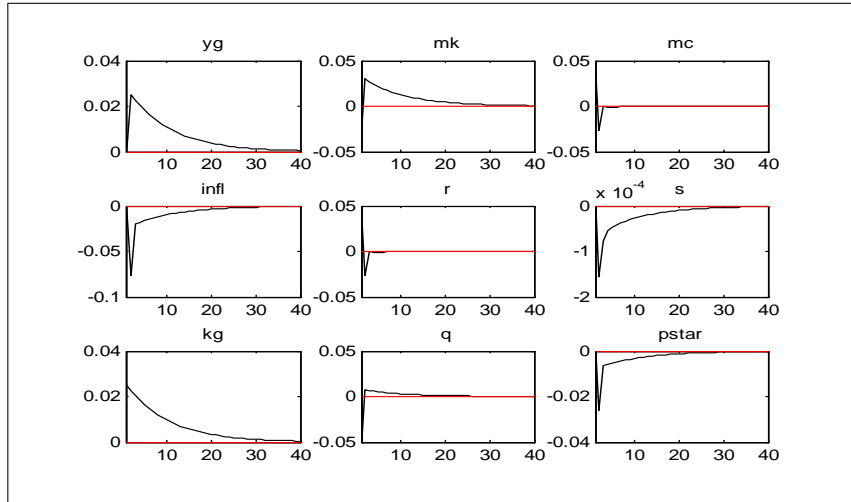


Figure 18: CQ impulse response for low level of price stickiness in Calvo framework

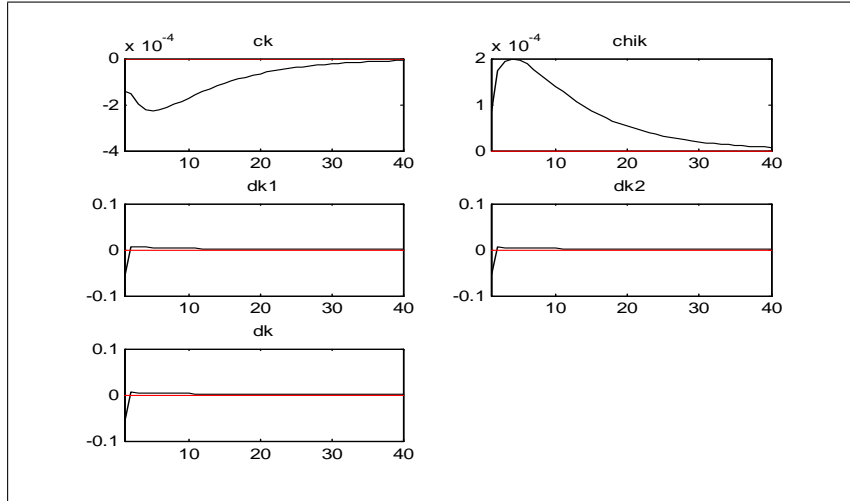


Figure 19: CQ impulse response for low level of price stickiness in Calvo framework

From Figures 18 and 19 it is clear that a good CQ shock, i.e. a fall in the depreciation rate of capital, increases output growth  $yg$ , market capitalization  $mk$ , expected capital growth  $kg$ , rental rate  $r$ , real marginal cost  $mc$  and investment to capital ratio  $chik$ . On the other hand, a positive CQ shock leads to a fall in inflation  $infl$ , price dispersion  $s$ , optimal price normalized by general price level  $pstar$ , consumption to capital ratio  $ck$ , Tobin's  $q$ , dividend to capital ratio of fix price firms  $dk1$ , dividend to capital ratio of flex price firms  $dk2$  and economywide dividend to capital ratio  $dk$ .

A fall in the depreciation of capital causes market capitalization ratio and growth to move in the same direction, but growth and inflation to move in opposite directions in the short run when the economy is characterized by a low level of price rigidity. Market capitalization ratio is affected in the period of realization of the shock, while growth is affected a period after. A fall in the depreciation rate of capital augments future accumulated capital, increasing capital growth and output growth in the next period. A good CQ shock also rises the rental rate and real marginal cost, thereby diminishing total dividends. A fall in the depreciation rate of physical capital induces investors to invest more in physical capital. This leads to an increase in the total investments. An increase in future capital signifies increased output and dividends in the next period, because of which consumers find it lucrative to increase their investment in stocks. This, along with a rise in the present market value of capital, increase the current market capitalization ratio.

Before comparing the impulse response graphs for high and low values of the price rigidity parameter and formally analyzing the reason behind the change in the market capitalization



- growth relationship in the two scenarios, it is useful to study the relative influence of the four different shocks in bringing about short run fluctuations in each of the above mentioned variables. The variance decomposition of the effect of the four shocks on each of these variables is captured by Table 18 for a low value of  $\theta$  ( $\theta = 0.25$ ) as well as a high value of  $\theta$  ( $\theta = 0.85$ ).<sup>35</sup>

From Table 18, it is clear that for  $\theta = 0.25$ , TFP is the main driving force for output growth, market capitalization, inflation, price dispersion, Tobin's q, real marginal cost, rental rate, optimal price normalised by general price level, dividend to capital ratio of the two types of firms and the total dividend to capital ratio. For expected capital growth, however, both shocks play important roles, the influence of TFP being 38.85%, while that of IST being a bit higher at 50.80%. Also for consumption to capital ratio and investment to capital ratio, the influence of both TFP and IST shocks are equally important. 33.27% of the fluctuations in consumption to capital ratio is influenced by the TFP shock, while 66.71% is influenced by the IST shock. For investment to capital ratio, the TFP shock explains 64.35% of its fluctuations, while the IST shock explains 35.64%. The relative influence of the shocks on the different variables remain like this throughout the range of the price stickiness parameter  $\theta \in (0.25, 0.75)$ .

For  $\theta = 0.85$ , output growth, inflation, price dispersion, real marginal cost, rental rate, optimal price of flex price firm as a ratio of general price level, dividend to capital ratio of the two types of firms and the total economywide dividend to capital ratio are influenced by TFP, whereas IST shock is the main influence for consumption to capital ratio and Tobin's q. For market capitalization ratio, expected capital growth and investment to capital ratio, however, both shocks play important roles. For market capitalization, TFP determines 45.40% and IST determines 54.47% of its total fluctuations. For expected capital growth, TFP explains 39.16% of its fluctuations, while IST explains 42.61%. For investment to capital ratio, TFP determines 65.90%, while IST explains 34.40% of its total fluctuations. For market capitalization ratio and Tobin's q, the importance of an IST shock increases strikingly as the value of the price rigidity parameter increases from 0.25 to 0.85. The relative influence of the shocks on the different variables remain like this for the range of the price stickiness parameter  $\theta \geq 0.80$ .

Since TFP and IST are the two most prominent shocks in the Calvo model for both high and low values of the price rigidity parameter, I next compare, for a low value of  $\theta$  ( $\theta = 0.25$ ) and a high value of  $\theta$  ( $\theta = 0.85$ ), the impulse responses of the relevant variables due to realizations

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<sup>35</sup>Table 18 can be found in the appendix.

of these two shocks only. Figures 20 and 21 compare the impulse responses of the variables due to a TFP shock and Figures 22 and 23 compare the impulse responses as a result of an IST shock. In each of these figures, the black line represents the impulse response path of a variable for  $\theta = 0.25$ , while the red line signifies the impulse response for  $\theta = 0.85$ .

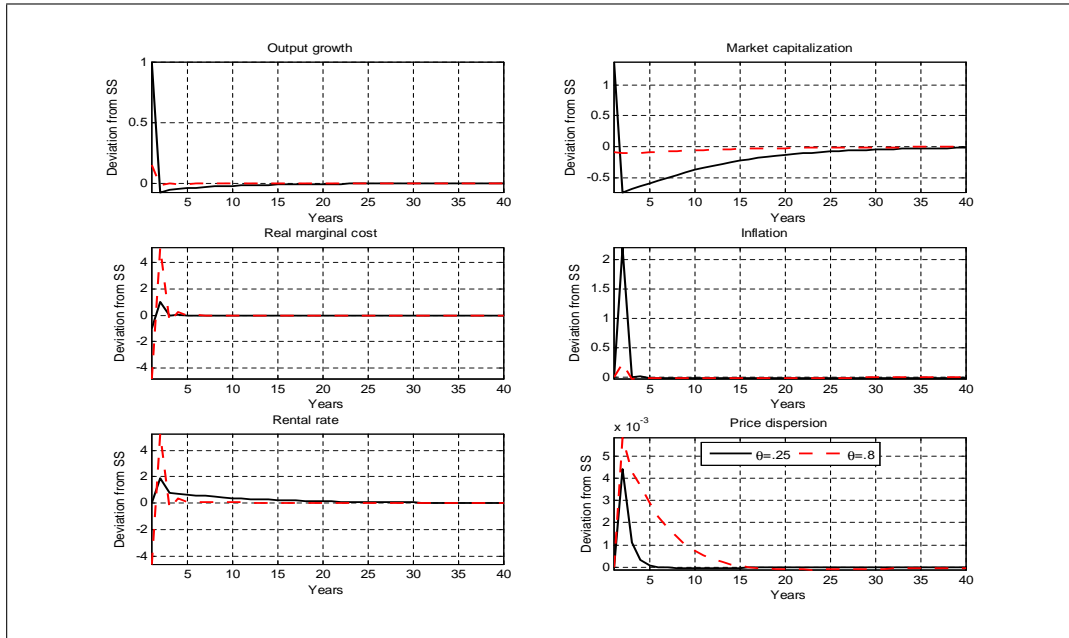


Figure 20: TFP impulse response comparison in Calvo framework

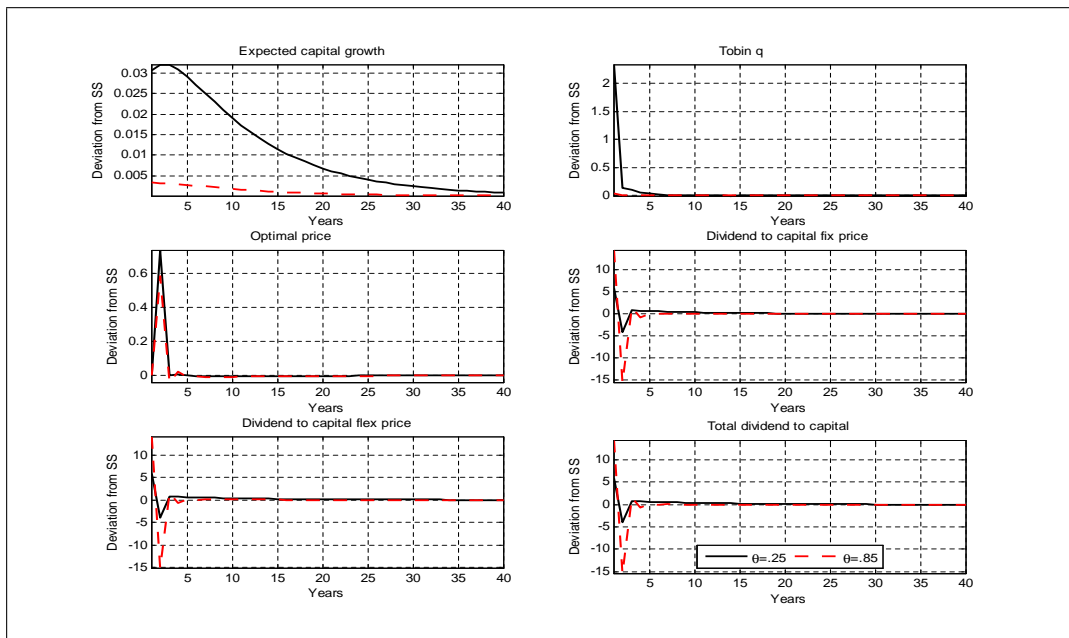


Figure 21: TFP impulse response comparison in Calvo framework

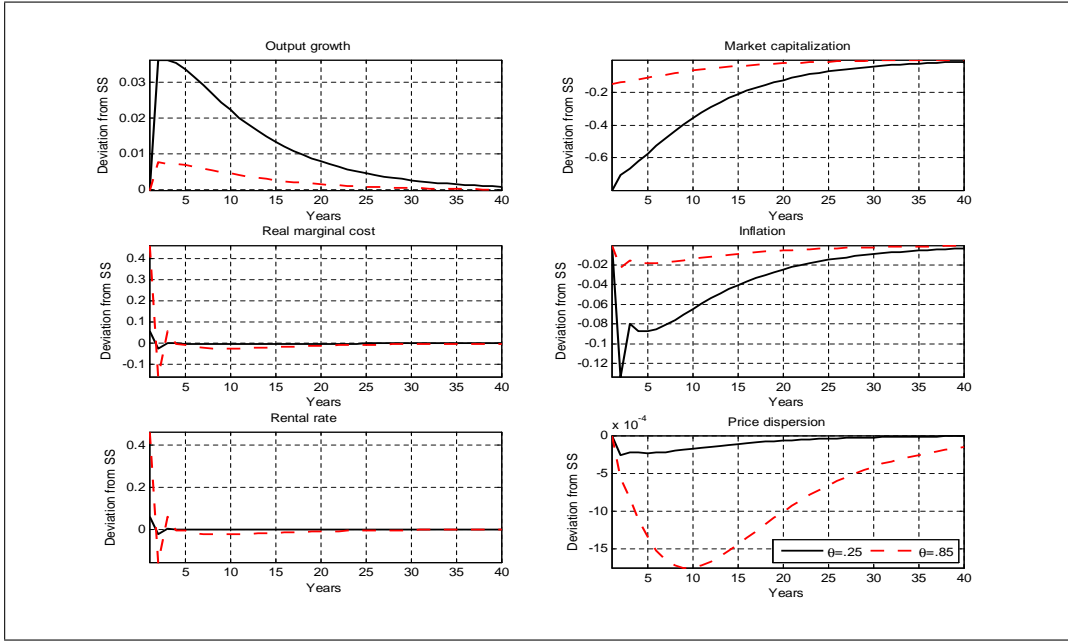


Figure 22: IST impulse response comparison in Calvo framework

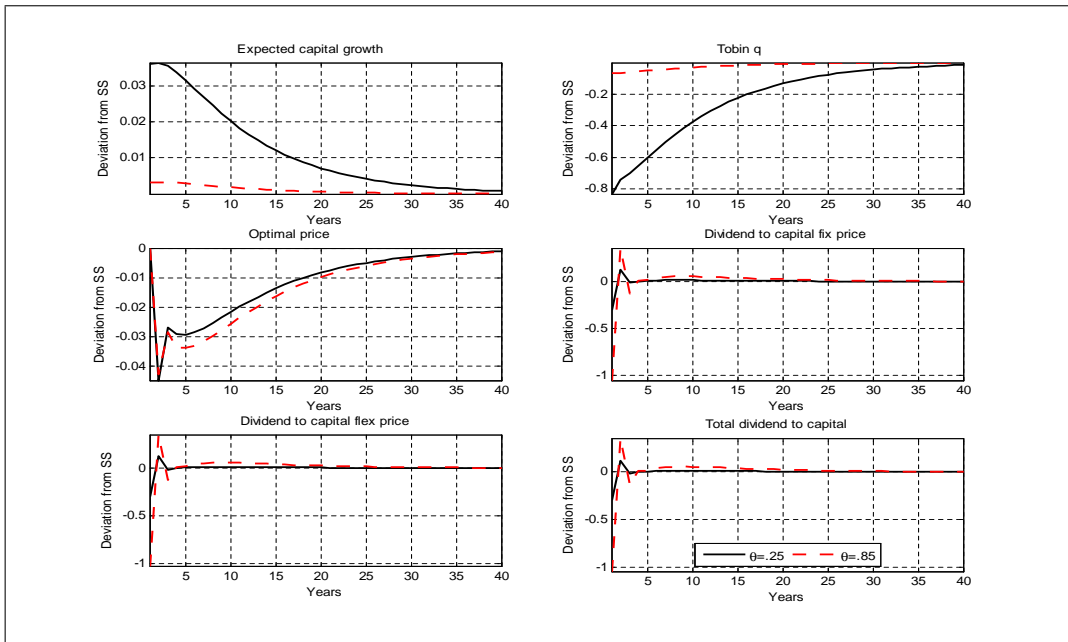


Figure 23: IST impulse response comparison in Calvo framework

From Figures 20 - 23, it is clear that for output growth, market capitalization, inflation, expected capital growth and Tobin's  $q$ , the impact effects of both TFP and IST shocks are slightly greater when  $\theta = 0.25$ , compared to when  $\theta = 0.85$ . For real marginal cost, rental rate, price dispersion, dividend to capital ratio of fix price firms, dividend to capital ratio of flex price firms and the economywide dividend to capital ratio, however, the effects of both shocks are slightly amplified when  $\theta = 0.85$ , as compared to when  $\theta = 0.25$ . For the optimal price set by

flex price firms as a ratio of general price level, the TFP and IST shock effects remain almost same for high as well as low values of the price rigidity parameter.

I must point out here that the impulse responses remain almost same for the price rigidity range  $\theta \in (0.25, 0.75)$ . Only when the price rigidity parameter exceeds the threshold value of  $\theta = 0.80$ , the impulse responses start changing. Short run dynamics of the variables for  $\theta \geq 0.80$  remain almost same. Thus in the Calvo price setting framework, the impulse response figures can be divided into two categories: impulse responses for  $\theta \in (0.25, 0.75)$  and impulse responses for  $\theta \geq 0.80$ . The black line in Figures 20 - 23 effectively represent the short run dynamics of the variables for the reasonable range of  $\theta \in (0.25, 0.75)$  and the red line can be taken as the impulse response of each of the variables for a relatively high range of the price rigidity parameter, i.e. when  $\theta \geq 0.80$ .

From Table 18 it is observed that for reasonably low values of  $\theta$ , the short run dynamics of market capitalization and Tobin's q are influenced by the TFP shock. From Figures 20 and 21, it follows that both these variables are augmented by this shock for a reasonable range of  $\theta$ . Also TFP shock remains the main determinant of the short run fluctuations in growth throughout different values of  $\theta$  and growth is always augmented due to a TFP shock as is evident from Figure 20. For a very high value of the price stickiness parameter, however, market capitalization and Tobin's q are influenced by the IST shock and from Figures 22 and 23 it is observed that both these variables decrease as a result of an IST shock. This leads to a fall in the market capitalization - growth correlation for considerably high values of  $\theta$ .

In the Calvo price setting framework, for reasonable range of values of the stickiness parameter, real marginal cost  $mc_t$  falls because of a TFP shock, as is clear from the impulse response Figure 20. This means a rise in average markup  $\frac{P_t}{MC_t}$ . Also a positive TFP shock augments output, which along with a rise in the average markup implies a rise in total dividends, thereby increasing the firm's incentive to supply more of their output and hence demand more capital, resulting in an increase in the rental rate  $r_t$ . From Figure 20 it is evident that the rental rate of capital increases following a favourable TFP shock. This leads to an increase in market value of capital, as a result of which the Tobin's q increases. Increase in market value of assets leads to an increase in market capitalization as well due to a positive TFP shock.

However, for a very high price stickiness value, although there is an initial fall in real marginal cost, the rental rate of capital behaves very similar to real marginal cost and it too falls

considerably. Short run movements in real marginal cost and rental rate are driven mainly by the TFP shock for high and low values of  $\theta$  as is evident from the variance decomposition of shocks in Table 18. In Figure 20 the short run behaviours of real marginal cost and rental rate, for high and low levels of price rigidity, provide important insights into understanding the reason behind a fall in market capitalization - growth correlation due to rise in nominal rigidity. In reality, a high value of  $\theta$  implies an increase in the proportion of sticky price firms, i.e. firms which do not optimize their price and stick to their previous period price. In such a sticky price environment, the fraction of the firms, who are fix price firms, will be unable to reduce their prices in response to a fall in marginal cost, as a result of which they would be facing lower demands from final good producing firms. In this scenario, there is decrease in the demand for capital for sticky price firms, compared to that of the flex price firms. An increase in the proportion of sticky price firms in the economy thus drives down the rental rate. In a framework with nominal rigidities, the rental rate is lower than in a framework without nominal rigidities, as the market rental rate is influenced by the fall in demand for capital on part of fix price firms. When the proportion of sticky price firms is sufficiently high, the rental rate will fall, as is observed for a higher value of  $\theta$  in Figure 20. A fall in the rental rate of capital implies a fall in the market value of capital, ultimately leading to a fall in Tobin's  $q$  and market capitalization. Hence in the Calvo price setting framework, a positive correlation between market capitalization and growth is found for reasonable values of the price stickiness parameter  $\theta$  while a negative market capitalization-growth correlation is observed for very high values of  $\theta$ , as established in Table 12

For high as well as low values of  $\theta$ , inflation and growth are both driven by the TFP shock. From Figure 20 it is observed that for both  $\theta = 0.25$  and  $\theta = 0.85$ , inflation and growth follow two different time paths. As a result of this in Table 13, the two variables are not found to be significantly correlated throughout a range of different values of  $\theta$ .

