



ESSAYS IN QUANTITATIVE MACROECONOMICS

PEDRO BRINCA

©Pedro Brinca, Stockholm University 2013

ISSN 1404-3491

ISBN 978-91-7447-742-9

Printed in Sweden by PrintCenter US-AB, Stockholm 2013
Distributor: Department of Economics, Stockholm University

To Pedrito, Jorge, Bombas
and Pedro

Contents

Acknowledgements

Introduction

Essay I: Distortions in the Neoclassical Growth Model: A Cross-Country Analysis

Essay II: Monetary Business Cycle Accounting for Sweden

Essay III: Consumer Confidence as a Predictor of Consumption Spending: Evidence for the United States and Euro-Area

Acknowledgements

Having a Ph.D. and becoming an academic is something that came later in my life. I doubt many children dream of being academics and even less in being economists. I was no exception. Though drawn to physics and math since young, the possibility of playing football at a higher level delayed my entrance in academics a few years. Once I realized that a career in football was not going to happen, going to the university and choosing economics as a main subject was a little act of rebellion against my mother, who had strongly lobbied, since my high-school years, for me to study business administration and join the family businesses. Coming from a country like Portugal, family obviously played a big part for me to get where I am today. They supported my undergraduate studies and also my decision to come abroad, both financially and emotionally and I will be forever grateful.

My first years as an undergraduate were very atypical of a future Ph.D. I was still playing football in minor leagues, living in a fraternity house where parties were the rule rather than the exception and my studies ranked comparably lower in my priority list. Eventually I gained the maturity to realize that my studies, rather than football or partying, should be my priority. I decided to apply for a year of exchange studies at Stockholm University. I wanted to isolate myself from all the distractions I had created in my life and focus solely on studying. This was probably the best decision I ever took. I am very thankful to my friend Lena and my Erasmus Coordinator Maria Conceição Pereira, who convinced and supported me in this decision.

I still remember the day I crossed the bridge from Denmark to arrive in Sweden, back in August, 12th, 2003. I was stopped by the police for a routine check. When I asked them about a place to camp, I was very puzzled by the answer. I could camp anywhere I wanted, as long as I would respect the privacy of the land owner and would not camp in the same place for more than a night or two. I was intrigued, to say the least. My priors about Sweden back then regarded beautiful blond women, lots of snow and Sven-Goran Eriksson. That day marked the beginning of my personal discovery of Swedish society and culture. It is an ongoing process that enriched my life in many more ways than I could ever have thought. Stockholm became the place where I have spent the biggest share of my adult life so far and I cannot help but feel privileged that it has been so. I never had much of a life

outside the university environment, but when venture away from it, I was very lucky to have met very special people such as Cecilia, Karl and Amy.

The exchange year was very productive and by the end of the year I was given the opportunity of transferring my credits to Stockholm and graduate here. I was so happy about Sweden and Stockholm University that I didn't even think twice. To this I am very grateful to Michael Lundholm, who made it possible. Often we are grateful to people because they did their job in a professional manner. Other times, we are grateful to significant ones, because they cared for us in ways that, in the end, we expect significant ones to. In Michael's case, it was neither his job to make my transfer happen, nor I was a significant one to him. Regardless, he cared for me and helped me in a way that went beyond anything I could have expected. It was because he cared, that he bothered, that I managed to move to Sweden and Stockholm University. To him I owe all the amazing things I came to experience as a consequence of that. Words cannot, sadly, describe the dimension of my gratitude to Michael.

Once in the Ph.D., I was confronted with a whole new reality. I found myself sometimes struggling to keep my head above the water, something I was not prepared psychologically for. I am very grateful to my colleagues for all the support they gave me. I don't think anyone can have an idea of the emotional and physical toll a Ph.D. takes without going through one. I am grateful to Emma, Ettore, Linnea, Jan, Anna Lindahl, Maria Cheung, Laurence, Daniel, Petra and many others who are not listed here but are as important. Many became great friends and, despite their help throughout the program, their friendship is the most precious gift they ever gave me.

At the end of the first year I had to choose a field to specialize in. Hesitant regarding all the possibilities, I was inclined for macroeconomics due to the extraordinary passion and magic that Lars Ljungqvist manages to put in his macro lectures. Per Krusell and John Hassler complemented Lars teachings with applications that made the whole DSGE framework feel more tangible and tractable. To help me decide, I enrolled in four summer schools. In one of those, I had the privilege of meeting Ellen McGrattan. Ellen possesses all the analytical rigor and passion for strong logical foundations that Lars had taught me to appreciate, and more... I was captivated by Ellen's pragmatism and discipline in taking the models to the data. It was then that I decided to specialize in quantitative macroeconomics. It just felt right.

When the second year came and so the decision on where to go abroad for the third year, U Minnesota came as a logical choice. I thank Per and John, who despite my inquiries regarding a sunnier and warmer place, relentlessly insisted that Minnesota was the place to go. I am very thankful again to El-

len, who made it possible. As with Michael, my gratitude to her knows no bounds.

My stay in Minneapolis was very inspiring. I had the possibility of attending the Federal Reserve Bank seminars as well as classes and seminars at the Department of Economics. The yearly workshop with Jose Victor Ríos-Rull was one of the most important events in my education as a Ph.D. My previous contacts with my references had inspired me, but it was with Victor that I learned how to think about macroeconomics. Victor is brilliant, borderline obsessive, with all the characteristics I had now learned to appreciate: a structural approach to modeling, strongly disciplined by the data.

The quest for a suitable dissertation topic continued and, inevitably, it was again with Ellen that I found the inspiration. It was in her classes that I learned the methodology of business cycle accounting. Her paper, joint with Patrick Kehoe and V.V. Chari, inspired dozens (hundreds?) of other publications. Two of the chapters in my dissertation build on their seminal work.

The stay in Minnesota was also enriched by many friends who made the time there quite special. I thank Diego, Ettore and Dyah in particular for that. After my time in Minnesota was over, I went to the European Central Bank for a research internship. I worked under the supervision of Stephane Dees. Our cooperation resulted in the one of the essays in my dissertation. I am very thankful to Stephane for all the support in guiding me through my first serious research project. My time at the ECB was very productive and insightful. Stephane has a way of bringing out the best in people. I hope someday I will have the privilege of working with him again. I made great friends at the ECB, like Dario, Cecilia and Francesco, to whom I am also grateful.

After the internship was over, I came back to Stockholm and started to work on the remaining chapters of my dissertation under the supervision of Martin Flodén. I cannot stress enough his availability, patience and perseverance. Very seldom Ph.D. students get a supervisor with whom they have a scheduled weekly meeting and are welcomed to go to his office, unannounced, whenever they see fit. To all the precious insights and comments Martin provided, he added guidance and an almost scary clairvoyance when anticipating the results of approaches to practical issues we would discuss. I was also privileged to have had other scholars who took the time to read my work and provide valuable comments and suggestions. Annika Alexius, John Hassler, Johan Söderberg, Alper Çenesiz, Alexandra Ramos and others provided valuable feedback for which I am most grateful. I am very thankful to Luis Aguiar-Conraria who lead the pre-defense of my dissertation and whose comments were very insightful and of great value. Luis is also a role-model, a true scholar and incisive thinker that I came to deeply admire.

I cannot stress enough either, the quality of the administrative staff at the Department of Economics. Ingela Arvidsson and Katrin Göpel are fantastic, not only for their professionalism, but also for their pragmatism, result oriented attitude and genuine care. Adam Jacobsson is a great Director of Studies to work with, even though my gratitude to him comes from further back, since he had already provided excellent supervision for my BSc. thesis.

During the time in Stockholm, I also taught a lot. I love teaching but the joy I got out of it was immensely enhanced by the fantastic students I had the privilege of having, many of whom became colleagues in the Ph.D. and great friends. I am grateful to all of them, but there is one to whom I am particularly grateful. Sirius Dehdari was as talented as hard-working, two characteristics that often are at odds with each other. He also provided valuable research assistance. Without any surprise, he then joined the Ph.D. and we strengthened our already strong friendship. I am also very grateful to the lecturers to whom I provided teaching assistance, but in particular to Markus Jantti, who gave me a lot of freedom and responsibility in teaching the course in MSc Time Series Econometrics. Thanks to his guidance and trust, I feel that I was given room to grow as a teacher.

In my last year of the Ph.D., I felt the need of taking a time out of teaching and focus solely on writing my dissertation. After having taught eleven courses, I needed the time and availability to make the dissertation happen. I went to visit the U Porto for a year and I am very grateful to Ana Paula Ribeiro and José Varejão for receiving me and giving me excellent working conditions. As before, my life got richer with the friendship of colleagues as Alper, Alexandra, Joana, Susana and friendships I got to develop outside the university with Ana Paula, Ester and Miguel. But most importantly, during the year in Porto I got to be close to my best friend for 19 years now, Ana Isabel, who became my girlfriend and now fiancée. To her I am immensely grateful for being a role model in terms of dedication and hard work, but above all, for her love and support.

Finally, I need to acknowledge also that all this took a lot of resources, mostly public funds that could have been used to alternative ends. I have to thank the European Commission, the Erik Ljungberg Foundation, the Portuguese Science and Technology Foundation and Handelsbanken for generous funding of my research activities. But above all I am indebted to the Swedish taxpayer who footed most of the bill, either directly or indirectly. I will try to do my best to be worthy of it.

Introduction

When young, I was very drawn to math and physics. I read a lot of books in both subjects but with regard to physics, what drawn me the most was the quest for a grand unified theory of physics. I would read these science books for non-specialists and I was fascinated by the deep held belief in physics that there exists a grand unified theory from which all phenomena can be explained. Rather than have many different models for seemingly unrelated phenomena, what impressed me was the attempt to find some sort of primitive theory, from which could be derived the laws that would describe the different phenomena.

I was also fascinated by how alternative representations of the same reality would rise and fall according to empirics. This constantly reminds me that if, in the words of Victor Rios-Rull, we aim to create theories of how the world is, rather than how the world should be, we need to have our modeling efforts constantly disciplined by the data.

A third fundamental point that captured my attention was how in history, many times empirics were ahead of theory or, sometimes, it was theory that was ahead of what could be empirically tested. If in physics we are apparently in the later, in economics things are not quite the same. There is a constant struggle between creating more complex models and paying the price in terms of identification ability and computational feasibility, or creating simpler models that will likely be lacking in power and accuracy.

The choice of topics in this dissertation, in some ways, reflects those three notions. Two of the papers build on the notion that a general model augmented by different shocks that once properly modeled, replicates all the movements in the main macroeconomic aggregates. This general theory consists in the neoclassical growth model, which became the workhorse of modern macroeconomics thanks to the seminal work of Kydland & Prescott (1982). The methodology to assess the relevance of each type of shock was developed by Chari et al (2007).

The first paper applies the methodology of business cycle accounting introduced by Chari et al (2007) to a sample of 19 OECD countries. The idea that underlines the essay is that the primitive forces (prototype economy) that

govern the economies of these 19 countries are the same and they potentially differ only across the shocks they are subject to. The goal is to gain insight with respect of the relevance and magnitude of such shocks across the sample. The first insight is that shocks that express themselves as total factor productivity and labor income taxes are comparably more synchronized than shocks that resemble distortions to the ability of allocating resources across time and states of the world, with U.S. recessions containing information with respect to their evolution across time. These two shocks are also the most important to model, in order to make the prototype economy closer to reality. Lastly, I document the importance of international channels of transmission for the shocks, given that these are spatially correlated and that international trade variables, such as trade openness correlate particularly well with them.

The second paper applies an extension of the business cycle accounting methodology introduced by Sustek (2010). The subject of analysis is the Swedish economy and the period of 1982 to 2010. Given that the analysis is focused in one country, we can extend the prototype economy to include a nominal interest rate setting rule and government bonds, something that could not be done in the previous paper since many countries in the sample belong to a currency union. The findings suggest, as in the previous essay, that distortions to the labor-leisure condition and total factor productivity are the most relevant margins to be modeled, now joined by deviations from the nominal interest rate setting rule. The period under analysis contains two major recessions. One is typically perceived as a domestic crisis and emerged in the early 1990's. The other is what came to be known as the Great Recession and originated in the United States. The opportunity of having a domestic crisis and an international one also provided valuable insight to the comparative dynamics of these distortions in both periods. The findings show that the distortions do not share a structural break during the Great Recession, but they do during the 1990's. Researchers aiming to model Swedish business cycles must take into account the structural changes the Swedish economy went through in the 1990's, though not so during the last recession.

These two applications of business cycle accounting provide evidence with regard to properties that extensions to the neoclassical growth model must possess in order to generate fluctuations as observed in the data. As stated in the beginning, our modeling efforts are therefore disciplined by what the data tells us.

The last paper regards consumer confidence and consumption spending. This is an example of how sometimes empirics are ahead of theory. What is confidence? How do we put it in our models? These are just two of many ques-

tions regarding confidence. There is hardly any consensus in answering them. There is however, evidence that confidence surveys are useful in terms of forecasting. This is an example of the third fundamental point I referred before. In this case, empirics are clearly ahead of theory. In the absence of a structural and consensual framework in which we can assess the empirical relevance of confidence surveys, Stephane and I restrict ourselves to a narrower research question, namely assessing the forecasting potential consumer confidence surveys possess with regard to forecasting private consumption spending.

The results show that, the consumer confidence index can be in certain circumstances a good predictor of consumption. In particular, out-of-sample evidence shows that the contribution of confidence in explaining consumption expenditures increases when household survey indicators feature large changes, so that confidence indicators can have some increasing predictive power during such episodes. Moreover, there is some evidence of a confidence channel in the international transmission of shocks, as U.S. confidence indices help predicting consumer sentiment in the euro area.

REFERENCES

Chari, Varadarajan V., Patrick J. Kehoe, and Ellen R. McGrattan. "Business cycle accounting." *Econometrica* 75.3 (2007): 781-836.

Kydland, Finn E., and Edward C. Prescott. "Time to build and aggregate fluctuations." *Econometrica: Journal of the Econometric Society* (1982): 1345-1370.

Šustek, Roman. "Monetary business cycle accounting." *Review of Economic Dynamics* 14.4 (2011): 592-612.

I

Distortions in the Neoclassical Growth Model: A Cross-Country Analysis*

Pedro Brinca[†]

August 21, 2013

Abstract

This paper investigates the properties of distortions that manifest themselves as wedges in the equilibrium conditions of the neoclassical growth model across a sample of OECD countries for the 1970-2011 period. The quantitative relevance of each wedge and its robustness in generating fluctuations in macroeconomic aggregates is assessed. The efficiency wedge proves to be determinant in enabling models to replicate movements in output and investment, while the labor wedge is important to predict fluctuations in hours worked. Modeling distortions to the savings decision holds little quantitative or qualitative relevance. Also, investment seems to be the hardest aggregate to replicate, as prediction errors concerning output and hours worked are typically one order of magnitude smaller. These conclusions are statistically significant across the countries in the sample and are not limited to output drops. Finally, the geographical distance between countries and their degree of openness to trade are shown to contain information with regard to the wedges, stressing the importance of international mechanisms of transmission between distortions to the equilibrium conditions of the neoclassical growth model.

JEL Classification: E27, E30, E32, E37

Keywords: Business cycle accounting, frictions, economic fluctuations

*I am grateful for comments from Martin Flodén, John Hassler, Tobias Broer, Alper Çenesiz, Luis Aguiar-Conraria, Alexandra Ramos, Joana Pinho, Vincenzo Quadrini, IIES, CEFUP, and GEMF seminar participants, PET2013 and the 7th Annual meetings of the PEJ conference participants and, in particular, Sirius Dehdari for excellent research assistance.

[†]Correspondence to Pedro Brinca, email pedro.brinca@ne.su.se. Address: Department of Economics, Stockholm University, SE-106 91 Stockholm, Sweden.

1 Introduction

The focus of this paper concerns the measurement and systematic analysis of different types of distortions to the equilibrium conditions of the neoclassical growth model. Their quantitative relevance in generating fluctuations at the business cycle frequency in macroeconomic aggregates is also analyzed and tentative structural explanations for such distortions are put forth by identifying relevant indicators that contain information with respect to the said distortions.

The interest in analyzing the properties of deviations from theoretically postulated relationships among macroeconomic aggregates within the neoclassical framework can be traced back at least to Solow (1957). Deviations from observed output and capital and labor inputs for a given aggregate production function were taken to be the source of long term growth and became known as the 'Solow residual' or total factor productivity. Growth accounting exercises became widespread in order to measure the contribution of each factor with respect to changes in output.

This was mainly a growth issue until Kydland and Prescott (1982) introduced a multiplicative persistent shock into an aggregate production function and managed to generate fluctuations in macroeconomic aggregates at business cycle frequencies. By then this was done in a context of a general equilibrium model, with endogenous labor supply and savings decision. Subsequent work aimed to provide structural explanations for these shocks as well as creating departures from the neoclassical growth model that could replicate fluctuations observed in the data. However, much of the focus was still on total factor productivity and in theories that could explain it.

Researchers started to be interested in the properties of deviations in other equilibrium conditions, such as the labor-leisure choice. Mulligan (2002) looks into data for the U.S. from 1889 until 1996 to describe the statistical properties of such deviations (in this case to the labor-leisure choice) and provide tentative explanations behind them. Other authors focused on models with financial frictions, such as Calstrom and Fuerst (1997) or Bernanke et al. (1999), that express themselves mostly as distortions to the savings

decision.

Much in the fashion of growth accounting, a business cycle accounting methodology was developed by Chari et al. (2007). Distortions to the equilibrium conditions, of what the authors dub a prototype growth model containing the key ingredients of the neoclassical framework, are measured. Their quantitative and qualitative relevance in generating fluctuations in macroeconomic aggregates through a series of simulations is assessed. In the work cited, the methodology is applied to both the Great Depression and the 1981 recession in the U.S.

Since then a large body of literature has developed based on Chari et al. (2007) methodology. Some authors provide methodological departures from Chari et al. (2007). Two examples can be found in Otsu (2009) that conducts the analysis in the context of a two country model and Sustek (2010), adding a Taylor type rule for nominal interest rate setting and government bonds.

Other have applied the methodology to other countries. Kobayashi and Inaba (2006) for Japan, Simonovska and Söderling (2008) for Chile and Lamas (2009) for Argentina, Mexico and Brazil are just few examples. The results seem to conclude, much in line with Chari et al. (2007), that total factor productivity and distortions to the labor choice are relevant, where distortions to the savings decision are considerably less important. Some authors focus their analysis to one type of deviations as in Restrepo-Echavarria and Cheremukhin (2010) or Cociuba and Ueberfeldt (2010) with distortions in the labor choice or other numerous studies concerning total factor productivity such as Islam et al. (2006). Finally, other line of work looks into a selected sample of countries and into specific periods of fluctuations such as output drops (see Dooyeon and Doblus-Madrid (2012) as one example).

This paper contributes to the literature in several dimensions. First the sample of countries chosen for analysis is driven purely by data availability. This avoids sample selection bias. Most business cycle accounting exercises restrict their samples by analyzing recessions, and, consequently, countries that experienced the recessive episodes. The validity of the conclusions are therefore restricted to the criteria that drove the sample selection.

Second, by taking a comparably large sample of countries and pooling the

measured distortions cross-sectionally when analyzing specific episodes that are perceived as having an international scope such as the oil shocks in the 1970s or the 2008 financial crisis, we can draw inference as to whether such episodes systematically generated distortions in the equilibrium conditions of the neoclassical growth model across the countries in the sample.

Third, by using data that goes back until 1970 at the quarterly frequency, we can decompose the distortions in their trend and cycle components. Mulligan (2002) highlights the importance of analyzing trend and cycle separately. The author finds that marginal tax rates are important in explaining the trend but not the cycle component of distortions to the labor decision.

Fourth, by applying the business cycle accounting methodology, we are able not only to measure and decompose the distortions but also to assess their quantitative relevance in generating fluctuations in macroeconomic aggregates that resemble movements in observed data. This was performed both for specific episodes and for the whole sample, and draw inference on whether specific distortions are systematically important across the countries. We compare simulations with observed data and determine the key distortions to be modeled in order to bring the neoclassical growth model closer to reality.

Lastly, these distortions are analyzed by country characteristics, in search for indicators that contain information with respect to the distortions and in this way suggest tentative extensions to the business cycle model that are general enough to be relevant for most countries in the sample. In the last section of the paper we show that point estimates of the correlation between the the cross-country per type of wedge correlation and the geographical distance between the countries is negative for all wedges and most countries, though only in the case of the efficiency wedge there is strong statistical significance. This type of analysis is common in the trade literature, where trade between countries is often (also) explained by gravitation equations, i.e., volumes of trade as a function of the physical distance between them. The degree of openness (exports plus imports as a share of output) is another factor found to contain significant information with regard to all wedges, underlining the relevance of international mechanisms of transmission with

regard to distortions to the equilibrium conditions of the model.

2 Data, model and calibration

2.1 Data

The data used to measure the wedges comes from OECD Economic Outlook. It concerns GDP, Government Consumption, Gross Fixed Capital Formation, Imports, Exports and their respective deflators, Total Employment and Total Hours Worked per Employee. Additionally there is also data on total population and percentage population below 16 and percentage population over 65. All series end on the last quarter of 2011 and, in very few exceptions such as some series concerning hours worked and population, data ends in the last quarter of 2010 and is extrapolated to end in 2011Q4).

Based on this, data are transformed according to the following procedure. Deflators are transformed to have 2005Q1 as base year. Data is then deflated accordingly. The four observables are output, hours worked, investment and government consumption (plus net exports), all in per-capita units. Sales and indirect taxes are not taken into account in the computation of model output because of availability and comparability. Hence, output, investment and government consumption plus net exports per capita are just the deflated series divided by quarterly interpolated active population. Hours worked are the product of Total Employment and Hours Worked per Employee divided by active population.

2.2 Model

The prototype economy is the same as in Chari et al. (2007). It is the neo-classical growth model with labor and savings decisions and four exogenous random variables. These variables are the efficiency wedge A_t , the labor wedge τ_{lt} , the investment wedge τ_{xt} and the government wedge g_t . Consumers maximize expected utility over per-capita consumption c_t and labor

l_t :

$$\max E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - l_t) \quad (1)$$

subject to the budget constraint

$$c_t + (1 + \tau_{xt})x_t = (1 - \tau_{lt})w_t l_t + r_t k_t + T_t \quad (2)$$

and the capital accumulation law

$$(1 + \gamma_n)k_{t+1} = (1 - \delta)k_t + x_t \quad (3)$$

where x_t is investment, w_t the wage rate, r_t the rental rate on capital, β the discount factor, $1 + \gamma_n$ is the population growth rate, k_t the stock and T_t lump sum transfers, all in per capita terms. The production function is given by $A_t F(k_t, (1 + \gamma_z)^t l_t)$ where y_t is per capita output and γ_z the rate of labor augmenting technical progress. The representative firm maximizes profits and pays factors their marginal products. The equilibrium in the economy is therefore pinned down by the aggregate resource constraint

$$c_t + x_t + g_t = y_t \quad (4)$$

where y_t is per capita output, the production function

$$y_t = A_t F(k_t, (1 + \gamma)^t l_t) \quad (5)$$

the labor-leisure choice

$$-\frac{u_{lt}}{u_{ct}} = (1 - \tau_{lt})A_t(1 + \gamma)F_{lt} \quad (6)$$

and the savings optimality condition

$$u_{ct}(1 + \tau_{xt}) = \beta E_t[u_{c,t+1}(A_{t+1}F_{k,t+1} + (1 - \delta)(1 + \tau_{x,t+1}))] \quad (7)$$

where a function's subscript denotes the derivative of the function with respect to the subscript argument, evaluated at subscript t . It is also assumed

that g_t fluctuates around the trend $(1 + \gamma_z)^t$.

2.3 Functional forms and calibration

The utility function is additive separable in logarithmic consumption and leisure, i.e., $u(c, l) = \log(c) + \psi \log(1 - l)$. The production function is linear homogeneous in capital and labor i.e. $F(k, l) = k^\theta l^{1-\theta}$. The values used for the parametrization of the models are the ones taken by Chari et al. (2007), with the exception of the population growth rate which is country specific. The growth rate of labor-augmenting technical change is taken from Kehoe and Prescott (2007).

Country specific calibration of the parameters for each economy was not performed because we didn't want cross-country differences to be driven by different parametrization but rather by the distortions themselves. The values are shown in Table 1 below, at annualized rates:

Table 1: Calibration

γ	β	δ	ψ	θ
0.02	0.97	0.05	2.24	0.35

Given the values for the parameters in the table above, the model is solved for the steady-state quantities and the equilibrium is found. Equilibrium decision rules are derived assuming that the exogenous states (the wedges) follow a four dimensional vector auto-regressive of order one where the error process is assumed to be multivariate normal with mean zero and variance-covariance matrix $Q = B'B$ as described below:

$$\omega_{t+1} = P_0 + P\omega_t + \epsilon_{t+1}, \epsilon \sim MVN(0, B'B) \quad (8)$$

The data is used as observables and the Kalman filter used to back out the innovations (wedges). The likelihood of the innovations being jointly normal is computed and the optimization program concerns the choice of the parameters of the VAR, i.e., the vector P_0 and the matrices P and B , such that the likelihood is maximized. This process is repeated for each country.

Stationarity is imposed in the estimation.

The purpose of performing simulations is to see to what extent models with just one distortion or a combination of distortions have the ability to replicate observed data. Hence, new decision rules are computed, setting the wedges, that are excluded in a specific simulation exercise, to their unconditional mean values throughout the simulation procedure. Since in they no longer are random variables in the simulations, the equilibrium decision rules and allocations in the simulated economies are consistent with the model.

3 Wedges' trends and cycles

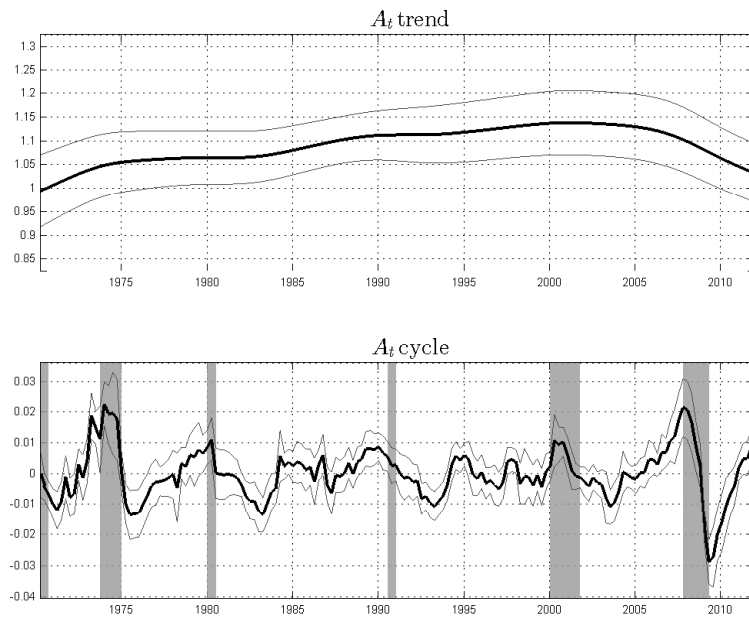
The wedges are filtered using the HP-filter as in Hodrick and Prescott (1997), with a smoothing factor of 1600. The original series, cycles and trends are presented in Appendix A. Average trends and cycles are computed by taking cross-country per quarter averages. Confidence intervals for the average trend and cycles are computed by drawing with replacement sample trend and cycles and computing their average. The empirical distribution of the average components is then used to compute the confidence intervals at the desired significance level. The shaded quarters in Figures 1 to 4 and 6, correspond to periods for which the NBER declared the U.S. economy to be in recession.

3.1 The efficiency wedge

The average trend for the efficiency wedge shows a modest positive slope until the early 2000's, and since then a steeper decline. For most of the sample (1975-2010), average detrended total factor productivity is significantly above one, indicating that its contribution for growth has been on average above the 2% that Kehoe and Prescott (2007) use. There is a slowdown after this period that was aggravated at the early stages of the 2008 financial crisis. The confidence intervals suggest that the series is relatively homoscedastic at the cross-sectional dimension as the amplitude remains fairly constant over the sample period.

With respect to the cyclical component we can see that fluctuations in total factor productivity are remarkably synchronized in the sense that for many periods the fluctuations are significantly different from zero. The most notable periods of accentuated fluctuations coincide with the Yom Kippur war and the oil crisis that ensued the autumn of 1973 and the 2008 financial crisis. It is notable however that the periods the NBER declared to mark recessions in the U.S. economy coincide with the extreme realizations of the wedges, given that the data was aggregated giving equal weight to each of the 19 countries in the sample. This suggests the weight that the U.S. economy still carries in determining business cycles for the countries in the sample.

Figure 1: Average trend and cycle for the efficiency wedge



95% Confidence intervals computed with bootstrapping, 1000 draws
 Shaded areas indicate U.S. recessions as declared by the NBER

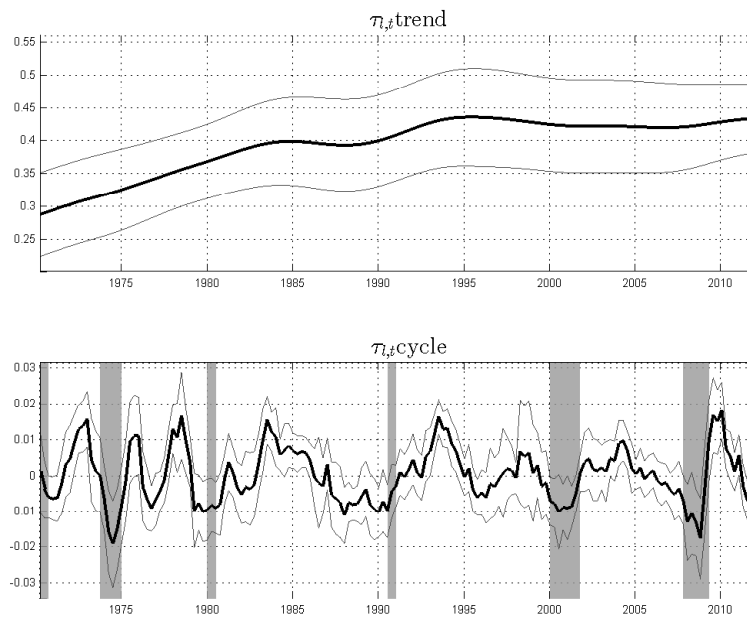
3.2 The labor wedge

In Figure 2 we see that there is an overall tendency for the labor wedge to increase over the sample period and the increase is statistically significant.

The average trend rose from just below 0.30 to 0.45. As in the case for the efficiency wedge, the cross-sectional variance is fairly stable. Nonetheless there are some countries, namely the U.S. and Canada, for which the trend is downward sloping. This is also documented by Shimer (2010) and Cociuba and Ueberfedt (2010) for the U.S. economy.

Concerning the cyclical component of the labor wedge, we can see that it is also fairly synchronized over the sample period. In fact there are, as in the case for total factor productivity, many instances where the aggregate labor wedge is statistically different from zero. The cycle is also similar in amplitude to the efficiency wedge, i.e., fluctuations are of about $\pm 3\%$. The series in itself, however, is more volatile, with more episodes comparable in magnitude to the fluctuations observed in the early 1970s and late 2000s.

Figure 2: Average trend and cycle for the labor wedge



95% Confidence intervals computed with bootstrapping, 1000 draws
 Shaded areas indicate U.S. recessions as declared by the NBER

As in the case of the efficiency wedge, the larger deviations from trend coincide with U.S. recessions, though where the efficiency wedge peaks at

those, here the recessions coincide with periods for which the labor wedge is at its lowest. With regard to the U.S., Shimer (2009) finds that the cyclical component of the labor wedge rises during recessive periods. In the case for the efficiency wedge, the drop in the sample average was coincident with U.S. recessions, but in this case there seems to be a lagging effect. As can be observed in Figure 2, recessions in the U.S. coincide with local minima of the average labor wedge in our sample, and it indeed rises during, or shortly after, later periods of the recessions.

Shimer (2009) argues that two obvious explanations would be that labor and consumption taxes rise during recessions.

Note that in our prototype economy there are no consumption taxes but these would be captured by the labor wedge. To see this, notice that if the budget constraint in (2) would include taxes on consumption:

$$(1 + \tau_{ct})c_t + (1 + \tau_{xt})x_t = (1 - \tau_{lt})w_t l_t + r_t k_t + T_t \quad (9)$$

the labor leisure choice would then be:

$$-\frac{u_{lt}}{u_{ct}} = \frac{1 - \tau_{lt}}{1 + \tau_{ct}} A_t (1 + \gamma) F_{lt} \quad (10)$$

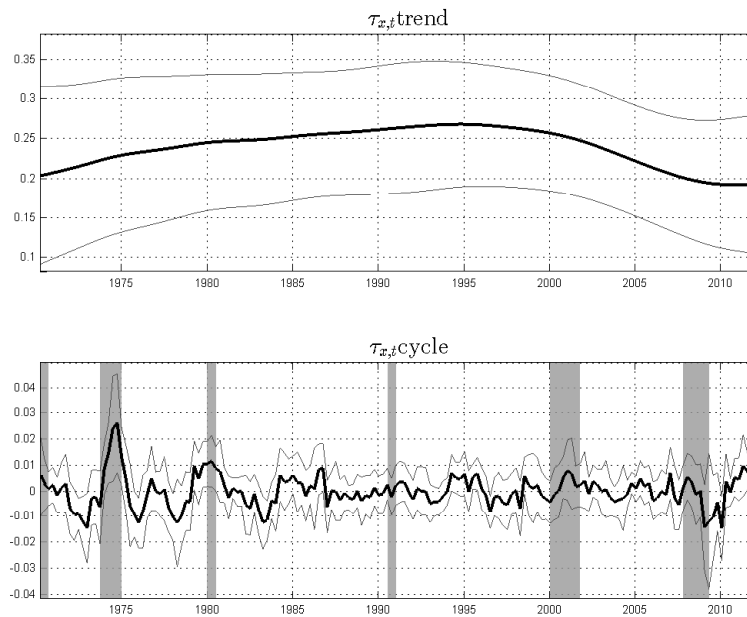
Since the labor wedge is computed residually to make the marginal rate of substitution between labor and consumption to equate the marginal product of labor, the labor wedge reflects changes in $\frac{1 - \tau_{lt}}{1 + \tau_{ct}}$. Shimer (2009) cites McGrattan and Prescott (2009) in arguing that changes in consumption taxes fit the data much better than tax changes in labor income. Mertens and Ravn (2008) however, put an upper bound of 18% to the variance of output explainable by tax shocks at the business cycle frequency. As argued before, this underlines the importance of decomposing the labor wedge between trend and business cycle frequencies.

3.3 Investment wedge

The investment wedge, unlike with the previous two cases, exhibits much larger cross-sectional volatility. Though the point estimates in Figure 3 show

a slight rise of the investment wedge until the late 1990s and a subsequent decline until the end of sample, the cross-sectional variance is such that we cannot reject that the average investment wedge was constant throughout our sample.

Figure 3: Average trend and cycle for the investment wedge



95% Confidence intervals computed with bootstrapping, 1000 draws
 Shaded areas indicate U.S. Recessions as declared by the NBER

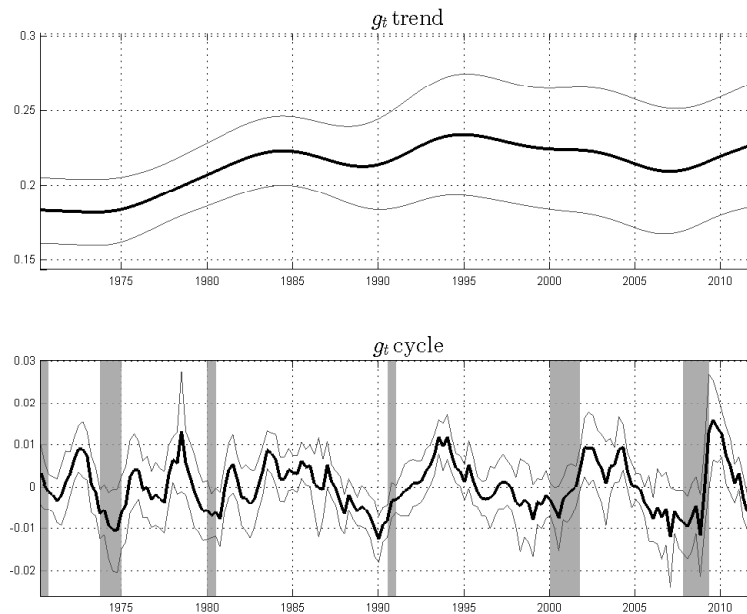
With respect to the cyclical component, both the amplitude of the deviations and the volatility are higher than in the previous two cases. Also, we find much fewer instances with statistical significance for average cyclical movements. This suggests that there is little synchronization in the sample with regard to distortions to the savings decision. Most notably, the period with the largest deviation from the trend was in the early 1970s and, unlike in the previous cases, there is hardly any co-movement with regard to the investment wedge for the last financial crisis. If we restrict ourselves though to the analysis of the point estimates, we can still partially observe the previous pattern of the wedges peaking during U.S. recessions, namely during the

mentioned 1970's period, the 1980's slowdown and the last financial crisis.

3.4 Government wedge

The government wedge (government consumption plus net exports) is expressed as a fraction of output. The trend is not nearly as smooth and there is an increasing dispersion though there is a marginally significant increase in the trend component of the government wedge over the sample period.

