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Discussing the role of fiscal policy in a demand-led agent-based growth model*

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Abstract

The global financial crisis led to a crisis in mainstream macroeconomic theory and to questioning the economic policies implemented before and after the crisis. One of the most relevant controversies concerns the role of fiscal policy. In order to present a different theoretical approach and discuss the role of fiscal policy, in this paper, we present an agent based micro-macro multisectoral model to analyze fiscal policy in a complex evolutionary economy. We evaluate the impact of different fiscal rules in terms of short run fluctuations and long-term growth. In particular, we analyze the impact of a new fiscal rule that prevents any real growth of federal public expenditures for at least ten years in Brazil. Based on the simulation model, we compare 5 different combinations of fiscal policies on how they affect macro variables, such as GDP growth rates, GDP volatility and likelihood of crisis. We also test how each fiscal policy combination reacts to an external shock. Results show that all scenarios imposing a tighter constraint to government spending present signs of self-defeating fiscal consolidation. On the other hand, unconstrained countercyclical policy prevents contagious effect of external crisis, leading to a better economic performance and reducing the likelihood of crisis.

Keywords: Agent-based models; Demand-led Growth; Fiscal policy

1. Introduction

The aftermath of the global financial crisis (GFC) has called both mainstream macroeconomic and political thinking into question. There is now growing recognition of some important theoretical aspects that heterodox economists have been trying to put forward for a long time. The dynamic stochastic general equilibrium (DSGE) models were questioned in terms of their plausibility and total impossibility to predict the GFC (Caiani et al., 2016). Thus, several scholars argued that one must put finance into the heart of the models, incorporate heterogeneous agents and more behavioral economics. For instance, as shown by Bezemer (2009) while most economists used mainstream equilibrium models and did not see the crisis coming, a few scholars that used non-orthodox accounting models were able to predict the crisis.

In terms of economic policy, the most important controversy concerns the role of fiscal policy, as pointed out by Krugman (2018). Before the GFC, the prevailing mainstream view was a restricted role of the state and the use of

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fiscal policy mostly to ensure the sustainability of public debt. Even those that advocated the necessity to use policies in controlling short run fluctuations attributed that role to monetary policy mainly.

Since then, the role of fiscal policy for both economic growth and income distribution has returned to the academic debate. After a long period of monetary policy hegemony, during the crisis many countries adopted expansionary fiscal policies with important results. As discussed by Krugman (2018), even when fiscal policy was not totally expansionist, at least, governments refrained from drastic tightening of fiscal policy, allowing automatic stabilizer, associated with large welfare states, to kick in. The worsening of the economic environment, associated to the crisis, led to the deterioration in the fiscal framework, increasing the pressure for countries to adopt austerity measures, which came in to place in 2011/2012.

As many countries promoted large austerity measures, recovery stopped. Since then, the economic literature has increasingly addressed the consequences of a possible self-defeating fiscal adjustment (DeLong et al., 2012; Fatás and Summers, 2018; Lopes and do Amaral, 2017). This phenomenon happens when the austerity policy lead to a depressed economic environment and tax revenues rapidly falls. In this scenario, austerity measures further aggravate fiscal results rather than improving it, imposing even larger fiscal adjustments and creating a vicious circle.

From a supply side economics, it is difficult to explain this result and it is necessary to introduce some rigidities to incorporate hysteresis phenomena. However, from a demand side economics, both in short and long run, this result is directly obtained from the theoretical hypothesis. Moreover, aggregate demand-led growth models overlook several important elements, such as technological change, financial constraints to investment and long run expectations. Clearly, a theory to explain the growth trend compatible with the structure of these models was missing.

This paper contributes to the debate on role of fiscal policy by presenting an agent based micro-macro multisectoral model to analyze fiscal policy in a complex evolutionary economy. We want to evaluate the impact of different fiscal rules in terms of short run fluctuations and long-term growth. The main motivations of the paper are both to influence the public debate and to present an important theoretical tool. In terms of economic policy debate, we want to analyze the impact of a new fiscal rule that prevents any real growth of federal public expenditures for at least ten years in Brazil.

In terms of a theoretical tool, the model combines keynesian/kaleckian tradition of demand led-growth with schumpeterian elements of innovation at the firm level. We contribute to recent developments of evolutionary or schumpeterian models that have introduced the demand side and its interrelated effects with the innovation process, building a non-orthodox interpretation of the growth process, which incorporates the Effective Demand Principle. Therefore, using an evolutionary model that describes intersectoral relations, firm's production and investment decisions and autonomous demand, this paper addresses the growth impact of those fiscal rules.

We introduce new formulations for fiscal policies to a previous simulation model presented by Possas and Dweck (2004, 2011) to address endogenous and interactive mechanisms related to agents' decisions. We consider the influence of specific sectoral components and dynamic effects associated to the productive and technological structure. This paper presents some of the simulation results of the latest version of this micro-macro dynamic multisectoral model, focusing on the macrodynamic properties of the growth trend and their main determinants, including those at the microeconomic level.

The paper is organized as follows: Section 2 addresses the recent debate on the role of fiscal policy, highlighting recent studies proposing the idea of a self-defeating fiscal consolidation in opposition to the main thesis that prevailed following the GFC, the expansionary fiscal austerity. Section 3 addresses the methodological motivation, the evolutionary models and how they historically introduced demand-side effects and incorporated the Effective Demand Principle. Section 4 describes the main structure of the model we used. We also describe new formulation for the government in the model and how the different fiscal rules we want to analyze are introduced. Section 5 presents the results of our simulations. Firstly, we present our simulation setting and some empirical validation. Then, we present the results of several different cases in a comparative analysis, addressing the impact of different combinations of those fiscal rules in the growth trend, in the business cycle, in the likelihood of a crisis, firm's debt and in the public debt/GDP ratio. Our concluding remarks summarize the analysis and reinforces its main conclusions.

2. From expansionary fiscal austerity to self-defeating fiscal consolidation

Fiscal policy, and its role during an economic crisis, is the subject of an intense debate in economic theory. In general, one can split the current debate on the role of the state and fiscal policy into two main theoretical perspectives.

On the one hand, there is the position of the New Neoclassical Synthesis supporters (Taylor, 2000, 2011; Gertler et al., 1999; Linnemann and Schabert, 2003), who argue for the restricted role of the state and the use of fiscal policy to ensure the sustainability of public debt. The main goal here is to provide signs to the market that there will be no risk of default, and to avoid the instability of the main macroeconomic variables, especially interest rates and inflation. The "expansionary fiscal austerity" thesis upheld this position. According to this thesis, both the credibility of an austere fiscal policy and the commitment to sustainability of public debt have beneficial effects on the expectations of economic agents, thus raising investment and growth. However, the increase in expenditures tends to produce expectations of raising taxes in the future and to cause private agents to reduce investments, with a consequent slowdown of activity.

On the other hand, we find the economists of Keynesian tradition Arestis and Sawyer (2003), Fazzari (1994), Davanzati et al. (2009), for whom public spending plays an essential role in the creation of a conducive environment to private investment, capable of sustaining economic agents' expectations and growth. This is due to the Keynesian multiplier mechanism – or even the supermultiplier, that includes also the induced effect of private investment on total expenditure. This mechanism shows that increases in public spending will give rise to an expansion of aggregate demand higher than that of the spending itself, which, given the existence of idle factors of production, leads to the expansion of economic activity and stimulates private investment. Whenever there is a slowdown of the activity or a recession, they advocate even more for the state's action through fiscal policy, since repressed private demand tends to lead to a decline in production, an increase in unemployment of productive factors, and consequently to a reduction of income, consumption, and investment, in a vicious circle that further deepens the recession. In this situation, an exogenous impulse in demand from public spending, or external demand, can reverse the recession.

Before the 2008 crisis, the "expansionary fiscal austerity" thesis prevailed, based on the idea that expansionist effects obtained by multipliers of public spending were low and that they would be smaller than the contractionary effects generated by the deterioration in agents' expectations after the increase in public debt, based on cases of fiscal adjustments in Europe in the 1980s (Giavazzi and Pagano, 1990; Alesina and Perotti, 1995).

Although this argument has had some impact during the first periods after the GFC, state of affairs changed when several countries made intense use of fiscal policy to stimulate aggregate demand and to avoid deepening the recession. The International Monetary Fund (IMF) itself, which was one of the main proponents of ideas of fiscal austerity, contributed to the debate by publishing a paper signed by its chief economist. The authors assume that the magnitude of the ongoing recession contests all the consolidated knowledge about economic policy since the period known as "The Great Moderation" (Blanchard et al., 2010). Therefore, even agencies such as the IMF began to change their historical positions on the role of fiscal policy (Fiebiger and Lavoie, 2017).

Schaechter et al. (2012) shows how fiscal rules were adapted in many countries after the financial crisis, in an effort to achieve greater flexibility to make use of countercyclical fiscal policy. These "new-generation" of rules provided a greater flexibility of short-term fiscal goals, with the enforcement of escape clauses. Those clauses allow the government to make active use of fiscal policy in times of significant growth slowdown while also adopting measures to ensure debt sustainability in the medium and long run, such as the enforcement of a limit for the trajectory of public debt or for expenditure.

Therefore, even though many countries, especially in Europe, reverted the initial Keynesian view and did adopt strong austerity measures after the crisis, it is important to notice that the debate about fiscal policy did not go back to the "Alesina-time" pre-crisis. As pointed out by Lavoie and Seccareccia (2017), among others, an increasing number of authors highlighted the effects of those austerity policies over economic activities, extensively described in Fatás and Summers (2018), which led to, what they called a "New Fiscalism". "Contrary to the reading of mainstream neoclassical economists, what has actually happened because of the financial crisis is the metamorphosis of fiscal policy into a distinct form, a New Fiscalism (. . .). This new form is neither compatible with the traditional theory of sound finance nor with the Lerner vision of functional finance" (Lavoie and Seccareccia, 2017).