### **I.5 Impulse response in Rotemberg model**

Like in the Calvo model, in the Rotemberg model too I first report the impulse response figures of the endogenous variables as a result of realization of the TFP, IST, MP and CQ shocks for baseline parametric values reported in Tables 10 and 11. The variables whose short run behaviours are investigated are market capitalization ( $mk$ ), output growth ( $yg$ ), inflation ( $infl$ ),

expected capital growth ( $kg$ ), Tobin's  $q$  ( $q$ ), real marginal cost ( $mc$ ), rental rate ( $r$ ), price adjustment cost measure ( $nu$ ) optimal price normalized by general price level ( $pstar$ ), consumption to capital ratio ( $ck$ ), economywide dividend to capital ratio ( $dk$ ). Like in the Calvo price setting framework, where the price distortionary effect was captured by  $s$ , in the Rotemberg framework this is captured by  $nu$ , which is expressed by the variable  $\nu_t$  in equation (135) in the Section IIIB2 where I discussed the Rotemberg price setting framework. A fall in  $nu$  signifies a rise in distortion due to higher price adjustment cost. As in the Rotemberg framework, all intermediate good firms are of the same kind, no distinction in the dividend to capital ratio is made, as opposed to the Calvo framework, where  $dk_1$  and  $dk_2$  stood for dividend to capital ratios of fix price and flex price firms respectively. Note that the following impulse responses are the result of a considerably high baseline value of the price adjustment cost parameter ( $\varphi = 178.76$ ).

Figures 24 and 25 represent the impulse response of each of the above mentioned variables due to a TFP shock.

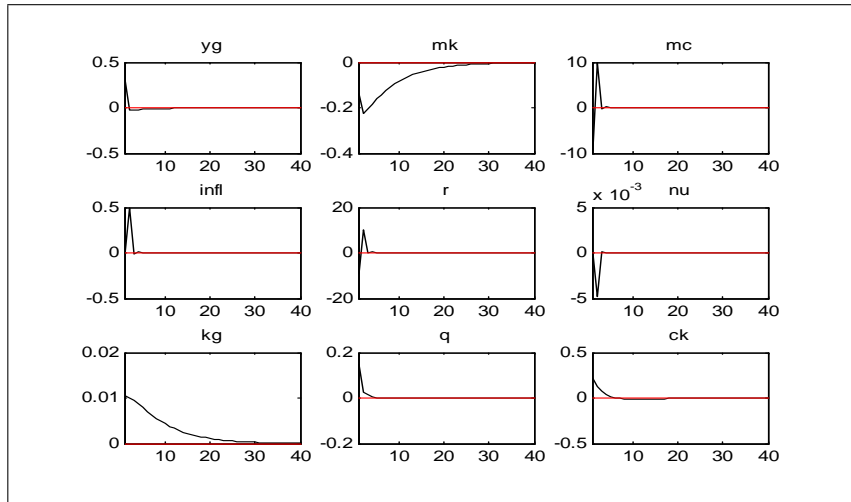


Figure 24: TFP impulse response for baseline parameters in Rotemberg framework

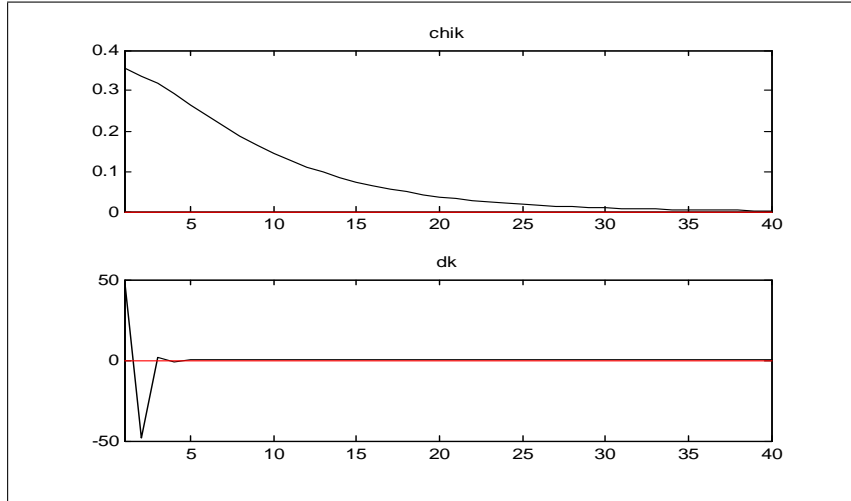


Figure 25: TFP impulse response for baseline parameters in Rotemberg framework

From Figures 24 and 25 it is clear that a positive TFP shock increases output growth  $yg$ , inflation  $infl$ , price dispersion  $s$ , expected capital growth  $kg$ , Tobin's  $q$ , consumption to capital ratio  $ck$ , investment to capital ratio  $chik$  and economywide dividend to capital ratio  $dk$ . On the other hand, due to a positive TFP shock, there is a fall in market capitalization  $mk$ , real marginal cost  $mc$  and rental rate  $r$ . Also there is a fall in  $nu$ , which signifies a rise in the distortionary effect of a price adjustment cost.

Thus, in a Rotemberg model, for a comparatively high baseline value of the price adjustment cost parameter  $\varphi$ , a positive TFP shock causes market capitalization ratio and growth to move in opposite directions in the short run although, the short run time paths followed by growth and inflation, are in the same direction. A positive TFP shock augments current output. A fall in the real marginal cost boosts the average mark up, which coupled with an increase in total output, increases the total economywide dividends. However, an increase in price adjustment cost signifies an adverse effect on dividends, leading to a fall in the demand for capital and hence the rental rate of capital.

Since the TFP shock follows an autoregressive process of the first order, a positive TFP shock in the current period implies a rise in output in the next period as well, which leads to an increase in present investment in physical capital. Also, consumers are risk averse and are willing to smooth out consumption over time. Hence an anticipated rise in future output and future consumption leads to a rise in present consumption as well. As a result of considerable increase in both consumption and investment by the household, there is fall in total demand for stocks, leading to a fall in the market capitalization. This, along with a rise in present output

as a result of a positive productivity shock, leads to a fall in the market capitalization to output ratio.

Figures 26 and 27 represent the impulse responses of each of the above mentioned variables due to an IST shock.

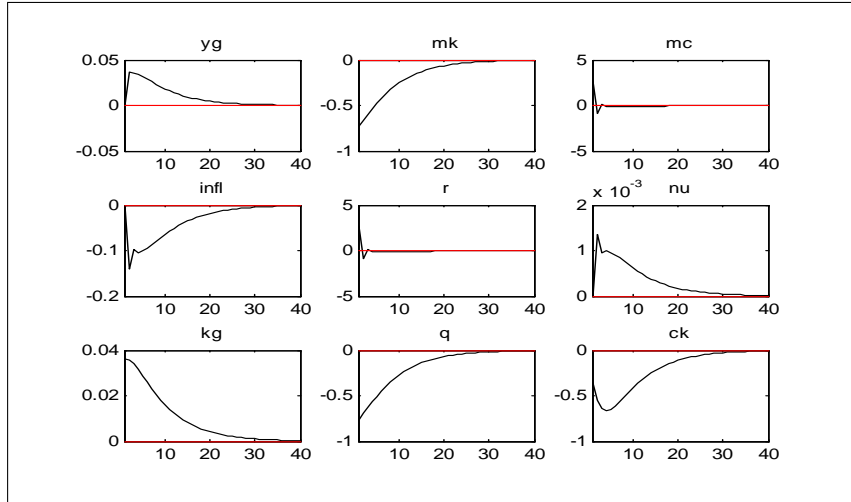


Figure 26: IST impulse response for baseline parameters in Rotemberg framework

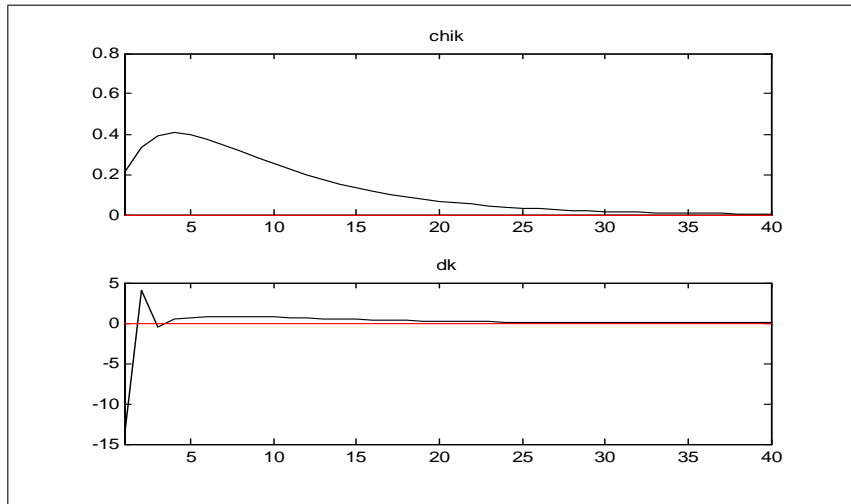


Figure 27: IST impulse response for baseline parameters in Rotemberg framework

From Figures 26 and 27 it is clear that a positive IST shock increases output growth *yg*, real marginal cost *mc*, rental rate *r*, expected capital growth *kg*, investment to capital ratio *chik* and *nu* (signifying a fall in the distortionary effect of a price adjustment cost). On the other hand, a positive IST shock leads to a fall in market capitalization *mk*, , inflation *infl*, Tobin's *q*, consumption to capital ratio *ck* and total dividend to capital ratio *dk*.

Hence for a high baseline value of the price stickiness parameter, due to a positive IST shock, market capitalization ratio and growth move in opposite directions in the short run. Market



capitalization ratio is affected in the period of realization of the shock, while growth is affected a period later. Also, due to a good IST shock, growth and inflation move in opposite directions as well. A good IST shock rises future capital stock, thereby augmenting capital growth and output growth in the next period. An IST shock also lowers the price adjustment cost, which encourages firms to produce more by demanding more capital, thereby increasing the rental rate of capital. A rise in the rental rate of capital contributes to a fall in total dividends. Also improvements in technological innovations specific to investment create an environment where it is more tempting to invest in physical capital, which is reflected in an increase in current physical investment. An increase in next period's output and consumption due to an IST shock increases the opportunity cost of consumption in the current period, lowering current consumption and current expenditure on stocks and driving up current investment on physical capital. A fall in the demand for financial assets contributes to the eventual decline in market capitalization ratio.

Figures 28 and 29 represent the impulse response paths of each of the above mentioned variables as a result of a MP shock.

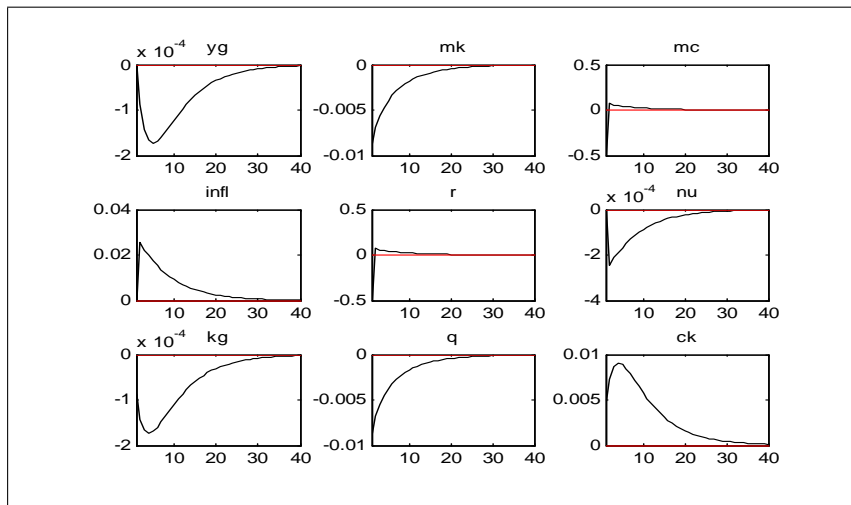


Figure 28: MP impulse response for baseline parameters in Rotemberg framework

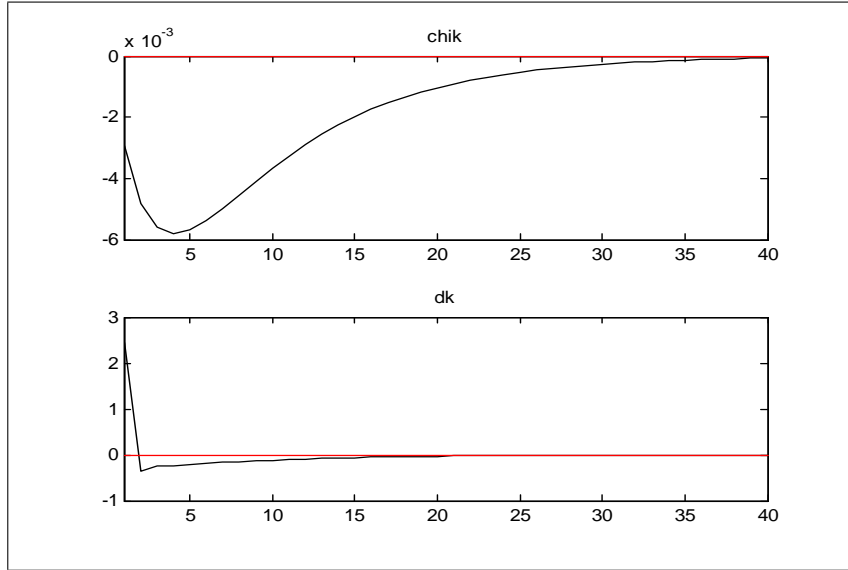


Figure 29: MP impulse response for baseline parameters in Rotemberg framework

From Figures 28 and 29 it is clear that a positive interest rate shock increases inflation  $infl$ , consumption to capital ratio  $ck$  and economywide dividend to capital ratio  $dk$ . and decreases output growth  $yg$ , market capitalization  $mk$ , real marginal cost  $mc$ , expected capital growth  $kg$ , Tobin's  $q$   $q$ , rental rate  $r$ ,  $nu$  (signifying a rise in the the distortionary effect of a price adjustment cost) and investment to capital ratio  $chik$ .

Therefore, for a high baseline value of the price stickiness parameter, a positive MP shock induces market capitalization ratio and growth to move in same directions in the short run, although growth and inflation follow opposite time paths as a result of a positive MP shock. Market capitalization ratio is affected in the period of realization of the shock, while growth is affected a period after. An increase in nominal interest rates slows down the economy, which is manifested in a reduction of current growth. A fall in the rental rate of capital contributes to a rise in total dividends. A rise in the nominal interest rate leads to more investments in the risk free bonds, leading to a reduction in investments in physical capital and demand for stocks. Demand for stocks also decrease along with the value of the Tobin's  $q$ , because of a fall in the market price of capital, brought about by a decrease in the rental rate. A fall in stock demand eventually diminishes the market capitalization ratio.

Figures 30 and 31 represent the impulse response path of each of the above mentioned variables as a result of a CQ shock.

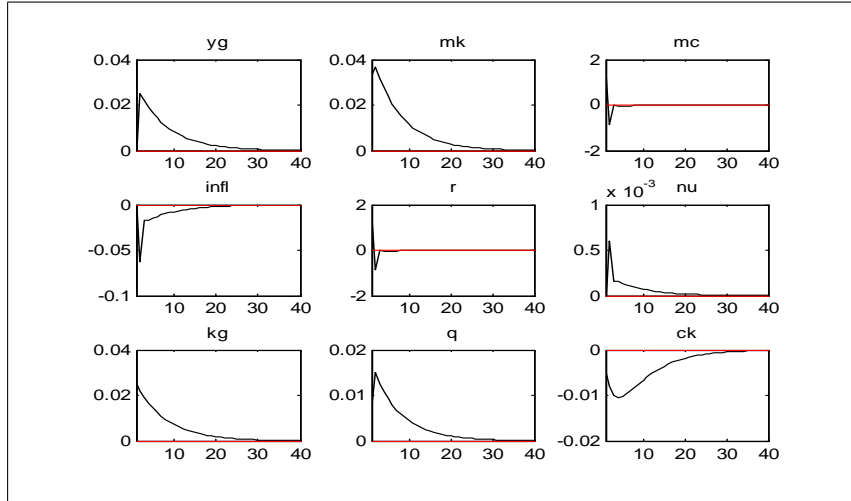


Figure 30: CQ impulse response for baseline parameters in Rotemberg framework

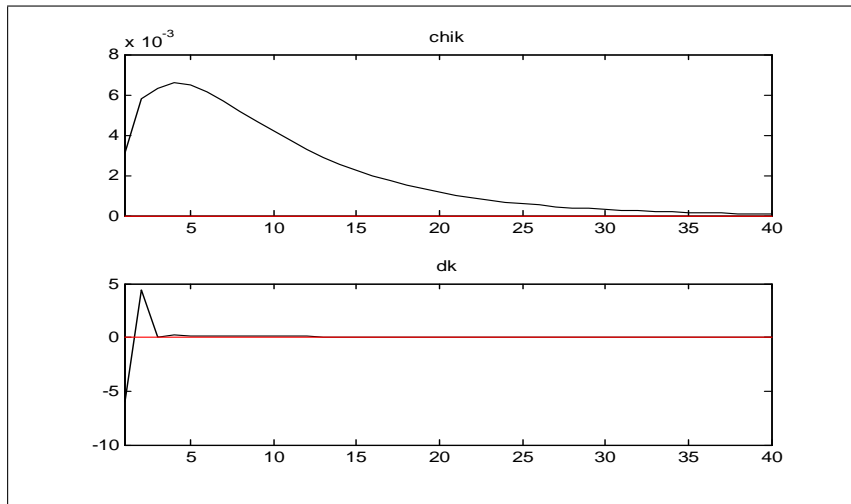


Figure 31: CQ impulse response for baseline parameters in Rotemberg framework

From Figures 30 and 31 it is clear that a good CQ shock increases output growth  $yg$ , market capitalization  $mk$ , real marginal cost  $mc$ , rental rate  $r$ ,  $nu$  (implying a fall in the distortionary effect of a price adjustment cost), expected capital growth  $kg$ , Tobin's  $q$   $q$  and investment to capital ratio  $chik$ . On the other hand, a positive CQ shock leads to a fall in inflation  $infl$ , consumption to capital ratio  $ck$  and total dividend to capital ratio  $dk$ .

A good CQ shock leading to a fall in the depreciation of capital induces market capitalization ratio and growth to move in the same direction, but growth and inflation to move in opposite directions in the short run. Market capitalization ratio is affected in the period in which the shock is realized, while growth is affected a period later. A fall in the depreciation rate increases future accumulated capital, thereby augmenting capital growth and output growth in the next period. An improvement in the quality of capital drives up the rental rate. This, coupled with

a rise in real marginal cost, contributes towards diminishing the total dividends of the firm.

A fall in depreciation of capital creates an environment where it is more attractive to invest in physical capital. This is reflected in an increase in total investments. Also, an increase in future capital signals increased future output and dividends, as a result of which consumers find it more profitable to increase their investments in financial assets. An increased investment in the stock market also occurs due to an increase in the present market value of capital, which, in turn, boosts up the market capitalization ratio.

Like in the Calvo price setting framework, for the Rotemberg framework, too, the initial impulse response analysis has been conducted with a reasonably high baseline value of the price distortion parameter. A high baseline value of the price stickiness parameter ( $\theta = 0.85$ ) in the Calvo price setting framework also corresponds to a considerably high value of the price adjustment cost parameter  $\varphi$  ( $\varphi = 178.76$ ). As in the Calvo price setting framework, here also I compare the baseline impulse responses with the ones obtained for a lower value of  $\varphi$ . Also, since the correlation between market capitalization and growth and the correlation between growth and inflation are much more sensitive to  $\varphi$  than to  $\gamma$ , as observed in Tables 12 and 13, I focus only on the change in short run dynamics for each of the variables with a change in  $\varphi$  from a low value to a high value. Since from Table 12 a highly significant correlation coefficient between market capitalization ratio and growth is observed for a low value of the price adjustment cost parameter at  $\varphi = 2.21$  (which corresponds to a price stickiness parameter value of  $\theta = 0.25$  in the Calvo price setting framework), it is worthwhile to check the impulse responses of the different variables for this low value of the price adjustment cost parameter as well. This is done in order to compare between the short run dynamics of the different variables for high and low values of the price distortion parameter, as was done in case of the Calvo price setting framework. Following is the impulse response analysis for  $\varphi = 2.21$ , keeping baseline values of all the other parameters unchanged.

Figures 32 and 33 represent the impulse responses to a TFP shock for a low level of price adjustment cost.