Figure 4: Average trend and cycle for the government wedge



95% Confidence intervals computed with bootstrapping, 1000 draws
Shaded areas indicate U.S. recessions as declared by the NBER

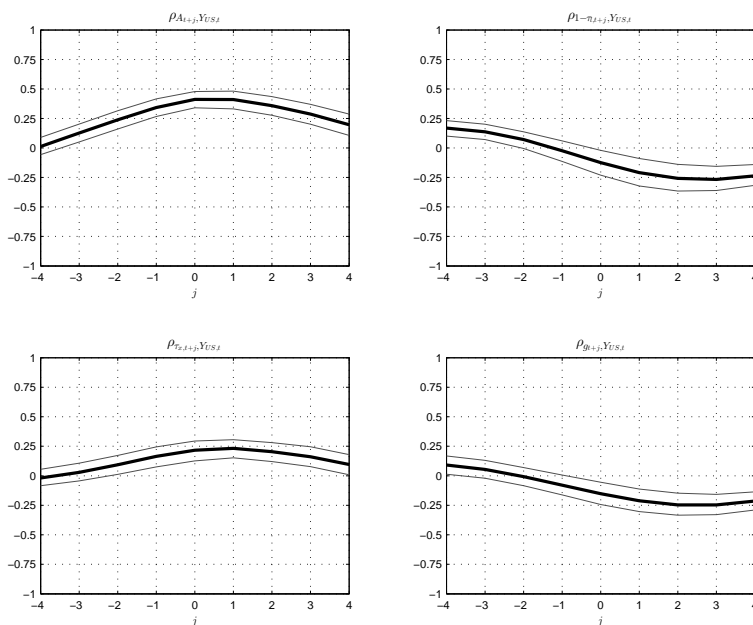
With regard to the cyclical variation, as in the case for the efficiency and labor wedges, there are many instances where the average cycle is comparable in magnitude and also statistically different from zero. U.S. recessions are still a good indicator of local minima for the government wedge, though as before, there are many other instances where the deviations are statistically significant.

3.5 Summary statistics

We have seen that movements in the efficiency, labor and government wedge are fairly synchronized and that have had changes in the trend component that are statistically different during several periods in the sample. The same cannot be said about the investment wedge. This indicates that there is a greater disparity in shocks to the savings decision that it is the case for the other equilibrium conditions, given the much fewer instances in which deviations from trend for the investment wedge behaved similarly enough such that they were significantly bigger(smaller) than zero.

We saw that U.S. recessions contain information regarding some features of the wedges. For example, U.S. recessions seem to lead significant drops in TFP and lead significant increases in the labor wedge. The Figure 5 below shows the lead-lag cross-correlation structure between each of the average wedges' cycles and the U.S. output cycle.

Figure 5: Lead-lag cross-correlation between ω_{t+j} and $Y_{US,t}$



95% Confidence intervals computed with bootstrapping, 1000 draws

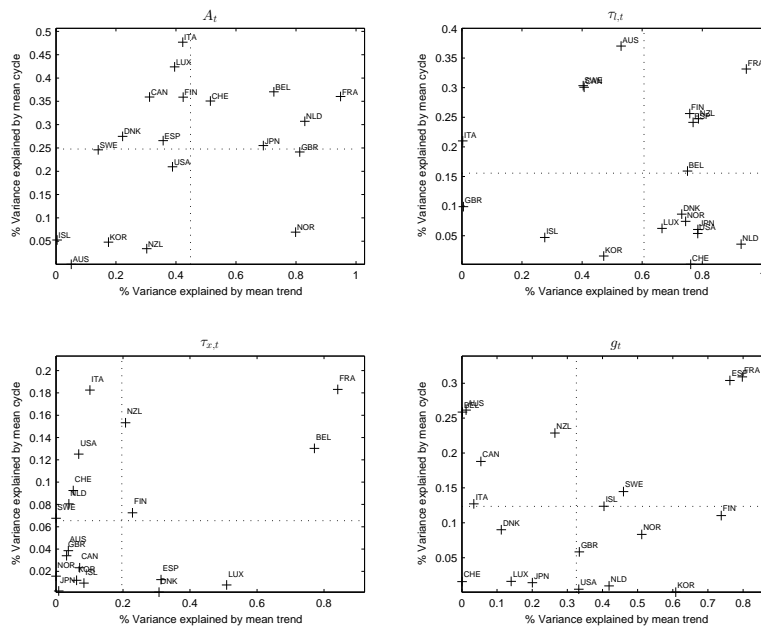
The U.S. cycle is positively correlated with TFP, with the higher point estimates suggesting it to be a coincident or leading (by one period) indicator of the rest of the sample average. With respect to the labor wedge, the contemporaneous correlation is negative, a result similar to what Shimer (2009) finds for the U.S. economy, and the estimate is statistically significant. The highest point estimate of the correlation (in absolute value) occurs with a three quarters lag making the U.S. cycle a leading indicator for the average labor wedge. The investment wedge shows a similar correlation structure as the efficiency wedge i.e. the correlation is positive and the U.S. output cycle is a coincident or leading indicator. In the case of the government wedge, the highest point estimate for the average correlation is obtained for $j = 3$ and it is negative. Note that in all cases, the correlations are 'skewed to the right' i.e. the higher point estimates are mostly found for $j \geq 0$. This provides further evidence of the relevance that the U.S. cycle may have with regard to the wedges in the rest of the countries in our sample.

In Figure 6, the percentage variation explained by both the mean cycle and variance can be depicted, for each country in the sample. The total variance explained is obtained by regressing the individual series on the average components (minus the respective series) and reporting the R^2 's of the regressions. Mean trend and cycle of the investment wedge explain less of the variation in the individual series compared to the other wedges. The average trend explains around 20% of the individual trends, against 45% for the efficiency wedge, 61% for the labor wedge and 33% of the government wedge. For the cycle, the differences are similar, with only 6% of the investment wedge cycle being explained by the average cycle against 25%, 15% and 13% for the efficiency, labor and government wedges respectively. This confirms our results that the investment wedge is significantly less synchronized than the other wedges, for both trend and cycle.

Another interesting aspect of Figure 6 is how France is the country whose wedges are most correlated with the average trend throughout the whole sample. With regard with the common cyclical component, France's wedges are also along the ones which show a higher degree of synchronization. A possible explanation is that out of our sample, seven countries are part of the Euro

Area. Following Aguiar-Contraria and Soares (2011), France and Germany were found to be the core of the Euro Area i.e. the most synchronized countries with the rest of Europe. Germany is not part of the sample due to data issues¹, but the fact that France is so synchronized with the average components of the wedges lends support to previous findings from Aguiar-Contraria and Soares (2011).

Figure 6: Percentage variation explained by average trend and cycle



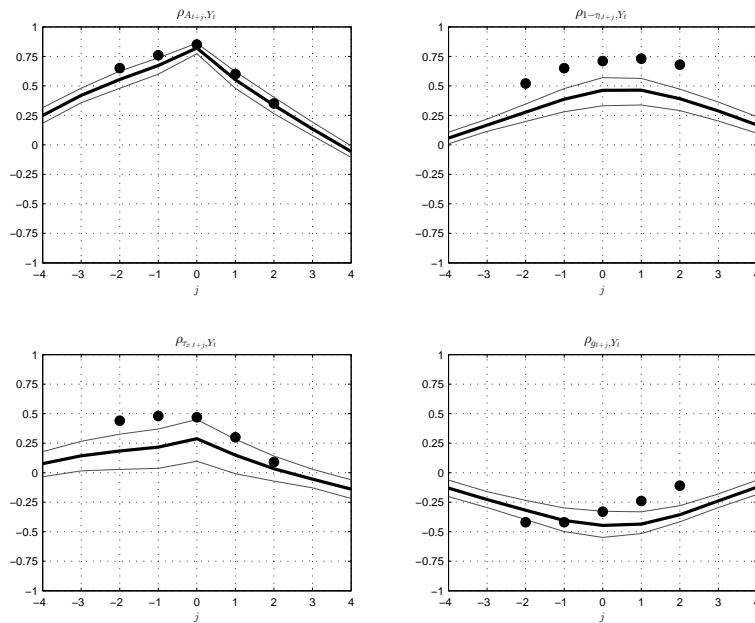
Vertical and horizontal lines concern total variance across all series explained by average cycle and trend respectively

Figure 7 shows the cross-correlations between each of the (HP-filtered) wedges and cyclical output. The patterns of correlation between each of the wedges and cyclical output is similar enough across countries such that it allows us to draw statistical significance. The first observation is that the wedges are coincident indicators of cyclical output i.e. the absolute value of the cross-correlation reaches its highest value for the contemporaneous correlation.

¹No available data on hours worked for Germany before the reunification

The efficiency and investment wedges are procyclical, even though the persistence and magnitude of the procyclicality is higher in the case of the efficiency wedge. These results are in line with Chari et al. (2007). The counter-cyclicality of the government wedge is also in line with Chari et al. (2007) but not for the case of the labor wedge. In fact, for the countries and periods in the sample (and even for the U.S.), the labor wedge is counter-cyclical.

Figure 7: Lead-lag cross-correlation between ω_t and $Y_t + j$



95% Confidence intervals computed with bootstrapping, 1000 draws
 ● - Estimates from Chari et al. (2007), for the U.S. economy

The cross-correlation structures found are similar enough across countries such that inference can be drawn at the 5% significance level, for all contemporaneous correlations and at least for one lead and lag. Comparing the results with Chari et al. (2007) with respect to the efficiency wedge, the similarity is striking. Point estimates reported in Chari et al. (2007) also show the efficiency wedge to be a coincident indicator for output. Their point estimate, 0.85, is very similar to ours, 0.82, and lies within our estimate's

95% confidence interval of [0.77, 0.87]. With respect to the cross-correlation at different lags, we find our estimates to be of the same order of magnitude and for $j = 1, 2$ we can reject that they are statistically different.

When it comes to the labor wedge, our results are statistically smaller in magnitude but qualitatively in line with Chari et al. (2007). We find the average labor wedge to be procyclical on average in our sample, and this to be statistically significant for all 4 lags/leads. The only exception, i.e. a countercyclical labor wedge is the Republic of Korea. Our findings are also in line with more recent work from Shimer (2009)².

In the case of the investment wedge, we find it to be moderately procyclical, on average, smaller in magnitude than what Chari et al. (2007) find for the U.S. Finally, the government wedge is found to be countercyclical, though in this case our findings are much closer to what Chari et al. (2007) find for the U.S.

Another feature studied in Chari et al. (2007) concerns the relative volatility of the wedges to output. Table 2 below, presents point estimates for the average relative volatility for each of the wedges and the associated 95% confidence interval.

Table 2: Standard Deviation Relative to Output

A_t	$\tau_{l,t}$	$\tau_{x,t}$	g_t
0.89	1.00	1.12	0.82
(0.82,0.98)	(0.89,1.14)	(0.86,1.37)	(0.69,0.96)

95% Confidence intervals computed with bootstrapping, 1000 draws

In our findings, the standard deviation of the efficiency wedge relative to that of output is found to be statistically higher than the one Chari et al. (2007) find for the U.S. (0.63). Our findings differ also in terms of the government wedge, which in our case is significantly smaller than the one found

²Notice however that Shimer (2009) results differ from ours only in the sense that the definition of labor wedge is different. We follow Chari et al. (2007) in defining the labor wedge in Figure 7 as $1 - \tau_{l,t}$ for comparability. Everywhere else in the paper, the labor wedge is defined as in Shimer (2009), i.e., just $\tau_{l,t}$. As a consequence, Shimer (2009) obviously documents the labor wedge to be countercyclical instead.

by the same authors (1.51). However, in the case of the labor and investment wedges, Chari et al. (2007) estimates of their relative volatility (of 0.92 and 1.18 respectively), fall within the 95% confidence interval computed for our estimates as shown in Table 2.

4 Simulations

Once measured the distortions, these can be considered the first best, with respect to the quantitative behavior that extensions that express themselves as distortions to the equilibrium conditions of the neoclassical growth model must exhibit. However, if the aim is to replicate movements observed in the macroeconomic aggregates, one needs also to assess the potential that the said distortions have to generate fluctuations in the data.

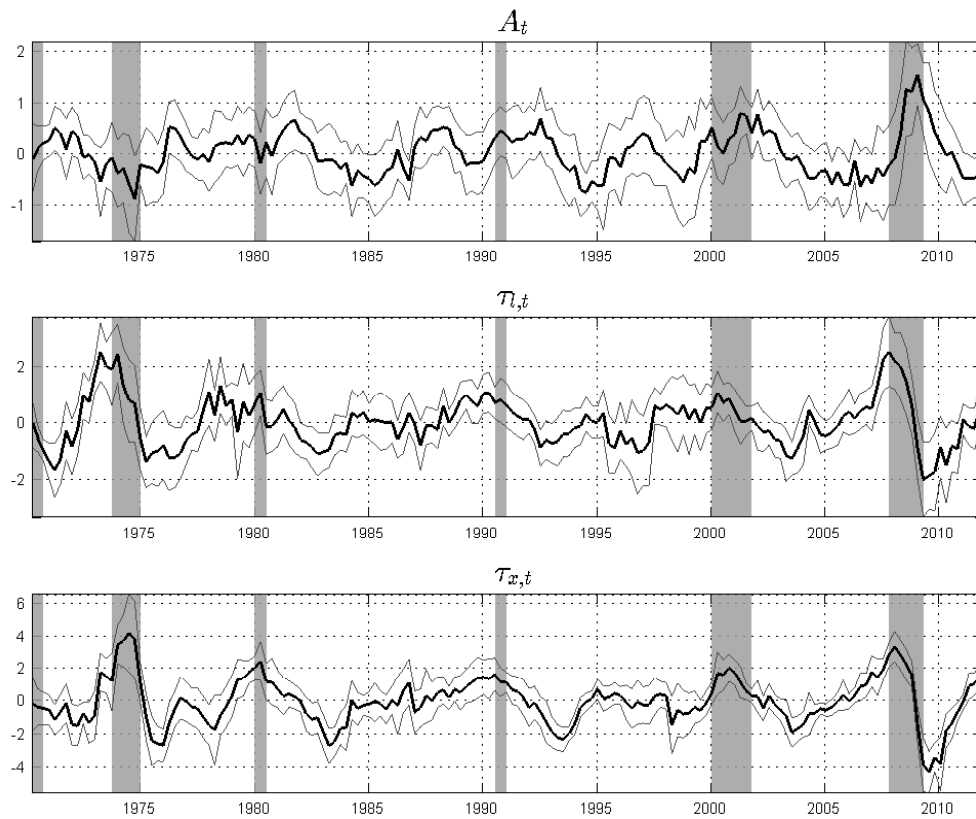
If we would simulate the model and feed the realizations of the four wedges as shocks i.e. the measured distortions, we would recover the original data. There is no surprise in this, since the distortions were measured precisely to make the equilibrium conditions hold with equality. However, if we do not feed all the measured wedges as shocks and simulate the model in general equilibrium allocations in the model and observed data will differ. The relevant question is then, by how much? If, for example, we model total factor productivity in such a way that we are able to exactly reproduce the efficiency wedge, how would equilibrium allocations compare with the data? Or, in a similar exercise, if we would be able to model all but one distortion in a way that would replicate exactly the measured wedges, how far could we go?

These questions are also typical applications of business cycle accounting exercises. In Chari et al. (2007), evidence points towards the efficiency and labor wedge being key margins to be modeled in order to be able to replicate movements in output, hours and investment such as the ones observed in the data for the 1981 recession and the Great Depression of 1929. Most studies seem to converge to the same conclusion. This section also adds to the literature by checking the robustness of this common finding i.e. that modeling the efficiency and labor wedges contribute to a superior performance versus

models that aim to replicate distortions in the savings decision.

In this section we assess the performance of models with just one or with all but one wedge. First we proceed in a manner similar to the preceding section. For each country in the sample, we simulate the four observables and measure the deviations from observed data. Then we compute the cross-

Figure 8: Simulation Errors for Cyclical Output in One Wedge Economies



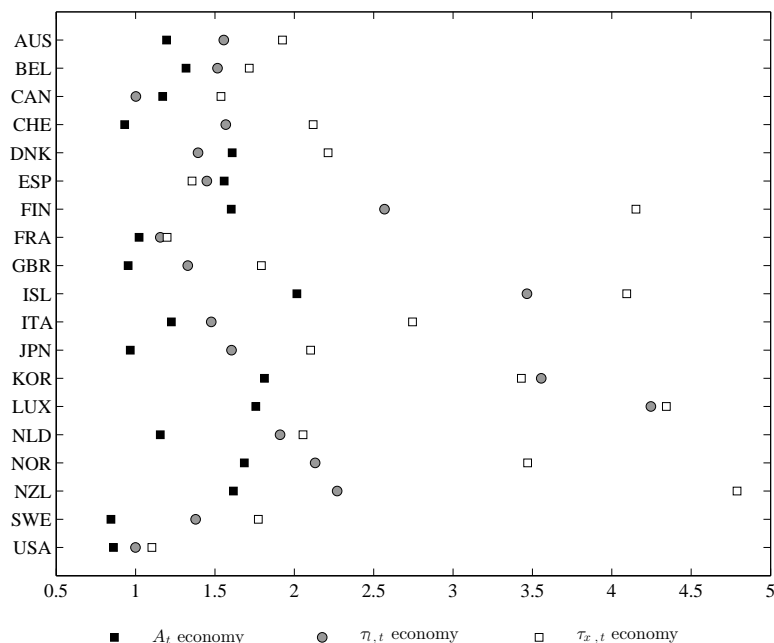
95% Confidence intervals computed with bootstrapping, 1000 draws
 Shaded quarters indicate US recessions as declared by the NBER

The analysis of Figure 8 leads to several conclusions. First, economies with just the efficiency wedge have much fewer periods where the difference between observed and simulated output is similar enough across countries such that it is statistically different from zero. This only happens for 28 periods, against a total of 85 and 101 for the labor and investment wedge

economies respectively.

Second, the efficiency wedge economies seem to produce the smaller deviations from the data, on average, followed by the labor and investment wedge economies. Third, the quarters for which simulated data more severely underestimate the magnitude of output deviations from trend coincide with recessions in the U.S. as declared by the NBER. This is even more remarkable given that the data in Figure 8 concerns (unweighted) aggregate data for the OECD countries. It seems that all models systematically underestimate the magnitude of such recessions, even though this effect is more severe in economies without the efficiency wedge. In fact, in this case, only during the 2001 and 2008 recessions, simulation errors in the efficiency wedge economy have shown to be statistically significant, where for the other three economies, this happened for all the recessions in the sample period.

Figure 9: RMSE's for Deviations from Output in One Wedge Economies



Note however, that since we are working with pooled data, smaller average deviations could just mean that the cross-sectional distribution is more symmetric. In order to check for that, Figure 9 shows the root mean square

errors (RMSEs) for the three types of economies, in the case of deviations from output cycle. The efficiency wedge economies produce the smallest RMSEs, followed by the labor wedge and then the investment wedge economies. This ordering is observed for almost all of the countries. Also average output RMSEs are 1.33 for the efficiency wedge, 1.92 for the labor wedge and 2.52 for the investment wedge economies.

In order to have a statistical assessment of the comparative performance of the three types of models, Table 3 shows the outcome of parametric and non-parametric, joint and pairwise tests concerning the RMSEs produced. The difference between the average RMSEs between the three models is statistically significant at least at the 10% level for all comparisons.

The joint ANOVA test and its non-parametric equivalent Friedman’s test both lead us to reject the null hypothesis that the average (median ranking of the) RMSEs for the three types of economies are equal.

In the first case, normality of the distribution of RMSEs is assumed and therefore the test statistic follows the F distribution. In the case of Friedman’s test, normality is not assumed and only the ranking of the measured RMSEs is compared between the one wedge economies, across countries. In this case, Friedman’s F statistic is asymptotically χ^2 distributed with two degrees of freedom.

Table 3: Statistical Tests of Comparative Performance

Joint	p-val	Pairwise	stat	p-val
ANOVA	< 0.01	A_t vs $\tau_{l,t}$	-2.62	0.01
Friedman	< 0.01	t -tests A_t vs $\tau_{x,t}$	-4.27	< 0.01
		$\tau_{l,t}$ vs $\tau_{x,t}$	-1.76	0.09
Economy	RMSEs			
A_t	1.33	Wilcoxon A_t vs $\tau_{l,t}$	300.00	0.04
$\tau_{l,t}$	1.92	A_t vs $\tau_{x,t}$	237.00	< 0.01
$\tau_{x,t}$	2.52	$\tau_{l,t}$ vs $\tau_{x,t}$	308.00	0.07

In the case of the pairwise tests, t -tests were performed where the assumption is, again, that the average difference between the RMSEs is normally distributed. When using Wilcoxon’s rank sum test we relax that assumption

and take only the relative ranks into account. As in the case of the joint tests, there is no qualitative difference between the parametric and non-parametric testing if we are set to reject the null hypothesis of equal average (median ranking of the) RMSEs between the three types of economies at the 10% significance level. The finding is that, when it comes to output, the efficiency wedge is the key margin to be modeled, followed by the labor wedge and last the investment wedge.

As in Chari et al. (2007), in order to test the robustness of this finding, simulations are performed where all but one wedge are included. The equivalent to Figure 9 is reproduced in Appendix B and so is the equivalent to Table 3. The average of RMSEs for the economies with all but one wedge are of 2.04, 1.93 and 1.39.

The economies with no efficiency wedge are the ones that perform the worst on average, followed by the economies with no labor wedge and lastly by the economies with no investment wedge, though only the comparisons of the no efficiency and no labor wedge economies against the no investment wedge economies have statistical significance.

A simple analysis of the magnitude of the RMSEs can miss an aspect that might be relevant to the researcher. A model may produce smaller RMSEs but still lead to predictions that, on average, often are more qualitatively wrong than a model that tends to produce larger RMSEs but leads to predictions that are qualitatively correct i.e. predictions that correctly indicate an expansion or contraction of output in this case.

To control for that, in Figure 10 I show the success ratios for each country's output predictions of each type of the three economies mentioned before.

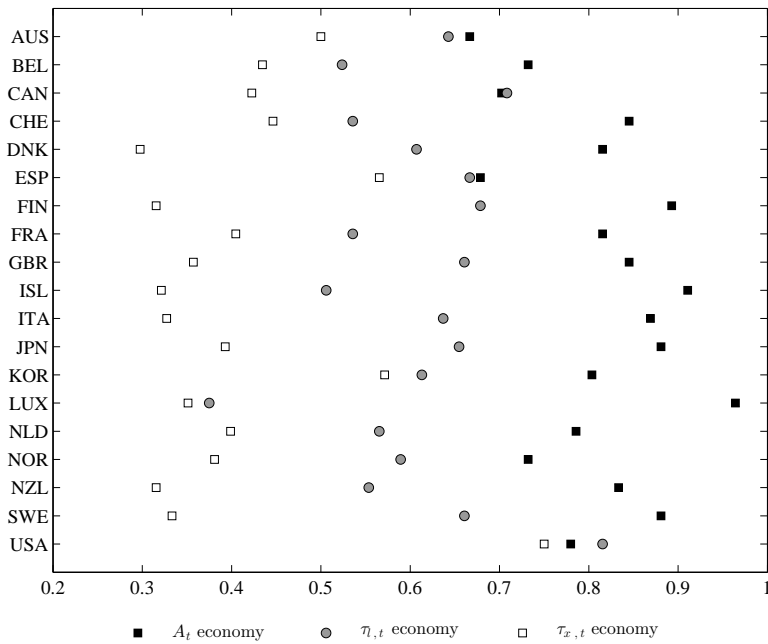
The statistic in this case indicates the percentage of times that simulated and observed output are of the same sign i.e. that simulated data is below/above trend when observed data is also below/above trend.

Figure 10 is even more stark relative to previous findings. The efficiency wedge economies produce, on average, qualitatively correct predictions about 81% of the times, against 61% for the labor wedge and only 42% for the investment wedge economies.

It is worth noticing that just as the efficiency wedge economy produces

RMSEs that are about half the size of the RMSEs associated with the investment wedge economies, the average success ratio for the efficiency wedge economy is about twice as high when compared to the same statistic regarding the investment wedge economies.

Figure 10: Success Ratios for Deviations from Output in 1 Wedge Economies



As before, statistical tests are performed and these differences are significant at the 1% level. The results also hold for all but one wedge economies, i.e., economies without the efficiency wedge have a success ratio of 51%, against 73% for the no labor and 87% for the no investment wedge economies.

Table 4: Statistical Tests of Comparative Performance

Output				
Joint	p-val	Pairwise	stat	p-val
ANOVA	< 0.01			
Friedman	< 0.01	<i>t</i> -tests	A_t vs $\tau_{l,t}$	7.19 < 0.01
			A_t vs $\tau_{x,t}$	12.34 < 0.01
			$\tau_{l,t}$ vs $\tau_{x,t}$	5.66 < 0.01
Economy	SRs			
A_t	81%		A_t vs $\tau_{l,t}$	537.00 < 0.01
$\tau_{l,t}$	61%	Wilcoxon	A_t vs $\tau_{x,t}$	546.00 < 0.01
$\tau_{x,t}$	42%		$\tau_{l,t}$ vs $\tau_{x,t}$	511.50 < 0.01

All this leads to the conclusion that, in terms of quantitative and qualitative relevance, the efficiency wedge is the key margin to address fluctuations in output. It is worth noting that modeling only the efficiency wedge leads to overall smaller average RMSEs than including all other wedges and leaving out the efficiency wedge, i.e., 1.33 vs 2.04, and this result is even more clear if the success ratio is taken as measure: 81% vs 51%.

The labor wedge also plays a role as it leads to better predictions concerning output than the investment wedge. This result is robust to the performance measure used (the RMSEs - 1.92 vs 2.52 or the success ratios - 61% vs 42%) and it is statistically significant at the 10% level in the case of the labor wedge vs investment wedge economy (t -statistic of -1.76 with a p -value of 0.09 and Wilcoxon's p -value of 0.07). In the case of the no labor wedge vs no investment wedge economy, the t -statistic is not significant (p -value of 0.12) but the Wilcoxon ranksum test leads us to reject the null hypothesis at the 5% significance level. The different conclusions in the joint tests suggests that even though the ordering for each type of economies' performance (ranks) shows a statistically significant pattern (p -value < 0.01 for Friedman's test), the magnitude of the differences between each type of economy for each country is quite heterogeneous, a result that can be confirmed by visual inspection of Figure 10 in Appendix B.

The investment wedge seems to be the less important margin to be mod-

eled. It leads to higher RMSEs and lower success ratios. Also, unlike the previous two cases, economies where only the investment wedge is modeled do not even lead to predictions that are qualitatively correct 50% of the time. The average success ratio of the investment wedge economies is only of 42% and the null hypothesis of it being equal to 50% can be rejected (t -statistic of -3.24 with p -value < 0.01).

4.1 Hours and Investment

The above results establish the efficiency and labor wedge as key margins to be modeled in order to replicate fluctuations in output. However, the researcher maybe interested in how the different models perform with regard to replicating fluctuations in the other two observables i.e. hours worked and investment. The figures and tables shown above for output are included in Appendix B also with regard to hours worked and investment.

With regard to hours worked, the point estimates for the mean RMSEs (1.66, 1.91 and 2.33 for the efficiency, labor and investment wedge economies respectively) still single out the efficiency wedge economies in producing the smaller RMSEs on average, though there is only statistical significance when it comes to comparing the efficiency to the investment wedge economy (t -statistic of -2.45 with a p -value of 0.02). When we look at the all-but-one-wedge economies, the results are different though. The no labor wedge economy is the one that produces the higher RMSEs, followed by the investment wedge and then the no efficiency wedge (1.91, 2.33 and 1.66, respectively) and in this case, statistical significance is found for all the t -tests and all but one of the Wilcoxon ranksum tests. The results are shown in Appendix B, Table 2.

The labor wedge thus seems to be relatively more relevant when it comes to simulating data that resembles observed fluctuations in hours worked. This importance is even clearer if we look at the success ratios. The labor wedge economy predictions are qualitatively correct about 76% of the time, against 52% and 48% for the efficiency and investment wedge economies. The labor wedge seems key in order to make the model qualitatively in line with

the data. This result is statistically significant for both comparisons of the success ratios of the labor wedge with the efficiency and investment wedge economies. The results are also confirmed by the analysis of the all-but-one-wedge economies, i.e., the no labor wedge economies fare comparably worse and the differences are statistically significant.

Lastly, with regard to investment, point estimates suggest the labor wedge again as being the most relevant with respect to producing the lower RMSEs on average (7.47, 9.74 and 11.80 for the labor, efficiency and investment wedge economies respectively). The all-but-one wedge economies also point in the same direction, though in both cases, there is no statistical significance. However, in terms of the success ratios, as it was the case for output, the efficiency wedge seems to matter the most and the differences are statistically significant. The efficiency wedge economy is also the only for which we can reject the null hypothesis that the success ratio (equal to 68%) is smaller or equal to 50%. As in the case of the RMSEs, this is also confirmed for the all-but-one-wedge economies.

4.2 Summary

The analysis of simulations for economies with just one wedge and economies with all but one wedge provide robustness to previous findings that stress the importance of modeling distortions that resemble TFP shocks in order to replicate movements in output and investment, and labor income taxes, in order to replicate movements in hours. Distortions to the savings decision, i.e., extensions that can be mapped to the investment wedge, seem of little promise both quantitatively and qualitatively.

As a final note it is worth noting that the model's ability to replicate output and hours is much higher compared with investment. As seen in Figures 1-6 in Appendix B, the average absolute simulation errors for deviations from the trend are one order of magnitude larger. This is also confirmed by the RMSEs. As an example, the RMSEs for output and hours in the efficiency wedge economy are of 1.33 and 1.66, against 9.74 for investment. A relationship of the same magnitude can be observed for the other types of

economies (see Tables 1-2 and Figures 7-12 in Appendix B).

5 Structural analysis of the wedges

The ultimate goal of a business cycle accounting exercise is to enable the reader to come forth with structural explanations for the wedges. If, for example, the the labor wedge is quantitatively relevant for a period of fluctuations, then researchers should focus in developing extensions to the prototype economy that, if mappable to the labor wedge, can replicate it. The current section contributes to the literature by bringing forth factors that contain information with respect to the said wedges.

5.1 Spatial correlation of the wedges

Table 5 shows that the wedges' correlations of the cyclical components across countries is correlated with the geographical distance between them (as measured by the geographical distance between each country's capital), in line with what Aguiar-Conraria and Soares (2011) find concerning business cycle synchronization in the Euro-Area.

The values correspond to Spearman's rank correlation coefficient for each of the wedges across countries (and its statistical significance). In only 11 cases out of 76 we see a positive association between the distance across two countries and the correlation coefficient between their corresponding wedges. However in all 11, these are not statistically significant.

Table 5: Distance vs Correlation between wedges

	A_t	$\tau_{l,t}$	$\tau_{x,t}$	g_t
AUS	-0.42*	-0.36	-0.14	-0.14
BEL	-0.56**	-0.38	-0.45*	-0.38
CAN	-0.40*	-0.14	-0.14	-0.02
CHE	-0.46**	-0.24	-0.33	-0.27
DNK	-0.49**	-0.22	-0.49**	-0.34
ESP	-0.51**	0.02	-0.18	-0.06
FIN	-0.51**	-0.10	-0.37	-0.07
FRA	-0.67***	-0.25	-0.57**	-0.34
GBR	-0.38	0.11	-0.49**	-0.02
ISL	-0.44*	0.03	-0.13	-0.08
ITA	-0.79***	-0.17	-0.47**	-0.24
JPN	0.08	0.01	-0.38	-0.17
KOR	0.03	-0.24	0.10	0.00
LUX	-0.77***	-0.40*	-0.34	-0.31
NLD	-0.57**	-0.60***	-0.33	-0.48**
NOR	-0.49**	-0.14	-0.10	-0.26
NZL	0.30	-0.38	0.14	-0.20
SWE	-0.75***	-0.36	-0.48**	-0.41*
USA	-0.33	-0.22	0.15	-0.28

Statistical significance levels for Spearman's rank order correlation coefficient

*** < 0.01, ** < 0.05, * < 0.10

It is thus suggested that the further two countries are apart, the lesser the wedges are correlated. This effect is especially strong in the case of the efficiency wedge, where many correlations found are indeed statistically significant at least at the 10% level.

5.2 Degree of Openness to Trade

The following table brings forth a second factor with potential to explain the fluctuations in the wedges at the business cycle frequency. A country's openness to trade is defined as the (HP-filtered) size of the sum of real exports and real imports as a share of real GDP.

The effect of openness in growth has been perceived in the literature as positive (Frankel and Romer (1999)). Output growth, however, can under the neoclassical model, be attributed to an increase in either capital, labor or total factor productivity. Much work has focused in the effects of trade

openness on total factor productivity growth (see for example Abizadeh and Pandey (2009)). Typical findings are that openness indeed leads to overall TFP growth too.

Much fewer work can be found relating total factor productivity fluctuations and openness. There is extensive literature relating macroeconomic volatility in general, or output growth volatility in particular, to openness. There is an ongoing debate regarding its effects but it also focuses more on developing countries (see Haddad et al. (2012) for example), whereas our sample consists of a subset of OECD countries.

In earlier work, Easterly et al. (2001) report a per capita GDP growth volatility correlation with our measure of openness of 0.00013 (t -statistic of 2.043) for the overall sample but found OECD countries to show overall less GDP growth volatility (average growth volatility to be -0.03515 smaller than the sample average, with a t -statistic of -4.44).

In Table 6 we provide evidence on the information that our measure of openness contains with regard to the measured wedges. With regard to TFP or the efficiency wedge, in 15 out of 19 countries, the correlations are significant at least at the 5% level. In all of those 15 cases, the correlation is positive.

With regard to the labor wedge, all significant (at least at the 10% level) correlations are negative, except one - Luxembourg. As in the case before, this happens for 15 out of the 19 countries in the sample.

For the investment wedge, fewer correlations (14) are found to be statistically significant and 11 to be positive. Finally for the government wedge, 13 correlations are found to be significant (at least at the 5% level) and all but one - again, Luxembourg - to be negative.

Table 6: Trade openness correlation with the wedges

	A_t	$\tau_{l,t}$	$\tau_{x,t}$	g_t
AUS	0.02	-0.41***	0.10	-0.43***
BEL	0.61***	-0.41***	0.67***	-0.46***
CAN	0.63***	-0.56***	0.30***	-0.46***
CHE	0.49***	0.02	0.22***	0.00
DNK	-0.06	-0.15*	0.14*	-0.02
ESP	0.36***	-0.47***	0.02	-0.57***
FIN	0.52***	-0.07	0.29***	0.05
FRA	0.61***	-0.44***	0.50***	-0.60***
GBR	0.20***	-0.30***	0.20***	-0.27***
ISL	0.18**	-0.25***	-0.14*	-0.42***
ITA	0.62***	-0.04	0.23***	-0.12
JPN	0.38***	-0.21***	0.14*	0.01
KOR	0.37***	-0.26***	-0.28***	-0.27***
LUX	0.32***	0.23***	0.07	0.19**
NLD	0.38***	-0.07	0.20***	-0.09
NOR	0.03	-0.17**	0.11	-0.21***
NZL	-0.10	-0.33***	0.04	-0.36***
SWE	0.45***	-0.24***	0.19**	-0.22***
USA	0.44***	-0.67***	-0.51***	-0.50***

Statistical significance levels for Spearman's rank order correlation coefficient

*** < 0.01, ** < 0.05, * < 0.10

6 Conclusion

This paper studies the properties of distortions to the neoclassical growth model that manifest themselves as shocks to productivity, labor income taxes, investment taxes, and government consumption. It is shown that deviations from the trend with regard to these distortions are relatively more synchronized in the case of the efficiency, labor and government wedge than in the case of the investment wedge. Recessions in the U.S. typically coincide with local extreme points in the wedges for the aggregate data and these movements are similar enough to be statistically significant in the case of the efficiency, labor and government wedges. This is even more remarkable given that the data used is unweighted and shows the impact the U.S. hold for business cycle fluctuations for the rest of the OECD countries in the sample.

Our simulations show that the efficiency wedge is paramount in providing

models the ability to replicate movements in output and investment. With regard to output, an economy with just an efficiency wedge outperforms, on average, an economy with all the other three wedges. The labor wedge is also of relevance in replicating movements in hours and investment where the investment wedge holds little to no qualitative or quantitative importance. These conclusions are statistically significant for the countries in the sample and do not limit themselves to periods such as output drops, as it has been traditionally done in the literature.

The original findings of Chari et al. (2007) with respect to the irrelevance of the investment wedge are therefore reinforced by these results and are also valid for business cycle fluctuations in general. However, how to reconcile the general notion that many of the recent recessions were due to failures of the financial system with such irrelevance? One should draw attention to the fact that the financial system has two purposes. First it allows the allocation of resources across time and states of the world. It allows consumers to smooth their consumption in a context of variable income, or firms to stabilize their liquidity in face of revenue/cost shocks. The second function is to channel savings to their most productive uses. The first purpose is reflected in the model by the Euler equation and its associated wedge is precisely the investment wedge. The second function of the financial markets is captured by the efficiency wedge. As mentioned before, Chari et al. (2007) describe a detailed two sectors economy with different costs of borrowing. In this case, they derive an equivalence theorem between the detailed economy and a prototype economy with an efficiency wedge.

The conclusion here is that promising theories of financial crisis should focus on the role of the financial system in channeling savings to their most efficient uses, and less so in its role of allocating resources across time. The issue of liquidity crisis is not persistent enough across time, and especially hard to capture at the quarterly frequency even in studies of financial crisis which has been typically the aim of much of the literature. An exception is precisely Dooyeon and Doblas-Madrid (2012) that find some relevance of the investment wedge for a selected sample of east Asian economies, but again, limited to financial crisis. In a context of distortions that aim to generate

fluctuations in aggregates that are not limited to output drops or crisis, the relevance of such channel is expected to be even less important.