In a recent paper, Girardi et al. (2017) presented an "anti-Alesina" type of empirical study. They analyzed 94 episodes of demand expansion in 34 OECD countries between 1960 and 2015. They look at the sum of primary public expenditure and exports, a variable they call "autonomous demand". They find a highly significant persistent positive effect on the GDP level of a one-off expansion in their autonomous demand variable. They also documented a strong persistent effect on capital stock, employment, and participation rates. Moreover, the authors did not find that expansions, on average, cause high or accelerating inflation. In addition, Fair (2018) shows, by using a structural macroecometric model, that the slow U.S recovery between 2010 and 2017 was due to sluggish government spending.

Fatás and Summers (2018), on the other hand, studied countries that implemented large fiscal consolidations in 2010-11 and tried to investigate if they might have found themselves in 2012 with a depressed economy that might have required even larger adjustments in fiscal policy that further depressed future growth. Their main conclusion is that the reduction in output makes the goal of fiscal consolidation harder as it raises the ratio of debt to GDP and it reduces tax revenues. As they highlight, hysteresis is crucial for the possibility of self-defeating fiscal consolidations.

To briefly summarize, the aftermath of the GFC reignited the debate around the role of fiscal policy. The main view that prevailed before the crises, the "expansionary fiscal austerity" thesis, was reinforced in the first periods just after the crisis, but since most of affected countries experienced slow recoveries, even the IMF started to search for other possible explanations. In practice, several countries started to implement flexible rules, allowing a more active use of fiscal policy. Recent papers had shown that not only those austerity rules can be self-defeating but also that most of the cases of recoveries through demand expansion in recent history had a crucial persistent role of fiscal policy. It's clear that there is no consensus on the role of fiscal policy, neither in theory and academic discussion or in practice, but what we know is that after the crisis, the tide started to change, and the sea of debate about fiscal policy is much more active.

3. The demand side and fiscal policy in the literature of evolutionary models

The path breaking work of Nelson and Winter (1982) paved the way for a family of models of Schumpeterian competition, inspired by the model presented in chapter 12 of their book. Models, such as Nelson and Winter (1982), Silverberg and Lehnert (1994), Silverberg and Verspagen (1998), Saviotti and Pyka (2004a,b,c, 2005), are good examples of first endogenous growth models and debate directly with neoclassical growth models. However, many of these models present basically the same causal mechanism, that is, the one that runs from the supply side. In general, the transition from micro to macro levels is done without macro-sectoral intermediate steps between the firms and the economy as a whole, either through input-output relations or income generation and final demand. In a few words, it means that these models have no macroeconomic level of analysis (Possas, 2002).

Our main hypothesis here is that without a compensation mechanism on the demand side, the effect of technological progress is only to reduce any possible constraint. This hypothesis is based on Kalecki's contribution. Kalecki (1941) highlights what he considers the main effects of technological progress to the economic development[1]: (i) an increase in the labor productivity - given the degree of capacity utilization; (ii) a change in the capital-output technical ratio, that can be positive (capital-saving), negative (capital-using) or nil (neutral); (iii) an increase in the degree of monopoly (measured by the effective markup) – industry concentration; (iv) a decrease in the general price index – since the reduction in marginal cost of labor tends to be greater than the increase in the degree of monopoly; and (v) an incentive to invest greater than if there was no technological progress. As Kalecki indicates, the first two have a direct effect on the employment level and the capital structure, while the rest only has an indirect effect. Given some hypotheses, Kalecki (1941) concludes that if the effects of the last three are discarded, the effect of technological progress would not be to increase production (demand), but to reduce the employment level. Therefore, his hypothesis, based on effective demand approach, is that without any demand side compensation mechanism (Vivarelli, 1995), the only effect of the increase in labor productivity is to alleviate a possible labor supply constraint.

The Silverberg (1987) model, a sectoral model, was the first evolutionary/Neo-Schumpeterian model concerned on the role of demand. Contrasting with the previous models, Silverberg describes the investment decision process from two distinct methods – investment in capacity expansion and replacement investment. But this is a sectoral model, so the market demand is determined exogenously and independently from the firms' decisions; therefore, it does not address economic growth issues. It is not possible to evaluate how these investment decisions will affect the aggregate demand, and consequently aggregate investment.

Breaking with the supply-side causal mechanism tradition and taking a step further of the Silverberg Sectorial model, Chiaromonte and Dosi (1993) incorporated the mechanisms for generating innovation and diffusion in a structure typical of models based in the interaction between multiplier and accelerator. The authors combine an evolutionary approach with the Keynesian mechanism of demand formation and the determination of aggregate income. The aggregate demand is endogenously determined for both sectors of the model: (1) in the consumer goods sector, it is equal to the total

[1] It is important to note that he was referring only to process innovation.

wages paid; (2) in the capital goods sector, it depends on the gross investment decisions of firms from the other sector. The original model was resumed in a more simplified version by Dosi et al. (2006), which maintains the combination of evolutionary and Keynesian elements. The most important aspect that differs this new line from the previous models is that it is "agent-based"[2] instead of sectorial. The main goal of the simple model proposed by Dosi et al. (2006) is to obtain long-term growth and business cycle and to reproduce a series of micro and macroeconomic stylized facts, maintaining the mechanisms of Chiaromonte and Dosi (1993). But it was only in Dosi et al. (2010) that the authors really presented a discussion on the role of demand, and fiscal policy in particular, on growth and business cycles.

The model that became known as K+S model[3] addresses three main questions: (i) how technological change, innovations, can affect the macro variables, such as the growth rate in the long term; (ii) how aggregate demand can modulate the impact of technological effect on the macro side and; (iii) if the long-term growth could be sustained only by the technological drive or if it is possible to identify different growth paths depending on the demand conditions. In line with Kalecki (1941), Dweck (2006) and Possas and Dweck (2011), the authors conclude that the "Schumpeterian engine" is not sufficient to sustain a long-term growth alone. It can only do it in the presence of a Keynesian demand generating process, which is represented by the Keynesian fiscal policy in the model. Without countercyclical Keynesian demand generation, a vicious feedback loop occurs: in the recession phase of the cycle, low output and low revenue reduce R&D investment and the innovation rates. The Schumpeterian engine alone may trap the economy into low growth trajectories. The introduction of fiscal policy in the model unlocks the economy from its trap, allowing higher growth rates. An "autonomous" demand is necessary to guarantee and modulate endogenous growth led by technological change. Fiscal policy, as the source of "autonomous" demand in the model, has a countercyclical role, to guarantee growth, but it's not actually a growth engine, since the causal mechanism to growth is technological change.

In the model presented below, we model the government in a slightly different way, trying to incorporate its role not only to stabilize the economy, but also being an important part of final demand components that can be an important engine for long-term growth. The idea is to incorporate the role of government to transfer income to households, but also, as an important employer and as an investor.

4. The structure of the model

The model we use for our analyzes is a micro-macro multisectoral evolutionary simulation model in which microeconomic features are explicitly introduced at the sectoral level – e.g. technical coefficients, input-output relations, import coefficients, technological opportunities – as well as at firm level – e.g. price and production strategies, productivity, profitability, long and short run expectations, investment and financial constraints, process and product innovation strategies. The results are sectoral and macroeconomic dynamic properties, in particular, trajectories with fluctuations and trend components for output and other aggregate demand items, as well as, the aggregate behavior of functional and personal income distribution. Main references are Nelson and Winter (1982), Simon (1979), Silverberg (1987), at the micro level and Keynes (1936), Kalecki (1954), Minsky (1975) at both the micro and the macro ones. The theoretical assumptions and the basic structure of the model we use have been extensively discussed in Possas and Dweck (2004, 2011) and Dweck (2006).

The model accounts for a complete and coherent accounting system. We incorporate the agents' balance sheets and we track the financial-real transactions undertaken by agents and the flows of real-financial stocks they create. Since our model is stock-flow consistent (SFC) and is agent-based, it anticipated, in a simple and still insipient way, an integrated approach to Agent Based - Stock and Flow Consistent (AB-SFC) modelling, as proposed by Caiani et al. (2016). In Appendix A, we present a balance-sheet matrix, a flow of funds table and a transaction-flows to account for the stock-flow consistency of our model.

[2] It is worth noticing that "agent-based" is an atheoretical methodology, an instrument, which can be applied to many different theoretical backgrounds. The theory in agent-based models lies on the specification of behavioral equations. This methodology became popular among evolutionary authors, since it allows the representation of the economic system as a complex system of interacting agents. See Tesfatsion (2006) and Fagiolo and Roventini (2016) for a broader discussion and definitions on agent-based modelling.