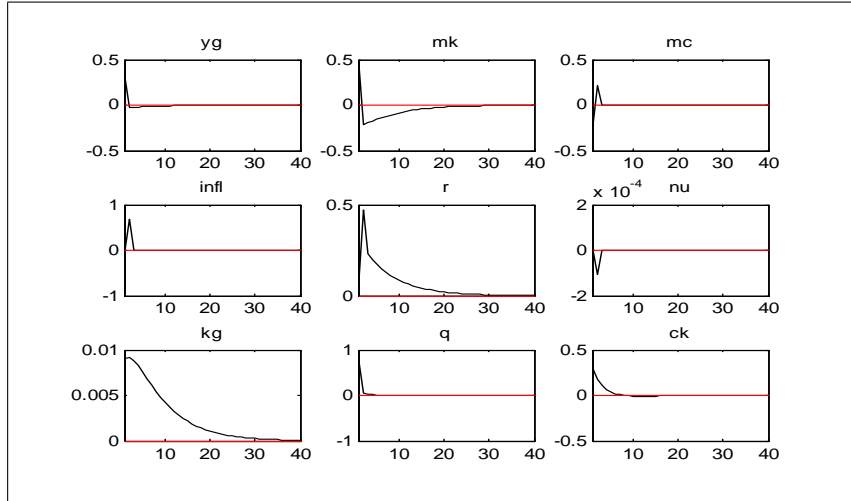


Figure 32: TFP impulse response in Rotemberg framework for low level of price adjustment cost

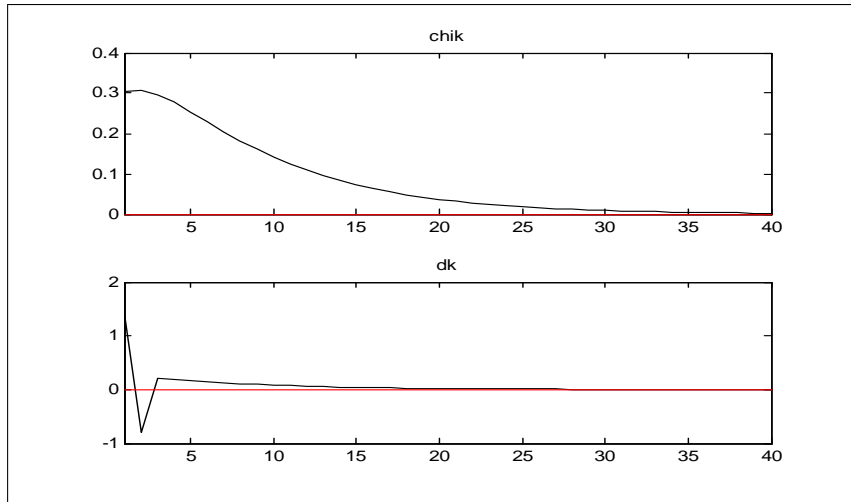


Figure 33: TFP impulse response in Rotemberg framework for low level of price adjustment cost

From Figures 32 and 33 it is clear that a positive TFP shock increases output growth  $yg$ , market capitalization  $mk$ , inflation  $infl$ , rental rate  $r$ , expected capital growth  $kg$ , Tobin's  $q$   $q$ , consumption to capital ratio  $ck$ , investment to capital ratio  $chik$  and total dividend to capital ratio  $dk$ . On the other hand, as a result of a positive TFP shock, there is a fall in real marginal cost  $mc$  as well as a fall in  $nu$  (implying a rise in the distortionary effect of price adjustment cost).

Thus, for a relatively low level of price adjustment cost, market capitalization ratio and growth move in the same direction in the short run as a result of a positive TFP shock. Also, a good TFP shock induces growth and inflation to move in the same direction as well. A positive

TFP shock increases total output and dividends in the present period. A fall in the real marginal cost, due to a positive TFP shock, along with the increase in total output, also contributes to an increase in total dividends, which in turn, leads to increased demand for capital and ultimately drives up the rental rate.

Since the TFP shock follows an autoregressive process, a positive TFP shock signifies a rise in output in the next period as well, which encourages investors to increase their present investment in physical capital. Also, consumers being risk averse and willing to smooth out consumption over time, an anticipated rise in future output and future consumption leads to a rise in present consumption as well. However, with lower price adjustment cost, although there is increase in both consumption and investment in physical capital, a fall in asset demand does not occur. A rise in the rental rate due to a positive TFP shock also signifies an increase in the market value of capital, which also contributes to an increase in Tobin's  $q$  and an increased asset demand. Like in the Calvo model, in the Rotemberg framework also, for a lower parametric value of the price distortion, the positive income effect of a good TFP shock gets translated into an increase in the households' demand for shares. This, however, does not happen for a considerably higher value of the price imperfection parameter. Increased asset demands can also be linked to the autoregressive nature of the shock, because of which an increase in present dividends signifies an increase in future dividends as well. This increase in demand for assets ultimately drives up in the market capitalization ratio.

Figures 34 and 35 represents the impulse responses to an IST shock for a low level of price adjustment cost.

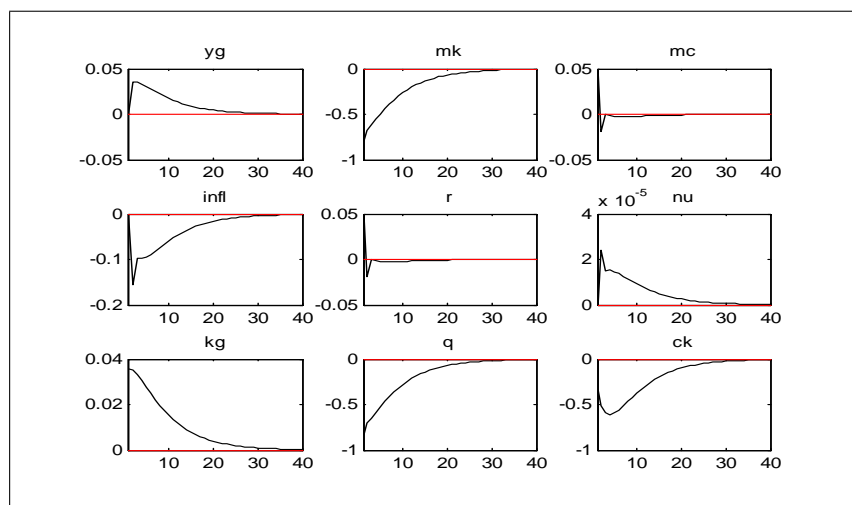


Figure 34: IST impulse response in Rotemberg framework for low level of price adjustment cost

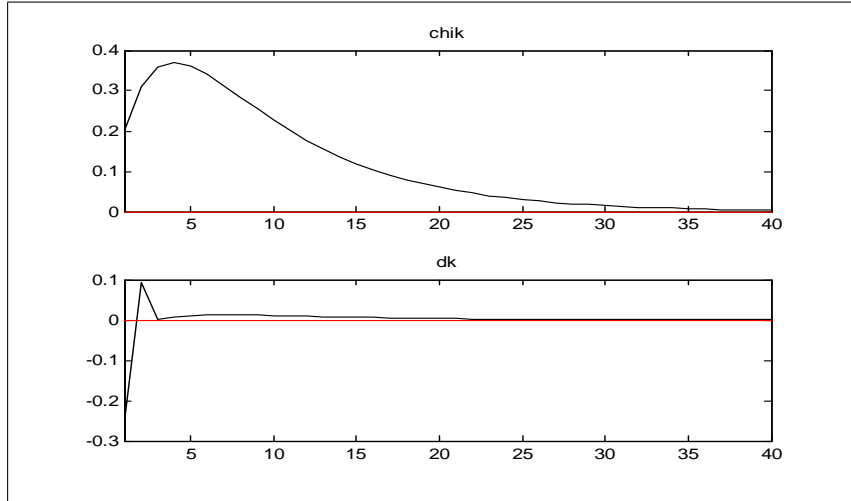


Figure 35: IST impulse response in Rotemberg framework for low level of price adjustment cost

From Figures 36 and 37 it is clear that a positive IST shock increases output growth  $yg$ , real marginal cost  $mc$ , rental rate  $r$ ,  $nu$  (signifying a fall in the distortionary effect due to price adjustment cost), expected capital growth  $kg$  and investment to capital ratio  $chik$ . On the other hand, a positive IST shock leads to a fall in market capitalization  $mk$ , , inflation  $infl$ , Tobin's  $q$   $q$  and total dividend to capital ratio  $dk$ .

Hence for a low level of price adjustment cost, a positive IST shock induces market capitalization ratio and growth as well as growth and inflation to move in opposite directions. A good IST shock augments future capital stock, leading to a rise in capital growth and output growth in the next period. Market capitalization ratio is affected in the period of realization of the shock, while growth is affected a period later. There is also an increase in the rental rate of capital, contributing to a fall in the total dividends. As with high price adjustment cost, with low price adjustment cost also, an IST shock lowers consumption and augments investment. As technological innovations specific to physical investment make it worthwhile for investors to invest more in physical capital, a considerable increase in current physical investment is observed. Also since there is increase in next period's anticipated output and consumption, the present opportunity cost of consumption goes up, thereby diminishing current consumption and current demand for stocks and increasing current investment in physical capital. A decline in the demand for financial assets lead to a fall in market capitalization ratio.

Figures 35 and 36 represents the impulse response to an MP shock for a low level of price adjustment cost.

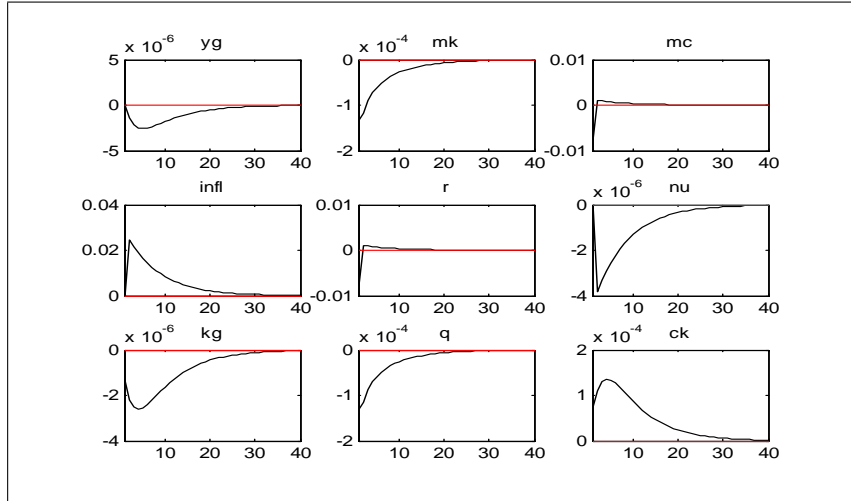


Figure 36: MP impulse response in Rotemberg framework for low level of price adjustment cost

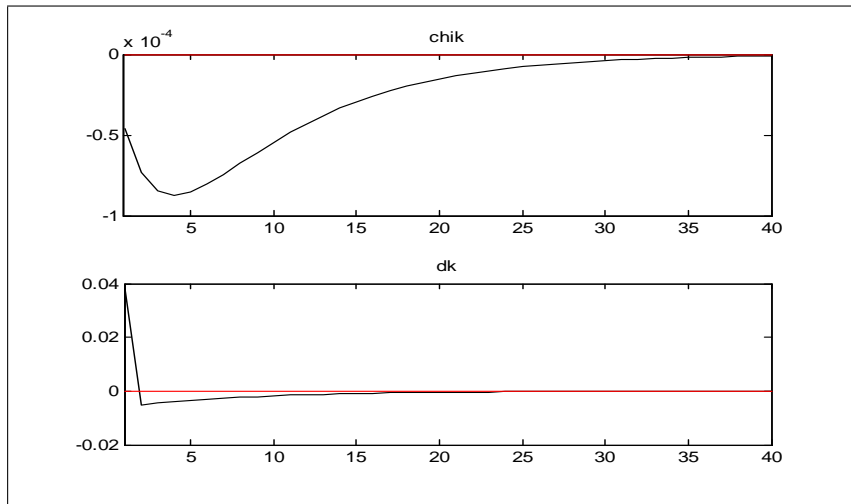


Figure 37: MP impulse response in Rotemberg framework for low level of price adjustment cost

From Figures 36 and 37 it is evident that as in case of a high price adjustment cost, for a low levels of price adjustment cost also, a positive interest rate shock increases inflation  $infl$ , consumption to capital ratio  $ck$  and total dividend to capital ratio  $dk$ . However, due to a positive interest rate shock, there is a fall in output growth  $yg$ , market capitalization ratio  $mk$ , real marginal cost  $mc$ , expected capital growth  $kg$ , Tobin's  $q$ , rental rate  $r$  and investment to capital ratio  $chik$  and  $nu$  (rise in the distortionary effect as a result of price adjustment cost).

Therefore, for a low parametric value of the price adjustment cost parameter, a positive interest rate shock induces market capitalization ratio and growth to move in the same direction, but growth and inflation to move in opposite directions in the short run. Market capitalization ratio is affected in the period of realization of the shock, while growth is affected a period after. An increase in nominal interest rate slows down the economy, reducing current growth and firms'



capital demand. A decreased demand for capital leads to a fall in the rental rate. A rise in the nominal interest rates also leads to increased investment in the risk free bonds, driving down investments in physical capital and demand for stocks. Also a fall in the rental rate implies a decrease in the market value of capital, which coupled with a fall in stock demand, eventually leads to a decline in the market capitalization ratio.

Figures 38 and 39 represents the impulse responses to a CQ shock for a low parametric value of the price adjustment cost.

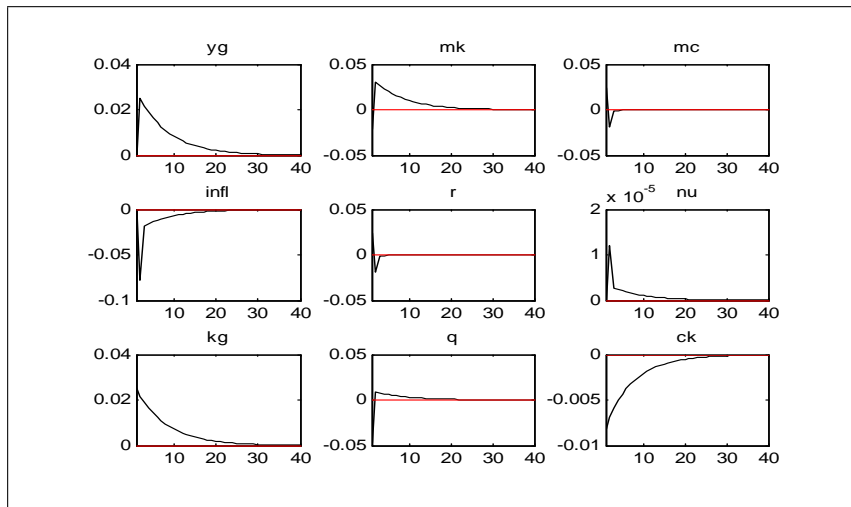


Figure 38: CQ impulse response in Rotemberg framework for low level of price adjustment cost

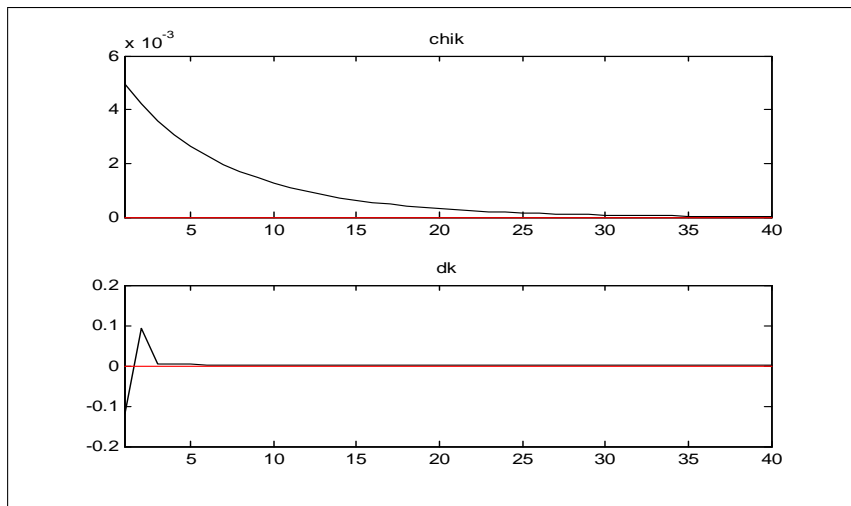


Figure 39: CQ impulse response in Rotemberg framework for low level of price adjustment cost

From Figures 38 and 39 it is clear that a good CQ shock, i.e. a fall in the depreciation rate of capital, increases output growth  $yg$ , market capitalization  $mk$ , expected capital growth  $kg$ , rental rate  $r$ ,  $nu$  (rise in price adjustment cost distortionary effect), real marginal cost  $mc$  and investment to capital ratio  $chik$ . On the other hand, due to a positive CQ shock, there is fall in

inflation  $infl$ , consumption to capital ratio  $ck$ , Tobin's  $q$  and economywide dividend to capital ratio  $dk$ .

As a result of a fall in the depreciation rate of capital, market capitalization ratio and growth move in the same direction, but growth and inflation to move in opposite directions in the short run when there is a low level of the price adjustment cost. Market capitalization ratio is affected in the period of realization of the shock, but growth is affected a period afterwards. A fall in depreciation of capital augments future capital accumulation, thereby increasing next period's capital growth and output growth. There is also a rise in the rental rate and real marginal cost, both of which have adverse effects on the total dividend. A fall in the depreciation rate of physical capital leads to an increase in total investments. Also, an increase in future capital signals an increase in output and dividends in the next period, as a result of which consumers find it more worthwhile to increase their investment in shares. This, along with a rise in the present market value of capital because of an increased rental rate, drives up the current market capitalization ratio.

Before comparing the impulse response graphs for high and low values of the price adjustment cost parameter and analyzing why there is a change in the short run dynamics of market capitalization ratio and growth with increase in the price adjustment cost parameter, I look into the relative contributions of the four different shocks towards influencing the short run fluctuations in each of the above mentioned variables. The variance decomposition of the effect of the four shocks on each of these variables is captured by Table 19 for a low value of the price adjustment cost parameter ( $\varphi = 2.21$ ) as well as a high value of the price adjustment cost parameter ( $\varphi = 178.76$ ).<sup>36</sup>

From Table 19, it is evident that for  $\varphi = 2.21$ , TFP is the main determinant of output growth, market capitalization, inflation, price distortion, Tobin's  $q$ , real marginal cost, rental rate, investment to capital ratio and dividend to capital ratio. For expected capital growth, however, both shocks play important roles, the influence of TFP being 34.45%, while that of IST being a bit higher at 45.49%. Also for consumption to capital ratio, the influence of both TFP and IST shocks are important. 78.07% of the fluctuations in consumption to capital ratio is influenced by the TFP shock, while 20.02% is influenced by the IST shock. The relative influence of the shocks on the different variables remain almost similar throughout the range of

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<sup>36</sup>Table 19 can be found in the appendix.

the price adjustment cost parameter  $\varphi \in (2.21, 58.25)$ .

For  $\varphi = 96.15$ , output growth, inflation, price distortion, real marginal cost, rental rate, investment to capital ratio and dividend to capital ratio are influenced by TFP, whereas IST shock is the main influence only in case of Tobin's  $q$ . For market capitalization ratio, expected capital growth and consumption to capital ratio, however, both shocks play important roles. For market capitalization, TFP determines 46.21% and IST determine 53.64% of its total fluctuations. For expected capital growth, TFP explains 38.14% of its fluctuations, while IST explains 43.38%. In case of consumption to capital ratio, TFP determines 61.26%, while IST explains 38.73% of its total fluctuations. Hence, like in the Calvo price setting framework, here also the importance of an IST shock increases strikingly for determining the dynamics of market capitalization ratio and Tobin's  $q$ , as the price distortion parameter changes from a low value to a high value. The relative influence of the shocks remains almost identical to this for  $\varphi \geq 96.15$ .

Also, just as in the Calvo model, in the Rotemberg model as well, TFP and IST are observed to be the two most important shocks for high as well as low values of the price distortion parameter. I next compare for a low value of  $\varphi$  ( $\varphi = 2.21$ ) and a high value of  $\varphi$  ( $\varphi = 178.76$ ), the impulse response graphs of the relevant variables as a result of the realization of a TFP and an IST shock. The comparison of the short run behaviour of the different variables for a high and low value of  $\varphi$  is demonstrated in Figures 40 and 41 for a TFP shock and Figures 42 and 43 for an IST shock. In each of the following figures, the black line and the red line represent short run impulse response paths of a variable for  $\varphi = 2.21$  and  $\varphi = 178.76$  respectively.