Also, we show that the per type of wedge across country correlation is negatively correlated with the distance between the countries, even though only for the efficiency wedge we can find strong statistical significance. As mentioned before, this type of analysis is common in the trade literature, where trade volumes are often (also) explained by gravitation equations. The degree of openness to trade of a country is also found to contain significant information with regard to all four wedges which reinforces the role of international mechanisms of transmission for distortions in the key margins of the neoclassical growth model.

Further analysis should focus in finding more factors that contain information with regard to these distortions, so that we can provide business cycle theorists hints of mechanisms that hold promise in generating fluctuations as observed in the data.

References

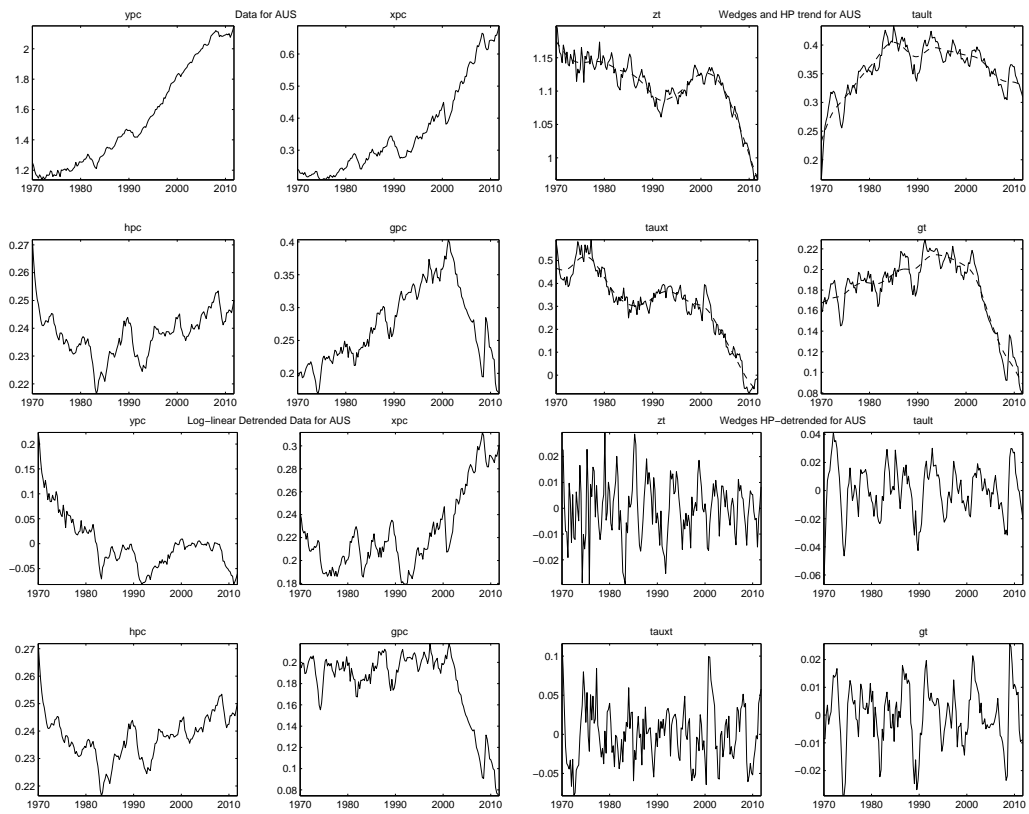
- Abizadeh, S. and Pandey, M. (2009). Trade openness, structural change and total factor productivity. *International Economic Journal*, 23(4):545–559.
- Aguiar-Conraria, L. and Soares, M. J. (2011). Business cycle synchronization and the Euro: A wavelet analysis. *Journal of Macroeconomics*, 33:477–489.
- Bernanke, B. M., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics*, 1C:1341–1393.
- Calstrom, C. T. and Fuerst, T. S. (1997). Agency costs, net worth and business cycle fluctuations: a computable general equilibrium analysis. *American Economic Review*, 87:893–910.
- Chari, V., Kehoe, P., and McGrattan, E. (2007). Business cycle accounting. *Econometrica*, 75:781–836.
- Cociuba, S. E. and Ueberfedt, A. A. (2010). Trends in U.S. hours and the labor wedge. *Bank of Canada Working Paper Series*, (28).
- Dooyeon, C. and Doblus-Madrid, A. (2012). Business cycle accounting east and west: Asian finance and the investment wedge. *Review of Economic Dynamics*. Available online 17 October 2012, ISSN 1094-2025, 10.1016/j.red.2012.10.003.
- Easterly, W., Islam, R., and Stiglitz, J. E. (2001). Shaken and stirred: explaining growth volatility. In *Annual World Bank conference on development economics*, volume 191, page 211.
- Frankel, J. A. and Romer, D. (1999). Does trade cause growth? *American economic review*, pages 379–399.
- Haddad, M., Lim, J. J., Pancaro, C., and Saborowski, C. (2012). Trade openness reduces growth volatility when countries are well diversified. *ECB Working Paper*.

- Hoddrick, R. and Prescott, E. (1997). Post-war U.S. business cycles: an empirical investigation. *Journal of Money, Credit and Banking*, 29:1–16.
- Islam, N., Dai, E., and Sakamoto, H. (2006). Role of TFP in China’s growth. *Asian Economic Journal*, 20(2):127–156.
- Kehoe, T. J. and Prescott, E. C. (2007). *Great depressions of the twentieth century*. Federal Reserve Bank of Minneapolis.
- Kobayashi, K. and Inaba, M. (2006). Business cycle accounting for the Japanese economy. *RETI Discussion Paper*, 05-E-023.
- Kydland, F. E. and Prescott, E. C. (1982). Time to build and aggregate fluctuations. *Econometrica*, 50(6):1345–70.
- Lamas, R. (2009). Accounting for output drops in Latin America. *IMF Working Paper Series*, 67.
- McGrattan, E. R. and Prescott, E. C. (2009). *Technical appendix: Unmeasured investment and the puzzling US boom in the 1990s*.
- Mertens, K. and Ravn, M. (2008). The aggregate effects of anticipated and unanticipated us tax policy shocks: Theory and empirical evidence. *CEPR Discussion Paper No. DP6673*.
- Mulligan, C. B. (2002). A century of labor-leisure distortions. *NBER Working Papers*, (8774).
- Otsu, K. (2009). International business cycle accounting. *IMES Discussion Paper Series*, 29.
- Restrepo-Echavarria, P. and Cheremukhin, A. A. (2010). The labor wedge as a matching friction. *Federal Reserve Bank of Dallas Working Paper Series*, (1004).
- Shimer, R. (2009). Convergence in macroeconomics: The labor wedge. *American Economic Journal: Macroeconomics*, 1(1):280–97.

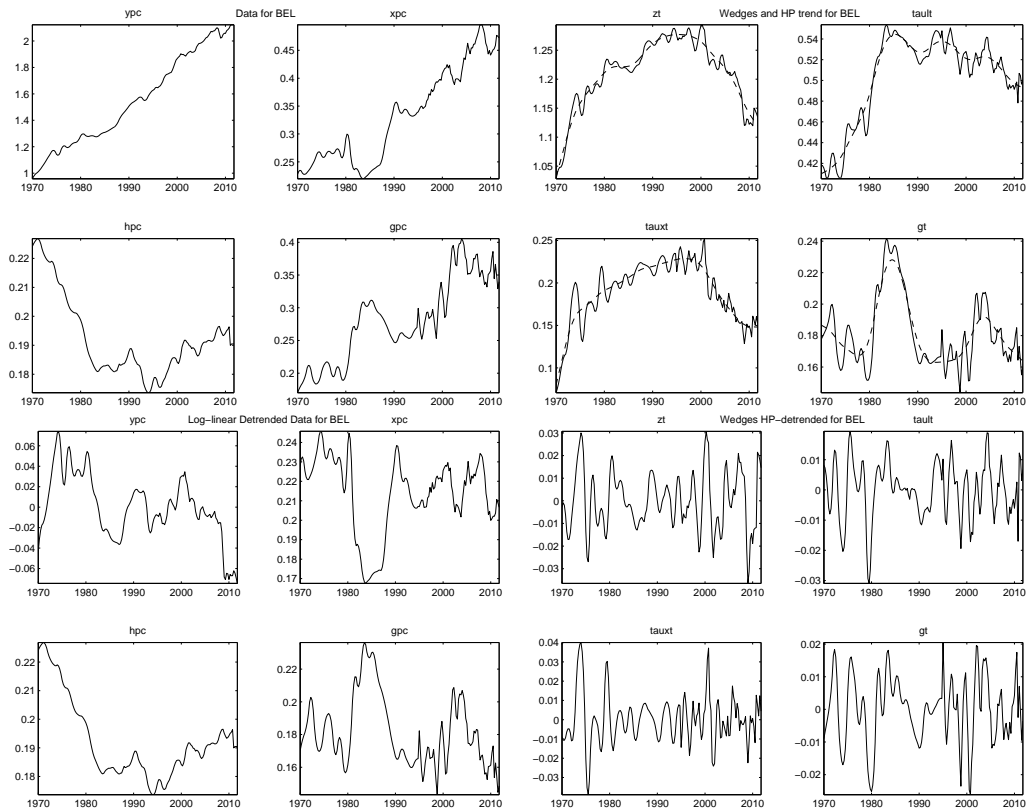
- Shimer, R. (2010). *Labor Markets and Business Cycles*. Princeton University Press.
- Simonovska, I. and Söderling, L. (2008). Business cycle accounting for Chile. *IMF Working Paper Series*, 61.
- Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, 39(3):312–320.
- Sustek, R. (2010). Monetary business cycle accounting. *Review of Economic Dynamics*, 14(4):592–612.