[3] We recognize the existence of an increasing number of models in the recent years, many of them already considering the role of effective demand and of fiscal policy, in particular. This section was not supposed to extensively review the entire literature but was, in contrast, to briefly discuss the historical increasing role of demand in these models. For a more extensive review, see Fagiolo and Roventini (2016) and Dawid and Gatti (2018)

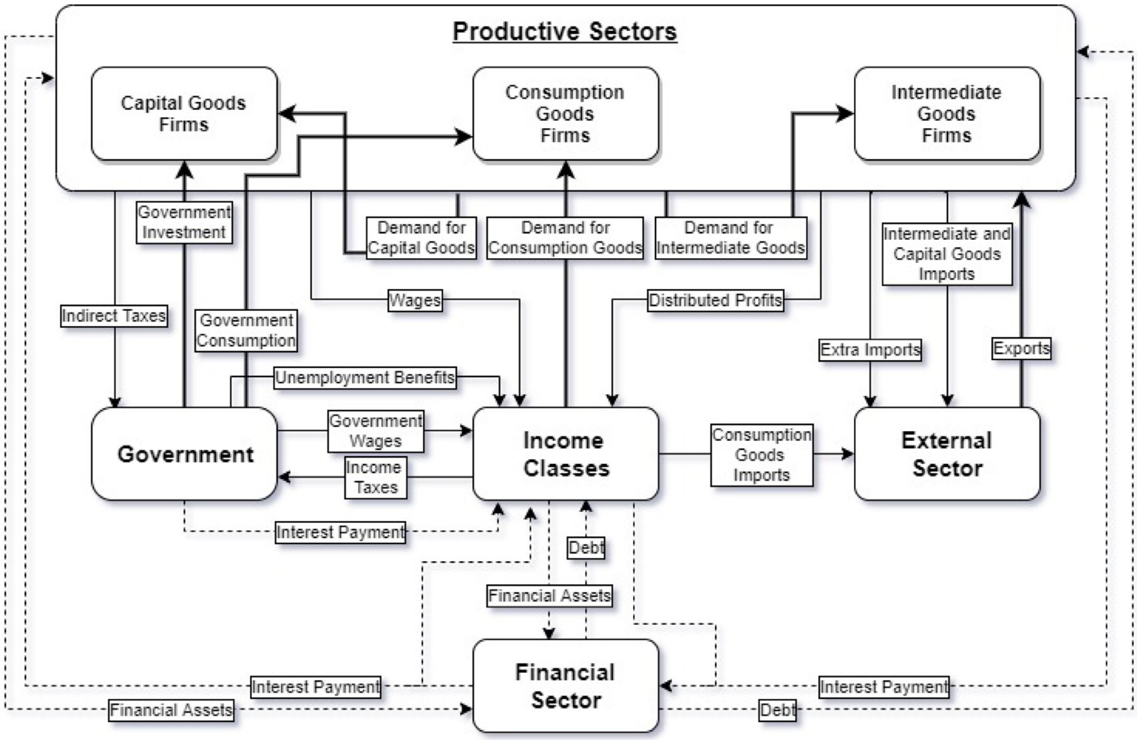

Fig. 1. Model structure and flows.

The main equations of the model[4] were presented elsewhere (Possas and Dweck, 2004) and are presented is a simplified version in Appendix D, so only the timeline of the main events, the main agents of the model [5] and the new formulations for the government and the fiscal policy rules will be presented here in detail. The agents are: (i) non-financial firms, which are organized in four different productive sectors; (ii) household income classes; (iii) the government; (iv) the external sector; and (v) the financial sector. They are connected in the following way: income classes, the government and the external sector buy consumption goods, generating demand for the consumption goods sector; all firms, the government and the external sector have investment decisions, generating demand for the capital goods sector; all firms and the external sector need inputs to produce, generating demand for the intermediate goods sector; these sectoral demands are subdivided among the firms according to their relative competitiveness, given a replicator equation; all firms pay wages and distribute profits, generating income to the households income classes; finally, firms, income classes and government have a balance sheets, thus they pay to and receive interests from the financial sector. Fig. 1 represents the structure and flows of the model where thick lines represent demand for goods, normal lines income flows and traced lines financial flows.

4.1. Timeline of events at each period

1. Firms receive new capital at the beginning of each investment period[6].

[4] Appendix B presents a description of our model in line with the extensive literature review done by Dawid and Gatti (2018). This way, some properties and features of our model can be compared to other models in the literature.

[5] This is an agent-based model, although part of the sectors is treated at the aggregated level, such as the financial and external sectors. Agents are part of the system and for each one there is a set of initial conditions and behavioral rules.

[6] Investment decisions are taken at the end of each investment period (time interval between consecutive investment decisions), which, for simplification, is assumed to comprise six production periods each for every sector. Decision making starts with a forecast of average sales for the next production periods [t+6; t+12] when the new capacity, resulting from current investment, will be operative - by definition, its “construction period”, also assumed to be equal to the investment period.

2. Planned Production – first firm's decision – differentiated among sectors: for consumption and intermediate goods it depends on expected sales; for capital goods it depends of effective orders. This is one of the most important effects of the effective demand principle and it was the way Keynes presented it: the decision to produce depends, given the cost structure, on the demand expectations of firms.
3. Effective Productions – it depends on the productive capacity and inputs availability, given de planned production. Firms in every sector use labor, capital and inputs in order to produce, based on a Leontief production function.
4. Price Decision – second firm's decision – weighted average among desired price and average market price; desired price is determined by a desired mark up over variable cost[7].
5. Total sectoral orders
   (a) Consumption Goods – depends on income classes, government consumption and exports.
   (b) Capital Goods – depends on firms' and government's decisions to invest.
   (c) Intermediate Goods – third firm's decision: depends on firms' decision to order intermediate goods for next period production.
6. External Sector – imports: part of the total expenditure is supplied by imports given fixed imports coefficient specific to each sector. Exports are determined by a fixed coefficient, over the "rest of the world" income, (measured in domestic currency) and the corresponding income elasticity on the world market. Additional imports can occur if domestic supply is not able to meet demand.
7. Government Sector – government hires workers, invest, consume goods and pay unemployment benefits. Total expenditures, as it will be explained bellow depends on the fiscal rule, which will be the main object of simulation. Tax revenues are both income tax and indirect tax over production.
8. Firm's orders – effective orders received by a firm depend on total sectorial demand, and on the firm's market share, determined by the replicator dynamic equation, under the effect of firm's competitiveness.
9. Sales – actual sales are determined by the effective orders, which may or may not correspond to the expectations that previously defined the level of production. This interaction between sales and production over time creates a mechanism of dynamic induction over the subsequent production decisions, via changes on the expected behavior of future sales.
10. Income creation
    (a) Functional Distribution
        - Wages – determined by government wages and the level of private employment which depends on total private production, given the unitary wage per sector;
        - Profits – determined by revenues of sales given total costs; part is distributed to households and the rest is reinvested or allocated at the financial sector.
    (b) Personal distribution: wages and profits are converted into personal income classes a matrix of personal income appropriation (personal income class x functional).
11. Investment Decision – fourth firm's decision: given the financial restriction, at the end of each investment period firms must decide the amount of investment. This decision is divided into three different components:
    (a) Investment on capacity expansion (induced liquid investment) - depends on expected sales and the capacity utilization level;
    (b) Investment on physical depreciation – added to the first one, they both comprise the induced gross investment;
    (c) Investment given the technological obsolescence of capital equipment (autonomous investment) – depends on the product and process innovative success;
12. Innovative Success – the innovation and diffusion (imitation) processes follow closely those 2 stage process proposed by Nelson and Winter (1982). Technological search by any firm is accomplished through process and product R&D. The assumption made here is that the industrial sector being modeled introduces technical change basically embodied in the equipment ordered or it changes the quality of its goods. Internal process R&D is assumed to be crucial for design and technical improvement of the capital equipment.
13. Entry and Exit – firms may exit the market due to low market-shares or high indebtness. In the second case, it allows market space for new possible firms to enter. Thus the number of firms is not constant in the model.

[7] The price equation used here, as shown in Possas et al. (2001), is a discrete version of Silverberg's, consistent with the version specified before for the replicator equation and it is also identical to the price equation used by Kalecki (1954) in his analysis of the "degree of monopoly" of a firm under imperfect competition.

4.2. The government and fiscal policy rules in the model

In our model, we tried to capture a more complete role of fiscal policy, although the government is introduced still in a very simple way. Tax revenues are both direct, as income taxes, and indirect taxes. Indirect taxes are paid by sectors according to their sales proceeds. Income taxes are applied over the total amount of personal income of each income class, with class specific rates. Government expenses are divided in four components: (i) wages; (ii) consumption of goods and services; (iii) investments and (iv) unemployment benefits. Wages are appropriated by each income class according to specific distribution while unemployment benefits are appropriated by the lower income class for simplicity reasons. Other consumption of goods and services and investments are considered as demand to the specific sectors, consumption and capital goods sectors respectively.

In Possas and Dweck (2004, 2011), public expenditures were modeled in a different ways: a fixed primary budget surplus target was assumed, which prevents it from having any effect over the long run growth trend. In the current work, in order to capture the recent debate on fiscal rules, we studied new scenarios, as follows.

The current standard initial condition consists in a case with no policy rule constraint. The initial distribution between the three components of government expenditure is fixed: 80% consists of wages, 10% is consumption and 10% is investment. There are no unemployment benefits initially. Each year, all components of expenditures are adjusted by the inflation. Government has a desired real growth rate, based on an average real rate without any government influence. Government wages, investment and consumption grow at this rate each year. Unemployment benefits are a percentage of the average wage of the economy. Unemployment is calculated based on the difference between aggregate effective employment (effective production over firm's labour productivity) and aggregate potential employment (productive capacity over firm's labour productivity). Unemployment is calculated this way because the model has no labour constraints, as most of developing economies like Brazil.

$$UB_t = \omega \times \overline{W}_t \times \sum_{i=1}^{N} \left(\left(\frac{Y*_{i,t}}{\overline{\pi}_{i,t}} \right) - \left(\frac{Y^e_{i,t}}{\overline{\pi}_{i,t}} \right) \right) \quad (1)$$

where $\overline{W}_t$ is the average wage of the economy, ω is the percentage of the average wage paid as benefits, $Y*_{i,t}$ is the productive capacity of firm i, $\overline{\pi}_{i,t}$ is the labour productivity of firm i, $Y^e_{i,t}$ is the effective production of firm i and N is the total number of firms in the economy.

The first fiscal policy rule is a primary budget surplus target. The government first calculates what is the potential total amount of expenditure determined by the surplus target based on expected tax revenue. Expected tax revenue is a simple extrapolation of the total amount of taxes in the last period by an expected growth rate based on the previous GDP growth rate adjusted by an expectation parameter.

$$G^P_t = [T_{t-1} \times (1 + \sigma \times_{t-1})] - [ps_t \times GDP_{t-1} \times (1 + \sigma \times g_{t-1})] \quad (2)$$

where G^P_t is the potential total amount of expenditures, T_{t-1} is the total tax revenue in the last period, σ is the expectation parameter, g_{t-1} is the GDP growth in the last period, ps_t is the primary budget surplus target rate and GDP_{t-1} is the gross domestic product in the last period.