It is observed that the impulse responses remain almost identical for the price adjustment cost parameter range  $\varphi \in (2.21, 58.25)$  which corresponds to a range of the price rigidity parameter  $\theta \in (0.25, 0.75)$  in the Calvo price setting framework. Only when the price rigidity parameter exceeds  $\varphi = 96.15$ , which corresponds to  $\theta = 0.80$ , the impulse responses start to change, with short run dynamics of the variables remaining almost same for  $\varphi > 96.15$ . Since the impulse response behaviours of the variables across different values of the price distortion parameters remain very similar for the Calvo and Rotemberg set ups, in the latter set up also the impulse response figures can be divided into two categories: impulse responses for  $\varphi \in (2.21, 58.25)$  and impulse responses for  $\varphi > 96.15$ . Thus in the Rotemberg framework, the black line in Figures represent in effect the short run dynamics of the variables for the reasonably large range of the price adjustment cost parameter i.e.  $\varphi \in (2.21, 58.25)$  and the red line can be interpreted as the

impulse response of each of the variables for a relatively high range of the price adjustment cost parameter, i.e.  $\varphi \geq 96.15$ .

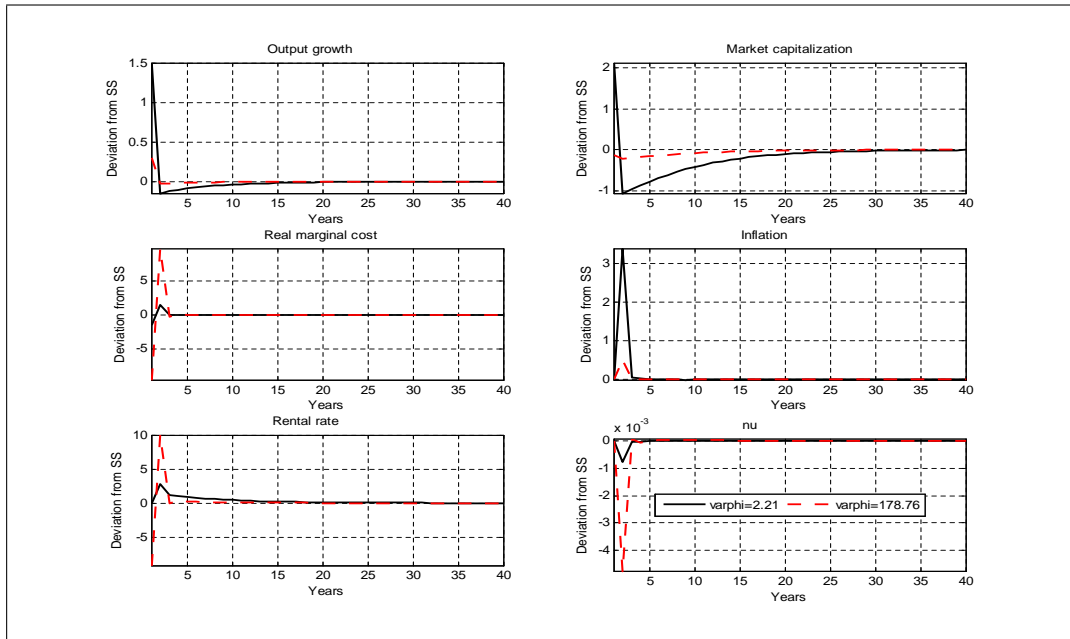


Figure 40: TFP impulse response comparison in Rotemberg framework

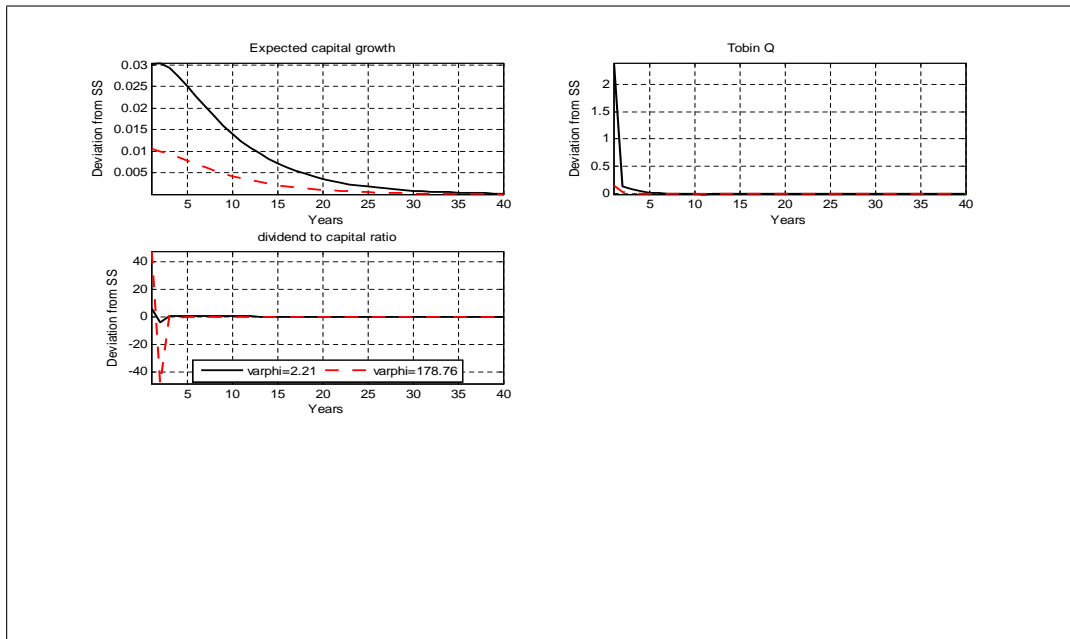


Figure 41: TFP impulse response comparison in Rotemberg framework

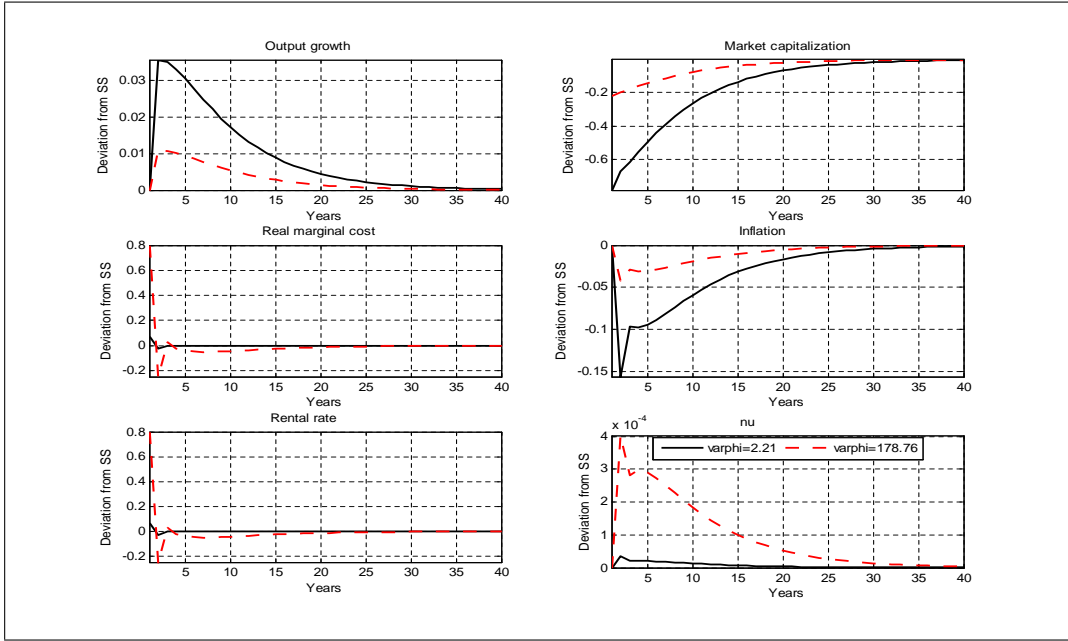


Figure 42: IST impulse response comparison in Rotemberg framework

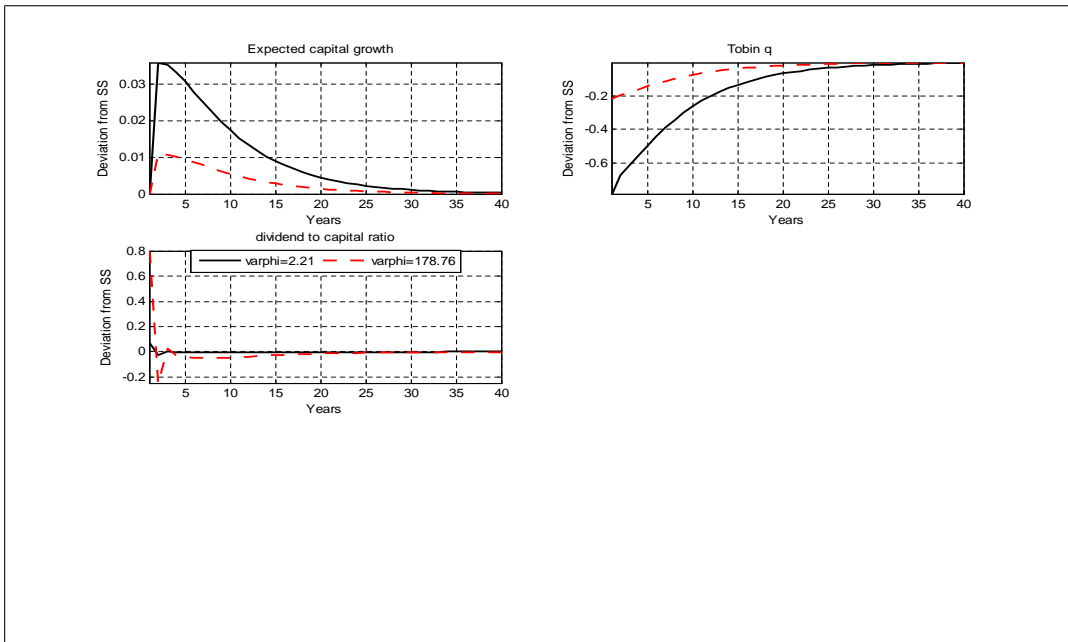


Figure 43: IST impulse response comparison in Rotemberg framework

Like in the Calvo framework, in the Rotemberg framework also the impact effects of both TFP and IST shocks are slightly magnified for output growth, market capitalization, inflation, expected capital growth and Tobin's q when  $\varphi = 2.21$ , which corresponds to  $\theta = 0.25$ , compared to when  $\varphi = 178.76$ , which corresponds to  $\theta = 0.85$ . For real marginal cost, rental rate, total dividend to capital ratio and the variable  $nu$ , which captures the distortionary effect of a price adjustment cost, however, the effects of both shocks are slightly greater when  $\varphi = 178.76$ ,

compared to when  $\varphi = 2.21$ .

It is clear from Figure 40 that in the Rotemberg price setting framework, for reasonable range of values of the price adjustment cost parameter, a TFP shock reduces the real marginal cost, leading to a rise in average markup. This, coupled with an increased output due to a positive TFP shock, leads to a rise in total dividends, thereby increasing the firm's incentive to produce more. This implies an increase in capital demand, resulting in an eventual rise in the rental rate. From Table 19 it is evident that the real marginal cost and the rental rate of capital are mainly influenced by a TFP shock for high and low values of the price adjustment cost parameter. Following a favourable TFP shock, an increase in market value of capital, as a result of a rise in the rental rate, leads to an increase in market capitalization and Tobin's  $q$ . This explains the positive market capitalization - growth correlation for reasonable values of  $\varphi$  as pointed out in Table 13.

Also from Figure 40, it follows that for very high levels of price adjustment cost, real marginal cost falls as a result of a positive TFP shock. But the rental rate of capital is also observed to fall considerably. A high value of  $\varphi$  implies an increase in the economywide optimally set their price, because of which there is a fall in demand for intermediate goods, coming from the final good producing firms. This reduces the demand for capital, which eventually drives down the rental rate. Thus, an increase in the price adjustment cost lowers the economywide rental rate. This result is similar to that in a Calvo framework, where an increase in price stickiness decreases the rental rate. A fall in the market value of capital diminishes total value of assets, leading to a fall in Tobin's  $q$  and market capitalization ratio. This explains the negative market capitalization - growth correlation for very high values of  $\varphi$  as pointed out in Table 13.

The short run dynamics of market capitalization and Tobin's  $q$  are influenced by a TFP shock,  $\epsilon$ , as observed from Table 19 and are augmented by this shock for reasonable values of  $\varphi$ . This is represented in Figure 40 and Figure 41. Also throughout different values of  $\varphi$  TFP shock remains the main driving force in bringing about short run fluctuations of output growth; the latter always increasing as a result of a positive TFP shock. This is evident from Figure 40. For a very high value of the price adjustment cost parameter, however, market capitalization and Tobin's  $q$  are influenced by the IST shock. From Figures 42 and 43 it is observed that both market capitalization and Tobin's  $q$  decrease as a result of an IST shock for a very high value of  $\varphi$ , leading to a fall in the market capitalization - growth correlation for considerably higher

values of  $\varphi$ .

For high as well as low values of  $\varphi$ , inflation and growth are both driven by the TFP shock. From Figure 40 it is observed that both for high and low values of  $\varphi$ , growth and inflation move in the same direction in the short run, although the movements in the two variables do not seem much correlated.

## I.6 Impact of different shocks for different degrees of price stickiness

The variance decompositions of the influence of different shocks and the impulse response of the relevant variables to all these different shocks is summarised in Table 21. It is evident from the variance decomposition analysis that all variables are influenced by either TFP or IST shocks. A (+) sign indicates a one time rise, whereas a (-) sign indicates a one time fall in a variable due to realization of a shock, i.e. the impact effect on a variable of its most dominant shock is captured by the (+) and (-) signs. Since the impulse responses and variance decompositions are found to be very similar for a range of  $\theta \in (0.25, 0.75)$  in the Calvo setting, which corresponds to a range of  $\varphi \in (2.21, 58.25)$  in the Rotemberg setting,  $\theta = 0.25$  i.e.  $\varphi = 2.21$  represent values of these nominal rigidity parameters within a reasonable range in the Table 20, while a considerably higher value of these parameters is represented by  $\theta = 0.80$  i.e.  $\varphi = 96.15$ .<sup>37</sup>

In both Calvo and Rotemberg price setting frameworks, for reasonable values of nominal rigidity parameters, both market capitalization and growth are influenced by a TFP shock and both these variables are augmented by this shock. However, for a very high value of the price imperfection parameter, output growth is influenced by a TFP shock, but market capitalization is driven by an IST shock instead of a TFP shock. For a considerably high nominal rigidity parameter value, growth increases due to the TFP shock but market capitalization falls due to an IST shock. This gives rise to a positive correlation between market capitalization and growth for reasonable values of the price imperfection parameter, but a negative correlation between market capitalization and growth for very high values of this parameter.

Thus it is observed that as a result of realization of all four shocks together, although market capitalization and growth move in opposite directions for a very high value of the nominal rigidity parameter, for reasonable values of the nominal rigidity parameter, however, both these variables move in the same direction.

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<sup>37</sup>Table 20 can be found in the appendix.

Growth depends on the price dispersion term  $s_t$  in the Calvo framework and in the Rotemberg framework, growth depends on  $\nu_t$  (a term that depends negatively on the price adjustment cost).

From equation (137) growth in Calvo price setting framework is given by

$$yg_t = \epsilon_t kg_{t-1} s_{t-1} (\epsilon_{t-1} s_t)^{-1}$$

For  $\theta = 0.25$  and  $\theta = 0.80$ , growth  $yg_t$  in the Calvo framework is driven by the TFP shock and is increased as a result of realization of this shock. Growth is inversely related to the price dispersion term  $s_t$ . The latter is also driven by the TFP shock and is increased as a result of it for all values of  $\theta$ . Also in the above expression for growth, the TFP shock  $\epsilon_t$  is directly related to output growth  $yg_t$  and hence a positive TFP shock increases growth. But the rise in growth is checked off to some extent by a rise in price dispersion due to a positive TFP shock. The net result, however, is still an increase in growth due to a TFP shock for all possible values of  $\theta$ .

From equation (142) growth in Rotemberg price setting framework is given by

$$yg_t = \nu_t kg_{t-1} \epsilon_t (\epsilon_{t-1} \nu_{t-1})^{-1}$$

For  $\varphi = 2.21$  and  $\varphi = 96.15$ , growth in the Rotemberg framework also is driven by the TFP shock and is increased by this shock. Growth is directly related to the term  $\nu_t$  (that depends negatively on price adjustment cost) and the TFP shock  $\epsilon_t$ . For all values of  $\varphi$ ,  $\nu_t$  is dominated by the TFP shock and is decreased as a result of it because higher productivity signifies higher output and higher adjustment cost. However the positive effect that a TFP shock has on growth dominates the negative effect on growth due to a rise in price adjustment cost, so much so that the realization of a TFP shock leads to an increase in growth for all different values of  $\varphi$ .

Market capitalization depends on Tobin's q i.e.  $q_t$  and expected capital growth i.e.  $kg_t$  along with price dispersion term  $s_t$  in the Calvo framework and adjustment cost term  $\nu_t$  in the Rotemberg framework. In both frameworks, the TFP shock enters the market capitalization expression and is inversely related to market capitalization.

From equation (140) market capitalization in Calvo framework is given by

$$mk_t = q_t . kg_t . s_t . \epsilon_t^{-1}$$



For  $\theta = 0.25$ , which effectively represents all reasonable values of the price stickiness parameter, market capitalization in Calvo price setting framework is dominated by a TFP shock and increases as a result of this shock. Apparently, since market capitalization  $mk_t$  is inversely related to TFP shock  $\epsilon_t$ , a TFP shock might seem to adversely affect market capitalization. However, TFP shock is also the main driving force behind the short run dynamics of Tobin's q i.e.  $q_t$  and price dispersion i.e.  $s_t$ ; both variables being augmented as a result of this shock. TFP, however, does not play much role in determining the short run dynamics of expected capital growth  $kg_t$ . Thus, as a result of the TFP shock, the negative effect of this shock on the market capitalization expression is off set by the combined effect of an increase in Tobin's q and price dispersion, the net result being an increase in market capitalization due to a TFP shock for  $\theta = 0.25$ .

For  $\theta = 0.80$ , i.e. for a considerably high value of the price stickiness parameter, market capitalization in Calvo price setting framework is dominated by an IST shock and decreases as a result of this shock. Apparently the IST shock does not enter directly into the expression of market capitalization, but it is the main driving force for expected capital growth i.e.  $kg_t$  and Tobin's q i.e.  $q_t$ , both of which fall as a result of this shock. Price dispersion, however, does not depend on the IST shock for a high value of the price stickiness parameter. Thus the combined effect of a decrease in Tobin's q and expected capital growth leads to a fall in market capitalization for a very high value of  $\theta$ .

From equation (146) market capitalization in Rotemberg framework is given by

$$mk_t = q_t.kg_t.(\epsilon_t\nu_t)^{-1}$$

For  $\varphi = 2.21$ , which in effect represents a plausible range of values for the price adjustment cost parameter, market capitalization in Rotemberg price setting framework is dominated by a TFP shock and increases as a result of this shock. Market capitalization depends on Tobin's q  $q_t$  and price adjustment cost expression  $\nu_t$ . A TFP shock leads to a rise in Tobin's q and a fall in  $\nu_t$  (rise in adjustment cost). Market capitalization also depends on expected capital growth which is not driven by the TFP shock for reasonable values of the price imperfection parameter as in the Calvo framework. Thus, as a result of the TFP shock, the negative effect of this shock on the market capitalization expression is off set by the combined effect of an increase in Tobin's

$q$  and a fall in  $\nu_t$ , the net result being an increase in market capitalization due to a TFP shock for plausible values of the adjustment cost parameter.

For  $\varphi = 96.15$ , i.e. for a very high value of the adjustment cost parameter, market capitalization in Rotemberg price setting framework is dominated by an IST shock and decreases as a result of this shock. As in the Calvo framework, here also the IST shock does not enter directly into the expression of market capitalization, but it is the main driving force for expected capital growth and Tobin's  $q$ , both of which fall as a result of this shock. The price adjustment cost term  $\nu_t$ , however, does not depend on the IST shock. Thus the combined effect of a decrease in Tobin's  $q$  and a decrease in expected capital growth leads to a fall in market capitalization for a very high value of the adjustment cost parameter  $\varphi$ .

Hence it is observed that in both price setting frameworks, for reasonable values of the nominal rigidity parameter, market capitalization is driven by a TFP shock and is augmented by this shock, whereas for a high value of the nominal rigidity parameter, market capitalization is driven by an IST shock and decreases as a result of this shock.