Appendix A - Country Profiles

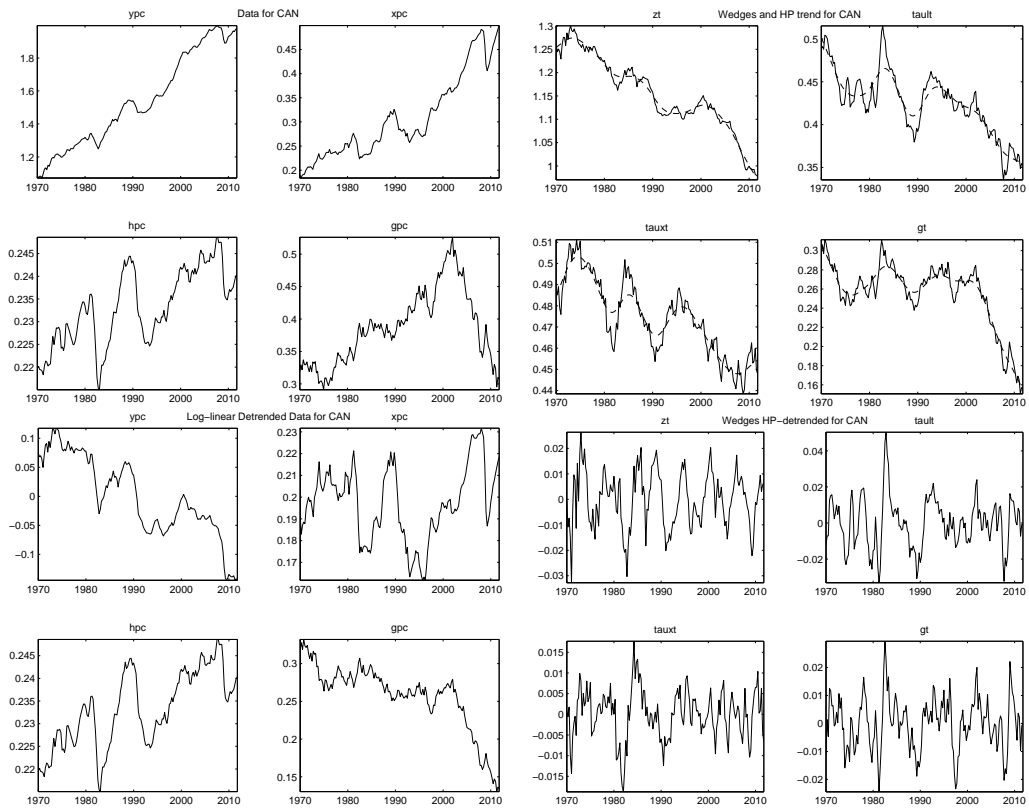
Australia



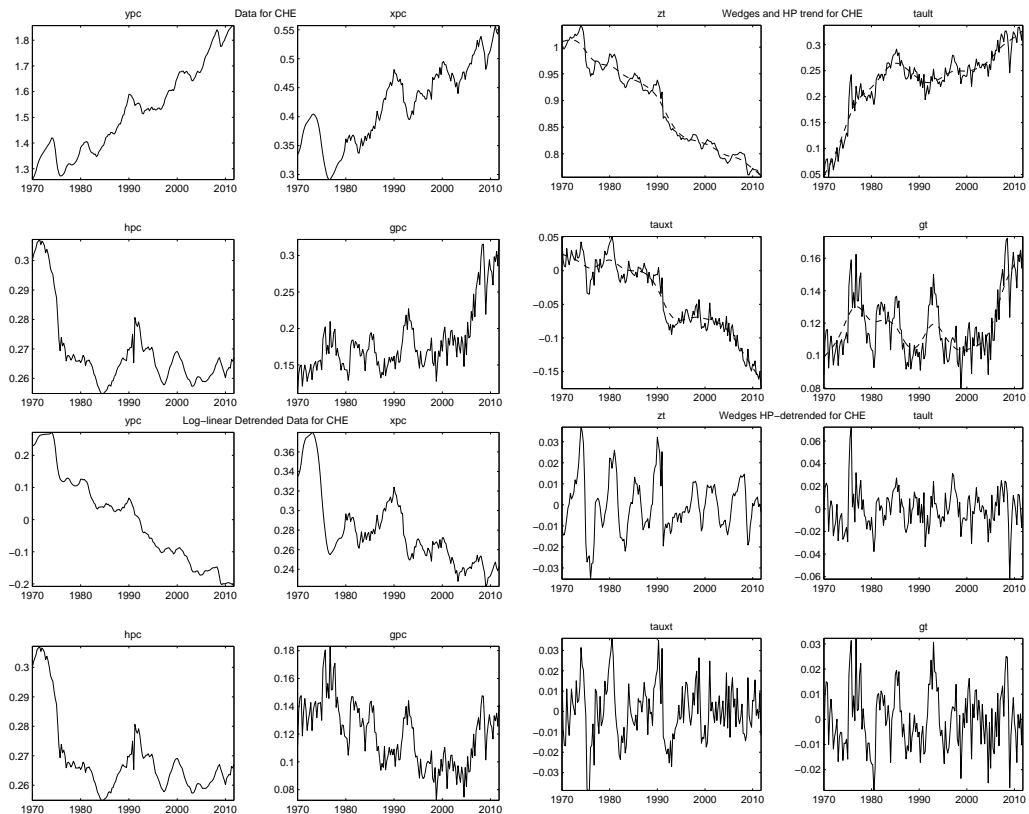
Belgium



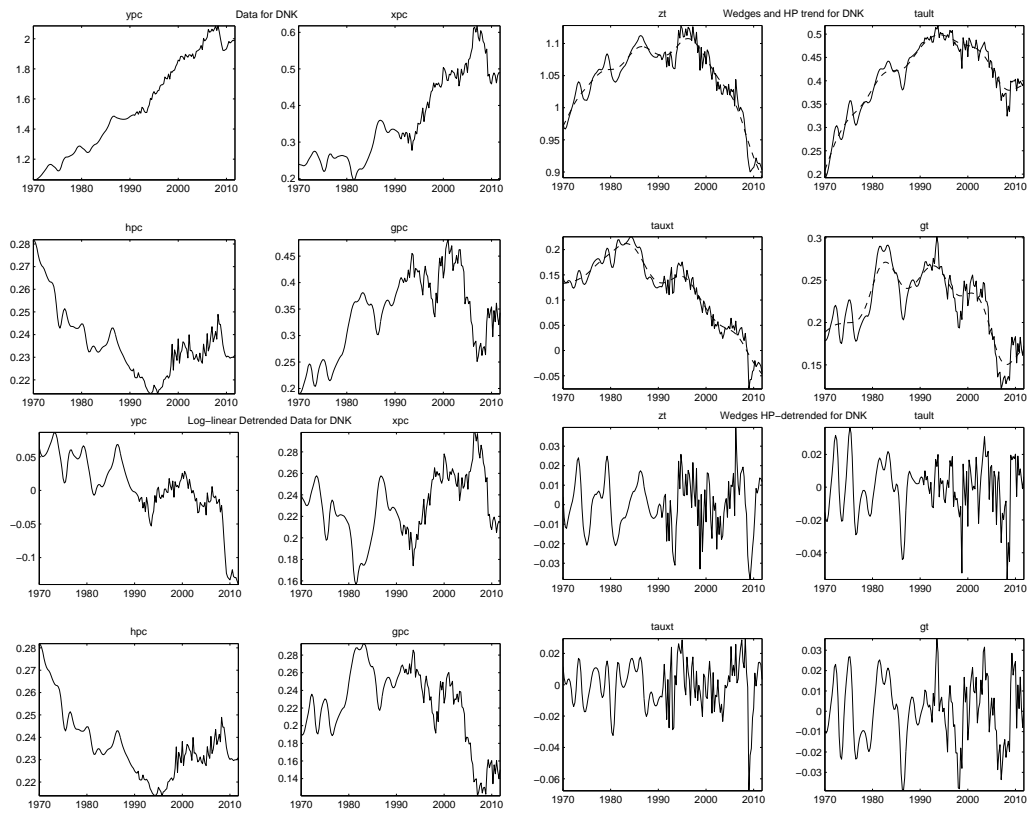
Canada



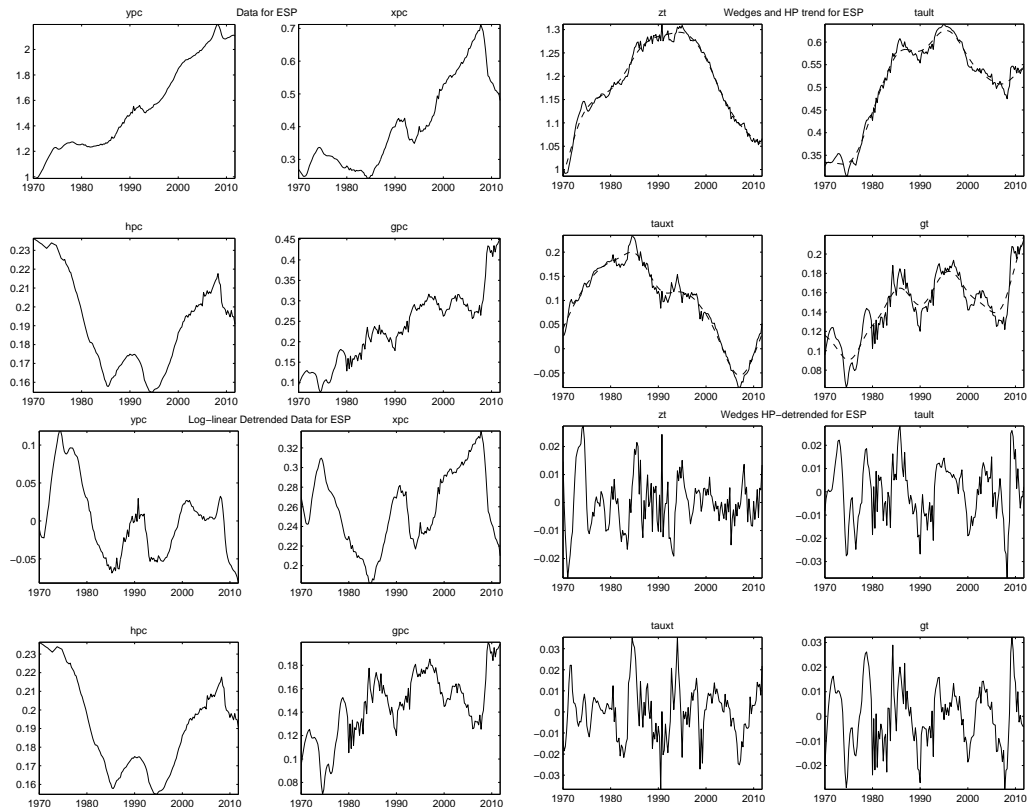
Switzerland



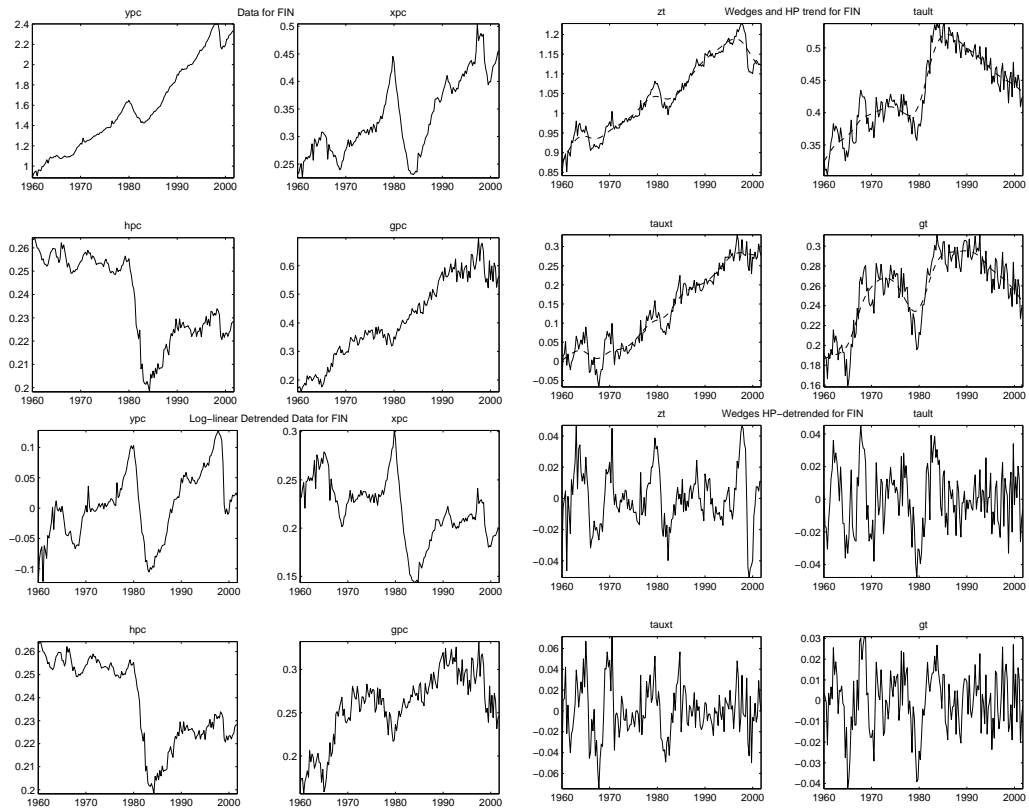
Denmark



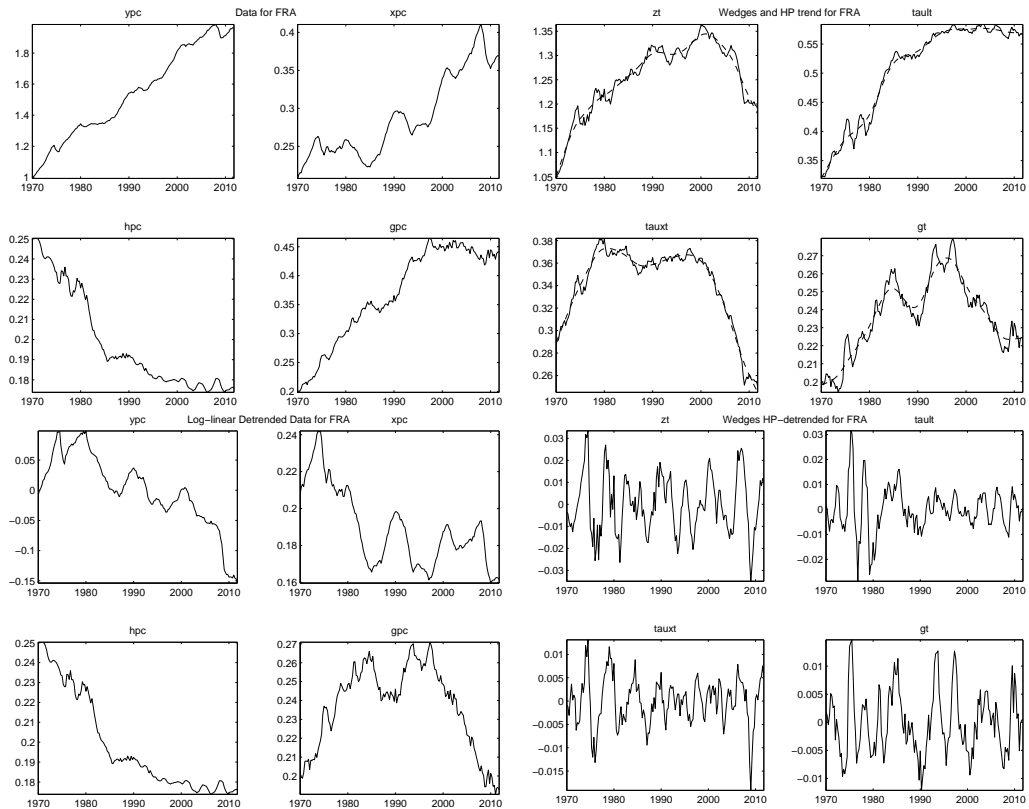
Spain



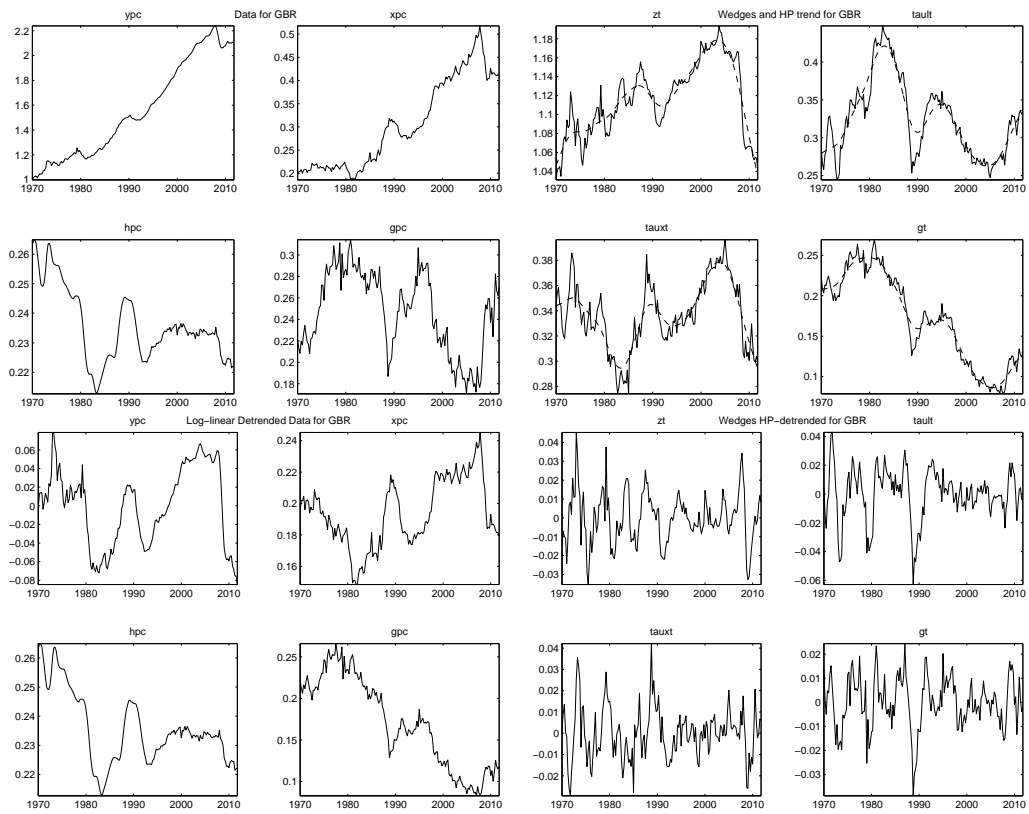
Finland



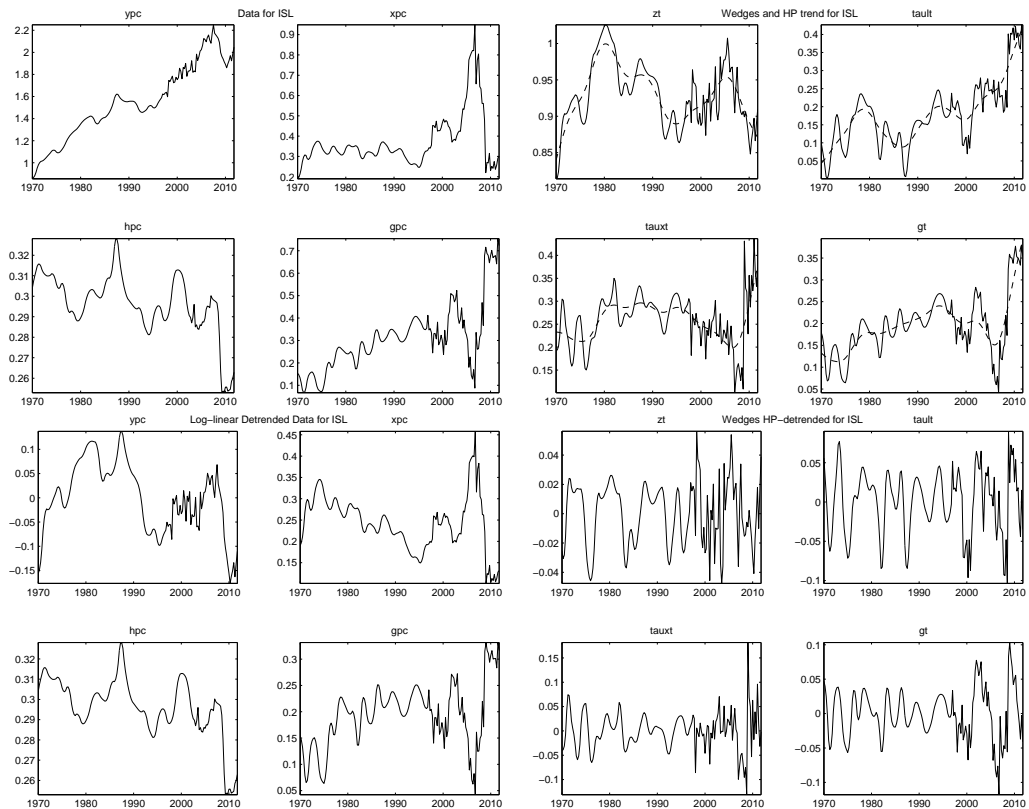
France



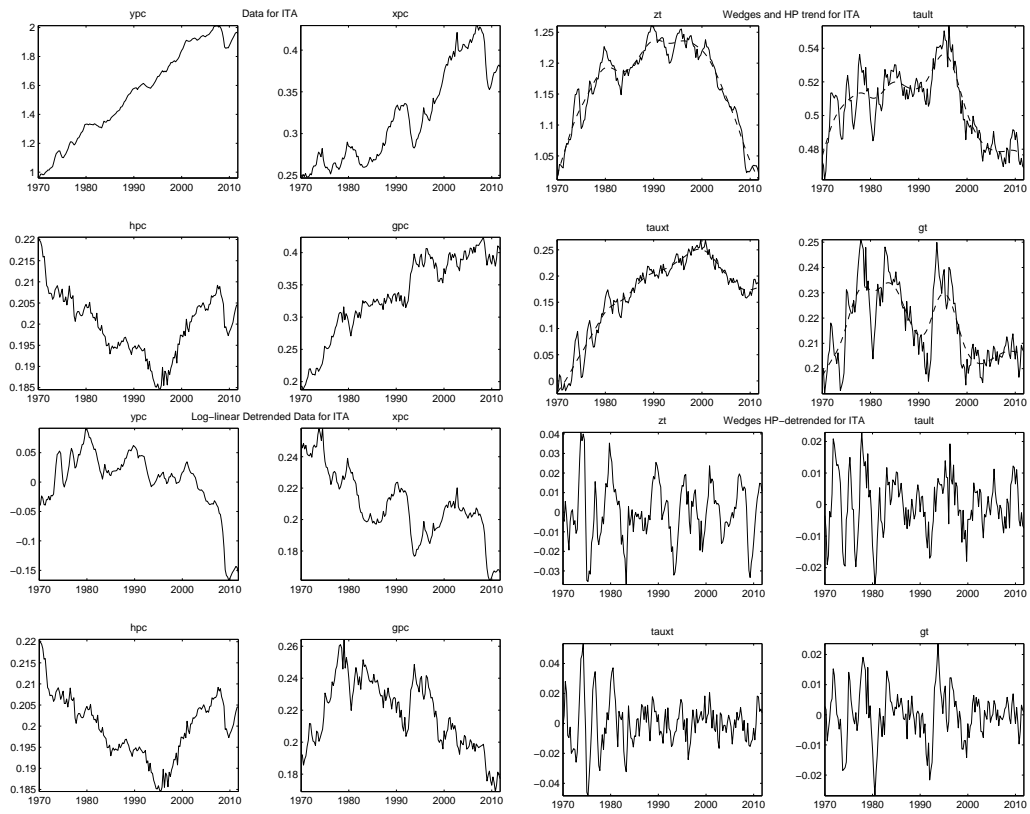
Great Britain



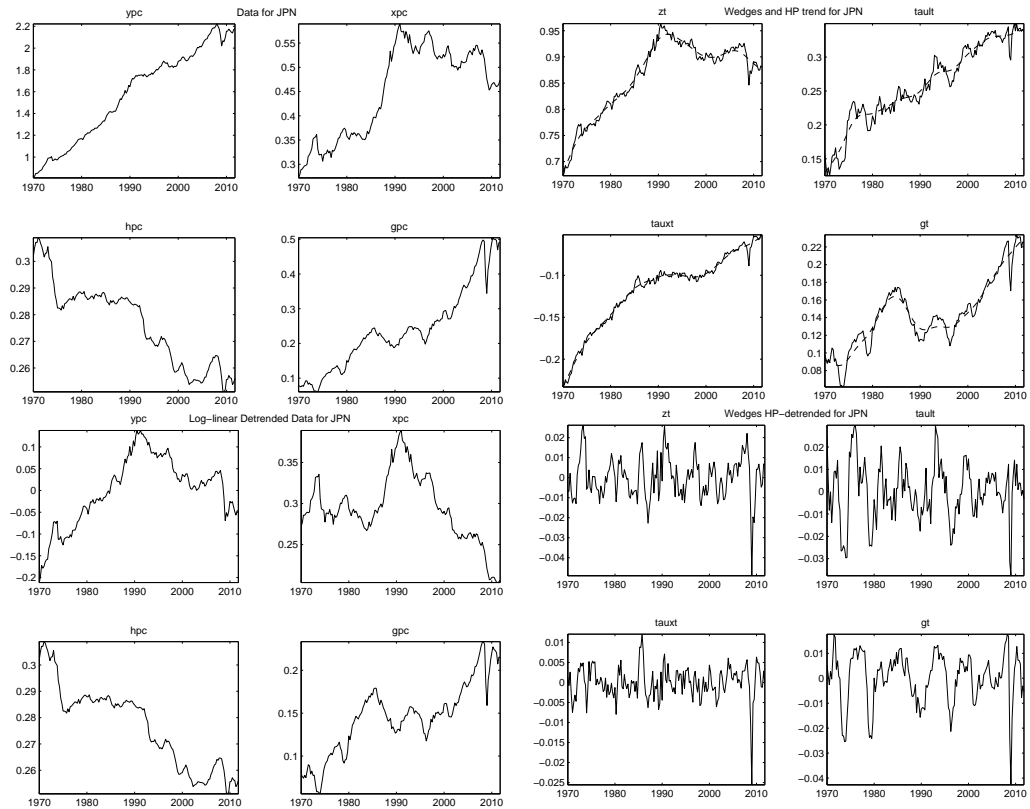
Iceland



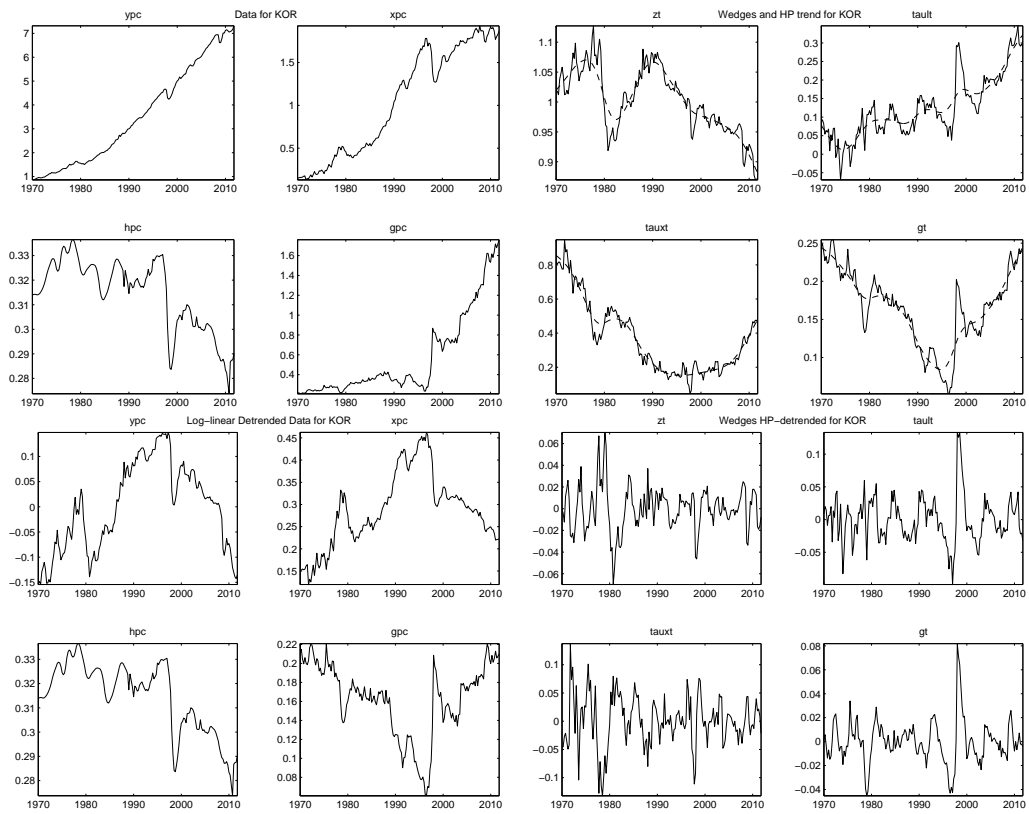
Italy



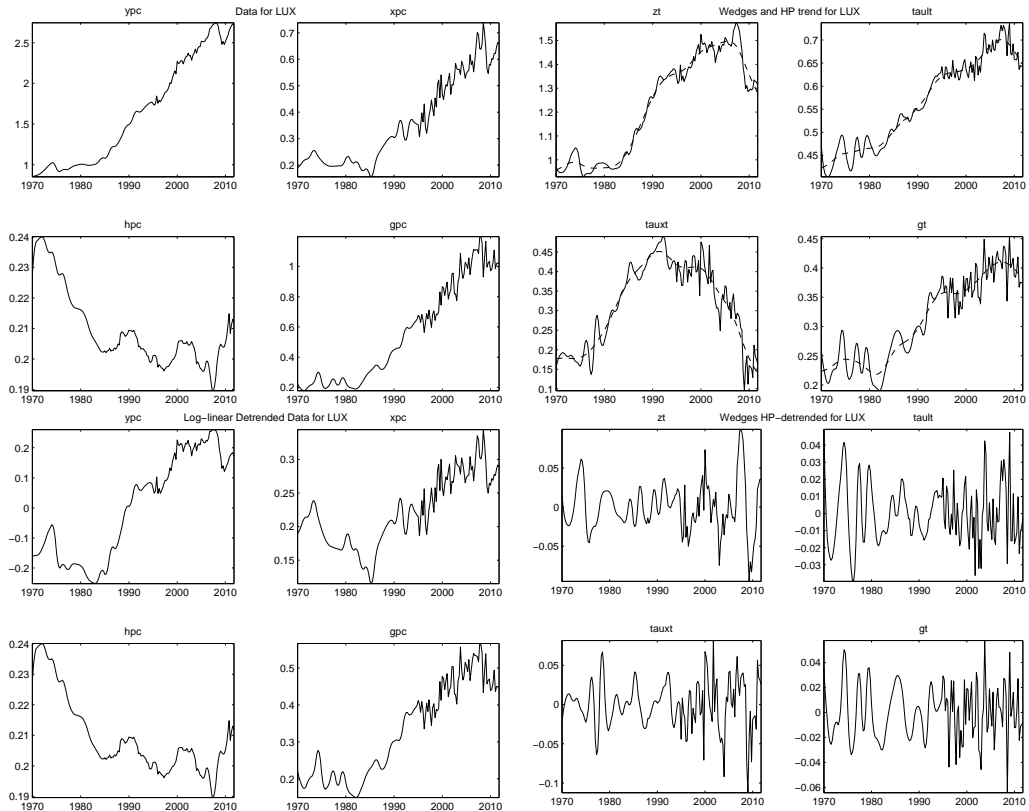
Japan



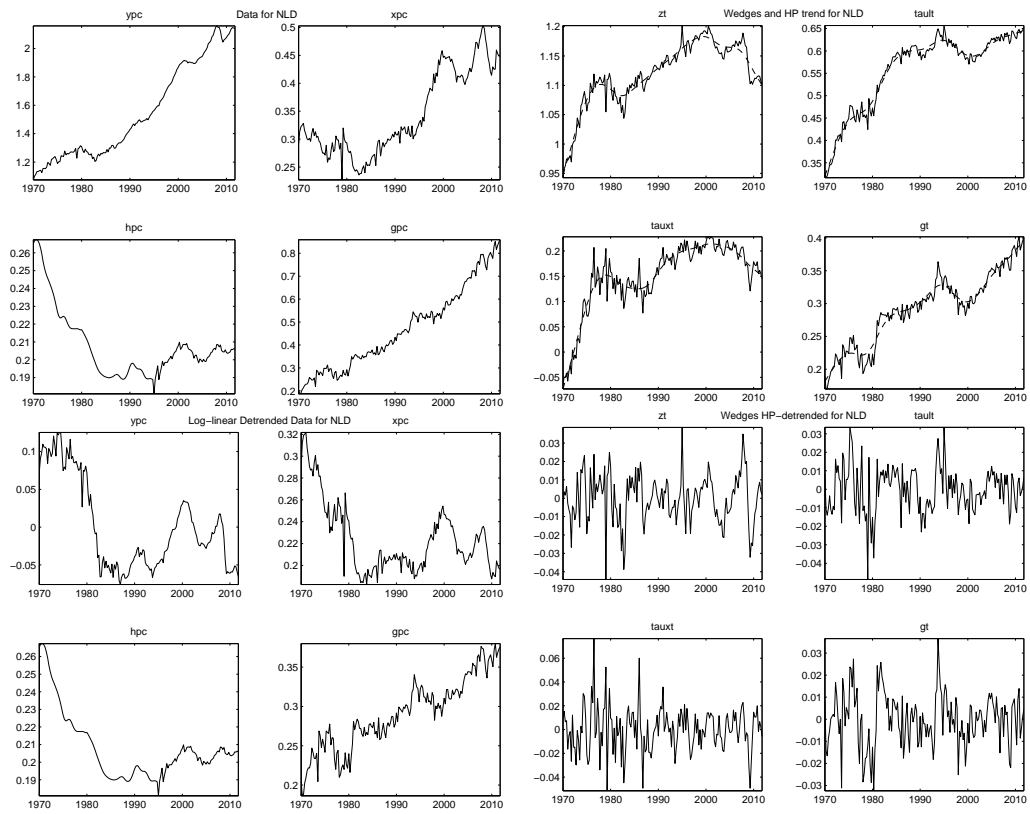
South Korea



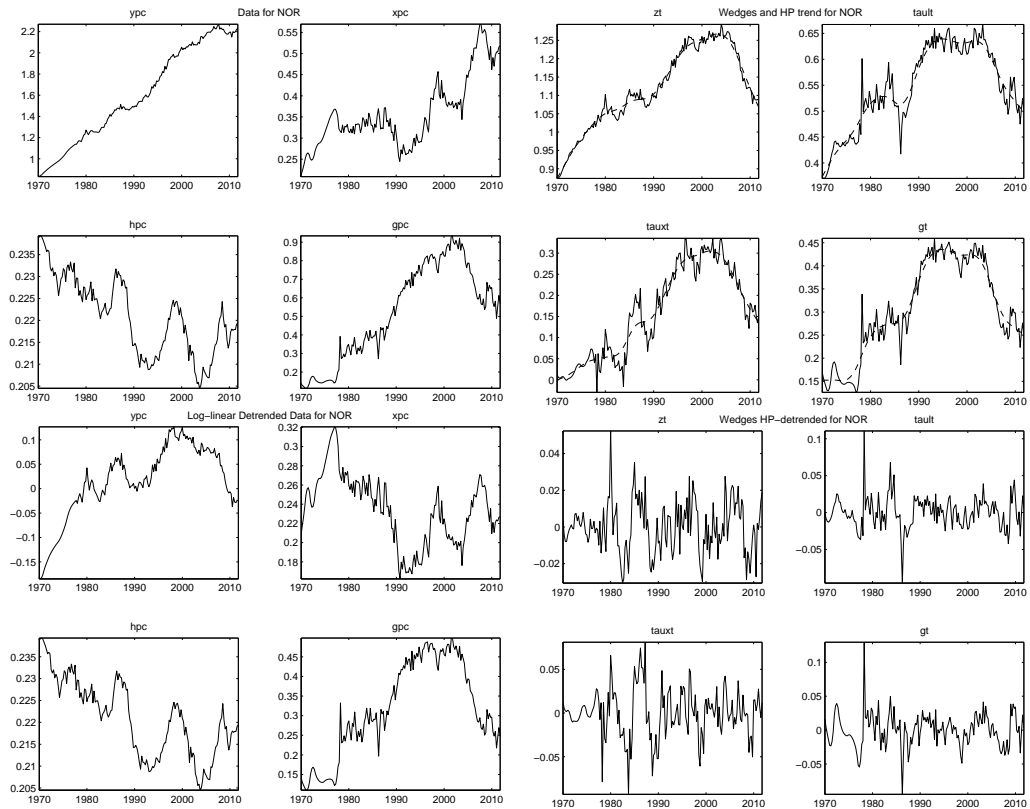
Luxembourg



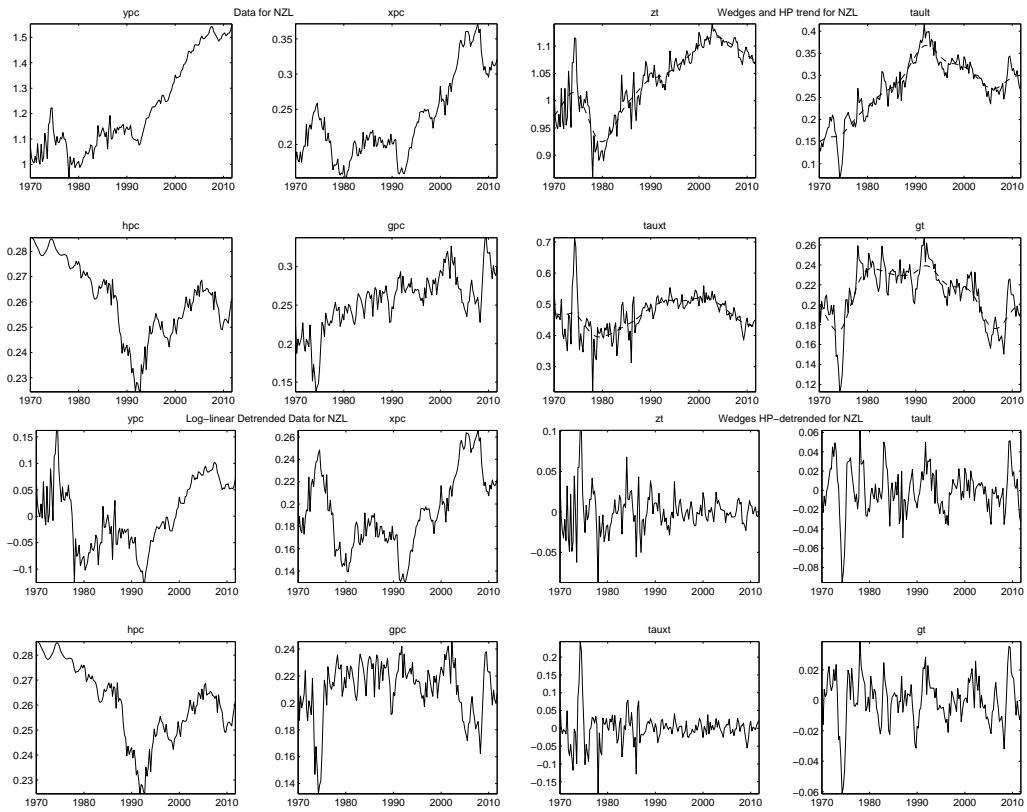
Netherlands



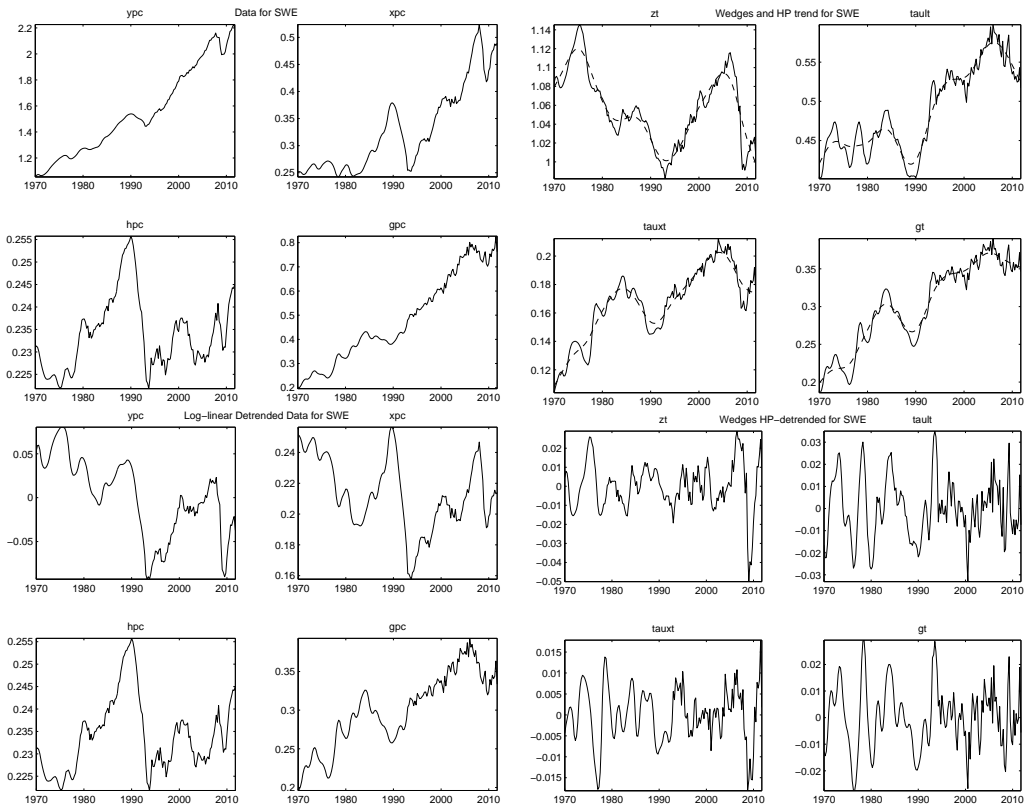
Norway



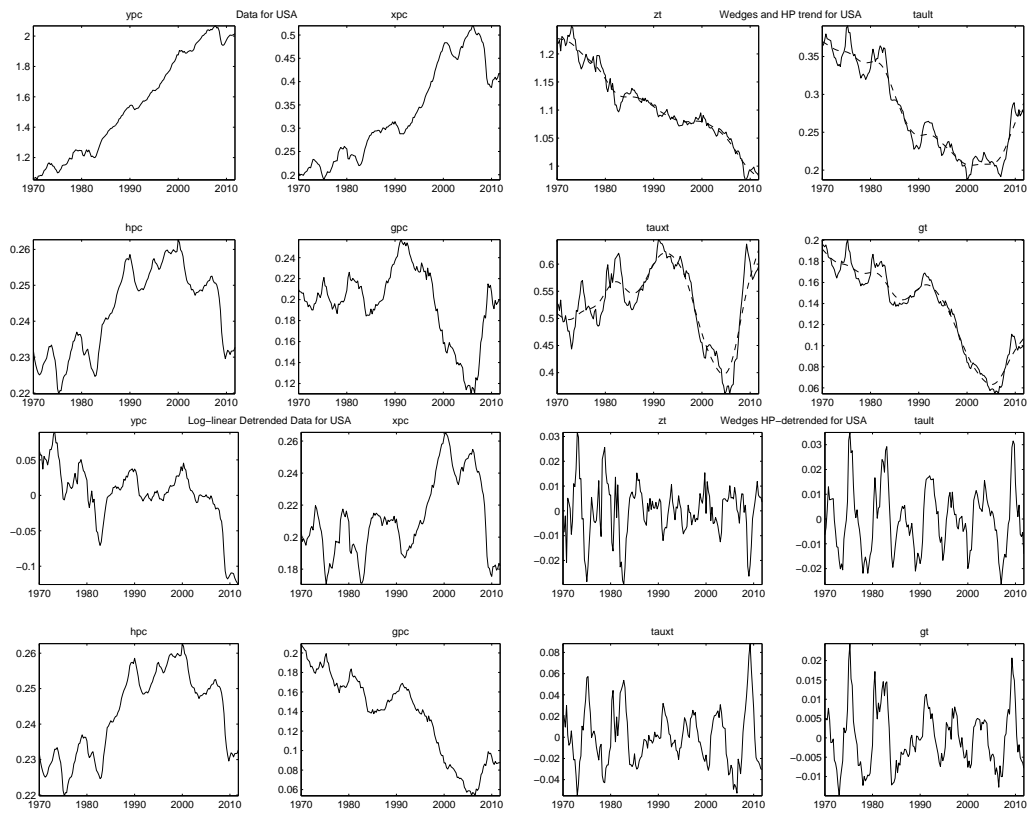
New Zealand



Sweden



USA



Appendix B - Simulations

Deviations from Cycle for 1 Wedge and 3 Wedge Economies

Figure 1: Output

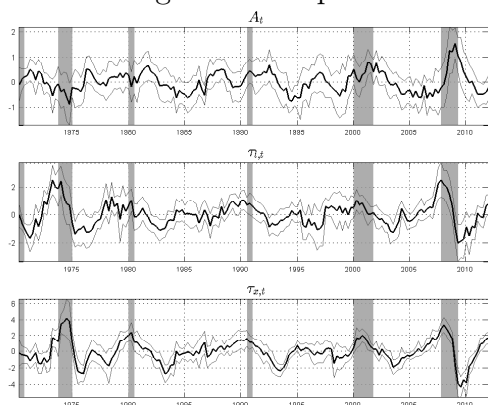


Figure 4: Output

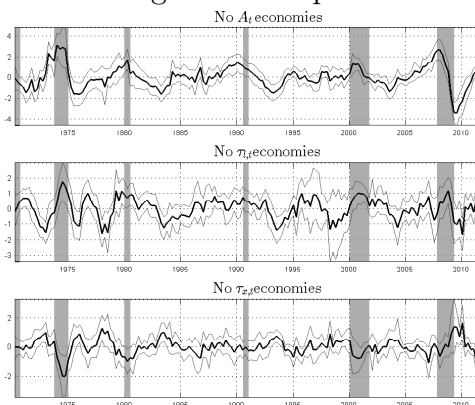


Figure 2: Hours worked

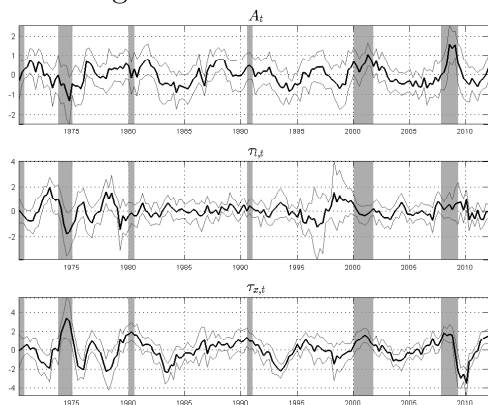


Figure 5: Hours worked

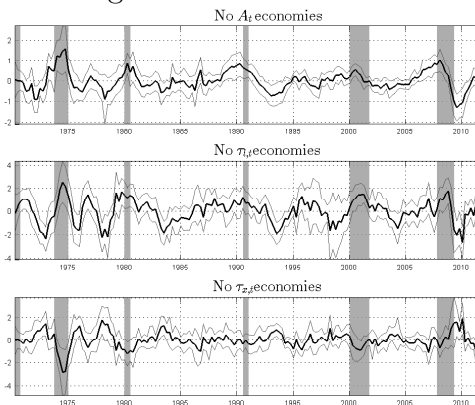


Figure 3: Investment

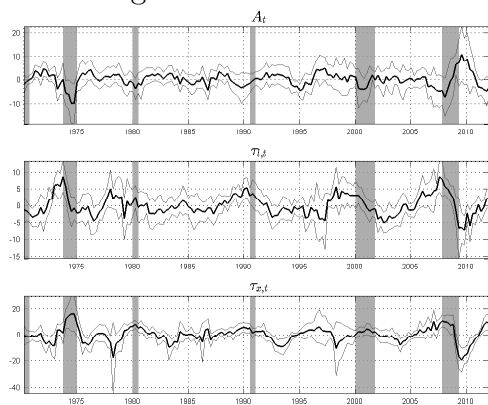
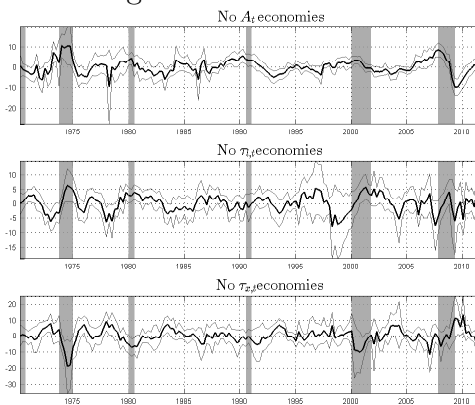


Figure 6: Investment



RMSEs for 1 Wedge and 3 Wedge Economies

Figure 7: Output

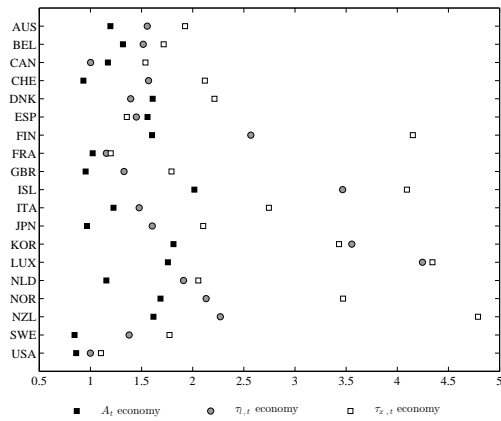


Figure 10: Output

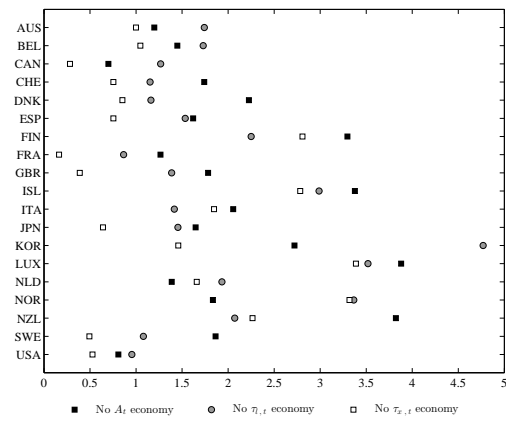


Figure 8: Hours worked

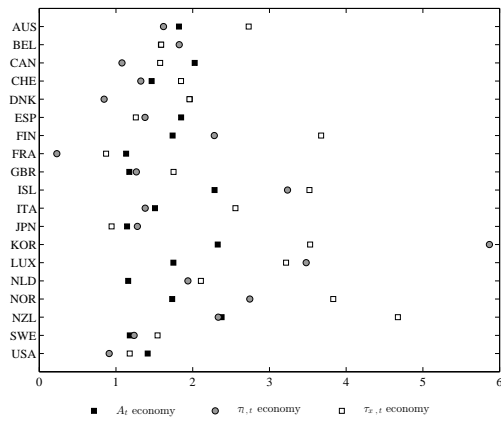


Figure 11: Hours worked

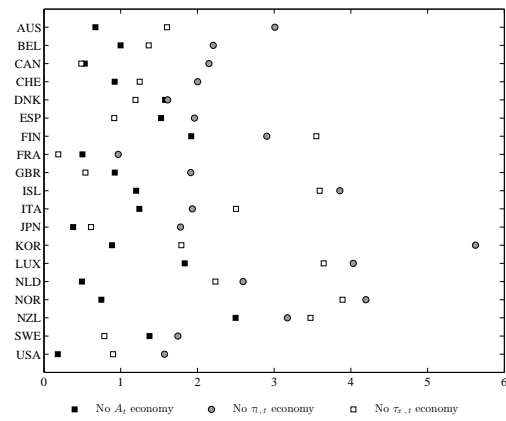


Figure 9: Investment

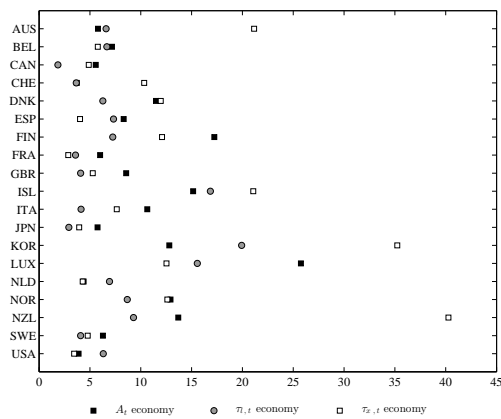
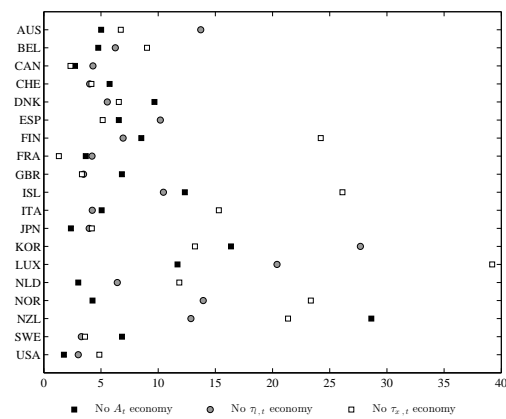


Figure 12: Investment



Statistical Tests of Comparative Performance - RMSEs

Table 1: Statistical Tests of Comparative Performance - 1 Wedge Economies

Output					
Joint	p-val	Pairwise		stat	p-val
ANOVA	< 0.01		A_t vs $\tau_{l,t}$	-2.62	0.01
Friedman	< 0.01	<i>t</i> -tests	A_t vs $\tau_{x,t}$	-4.27	< 0.01
			$\tau_{l,t}$ vs $\tau_{x,t}$	-1.76	0.09
Economy	RMSEs				
A_t	1.33		A_t vs $\tau_{l,t}$	300.00	0.04
$\tau_{l,t}$	1.92	Wilcoxon	A_t vs $\tau_{x,t}$	237.00	< 0.01
$\tau_{x,t}$	2.52		$\tau_{l,t}$ vs $\tau_{x,t}$	308.00	0.07
Hours					
Joint	p-val	Pairwise		stat	p-val
ANOVA	0.12		A_t vs $\tau_{l,t}$	-0.80	0.43
Friedman	0.08	<i>t</i> -tests	A_t vs $\tau_{x,t}$	-2.45	0.02
			$\tau_{l,t}$ vs $\tau_{x,t}$	-1.10	0.28
Economy	RMSEs				
A_t	1.66		A_t vs $\tau_{l,t}$	375.00	0.91
$\tau_{l,t}$	1.91	Wilcoxon	A_t vs $\tau_{x,t}$	310.00	0.08
$\tau_{x,t}$	2.33		$\tau_{l,t}$ vs $\tau_{x,t}$	322.00	0.16
Investment					
Joint	p-val	Pairwise		stat	p-val
ANOVA	0.22		A_t vs $\tau_{l,t}$	1.33	0.19
Friedman	0.03	<i>t</i> -tests	A_t vs $\tau_{x,t}$	-0.74	0.46
			$\tau_{l,t}$ vs $\tau_{x,t}$	-1.60	0.12
Economy	RMSEs				
A_t	9.74		A_t vs $\tau_{l,t}$	414.00	0.21
$\tau_{l,t}$	7.47	Wilcoxon	A_t vs $\tau_{x,t}$	385.00	0.68
$\tau_{x,t}$	11.80		$\tau_{l,t}$ vs $\tau_{x,t}$	335.00	0.31

Table 2: Statistical Tests of Comparative Performance - 3 Wedge Economies

Output					
Joint	p-val	Pairwise		stat	p-val
ANOVA	0.12		No A_t vs No $\tau_{l,t}$	0.33	0.74
Friedman	< 0.01	t -tests	No A_t vs No $\tau_{x,t}$	1.98	0.06
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	1.59	0.12
Economy	RMSEs				
No A_t	2.04		No A_t vs No $\tau_{l,t}$	393.00	0.52
No $\tau_{l,t}$	1.93	Wilcoxon	No A_t vs No $\tau_{x,t}$	441.00	0.04
No $\tau_{x,t}$	1.39		No $\tau_{l,t}$ vs No $\tau_{x,t}$	438.00	0.05
Hours					
Joint	p-val	Pairwise		stat	p-val
ANOVA	< 0.01		No A_t vs No $\tau_{l,t}$	-5.07	< 0.01
Friedman	< 0.01	t -tests	No A_t vs No $\tau_{x,t}$	-2.32	0.03
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	1.98	0.06
Economy	RMSEs				
No A_t	1.07		No A_t vs No $\tau_{l,t}$	283.00	0.01
No $\tau_{l,t}$	2.59	Wilcoxon	No A_t vs No $\tau_{x,t}$	243.00	< 0.01
No $\tau_{x,t}$	1.82		No $\tau_{l,t}$ vs No $\tau_{x,t}$	403.00	0.35
Investment					
Joint	p-val	Pairwise		stat	p-val
ANOVA	0.25		No A_t vs No $\tau_{l,t}$	-0.48	0.64
Friedman	0.53	t -tests	No A_t vs No $\tau_{x,t}$	-1.50	0.14
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	-1.13	0.26
Economy	RMSEs				
No A_t	7.68		No A_t vs No $\tau_{l,t}$	362.00	0.82
No $\tau_{l,t}$	8.68	Wilcoxon	No A_t vs No $\tau_{x,t}$	327.00	0.21
No $\tau_{x,t}$	11.89		No $\tau_{l,t}$ vs No $\tau_{x,t}$	346.00	0.48

Success Ratios for 1 Wedge and 3 Wedge Economies

Figure 13: Output

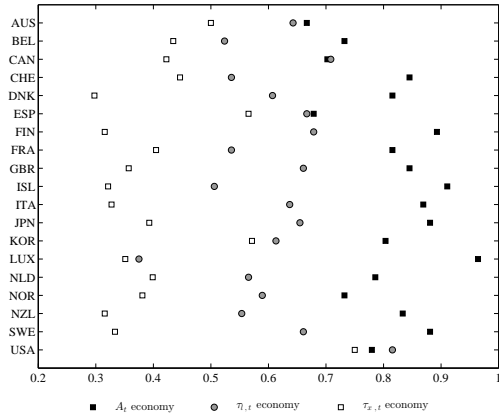


Figure 16: Output

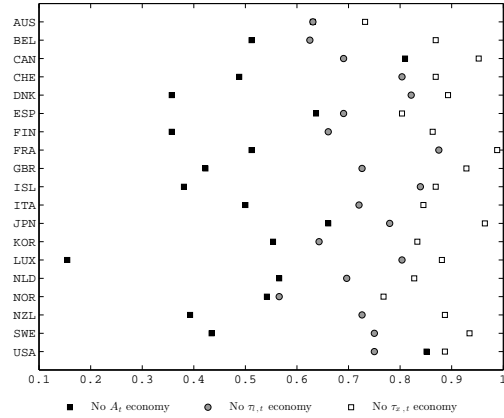


Figure 14: Hours worked

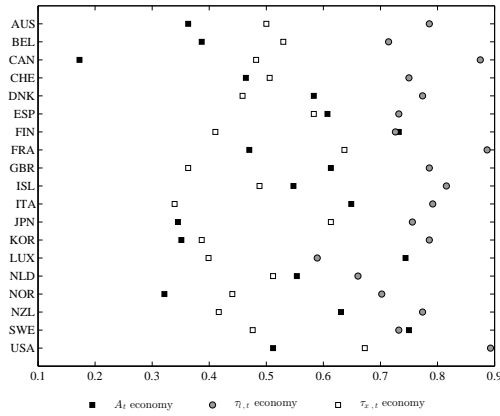


Figure 17: Hours worked

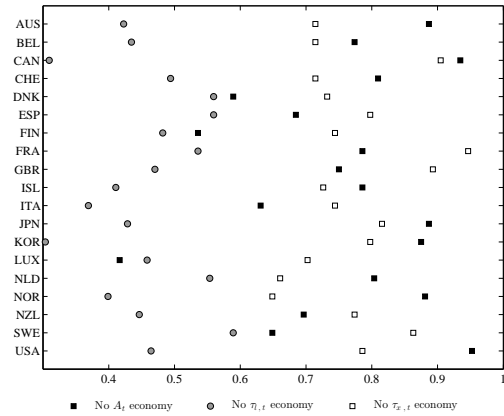


Figure 15: Investment

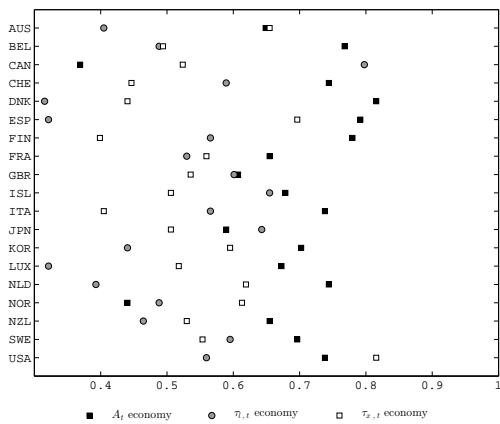
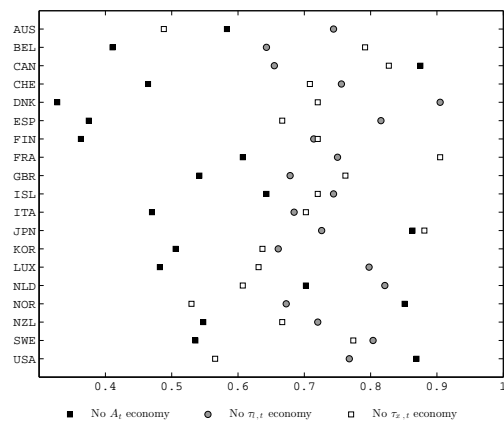


Figure 18: Investment



Statistical Tests of Comparative Performance - SRs

Table 3: Statistical Tests of Comparative Performance - 1 Wedge Economies

Output				
Joint	p-val	Pairwise	stat	p-val
ANOVA	< 0.01	A_t vs $\tau_{l,t}$	7.19	< 0.01
Friedman	< 0.01	A_t vs $\tau_{x,t}$	12.34	< 0.01
		$\tau_{l,t}$ vs $\tau_{x,t}$	5.66	< 0.01
Economy	Success Ratios			
A_t	81%	A_t vs $\tau_{l,t}$	537.00	< 0.01
$\tau_{l,t}$	61%	A_t vs $\tau_{x,t}$	546.00	< 0.01
$\tau_{x,t}$	42%	$\tau_{l,t}$ vs $\tau_{x,t}$	511.50	< 0.01
Hours				
Joint	p-val	Pairwise	stat	p-val
ANOVA	< 0.01	A_t vs $\tau_{l,t}$	-6.12	< 0.01
Friedman	< 0.01	A_t vs $\tau_{x,t}$	0.72	0.48
		$\tau_{l,t}$ vs $\tau_{x,t}$	10.26	< 0.01
Economy	Success Ratios			
A_t	52%	A_t vs $\tau_{l,t}$	214.50	< 0.01
$\tau_{l,t}$	76%	A_t vs $\tau_{x,t}$	395.50	0.47
$\tau_{x,t}$	48%	$\tau_{l,t}$ vs $\tau_{x,t}$	547.00	< 0.01
Investment				
Joint	p-val	Pairwise	stat	p-val
ANOVA	< 0.01	A_t vs $\tau_{l,t}$	4.15	< 0.01
Friedman	< 0.01	A_t vs $\tau_{x,t}$	3.62	< 0.01
		$\tau_{l,t}$ vs $\tau_{x,t}$	-0.94	0.35
Economy	Success Ratios			
A_t	68%	A_t vs $\tau_{l,t}$	497.00	< 0.01
$\tau_{l,t}$	51%	A_t vs $\tau_{x,t}$	482.50	< 0.01
$\tau_{x,t}$	55%	$\tau_{l,t}$ vs $\tau_{x,t}$	345.00	0.47

Table 4: Statistical Tests of Comparative Performance - 3 Wedge Economies

Output					
Joint	p-val	Pairwise	stat	p-val	
ANOVA	< 0.01				
Friedman	< 0.01				
<hr/>					
Economy	Success Ratios				
No A_t	51%				
No $\tau_{l,t}$	73%				
No $\tau_{x,t}$	87%				
		t -tests	No A_t vs No $\tau_{l,t}$	-5.06	< 0.01
			No A_t vs No $\tau_{x,t}$	-8.90	< 0.01
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	-6.16	< 0.01
		Wilcoxon	No A_t vs No $\tau_{l,t}$	234.50	< 0.01
			No A_t vs No $\tau_{x,t}$	199.00	< 0.01
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	217.00	< 0.01
<hr/>					
Hours					
Joint	p-val	Pairwise	stat	p-val	
ANOVA	< 0.01				
Friedman	< 0.01				
<hr/>					
Economy	Success Ratios				
No A_t	75%				
No $\tau_{l,t}$	46%				
No $\tau_{x,t}$	77%				
		t -tests	No A_t vs No $\tau_{l,t}$	7.87	< 0.01
			No A_t vs No $\tau_{x,t}$	-0.49	0.63
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	-11.91	< 0.01
		Wilcoxon	No A_t vs No $\tau_{l,t}$	283.00	0.01
			No A_t vs No $\tau_{x,t}$	243.00	< 0.01
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	403.00	0.35
<hr/>					
Investment					
Joint	p-val	Pairwise	stat	p-val	
ANOVA	< 0.01				
Friedman	0.01				
<hr/>					
Economy	Success Ratios				
No A_t	58%				
No $\tau_{l,t}$	74%				
No $\tau_{x,t}$	70%				
		t -tests	No A_t vs No $\tau_{l,t}$	-3.66	< 0.01
			No A_t vs No $\tau_{x,t}$	-2.50	0.02
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	1.33	0.19
		Wilcoxon	No A_t vs No $\tau_{l,t}$	268.50	< 0.01
			No A_t vs No $\tau_{x,t}$	286.00	0.01
			No $\tau_{l,t}$ vs No $\tau_{x,t}$	415.00	0.20

III

Monetary Business Cycle Accounting for Sweden*

Pedro Brinca[†]

August 27, 2013

Abstract

When creating competing models of economic fluctuations, researchers typically introduce frictions in their models aiming at replicating the observed movements in the data. This paper implements a business cycle accounting procedure for the Swedish economy. Both the 1990's and the 2008 recessions are given special focus. Evidence is provided for properties that structural extensions to the business cycle model need to have in order to replicate the movements in the data. Distortions to the labor market and movements in total factor productivity are the most determinant features to be modeled with respect to real variables as well as deviations from a Taylor rule for interest rate setting, though the latter plays little role for both the 1990's and the 2008 recessions. The distortions share a structural break during the 1990's crisis but not during the recent one.