The most relevant fiscal policy rule for this analysis is the one implemented in the recent years in Brazil: no real growth for total government expenditures. With this rule, the potential total amount of expenditures in a year cannot exceed the total amount of expenditures in the last period adjusted by inflation.

$$G^P_t = G_{t-1} \times (1 + \pi_{t-1}) \quad (3)$$

where $G^{\max}_t$ is the maximum potential total amount of expenditures, G_{t-1} is the total amount of expenditures in the last period and π_{t-1} is the inflation in the last period.

In order to analyze the current Brazilian situation,[8] we have tested both rules individually and together. Individually, we test the "pure" effect of the introduction of this rule. When both rules are valid, the maximum expenditures will be always the minimum between the two rules. Therefore, even if the potential total amount of expenditures defined by

[8] Although we want to analyze the Brazilian case, our model does not replicate Brazilian particularities nor is calibrated to Brazil's data, so it is not an empirical model. It's a theoretical model in which we apply the current fiscal rules in effect in Brazil.

the primary budget surplus target rule is greater, the no real growth rule determines the maximum of the potential total amount of expenditures.[9]

When one or more fiscal policy rule is in effect, government wages are considered as mandatory spending. Other components follow a priority order: government prioritises unemployment benefits, then consumption expenditures, and lastly the investment.

$$W_t^G = \min[G_t^P, (W_{t-1}^G \times (1 + g*) \times (1 + \pi_{t-1}))] \quad (4)$$

$$UB_t^G = \min[(G_t^P - W_t^G), \quad (UB_t)] \quad (5)$$

$$C_t^G = \min[(G_t^P - W_t^G - UB_t^G), \quad (C_{t-1}^G \times (1 + g*) \times (1 + \pi_{t-1}))] \quad (6)$$

$$I_t^G = \min[(G_t^P - W_t^G - UB_t^G - C_t^G), \quad (I_{t-1}^G \times (1 + g*) \times (1 + \pi_{t-1}))] \quad (7)$$

where W_t^G is effective government wages, UB_t^G is effective unemployment benefits, C_t^G is effective government consumption and I_t^G is effective government investment. G_t^P is the government potential total amount of expenditures, determined by fiscal rules.

5. Simulation and results

The main purpose of the simulations in this paper is to test theories on complex processes, more specifically investigating the dynamics emerging from the hypotheses and parameters introduced in the model, instead of replicating real phenomena.[10] This involves not only to restate some expected results - and to verify the conditions under which they take place -, but also to find out new properties. The relevance of simulations for the latter objective results from such ("emergent") properties not only being unintuitive, from the sheer complexity of the processes involved, but also from often not being able to obtain from mathematical solutions without introducing too strong simplifications as to become potentially harmful for the reliability of results or their interpretation.

5.1. Simulation settings

We have run 10 independent simulations for each case, each of them involving at least 500 periods. Most of the time, the first 100 periods are discarded to reduce the effects of the selected initial values of state variables.

The first case (S1) is our current initial condition, without constraint to total spending. In order to define the desired growth rate $g*$ we calibrated the model using the previous model's standard condition where the government spending was totally pro-cyclical. The average GDP growth rate of this case was used as the desired growth rate for government spendings in the standard setting.

The following scenarios were: (S2) to include a primary budget surplus rule; (S3) to include only a no real growth celling; (S4) to include both the primary budget surplus rule and no real growth celling; (S5) the same rule as in S1, but with a higher desired growth rate. All five scenario were tested including an external shock, a decrease in external income during 20 consecutive periods. It is worth mentioning that in our simulations, interest rates[11] and exchange rates are fixed for all periods.

Since our model includes both deterministic and very few stochastic components, the simulations shown ahead will exhibit three main factors generating variety: changes in initial conditions and in parameters, as usual, but also in the random seeds employed. Instead of an extensive and systematic analysis, we chose to perform a simpler one: to replicate the same configuration for a number of runs, in order to detect the stochastic variability. The stochastic component of the model is practically reduced to technological success of firms, so that changes in initial conditions and in parameters remain the main explanation of the results.[12] Appendix C shows the values of our parameters and initial values of some variables.

[9] This is the case in Brazil nowadays.

[10] In this sense it keeps away from so-called "history-friendly" models.

[11] This will be the theme of a future work where we will analyze the effects of different monetary policy rules in a very similar way that is done in this work.

[12] An extensive sensitivity analysis of parameters and initial conditions will also be done in future work.

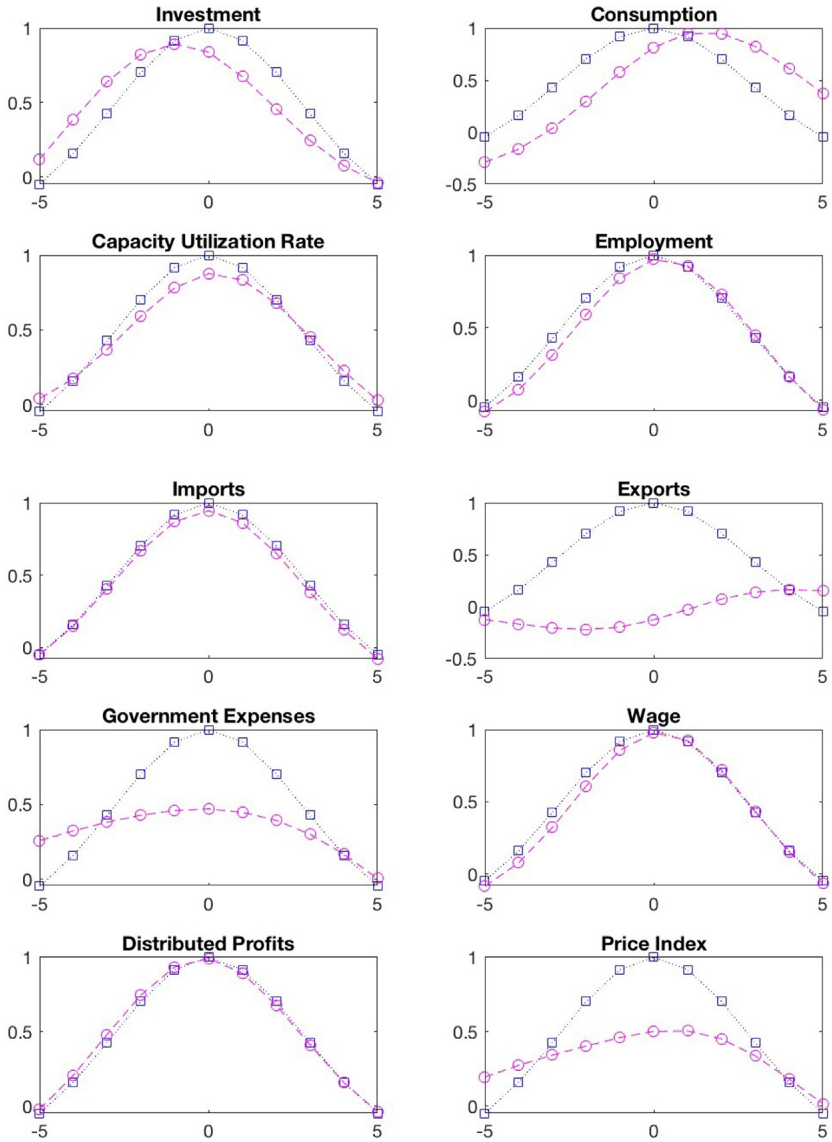

Fig. 2. Cross-correlations with GDP of Investment, Consumption, Capacity Utilization Rate, Employment, Exports, Imports, Government Expenses, Wages, Distributed Profits and Price Index, at different leads and lags.

5.2. Standard case and empirical validation

As shown in Possas and Dweck (2011) the general macrodynamic properties derived by the simulations as regards growth trends follow those of the theories and models centered in the principle of effective demand, namely: (i) although the fluctuations are very irregular, they are relatively stable; (ii) the existence of a long run growth trend, also irregular, related to the autonomous components of aggregate demand – investment and consumption, public expenditures and net exports - and not to any supply impulse or shock as in most mainstream models.

The effect of autonomous investment over the long run trend, in particular associated to innovation, is significant only when a high technological dynamism is assumed and the financial constraint is taken out. The autonomous consumption associated with product innovation, on the other hand, plays a more important role, increasing with the innovation pace. Net exports, as expected, have a direct impact when they are supposed to grow at a positive rate. As for the microdynamic effects of the benchmark simulations, some important results were the effects of product differentiation strategy in terms of market concentration, increasing mark ups, and their effects on income distribution. As price competition becomes less important as compared to product differentiation there is a significant increase in prices, mark ups, and therefore in profit share on income.

Table 1
Average values of variables across simulations for each case.

Case	S1	S2	S3	S4	S5
Average GDP Growth Rate	0.015772	0.016192	0.012938	0.013328	0.017819
Std. Dev. GDP Growth Rate	0.014678	0.020972	0.016778	0.015829	0.014253
Average Investment Growth Rate	0.019327	0.025922	0.020773	0.020395	0.021492
Std. Dev. Investment Grwoth rate	0.097489	0.125395	0.122168	0.117556	0.100814
Likelihood of Crisis	26.10	32.40	39.20	38.40	21.90

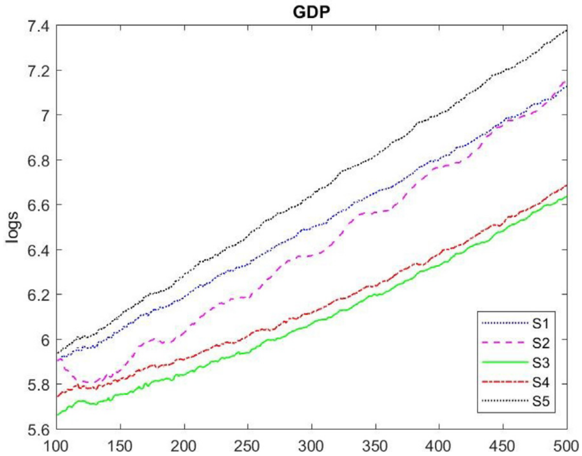

Fig. 3. Cross-simulation average of GDP growth rates (in log) in time.