Thus in both Calvo and Rotemberg price setting frameworks, the short run dynamics of market capitalization are quite different for a very high value and for a comparatively lower value of the nominal rigidity parameter. Among the variables influencing market capitalization, only Tobin's  $q$  follows the exact same kind of dynamics as market capitalization. For all the other determinants of market capitalization, short run behaviour is almost identical regardless of high or low values of the nominal rigidity parameter.

## **I.7 Model - data comparison**

I compare the market capitalization - growth and growth - inflation correlation coefficient calculated from the Calvo price setting framework and the Rotemberg price setting framework with that obtained from the data. When the correlation coefficients obtained from the data are represented in the form of a quartile distribution, I find that for specific values of the price rigidity parameters, the model can reproduce the correlation coefficient values in the data belonging to different quartiles. For this purpose I take all the different values of the market capitalization - growth correlation coefficients and the growth - inflation correlation coefficients and report the first quartile ( $Q_1$ ), second quartile ( $Q_2$ ), third quartile ( $Q_3$ ), an upper fence and a lower fence of these correlation coefficient values in order to compare them with those corresponding to the

different price rigidity parameter values, as obtained from the model. This is done in Tables 21, 22, 23 and 24.

In these tables, 75% of all countries in the data have a correlation coefficient greater than the value corresponding to  $Q_1$ , 50% have a correlation coefficient greater than that corresponding to  $Q_2$  and 25% have a correlation coefficient greater than the value corresponding to  $Q_3$ . The upper fence is given by

$$\text{Upper Fence} = Q_3 + 1.5(\text{inter quartile range}) \quad (191)$$

and the lower fence is given by

$$\text{Lower Fence} = Q_1 - 1.5(\text{inter quartile range}) \quad (192)$$

where inter quartile range is the difference between  $Q_3$  and  $Q_1$ .

In Tables 21-24 the market capitalization - growth correlation coefficient is denoted by  $r_{mk,yg}$  and the growth - inflation correlation coefficient is denoted by  $r_{yg,infl}$ .

Table 21 compares the market capitalization - growth correlation coefficient calculated from the Calvo price setting framework with that obtained from the data.<sup>38</sup> All other baseline parametric values remaining the same, for  $\theta = 0.76$ , the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_1$  of the values of  $r_{mk,yg}$  as obtained from the data. Similarly, for  $\theta = 0.72$ , the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_2$  of the values of  $r_{mk,yg}$  as obtained from the data and for  $\theta = 0.70$ , the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_3$  of the values of  $r_{mk,yg}$  as obtained from the data. The upper fence of the values of  $r_{mk,yg}$  obtained from the data corresponds to the value of  $r_{mk,yg}$  for  $\theta = 0.50$  of the model and the lower fence of the values of  $r_{mk,yg}$  obtained from the data is closest to the value of  $r_{mk,yg}$  for  $\theta = 0.79$  of the model.

Table 22 compares the growth - inflation correlation coefficient calculated from the Calvo price setting framework with that obtained from the data.<sup>39</sup> All parameters remaining at their baseline values, for  $\theta = 0.75$ , the value of  $r_{yg,infl}$  obtained from the model is closest to  $Q_1$  of the values of  $r_{yg,infl}$  that was obtained from the data. Similarly for  $\theta = 0.73$ , the value of  $r_{yg,infl}$

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<sup>38</sup>Table 21 can be found in the appendix.

<sup>39</sup>Table 22 can be found in the appendix.

obtained from the model is closest to  $Q_2$  of the values of  $r_{yg,inf l}$  as obtained from the data and for  $\theta = 0.70$ , the value of  $r_{yg,inf l}$  obtained from the model is closest to  $Q_3$  of the values of  $r_{yg,inf l}$  as obtained from the data. The upper fence of the values of  $r_{yg,inf l}$  obtained from the data corresponds to the value of  $r_{yg,inf l}$  for  $\theta = 0.20$  of the model and the lower fence of the values of  $r_{yg,inf l}$  obtained from the data is closest to the value of  $r_{yg,inf l}$  for  $\theta = 0.85$  of the model.

Table 23 compares the market capitalization - growth correlation coefficient calculated from the Rotemberg price setting framework with that obtained from the data.<sup>40</sup> All other baseline parametric values remaining the same, for  $\varphi = 58.25$  ( $\theta = 0.75$ ), the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_1$  of the values of  $r_{mk,yg}$  as obtained from the data. For  $\varphi = 44.77$  ( $\theta = 0.72$ ), the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_2$  of the values of  $r_{mk,yg}$  which was obtained from the data and for  $\varphi = 38$  ( $\theta = 0.70$ ), the value of  $r_{mk,yg}$  obtained from the model is closest to  $Q_3$  of the values of  $r_{mk,yg}$  as obtained from the data. Similarly, the upper fence of the values of  $r_{mk,yg}$  obtained from the data matches the value of  $r_{mk,yg}$  for  $\varphi = 8.79$  ( $\theta = 0.48$ ) of the model and the lower fence of the values of  $r_{mk,yg}$  obtained from the data is closest to the value of  $r_{mk,yg}$  for  $\varphi = 8.79$  ( $\theta = 0.48$ ) of the model.

Table 24 compares the growth - inflation correlation coefficient calculated from the Rotemberg price setting framework with that obtained from the data.<sup>41</sup> All other parameters remaining at their baseline values, for  $\varphi = 58.25$  ( $\theta = 0.75$ ), the value of  $r_{yg,inf l}$  obtained from the model is closest to  $Q_1$  of the values of  $r_{yg,inf l}$  as obtained from the data. For  $\varphi = 53.21$  ( $\theta = 0.74$ ), the value of  $r_{yg,inf l}$  obtained from the model is closest to  $Q_2$  of the values of  $r_{yg,inf l}$  that was obtained from the data and for  $\varphi = 38$  ( $\theta = 0.70$ ), the value of  $r_{yg,inf l}$  obtained from the model is closest to  $Q_3$  of the values of  $r_{yg,inf l}$  as obtained from the data. The upper fence of the values of  $r_{yg,inf l}$  obtained from the data is closest to the value of  $r_{yg,inf l}$  for  $\varphi = 1.56$  ( $\theta = 0.20$ ) of the model and the lower fence of the values of  $r_{yg,inf l}$  obtained from the data is closest to the value of  $r_{yg,inf l}$  for  $\varphi = 178.76$  ( $\theta = 0.85$ ) of the model.

Thus for both price setting frameworks of Calvo and Rotemberg, there exists specific values of the price rigidity parameter ( $\theta$  in case of the Calvo framework and  $\varphi$  in case of the Rotemberg framework) for which the market capitalization - growth and the growth - inflation correlation coefficients can accurately match the first quartile, the second quartile, the third quartile, the upper fence and the lower fence of the same correlation coefficient values as obtained from the

<sup>40</sup>Table 23 can be found in the appendix.

<sup>41</sup>Table 24 can be found in the appendix.

data.

## **J. Main findings from New-Keynesian model**

Thus in this section I mainly look into the short run behaviour of market capitalization ratio and growth due to different aggregate macroeconomic shocks in a New Keynesian endogenous growth framework with real and nominal frictions. I discuss two different sources of price rigidities: (1) price rigidity due to the staggered pricing inspired by Calvo (1983) and (2) price rigidity as in Rotemberg (1982) due to a fixed price adjustment cost which firms have to take into account while setting their prices. Apart from price rigidities, imperfect inflation indexation is another key instrument of nominal rigidity. The sources of real rigidities include investment adjustment cost and habit formation (external) in the consumer's utility function. Among the different real and nominal frictions, investment adjustment cost and price stickiness are most important in determining the short run behaviour of market capitalization ratio and growth.

In both Calvo and Rotemberg price setting frameworks, for reasonable values of the nominal rigidity parameters, short run cyclical fluctuations of market capitalization and growth are influenced by a TFP shock and both these variables are augmented by this shock. Because of a positive TFP shock, investment in financial assets is going to increase on both counts, firstly because of a positive income effect of an increase in output and secondly due to the fact that consumers will try to take advantage of increased dividends (which occurs because the shock follows an AR(1) process) in the next period. Hence total rise in market capitalization will exceed the rise in output, thereby leading to a rise in market capitalization to output ratio. However, for a very high nominal rigidity parameter value, output growth is influenced by a TFP shock, whereas market capitalization is driven by an IST shock. For very high degrees of nominal rigidity, growth increases due to the TFP shock, but market capitalization falls due to an IST shock. A good IST shock guarantees higher capital stock in the next period and thus induces the consumer to increase investment in physical capital but lower investments in financial capital, thereby leading to a fall in the market capitalization ratio. When nominal rigidity parameter value becomes extremely high, it means that in the Calvo framework the proportion of sticky price firms have gone up considerably and in the Rotemberg framework, it signifies very high price adjustment cost. Thus, in both price setting frameworks, price rigidity parameter exceeding a certain threshold value pushes up the general price level, which has an

adverse effect on the demand for intermediate goods coming from the final good producing firms. This leads to a fall in the demand for capital, thereby driving down the economywide rental price of capital. A fall in the value of physical capital, in turn, diminishes market capitalization. So in both price setting frameworks, for reasonable values of nominal rigidity parameters, I find the correlation coefficients between short run fluctuations in market capitalization and growth to be positive and significant, as found in the data for most developed and developing countries. On the other hand, the correlation coefficient between inflation and growth, as calculated from the model turns out to be insignificant for all possible values of the nominal rigidity parameter and this holds true for both the Calvo as well as the Rotemberg price setting frameworks, thereby once again supporting the empirical findings.

The lead-lag relationship between market capitalization ratio and growth is supported by an IST shock. The effect of TFP and other shocks on market capitalization and growth is amplified in the presence of real and nominal frictions, which can help explain the positive significant market capitalization-growth correlation. When there is a favourable TFP shock in the absence of price stickiness, all firms respond by adjusting prices proportionately due to a change in marginal cost, because of which the average mark-up remains a constant . With price stickiness, however, in a similar situation, some firms cannot lower their prices, while others can, which leads to a rise in their average mark up. This, along with overall output increase due to positive productivity shocks lead to an overall increase in dividends, thereby making stock markets more attractive and increasing market capitalization. On the other hand, current growth is augmented unambiguously due to a positive TFP shock, due to increase in current output, which explains the positive market capitalization-growth correlation in a framework with staggered pricing for reasonable values of the nominal rigidity parameter.

It should be noted that price stickiness, modelled either through staggered price setting as in Calvo, or quadratic price adjustment costs as in Rotemberg, is crucial in incorporating a New-Keynesian element into this particular theoretical framework. However, in a standard Keynesian model, one expects a pure demand side shock such as a monetary policy shock to have an immediate impact on output. But from Figures 8 and 16 (Calvo model) and Figures 28 and 36 (Rotemberg model), it follows that a monetary policy shock brings about a change in output growth only after a one period lag. This happens because in this theoretical set-up the only input to production is capital, which is determined a period in advance. Thus output at

any time period  $t$  is tied down via the production function by the predetermined capital stock. There is a limited scope for output to change in the period of realization of the shock; this can happen due to reallocation of capital across heterogeneous firms instantaneously in the Calvo framework, or loss of some capital input as a result of price adjustment cost in the Rotemberg framework, although these mechanisms seem likely to account for very minor effects. This makes the model a bit restrictive, preventing it from behaving like an usual Keynesian model.

## IV. Conclusion

In the previous chapter, it was established that incorporating a borrowing constraint friction to a Lucas tree type asset pricing model with production could reproduce the positive significant market capitalization - growth correlation as found empirically. In the absence of this borrowing constraint friction, however, the positive significant correlation could not be replicated. The present theoretical structure takes into account real as well as nominal rigidities and can be broadly classified into two parts: (1) model with imperfect market structure but full price flexibility and (2) model with imperfect market structure and price rigidities. In the second theoretical set up, which is essentially a New Keynesian endogenous growth model, nominal rigidities are present in the form of imperfect inflation indexation, price stickiness (Calvo framework) and price adjustment cost (Rotemberg framework), while real rigidities are present in the form of investment adjustment cost and external habit formation in the consumer's utility function. In a dynamic stochastic general equilibrium structure, with aggregate macroeconomic shocks, each following an autoregressive process, simultaneously in action, it is found that the first theoretical framework with only market imperfections is able to reproduce a positive correlation between the short run fluctuations of market capitalization and growth, although the value of the correlation coefficient is not significant as found in the data. In this flexible price model, however, the lead-lag relationship between market capitalization ratio and growth holds true for both IST and CQ shocks. Next I work with a New Keynesian model in an attempt to bring the theoretical framework closer to the data. Since staggered pricing is a key element in the New Keynesian structure, I also explore the short run inflation - growth relationship. This framework can perfectly reproduce the positive significant short run market capitalization - growth correlation and the negative short run growth - inflation correlation as observed em-

pirically. Thus, as in the previous chapter, in the present set up also I find that introducing a friction within the existing theoretical framework can bring the model much closer to the data. In the previous chapter, a friction in the form of a borrowing constraint incorporated in a Lucas type asset pricing model with production could nicely reproduce the desired result of positive significant market capitalization - growth correlation. In the present chapter I find that an imperfectly competitive market structure can induce market capitalization and growth to move in same directions in the short run, although the short run market capitalization - growth correlation is not found to be quantitatively close to the values observed for majority of the countries in the data. Also with change in parameter values, little variation is observed in the correlation coefficient reproduced by the model. However, introducing real and nominal frictions within this imperfectly competitive market structure can reproduce the empirically observed positive significant correlation very accurately. Although nothing definite can be inferred about the lead-lag relationship between market capitalization ratio and growth due to lack of closed form solutions in the model with nominal rigidities, the effect of an IST shock and a CQ shock is found to influence market capitalization immediately, but growth after a lag, for both high and low degrees of price rigidities. Investment adjustment cost and price rigidities are the two most important sources of frictions that drive the short run market capitalization - growth dynamics. It is primarily due to the effect of these real and nominal frictions that the effect of a TFP and other shocks on the different variables get magnified. Everything else remaining unchanged, due to a positive TFP shock, there is a fall in real marginal cost, which in the presence of price rigidities push up the general price level, leading to a fall in the demand for intermediate goods and a subsequent fall in the demand for capital by the intermediate firms. This, in turn, lowers the economywide rental rate. Although the consumers cannot be hedged against the fix price firms in the capital market and face the same lowered rental rate, they can hedge against them in the financial market by buying less of their shares and more of the shares of the flex price firms. This creates a bias in favour of the stock market as opposed to the capital market, which drives the positive significant market capitalization - growth correlation in the short run for a reasonable degree of nominal rigidity.



## Appendix

### A. Derivation of the intermediate good's general demand function and the price aggregator

The objective function of the F firm is

$$\begin{aligned} \text{Max} & : P_t y_t - \int_0^1 P_t(i) x_t(i) di \\ \text{st} & : y_t = \left( \int_0^1 x_t(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \end{aligned}$$

Since the firm is competitive, profits will end up being equal to zero. Hence the problem the F firm will solve in time period  $t$  is

$$\text{Max} : P_t \left( \int_0^1 x_t(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} - \int_0^1 P_t(i) x_t(i) di$$

and this results in the first order condition of

$$P_t \left( \int_0^1 x_t(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{1}{\sigma-1}} x_t(i)^{-\frac{1}{\sigma}} = P_t(i)$$

which simplifies to a demand function of the  $i$ th intermediate good as

$$x_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} y_t$$

represented in equation (14).

Putting this demand for the  $i$ th intermediate good into the aggregate production function gives

$$y_t = \left( \int_0^1 \left( \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} y_t \right)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} = y_t \left( \int_0^1 \left( \frac{P_t(i)}{P_t} \right)^{1-\sigma} di \right)^{\frac{\sigma}{\sigma-1}}$$

which can be written as

$$\frac{1}{P_t} = \left( \int_0^1 \left( \frac{1}{P_t(i)} \right)^{\sigma-1} di \right)^{\frac{1}{\sigma-1}}$$

or as a final goods pricing rule of

$$P_t = \left( \int_0^1 (P_t(i))^{1-\sigma} di \right)^{\frac{1}{1-\sigma}}$$

represented by equation (15).

## B. Derivation of equations (33), (35), (34), (41) and (42) of the flexible price model without nominal frictions

Refer to the rental Euler equation, stock Euler equation and the equilibrium resource constraint in eqns (31), (30) and (32) given by

$$u'(c_t) = \beta E_t u'(c_{t+1})(r_{t+1} + 1 - \delta)$$

$$u'(c_t) = \beta E_t u'(c_{t+1}) \left( \frac{d_{t+1}(i) + p_{t+1}^z(i)}{p_t^z(i)} \right)$$

and

$$c_t + k_{t+1} - (1 - \delta)k_t = \epsilon_t k_t$$

I use  $u(c_t) = \frac{c_t^{1-\rho} - 1}{1-\rho}$  and make the conjecture

$$c_t = \lambda(\epsilon_t + 1 - \delta)k_t \tag{193}$$

Using (193) in the equilibrium resource constraint I have

$$k_{t+1} = (1 - \lambda)(\epsilon_t + 1 - \delta)k_t \tag{194}$$

Using the conjectures (193) and (194) and also plugging in the value of  $r_{t+1}$  in the rental Euler equation I have

$$(1 - \lambda)^\rho = \beta \tilde{u} \tag{195}$$

where

$$\tilde{u} = E_t \left( \frac{\left( \frac{\sigma-1}{\sigma} \right) \epsilon_{t+1} + 1 - \delta}{(\epsilon_{t+1} + 1 - \delta)^\rho} \right)$$

From (195) it is evident that

$$\lambda = 1 - (\beta\tilde{u})^{\frac{1}{\rho}} \quad (196)$$

Plugging in the value of  $\lambda$  in the conjectures in (193) and (194) I get

$$c_t = [1 - (\beta\tilde{u})^{\frac{1}{\rho}}][\epsilon_t + 1 - \delta]k_t$$

$$k_{t+1} = (\beta\tilde{u})^{\frac{1}{\rho}}[\epsilon_t + 1 - \delta]k_t$$

which represent equations (33) and (34) respectively.

Now, from the asset Euler equation I have

$$u'(c_t) = \beta E_t u'(c_{t+1}) \left( \frac{d_{t+1} + p_{t+1}^z}{p_t^z} \right)$$

Using  $u(c_t) = \frac{c_t^{1-\rho}-1}{1-\rho}$  this becomes

$$\frac{p_t^z}{c_t^\rho} = \beta E_t \left( \frac{d_{t+1}}{c_{t+1}^\rho} + \frac{p_{t+1}^z}{c_{t+1}^\rho} \right) \quad (197)$$

Plugging in values of  $d_{t+1}$  and  $c_{t+1}$  I get

$$\frac{d_{t+1}}{c_{t+1}^\rho} = \frac{\epsilon_{t+1}}{(\epsilon_{t+1} + 1 - \delta)^\rho} \eta c_t^{1-\rho} \quad (198)$$

where

$$\eta = \frac{(\beta\tilde{u})^{\frac{1-\rho}{\rho}}}{\sigma(1 - (\beta\tilde{u})^{\frac{1}{\rho}})}$$

Using (198) in (197) I have

$$\frac{p_t^z}{c_t^\rho} = \beta E_t \left( \frac{p_{t+1}^z}{c_{t+1}^\rho} \right) + \eta \beta E_t \left( \frac{\epsilon_{t+1}}{(\epsilon_{t+1} + 1 - \delta)^\rho} \right) c_t^{1-\rho} \quad (199)$$

Let

$$\frac{p_t^z}{c_t^\rho} = x_t$$

and

$$E_t \left( \frac{\epsilon_{t+1}}{(\epsilon_{t+1} + 1 - \delta)^\rho} \right) = \tilde{v}$$

as a result of which equation (199) becomes

$$x_t = \beta E_t(x_{t+1}) + \eta \beta \tilde{v} c_t^{1-\rho} \quad (200)$$

I make another conjecture

$$x_t = \Omega c_t^{1-\rho} \quad (201)$$

Also from the solutions of  $c_t$  and  $k_{t+1}$  I have

$$c_{t+1} = (\beta \tilde{u})^{\frac{1}{\rho}} [\epsilon_t + 1 - \delta] c_t \quad (202)$$

Using (90) and (202) in (200) I solve  $\Omega$

$$\Omega = \frac{\eta \beta \tilde{v}}{(1 - \beta (\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{w})}$$

where

$$\tilde{w} = E_t[(\epsilon_{t+1} + 1 - \delta)^{1-\rho}]$$

which implies

$$\frac{p_t^z}{c_t^\rho} = \left( \frac{\eta \beta \tilde{v}}{(1 - \beta (\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{w})} \right) c_t^{1-\rho}$$

Hence,

$$p_t^z = \left( \frac{\eta \beta \tilde{v}}{(1 - \beta (\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{w})} \right) c_t$$

Substituting the values of  $\eta$  and  $c_t$  in the above equation I get

$$p_t^z = \frac{\beta \tilde{v} (\beta \tilde{u})^{\frac{1-\rho}{\rho}}}{[1 - \beta (\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{w}] \sigma} [\epsilon_t + 1 - \delta] k_t$$

which represents equation (35)

Using the value of  $p_t^z$  from the above equation and the value of  $k_{t+1}$  I get

$$\frac{p_t^z}{k_{t+1}} = \frac{1}{\sigma} \left( \frac{\tilde{v}}{\tilde{u}} \frac{1}{(1 - \beta (\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{w})} \right) \quad (203)$$

which is the Tobin's q expression with an i.i.d. shock.