JEL Classification: E31, E32, E37, E43

Keywords: Business cycle accounting, frictions, economic fluctuations

*I am grateful for comments from Martin Flodén, Annika Alexius, Johan Söderberg, John Hassler, Almut Baleer, Abdulaziz Shifa, Yangzhou Yuan, Anna Lindahl, Alper Çenesiz, Kjetil Storesletten, Tiago Cavalcanti (the editor), anonymous referees, seminar participants at NESU, FEUC, NIPE and, in particular, Sirus Dehdari for excellent research assistance

[†]Correspondence to Pedro Brinca, email pedro.brinca@ne.su.se. Address: Department of Economics, Stockholm University, SE-106 91 Stockholm, Sweden.

1 Introduction

This paper aims at measuring the quantitative relevance of different types of distortions with respect to business cycle fluctuations in Sweden. Sweden has experienced two major recession episodes in the last 30 years, in the early 1990's and during the recent financial crisis. What do they have in common and what is it that makes them different are questions that constitute one of the main focuses of the paper. This way the hope is that we get a better grasp of which theories hold most promise in explaining these two recessions.

The issue of business cycle fluctuations in Sweden has been studied before. Hassler et al. (1992) go through 130 years of macroeconomic data to establish some stylized facts about the Swedish business cycle. Though departing from a more statistical approach, they nonetheless bring to light a series of correlations between macroeconomic aggregates that successful theories of business cycle fluctuations must replicate. They establish the countercyclicality of the real wage as a key feature that distinguishes the Swedish labor market from other economies. Moreover, they find no link between Swedish output and foreign demand, which only has a meaningful impact in the inter-war period.

Assarsson and Jansson (1998) address the issue of unemployment persistence in Sweden, focusing precisely on the 1990's recession and conclude that shocks to the natural rate of unemployment constituted a key determinant for the unemployment trend during and after the crisis.

Hassler (2010) suggests structurally different explanations for both crises. The 1990's movements in the labor market are more associated with the destruction of non-competitive jobs and claims that the recent crisis is fundamentally different in the sense that it is much more connected to a huge drop in capacity utilization and the ensuing labor hoarding.

In more recent work, Christiano et al. (2011) create a small open economy model for the Swedish economy where they find that financial and employment frictions are important in measuring the contribution of financial and export demand shocks during the recent recession. The very same frictions are also essential for modeling inflation and the nominal interest rate.

As previously mentioned, the purpose of this paper is to provide researchers with guidance for their modeling exercises so that they can successfully replicate the observed movements in the data. It also provides evidence that can be used to explain why past attempts at modeling business cycle fluctuations in Sweden may have had different degrees of success.

Methodologically, this paper uses the prototype economy set up by Sustek (2010) but it does not limit itself to analyze the lead-lag correlation structure of inflation and the nominal interest rate with respect to output. It proceeds like Chari et al. (2007a) in analyzing time paths of simulated economies

and comparing them with data to analyze the quantitative relevance of each wedge for the two recessions, but in a model that enables us explicitly to gather evidence with respect to the dynamics of variables such as inflation and the nominal interest rate.

In fact, most applications of business cycle accounting exercises to date have been straight applications of the Chari et al. (2007a) methodology. Gao and Ljungwall (2009) analyze business cycle fluctuations for China and India, Simonovska and Söderling (2008) for Chile, Kobayashi and Inaba (2006) for Japan and Lama (2009) for Argentina, Brazil and Mexico. Cavalcanti (2007) also conducts a business cycle accounting exercise in the context of the Portuguese economy, a case particularly relevant given that, as is also the case for Sweden, Portugal is a small open economy. The author also deepens the analysis by implementing a growth accounting exercise, following the methodology of Prescott (2002), to account for the differences in levels of Portugal relative to the U.S. in terms of output per worker.

The ultimate purpose of business cycle accounting exercises, though, is to provide business cycle theorists with hints regarding promising extensions to the neoclassical growth model or, even better, to provide structural explanations of the measured wedges. This is a more recent trend in the literature (see, for example, Cho and Doblus-Madrid (2012)), where authors go beyond the original Chari et al. (2007a) methodology and come forth with structural explanations, or at least seek structural indicators that may contain information with regard to the distortions. In that sense, regarding the Japanese interwar period, Saijo (2008) was innovative, given that the author performs the usual business cycle accounting exercise and also, in the same paper, proposes and tests a structural explanation for the distortions. The author comes forth with time-varying markups, interpreted as variations in the degree of competition between firms, as a factor accounting for 60% to 70% of the slow recovery of Japanese output in the 1930's.

More recent work by Chakraborty and Otsu (2012) also tests the robustness of shocks to the cyclical component of total factor productivity to shocks to its trend, an important identification issue to take into account, especially in the context of developing or fast growing economies. Their work concerns an application to Brazil, Russia, India and China (BRICs) and the authors document an increasing importance of the investment wedge since the 2000's for India and China.

The typical findings are similar to those of Chari et al. (2007a) who find that distortions that manifest themselves as time-varying labor income taxes and time-varying fluctuations to total factor productivity hold the most potential in explaining the movements in the data, although the labor wedge seems to be the most quantitatively relevant for Japan and Argentina.

Other changes to the Chari et al. (2007a) methodology have been brought forth. Lama (2009) provides a novelty in the methodology in explicitly modeling international borrowing. He also includes a distortion that manifests itself as a time-varying tax on capital returns rather than on investment as in most applications. Otsu (2009) extends Chari et al. (2007a) to a two-country setting and applies it to the U.S. and Japan, although their main findings still remain the same as in previous studies.

In retrospect, the very notion that detailed economies are equivalent to a prototype economy with primitive shocks, from the perspective of equilibrium allocation and prices, can be traced back to Mulligan (2002). The overall idea of the research agenda is to find which classes of extensions to the business cycle model are of quantitative relevance, though as previously mentioned, the literature is evolving towards complementing such analysis with structural indicators containing information with regard to the distortions.

The prototype economy laid out by Sustek has the merit of including a theoretical extension to the standard business cycle model that has become prevalent, namely a Taylor rule for nominal interest rate setting. Historically, and especially in the recent macroeconomic context, including government bonds is also quite important since it allows us to monetize the model and have a say in inflation dynamics.

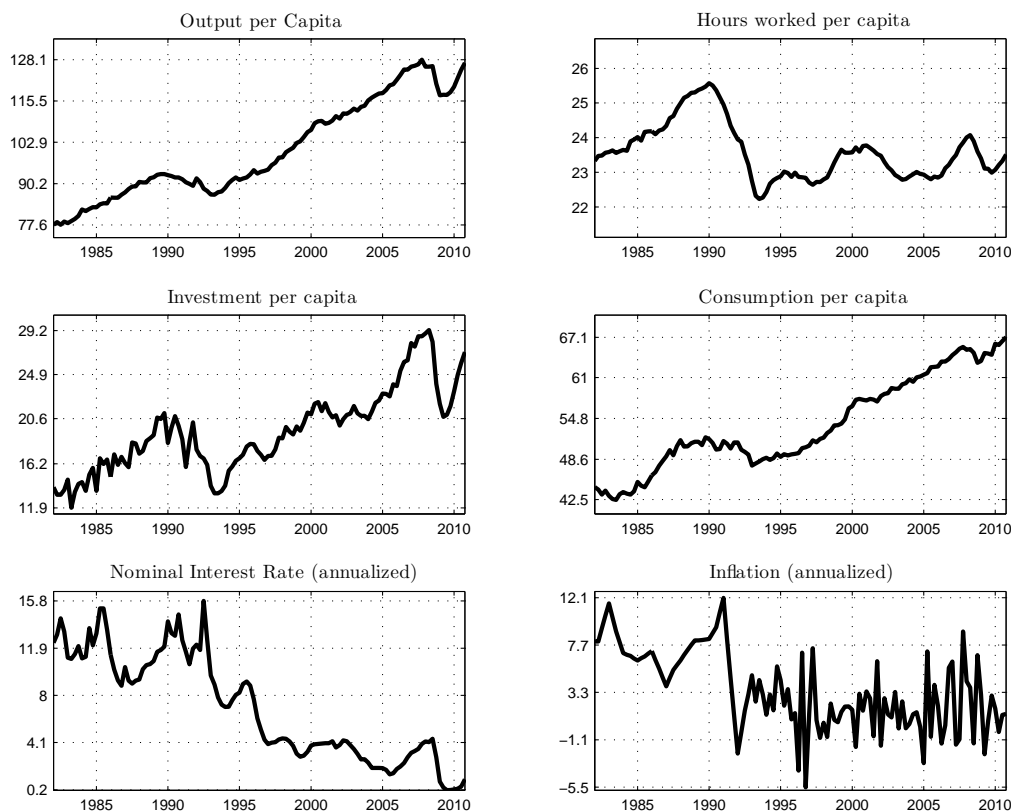
2 The Swedish Economy from 1982 to 2010

In Figure 1 below, we have the six macroeconomic aggregates that constitute the focus of this paper. Both crises can be seen from the series, especially from observing output, hours worked, investment and consumption per capita. We see a declining trend of the nominal interest and inflation rates since 1982, in line with the trends in other developed economies. Even though we can see both crises in the data, we can also draw some initial conclusions about how they compare to each other. Output and investment experience have similar drops in the recent recession and in the 1990's. However, the fall into and the recovery from recession was much quicker in the crisis in 2008. It took about six years for output to recover to the same level as before 1990 while it took around half that time for the recent crisis.

With respect to investment, even though it has not yet recovered to the same levels as before the 2008 crisis, in almost three years (see last quarter of 2010), it has already returned to 94% of its value in the first quarter of 2008. For the 1990's recession, it took eight years for investment to grow back to the same level as in the last quarter of 1989.

Consumption behaves somehow differently from the two previous aggre-

Figure 1: Macroeconomic Aggregates 1982-2010



Output, Investment and Consumption in billion 2010 SEK. Hours worked as percentage of a day.
 Nominal interest and Inflation rates in percentage
 Source: OECD and NIER.

gates in the sense that though it shares the same slower decline and has a slower recovery pattern for the 1990's recession as compared to 2008, i.e. eight years versus four for consumption to bounce back to its pre-crisis levels, the decline was deeper in the 1990's.

Hours worked is the aggregate that exhibits the greatest change during this sample period. There was an enormous decline starting in 1990 from which the economy never went back to. In the recent crisis, however, hours exhibit a pattern similar to investment. They show a strong decline but are bouncing back fast and already in the last quarter of 2010, they are at around 97% of what they were in the first quarter of 2008.

With respect to the nominal interest rate setting, we can see that there was a much more aggressive response to the recent crisis than in the 1990's.

Sweden was, in fact, in the middle of a bursting real estate bubble that left banks in such a liquidity crisis that the government had to take over almost a quarter of all banking assets. The government deficit reached 12% of GDP in 1993. Since there was a fixed exchange rate regime that lasted until the third quarter of 1992, instead of the typical response of lowering interest rates to stimulate the economy, large interventions were made to defend the Swedish Krona.

The interest rate actually increased at the beginning of the recession and only after the change in the exchange rate regime did it start its declining trend. This is in stark contrast to the context of the 2008 crisis. The government had a relatively high fiscal surplus and low debt before the crisis. This put little or no pressure on government bond prices and, at the same time, the flexible exchange rate regime allowed the central bank to lower the interest rates in order to stimulate the economy.

With respect to inflation, there has been an overall declining trend since the 1980's in line with what has been observed in other developed economies.

3 Methodology

The idea behind business cycle accounting is that a large class of detailed economies where distortions with structural foundations are introduced to the business cycle model are equivalent, allocation-wise, to a prototype economy with time-varying wedges. This is what Chari et al. (2007a) call the *the equivalence principle*.

The wedges are named *efficiency wedge*, *labor wedge*, *investment wedge* and *government consumption wedge*, precisely because they look like time-varying productivity, labor income taxes, investment taxes and government consumption.

Chari et al. (2007a) derive *equivalence theorems*, i.e. mappings from distortions in the detailed economies to wedges in the prototype economy such that both economies are equivalent allocation-wise.

As previously mentioned, the monetary business cycle accounting procedure was introduced by Sustek (2010). In his paper, he extends the methodology created by Chari et al. (2007a) to include financial variables, such as the nominal interest rate and the price level. This is achieved by including an Euler equation in bonds and a Taylor rule. Two new wedges are introduced in these equations, called the asset market wedge and the monetary policy or the Taylor wedge, respectively, and like in Chari et al. (2007a), equivalence theorems are also derived.

3.1 The Prototype Economy

The prototype economy consists of a neoclassical growth model with labor-leisure choice, a monetary policy rule and six exogenous random shocks, i.e. wedges and nominal bonds. For a detailed description of the prototype economy, see Sustek (2010). There is an infinitely-lived representative household that maximizes expected discounted utility, choosing how much to consume c_t and labor to supply l_t , given the discount factor β :

$$\max E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - l_t) \quad (1)$$

subject to the budget constraint:

$$c_t + (1 + \tau_{x,t})x_t + (1 + \tau_{b,t}) \left[\frac{b_t}{(1 + R_t)p_t} - \frac{b_{t-1}}{p_t} \right] = (1 - \tau_{lt})w_t l_t + r_t k_t + T_t \quad (2)$$

where τ_{xt} , τ_{bt} and τ_{lt} are the investment, asset-market and labor wedges, respectively, x_t is investment, b_t are bond holdings that pay a net nominal rate of return R_t , p_t is the price level, w_t is the real wage, r_t is the real rental rate of capital, k_t are capital holdings at the beginning of the period t and T_t are lump-sum transfers from the government. Capital accumulates according to:

$$k_{t+1} = (1 - \delta)k_t + x_t \quad (3)$$

where δ is the capital depreciation rate. The production function is given by

$$y_t = A_t F(k_t, (1 + \gamma_A)^t l_t) \quad (4)$$

where y_t is output and γ_A is the growth rate of labor-augmenting technical progress. The aggregate resource constraint consists of

$$c_t + x_t + g_t = y_t \quad (5)$$

where g_t are government consumption expenditures. There is a central bank that sets the nominal interest rate according to:

$$R_t = (1 - \rho_r)[R + \omega_y(\ln y_t - \ln \bar{y}) + \omega_\pi(\pi_t - \pi)] + \rho_r R_{t-1} + \tilde{R}_t. \quad (6)$$

The nominal interest rate is set as a weighted average (by ρ_r) of the previous period nominal interest rate and an interest rate as prescribed by a Taylor-type interest rate setting rule. This takes into account a steady-state nominal interest rate R and preference parameters ω_y and ω_π that capture the central bank's sensitivity to deviations from steady-state output y and steady-state inflation π . \tilde{R}_t is the nominal interest rate or Taylor rule wedge.

There is a representative firm that maximizes profits and pays factors their marginal products. Both households and firms are price takers in all markets.

3.2 Equilibrium

The conditions that will define the equilibrium prices and allocations consist of the labor-leisure choice

$$[1 - \tau_t]A_t(1 + \gamma_A)^t F_{lt} u_{ct} = u_{ht} \quad (7)$$

an Euler equation for consumption

$$E_t \left[\beta \frac{u_{c,t+1}}{u_{c,t}} \frac{(1 + \tau_{x,t+1})(1 - \delta) + A_{t+1} F_{k,t+1}}{1 + \tau_{x,t}} \right] = 1 \quad (8)$$

and an Euler equation in bonds.

$$E_t \left[\beta \frac{u_{c,t+1}}{u_{c,t}} \frac{1 + \tau_{b,t+1}}{1 + \tau_{b,t}} \frac{p_t}{p_{t+1}} [1 + R_t] \right] = 1 \quad (9)$$

The nominal interest rate rule, the production function and the aggregate resource constraint close the model. These six conditions will determine the equilibrium allocations and prices:

$$c_t^*, x_t^*, y_t^*, l_t^*, p_t^*, R_t^*. \quad (10)$$

Note that each equilibrium condition has an associated wedge. A_t , the *efficiency wedge*, is a time-varying parameter that makes the production hold for all t , i.e. what is commonly referred in the literature as the Solow residual. Following the same reasoning, the leisure-labor condition includes the *labor wedge* $\tau_{l,t}$ and the Euler equations for consumption and bonds, an *investment wedge* $\tau_{x,t}$ and an *asset-market wedge* $\tau_{b,t}$. Finally, the aggregate resource constraint includes the *government wedge* g_t and the nominal interest rate rule, i.e. a *Taylor rule wedge* \tilde{R}_t . All these wedges are exogenous random variables, i.e. measurable functions of the history of events.

3.3 The equivalence principle

As previously mentioned, detailed models that introduce distortions to the business cycle model are allocation-wise equivalent to the prototype economy described above, given that a suitable mapping from the distortions to the wedges is found.

Chari et al. (2007a) call these mappings equivalence theorems. They show that a detailed economy with sticky wages is equivalent to a prototype economy with a labor market wedge. They also show that a model with input-financing restrictions is equivalent to a prototype economy with an efficiency

wedge. With respect to the efficiency wedge, Chari et al. (2007a) also show that a model with variable capacity utilization is equivalent to a prototype economy with an efficiency wedge. Sustek (2010) shows that the detailed economy brought forth by Christiano and Eichenbaum (1992) with costs for adjusting sectoral flow of funds is equivalent to a prototype economy with a Taylor rule wedge.

Another example in Sustek (2010) concerns a sticky prices model that is shown to be equivalent to a prototype economy with capital¹ and labor market wedges.

Finally, it is worth noting that, unlike the U.S., Sweden is a small open economy. A simple open-economy model with an exogenous real rate of return to capital can be shown to be equivalent to the prototype economy described above where the investment wedge is chosen so as to make the path of the interest rate coincide with the given process for the exogenous rate of return to capital.

3.4 The accounting principle

By measuring the wedges over time, we have a quantitative assessment of their impact in a given period of fluctuations. The identification of the quantitatively relevant wedges will help direct the research efforts towards mechanisms that express themselves as one or more wedges. Therefore, these mechanisms will have a much higher potential to match the data if they share the same properties of the wedges.

Once measured, feeding the wedges back to the prototype economy as shocks and simulating the model makes model equilibrium allocations and data the same. This should not come as a surprise since, by construction, the wedge is precisely time-series that make the equilibrium conditions of the model hold.

The interesting question is what happens if we do not feed one of the wedges back into the model, i.e. if we fix one wedge to its steady-state level. Model equilibrium allocations and data will no longer be the same, but how far off will we be? By fixing one wedge at a time, but feeding back the other wedges as shocks to the model and comparing simulated data to real data, we learn about the quantitative relevance of each wedge for a given period

¹In the prototype economy, the wedge appears as a tax to investment rather than capital holdings. Chari et al. (2007b) show that in theory, it makes no difference. However, it does affect the probability space for the wedges when we work with approximated economies, though the effect of including a wedge that appears as a tax to investment versus capital holdings is found by Sustek (2010) to be quantitatively irrelevant in the context of the US economy.

of economic fluctuations.

3.5 Data

For estimation and simulation of the prototype and simulated economies, data is needed for investment, output, government expenditures plus net exports and hours worked, price level and the nominal interest rate on the three-month treasury bill. Most national accounts data is obtained from the National Institute of Economic Research (NIER). Hours worked, population and prices (GDP deflator) are taken from the OECD Economic Outlook database and data on sales taxes from OECD Tax Statistics.

The data covers the period from the first quarter of 1982 until the last quarter of 2010. Since sales tax data is annual, the quarterly variation in consumption is used to interpolate sales taxes to quarterly frequency and remove it from real GDP in order to get model output. Data on population is also annual but interpolated to quarterly values. Investment is the outcome of total real gross fixed capital formation plus real net changes in inventories and, finally, we add the difference between real exports and imports of goods and services to real government final consumption expenditures.

Finally, it is important to notice that the GDP deflator is interpolated from yearly to quarterly frequency up to 1993. Hours worked are also interpolated until 1992, which means that the quarterly variation on hours worked per capita up to 1992 mainly comes from total employment.

3.6 Functional forms, calibration and estimation

The functional forms and most of the calibration follow Chari et al. (2007). The production function is linear homogeneous

$$F(k_t, (1 + \gamma_A)^t l_t) = k_t^\alpha ((1 + \gamma_A)^t l_t)^{1-\alpha} \quad (11)$$

and instantaneous utility is a weighted sum of leisure and consumption in logarithms

$$u(c_t, 1 - l_t) = \lambda \ln c_t + (1 - \lambda) \ln(1 - l_t). \quad (12)$$

The calibration targets are computed by taking averages over the entire sample with the exception of the capital-output ratio, which is taken from Domeij and Flodén (2006)

$$\frac{\text{KY ratio} \quad \text{Labor fraction} \quad \text{XY ratio}}{12.44 \quad \quad 0.24 \quad \quad 0.19} \quad (13)$$

This calibration implies values for λ , δ and β :

$$\frac{\beta \quad \delta \quad \lambda}{0.99 \quad 0.04 \quad 0.35} \quad (14)$$

The other parameters are standard in the business cycle literature. In particular, ω_π is set to be greater than one to avoid explosive inflation paths:

$$\frac{\alpha \quad \gamma_A \quad \gamma_N \quad \rho_R \quad \omega_Y \quad \omega_\pi \quad \pi}{0.3500 \quad 0.0043 \quad 0.0010 \quad 0.7500 \quad 0.1250 \quad 1.5000 \quad 0.0089} \quad (15)$$

The wedges are modeled as a six dimensional vector autoregressive of order one where the error process is assumed to be multivariate normal with the mean zero and the variance-covariance matrix $Q = B'B$ as described below:

$$\omega_{t+1} = P_0 + P\omega_t + \epsilon_{t+1}, \quad \epsilon \sim MVN(0, B'B) \quad (16)$$

The estimates for P_0 , P and B are shown below. To obtain these estimates, I proceed like Sustek (2010). First, the calibration targets are met. Then, steady-state values are computed and the equilibrium found. Equilibrium decision rules are derived and a state-space representation of the model is built. The data is used as observables and the Kalman filter is used to recursively compute the innovations to the unobserved states (wedges). Under the assumption of normality, a likelihood function is built as a function of the parameters for the stochastic process described above. The final step is to maximize the likelihood function. The results are presented below:

$$P_0 = [\quad 0.1222 \quad 0.7301 \quad 0.1441 \quad -0.6831 \quad 0.8858 \quad -0.7792 \quad] \quad (17)$$

$$P = \begin{bmatrix} 0.9376 & -0.2224 & 0.3235 & 0.1132 & -0.4221 & 0.3238 \\ -0.3738 & 0.1107 & -0.1929 & 0.2336 & -0.6359 & 0.5642 \\ -0.6264 & -0.9353 & 0.4188 & 0.0412 & -0.3771 & 0.1061 \\ -0.3874 & -0.2823 & -0.2911 & 0.5690 & 0.2599 & -0.3349 \\ -0.4272 & -0.3888 & -0.6259 & -0.0268 & 1.0142 & -0.2900 \\ -0.0295 & 0.1771 & -0.2396 & 0.0765 & 0.1642 & -0.1485 \end{bmatrix} \quad (18)$$

$$B = \begin{bmatrix} -0.0100 & -0.0038 & 0.0154 & -0.0134 & -0.0034 & -0.0063 \\ & 0.0098 & -0.0150 & 0.0019 & 0.0116 & -0.0182 \\ & & -0.0012 & 0.0173 & -0.0161 & -0.0086 \\ & & & 0.0009 & -0.0012 & -0.0104 \\ & & & & -0.0025 & 0.0186 \\ & & & & & 0.0232 \end{bmatrix} \quad (19)$$

The steady-state values for the wedges and endogenous variables are

$$\begin{array}{cccccc} A & \tau_l & \tau_x & g & \tau_b & \tilde{R} \\ \hline 0.9059 & 0.5914 & 0.6135 & 0.2919 & 0.0000 & 0.0000 \end{array} \quad (20)$$

$$\begin{array}{cccccc} y & k & x & c & l & R \\ \hline 0.7873 & 9.7914 & 0.1510 & 0.3445 & 0.2359 & 0.0646 \end{array} \quad (21)$$

4 Measured wedges

Below in Figure 2, we can observe the measured wedges in deviation from their steady-state values. From a univariate perspective, they seem to share a structural break precisely around the 1990's, with the exception of the asset market wedge. However, for the recent crisis, the wedges seem to exhibit a much stronger mean reversion, with the exception of the government wedge, though it is still early to draw any definite conclusions. This seems to lend support to Hassler (2010) who claims that as the Swedish economy entered into the 1990's it "(...) *quite soon became clear that substantial and painful structural changes needed to be undertaken (...)*" (pp. 5). It should, however, be noted, that other explanations are observationally equivalent, given our set of observables. Saijo (2008) also manages to explain most of the fluctuations in hours worked for the Japanese interwar period, with a detailed model with time-varying markups, as described earlier.

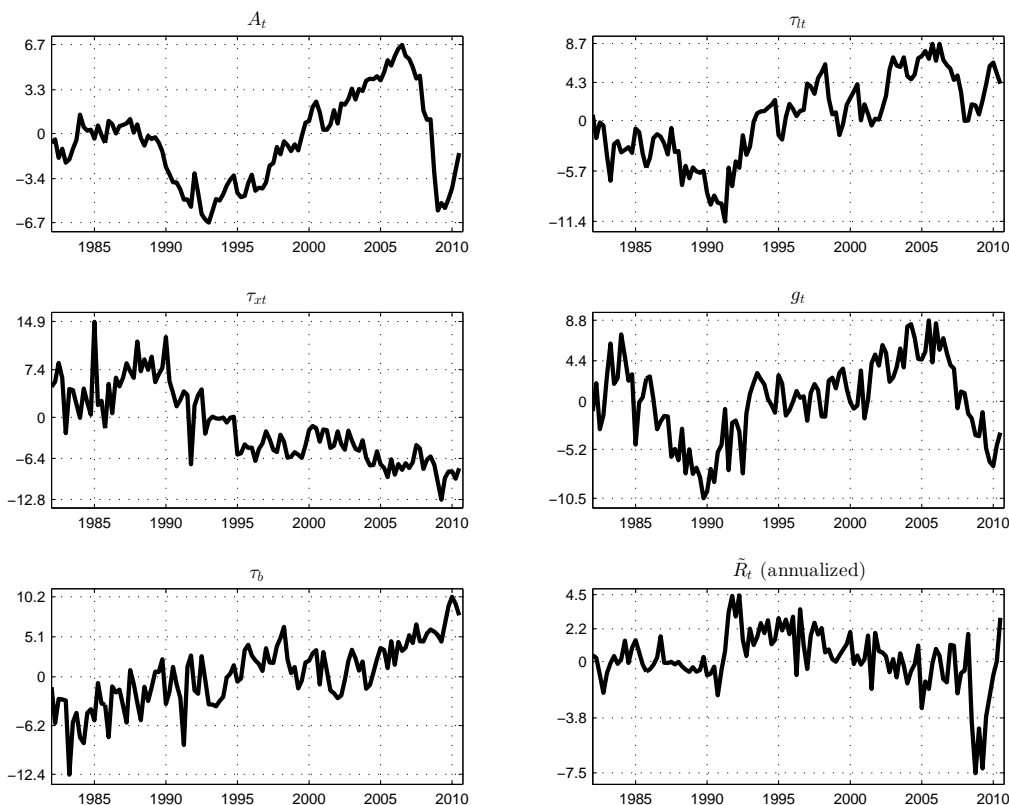
These structural changes, not modeled by the prototype economy, are then captured by the wedges. This suggests that such policies had structural impacts especially in the labor-leisure choice, total factor productivity, saving decisions and the nominal interest rate setting, as captured by the labor, efficiency and investment wedges. These structural changes are not yet suggested by the measured wedges for the recent financial crisis.

We can also observe that the government wedge shows a shift in the trend in both crises. There is a marked increase in the 1990's that reflects both the increase in net exports (motivated by the depreciation of the SEK) and government expenditures and a marked decrease since around 2006 that reflects government austerity and the contraction of international trade.

In order to provide a rigorous analysis of the graphical intuition leading to the suggestion of a structural break during the 1990's crisis, I conduct a Likelihood Ratio (LR) test to test the null hypothesis of no structural break. For this purpose, I define the breaking point to be tested to be the first quarter of 1993.² Under the null hypothesis:

²The result is robust to different specifications of the breaking point during the crisis.

Figure 2: Wedges in deviation from Steady State



\tilde{r}_t in absolute % deviation from steady state. All others in relative % deviations.

$$LR = (T - m)(\ln |\Sigma_r| - \ln |\Sigma_u|) \sim \chi^2(q) \quad (22)$$

where $T = 115$, $m = 8$, $\ln |\Sigma_r| - \ln |\Sigma_u| = 0.08$ and $q = 6$. This yields an LR statistic of 22.81 with a p -value of 0.02 and, consequently, we can reject the null hypothesis of no structural break.

With regard to the last financial crisis, the same criteria of three years after the pre-crisis period were used and, therefore, the breaking point chosen for the structural break test was the first quarter of 2009.³ Three years is the half life of a typical business cycle for the post-war U.S. economy (1945-2009), as reported by the NBER. The computed LR statistic in this case is

³In this case, the results are more sensitive to the choice of the breaking point, given that we are too close to the end of the sample and the power of the test is thus greatly decreased

11.00 with a p -value of 0.08 and we cannot reject the null hypothesis of no structural break at the 5% significance level.

The mean reversion in the wedges previously referred to fits into the idea of the "crisis from the outside" and in the good prospects of recovery that are suggested in Figure 1. More important, though, it means that in spite of the fact that the business cycle model fails to fully capture the amplitude of the distortions during the recession, the mean reversion of the wedges suggests that whatever hidden mechanisms in the wedges that are driving forces of the business cycle, they do not seem to change fundamentally relative to the pre-crisis periods. Some amplification mechanisms are clearly needed, though, or we would not see the recent crisis in some of the wedges as large deviations from their normal processes.

This is one of the main findings. Whatever modeling attempts are made of the 1990's recession, they must reflect structural changes in how business cycles were generated before and after the 1990's crisis. However, so far, it does not seem to be the case for the 2008 crisis.

As an example, in 1993, the Riksbank announced that it would actively pursue a target of 2% inflation, to be implemented from 1995 onward. There was a big shock to the Taylor rule wedge at the beginning of 1991 that pushed it to around 4.5% for three quarters until it stabilized around 2.2%. In Svensson (2012), the author describes this process and claims that by 1997, the inflation expectations were already anchored to the announced target of 2%. The Taylor rule wedge floated around 2% between 1993 and 1997 and and after that, it has converged to around zero, at least until the onset of the 2008 financial crisis.

4.1 Business cycle properties of the estimated wedges

As in Sustek (2010) and Chari et al. (2007a), business cycle statistics for the wedges are provided. The below table shows the correlation structure of the wedges with respect to output across the sample. The first column shows the standard deviation of each of the wedges relative to the standard deviation of output (1.63). All data is HP filtered with a smoothing factor of 1600 before correlations are computed.

The efficiency wedge is slightly more volatile relative to output in this case than what both Chari et al. (2007a) and Sustek (2010) find for the US economy (0.78 vs 0.63) and also positively correlated, though the magnitude of the correlations is somewhat smaller.

The relative labor wedge volatility is much higher than what is found in these two papers (1.29 vs .92) and somewhat different in nature. Sustek (2010) finds the labor wedge to be strongly countercyclical in line with Chari

Table 1: Correlation of Y_t with $\omega_{i,t+j}$

	$\sigma_\omega^2/\sigma_Y^2$	-3	-2	-1	0	1	2	3
A_{t+j}	0.78	0.39	0.43	0.55	0.56	0.41	0.15	-0.04
$\tau_{l,t+j}$	1.29	0.26	0.16	0.10	0.02	-0.36	-0.49	-0.61
$\tau_{x,t+j}$	1.57	0.01	0.07	0.11	0.08	0.27	0.19	0.03
g_{t+j}	1.46	0.09	0.08	0.04	-0.10	-0.39	-0.43	-0.29
$\tau_{b,t+j}$	1.36	0.01	-0.05	-0.03	0.13	0.21	0.21	0.06
\tilde{R}_{t+j}	0.23	-0.21	-0.14	-0.10	0.16	0.09	-0.00	-0.13

et al. (2007a)⁴. For Sweden, the labor wedge is weakly correlated with future output, though for future realizations of output, the correlation increase significantly and are found to be negative.

The investment wedge is more volatile than what is found in Chari et al. (2007a) and much more than in Sustek (2010), i.e. 1.57 vs 1.18 and 0.50, respectively. It is procyclical as in both these cases but at a much smaller magnitude for all lag lengths.

When it comes to the government wedge, the relative volatility is very similar - 1.46 vs 1.51 in both Chari et al. (2007a) and Sustek (2010). Both papers also show that for the US, the government wedge is strongly countercyclical across all leads/lags. In the case for Sweden, however, the correlation of output with past and contemporaneous realizations of the government wedge is very small but the correlation with future realizations is much higher in magnitude and countercyclical as in previous findings.

The lead-lag correlation structures of the wedges for the real side of the economy are of lower magnitude than those previously found by Chari et al. (2007a) or Sustek (2010). This provides a hint to researchers that promising structural explanations of the wedges may not be as strongly connected to changes in output as is the case for the US economy.

Now, turning to financial variables, the relative volatility is about twice as high (0.23 vs 0.12) in the case of the Taylor wedge. Sustek (2010) finds most cross correlations to be positive, whereas for Sweden they are found to be almost all negative but, in both cases, they are relatively small in magnitude. With respect to the asset market wedge, however, Sustek (2010) finds a strong and positive cross correlation structure for Sweden. Not only is there no clear discernible pattern of cross correlations, they are also much weaker. The relative volatility is smaller when compared to the US case, i.e. 1.36 vs 2.59. Sustek (2010) argues that the high volatility of the asset market

⁴Bear in mind that Chari et al. (2007a) define $1 - \tau_{l,t}$ as the labor wedge which leads the authors to conclude it to be procyclical

wedge is due to the fact that Euler-equation based pricing models tend to have very poor performance in explaining volatility in asset prices, though that problem is not as stringent in our case.

Another interesting feature of the business cycle statistics of the wedges is how they correlate with each other. As mentioned before, detailed economies can be mapped into the prototype economy through more than just one wedge. Hence the contemporaneous cross-correlations for the wedges are documented below in Table 2.

Table 2: Contemporaneous cross-correlation of the wedges

	A_t	$\tau_{l,t}$	$\tau_{x,t}$	g_t	$\tau_{b,t}$	\tilde{R}_t
A_t	1.00	0.33	0.19	0.14	0.16	0.44
$\tau_{l,t}$		1.00	0.25	-0.24	0.52	0.13
$\tau_{x,t}$			1.00	-0.56	-0.02	0.06
g_{t+j}				1.00	-0.67	0.13
$\tau_{b,t}$					1.00	0.07
\tilde{R}_t						1.00

The efficiency wedge is weakly correlated with the investment, government and asset market wedges. However, with respect to the labor wedge and deviations from the Taylor rule, the correlations are much higher and structural explanations of these two wedges, such as search and matching, sticky wages or costs of adjusting sectoral flows of funds as in Christiano and Eichenbaum (1992), will provide a better fit to the data if they correlate with total factor productivity.

The correlation found between the government and the asset market wedge (-0.67) is consistent with the general view that Euler-based equations tend to have severe performance problems in pricing assets, see Hansen and Singleton (1983). In the case of the 1990's recession, the increase in the government deficit is consistent with the dynamics of the asset-market wedge as a correction mechanism for the miss-pricing of the Euler equation. The asset market wedge also produces sizable correlations with the labor wedge, though it is almost uncorrelated to distortions in the investment wedge.

5 Simulated Economies

Next, we will present sets of “economies” where all but one of the wedges are fed back to the model as shocks. The “missing” wedge will be set to a constant and equal to its steady-state value. If we feed the model with shocks

equal to the measured wedges, by construction, observed and simulated data will coincide. However, since all wedges are no longer fed, simulated data will, in general, deviate from real data and, as previously mentioned, the magnitude of the deviations from the real data for each economy and each macroeconomic aggregate in particular will provide hints of the quantitative relevance of each of the wedges. Appendices A, B and C include figures of observed versus simulated data. It can also be seen, both through the figures in the Appendices and the regression results, that movements in nominal variables are relatively much harder to replicate.