The model, as shown in Possas and Dweck (2011), is then able to reproduce at the same time a wide set of empirical regularities, like macro and micro stylized facts, while holding the set of parameters fixed. For instance, the model is able to generate: (a) endogenous self-sustained growth with persistent fluctuations; (b) relative volatility of GDP, consumptions and investment; (c) cross-correlation of macro variables such as employment, aggregate inventories, wages and profits, price level and capital stock; (d) pro-cyclical aggregate R&D investment; (e) cross-correlation between firms debt and loan losses; (f) productivity heterogeneity among firms; (g) persistent productivity differential among firms; (h) firms are main locus of technological accumulation; (i) asymmetry among firms; (j) path-dependence and increasing dynamic returns in the process of technological change. Fig. 2 show some of the cross-correlations reproduced by our Standard Case in this version (S1).

In addition, tests have shown that the average GDP growth rate of our standard case (S1) is the same as in the previous model, where government expenses had no impact on economic growth and there was a reduction of 15% of the standard deviation. Therefore, the introduction of countercyclical unemployment benefits policy is unbiased and reduces GDP volatility. By using this unbiased countercyclical policy in addition to the fixed desired growth rate for the other components in the stardard case, total government expenses are practically not correlated with GDP, as can be shown in Fig. 2.

5.3. Comparative results

Table 1 shows average values of some variables across simulations, discarding the first 100 periods. Average growth rates for GDP and Investment reflects their trend component while Standard Deviation reflects their volatility. In addition, Likelihood of Crisis is a counter that shows how many times real GDP growth rate was negative during the 500 periods.[13] Fig. 3 shows a cross-simulation average trajectories of GDP growth rates. We can clearly see that:

- Compared to the standard case, the introduction of a Primary Surplus Target rule (S2) presents a greater GDP growth, this is because the final level of GDP is the same as in the standard case (S1), but, in the first 100 periods, there is a much lower increase in S2 than in S1. In the other hand, since the government expenses became pro-cyclical, it

[13] Altought a little bit different, this is very much inspired by Dosi et al. (2010, 2013, 2015).

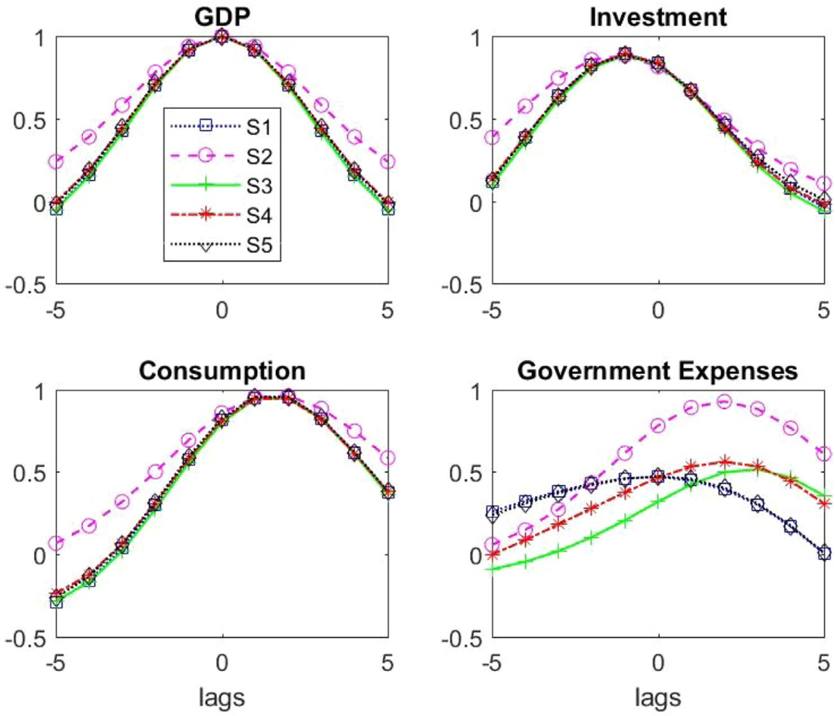

Fig. 4. Cross-correlations of GDP, Investment and Government Expenses, with GDP, at different leads and lags.

increases GDP volatility (it can also be seeing in Fig. 3). Investment has the same pattern as GDP. Another important remark is that, since it creates a "stop-and-go" scenario, it also increases the likelihood of a crisis.

- Compared to the standard case, the introduction of a no real growth rule (S3) decreases the GDP growth trend, since it limits one of the main components that leads economic growth, and it does not reduce its volatility. On the contrary, it increases the volatility, since it does not allow the automatic stabilizers to act when the economy is in a low growth trajectory. This is also visible in the Likelihood of Crisis, which increases significantly compared to the standard case (S1).
- Compared to the standard case, when both rules are in effect (S4), the results are very similar to S3, but the effect of the primary surplus rule in the first periods increases the growth rate, generating an average GDP growth rate a little bit higher. The Likelihood of Crisis is as high as in the S3 case.
- Compared to the standard case, the introduction of a greater positive real growth rate for the government expenses allowing the countercyclical policy to happen (S5), the long-term GDP growth is higher, GDP volatility is lower, Investment growth is also higher and finally, this case is the less likely to generate crisis.
- Of all cases, S5 has the highest GDP and Investment growth trend, lowest GDP volatility and lowest Likelihood of Crisis. Of all cases, S3 presents the lowest GDP growth trend, followed closely by S4. Both cases present the higher Likelihood of Crisis. S2 presents the highest GDP volatility.

Fig. 4 presents the comparison of cross-correlations among the different simulation scenarios. In line with the results of Table 1, S2 scenario is the most volatile one, which increases the lagged cross-correlation. In all scenarios, consumption and investment are pro-cyclical, and are lagging and leading, respectively. The greatest difference, as expected, are the cross-correlation of government expenses. In S2 scenario, government spending is very pro-cyclical and lagging, while in all other scenario, which incorporate some kind of government expenses rule, it becomes acyclical. The main differences among them is that in scenarios S3 and S4 the highest cross-correlation is at lag 2.

In addition, our simulations show that, when facing an external crisis, an unconstrained countercyclical policy is much more able to mitigate the negative effects. Fig. 5 shows how the external shock effects are lower in cases S1 and S5. The economy is able to maintain the level of GDP because government expenditures compensate the reduction of external income as source of growth. When fiscal rules constraints the countercyclical policy, the economy faces a slow recovery, taking almost 20 periods (5 years) to catch up with its GDP growth trend. The level impact of the crisis is never recovered.

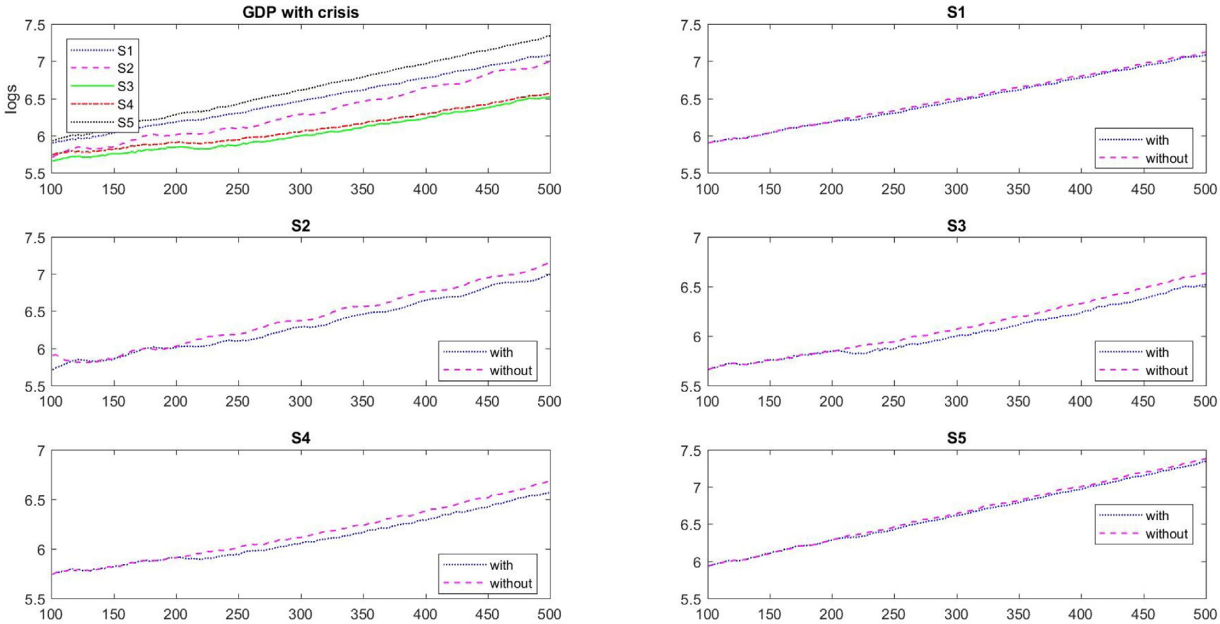

Fig. 5. Cross-simulation average of GDP trend with external shock. First graph compares all five cases with external shock. All others compare each case, with and without external shock.