Also

$$\frac{y_t}{y_{t-1}} = \frac{\epsilon_t k_t}{\epsilon_{t-1} k_{t-1}} = \frac{y_t}{y_{t-1}} = \epsilon_t \left( (\beta \tilde{u})^{\frac{1}{\rho}} + \frac{(\beta \tilde{u})^{\frac{1}{\rho}} (1 - \delta)}{\epsilon_{t-1}} \right)$$

which is equation (42) in the flexible price model.

Finally, using the solution of  $p_t^z$  from equation (35) and  $y_t = \epsilon_t k_t$  I obtain

$$\frac{p_t^z}{y_t} = \frac{\beta (\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{v}}{[1 - \beta (\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{w}] \sigma} \left( 1 + \frac{(1 - \delta)}{\epsilon_t} \right)$$

which represents equation (41) in the flexible price model.

### C. Social Planning Problem reproducing allocations of consumption and capital given by equations (33) and (34) in the flexible price model without nominal frictions

I consider a benevolent social planner who allocates optimal consumption and optimal investment for each household and thus decides aggregate consumption and investment.

Planner's resource constraint is an aggregation of each of the household's equilibrium resource constraints.

Planner's objective function:

$$\begin{aligned} \text{Max:} \quad & E_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \\ \text{s.t.} \quad & : c_t + k_{t+1} - (1 - \delta)k_t = y_t \end{aligned} \quad (204)$$

$c_t$  and  $y_t$  are the aggregate consumption and income and  $k_{t+1} - (1 - \delta)k_t$  is the aggregate level of physical investment in the economy. These are same as that of each representative household because of the fact that the economy consists of a very large number of identical households within a continuous interval.

After solving the optimization problem in equation (204), taking  $c_t$  and  $k_{t+1}$  as the choice variables, the planner allocates consumption and physical investment for each household as:

$$c_t = [1 - (\beta \tilde{u})^{\frac{1}{\rho}}] [\epsilon_t + 1 - \delta] k_t \quad (205)$$

$$k_{t+1} = (\beta \bar{u})^{\frac{1}{\rho}} [\epsilon_t + 1 - \delta] k_t \quad (206)$$

where

$$\bar{u} = E_t [(\epsilon_{t+1} + 1 - \delta)^{1-\rho}] \quad (207)$$

Comparing the above equations with the monopolistically competitive allocations of consumption and capital in equations (33) and (34), the planner's allocations and the monopolistically competitive market solutions are the same when  $\bar{u} = \tilde{u}$ . From (36) it is evident that this becomes possible only when  $\sigma \rightarrow \infty$  i.e. when there is perfect competition. Goods being perfect substitutes washes away the possibility of any profit and thus any source of imperfection promoted by monopoly. Planner's allocation will replicate the allocation of this imperfectly competitive economy if, assuming full depreciation of capital, he uses a modified discount factor

$$\beta^* = \beta \frac{(\sigma - 1)}{\sigma}$$

The value of the entire output goes to the households in the form of dividend income and rental income, which they use to consume and invest. In a perfectly competitive set up, the firms make no profit, making rental income the only source of income for households. This gives incentive to the households to increase their physical capital accumulation in favour of current consumption. Alternatively, in an imperfectly competitive set-up, households will tend to decrease their physical investments as compared to a perfectly competitive set-up. Thus, in order to replicate an imperfectly competitive economy, since the social planner's physical capital accumulation goes down, as compared to a perfectly competitive economy, he appears to be short-sighted which is also reflected by the fact that he uses a discount factor  $\beta^* < \beta$ .

#### **D. Tobin's q expression with only TFP shock in the flexible price model without nominal frictions**

From equation (203) in the appendix, I have

Tobin's q:

$$\frac{p_t^z}{k_{t+1}} = \frac{1}{\sigma} \left( \frac{\tilde{v}}{\left(1 - \beta(\beta \tilde{u})^{\frac{1-\rho}{\rho}} \tilde{w}\right) \tilde{u}} \right) \quad (208)$$

Tobin's q is defined as the ratio of the total market value to the total asset value of a firm.

Here I use the ratio of the asset price to capital accumulation in a certain period to be the Tobin's q for that particular period. In fact, in the expressions for market capitalization ratio i.e.  $\left(\frac{p_t^z}{y_t}\right)$  and Tobin's q i.e.  $\left(\frac{p_t^z}{k_{t+1}}\right)$ ,  $p_t^z$  represents the aggregate stock price index for the economy, which is stock price times number of outstanding shares.

Also from equation (208) it is evident that the Tobin's q expression is independent of the total factor productivity shock  $\epsilon_t$ .

The value of Tobin's q depends on the values of a number of parameters viz.  $\sigma, \rho, \beta, \tilde{v}, \tilde{u}$  and  $\tilde{w}$ .

Assuming  $\delta = 1$  and also  $\epsilon$  follows a lognormal distribution with mean 0 and variance  $\sigma_\epsilon^2$ ,

$$\begin{aligned}\tilde{u} &= \left(\frac{\sigma - 1}{\sigma}\right)e^{[0.5(1-\rho)^2\sigma_\epsilon^2]} \\ \tilde{v} &= e^{[0.5(1-\rho)^2\sigma_\epsilon^2]} \\ \tilde{w} &= e^{[0.5(1-\rho)^2\sigma_\epsilon^2]}\end{aligned}$$

I fix the value of the parameters at  $\rho = 3, \beta = 0.96$  and  $\sigma_\epsilon = 0.25$ . In figure 4 I plot Tobin's q for the value of  $\sigma$  ranging from 2 to 6 and find Tobin's q to be greater than 1 (implying overvaluation of stock market) throughout the entire range.

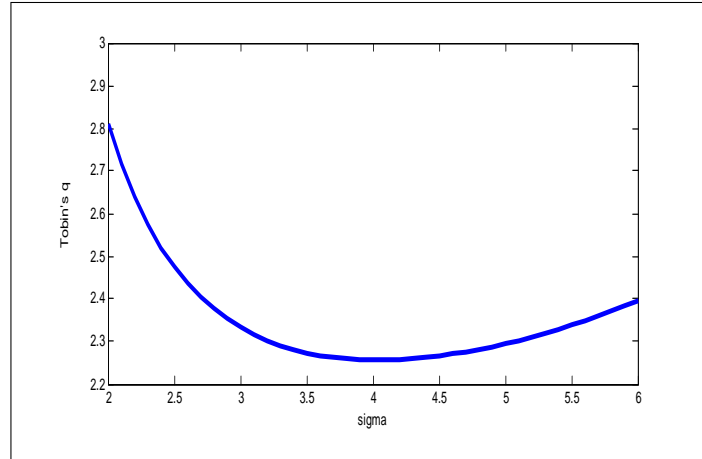


Figure 44: Tobin's q plot for different demand elasticities

### E. Derivation of the price dispersion recursion (equation (91)) from the price dispersion term (equation (90))

From equation (90) I have

$$\begin{aligned}
s_t &= \int_0^1 \left( \frac{P_t(i)}{P_t} \right)^{-\sigma} di \\
&= \int_0^\theta \left( \frac{P_{t-1}(i)}{P_t} \right)^{-\sigma} di + \int_\theta^1 \left( \frac{P_t^*}{P_t} \right)^{-\sigma} di \\
&= \theta \int_0^1 \left( \frac{\bar{\Pi}^\gamma P_{t-1}(i)}{P_{t-1}} \right)^{-\sigma} \left( \frac{P_{t-1}}{P_t} \right)^{-\sigma} di + (1-\theta) \left( \frac{P_t^*}{P_t} \right)^{-\sigma} \\
&= \Pi_t^\sigma \bar{\Pi}^{-\gamma\sigma} \theta \int_0^1 \left( \frac{P_{t-1}(i)}{P_{t-1}} \right)^{-\sigma} + (1-\theta) \left( \frac{P_t^*}{P_t} \right)^{-\sigma} \\
&= \theta \Pi_t^\sigma \bar{\Pi}^{-\gamma\sigma} s_{t-1} + (1-\theta) \left( \frac{P_t^*}{P_t} \right)^{-\sigma}
\end{aligned}$$

which is equation (91).

#### F. Derivation of $\left(\frac{P_t^*}{P_t}\right)$ in eqn (106) and recursion for $w_t$ and $\left(\frac{P_t^*}{P_t}\right)$ in eqn (110) and (108) for the Calvo price setting framework

The demand function with imperfect indexation ( $\gamma$ ) is same for all flex price firms and is given by:

$$x_{t+k|t} = \left( \frac{\bar{\Pi}^{\gamma k} P_t^*}{P_{t+k}} \right)^{-\sigma} y_{t+k}$$

where the general price level in the economy at time  $t+k$  is given by  $P_{t+k}$  and  $P_{t+k} = \Pi_{t,t+k} P_t$

I define  $\Pi_{t,t+k} = \Pi_{t,t+1} \cdot \Pi_{t+1,t+2} \dots \Pi_{t+k-1,t+k}$  as the level of general inflation between time period  $t$  and time period  $t+k$ .

Therefore I have

$$\frac{\partial x_{t+k|t}}{\partial P_t^*} = -\sigma \frac{\bar{\Pi}^{-\sigma\gamma k}}{P_{t+k}^{-\sigma}} y_{t+k} P_t^{*-\sigma-1}$$

Objective function becomes:

$$\max: E_t \sum_{k=0}^{\infty} \theta^k M_{t,t+k} (\bar{\Pi}^{\gamma k} P_t^* \left( \frac{\bar{\Pi}^{\gamma k} P_t^*}{P_{t+k}} \right)^{-\sigma} y_{t+k} - TC_{t+k|t}(x_{t+k|t}))$$

First Order Condition with respect to  $P_t^*$  gives:

$$E_t \sum_{k=0}^{\infty} \theta^k M_{t,t+k} (\bar{\Pi}^{\gamma k(1-\sigma)} (1-\sigma) \left( \frac{P_t^*}{P_{t+k}} \right)^{-\sigma} y_{t+k} - MC_{t+k|t} \frac{\partial x_{t+k|t}}{\partial P_t^*} = 0$$



Plugging the value of  $\frac{\partial x_{t+k|t}}{\partial P_t^*}$  in the above I have

$$E_t \sum_{k=0}^{\infty} \theta^k M_{t,t+k} (\bar{\Pi}^{\gamma k(1-\sigma)} (1-\sigma) \left( \frac{P_t^*}{P_{t+k}} \right)^{-\sigma} y_{t+k} - MC_{t+k|t} \left( \frac{\bar{\Pi}^{\gamma k} P_t^*}{P_{t+k}} \right)^{-\sigma} y_{t+k} = 0 \quad (209)$$

Using  $P_{t+k} = \pi_{t,t+k} P_t$  and also  $MC_{t+k|t} = P_{t+k} mc_{t+k|t}$  (where  $mc_{t+k|t}$  is the real marginal cost at time  $t+k$ ) in equation (209) I have

$$E_t \sum_{k=0}^{\infty} \theta^k M_{t,t+k} (\bar{\Pi}^{\gamma k(1-\sigma)} (\Pi_{t,t+k})^\sigma \left( \frac{P_t^*}{P_t} \right) y_{t+k} - \left( \frac{\sigma}{\sigma-1} \right) mc_{t+k|t}^{-\sigma \gamma k} \bar{\Pi}^{-\sigma \gamma k} (\Pi_{t,t+k})^{\sigma+1} y_{t+k} = 0$$

From this I can derive equation (106) as

$$\frac{P_t^*}{P_t} = \left( \frac{\sigma}{\sigma-1} \right) \frac{E_t \sum_{k=0}^{\infty} (\theta \bar{\Pi}^{-\sigma \gamma})^k M_{t,t+k} \Pi_{t,t+k}^{\sigma+1} mc_{t+k|t} \left( \frac{y_{t+k}}{y_t} \right)}{E_t \sum_{k=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^k M_{t,t+k} \Pi_{t,t+k}^\sigma \left( \frac{y_{t+k}}{y_t} \right)}$$

Let

$$w_t = E_t \sum_{k=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^k M_{t,t+k} \Pi_{t,t+k}^\sigma \left( \frac{y_{t+k}}{y_t} \right) \quad (210)$$

=>

$$w_t = 1 + (\theta \bar{\Pi}^{\gamma(1-\sigma)}) E_t M_{t,t+1} \Pi_{t,t+1}^\sigma \left( \frac{y_{t+1}}{y_t} \right) \sum_{k=1}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^{k-1} M_{t+1,t+k} \Pi_{t+1,t+k}^\sigma \left( \frac{y_{t+k}}{y_{t+1}} \right)$$

=>

$$w_t = 1 + (\theta \bar{\Pi}^{\gamma(1-\sigma)}) E_t M_{t,t+1} \Pi_{t,t+1}^\sigma \left( \frac{y_{t+1}}{y_t} \right) E_{t+1} \sum_{s=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^s M_{t+1,t+s+1} \Pi_{t+1,t+s+1}^\sigma \left( \frac{y_{t+s+1}}{y_{t+1}} \right)$$

(where  $k-1 = s$ )

=>

$$w_t = 1 + (\theta \bar{\Pi}^{\gamma(1-\sigma)}) E_t M_{t,t+1} \Pi_{t,t+1}^\sigma \left( \frac{y_{t+1}}{y_t} \right) w_{t+1}$$

which represents equation (110) in the Calvo price setting framework.

From equation (106) I have

$$\frac{P_t^*}{P_t} = \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{1}{w_t} \right) mc_t + \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{1}{w_t} \right) E_t \sum_{k=1}^{\infty} (\theta \bar{\Pi}^{-\gamma\sigma})^k M_{t,t+k} mc_{t+k} \Pi_{t,t+k}^{\sigma+1} \left( \frac{y_{t+k}}{y_t} \right)$$

=>

$$\begin{aligned} \frac{P_t^*}{P_t} &= \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{1}{w_t} \right) mc_t + \\ &\quad \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{1}{w_t} \right) (\theta \bar{\Pi}^{-\gamma\sigma}) E_t M_{t,t+1} \Pi_{t,t+1}^{\sigma+1} \left( \frac{y_{t+1}}{y_t} \right) \\ &\quad E_{t+1} \sum_{s=0}^{\infty} (\theta \bar{\Pi}^{-\gamma\sigma})^s M_{t+1,t+s+1} mc_{t+s+1} \Pi_{t+1,t+s+1}^{\sigma+1} \left( \frac{y_{t+s+1}}{y_{t+1}} \right) \end{aligned}$$

=>

$$\begin{aligned} \frac{P_t^*}{P_t} &= \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{1}{w_t} \right) mc_t + \\ &\quad \left( \frac{1}{w_t} \right) (\theta \bar{\Pi}^{-\gamma\sigma}) E_t M_{t,t+1} \Pi_{t,t+1}^{\sigma+1} \left( \frac{y_{t+1}}{y_t} \right) E_{t+1} \sum_{s=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^s M_{t+1,t+s+1} \Pi_{t+1,t+s+1}^{\sigma} \left( \frac{y_{t+s+1}}{y_{t+1}} \right) \\ &\quad \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{E_{t+1} \sum_{s=0}^{\infty} (\theta \bar{\Pi}^{-\gamma\sigma})^s M_{t+1,t+s+1} mc_{t+s+1} \Pi_{t+1,t+s+1}^{\sigma+1} \left( \frac{y_{t+s+1}}{y_{t+1}} \right)}{E_{t+1} \sum_{s=0}^{\infty} (\theta \bar{\Pi}^{\gamma(1-\sigma)})^s M_{t+1,t+s+1} \Pi_{t+1,t+s+1}^{\sigma} \left( \frac{y_{t+s+1}}{y_{t+1}} \right)} \right) \end{aligned}$$

=>

$$\frac{P_t^*}{P_t} = \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{1}{w_t} \right) mc_t + \left\{ \left( \frac{1}{w_t} \right) (\theta \bar{\Pi}^{-\gamma\sigma}) \left( M_{t,t+1} \Pi_{t,t+1}^{\sigma+1} \left( \frac{y_{t+1}}{y_t} \right) w_{t+1} \right) \left( \frac{P_{t+1}^*}{P_{t+1}} \right) \right\} \quad (211)$$

From (110) I have

$$(\theta \bar{\Pi}^{-\gamma\sigma}) M_{t,t+1} \Pi_{t,t+1}^{\sigma+1} \left( \frac{y_{t+1}}{y_t} \right) w_{t+1} = \Pi_{t,t+1} \bar{\Pi}^{-\gamma} (w_t - 1) \quad (212)$$

Using the relation from equation (212) in equation (211) I get

$$\frac{P_t^*}{P_t} = w_t^{-1} \left( \frac{\sigma}{\sigma-1} \right) mc_t + \left\{ (1 - w_t^{-1}) \bar{\Pi}^{-\gamma} \Pi_{t,t+1} \left( \frac{P_{t+1}^*}{P_{t+1}} \right) \right\}$$

which is equation (108) in the Calvo price setting framework.

## G. Derivation of equation (150)

Refer to equation (12) where

$$y_t = \left( \int_0^1 x_t(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$$

This implies

$$\begin{aligned} y_t &= \left( \theta x_t^s(1)^{\frac{\sigma-1}{\sigma}} + (1-\theta) x_t^s(2)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \\ &= \left( \theta (\epsilon_t k_t(1))^{\frac{\sigma-1}{\sigma}} + (1-\theta) (\epsilon_t k_t(2))^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \end{aligned}$$

where  $x_t^s(1)$  denotes supply of output by fix price firms and  $x_t^s(2)$  denotes supply of output by flex price firms.

Plugging in the value of  $k_t(1)$  and  $k_t(2)$  from (118) and (119) I get

$$y_t = \Omega_t \epsilon_t k_t$$

where

$$\Omega_t = \left[ \theta \left( \frac{\psi_t}{1-\theta+\theta\psi_t} \right)^{\frac{\sigma-1}{\sigma}} + (1-\theta) \left( \frac{1}{1-\theta+\theta\psi_t} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

## H. Derivation of equation (159)

Start with the optimal price setting equation (106)

$$\frac{P_t^*}{P_t} = \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{E_t \sum_{k=0}^{\infty} \left( \theta \bar{\Pi}^{-\sigma\gamma} \right)^k M_{t,t+k} \Pi_{t,t+k}^{\sigma+1} m c_{t,t+k} \left( \frac{y_{t+k}}{y_t} \right)}{E_t \sum_{k=0}^{\infty} \left( \theta \bar{\Pi}^{\gamma(1-\sigma)} \right)^k M_{t,t+k} \Pi_{t,t+k}^{\sigma} \left( \frac{y_{t+k}}{y_t} \right)} \right)$$

where

$$M_{t,t+k} = \beta^k \left( \frac{u'(c_{t+k})}{u'(c_t)} \right) \left( \frac{P_t}{P_{t+k}} \right)$$

Assuming a logarithmic utility function of the form  $u(c_{t+k}) = \ln(c_{t+k})$ , we have

$$M_{t,t+k} = \beta^k \left( \frac{c_t}{c_{t+k}} \right) \left( \frac{P_t}{P_{t+k}} \right)$$

Along the BGP, denoting  $M_{t,t+k}$  by  $\bar{M}$ , growth of consumption i.e.  $\frac{c_{t+1}}{c_t}$  by the balanced growth rate  $G$  and inflation  $\frac{P_{t+1}}{P_t}$  by  $\bar{\Pi}$ , we get

$$\bar{M} = \left( \frac{\beta}{\bar{\Pi}G} \right)^k$$

Therefore, the numerator is  $\frac{MC_t}{P_t} \sum_{k=0}^{\infty} (\theta\beta\bar{\Pi}^{\sigma(1-\gamma)})^k = \left( \frac{1}{1-\theta\beta\bar{\Pi}^{\sigma(1-\gamma)}} \right) \frac{MC_t}{P_t}$  and the denominator is  $\sum_{k=0}^{\infty} \left( \theta\beta\bar{\Pi}^{(\sigma-1)(1-\gamma)} \right)^k = \frac{1}{1-\theta\beta\bar{\Pi}^{(\sigma-1)(1-\gamma)}}$ .