If simulated data is a good approximation to the observed data, then, it should explain most of the variation. Following Mincer and Zarnowitz (1969), regressions of observations on simulated data are conducted and the estimates are reported below. The closer to observed data that simulations are, the closer α should be to zero and β and R^2 to one. We start by observing the behavior of the simulated economies for the entire sample. The results are shown in Table 3.

Looking at the overall results, it is worth noting that in the 36 comparisons of simulated and real data below, the models generate data that is qualitative according to observed data in 31 cases. Out of these, almost half - 14 out of 31 - explain 50% or more of the linear variation in observed aggregates and only in 5 cases, the explained variation is below 20%. The intercept, i.e. α , is the expected value of the observed deviation from steady state in the data when the simulated data is at the steady state. It never exceeds 3% and in 30 out of 36 cases, it is smaller than or equal to 1%. This also provides support for the fact that in most cases, the models generate data that is, at least in the vicinity of the steady state, level-wise in the same order of magnitude as the observed data.

In line with previous applications of business cycle accounting, the government wedge is found to be of little relevance with respect to real and nominal variables alike. Investment seems to be the hardest observable to match. Simulated investment performs poorly in all (except no-government wedge) economies as compared to other variables. Still, the efficiency, investment and Taylor rule wedges are those whose absence implies simulated movements in investment that are less correlated with the data.

Consumption is a variable that is well replicated by most models, except in the case where we fix the labor wedge to its steady-state value. When it comes to output, omitting the efficiency wedge will generate data that is qualitatively wrong and, judging from 5, that together with the Taylor rule wedge is the most determinant ones in matching output fluctuations. When it comes to movements in hours worked, the labor wedge seems to be the most important one. Without it, the model generates data that is qualitatively

Table 3: Linear fitting for the 1982-2010 period

No efficiency wedge	Y	L	X	C	R	π
α	-0.01	-0.00	-0.02	-0.03	0.01	-0.01
β	-0.45	0.34	-0.05	0.79	0.76	0.33
R^2	0.25	0.37	0.02	0.47	0.62	0.36
No asset market wedge	Y	L	X	C	R	π
α	-0.01	-0.00	-0.03	-0.01	-0.01	-0.01
β	0.63	0.37	0.42	1.16	0.11	0.18
R^2	0.54	0.48	0.48	0.96	0.28	0.25
No government wedge	Y	L	X	C	R	π
α	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
β	0.83	0.81	0.68	0.96	0.91	0.96
R^2	0.99	0.98	0.67	0.98	0.91	0.89
No labor wedge	Y	L	X	C	R	π
α	-0.01	0.00	-0.02	-0.01	-0.01	-0.01
β	0.14	-0.09	0.08	0.18	0.08	0.13
R^2	0.30	0.17	0.20	0.07	0.42	0.31
No Taylor rule wedge	Y	L	X	C	R	π
α	-0.01	0.00	-0.02	-0.01	0.01	-0.01
β	0.10	0.18	0.01	0.53	-0.03	-0.12
R^2	0.03	0.31	0.00	0.60	0.32	0.17
No investment wedge	Y	L	X	C	R	π
α	-0.00	0.01	-0.00	-0.02	-0.00	-0.01
β	0.58	0.51	0.19	0.83	0.25	0.15
R^2	0.58	0.81	0.10	0.83	0.28	0.10

different from what is observed. In terms of nominal variables, i.e. interest rate and inflation, the investment wedge is the most important. Without it, a model generates data that only explains 28% and 10%, respectively. The Taylor rule and asset market wedges are also relatively relevant.

This exercise suggests that in order to build models of the Swedish economy that manage to replicate business cycle movements as observed in the data, researchers primarily aiming at replicating movements in real variables should focus their efforts on providing structural explanations of the efficiency (especially for output and investment) and labor wedges (for hours worked and consumption). This is in line with the findings in Chari et al. (2007a), though they reach the same conclusion, not looking at the whole sample but at the Great Depression and the 1981 recession in the US. We

also add the relevance of the Taylor rule wedge, whose absence implies the inability of the model to match movements in output, investment and to a lesser degree, hours worked.

5.1 The 1990's vs the 2008 recession

The analysis is now conducted to study two particular episodes in the sample, namely the crisis in the 1990's and the recent financial crisis. As previously mentioned, assessing model performance in the context of economic recessions was the approach taken by Chari et al. (2007a). Moreover, the two crises have been referred to as fundamentally different in nature. The 1990's crisis was an internal phenomenon while the 2008 crisis was an international one. In Table 4, we take a closer look at how the models perform in the 1990-1995 period. The deviations are not normalized to the first quarter of 1990 in order to maintain comparability with the results of the previous section.

The overall results on what α is are relatively larger. This is true with respect to most variables and models in general but with respect to the no-efficiency wedge economy in particular. However, looking at the correlations, there is only one case where the predictions are qualitatively incorrect - hours worked in the no-labor wedge economy. All other variable movements for all models are qualitatively in line with the data or are too small to be meaningful. In fact, there are more variables for which the model generates data that has very little predictive power, i.e. a total of seven cases where the R^2 is below 10%. However, there are also many more cases of variables for which we have R^2 s, i.e. 23 of them are greater or equal to 50%.

Another distinctive feature of the model's performance for the 1990's crisis is the relevance of the labor wedge and the relatively smaller role of the efficiency wedge when compared to the whole sample. The no-efficiency economy generates movements in the data for this period that are qualitative according to the data. The R^2 s are also high although, level wise, the model does not perform so well. For investment, the difference between investment at its steady-state level in the model is 32% and 13% with respect to output. However, it is with respect to the no-labor wedge economy that we observe the largest deviations from the observed data. Simulated output does not at all replicate observed output, hours worked go in the opposite direction, investment is also poorly replicated and only simulated consumption reasonably resembles the movements observed in the data, though even then the performance of the model is the worst across all models.

The nominal side of the economy is hard to capture, with only the no-efficiency and no-government wedge economies having relatively higher explanatory power. The asset market, investment and Taylor rule wedges are

Table 4: Linear fitting for the 1990-1995 period

No efficiency wedge	Y	L	X	C	R	π
α	-0.13	-0.06	-0.32	-0.05	0.03	0.03
β	1.42	0.96	0.69	1.32	0.47	0.48
R^2	0.52	0.86	0.53	0.81	0.73	0.68
No asset market wedge	Y	L	X	C	R	π
α	-0.04	-0.01	-0.08	-0.02	0.03	-0.02
β	0.55	0.45	0.48	1.06	-0.00	0.12
R^2	0.75	0.76	0.78	0.98	0.00	0.14
No government wedge	Y	L	X	C	R	π
α	-0.00	0.00	0.08	0.01	-0.01	-0.01
β	0.81	0.81	1.10	1.01	0.89	1.09
R^2	1.00	0.99	0.90	1.00	0.66	0.89
No labor wedge	Y	L	X	C	R	π
α	-0.01	-0.05	-0.02	0.07	0.02	-0.02
β	0.15	-0.32	0.07	1.29	0.04	0.14
R^2	0.03	0.32	0.02	0.49	0.25	0.27
No Taylor rule wedge	Y	L	X	C	R	π
α	-0.08	-0.06	-0.24	-0.03	-0.01	-0.02
β	1.18	0.75	0.72	0.94	-0.88	-0.09
R^2	0.76	0.71	0.50	0.98	0.08	0.05
No investment wedge	Y	L	X	C	R	π
α	-0.02	0.00	-0.10	-0.01	0.03	-0.01
β	0.80	0.72	0.77	0.88	-0.00	0.03
R^2	0.93	0.89	0.65	0.93	0.00	0.01

all fundamental, and to a lesser degree also the labor wedge. Without these, inflation and nominal interest rate dynamics are poorly replicated in this period.

When it comes to the last financial crisis, the overall explanatory power of the different economies shares some of the features of the 1990's recession, namely higher overall explanatory power, though simulated data now moves in the wrong direction for five of the variables.

The major distinctive feature of this period is, however, the relevance of the efficiency wedge. A model where the efficiency wedge is set to a constant will generate an expansion of output instead of the observed recession. The same happens to investment and the movements generated in hours worked are almost uncorrelated to those observed in the data. Moreover, the labor

Table 5: Linear fitting for the 2006-2010 period

No efficiency wedge	Y	L	X	C	R	π
α	-0.02	-0.01	0.07	0.03	-0.03	-0.03
β	-0.92	0.05	-0.22	0.91	0.41	0.33
R^2	0.80	0.04	0.40	0.54	0.98	0.41
No asset market wedge	Y	L	X	C	R	π
α	-0.03	-0.01	-0.01	-0.02	0.04	-0.02
β	1.09	0.16	0.46	1.75	1.51	0.11
R^2	0.59	0.23	0.21	0.90	0.56	0.05
No government wedge	Y	L	X	C	R	π
α	-0.00	0.00	0.04	-0.01	0.01	0.00
β	0.95	0.94	0.58	0.95	1.20	0.98
R^2	1.00	0.98	0.84	0.99	1.00	0.96
No labor wedge	Y	L	X	C	R	π
α	-0.07	0.01	-0.02	-0.00	0.15	0.02
β	0.40	-0.11	0.13	-0.26	3.28	0.24
R^2	0.51	0.43	0.21	0.24	0.75	0.35
No Taylor rule wedge	Y	L	X	C	R	π
α	0.07	0.02	0.22	0.02	-0.03	-0.03
β	0.53	0.20	0.46	0.37	-0.01	-0.02
R^2	0.92	0.79	0.89	0.85	0.53	0.00
No investment wedge	Y	L	X	C	R	π
α	0.05	0.02	0.23	-0.01	-0.01	-0.03
β	0.78	0.54	0.68	0.48	0.85	0.23
R^2	0.99	0.84	0.92	0.69	0.63	0.24

wedge is still of importance. In fact, hours worked and consumption move in the opposite direction during the recession for the no labor wedge economy, though the movements in output are reasonably captured. Another aspect that is relevant is that the asset market wedge seems to be more relevant for hours worked and investment than in neither the previous crisis nor for the whole sample.

With respect to the nominal side of the economy, the Taylor and asset market wedges are those that matter most to replicate movements in inflation and all models seem to capture more than half of the linear variation in the nominal interest rate.

Notice that some wedges that were important for fluctuations for the whole sample are not so important for the fluctuations in these two peri-

ods. This is the case for the Taylor rule wedge, for example. As previously mentioned, there was an announcement by the Riksbank of a new target for monetary policy that coincided with a structural break in the process of the Taylor rule wedge. As a result of the new policy, there was most likely a change in the relationship between the interest rate and other macroeconomic variables. In the context of the model, the overall Pearson's correlation coefficient between output and simulated output for the no-Taylor wedge economy was 0.59. This was the case from the beginning of the sample until the beginning of the inflation targeting by the Riksbank to 2% in 1995. That same coefficient between 2005 and the end of the sample was 0.96. However, in between those two periods, the coefficient was even negative, namely -0.59. This also serves as a reminder that prospective theories that may be successful in explaining certain periods of fluctuations may have severe performance issues outside that window.

6 Conclusion

The purpose of this paper is to identify the properties that distortions to the business cycle model need to have in order to successfully replicate the fluctuations observed in the data for the Swedish economy, in the period between 1992 and 2010. For this purpose, a business cycle accounting exercise is conducted as in Sustek (2010).

The first result is that, from a univariate perspective, these distortions seem to share a structural break in the early 1990's. This coincides with a major recession experienced by Sweden and provides support for the notion that successful theories of business cycles in Sweden for the analyzed sample must reflect structural changes in the way these fluctuations are generated before and after the 1990's crisis.

For the recent financial crisis, though with a limited number of data points after 2008, this does not seem to be the case so far, with the exception of the behavior of government consumption plus net exports. This provides evidence for the idea that Hassler (2010) presents and referring to the labor market in particular, the 1990's crisis was a period of structural changes in the economy, where the last recession seems more associated with labor hoarding and capacity under-utilization, though one should keep in mind that this does not exclude other possible structural explanations such as in Saijo (2008) for example. This notion is also reinforced by the much stronger fall in total factor productivity after 2008 than in the 1990's. Agents seem to regard the latter crisis as a temporal phenomenon and refrain from adjusting production capacity accordingly.

I perform a likelihood ratio test using the VAR(1) process that fits the wedges to test for structural breaks during the 1990's and 2008 crisis. We can reject the null hypothesis of no structural break during the 1990's, but cannot do the same regarding the last financial crisis.

The cross correlation structure of the wedges with output throughout the sample is lower in magnitude than what was found for the US ,which hints that structural explanations of these distortions are not as connected to changes in output as it is the case for the US.

From the simulation of economies where all but one wedge are fed back into the model as shocks, I find that in order to replicate movements in real variables, deviations from the Taylor rule, total factor productivity and the labor wedge are essential. The nominal side of the economy is harder to replicate and the movements in inflation and nominal interest rate depend on distortions to most margins, though to a lesser degree on total factor productivity or the government wedge. However, when the analysis is restricted to the period of the two crises, the Taylor rule wedge plays little role with respect to real variables. The labor wedge is essential for both recessions where the efficiency wedge matters the most for the 2008 recession.

References

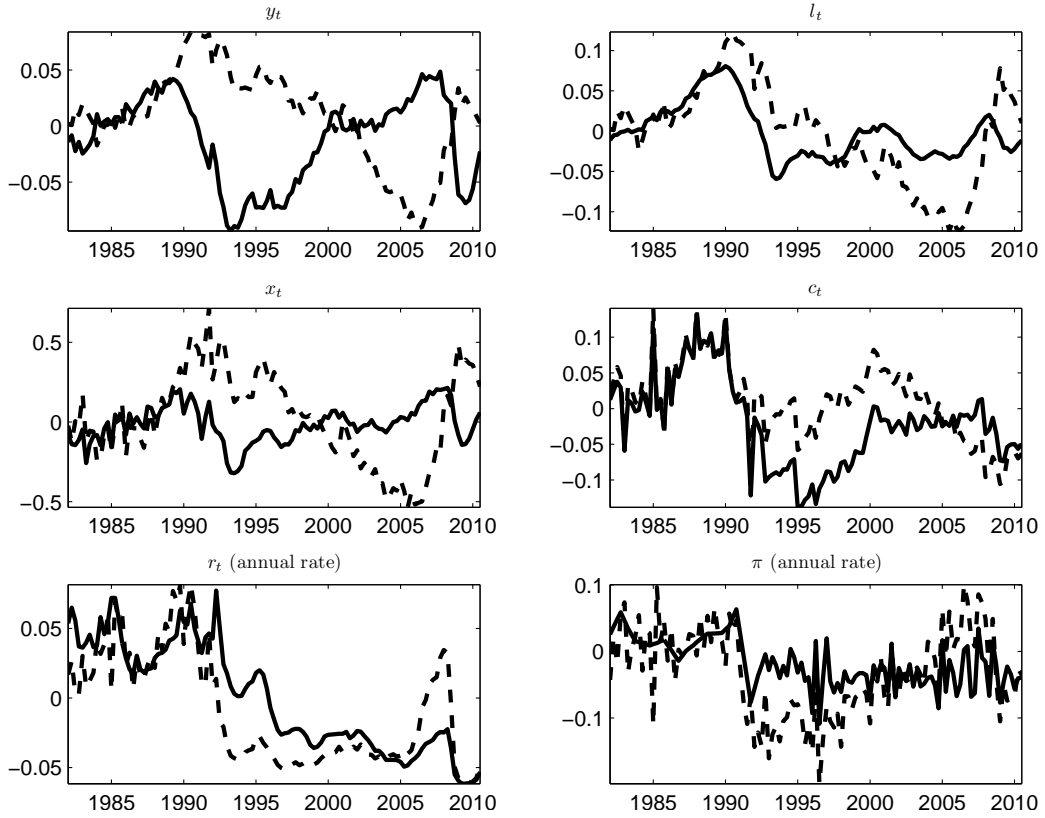
- Assarsson, B. and Jansson, P. (1998). Unemployment persistence: the case of Sweden. *Applied Economic Letters*, 5(1):25–29.
- Cavalcanti, T. V. (2007). Business cycle and level accounting: the case of portugal. *Portuguese Economic Journal*, 6(1):47–64.
- Chakraborty, S. and Otsu, K. (2012). Deconstructing growth-a business cycle accounting approach with application to brics. *MPRA Paper No. 41076*.
- Chari, V., Kehoe, P., and McGrattan, E. (2007a). Business cycle accounting. *Econometrica*, 75:781–836.
- Chari, V., Kehoe, P., and McGrattan, E. (2007b). Comparing alternative representations, methodologies and decompositions in business cycle accounting. *Federal Reserve Bank of Minneapolis Staff Reports*, 384.
- Cho, D. and Doblus-Madrid, A. (2012). Business cycle accounting east and west: Asian finance and the investment wedge. *Review of Economic Dynamics*, *Forthcoming*.
- Christiano, L. and Eichenbaum, M. (1992). Liquidity effects and the monetary transmission mechanism. *American Economic Review*, 82:346–353.
- Christiano, L., Trabandt, M., and Walentin, K. (2011). Introducing financial frictions and unemployment into a small open economy model. *Sveriges Riksbank Working Paper Series*, 214.
- Domeij, D. and Flodén, M. (2006). Population ageing and international capital flows. *International Economic Review*, 47(3):1013–1032.
- Gao, X. and Ljungwall, C. (2009). Sources of business cycle fluctuations: comparing China and India. *China Economic Research Center Working Paper Series*, May(7).
- Hansen, G. and Singleton, K. (1983). Stochastic consumption, risk aversion and the temporal behavior of asset returns. *Journal of Political Economy*, 91:249–265.
- Hassler, J. (2010). Sweden in past, current and future economic crisis - a report for the oecd economics department. Technical report, Institute for International Economic Studies - Stockholm University.

- Hassler, J., Lundvik, P., Persson, T., and Söderlind, P. (1992). The Swedish business cycle: Stylized facts over 130 years. *Federal Reserve Bank of Minneapolis, Institute for Empirical Macroeconomics Discussion Papers*, 63.
- Kobayashi, K. and Inaba, M. (2006). Business cycle accounting for the Japanese economy. *RETI Discussion Paper*, 05-E-023.
- Lama, R. (2009). Accounting for output drops in Latin America. *IMF Working Paper Series*, 67.
- Mincer, J. and Zarnowitz, V. (1969). The evaluation of economic forecasts. *Economic Forecasts and Expectations*.
- Mulligan, C. (2002). A dual method of empirically evaluating dynamic competitive equilibrium models with market distortions, applied to the Great Depression and world war ii. *NBER Working Paper*, 8775.
- Otsu, K. (2009). International business cycle accounting. *IMES Discussion Paper Series*, 29.
- Prescott, E. C. (2002). Prosperity and depression. *The American Economic Review*, 92(2):1–15.
- Saijo, H. (2008). The japanese depression in the interwar period: A general equilibrium analysis. *The BE Journal of Macroeconomics*, 8(1).
- Simonovska, I. and Söderling, L. (2008). Business cycle accounting for Chile. *IMF Working Paper Series*, 61.
- Sustek, R. (2010). Monetary business cycle accounting. *Review of Economic Dynamics*, 14(4):592–612.
- Svensson, L. (2012). The possible unemployment cost of average inflation below a credible target. preprint (2012), available at <http://people.su.se/leosven/papers/Phillips.pdf>.