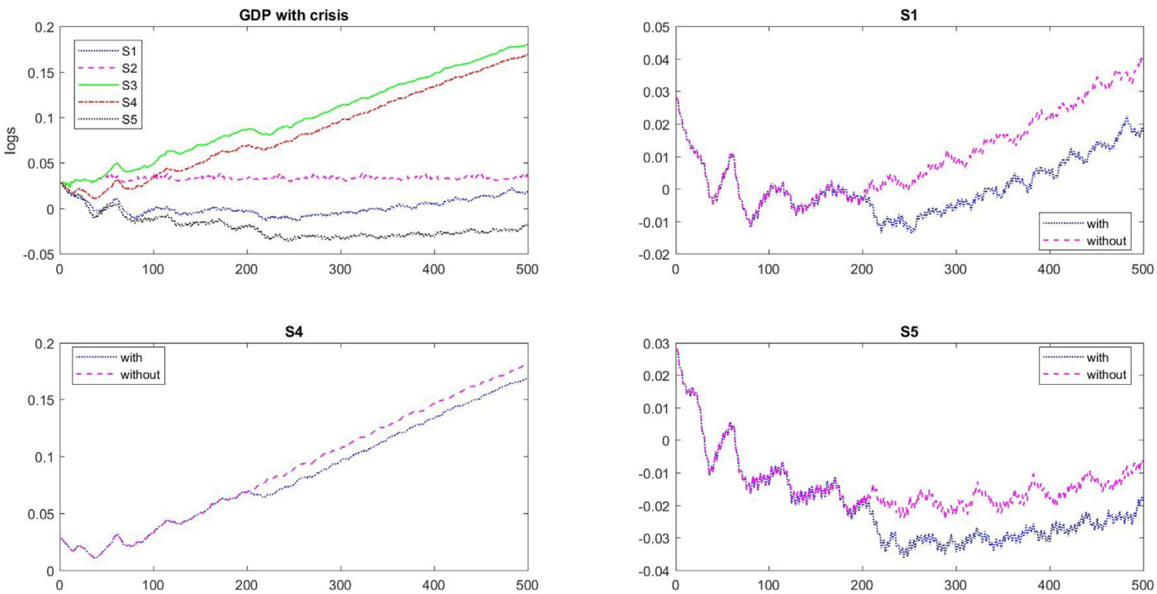

Fig. 6. Cross-simulations average of Government Primary Surplus with external shock. The first graph compares all cases with external shock while the others shows some cases with and without external shock.

As happened in many countries during the GFC, countercyclical policies had a negative effect in fiscal results, as can be seen in Fig. 6. However, a few periods after the crisis it stabilizes and even starts to grow as the economy recovers. An important remark related to no real growth rule is that primary surplus increases continuously, since government expenses growth is always lower than tax revenues and GDP growth. Another very important remark related to primary surplus trajectories: in scenarios S1 and S5 there is a decrease in primary surplus because government increases expenditures, but tax revenues is practically the same as before, since as shown in Fig. 6 there is no decrease in GDP level. On the other hand, in all other scenarios the decrease of tax revenues explains the decrease in primary surplus. This last result is a feature related to self-defeating fiscal consolidation.

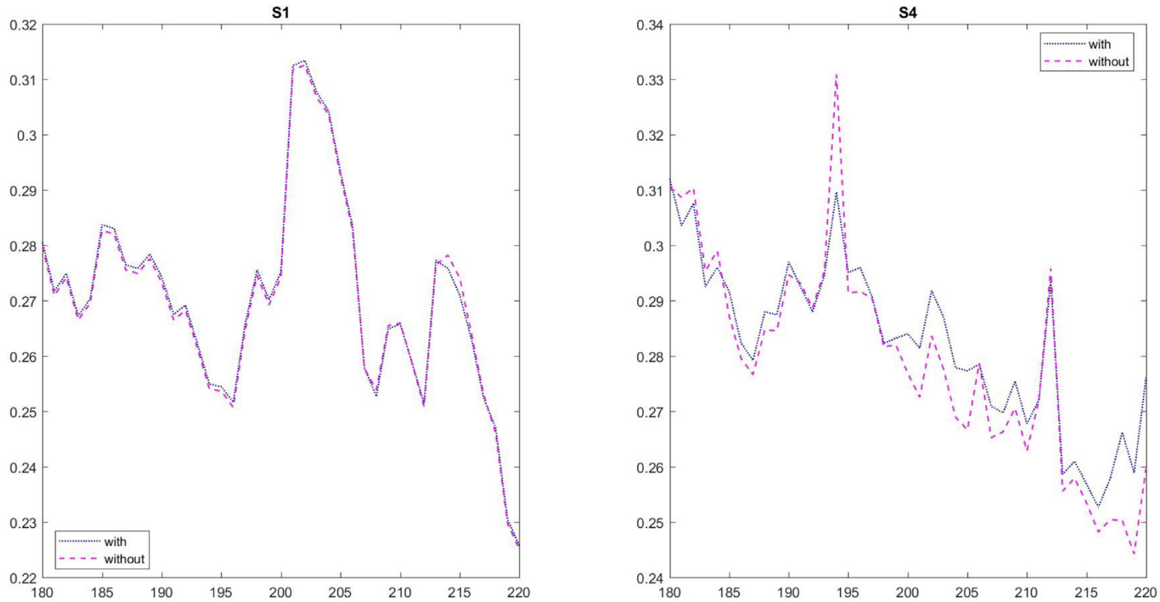

Fig. 7. Average Firm's indebtedness in the capital goods sector, with and without external shock.

Finally, the model is able to replicate another typical element of self-defeating fiscal consolidation related to the indebtedness of firms, captured only in an AB-SFC model. In scenarios where there is no countercyclical policy during the crisis, such as in S4, there was an increase in firms' indebtedness, during the external crisis, as can be seen in Fig. 7. On the other hand, in S1 scenario there is almost no difference in firms' indebtedness, since fiscal policy prevented the negative effects of the external crisis in national GDP[14].

6. Final remarks

The aftermath of the GFC reignited the debate around the role of fiscal policy. To analyze the role of fiscal policy, in this paper, we propose an Agent-Based micro-macro multisectoral model incorporating some government expenses feature and fiscal policy rules in the model developed by Possas and Dweck (2004, 2011). The role of demand and, in particular, of fiscal policy in evolutionary models were reviewed, highlighting specially the developments proposed by Dosi, et al. (2010, 2013, 2015), that inspired new formulations in our model.

We then simulated five different scenarios concerning fiscal rules: one base scenario with a neutral countercyclical policy, one with primary budget target rule, one with the Brazilian no real growth rule, one with both rules and a fifth one with an unconstrained countercyclical policy targeting a higher desired growth rate than the neutral one. We evaluated how each combination of fiscal rules affects the long-term growth trend and fluctuations of the business cycle. We also analyze how each scenario responds to an external crisis.

The second scenario, with fixed primary budget surplus target is the most volatile one, and the fifth scenario is the one with highest GDP growth rate. When exposed to a crisis, all scenarios that impose a tighter constrain to government spending, such as the second, third and fourth scenario, present signs of self-defeating fiscal consolidation. These scenarios present a worse economic performance during and after the crisis, leading to a decrease in government tax revenues and therefore worsening the fiscal result. The worse scenario also affects the firms' indebtedness creating a possibility of a systemic crisis. On the other hand, in the first and fifth scenario, there was no contagious effect of the external crisis, leading to a better economic performance and reducing the likelihood of crisis.

In sum, our results show that fiscal policy rules that impose tighter constraints to government spending may lead to self-defeating fiscal consolidations, might not respond well when facing an external shock, and ultimately may create the possibility of a systemic crisis, compared to a unconstrained countercyclical fiscal policy, which may prevents contagious effects from external crisis and might lead to better economic performance. Our analysis also reinforce the

[14] Further investigations at the firm level is necessary and will be done in future work.

role of government spending not only as a countercyclical short-term policy to reduce GDP volatility and likelihood of crisis, but also as one of the most important source of long-term growth. Altought it Is not our goal to analyze the precise case of Brazil empirically, it is clear to us that the brazilian combination of fiscal rules is affecting economic performance for a few years now and might not generate higher growth rates in the future while this combination of primary budget surplus target and no real growth rule for the government spendings remains.

Appendix A. Stock-flow consistency tables

Table A.1
Table A.2
Table A.3

Table A.1
Balance sheet matrix.

	Income Classes	Firms Sectors	Financial Sector	External Sector	Government	Total
Financial Assets (A)	$+A^c$	$+A^f$	$-A$			0
Debt (D)	$-D^c$	$-D^f$	$+D$		$-D^g$	0
Fixed Capital (K)		$+K$				$+K$
Net Worth (NW)	NW^c	NW^f	NW	0	$-D^g$	$+K$

Table A.2
Transaction flows.

	Income Classes	Firms Sectors	Financial Sector	External Sector	Government	Total
Financial Assets (A)	$+\Delta A^c$	$+\Delta A^f$	$-\Delta A$			0
Debt (D)	$-\Delta D^c$	$-\Delta D^f$	$+\Delta D$		$-\Delta D^g$	0
Fixed Capital (K)		$+\Delta K$				$+\Delta K$
Total	S		ΔNW^{fs}		$-\Delta D^g$	
Net Worth variation	S		ΔNW^{fs}		$-\Delta D^g$	

Table A.3
Flow of funds.