Thus along the BGP, the optimal price setting equation reduces to:

$$\bar{m}\bar{c} = \left( \frac{\sigma-1}{\sigma} \right) \left( \frac{1-\theta\beta\bar{\Pi}^{(1-\gamma)\sigma}}{1-\theta\beta\bar{\Pi}^{(1-\gamma)(\sigma-1)}} \right) \left( \frac{\bar{P}^*}{\bar{P}} \right)$$

which is equation (159). From this the long run average mark up in the Calvo model can be obtained as

$$\frac{P_t}{MC_t} = \mu_n \frac{P_t}{P_t^*} \quad (213)$$

where

$$\mu_n = \left( \frac{\sigma}{\sigma-1} \right) \left( \frac{1-\theta\beta\bar{\Pi}^{(\sigma-1)(1-\gamma)}}{1-\theta\beta\bar{\Pi}^{\sigma(1-\gamma)}} \right)$$

which is equation (189)

## I. Derivation of equation (180)

From (129)

$$(1-\sigma) + \frac{r_t}{\epsilon_t} \sigma - \frac{\varphi \Pi_t}{\bar{\Pi}^\gamma} \left( \frac{\Pi_t}{\bar{\Pi}^\gamma} - 1 \right) + \beta \frac{u'(c_{t+1})}{u'(c_t)} \varphi \bar{\Pi}^{-\gamma} \Pi_t \left( \bar{\Pi}^{-\gamma} \Pi_t - 1 \right) \frac{y_{t+1}}{y_t} = 0$$

Along the BGP,  $\Pi_t = \bar{\Pi}$ ,  $r_t = \bar{r}$  and  $\frac{y_{t+1}}{y_t} = \frac{c_{t+1}}{c_t} = G$ . With log utility, eq (129) reduces to

$$\frac{\bar{r}}{\bar{\epsilon}} = \left[ \frac{\varphi(1-\beta)\bar{\Pi}^{1-\gamma}(\bar{\Pi}^{1-\gamma}-1)}{\sigma} + \frac{\sigma-1}{\sigma} \right]$$

$$\bar{m}\bar{c} = \left[ \frac{\varphi(1-\beta)\bar{\Pi}^{1-\gamma}(\bar{\Pi}^{1-\gamma}-1)}{\sigma} + \frac{\sigma-1}{\sigma} \right]$$

which is equation (180).

Since  $\frac{\bar{r}}{\bar{\epsilon}} = \frac{MC_t}{P_t}$ , from the above equation the steady state average mark up can be expressed

as

$$\frac{P_t}{MC_t} = \left[ \frac{\varphi(1-\beta)\bar{\Pi}^{1-\gamma}(\bar{\Pi}^{1-\gamma}-1)}{\sigma} + \frac{\sigma-1}{\sigma} \right]^{-1} \quad (214)$$

## J. Loglinearized system of equations for Calvo and Rotemberg models

### Calvo price setting framework

(1) Loglinearized form of equilibrium budget constraint represented by equation (151)

$$\overline{ck} \widehat{ck}_t + \overline{\chi k} \widehat{\chi k}_t = \overline{yk} \widehat{yk}_t \quad (215)$$

(2) Loglinearized form of investment equation with Investment adjustment cost represented by equation (77)

$$\overline{\chi k} \xi \left( \widehat{\chi k}_t + \widehat{\xi}_t \right) = \overline{kg} \widehat{kg}_t + \overline{\delta} \widehat{\delta}_t \quad (216)$$

(3) Loglinearized form of production function represented by equation (148)

$$\widehat{yk}_t = \widehat{\epsilon}_t - \widehat{s}_t \quad (217)$$

(4) Loglinearized form of equation (150)

$$\widehat{\Omega}_t = \left( \frac{\overline{\psi} \theta (1 - \theta) \left( \frac{1}{\theta \overline{\psi} + 1 - \theta} \right)^{-\frac{1}{\sigma}} \left( \psi^{-\frac{1}{\sigma}} - 1 \right)}{\theta a^{\frac{\sigma-1}{\sigma}} + (1 - \theta) b^{\frac{\sigma-1}{\sigma}}} \right) \widehat{\psi}_t \quad (218)$$

(5) Loglinearized form of price dispersion recursion represented by equation (91)

$$\widehat{s}_t = \theta \overline{\Pi}^{\sigma(1-\gamma)} \widehat{s}_{t-1} + \theta \overline{\Pi}^{\sigma(1-\gamma)} \sigma \widehat{\Pi}_t - \sigma \left( 1 - \theta \overline{\Pi}^{\sigma(1-\gamma)} \right) \frac{\widehat{P}_t^*}{\overline{P}_t} \quad (219)$$

(6) Loglinearized form of equation (121)

$$\widehat{a}_t = \left( \frac{1 - \theta}{\theta \overline{\psi} + 1 - \theta} \right) \widehat{\psi}_t \quad (220)$$

(7) Loglinearized form of equation (123)

$$\widehat{b}_t = \left( \frac{-\theta \overline{\psi}}{\theta \overline{\psi} + 1 - \theta} \right) \widehat{\psi}_t \quad (221)$$

(8) Loglinearized form of capital allocation ratio of fix price firms to flex price firms given

by  $\psi_t$  in equation (116)

$$\widehat{\psi}_t = \sigma \left( \widehat{\Pi}_t + \frac{\widehat{P}_t^*}{\widehat{P}_t} \right) + \widehat{s}_{t-1} \quad (222)$$

(9) Loglinearized form of price aggregation eqn given by equation (111)

$$\frac{\widehat{P}_t^*}{\widehat{P}_t} = \left( \frac{\theta \bar{\Pi}^{(1-\sigma)(\gamma-1)}}{1 - \theta \bar{\Pi}^{(1-\sigma)(\gamma-1)}} \right) \widehat{\Pi}_t \quad (223)$$

(10) Loglinearized form of price optimisation eqn given by equation (108)

$$\begin{aligned} \frac{\widehat{P}_t^*}{\widehat{P}_t} \left( \frac{\overline{P^*}}{\overline{P}} \right) &= \left[ - \left( \frac{\sigma}{\sigma-1} \right) \frac{\overline{m\bar{c}}}{\overline{w}} + \frac{\bar{\Pi}^{1-\gamma}}{\overline{w}} \left( \frac{\overline{P^*}}{\overline{P}} \right) \right] \widehat{w}_t + \\ &\left( \frac{\sigma}{\sigma-1} \right) \frac{\overline{m\bar{c}}}{\overline{w}} \widehat{m\bar{c}}_t + \left[ (1 - \overline{w}^{-1}) \bar{\Pi}^{1-\gamma} \left( \frac{\overline{P^*}}{\overline{P}} \right) \right] \frac{\widehat{P}_{t+1}^*}{\widehat{P}_{t+1}} + \left[ \left( \frac{\overline{P^*}}{\overline{P}} \right) (1 - \overline{w}^{-1}) \bar{\Pi}^{1-\gamma} \right] \widehat{\Pi}_{t+1} \end{aligned} \quad (224)$$

(11) Loglinearized form of rental equation represented by equation (107)

$$\widehat{r}_t = \widehat{m\bar{c}}_t + \widehat{\epsilon}_t \quad (225)$$

(12) Loglinearized form of recursion for  $w_t$  represented by equation (110)

$$\widehat{w}_t = \theta \bar{\Pi}^{\nu(1-\sigma)} \overline{M\bar{\Pi}}^\sigma \overline{y\bar{g}} \left[ y\widehat{g}_{t+1} + \widehat{w}_{t+1} + \sigma \widehat{\Pi}_{t+1} + \widehat{M}_{t,t+1} \right] \quad (226)$$

(13) Loglinearized form of firm's discount factor in nominal terms given by eqn (103)

$$\widehat{M}_{t,t+1} = \left[ \frac{\overline{kg} + \gamma_c}{\overline{kg} - \gamma_c} \right] \widehat{ck}_t + \left[ \frac{\gamma_c}{\overline{kg} - \gamma_c} \right] \left[ \widehat{kg}_{t-1} - \widehat{ck}_{t-1} \right] - \left[ \frac{\overline{kg}}{\overline{kg} - \gamma_c} \right] \left[ \widehat{kg}_t + \widehat{ck}_{t+1} \right] - \widehat{\Pi}_{t+1} \quad (227)$$

(14) Loglinearized form of dividend to capital for fix price firms which follows from equation (120)

$$\left[ \bar{\Pi}^{\gamma-1} \bar{\epsilon} - \bar{r} \right] \widehat{dk}_t(1) = \bar{\epsilon} \bar{\Pi}^{\gamma-1} \left[ \widehat{\epsilon}_t - \widehat{\Pi}_t \right] - \widehat{r}_t \bar{r} + \left[ \bar{\Pi}^{\gamma-1} \bar{\epsilon} - \bar{r} \right] \widehat{a}_t \quad (228)$$

(15) Loglinearized form of dividend to capital for flex price firms which follows from equation (122)

$$\left[ \left( \frac{\overline{P^*}}{\overline{P}} \right) \bar{\epsilon} - \bar{r} \right] \widehat{dk}_t(2) = \left( \frac{\overline{P^*}}{\overline{P}} \right) \bar{\epsilon} \left[ \widehat{\epsilon}_t + \frac{\widehat{P}_t^*}{\widehat{P}_t} \right] - \widehat{r}_t \bar{r} + \left[ \left( \frac{\overline{P^*}}{\overline{P}} \right) \bar{\epsilon} - \bar{r} \right] \widehat{b}_t \quad (229)$$

(16) Loglinearized form of economywide dividend to capital represented by equation (124)

$$\overline{dk} \widehat{dk}_t = \theta dk_1 \widehat{dk}_t(1) + (1 - \theta) \widehat{dk}_t(2) \quad (230)$$

Loglinearized form of euler eqn w.r.t.  $\chi_t$  represented by equation (85)

$$\widehat{q}_t = \widehat{m}_{t,t+1} + \frac{\bar{r} \widehat{r}_{t+1} + (1 - \bar{\delta})\bar{q} \widehat{q}_{t+1}}{\bar{r} + (1 - \bar{\delta})\bar{q}} - \bar{\delta}\bar{q} \widehat{\delta}_{t+1} \quad (231)$$

Loglinearized form of euler eqn w.r.t.  $k_{t+1}$  represented by equation (87)

$$\widehat{q}_t = s'' \bar{k} \bar{g}^2 \bar{\xi} \left[ (1 + \bar{m} \bar{k} \bar{g}) \widehat{\chi} k - \widehat{\chi} k_{t-1} + \widehat{k} g_{t-1} - \bar{m} \bar{k} \bar{g} \left( \widehat{\chi} k_{t+1} + \widehat{k} g_t \right) \right] - \widehat{\xi}_t \quad (232)$$

(17) Using the no arbitrage condition, the two loglinearized euler equations can be combined as

$$\widehat{m}_{t,t+1} + \frac{\bar{r} \widehat{r}_{t+1} + (1 - \bar{\delta})\bar{q} \widehat{q}_{t+1}}{\bar{r} + (1 - \bar{\delta})\bar{q}} - \bar{\delta}\bar{q} \widehat{\delta}_{t+1} = s'' \bar{k} \bar{g}^2 \bar{\xi} \left[ (1 + \bar{m} \bar{k} \bar{g}) \widehat{\chi} k - \widehat{\chi} k_{t-1} + \widehat{k} g_{t-1} - \bar{m} \bar{k} \bar{g} \left( \widehat{\chi} k_{t+1} + \widehat{k} g_t \right) \right] - \widehat{\xi}_t \quad (233)$$

(18) Loglinearized form of asset Euler equation given by equation (88)

$$\widehat{q}_t = \widehat{m}_{t,t+1} + \left[ \frac{\overline{dk}}{\overline{dk} + \overline{qkg}} \right] \widehat{dk}_{t+1} + \left[ \frac{\overline{qkg}}{\overline{dk} + \overline{qkg}} \right] \left[ \widehat{q}_{t+1} + \widehat{k} g_{t+1} \right] \quad (234)$$

(19) Loglinearized form of bond Euler Equation given by equation (89)

$$\left[ \frac{\bar{i}}{1 + \bar{i}} \right] \widehat{i}_t + \widehat{m}_{t,t+1} = \widehat{\Pi}_{t+1} \quad (235)$$

(20) Loglinearized form of household discount factor given by equation (104)

$$\widehat{m}_{t,t+1} = \widehat{M}_{t,t+1} + \widehat{\Pi}_{t+1} \quad (236)$$

(21) Loglinearized form of market capitalisation given by equation (140)

$$\widehat{mk}_t = \widehat{q}_t + \widehat{k} g_t + \widehat{s}_t - \widehat{\epsilon}_t \quad (237)$$

(22) Loglinearized form of growth given by equation (137)

$$\widehat{yg}_t = \widehat{\epsilon}_t - \widehat{\epsilon}_{t-1} + \widehat{s}_{t-1} - \widehat{s}_t + \widehat{kg}_{t-1} \quad (238)$$

(23) Loglinearized form of MP shock represented by equation (156)

$$\widehat{i}_t = \rho_m(\widehat{i}_{t-1}) + (1 - \rho_m)(\phi_\Pi \widehat{\Pi}_t + \phi_y \widehat{yg}_t) + \widehat{\zeta}_t^i \quad (239)$$

(24) Loglinearized form of TFP shock represented by equation (154)

$$\widehat{\epsilon}_t = \rho_\epsilon \widehat{\epsilon}_{t-1} + \widehat{\zeta}_t^\epsilon \quad (240)$$

(25) Loglinearized form of IST shock represented by equation (155)

$$\widehat{\xi}_t = \rho_\xi \widehat{\xi}_{t-1} + \widehat{\zeta}_t^\xi \quad (241)$$

(26) Loglinearized form of CQ shock represented by equation (157)

$$\widehat{\delta}_t = \rho_\delta \widehat{\delta}_{t-1} + \widehat{\zeta}_t^\delta \quad (242)$$

In the above system of equations I have 26 equations and 26 unknowns (endogenous variables) in the Calvo framework which indicates that the model is solvable.

### Rotemberg price setting framework

(1) Loglinearized equilibrium resource constraint represented by equation (152)

$$\overline{ck} \widehat{ck}_t + \overline{ik} \widehat{ik}_t + \left[ \frac{\varphi}{2} (\overline{\Pi}^{1-\gamma} - 1)^2 - 1 \right] \overline{\epsilon} \widehat{\epsilon}_t + \overline{\epsilon} \varphi (\overline{\Pi}^{1-\gamma} - 1) \overline{\Pi}^{1-\gamma} \widehat{\Pi}_t = 0 \quad (243)$$

(2) Loglinearized capital accumulation equation and is represented by equation (216).

(3) Loglinearized version of firm First Order Condition in equation (129).

$$\left( \frac{\sigma \bar{r}}{\bar{\epsilon}} \right) (\widehat{r}_t - \widehat{\epsilon}_t) + \left[ \beta \varphi \overline{\Pi}^{1-\gamma} (\overline{\Pi}^{1-\gamma} - 1) \right] (\widehat{ck}_t - \widehat{ck}_{t+1} - \widehat{kg}_t + \widehat{yg}_{t+1}) - \overline{\Pi}^{1-\gamma} \varphi (2\overline{\Pi}^{1-\gamma} - 1) (\widehat{\Pi}_t - \beta \widehat{\Pi}_{t+1}) = 0 \quad (244)$$



(4) Loglinearized version of dividend to capital ratio of the firm in equation (134).

$$\overline{dk} \widehat{dk}_t - \overline{\nu} \widehat{\epsilon}_t + \overline{r} \widehat{r}_t = 0 \quad (245)$$

(5) Loglinearized nominal marginal rate substitution of firm represented by equation (227).

(6) Loglinearized real marginal rate of substitution of household in terms of the nominal discount factor represented by equation (236).

(7) Arbitrage condition equating loglinear versions of the Euler equations with respect to  $k_{t+1}$  and  $i_t$  and represented by equation (233).

(8) Loglinear version of the asset Euler equation represented by equation (234).

(9) Loglinear version of the bond Euler equation represented by equation (235).

(10) Loglinearized form of market capitalization taken from equation (146) and represented by

$$\widehat{mk}_t = \widehat{q}_t + \widehat{kg}_t - \widehat{\epsilon}_t - \widehat{\nu}_t$$

(11) Loglinearized form of growth taken from equation (142) and represented by

$$\widehat{yg}_t = \widehat{\epsilon}_t - \widehat{\epsilon}_{t-1} + \widehat{kg}_{t-1} + \widehat{\nu}_t - \widehat{\nu}_{t-1} \quad (246)$$

(12) Loglinearized form of rental equation represented by equation (225).

(13) Loglinearized version of the price adjustment cost term  $\nu_t$  taken from equation (135) and represented by

$$\widehat{\nu}_t = \left[ \frac{\varphi(1 - \overline{\Pi}^{1-\gamma}) \overline{\Pi}^{1-\gamma}}{\overline{\nu}} \right] \widehat{\Pi}_t \quad (247)$$

(14) Loglinearized MP shock represented by equation (239).

(15) Loglinearized TFP shock represented by equation (240).

(16) Loglinearized IST shock represented by equation (241).

(17) Loglinearized CQ shock represented by equation (242).

In the above system I have 17 equations and 17 unknowns in the Rotemberg framework which indicates that the model is solvable.

## K. Derivation of $\varphi$ in (190)

Using the average mark up expressions in the Calvo and Rotemberg frameworks from equations (213) and (214) respectively, using the balanced growth expression from (163) (assuming  $\bar{\xi} = 1$ ) and using the relationship  $\bar{\epsilon} = \frac{MC_t}{P_t}$ , balanced growth expressions in the Calvo and Rotemberg frameworks can be expressed as

$$G^C = \beta \left[ \bar{\epsilon} \left\{ \frac{\sigma}{\sigma - 1} \mu_n \frac{P_t}{P_t^*} \right\}^{-1} + 1 - \delta \right]$$

and

$$G^R = \beta \left[ \bar{\epsilon} \left\{ \frac{\varphi(1 - \beta)\bar{\Pi}^{1-\gamma}(\bar{\Pi}^{1-\gamma} - 1)}{\sigma} + \frac{\sigma - 1}{\sigma} \right\} + 1 - \delta \right]$$

Since balanced growth rate is a crucial link between Calvo and Rotemberg models, we calibrate  $\varphi$  by matching the balanced growth rates,  $G^C$  and  $G^R$  i.e. by equating the steady state average mark up in the Calvo model (equation (213)) and the Rotemberg model (equation (214)) which yields an analytical expression for  $\varphi$  as follows:

$$\varphi = \left[ \frac{(\sigma - 1) \left( \left( \frac{P_t^*}{P_t} \right) \mu_n^{-1} - 1 \right)}{(1 - \beta)\bar{\Pi}^{1-\gamma}(\bar{\Pi}^{1-\gamma} - 1)} \right]$$

which is equation (188). It is to be noted that  $\varphi$  depends nonlinearly on the trend inflation  $\bar{\Pi}$ .

The numerator of the expression for  $\varphi$  is

$$(\sigma - 1) \left( \left( \frac{P_t^*}{P_t} \right) \mu_n^{-1} - 1 \right) = X \text{ (say)}$$

The denominator of the expression for  $\varphi$  is

$$(1 - \beta)\bar{\Pi}^{1-\gamma}(\bar{\Pi}^{1-\gamma} - 1) = Y \text{ (say)}$$

In order to derive an expression for  $\varphi$  at zero inflation i.e. at  $\bar{\Pi} = 1$ , apply L'hospital's Rule to evaluate  $\lim_{\bar{\Pi} \rightarrow 1} \left( \frac{\partial X}{\partial \bar{\Pi}} / \frac{\partial Y}{\partial \bar{\Pi}} \right)$ .

Using the value of  $\left(\frac{P_t^*}{P_t}\right)$  and  $\mu_n$  from (158) and (189) respectively, I have

$$\lim_{\Pi \rightarrow 1} \left( \frac{\partial X}{\partial \Pi} \right) = (1 - \gamma)(\sigma - 1) \left( \frac{\theta}{1 - \theta} - \frac{\theta\beta}{1 - \theta\beta} \right)$$

and

$$\lim_{\Pi \rightarrow 1} \left( \frac{\partial Y}{\partial \Pi} \right) = (1 - \beta)(1 - \gamma)$$

which implies that the value of  $\varphi$  at a zero inflation is given by

$$\lim_{\Pi \rightarrow 1} \left( \frac{\partial X}{\partial \Pi} / \frac{\partial Y}{\partial \Pi} \right) = \left( \frac{\sigma - 1}{1 - \beta} \right) \left( \frac{\theta}{1 - \theta} - \frac{\theta\beta}{1 - \theta\beta} \right)$$

which is equation (190).