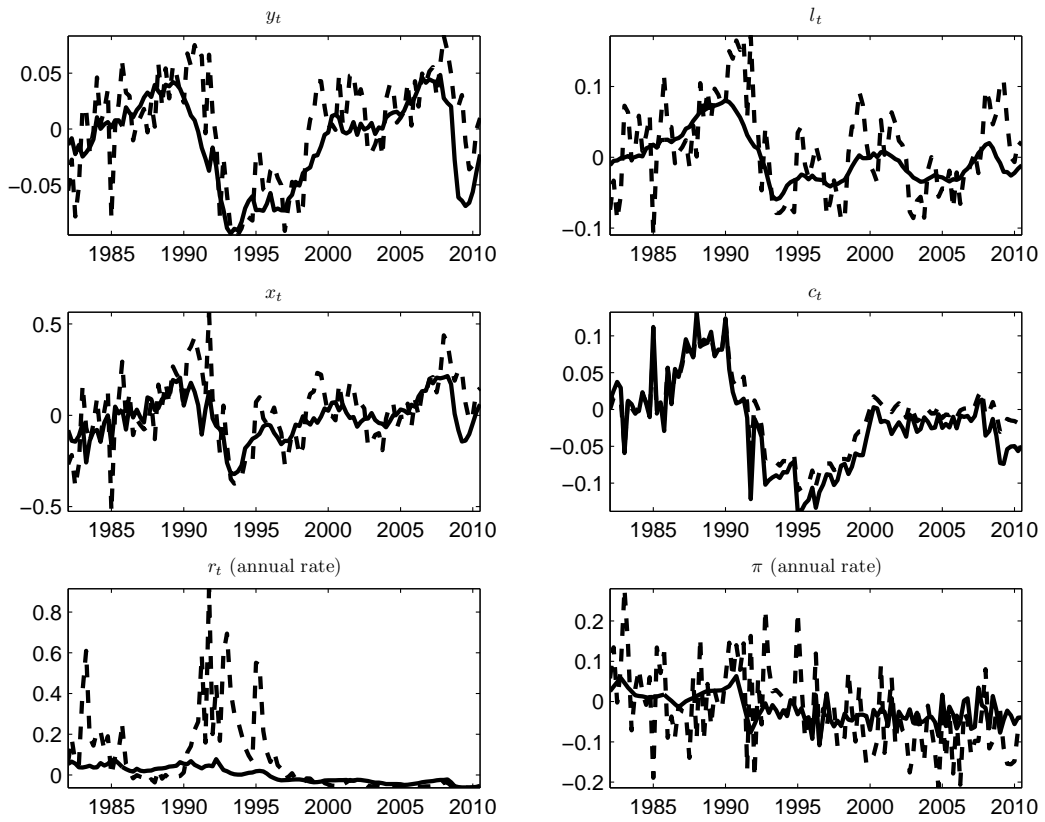
Appendix A

Simulated vs Observed data for 1982-2010

SWE: No efficiency wedge economy 1982–2010

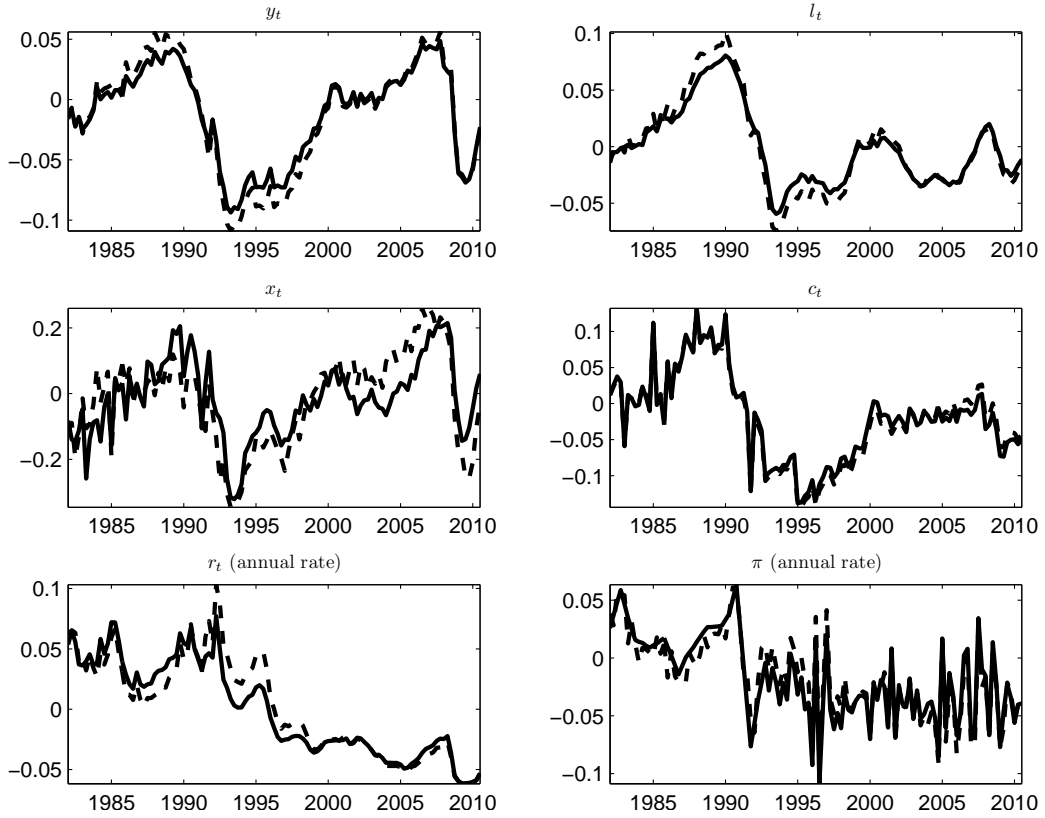


SWE: No asset market wedge economy 1982–2010

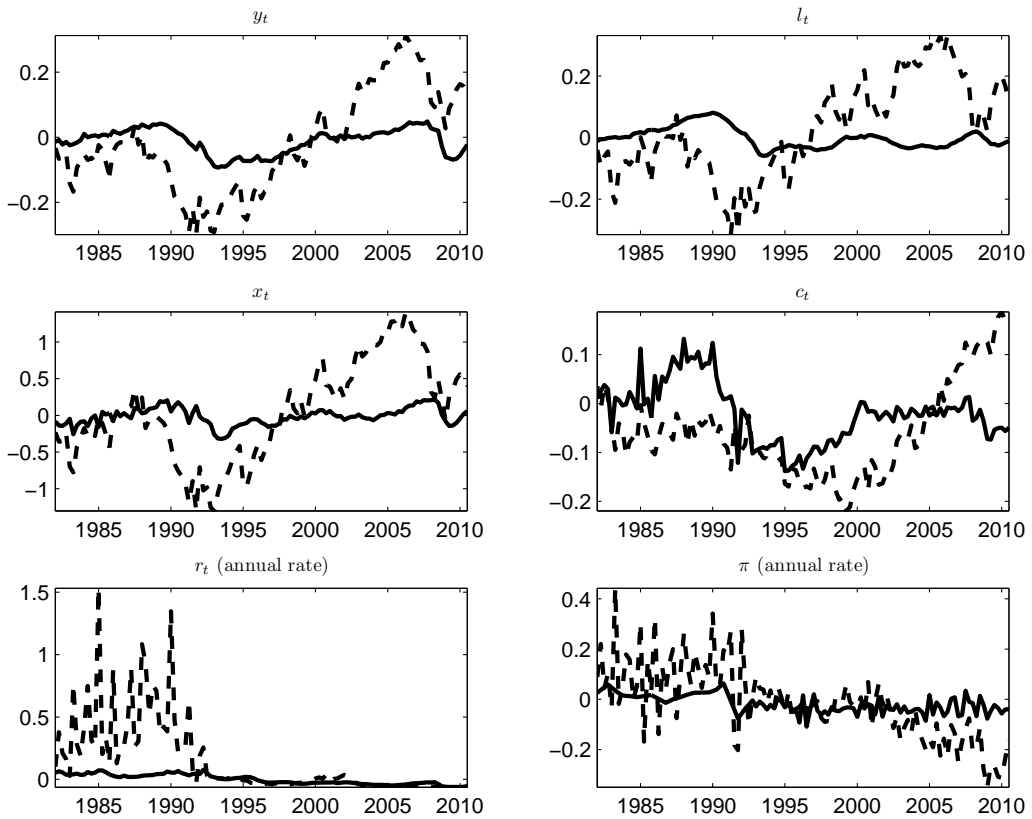


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

SWE: No government wedge economy 1982–2010

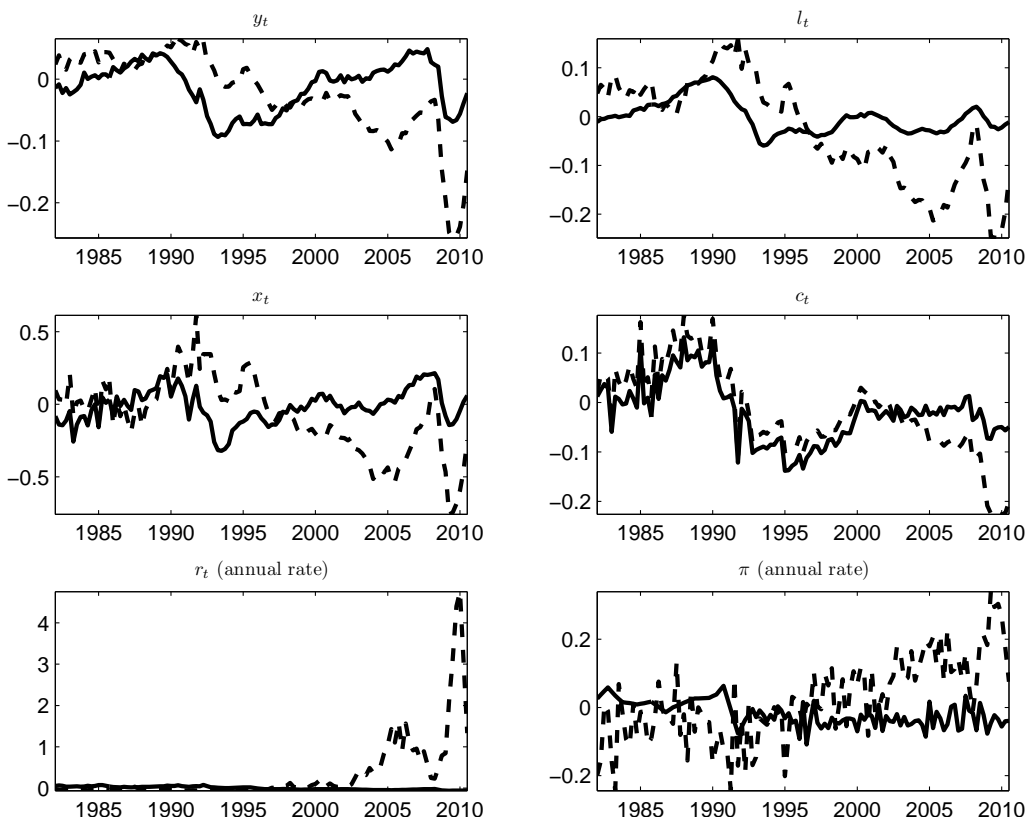


SWE: No labor wedge economy 1982–2010

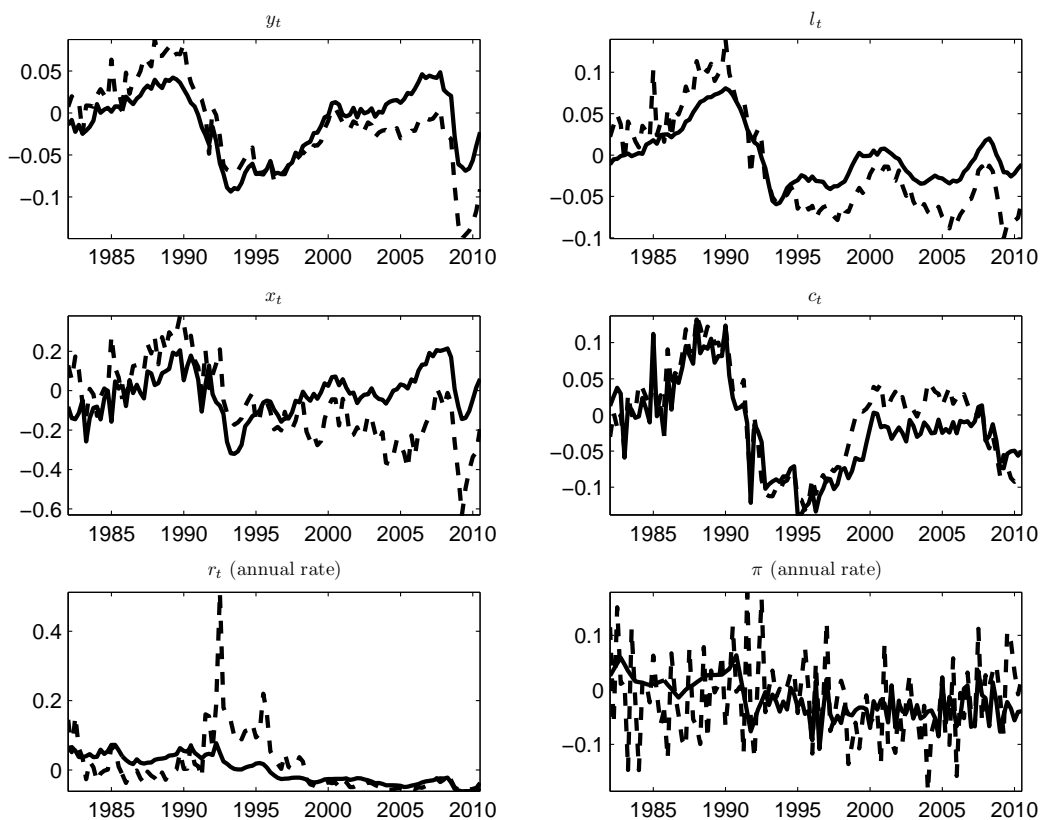


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

SWE: No Taylor wedge economy 1982–2010



SWE: No investment wedge economy 1982–2010

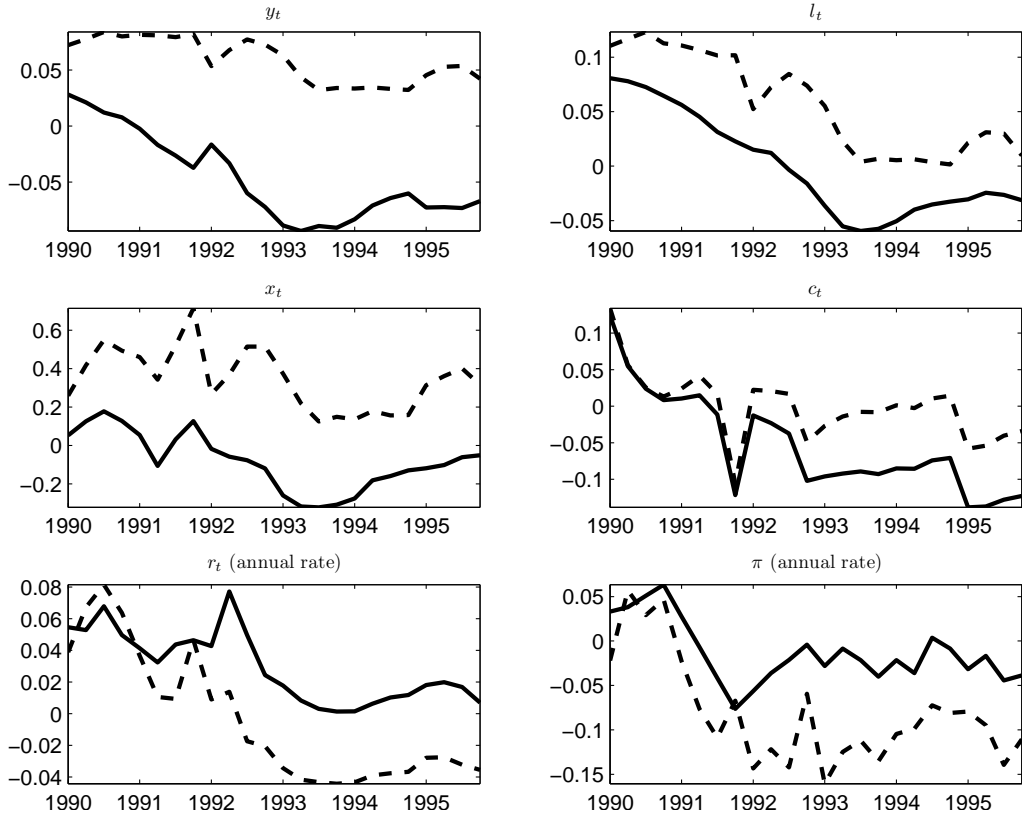


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

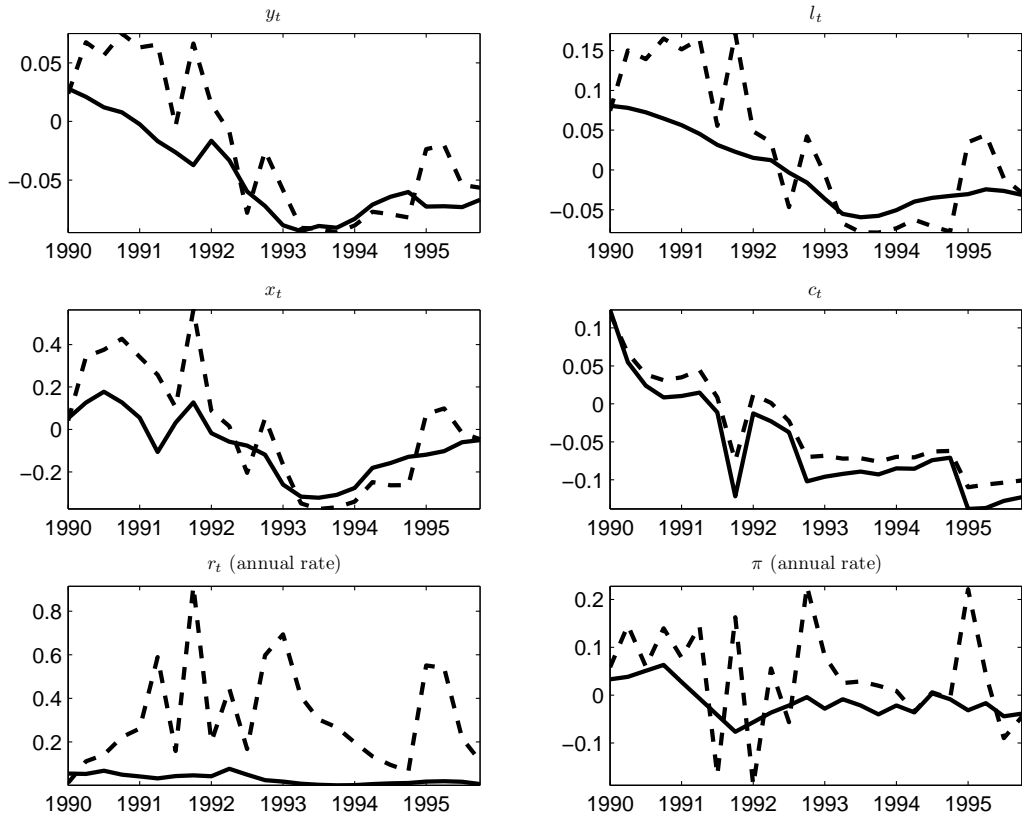
Appendix B

Simulated vs Observed data for 1990-1995

SWE: No efficiency wedge economy 1990–1995

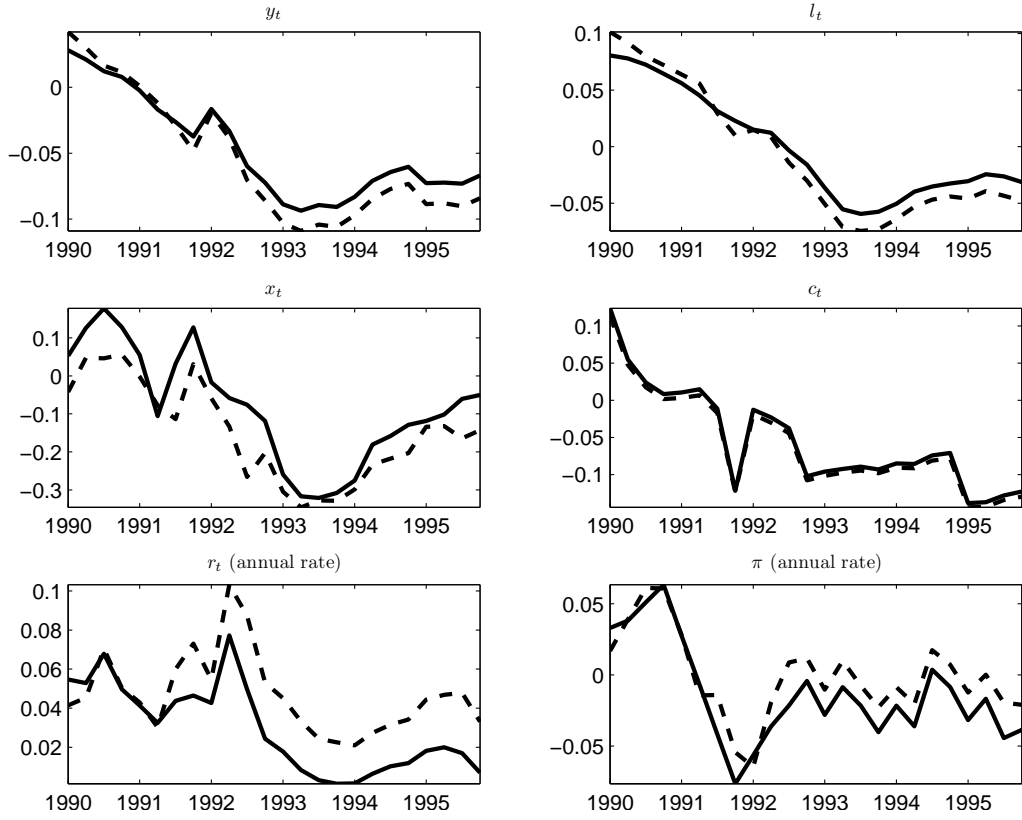


SWE: No asset market wedge economy 1990–1995

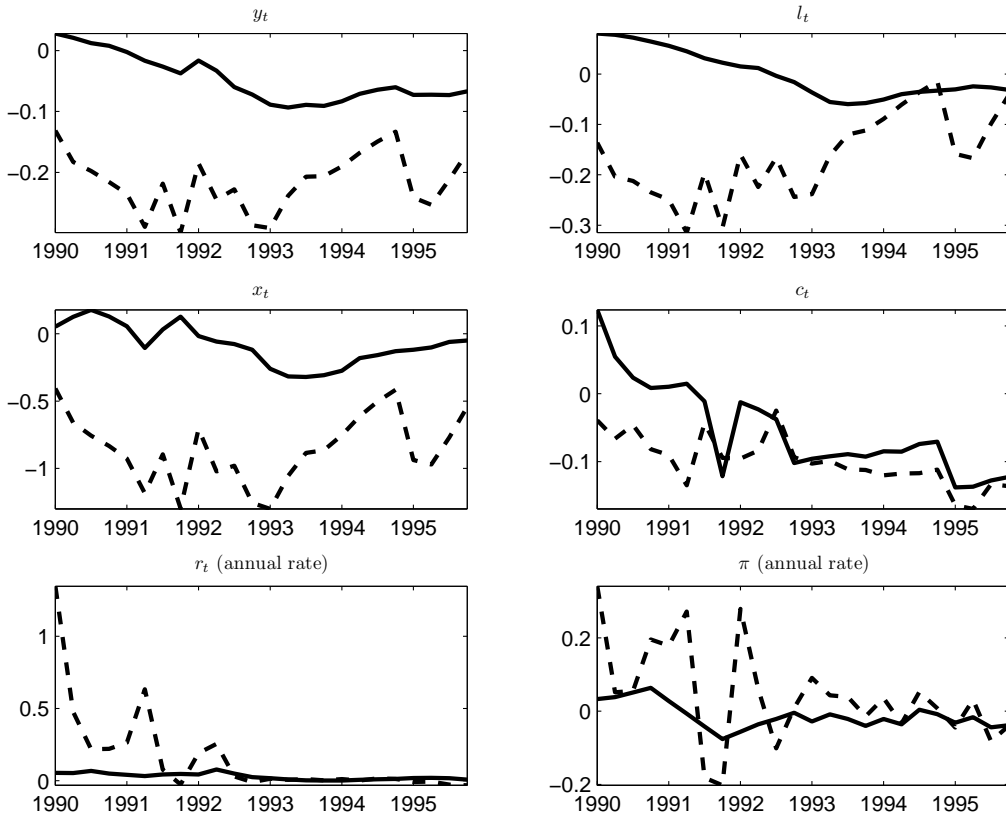


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

SWE: No government wedge economy 1990–1995

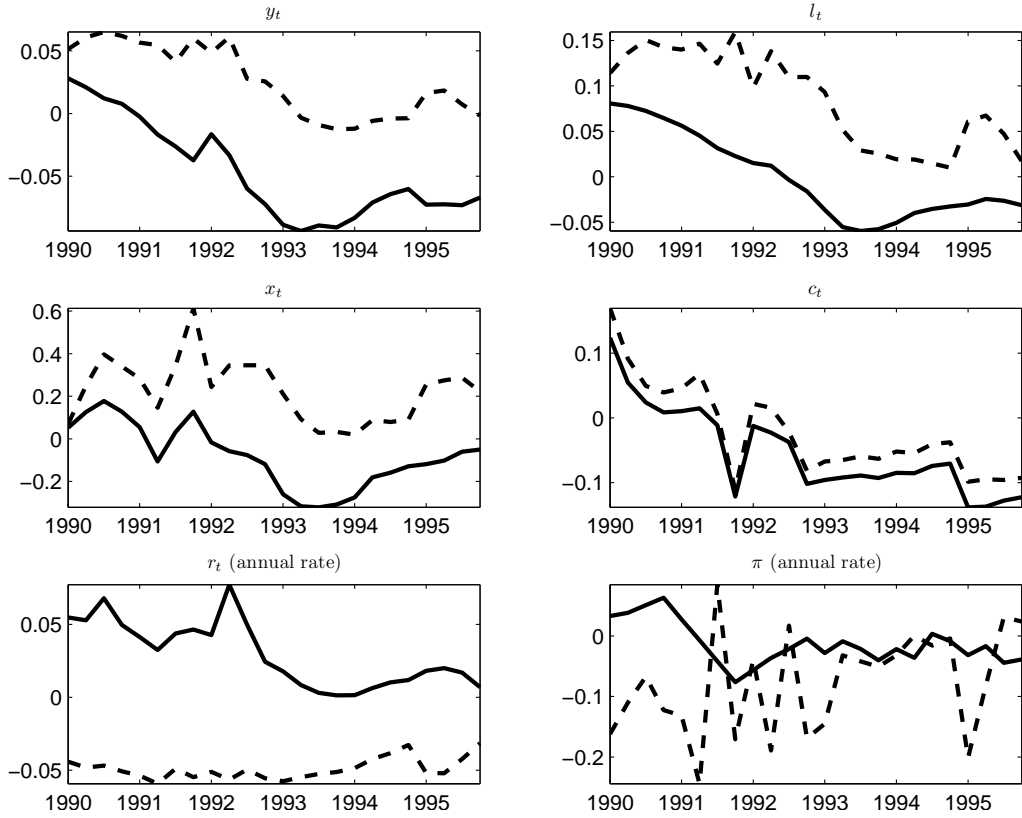


SWE: No labor wedge economy 1990–1995

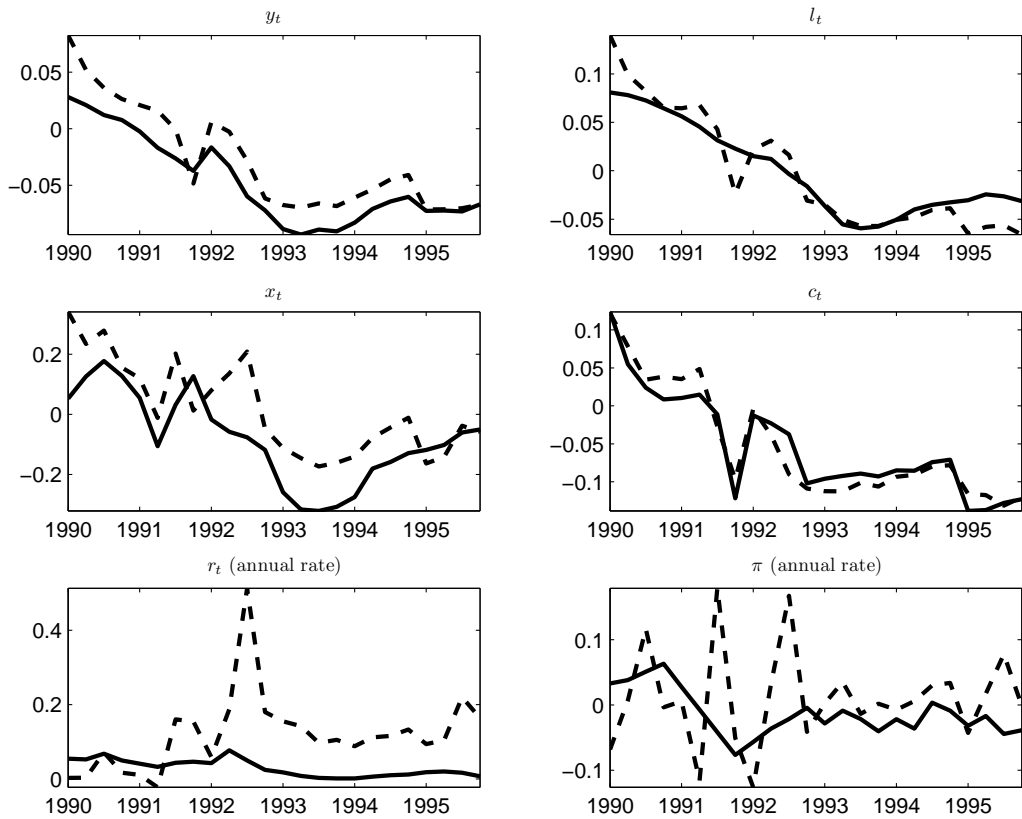


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

SWE: No Taylor wedge economy 1990–1995



SWE: No investment wedge economy 1990–1995

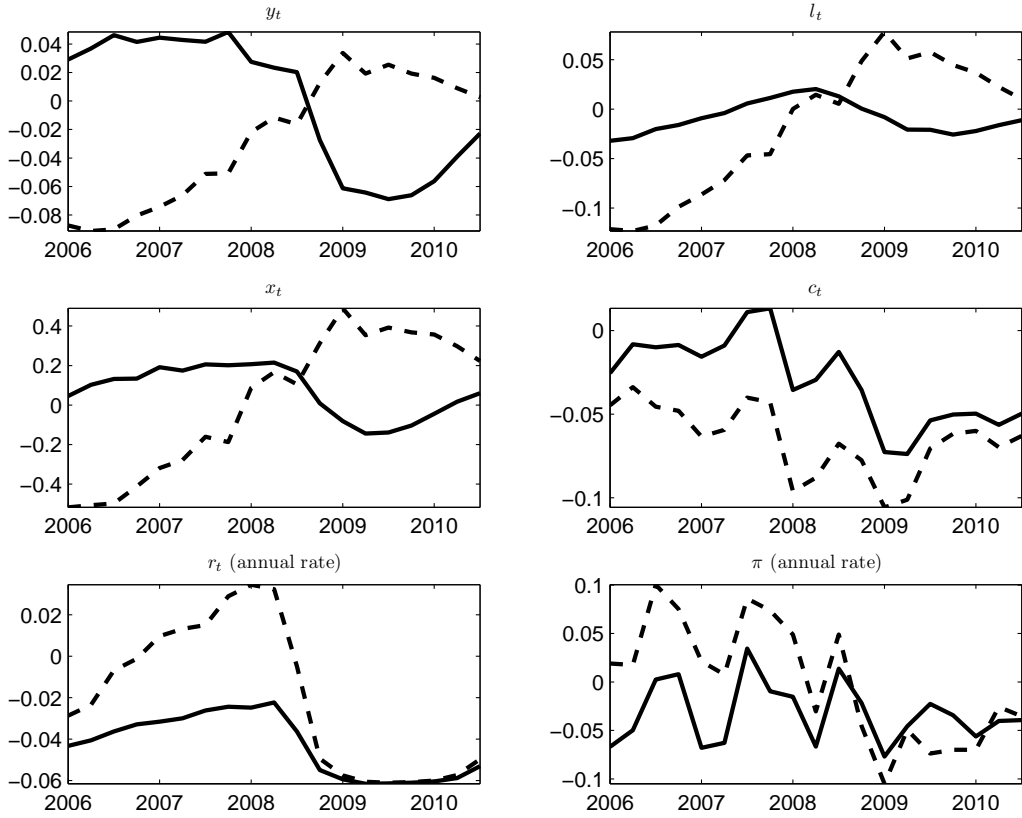


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

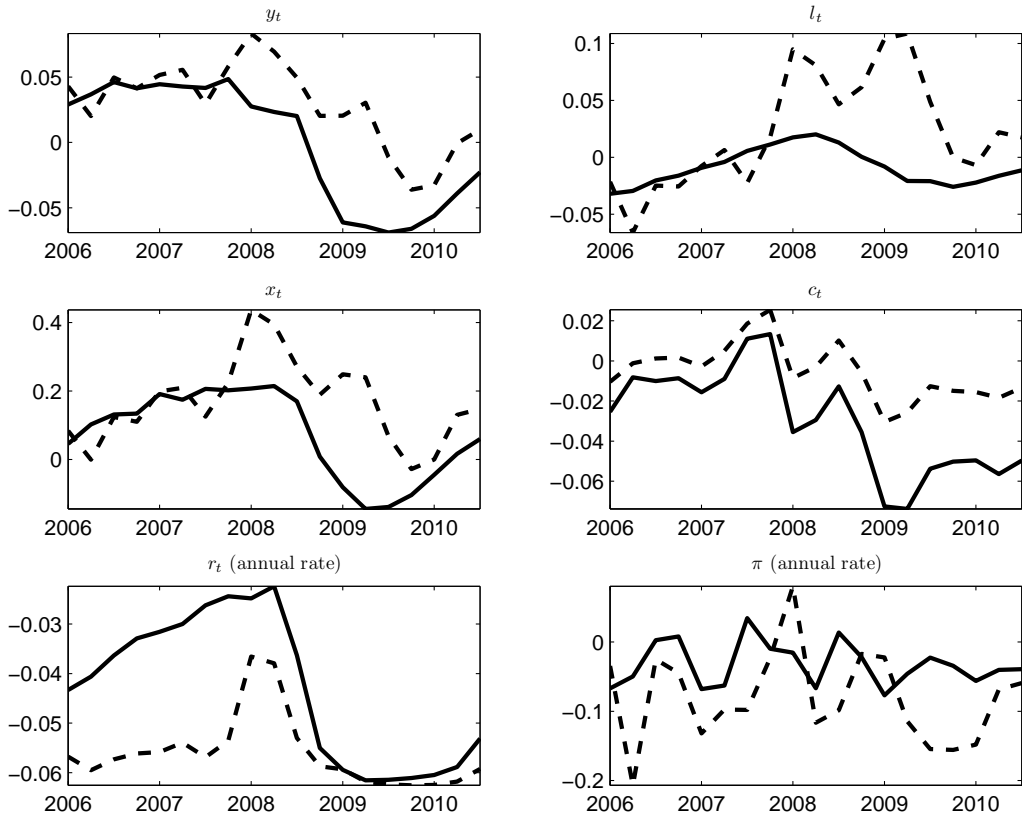
Appendix C

Simulated vs Observed data for 2006-2010

SWE: No efficiency wedge economy 2006–2010

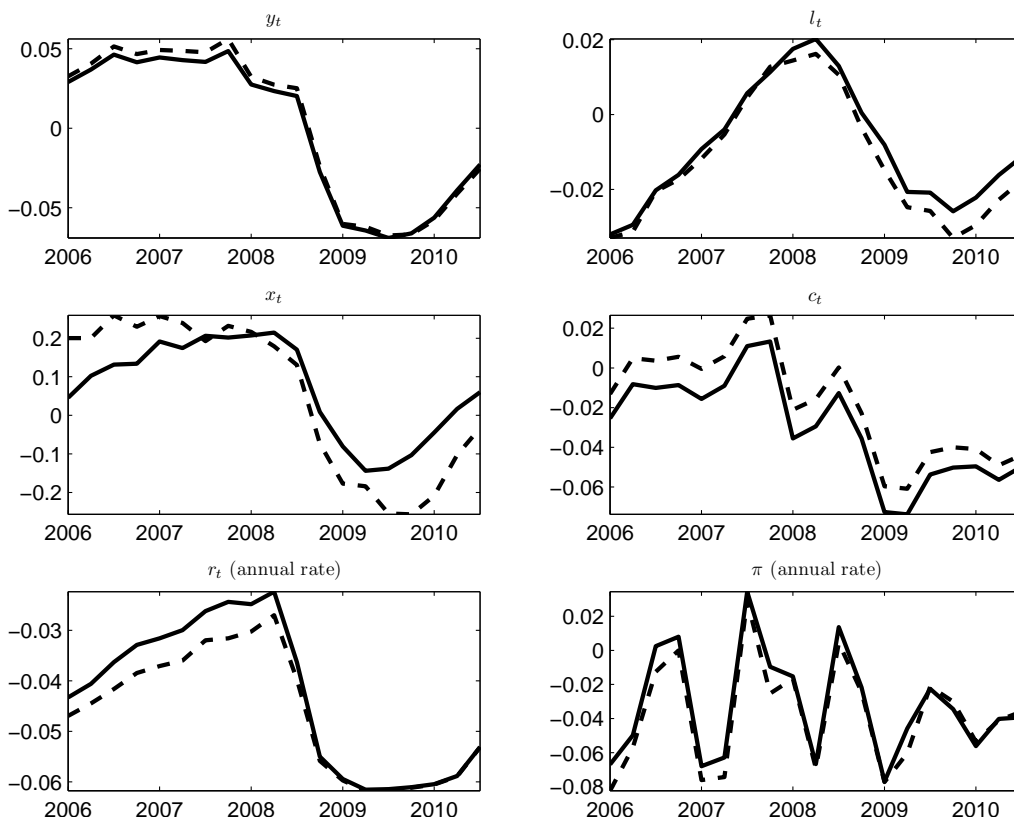


SWE: No asset market wedge economy 2006–2010

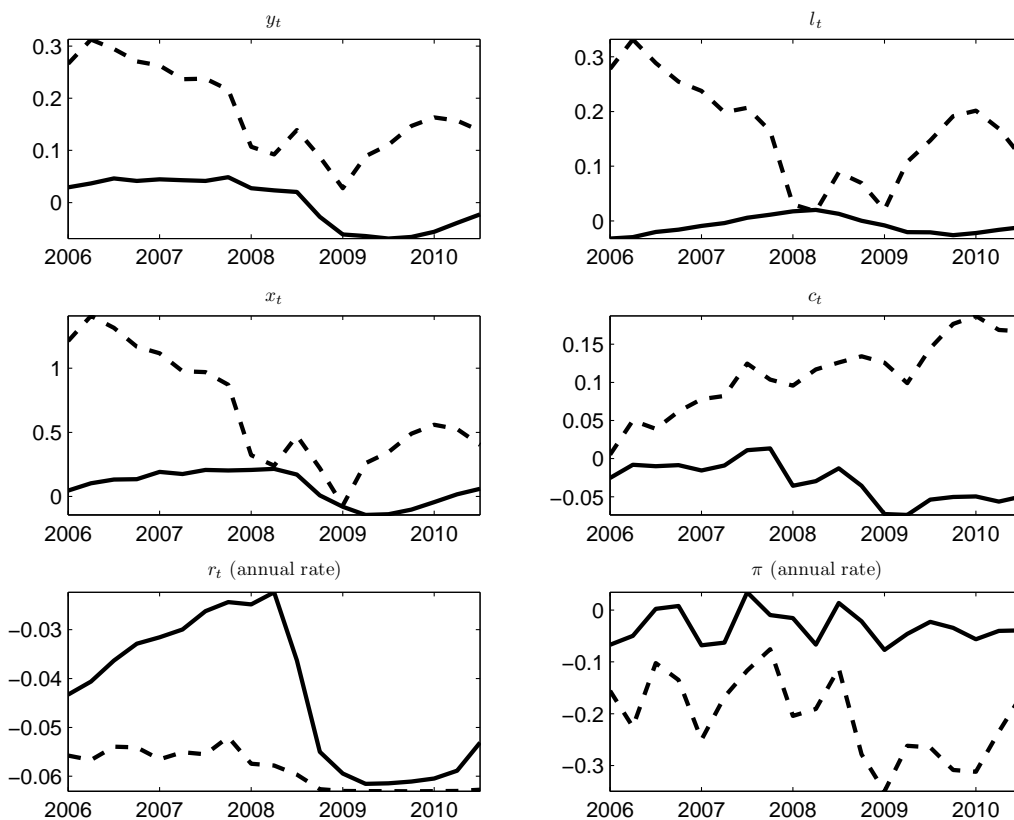


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

SWE: No government wedge economy 2006–2010

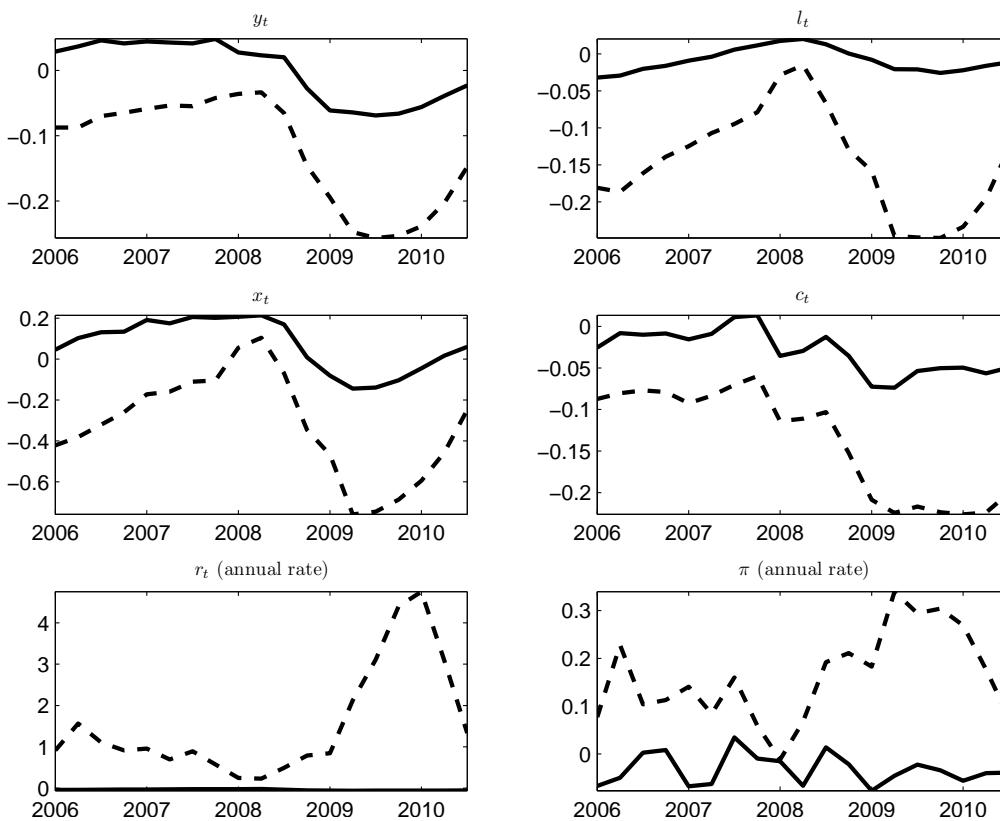


SWE: No labor wedge economy 2006–2010

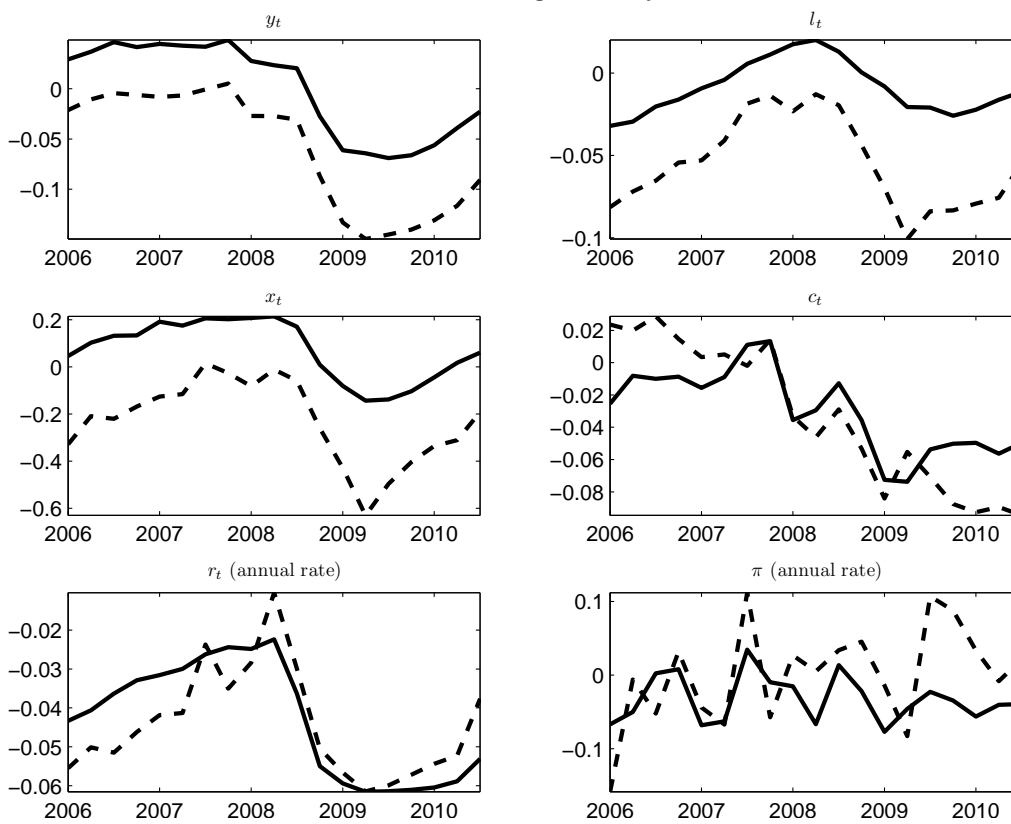


Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

SWE: No Taylor wedge economy 2006–2010



SWE: No investment wedge economy 2006–2010



Observed data “—”, Simulated data “- - -”
 r_t and π_t in absolute % deviation from steady state. All others in relative % deviations.

III



Contents lists available at [ScienceDirect](http://www.sciencedirect.com)

International Economics

journal homepage: www.elsevier.com/locate/inteco



Consumer confidence as a predictor of consumption spending: Evidence for the United States and the Euro area

Stephane Dees^{*,a}, Pedro Soares Brinca^b

^a European Central Bank, Kaiserstrasse 29, 60311, Germany

^b Stockholm University, SE-106 91 Stockholm, Sweden

ARTICLE INFO

Available online 19 June 2013

JEL classification:

C32

E17

F37

F42

Keywords:

Consumer confidence

Consumption

International linkages

Non-linear modeling

ABSTRACT

For most academics and policy makers, the depth of the 2008–09 financial crisis, its longevity and its impacts on the real economy resulted from an erosion of confidence. This paper proposes to assess empirically the link between consumer sentiment and consumption expenditures for the United States and the euro area. It shows under which circumstances confidence indicators can be a good predictor of household consumption even after controlling for information in economic fundamentals. Overall, the results show that, the consumer confidence index can be in certain circumstances a good predictor of consumption. In particular, out-of-sample evidence shows that the contribution of confidence in explaining consumption expenditures increases when household survey indicators feature large changes, so that confidence indicators can have some increasing predictive power during such episodes. Moreover, there is some evidence of a “confidence channel” in the international transmission of shocks, as U.S. confidence indices help predicting consumer sentiment in the euro area.

© 2013 CEPII (Centre d'Etudes Prospectives et d'Informations Internationales), a center for research and expertise on the world economy. Published by Elsevier Ltd. All rights reserved.

* Tel.: +49 69 1344 8784.

E-mail address: stephane.dees@ecb.int (S. Dees).

1. Introduction

The 2008–09 financial crisis has led to the most severe global economic recession since the Great Depression. Just after the bankruptcy of Lehman Brothers, Nobel Laureate Joseph Stiglitz said that this “financial crisis springs from a catastrophic collapse in confidence”.¹ While it remains difficult to assert whether the collapse of confidence was the cause or the consequence of the financial crisis, most academics and policy makers agree to say that it is this erosion of confidence that has ensured the depth and the longevity of the crisis, especially as regards its impacts on the real economy.

The link between confidence and economic decisions has been widely covered in the literature, which has focused on two main aspects. First, from a theoretical viewpoint, the literature has concentrated on the conceptualization of confidence and its role in modern theories of consumption. If consumers were to behave according to the Permanent Income Hypothesis (PIH), no information known to the consumer when the consumption choice was made could have any predictive power for how consumption will change in future periods (Hall, 1978). Any deviation from the PIH can be theoretically justified by liquidity constraints or uncertainty relative to future income. This uncertainty can then lead households to decrease their current consumption and build precautionary savings to face a possible drop in their income. Against this background, consumer confidence indices could be helpful as they might capture information about expected income. Another approach to consumption relates to the existence of “animal spirits” (Katona, 1975 or Eppright et al., 1998). Consumer expenditures could be influenced by non-economic factors, such as political tensions or wars, that would affect the willingness of households to consume by increasing perceived uncertainty (Acemoglu and Scott, 1994).

Second, for an empirical viewpoint, the literature has been concerned with whether or not confidence indicators contain any information beyond economic fundamentals. The concern is whether confidence can be explained by current and past values of variables such as income, unemployment, inflation or consumption or, in other way, whether confidence measures have any statistical significance in predicting economic outcomes once information from the variables cited above is used. While the evidence is overall rather mixed, most authors seem to, at least, find a significant statistical relationship between confidence measures and economic variables, current and future.² In particular, some stress the special importance of confidence indicators in predicting periods of strong fluctuations in the economy, such as recessions and recoveries (Howrey, 2001; Haugh, 2005) and others (Throop, 1992; Garner, 2002) suggest that they could be helpful during periods of major economic or political shocks. Such periods are usually associated with high volatility of consumer confidence, suggesting that large swings in confidence could be useful indicators of consumption. Carroll et al. (1994), for instance, cite consumer confidence as the leading cause for the U.S. 1990–91 recession.

There is an important caveat to stress upfront as regards the measurement of confidence. Household sentiment is a personal and subjective assessment of the environment (current and future) in which agents take economic decisions. Moreover, as shown for instance by Dominitz and Manski (2004), the consumer sentiment indices might suffer from measurement errors as survey questions are very often ambiguous for the respondent and too qualitative to be used for quantitative assessment. Here, like in most previous research, we assume that confidence indices derived from surveys are a relatively good proxy of households' perceptions about their economic environment and could be used as explanatory variables of their consumption expenditures.

¹ See Stiglitz, “The fruit of hypocrisy”, *The Guardian*, 16 September 2008, <http://www.guardian.co.uk/commentisfree/2008/sep/16/economics.wallstreet>.

² Many authors find that consumer confidence can reduce forecast errors made by models including traditional macroeconomic variables: Ludvigson (2004) or Wilcox (2007) for the U.S.; Kwan and Cotsomitis (2006) for Canada; Easaw and Heravi (2004) for the UK. However, Smith (2009) using real-time data for the UK shows that including consumer sentiment in a VAR model to predict consumer expenditures does not improve its forecast accuracy. Similarly, Al-Eyd et al. (2008) show that confidence effects on consumption are weak when other key determinants of consumption are taken into account across five major OECD countries. Claveria et al. (2007) show that despite survey indicators provide useful information for improving forecasts of many euro area macroeconomic variables, such improvements are significant in a limited number of cases.

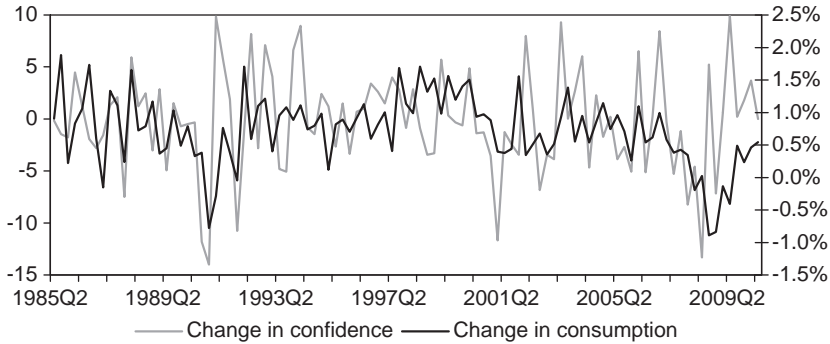


Fig. 1. United States: consumption growth (rhs) and change in confidence (lhs).

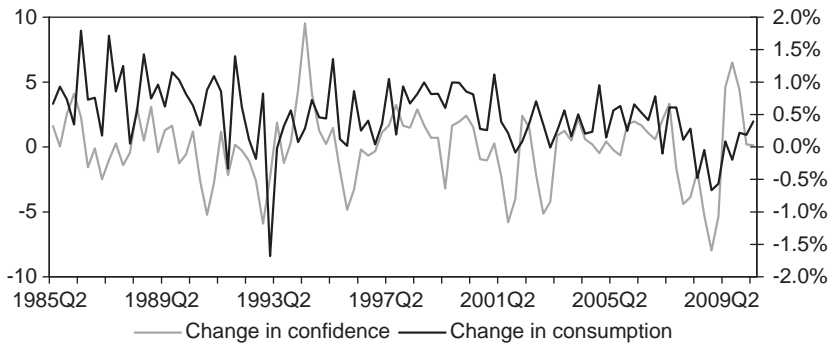


Fig. 2. Euro area: consumption growth (rhs) and change in confidence (lhs).

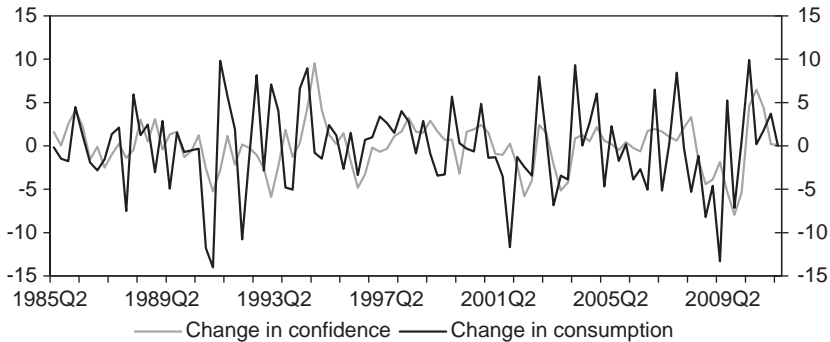


Fig. 3. Change in confidence in the United States and the euro area.

Empirically, as shown for instance by [Carroll et al. \(1994\)](#), measures of consumer confidence are highly correlated with real consumption. A plot of the series for the United States ([Fig. 1](#)) and the euro area ([Fig. 2](#)) shows indeed some comovement between the (log) change in real consumption and the change in consumer confidence index. In the United States, the correlation between real consumption growth and the change in consumer sentiment (measured by the University of Michigan Consumer Sentiment Index) is rather high. While it is the highest when computed contemporaneously (0.28), the correlation between lagged consumer confidence and consumption remains however relatively elevated (0.25 with a one-period lag and 0.24 with a two-period lag), indicating some potential leading properties for consumer sentiment. In the euro area, the correlation between confidence and

consumption is the highest when confidence is lagged by one period (0.42). The correlation remains large for higher lags (0.20 for a 2-period lag and 0.21 for a 4-period lag).