	Income Classes	Consumption Goods Firms (cf)	Capital Goods Firms (kf)	Intermediate Goods Firms (if)	Financial Sector	External Sector	Government	Total
Consumption (C)	$-C$	$+C$						0
Intermediate Goods (In)		$-In^{cf}$	$-In^{kf}$	$-In^{if} + Im$				0
Exports (X)		$+X^{cf}$	$+X^{kf}$	$+X^{if}$		$-X$		0
Imports (M) [a]	$-M^c$	$-M^{cf}$	$-M^{kf}$	$-M^{if}$		$+M$		0
Gov. Expenses (G) [b]	$+UB^g$	$+C^g$	$+\Delta K^g$				$-G$	0
Investment (I)		$-\Delta K^{cf}$	$-\Delta K^{kf} + \Delta K$	$-\Delta K^{if}$				0
Wages (W)	$+W^f + W^g$ [c]	$-W^{cf}$	$-W^{kf}$	$-W^{if}$			$-W^g$	0
Total Taxes (T) [d]	$-DT$	$-IT^{cf}$	$-IT^{kf}$	$-IT^{if}$			$+T$	0
Debt Interest (r^d)	$-r^d_{t-1}D^c_{t-1}$	$-r^d_{t-1}D^{cf}_{t-1}$	$-r^d_{t-1}D^{kf}_{t-1}$	$-r^d_{t-1}D^{if}_{t-1}$	$+r^d_{t-1}D_{t-1}$		$-r^d_{t-1}D^g_{t-1}$	0
Financial Assets Interest (r^a)	$+r^a_{t-1}A^c_{t-1}$	$+r^a_{t-1}A^{cf}_{t-1}$	$+r^a_{t-1}A^{kf}_{t-1}$	$+r^a_{t-1}A^{if}_{t-1}$	$-r^a_{t-1}A_{t-1}$			0
Divedends (P^d) [e]	$+P_d$	$-P^{cf}_d$	$-P^{kf}_d$	$-P^{if}_d$				0
Total	S	P^{cf}_f	P^{kf}_f	P^{if}_f	ΔNW^{fs}	$M - X$	ΔD^g [f]	0

[a] All firms import capital goods and inputs if domestic supply do not meet the demand.
[b] Except wage payments. $G = C^g + \Delta K^g + UB^g$.
[c] $W^f = W^{cf} + W^{kf} + W^{if}$.
[d] DT is Direct Taxes and IT Indirect.
[e] P_d and P_f are distributed profits and retained profits respectively.
[f] ΔD^g is the nominal public deficit.

Appendix B. Model description as in Dawid and Gatti (2018)

Categories	MMM Model
1. General Properties	
Stock-flow consistent?	Yes
Expectations	Firms of every sector have expectations on short-term demand, except for capital goods firms which produce based on current orders. All firms have expectations on long-term demand, for the investment decisions
Type of expectation rules	Simple extrapolative/adaptative rule
Entry of agents?	Only to replace exited firms due to indebtedness and only occur when the sector's expected sales are in a growing trajectory
Spatial structure?	No
2. Consumption Goods Market	
Producers	
Single/multiple goods?	Single differentiated goods
Production technology	Capital vintages with different labor productivities
Pricing rule	Effective price is a weighted average between desired price and industry's average price. Desired mark-ups (desired price) evolving based on firms' market share, technological progress and product differentiation;
Quantity choice	Expected demand plus desired inventories variation
Physical investment	Investment is divided in three parts: replacement due to physical depreciation, expantion due to expected demand and technological replacement based on a payback rule
Households	
Consumption budget	Disposable income, assets and loans
Purchasing decision	Induced consumption depends on each class' income and autonomous consumption of each class increases with average quality
Interaction Protocol	Replicator dynamics. market shares of firms determined by prices, quality and delivery delay
3. Capital Goods Market	
Capital Goods Producers	
Differentiated physical capital?	Multiple vintages
Technological change	Competing firms in every sector update their possible vintage through innovation and imitation, process modeled in the spirit of Nelson and Winter (1982). Innovation is implemented by aquisition of CaG
Pricing rule	Effective price is a weighted average between desired price and industry's average price. desired mark-ups (desired price) evolving based on firms' market share, technological progress and product differentiation
Interaction Protocol	Replicator dynamics. Production based on received orders, limited to productive capacity; delivered after one investment period (6 time steps)
Capital Goods Demand	Orders to CaG sector depend on firms decisions to invest which is divided in three parts: replacement due to physical depreciation, expantion due to expected demand and technological replacement based on a payback rule
4. Labor Market	
Firms	
Labor demand	All firms demand labor based on effective production and productivity
Wage offers	Homogeneous wage in each sector, adjusted over time based on sector average productivity and inflation
Workers	
Differentiated workers?	No
Labor supply	Unlimited labor supply
Reservation wage	Not applicable
Interaction Protocol	No explicit interaction protocol
5. Credit Market	
Firms	
Demand for external financing (third party finance)	Liquidity needs that cannot be financed internally from the own funds and liquid assets, limited to a maximum indebtedness. Over the maximum level of indebtedness, internal funds must be used to repay debt. Firms also keep a buffer of liquid assets, proportional to capital stock
External financing options	Only bank credit
Bankruptcy rule	If the firm's level of indebtedness is higher than desired and growing for a sequence of periods

Banks	
Credit supply	Unlimited credit supply unless the firm is over the indebtedness threshold
Interest rate	Firm-specific spread over CB rate, based on past indebtedness
Regulatory constraints	None
Bank exit	Not applicable
Interaction protocol	None
6. Stock Market/Financial Management	
Firms	
Dividend payout	No dividends. Firms have a fixed profit distribution rate on net profits, after interest payments and depreciation expenses.
Households	
Financial investment	Income classes can save and have financial assets, as well get debt to spend more than its income
Interaction protocol	None
7. Policy Makers	
Government	
Fiscal measures	Public employnent, unemployment benefits, investment and consumption
Balaced budget?	Fiscal rules are the subject of this paper
Central Bank	
CB interest rate	Fixed interest rate

Appendix C. Initial conditions

Tables C.1, C.2, C.3 and C.4

Table C.1
Sectorial parameters and initial conditions.

Sectors	C. Goods	K. Goods	I. Goods 1	I. Goods 2
Input Output Coefficients	Table B3	Table B3	Table B3	Table B3
Capital/Output relation	1	1	1	1
Labor Productivity (Vintages)	1	1	1	1
Desired Capacity Utilization	0.8	0.8	0.8	0.8
Desired proportion of stocks	0.1	0.1	0.1	0.1
Desired Debt Rate	0.6	0.6	0.6	0.6
Desired liquidity rate	0.05	0.05	0.05	0.05
Profits distribution rate	0.7	0.7	0.7	0.7
Learning by doing Parameter:				
Bonus	0.1	0.1	0.1	0.1
Skill increase	0.05	0.05	0.05	0.05
Expectations Parameter	0.3	0.3	0.3	0.3
Mark up	1.5	1.6	1.6	1.6
Technological Parametes:				
Technological Opportunities	0.001	0.005	0.003	0.003
an	0.175	0.7	0.427	0.347
am	0.0874	0.35	0.213	0.173
Sector Wage	0.22	0.18	0.18	0.18
Physical Depretiation Period	60	60	60	60
Payback Period	42	42	42	42

Table C.2
Macro parameters and initial values.

Macro	
Quarterly GDP	271
Quarterly Government Expenses	70
Quarterly Government Wages	56
Quarterly Government Investment	7
Quarterly Government Consumption	7
Quarterly Interest Rate	0.04
Expectation Parameter	0.3
Desired Real Growth Rate	0.011
Countercyclical Adjustment Parameter	0.0005
Wage Growth Rate Maximum	0.014
Wage Growth Rate Minimum	0.008
Primary Surplus Target [a]	0.3
Public Debt	400
Consumer Price Index	1
External Income	10000
External Income Growth	0.005
External Shock Period [b]	200
External Shock Duration[b]	20
Exchange Rate	1

[a] Used only in scenarios witch Primary Surplus rule was in effect.
[b] Used only in scenarios with external shock.

Table C.3
Sectorial input-output matrix.

	I. Goods 1		I. Goods 2	
	Domestic	External	Domestic	External
C. Goods	0.15	0.01875	0.25	0.03125
K. Goods	0.25	0.03125	0.15	0.01875
I. Goods 1	0.3	0.0375	0.1	0.0125
I. Goods 2	0.1	0.0125	0.3	0.0375

Table C.4
Income class parameters.

	Class A	Class B	Class C	Class D
Income	67	42	26	15
Profit Share	0.6	0.25	0.1	0.05
Wage Share	0.4	0.3	0.2	0.1
Income Tax	0.2	0.15	0.1	0

Appendix D. Equations

Planned production

$$y*_{i,t} = y^e_{i,t}(1+\sigma) - y^s_{i,t-1} \tag{D.1}$$

subjected to $0 < y*_{i,t} < \overline{y}_{i,t}$ and $0 < y*_{i,t} < in^s_{i,t-1}a^{-1}$

where

$y*_{i,t}$ is the effective production of firm i in period t

$y^e_{i,t}$ is the expected demand for sales of firm i in period t

σ is the desired inventories proportion of firm i in period t

$y^s_{i,t-1}$ is the stock of inventories of firm in period $t-1$
$\overline{y}_{i,t}$ is the productive capacity of firm i in period t
$in^s_{i,t-1}$ is the stock of inputs of firm i in period $t-1$
a is the technical coefficient of inputs

$$^k y*_{i,t} = {}^k e_i, t \tag{D.2}$$

subjected to $0 < {}^k y*_{i,t} < {}^k\overline{y}_{i,t}$ and $0 < {}^k y*_{i,t} < {}^k in^s_{i,t-1} a^{-1}$
where
$^k y*_{i,t}$ is the effective production of firm i in the capital goods sector in period t
$^k e_i, t$ is the effective orders of firm i in the capital goods sector in period t

Expected sales

$$y^e_{i,t} = e_{i,t-1} + \gamma(e_{i,t-1} - e_{i,t-2}) \tag{D.3}$$

where
$y^e_{i,t}$ is the expected demand for sales of firm i in period t
$e_{i,t-1}$ is the effective orders of firm i in period $t-1$
$e_{i,t-2}$ is the effective orders of firm i in period $t-2$
γ is the expectational parameter