**Table 1: Short run growth-market capitalization correlation (1988-2012)**

	minimum value	median value	maximum value
Data	-0.025	0.412	0.796

**Table 2: Median growth-inflation correlation for all countries (1971-2014)**

	All countries	High Income	Medium Income	Low Income
Median	-0.07	0.02	-0.12	-0.17
Range	(-0.65,0.48)	(-0.38,0.48)	(-0.65,0.45)	(-0.41,0.27)

**Table 3: Parameter values (Flexible price model without nominal frictions)**

$\beta$	$\sigma$	$\bar{\delta}$	$\bar{\epsilon}$	$\bar{\xi}$	$\rho$
0.99	6	0.025	0.048	1	1

**Table 4: Second Moment Parameter Values of Forcing Processes (Flexible price model without nominal frictions)**

$\rho_\epsilon$	$\rho_\xi$	$\rho_\delta$	$\sigma_\epsilon^2$	$\sigma_\xi^2$	$\sigma_\delta^2$
0.75	0.75	0.75	1	1	1

**Table 5: Sensitivity analysis of market capitalization - growth correlation in flexible price model without nominal frictions**

	$\sigma = 2$	$\sigma = 4$	$\sigma = 6$	$\sigma = 8$	$\sigma = 10$
$\delta = 0.01$	$r_{mk,yg}=0.282$	$r_{mk,yg}=0.283$	$r_{mk,yg}=0.323$	$r_{mk,yg}=0.363$	$r_{mk,yg}=0.363$
$\delta = 0.03$	$r_{mk,yg}=0.284$	$r_{mk,yg}=0.284$	$r_{mk,yg}=0.324$	$r_{mk,yg}=0.365$	$r_{mk,yg}=0.365$
$\delta = 0.05$	$r_{mk,yg}=0.285$	$r_{mk,yg}=0.285$	$r_{mk,yg}=0.324$	$r_{mk,yg}=0.365$	$r_{mk,yg}=0.365$
$\delta = 0.07$	$r_{mk,yg}=0.285$	$r_{mk,yg}=0.285$	$r_{mk,yg}=0.324$	$r_{mk,yg}=0.365$	$r_{mk,yg}=0.365$
$\delta = 0.09$	$r_{mk,yg}=0.285$	$r_{mk,yg}=0.286$	$r_{mk,yg}=0.324$	$r_{mk,yg}=0.365$	$r_{mk,yg}=0.365$

**Table 6: Market capitalization - growth comparison between data and flexible price model without nominal frictions**

Data		Model	
Quartiles	$r_{mk,yg}$	$\sigma$	$r_{mk,yg}$
$Q_1$	0.320	6	0.324
$Q_2$	0.412	8	0.365
$Q_3$	0.527		

**Table 7: Impact effect of three shocks in flexible price model without nominal frictions**

	<i>TFP</i>	<i>CQ</i>	<i>IST</i>
<i>yg</i>	+	+	+
<i>mk</i>	+	+	-

**Table 8: Variance Decomposition (in percent) of three shocks in flexible price model without nominal frictions**

	<i>TFP</i>	<i>CQ</i>	<i>IST</i>
<i>yg</i>	51.06	48.83	0.11
<i>mk</i>	14.79	58.01	27.20
<i>q</i>	4.98	5.03	90.00
<i>ck</i>	38.15	38.38	23.46
<i>kg</i>	49.95	49.94	0.12

**Table 9: Nominal rigidity parameters (Price stickiness and Price adjustment cost)**

$\theta$	$\varphi$
0.25	2.21
0.50	9.90
0.70	38.00
0.75	58.25
0.80	96.15

**Table 10: Deep parameter values in model with noimnal frictions**

$\sigma$	$\beta$	$\bar{\delta}$	$\bar{\Pi}$	$\bar{q}$	$\bar{\xi}$	$\bar{\epsilon}$	$\gamma_c$	$s''$	$\theta$	$\gamma$	$\varphi$
6	0.99	0.025	1.03	1	1	0.48	0.6	2.5	0.85	0.52	178.76

**Table 11: Second moment parameter values of the forcing processes in model with nominal frictions**

$\rho_m$	$\rho_\epsilon$	$\rho_\xi$	$\rho_\delta$	$\phi_\Pi$	$\phi_y$	$\sigma_m^2$	$\sigma_\epsilon^2$	$\sigma_\xi^2$	$\sigma_\delta^2$
0.6	0.6	0.6	0.6	1.64	0.5	1	1	1	1

**Table 12: Sensitivity analysis of the market capitalization - growth correlation in Calvo and Rotemberg Models**

	$\theta = 0.25$ $\varphi = 2.21$	$\theta = 0.50$ $\varphi = 9.90$	$\theta = 0.70$ $\varphi = 38$	$\theta = 0.75$ $\varphi = 58.25$	$\theta = 0.80$ $\varphi = 96.15$
$\gamma = 0.40$	Calvo = 0.87 Rotem = 0.88	Calvo = 0.84 Rotem = 0.78	Calvo = 0.51 Rotem = 0.47	Calvo = 0.23 Rotem = -0.49	Calvo = -0.24 Rotem = -0.5
$\gamma = 0.50$	Calvo = 0.87 Rotem = 0.88	Calvo = 0.84 Rotem = 0.81	Calvo = 0.55 Rotem = 0.50	Calvo = 0.28 Rotem = -0.49	Calvo = -0.22 Rotem = -0.5
$\gamma = 0.60$	Calvo = 0.87 Rotem = 0.88	Calvo = 0.84 Rotem = 0.83	Calvo = 0.55 Rotem = 0.51	Calvo = 0.37 Rotem = 0.33	Calvo = -0.15 Rotem = -0.19
$\gamma = 0.70$	Calvo = 0.87 Rotem = 0.88	Calvo = 0.84 Rotem = 0.84	Calvo = 0.59 Rotem = 0.51	Calvo = 0.39 Rotem = 0.35	Calvo = -0.13 Rotem = -0.19
$\gamma = 0.80$	Calvo = 0.87 Rotem = 0.88	Calvo = 0.84 Rotem = 0.85	Calvo = 0.62 Rotem = 0.59	Calvo = 0.39 Rotem = 0.35	Calvo = -0.13 Rotem = -0.20
$\gamma = 0.90$	Calvo = 0.87 Rotem = 0.88	Calvo = 0.84 Rotem = 0.85	Calvo = 0.65 Rotem = 0.65	Calvo = 0.40 Rotem = 0.37	Calvo = -0.11 Rotem = -0.20

**Table 13: Sensitivity analysis of the growth - inflation correlation in Calvo and Rotemberg Models**

	$\theta = 0.25$ $\varphi = 2.21$	$\theta = 0.50$ $\varphi = 9.90$	$\theta = 0.70$ $\varphi = 38$	$\theta = 0.75$ $\varphi = 58.25$	$\theta = 0.80$ $\varphi = 96.15$
$\gamma = 0.40$	Calvo = 0.30 Rotem = 0.31	Calvo = 0.22 Rotem = 0.27	Calvo = 0.03 Rotem = 0.10	Calvo = -0.28 Rotem = -0.22	Calvo = -0.49 Rotem = -0.44
$\gamma = 0.50$	Calvo = 0.30 Rotem = 0.31	Calvo = 0.23 Rotem = 0.27	Calvo = 0.04 Rotem = 0.10	Calvo = -0.28 Rotem = -0.22	Calvo = -0.44 Rotem = -0.42
$\gamma = 0.60$	Calvo = 0.31 Rotem = 0.33	Calvo = 0.23 Rotem = 0.29	Calvo = 0.05 Rotem = 0.10	Calvo = -0.25 Rotem = -0.20	Calvo = -0.35 Rotem = -0.38
$\gamma = 0.70$	Calvo = 0.31 Rotem = 0.33	Calvo = 0.24 Rotem = 0.29	Calvo = 0.05 Rotem = 0.10	Calvo = -0.23 Rotem = -0.20	Calvo = -0.34 Rotem = -0.38
$\gamma = 0.80$	Calvo = 0.33 Rotem = 0.34	Calvo = 0.24 Rotem = 0.29	Calvo = 0.07 Rotem = 0.10	Calvo = -0.23 Rotem = -0.20	Calvo = -0.28 Rotem = -0.38
$\gamma = 0.90$	Calvo = 0.33 Rotem = 0.35	Calvo = 0.24 Rotem = 0.29	Calvo = 0.08 Rotem = 0.10	Calvo = -0.22 Rotem = -0.20	Calvo = -0.28 Rotem = -0.38



**Table 14: Sensitivity analysis of the market capitalization - growth correlation  
in Calvo and Rotemberg models in absence of habit persistence**

	$\theta = 0.25$ $\varphi = 2.21$	$\theta = 0.50$ $\varphi = 9.90$	$\theta = 0.70$ $\varphi = 38$	$\theta = 0.75$ $\varphi = 58.25$	$\theta = 0.80$ $\varphi = 96.15$
$\gamma = 0.40$	Calvo = 0.59 Rotem = 0.60	Calvo = 0.53 Rotem = 0.55	Calvo = 0.47 Rotem = 0.50	Calvo = 0.11 Rotem = 0.17	Calvo = -0.31 Rotem = -0.25
$\gamma = 0.50$	Calvo = 0.59 Rotem = 0.60	Calvo = 0.53 Rotem = 0.55	Calvo = 0.47 Rotem = 0.50	Calvo = 0.11 Rotem = 0.17	Calvo = -0.31 Rotem = -0.25
$\gamma = 0.60$	Calvo = 0.59 Rotem = 0.60	Calvo = 0.53 Rotem = 0.55	Calvo = 0.47 Rotem = 0.50	Calvo = 0.11 Rotem = 0.17	Calvo = -0.31 Rotem = -0.25
$\gamma = 0.70$	Calvo = 0.59 Rotem = 0.62	Calvo = 0.53 Rotem = 0.55	Calvo = 0.47 Rotem = 0.53	Calvo = 0.11 Rotem = 0.18	Calvo = -0.31 Rotem = -0.25
$\gamma = 0.80$	Calvo = 0.60 Rotem = 0.62	Calvo = 0.54 Rotem = 0.55	Calvo = 0.47 Rotem = 0.53	Calvo = 0.14 Rotem = 0.19	Calvo = -0.28 Rotem = -0.15
$\gamma = 0.90$	Calvo = 0.60 Rotem = 0.62	Calvo = 0.54 Rotem = 0.55	Calvo = 0.47 Rotem = 0.53	Calvo = 0.14 Rotem = 0.19	Calvo = -0.28 Rotem = -0.15

**Table 15: Sensitivity analysis of the market capitalization - growth correlation  
in Calvo and Rotemberg models in absence of investment adjustment cost**

	$\theta = 0.25$ $\varphi = 2.21$	$\theta = 0.50$ $\varphi = 9.90$	$\theta = 0.70$ $\varphi = 38$	$\theta = 0.75$ $\varphi = 58.25$	$\theta = 0.80$ $\varphi = 96.15$
$\gamma = 0.40$	Calvo = 0.33 Rotem = 0.43	Calvo = 0.24 Rotem = 0.33	Calvo = 0.15 Rotem = 0.17	Calvo = 0.03 Rotem = 0.05	Calvo = -0.25 Rotem = -0.10
$\gamma = 0.50$	Calvo = 0.33 Rotem = 0.43	Calvo = 0.24 Rotem = 0.33	Calvo = 0.15 Rotem = 0.17	Calvo = 0.03 Rotem = 0.05	Calvo = -0.25 Rotem = -0.09
$\gamma = 0.60$	Calvo = 0.37 Rotem = 0.44	Calvo = 0.24 Rotem = 0.33	Calvo = 0.15 Rotem = 0.17	Calvo = 0.03 Rotem = 0.06	Calvo = -0.25 Rotem = -0.09
$\gamma = 0.70$	Calvo = 0.37 Rotem = 0.45	Calvo = 0.24 Rotem = 0.33	Calvo = 0.15 Rotem = 0.19	Calvo = 0.04 Rotem = 0.06	Calvo = -0.25 Rotem = -0.09
$\gamma = 0.80$	Calvo = 0.37 Rotem = 0.45	Calvo = 0.25 Rotem = 0.33	Calvo = 0.15 Rotem = 0.19	Calvo = 0.05 Rotem = 0.06	Calvo = -0.26 Rotem = -0.09
$\gamma = 0.90$	Calvo = 0.37 Rotem = 0.45	Calvo = 0.25 Rotem = 0.33	Calvo = 0.15 Rotem = 0.19	Calvo = 0.05 Rotem = 0.06	Calvo = -0.26 Rotem = -0.09

**Table 16: Sensitivity analysis of the market capitalization - growth correlation  
in Calvo and Rotemberg models in absence of price distortion**

$\gamma = 0.40$	Calvo = 0.35 Rotem = 0.38
$\gamma = 0.50$	Calvo = 0.35 Rotem = 0.37
$\gamma = 0.60$	Calvo = 0.35 Rotem = 0.37
$\gamma = 0.70$	Calvo = 0.34 Rotem = 0.37
$\gamma = 0.80$	Calvo = 0.34 Rotem = 0.37
$\gamma = 0.90$	Calvo = 0.34 Rotem = 0.37

**Table 17: Sensitivity analysis of the market capitalization - growth correlation in Calvo and Rotemberg models with full inflation indexation**

$\theta = 0.25$	Calvo = 0.87
$\varphi = 2.21$	Rotem = 0.88
$\theta = 0.50$	Calvo = 0.84
$\varphi = 9.90$	Rotem = 0.85
$\theta = 0.70$	Calvo = 0.65
$\varphi = 38$	Rotem = 0.67
$\theta = 0.75$	Calvo = 0.40
$\varphi = 58.25$	Rotem = 0.39
$\theta = 0.80$	Calvo = -0.11
$\varphi = 96.15$	Rotem = -0.16

**Table 18: Variance decomposition of four shocks in Calvo framework**

$\theta = 0.25$					$\theta = 0.85$				
	<i>TFP</i>	<i>MP</i>	<i>CQ</i>	<i>IST</i>		<i>TFP</i>	<i>MP</i>	<i>CQ</i>	<i>IST</i>
<i>yg</i>	79.65%	0%	0.06%	20.29%	<i>yg</i>	80.79%	0%	0.06%	19.15%
<i>mk</i>	83.75%	0%	0.05%	16.20%	<i>mk</i>	45.40%	0.02%	0.13%	54.47%
<i>infl</i>	99.28%	0.03%	0.10%	0.58%	<i>infl</i>	98.71%	0.09%	0.14%	1.06%
<i>s</i>	99.17%	0.04%	0.11%	0.68%	<i>s</i>	96.51%	0.29%	0.20%	3%
<i>kg</i>	38.85%	0%	10.35%	50.80%	<i>kg</i>	39.16%	0%	18.23%	42.61%
<i>q</i>	87.585	0%	0.04%	12.38%	<i>q</i>	18.61%	0.01%	0.02%	81.36%
<i>mc</i>	99.70%	0.01%	0.10%	0.20%	<i>mc</i>	99.62%	0.01%	0.11%	0.26%
<i>r</i>	99.76%	0%	0.07%	0.16%	<i>r</i>	99.62%	0.01%	0.11%	0.26%
<i>pstar</i>	99.60%	0.01%	0.10%	0.29%	<i>pstar</i>	99.43%	0.03%	0.12%	0.43%
<i>ck</i>	33.27%	0%	0.01%	66.71%	<i>ck</i>	17.43%	0.02%	0.02%	82.53%
<i>chik</i>	64.35%	0%	0.01%	35.64%	<i>chik</i>	65.90%	0.01%	0.01%	34.07%
<i>dk1</i>	99.71%	0.01%	0.09%	0.19%	<i>dk1</i>	99.62%	0.01%	0.11%	0.26%
<i>dk2</i>	99.71%	0.01%	0.09%	0.19%	<i>dk2</i>	99.62%	0.01%	0.11%	0.26%
<i>dk</i>	99.71%	0.01%	0.09%	0.19%	<i>dk</i>	99.62%	0.01%	0.11%	0.26%

**Table 19: Variance decomposition of four shocks in Rotemberg framework**

$\varphi = 2.21$					$\varphi = 178.76$				
	<i>TFP</i>	<i>MP</i>	<i>CQ</i>	<i>IST</i>		<i>TFP</i>	<i>MP</i>	<i>CQ</i>	<i>IST</i>
<i>yg</i>	99.80%	0%	0.06%	0.14%	<i>yg</i>	99.80%	0%	0.06%	0.14%
<i>mk</i>	84.25%	0%	0.05%	15.70%	<i>mk</i>	46.21%	0.01%	0.14%	53.64%
<i>infl</i>	99.60%	0.01%	0.10%	0.29%	<i>infl</i>	99.46%	0.02%	0.12%	0.4%
<i>nu</i>	99.60%	0.01%	0.10%	0.29%	<i>nu</i>	99.46%	0.02%	0.12%	0.4%
<i>kg</i>	34.45%	0%	20.05%	45.49%	<i>kg</i>	38.14%	0%	18.47%	43.38%
<i>q</i>	88.42%	0%	0.04%	11.54%	<i>q</i>	16.58%	0.01%	0.02%	83.38%
<i>mc</i>	99.70%	0.01%	0.10%	0.20%	<i>mc</i>	99.62%	0.01%	0.11%	0.26%
<i>r</i>	99.76%	0%	0.07%	0.16%	<i>r</i>	99.62%	0.01%	0.11%	0.26%
<i>ck</i>	78.07%	0%	1.91%	20.02%	<i>ck</i>	61.26%	0.01%	0.01%	38.73%
<i>chik</i>	91.76%	0%	0.33%	7.91%	<i>chik</i>	92.62%	0.01%	0.02%	7.35%
<i>dk</i>	99.66%	0.1%	0.9%	0.25%	<i>dk</i>	99.52	0.01	0.11%	0.36%

**Table 20: Impact effect of the most dominant shock in Calvo and Rotemberg frameworks**

Calvo			Rotemberg		
	$\theta = 0.25$	$\theta = 0.80$		$\varphi = 2.21$	$\varphi = 96.15$
<i>yg</i>	TFP (+)	TFP (+)	<i>yg</i>	TFP (+)	TFP (+)
<i>mk</i>	TFP (+)	IST (-)	<i>mk</i>	TFP (+)	IST (-)
<i>infl</i>	TFP (+)	TFP (+)	<i>infl</i>	TFP (+)	TFP (+)
<i>s</i>	TFP (+)	TFP (+)	<i>neu</i>	TFP (-)	TFP (-)
<i>kg</i>	IST (+)	IST (-)	<i>kg</i>	IST (+)	IST (-)
<i>q</i>	TFP (+)	IST (-)	<i>q</i>	TFP (+)	IST (-)
<i>mc</i>	TFP (-)	TFP (-)	<i>mc</i>	TFP (-)	TFP (-)
<i>r</i>	TFP (+)	TFP (-)	<i>r</i>	TFP (+)	TFP (-)

**Table 21: Market capitalization - growth correlation comparison between data and Calvo model**

Data		Calvo Model	
Quartiles	$r_{mk, yg}$	Price distortion parameter	$r_{mk, yg}$
Q1	0.320	$\theta = 0.76$	0.327
Q2	0.412	$\theta = 0.72$	0.418
Q3	0.527	$\theta = 0.70$	0.552
Upper Fence	0.838	$\theta = 0.50$	0.839
Lower Fence	0.009	$\theta = 0.79$	0.019

**Table 22: Growth - inflation correlation comparison between data and Calvo model**

Data		Calvo Model	
Quartiles	$r_{yg, infl}$	Price distortion parameter	$r_{yg, infl}$
Q1	-0.21	$\theta = 0.75$	-0.25
Q2	-0.08	$\theta = 0.73$	-0.13
Q3	0.08	$\theta = 0.70$	0.05
Upper Fence	0.53	$\theta = 0.20$	0.33
Lower Fence	-0.66	$\theta = 0.85$	-0.45

**Table 23: Market capitalization - growth correlation comparison between data and Rotemberg model**

Data		Rotemberg Model	
Quartiles	$r_{mk, yg}$	Price distortion parameter	$r_{mk, yg}$
Q1	0.320	$\varphi = 58.25 (\theta = 0.75)$	0.332
Q2	0.412	$\varphi = 44.77 (\theta = 0.72)$	0.435
Q3	0.527	$\varphi = 38 (\theta = 0.70)$	0.512
Upper Fence	0.838	$\varphi = 8.79 (\theta = 0.48)$	0.839
Lower Fence	0.009	$\varphi = 70.42 (\theta = 0.77)$	0.015

**Table 24: Growth - inflation correlation comparison between data and Rotemberg model**

Data		Rotemberg Model	
Quartiles	$r_{yg,inf l}$	Price distortion parameter	$r_{yg,inf l}$
Q1	-0.21	$\varphi = 58.25 (\theta = 0.75)$	-0.21
Q2	-0.08	$\varphi = 53.21(\theta = 0.74)$	-0.06
Q3	0.08	$\varphi = 38 (\theta = 0.70)$	0.10
Upper Fence	0.53	$\varphi = 1.56 (\theta = 0.20)$	0.36
Lower Fence	-0.66	$\varphi = 178.76 (\theta = 0.85)$	-0.40

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