Another aspect that has been neglected in the literature is the cross-country correlation of confidence indicators (Fig. 3). Here again, the correlation between the changes in U.S. and euro area confidence is relatively large (0.27 contemporaneously). Changes in U.S. confidence seem to lead in some periods changes in the euro area confidence. The correlation between the two variables is the highest when the euro area confidence is lagged by two periods (0.32).

These comovements do not preclude however any causal link between confidence indicators across countries and between confidence and consumption. Confidence indicators could also be just a good proxy for other fundamental variables.

The purpose of the paper is to empirically assess the role of confidence in explaining household consumption in the United States and the euro area and show to what extent confidence indicators bring additional information beyond variables usually found to have some explanatory power for household real consumption expenditures (e.g. income, wealth or interest rates). In particular, it identifies under which circumstances confidence indicators can be a good predictor of household consumption, by measuring the contribution of confidence during periods associated with large movements in household survey indicators. Although not providing any methodological novelty to the empirical literature, the value added of this paper concerns first the use of a relatively long and up-to-date database that in particular includes the 2007–09 financial crisis. It also provides a comparison between the United States and the euro area. Finally, it allows for international linkages in confidence by accounting for the role of foreign confidence in determining domestic consumption.

Overall, the results show that the consumer confidence index can be in certain circumstances a good predictor of consumption. In particular, out-of-sample evidence shows that the contribution of confidence in explaining consumption expenditures increases when household survey indicators feature large changes, so that confidence indicators can have some increasing predictive power during such episodes. Moreover, there is some evidence of a “confidence channel” in the international transmission of shocks, as U.S. confidence indices help predicting consumer sentiment in the euro area.

The rest of the paper is organised as follows. Section 2 describes the data and the empirical framework used for our research and reports results from both univariate and multivariate analyses. Section 3 extends the previous analysis by proposing a non-linear approach in order to isolate periods where confidence explains significantly more consumption developments. Section 4 brings some evidence on the existence of a “confidence channel” between the United States and the euro area. Section 5 contains some concluding remarks.

2. Do confidence indicators bring additional information beyond economic fundamentals?

2.1. Data

The dataset used covers the period from the first quarter of 1985 to the second quarter of 2010. The observations are seasonally adjusted. We use the data without any transformation or smoothing. In particular, no detrending or business cycle adjustments are made. Real personal consumption series are taken from the national account sources (Bureau of Economic Analysis for the United States and Eurostat for the euro area). For the euro area, national account series are available from 1995 only. To backdate the series, we use the rates of growth of the series in the Area Wide Model (AWM) database (see Fagan et al., 2001 for details).

Concerning the confidence indicators, we use the University of Michigan's Consumer Sentiment Index for the United States (a comprehensive description of the index can be found in Bram and Ludvigson, 1998).³ For the euro area, we use the index constructed by the Directorate General for Economic and Financial Affairs of the European Commission.

³ We also use as a robustness check the Conference Board's Consumer Confidence Index. As the main results are robust whatever index used, we present here only those based on the University of Michigan Index. Results based on the Conference

Table 1
Granger causality tests.

Variables	United States		Euro area	
	ln C	con f	ln C	con f
con f	0.00	–	0.00	–
ln C	–	0.04	–	0.32
ln Y	0.77	0.92	0.21	0.07
ln W	–	–	0.78	0.25
ln W ^f	0.02	0.14	–	–
ln W ^h	0.54	0.28	–	–
ln q	0.03	0.01	0.08	0.14
i	0.34	0.80	0.00	0.39
u	0.01	0.08	0.37	0.04
roil	0.01	0.12	0.00	0.24
con f*	0.64	0.07	0.14	0.01

Notes: con f: confidence index; C: real consumption expenditures; Y: real disposable income; W: wealth; q: real equity prices; i: short-term interest rates; u: unemployment rate; roil: real oil price; con f*: foreign confidence. *P*-values reported for the probability of Row NOT Granger-causing Column. We follow the methodology in Toda and Yamamoto (1995). For the euro area, only total wealth is available, whereas for the United States, both financial wealth (W^f) and housing wealth (W^h) are used as fundamentals.

The explanatory variables that we will treat later as “economic fundamentals” are variables usually found to have some predictive power to explain changes in consumption. They include real disposable income, financial and housing wealth, real stock prices, short-term interest rates, unemployment rate and real oil prices. For the United States, we mostly use data from the Bureau of Economic Analysis. To proxy real income, we use wages and supplements net of transfers and then divided by the personal consumption expenditures deflator. For interest rates, we use the quarterly averages of the 3 month treasure bill rate, available from the Board of Governors of the Federal Reserve System. In addition to equity prices (Standard and Poor’s 500 composite index), we also account for wealth effects by using data for financial and real estate wealth stocks. Finally the unemployment rate is obtained from the Bureau of the Labor statistics and we take the average of Brent, Dubai and WTI as oil prices. All nominal variables are deflated making use of the above referred consumption deflator.

With respect to the data related to the euro area variables, they are taken from the AWM database. The historical data are based on the aggregation of available country information when the original AWM database was compiled.⁴ Finally, for the stock market we use the Euro Area Share Real Price Index.

2.2. Unit root, Granger causality and cointegration

We first perform Augmented Dickey–Fuller tests in order to determine the order of integration of the variables. For the United States, most variables are integrated of order one or I(1) (U.S. interest rate is the exception). For the euro area, all variables, including consumption, are found to be I(1).

We then study pairwise Granger causality among the various variables of our dataset. Table 1 presents the results of the Granger causality analysis following the methodology in Toda and Yamamoto (1995). As described in Bauer and Maynard (2012), the methodology of Toda and Yamamoto (1995) pertains to the class of “surplus-lag” testing procedures and is appropriate for testing Granger-causality in the context of possibly integrated variables. *P*-values are reported in Table 1 for the probability of Row NOT

(footnote continued)

Board Index are available upon request. A comprehensive description of these indicators can be found in Bram and Ludvigson (1998).

⁴ The data, as well as methodology notes are available at <http://www.eabcn.org/data/awm/index.htm>.

Granger-causing Column. Rejections of the null hypothesis for 5% significance level are in bold. For the United States, consumption is Granger-caused by confidence, financial wealth, the stock market index, unemployment and oil prices. For the euro area, consumption is Granger-caused by confidence, interest rates and oil prices only.

Since the Granger causality analysis is performed on pairs of variables, the robustness of the information of each variable with respect to future realizations of the other to the inclusion of covariates is not assessed. This can be inferred with respect to key variables in Sections 2.3 and 2.4. Here we restrict ourselves to the seminal idea behind Granger causality in the sense that X is said to Granger-cause Y if Y can be better predicted using past realizations of both X and Y than it can by using past realizations of Y alone. We do this per country and per variable.

We also perform the Granger causality tests for confidence. In the United States, confidence is Granger-caused by consumption and equity prices, while in the euro area, unemployment rate is the only domestic variable that Granger cause confidence.

The results of the Granger causality tests are somewhat informative. They confirm that equity price effects might be stronger in the United States than in the euro area. In the U.S. case, equity prices seem not only to Granger-cause consumption but also consumer confidence. Also, confidence seems to influence consumption in both the euro area and the United States.

Finally, as many of the variables used are I(1), cointegration tests are performed to each and every specification estimated to check whether any cointegration relationship could be added in the modelling of consumption. However, cointegration is rejected in almost all cases, so that we chose to model the change in consumption as a function of changes in other economic variables. Thus, no variable in level will enter our consumption models.

2.3. Estimation of a simple model for consumption

We extend the previous analysis with the estimation of a very simple model where the change in (ln) consumption ($\Delta \ln C_t$) only depends on the change in lags of the confidence indicator ($\Delta \text{con} f_t$),

$$\Delta \ln C_t = \alpha + \sum_{i=1}^q \beta_i \Delta \text{con} f_{t-i} + \epsilon_i \quad (1)$$

where ϵ_i is the error term.

Table 2 presents the results for both the United States and the euro area. The lag order (q) is determined using standard information criteria and 2 lags are found to be optimal for all models estimated. Using only the past changes in consumer confidence indicators could explain 8% and 10% of the variation of consumption changes in the U.S. and the euro area respectively and the confidence variables are jointly significant.

We then compare this simple model with alternatives that include a set of fundamental variables. We study three different sets of fundamentals. The first (Z_t^A) only includes past changes in consumption together with past changes in (ln) real disposable income ($\Delta \ln Y_t$). The second one (Z_t^B) also includes changes in wealth (both financial and housing wealth $-\Delta \ln W_{t-}$). The third set of fundamentals (Z_t^C) includes variables that might influence consumption behaviours even though no theory includes them directly as fundamentals. These variables are the changes in (ln) real equity prices ($\Delta \ln q$), the changes in short-term interest rates (Δi), in unemployment rate (Δu) and in (ln) real oil prices ($\Delta \ln \text{roil}$). For each set of fundamentals (Z_t^A , Z_t^B and Z_t^C), we compare the \bar{R}^2 of the model (Eq. (2)) with that of an alternative version that also includes changes in confidence indicators (Eq. (3)).

$$\Delta \ln C_t = \alpha + \sum_{i=1}^q \gamma_i Z_{t-i}^k + \epsilon_i, \quad \text{for } k = A, B, C. \quad (2)$$

$$\Delta \ln C_t = \alpha + \sum_{i=1}^q \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^q \gamma_i Z_{t-i}^k + \epsilon_i, \quad \text{for } k = A, B, C. \quad (3)$$

As shown by Table 2, expanding the set of fundamentals increases the \bar{R}^2 . While Z_t^A already explains 18% of the linear variation in U.S. consumption expenditure changes, the \bar{R}^2 increases to

Table 2
Univariate specifications.

Equation	\bar{R}^2	
	United States	Euro area
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \beta_i \Delta \text{con} f_{t-i}$	0.08	0.10
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^A$	0.18	0.09
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^A$	0.20	0.14
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^B$	0.35	0.07
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^B$	0.34	0.13
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^B$	0.42	0.16
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^C$	0.42	0.18
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^C + \sum_{i=1}^2 \delta_i \Delta Z_{t-i}^{C*}$	0.42	0.27
$\Delta \ln C_t = \alpha + \sum_{i=1}^2 \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^2 \gamma_i \Delta Z_{t-i}^C + \sum_{i=1}^2 \delta_i \Delta Z_{t-i}^{C*} + \sum_{i=1}^2 \lambda_i \Delta \text{con} f_{t-i}^*$	0.41	0.30

Notes: $Z_t^A = (\Delta \ln C_t, \Delta \ln Y_t)$, $Z_t^B = (\Delta \ln C_t, \Delta \ln Y_t, \Delta \ln W_t)$, $Z_t^C = (\Delta \ln C_t, \Delta \ln Y_t, \Delta \ln W_t, \Delta \ln q, \Delta i, \Delta u, \Delta \ln \text{roil})$. “*” for foreign variables.

35% with Z_t^B and 42% with Z_t^C . For the euro area, the \bar{R}^2 are surprisingly lower with Z_t^A and Z_t^B (9% and 7% respectively). The \bar{R}^2 increases however to 16% when using Z_t^C .

Differences between the two economic areas are even more striking when adding confidence indicators to the models. While for the United States, including confidence indicators does not increase the goodness of fit of the model, it improves that of the euro area. Indeed, in the U.S. case, the \bar{R}^2 are similar for models (3) and (2), except for the case when we compare the Z_t^A model with one with just confidence. For the euro area the best model is the one including confidence indicators together with Z_t^C , explaining almost 18% of the linear variation in consumption expenditure changes. While the \bar{R}^2 might appear low given the number of variables used, it is important to notice that no contemporaneous variables are used in these estimations, since we focus on the predictive power of variables at a one-period ahead horizon.

Although this analysis remains relatively simple, it shows that, while for the U.S. confidence indicators do not seem to help predicting consumption expenditures when taking fundamentals into account, they may contain some valuable information in the euro area case.

2.4. VAR analysis

We now set up a VAR modelling framework to help us analyse the dynamics of the impacts of a shock to confidence on consumption expenditures through impulse response functions. In a first step, we estimate country-specific VAR models using the same variables as in the univariate estimations above. This allows us to test the statistical significance of the confidence indicators through the error bounds of the impulse response functions. In a second step, we compute historical forecast error decomposition to graphically see how the contribution of confidence shocks has changed over time.

We estimate the following VAR model, using the largest set of fundamentals (Z_t^C), as defined above:

$$y_t = \sum_{i=1}^q A_i y_{t-i} + \mu_i, \tag{4}$$

$$\text{where } y = \begin{pmatrix} \Delta \ln C_t \\ \Delta \text{con} f_t \\ Z_t^C \end{pmatrix} \tag{5}$$

and μ_i is a vector of orthogonalised shocks. The orthogonalisation is done via a Cholesky approach using the following ordering: confidence, financial variables, interest rates, wealth, consumption and income. We use the same Cholesky ordering as in Bram and Ludvigson (1997) for the sake of

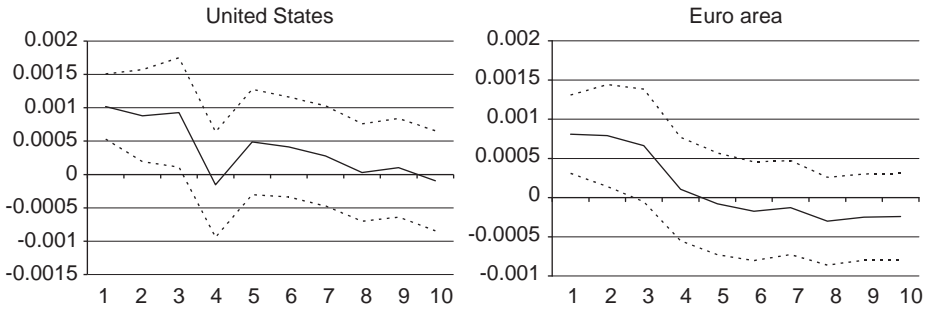


Fig. 4. Responses to a 1 s.d. innovation in confidence on consumption growth with 95% error bounds.

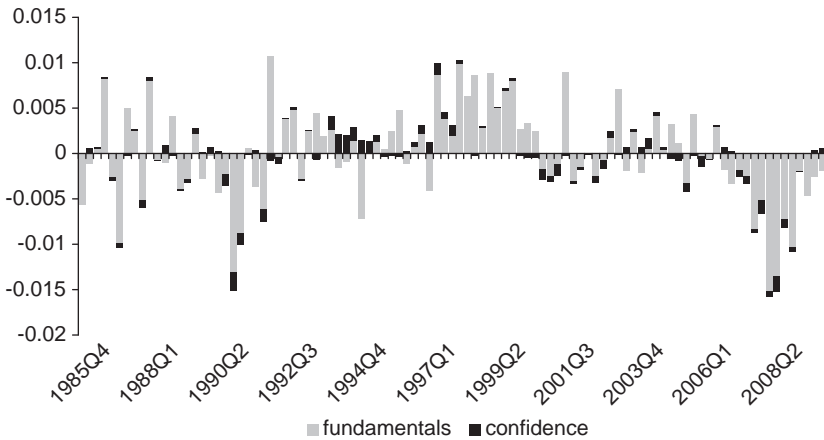


Fig. 5. Historical decomposition of real consumption forecast errors – United States.

comparison.⁵ However, using alternative orderings do not change qualitatively the results. Here again, the optimal lag order (q) is found to be equal to 2 according to standard information criteria.⁶

Fig. 4 (left panel) shows the impulse response functions of a shock to confidence on real consumption in the United States. The impulse responses of the confidence shocks appear significant for two periods ahead but insignificant at the 95% level for future periods.

For the euro area (Fig. 4, right panel), a shock to confidence has some short-term, significant impact on consumption. Nonetheless, as for the United States, there is no long-run significant impact of confidence shocks on consumption growth.

⁵ The Cholesky decomposition is equivalent to transforming the system in a recursive VAR for identification purposes. The identifying assumption is that the variables that come first in the ordering affect the following variables contemporaneously, as well as with a lag, while the variables that come later affect the previous variables only with a lag. Though our results are robust to different Cholesky factorisations, confidence is placed first because our focus is to investigate the information content of confidence indicators with respect to consumption both directly and indirectly. Therefore we allow confidence to have within quarter effects with respect to other variables. By ordering most other variables between confidence and consumption, we explore the full potential of confidence in explaining movements in consumption.

⁶ The lag order was selected by using various criteria, including the Sequential modified LR test statistic, Final prediction error, Akaike information criterion, Schwarz information criterion and Hannan–Quinn information criterion. Although the final selection has remained subjective – since the various criteria often give conflicting results –, we decided to keep the same lag order whatever model considered for the sake of comparability and consistency.

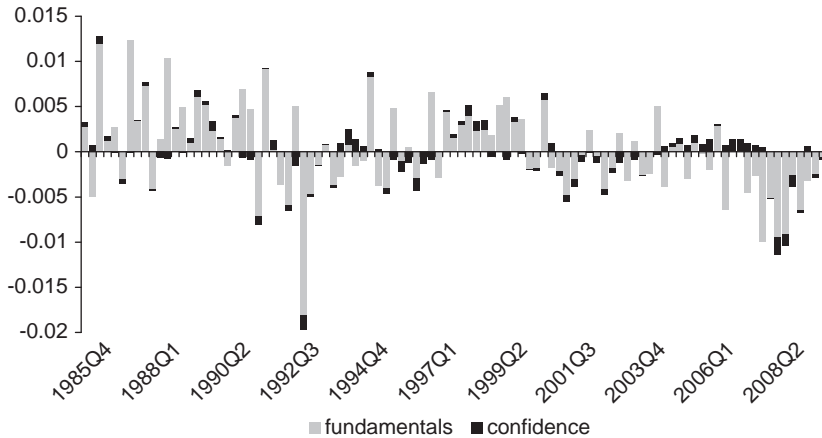


Fig. 6. Historical decomposition of real consumption forecast errors – Euro area.

We use next the historical decomposition technique to describe the relative importance of shocks to confidence and shocks to the other fundamental variables.⁷ Figs. 6 and 7 show respectively for the U.S. and the euro area the contributions to the deviations between actual consumption and its VAR-based forecasts of shocks to confidence and the set of fundamental variables (Z_t^c). As expected the confidence shocks play a relatively small role on average relative to shocks to fundamentals. However, there are periods during which confidence seems to play an important role.

Looking at the U.S. results first (Fig. 5), we can notice that while the contribution of confidence shocks tends to oscillate around zero, such shocks had larger negative influences to forecast errors during very specific episodes. We can try to map such negative contributions to particular events that are likely to have affected consumer confidence. For instance, confidence shocks contribute negatively to forecast errors during geopolitical tensions or U.S. military interventions in the Middle East in early 1990s and in 2001–02. Negatively contributions also appear clearly during the 2007–09 financial crisis (2008Q2 following Bear Stearns and 2008Q4 following Lehman Brothers). Positive contributions could also be found in 1994, as confidence increased quite sharply in that year, recovering from the low levels reached during the early 1990s recession.

Concerning the euro area (Fig. 6), confidence shock contributions are clearly negative during recessions and financial crises (like in 1992–93 or 2008–09), going therefore in the same direction as shocks to fundamentals and even anticipating them sometimes (like in the early 1990s). Negative confidence shock contributions are however sometimes absorbed by positive contributions of other shocks, like during the Asian crisis in 1997 or at the turn of the millennium. On the contrary, strong positive contributions can also be found in 1994 (following with a lag the increase in U.S. confidence) at the time where contributions to shocks to fundamentals were clearly negative. Similarly, confidence shocks contributed positively in 2006–07, counterbalancing negative contributions by shocks to fundamentals.

Overall, the historical contribution exercise shows that confidence seems to matter in some specific episodes, which in most cases corresponds to periods where there are large changes in household survey indicators, like during financial crises or geopolitical tensions for instance.

3. Isolating periods in which confidence matters

To capture better the fact that confidence might play a role only in some particular circumstances, we perform a non-linear estimation of our consumption equation, using a threshold model to forecast the U.S. and the euro area consumption out of sample.

⁷ For more details, see Burbidge and Harrison (1985).

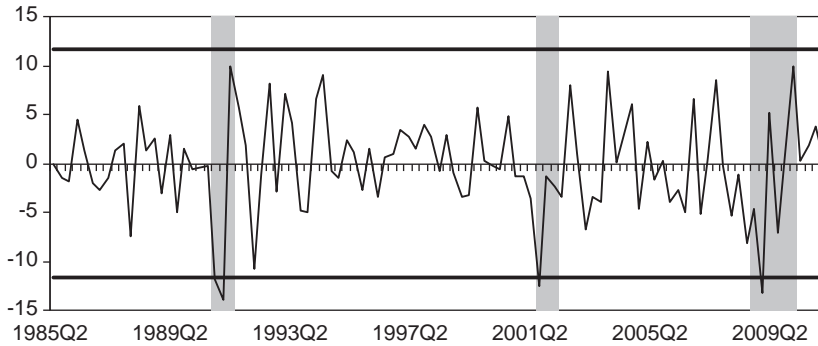


Fig. 7. United States: change in confidence and model-based thresholds (grey areas correspond to NBER U.S. recession periods).

3.1. A threshold model

In this exercise we try to test to what extent removing low frequency observations from the confidence indicators can improve the goodness of fit of the forecasting equations. Following Desroches and Gosselin (2004), we use the following criterion to censor observations:

$$\Delta con f_t^{cs} = \begin{cases} 0 & \text{if } |\Delta con f_t| < \theta \\ \Delta con f_t & \text{otherwise} \end{cases} \quad (6)$$

where the superscript *cs* stands for “censored” i.e. some observations were set to zero.

The threshold (θ) is determined by a grid search minimising the empirical errors of the following regression including $\Delta con f_t^{cs}$. Here again, the optimal lag order (q) is found to be equal to 2 according to standard information criteria

$$\Delta \ln C_t = \alpha + \sum_{i=1}^q \beta_i \Delta con f_{t-i}^{cs} + \sum_{i=1}^q \gamma_i \Delta Z_{t-i}^C + \epsilon_t. \quad (7)$$

By following the above threshold methodology, we test the assumption that small changes in confidence do not matter much to explain future consumption expenditures but that large confidence shocks is likely to bring some extra information beyond economic fundamentals. This can be understood as a study of a particular type of non-linear behavior of confidence with respect to consumption growth or as a structural break test to the standard linear relation estimated in the previous sections.

In-sample estimation shows that, for the United States, only 4 are left uncensored, which is in line with our previous findings (i.e. confidence is indeed not robust to the inclusion of fundamentals). The optimal threshold is found to be equal to 11.7, i.e. larger than two standard deviations of confidence (Fig. 7). The point that in the context of this model, “extreme” confidence changes are the ones that matter the most is therefore reinforced. It is then not surprising to find the uncensored values in the recession periods. For the euro area, in line with our previous findings, the information contained in confidence is comparably more robust to the inclusion of economic fundamentals than in the U.S. case. The point estimate of the censored confidence variable is equal to 1.3. As a result, only 40 observations are censored by the threshold approach. While it is difficult to try to map the uncensored observations into some historical events, it is worth noting that the time where confidence was uncensored in the threshold model for the larger consecutive number of periods were precisely the last 3 quarters of 2006 and the 2007 and 2008 years. Recessions or low-growth period also correspond to periods with uncensored confidence (Fig. 8).

3.2. Out-of-sample evidence

Using the threshold modelling approach, we perform some out-of-sample analysis to check to what extent and in which circumstances the threshold models outperform models where the

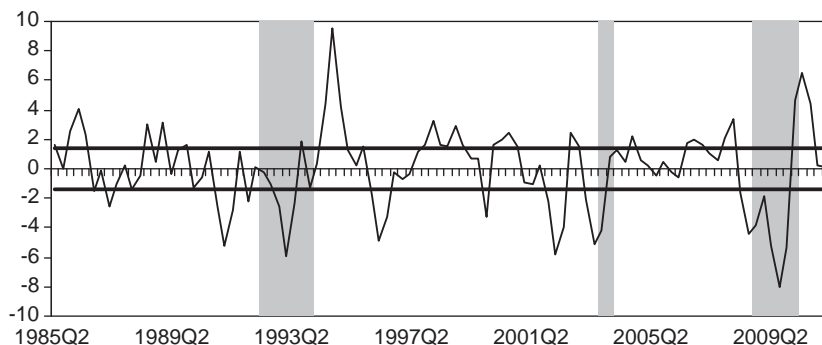


Fig. 8. Euro area: change in confidence and model-based thresholds (grey areas correspond to CEPR euro area recession or low growth periods).

confidence vector is subject to no censoring or not included at all. Each exercise is performed both for the United States and the euro area and consists of one-step ahead forecasts over the period 2002Q1–2010Q2. These forecasts are obtained using models, whose parameters are estimated using data up to $t-1$. Root mean square errors are computed and used as comparison between models.

The results (Table 3) show that the threshold models result in a smaller RMSE when compared with the model with no confidence (relative RMSE equal to 0.897 for the United States and 0.899 for the euro area), while the model with uncensored confidence has a relative RMSE slightly higher than one. Forecast accuracy tests (based on Clark and West, 2007) show that the threshold models provide significant improvements compared with models without confidence for both the U.S. and the euro area. This results show that the improvement in forecast accuracy due to nonlinearity is statistically significant.

Table 3

Out-of-sample forecasting exercise over 2002Q1–2010Q2.

Model comparison	United States		Euro area	
	RRMSE	<i>t</i> -stat	RRMSE	<i>t</i> -stat
Eq. with $con f_t$ wrt Eq. without confidence	1.0259	0.7553	1.0203	0.3957
Eq. with $con f_t^{cs}$ wrt Eq. without confidence	0.8967	3.0019 ^a	0.8993	3.8884 ^a

Notes: Model with $con f_t$ corresponds to the model with uncensored confidence; model with $con f_t^{cs}$ corresponds to the threshold model with censored confidence.

^a Equal predictive power test rejected at 95% (rejection if *t*-stat higher than 1.65) – see Clark and West (2007).

4. Evidence of a “confidence channel” in the international linkages

The last part of our research focuses on a possible “confidence channel” in the international linkages. A shock in one country could lead to an immediate decline in confidence that would affect other countries through a reassessment of global economic prospects. While these confidence spillover effects may partly reflect linkages in fundamentals, some empirical work provides evidence of other factors, related to investor and consumer behaviour, which are transmitted across borders. These factors are given various names, such as information “cascades”, “fads” or “herd” behaviour. They seem to increase in importance during periods of financial crises or geopolitical events (see, among others, Avery and Zemsky, 1998 and IMF, 2001).

As before, we try to isolate what could be the impact of foreign confidence on domestic consumption in addition to other economic fundamentals. As shown by Table 1, the Granger causality

found between U.S. confidence and euro area confidence already indicates possible confidence linkages between the two economic areas. The confidence linkage is more significant when considering the causal link from the United States to the euro area than in the other way around. To get more evidence of such a confidence channel, we consider a model that include on top of the largest set of fundamentals considered earlier (Z_t^c) and the domestic confidence indicators, the corresponding foreign fundamentals (Z_t^{c*}).

$$\Delta \ln C_t = \alpha + \sum_{i=1}^q \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^q \gamma_i Z_{t-i}^c + \sum_{i=1}^q \delta_i \Delta Z_{t-i}^{c*} + \epsilon_i \quad (8)$$

As before, we test if adding the confidence indicators abroad ($\text{con} f_t^*$, i.e. euro area confidence in the U.S. model and U.S. confidence in the euro area model) improves the fit by comparing the \bar{R}^2 of (8) and that of the following equation:

$$\Delta \ln C_t = \alpha + \sum_{i=1}^q \beta_i \Delta \text{con} f_{t-i} + \sum_{i=1}^q \gamma_i Z_{t-i}^c + \sum_{i=1}^q \delta_i \Delta Z_{t-i}^{c*} + \sum_{i=1}^2 \lambda_i \Delta \text{con} f_{t-i}^* + \epsilon_i \quad (9)$$

We consider first the improvement in the goodness of fit by adding foreign fundamentals (i.e. from (3) to (8)). Here again while adding euro area variables does not improve the U.S. model's goodness-of-fit, the euro area one improves when adding U.S. fundamentals (Table 2). The \bar{R}^2 rises from 18% to 27% and variables are jointly significant.

We then consider the improvement when adding foreign confidence to the previous model (i.e. from (8) to (9)). While including euro area confidence slightly deteriorates the performance of the U.S. equation (the \bar{R}^2 declines from 42% to 41%), the goodness of fit improves further when adding U.S. confidence to the euro area equation (the \bar{R}^2 rises from 27% to 30%). This result underlines the role of U.S. developments to predict euro area ones. As shown by Giannone et al. (2009) the U.S. business cycle is leading the euro area business cycle. The increase in the predictive power in the euro area models when including U.S. variables then reflects the fact the U.S. consumers perceive earlier than the euro area consumers a change in the business cycle. Moreover, the further increase in the fit between (8) and (9) suggests the existence of a “confidence channel” that reflects the fact that news spreads across the globe quickly. A change in the U.S. confidence, anticipating a future change in the business cycle, might then affect domestic confidence, which in turn has an impact on domestic business cycle. This result is in line with a recent study by Fei (2011) who finds empirical evidence of the existence of a confidence channel from “large countries” to “smaller countries”. Even after having controlled for domestic macroeconomic causes of confidence level variations, the level of confidence of agents in large countries does have an influence on the level of confidence of agents in smaller countries.

Moreover, the results of model (9) indicate the presence of a one-way “confidence linkage” between the United States and the euro area. In other words, past changes in the U.S. confidence indicators would contain information about current changes in euro area consumption. The opposite would not be true. This result is not necessarily surprising, given the importance the release of U.S. confidence indicators has in the economic press and on financial markets. This is less so when euro area confidence indicators are released.

Finally, we also consider a VAR model similar to (4), in which we also add to our set of fundamental variables the foreign variables corresponding to Z_t^{c*} as well as the change in foreign confidence ($\Delta \text{con} f_t^*$). This allows us to check in a multiple equation system to what extent foreign confidence could have some impact on domestic confidence, while controlling for the foreign influences going through the linkages between foreign and domestic fundamentals. The earlier results are confirmed: while for the United States, a shock to euro area confidence has no impact on neither U.S. confidence nor U.S. consumption, the impact of a U.S. confidence shock has some significant impact on the euro area confidence in the short run (Fig. 9), thus confirming the existence of a “confidence channel” between the U.S. and euro area economies. At the same time, the response of the U.S. confidence shock on euro area consumption is not statistically significant (not shown here). In other words, a change in U.S. confidence would not affect directly euro area consumption but indirectly by affecting euro area confidence. On the contrary, we cannot find any evidence of confidence linkages between the euro area and the United States.

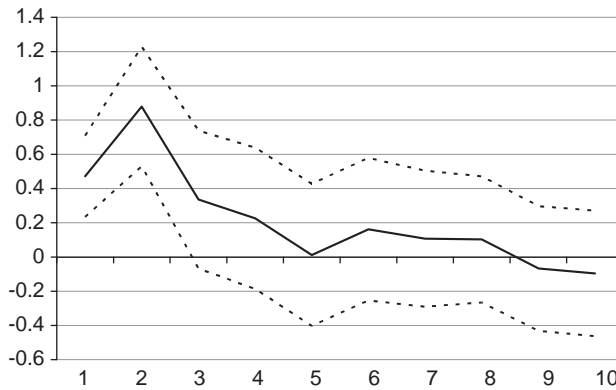


Fig. 9. Response to a 1 s.d. innovation in US confidence on EA confidence with 95% error bounds.

5. Conclusions

This paper has proposed an empirical assessment of the link between consumer sentiment and consumption expenditures for the United States and the euro area. Overall, the results show that the consumer confidence index can be in certain circumstances a good predictor of consumption. In particular, out-of-sample evidence shows that the contribution of confidence in explaining consumption expenditures increases when household survey indicators feature large changes, so that confidence indicators can have some increasing predictive power during such episodes. Moreover, there is some evidence of a “confidence channel” in the international transmission of shock, as U.S. confidence indices help predicting consumer sentiment in the euro area.

Future research includes extensions to other countries. In the euro area case, in particular, it would be interesting to verify whether the conclusions at the area level are confirmed at the level of the different countries. For instance, our results contrast with those found by [Al-Eyd et al. \(2008\)](#), who do not find consumer confidence to be a good predictor for consumption for the three largest euro area countries (Germany, Italy and France). It would then be worth understanding whether aggregation could be responsible for these differences. Moreover, extensions could concern other variables. As surveys also report business sentiment, similar research could be done on the predictive power of confidence on investment decisions. By extension, combining consumer and business survey data could help improve the forecast of GDP fluctuations.⁸ Finally, we have only used the aggregate index of confidence surveys. Various subcomponents could be used as alternatives, as they might provide more precise information about agents' perceptions about the future.

Acknowledgements

We are grateful to Annika Alexius, Robert Anderton, Filippo di Mauro as well as two anonymous referees for helpful comments. Any views expressed represent those of the authors and not necessarily those of the European Central Bank or the Eurosystem.

References

Acemoglu D, Scott A. Consumer confidence and rational expectations: are agents beliefs consistent with the theory? *The Economic Journal* 1994;104:1–19.

⁸ Taylor and McNabb (2007) provide some evidence for Europe that both consumer and business confidence indicators are procyclical and generally play a significant role in predicting business cycle downturns.

- Al-Eyd A, Barrell R, Philip E. Consumer confidence indices and short-term forecasting of consumption. *The Manchester School* 2008;77:96–111.
- Avery C, Zemsky P. Multidimensional uncertainty and herd behaviour in financial markets. *American Economic Review* 1998;88:724–48.
- Bauer D, Maynard A. Persistence-robust surplus-lag Granger causality testing. *Journal of Econometrics* 2012;169:293–300.
- Bram J, Ludvigson SC. Does consumer confidence forecast household expenditure? a sentiment index horse race. Federal Reserve Bank of New York Research Paper 9708; 1997.
- Bram J, Ludvigson SC. Does consumer confidence forecast household expenditure? a sentiment index horse race. Federal Reserve Bank of New York Economic Policy Review 1998:59–78.
- Burbidge J, Harrison A. A historical decomposition of the great depression to determine the role of money. *Journal of Monetary Economics* 1985;16:45–54.
- Carroll C, Fuhrer J, Wilcox D. Does consumer sentiment forecast household spending? If so, why?. *American Economic Review* 1994;84:1397–408.
- Claveria O, Pons E, Ramos R. Business and consumer expectations and macroeconomic forecasts. *International Journal of Forecasting* 2007;23:47–69.
- Clark TE, West K. Approximately normal tests for equal predictive accuracy in nested models. *Journal of Econometrics* 2007;138:291–311.
- Desroches B, Gosselin M-A. Evaluating threshold effects in consumer sentiment. *Southern Economic Journal* 2004;70:942–52.
- Dominitz J, Manski CF. How should we measure consumer confidence? *The Journal of Economic Perspectives* 2004;18:51–66.
- Easaw JZ, Heravi SM. Evaluating consumer sentiments as predictors of UK household consumption behavior: are they accurate and useful?. *International Journal of Forecasting* 2004;20:671–81.
- Eppright DR, Arguea NM, Huth WL. Aggregate consumer expectation indexes as indicators of future consumer expenditures. *Journal of Economic Psychology* 1998;19:215–35.
- Fagan G, Henry J, Mestre R. An area-wide model (AWM) for the euro area. ECB Working Paper 42; 2001.
- Fei S. The confidence channel for the transmission of shocks. Banque de France Working Paper 314; 2011.
- Garner CA. Consumer confidence after September 11'. Federal Reserve Bank of Kansas City Economic Review 2002;2002(2): 1–21.
- Giannone D, Lenza M, Reichlin L. Business cycles in the euro area. In: Alesina A, Giavazzi F, editors. *Europe and the euro*. Chicago: University of Chicago Press; 2009.
- Hall RE. Stochastic implications of the life-cycle/permanent income hypothesis: theory and evidence. *Journal of Political Economy* 1978;96:971–87.
- Haugh DL. The influence of consumer confidence and stock prices on the United States business cycle. ANU University. CAMA Working Papers 3/2005; 2005.
- Howrey EP. The predictive power of the index of consumer sentiment. *Brookings Papers on Economic Activity* 2001;32:175–16.
- International Monetary Fund. International linkages: three perspectives. *World Economic Outlook*; 2001 October.
- Katona G. *Psychological economics*. New York: Elsevier Scientific Publishing Company; 1975.
- Ludvigson SC. Consumer confidence and consumer spending. *Journal of Economic Perspectives* 2004;18:29–50.
- Kwan ACC, Cotsomitis JA. The usefulness of consumer confidence in forecasting household spending in Canada: a national and regional analysis. *Economic Inquiry* 2006;44:185–97.
- Smith BM. Forecasting utility of UK consumer sentiment indexes in real time: do consumer sentiment surveys improve consumption forecasts in real time? University of Richmond, Department of Economics Honors Thesis; 2009.
- Taylor K, McNabb R. Business cycles and the role of confidence: evidence for Europe. *Oxford Bulletin of Economics and Statistics* 2007;309:185–208.
- Toda HY, Yamamoto T. Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics* 1995;66:225–50.
- Throop AW. Consumer sentiment: its causes and effects. Federal Reserve Bank of San Francisco Economic Review 1992;1992(1): 35–59.
- Wilcox J. Forecasting components of consumption with components of consumer sentiment. *Business Economics* 2007;42: 22–32.