Sectoral demand

$$^i e_t = \sum_{i=1}^{N} (ay*_{i,t}(1+\gamma) - in^s_{i,t}) \tag{D.4}$$

where
$^i e_t$ is the sectoral orders of the intermediate goods sector in period t
N is number of firms
a is the technical coefficient of inputs
$y*_{i,t}$ is the effective production of firm i in period t
γ is the expectational parameter
$in^s_{i,t}$ is the stock of inventories of firm in period t

$$^c e_t = \sum_{i=1}^{K} (c_i \overline{Y}_{i,t} + C^a_{i,t}) + C^{gov}_t \tag{D.5}$$

where
$^c e_t$ is the sectoral orders of the consumption goods sector in period t
K is number of income classes
c_i is the propensity to consume on income of class i
$\overline{Y}_{i,t}$ is the average income of class i in period t, based on last four periods
$C^a_{i,t}$ is the autonomous consumption of class i in period t, based on financial assets growth and consumption goods quality growth
C^{gov}_t is the government consumption in period t

$$^k e_t = \sum_{i=1}^{N} (I_{i,t}) + I^{gov}_t \tag{D.6}$$

where
$^k e_t$ is the sectoral orders of the capital goods sector in period t
N is number of firms
$I_{i,t}$ is the investment of firm i in period t

I_t^{gov} is the government investment in period t

Firm's demand (replicator dynamics)

$$s_{i,t} = s_{i,t-1}[1 + \mu(\frac{E_{i,t}}{\overline{E}_t} - 1)] \tag{D.7}$$

where
$s_{i,t}$ is the market share of firm i in period t
$s_{i,t-1}$ is the market share of firm i in period $t-1$
μ is market share adjustment parameter and $0 < \mu < 1$
$E_{i,t}$ is the competitiveness of firm i in period t
$\overline{E}_t$ is the average competitiveness of the sector in period t

$$E_{i,t} = \frac{Q_{i,t}^{\varepsilon^q}}{p_{i,t}^{\varepsilon^p} \times dd_{i,t}^{\varepsilon^{dd}}} \tag{D.8}$$

where
$E_{i,t}$ is the competitiveness of firm i in period t
$Q_{i,t}$ is the quality of firm i in period t
$p_{i,t}$ is the price of firm i in period t
$dd_{i,t}$ is the delivery delay of firm i in period t
ε is the respective elasticicty

$$e_{i,t} = s_{i,t}e_t \tag{D.9}$$
[15]

where
$e_{i,t}$ is the effective orders of firm i in period t
$s_{i,t}$ is the market share of firm i in period t
e_t is the sectoral effective orders in period t

Sales

$$x_{i,t} = \min(e_{i,t}, (y*_{i,t} + y^s_{i,t-1})) \tag{D.10}$$

where
$x_{i,t}$ is sales of firm i in period t
$e_{i,t}$ is the effective orders of firm i in period t
$y*_{i,t}$ is the effective production of firm i in period t
$y^s_{i,t-1}$ is the stock of inventories of firm i in period $t-1$

$$y^s_{i,t} = y^s_{i,t-1} + y*_{i,t} - x_{i,t} \tag{D.11}$$

where
$y^s_{i,t}$ is the stock of inventories of firm i in period t
$y^s_{i,t-1}$ is the stock of inventories of firm i in period t-1
$y*_{i,t}$ is the effective production of firm i in period t
$x_{i,t}$ is sales of firm i in period t

$$dd_{i,t} = \frac{e_{i,t}}{x_{i,t}} \tag{D.12}$$

where
$dd_{i,t}$ is the delivery delay of firm i in period t
$e_{i,t}$ is the effective orders of firm i in period $t-1$
$x_{i,t}$ is sales of firm i in period t

Price

$$p_{i,t} = \theta p^d_{i,t} + (1-\theta)\overline{p}_{t-1} \tag{D.13}$$

$$p^d_{i,t} = k^d_{i,t} u_{i,t} \tag{D.14}$$

where
$p_{i,t}$ is the price of firm i in period t
θ is the price strategy parameter
$p^d_{i,t}$ is the desired price of firm i in period t
$k^d_{i,t}$ is the desired markup of firm i in period t
$u_{i,t}$ is the unit variable cost of firm i in period t
$\overline{p}_{t-1}$ is the sector average price in period $t-1$

Income generation

$$P_t = \sum_{i=1}^{N} ((1-t^i)x_{i,t}p_{i,t} - u_{i,t}y*_{i,t}) \tag{D.15}$$

where
P_t is the total net profits in period t
N is the number of firms
t^i is the indirect tax of firm i
$x_{i,t}$ is sales of firm i in period t
$p_{i,t}$ is the price of firm i in period t
$u_{i,t}$ is the unit variable cost of firm i in period t
$y*_{i,t}$ is the effective production of firm i in period t

$$W_t = \sum_{i=1}^{N} (w_{j,t}(\frac{y*_{i,t}}{\overline{\pi}_{i,t}})) + w^{gov}_t \tag{D.16}$$

where
W_t is the total wages in period t
N is the number of firms
$w_{j,t}$ is the wage unit of sector j corresponding to firm i
$y*_{i,t}$ is the effective production of firm i in period t
$\overline{\pi}_{i,t}$ is labour productivity of firm i in period t
w^{gov}_t is the goverment wages in period t

$$w_{j,t} = w_{j,t-1}(1 + e^p(\frac{\Delta\overline{p}_{j,t}}{\overline{p}_{j,t-4}}) + e^{\pi}(\frac{\Delta\overline{\pi}_{j,t}}{\overline{\pi}_{j,t-4}})) \tag{D.17}$$

where
$w_{j,t}$ is the wage unit of sector j in period t
$w_{j,t-1}$ is the wage unit of sector j in period $t-1$
$\Delta\overline{p}_{j,t}$ is sector j average price variation on period t, in relation to 4 periods behind
$\Delta\overline{\pi}_{j,t}$ is sector j average productivity variation on period t, in relation to 4 periods behind
e are the respectives elasticities

$$Y_{i,t} = (1-t^d_i)(b^W_i W_t + b^P_i(dP_t)) + b^{UB}_i UB_t \tag{D.18}$$

where
$Y_{i,t}$ is net income of income class i in period t
t^d_i is direct tax of class i
P_t is the total surplus of the economy in period t

d is profits distribution proportion parameter
UB_t is the unemployment benefits in period t
b_i are the respectives apropriation parameters of each income class i

Investment

$$I^d_{i,\tau} = p^k_{\tau-1}(\overline{y}^\delta_{i,\tau} + \Delta\overline{y}*_{i,\tau}) \tag{D.19}$$

$$\Delta\overline{y}*_{i,\tau} = (1+\sigma)(y^e_{i,\tau+2}) - (1-\delta)\overline{y}_{i,\tau} \tag{D.20}$$

$I^d_{i,\tau}$ is the nominal desired investment of firm i in the investment period τ
$p^k_{\tau-1}$ is the price of capital goods in the period $\tau - 1$
$\overline{y}^\delta_{i,\tau}$ is the the amount of productivie capacity that depreciated in the investment period τ
$\Delta\overline{Y}*_{i,\tau}$ is the desured amount of increase in productive capacity in the investment period τ
σ is desired inventories proportion
$y^e_{i,\tau+2}$ is the expected sales of firm i for two investment periods τ ahead
$(1-\delta)\overline{y}_{i,\tau}$ is the current amount of productive capacity not depreciated of firm i in the investment period τ

$$I_{i,\tau} = \min(I^d_{i,\tau}, F_{i,\tau}) \tag{D.21}$$

$$F_{i,t} = F^I_{i,t} + F^X_{i,t} - A*_{i,t} \tag{D.22}$$

where
$I_{i,\tau}$ is effective investment of firm i in investment period τ
$I^d_{i,\tau}$ is the nominal desired investment of firm i in the investment period τ
$F_{i,t}$ is amount of funds available for firm in the investment period τ
$F^I_{i,t}$ is the amount of internal funds available for firm i in period t
$F^X_{i,t}$ is the amount of external funds available for firm i in period t
$A*_{i,t}$ is the amount of desired additional liquid assetsfor firm i in period t

Productivity

$$\pi^f_{i,t} = \max(\pi^{im}_{i,t}, \pi^{in}_{i,t}, \pi^f_{i,t-1}) \tag{D.23}$$

$\pi^f_{i,t}$ is the frontier productivity of firm i in period t
$\pi^{im}_{i,t}$ is the possible productivity due to imitation of firm i in period t
$\pi^{in}_{i,t}$ is the possible productivity due to innovation of firm i in period t
$\pi^f_{i,t-1}$ is the frontier productivity of firm i in period -1

$$\pi^{im}_{i,t} = d^{im}\pi^{\max}_{j,t-1} \tag{D.24}$$

$$p(d^{im} = 1) = 1 - \exp(-\rho^{im}_i R_{i,t} a^{im}_j) \tag{D.25}$$

where $\pi^{im}_{i,t}$ is the possible productivity due to imitation of firm i in period t
d^{im} is a dummy variable that assumes values 1 or 0 depending on the imitation probability
$\pi^{\max}_{j,t-1}$ in the maximum productivity of sector j in period $t-1$
ρ^{im}_i is the share of revenues of firm i invested in imitation
$R_{i,t}$ is the revenue of firm i in period t
a^{im}_j is a sector j parameter of technological opportunity in imitation

$$\pi^{in}_{i,t} \sim N(\mu, \sigma^2) \quad if \quad d^{in} = 1 \tag{D.26}$$

$$p(d^{in} = 1) = 1 - \exp(-\rho^{in}_i R_{i,t} a^{in}_j) \tag{D.27}$$

where $\pi_{i,t}^{in}$ is the possible productivity due to innovation of firm i in period t
μ is the mean of innovation distribution, given exogenously
σ^2 is the standard deviation of innovation distribution, given exogenously
d^{in} is a dummy variable that assumes values 1 or 0 depending on the innovation probability
ρ_i^{in} is the share of revenues of firm i invested in innovation
$R_{i,t}$ is the revenue of firm i in period t
a_j^{in} is a sector j parameter of technological opportunity in innovation

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