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An Agent Based Model of Complex Investment Dynamics along Kaleckian lines

Abstract: Assumptions used by most mainstream models don't seem coherent with most empirical studies about investment. We argue that studying investment in a complex adaptive system following Dosi et al.(2010) and Possas et al.(2001) is a suitable alternative, incorporating Neo-Schumpeterian insights to a Kaleckian framework. This paper motivates, describes and builds an Agent-Based Model incorporating to the firms' expected demand an optimism rule, based on Lima and Freitas(2007), and a local interaction mechanism. This extension may contribute to the study of phenomena as Kaleckian "Investment Strikes", psychological shocks in investors' confidence and Soros' concept of reflexivity. This preliminary model was capable of reproducing cyclical endogenous growth, with cyclical employment rates. Also, we find a version of Kalecki's Paradox of Costs, and run simulation testing the effects of i) optimism shocks, ii) firms having an endogenous political or psychological aversion to government's deficits and iii) the addition of pro-austerity view in firms' demand expectations. Our preliminary results show that singular shocks in optimism may have permanent effects in our model's economy, that only a few pessimistic firms can spread their pessimism to their entire sector, and that firms' beliefs on their demand determinants may affect aggregates and the government's debt position.

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Introduction

The study of investment dynamics has been consistently considered one of the most challenging topics in economics. Acknowledged by Kalecki as the main *Pièce de résistance* of economic theory, investment is considered by many authors the main driver of growth and still is one of the most important themes in economic theory.

The reason for all this prominence is probably related to the double role investment plays in the economy: it demands goods in the period it has taken place, but assures the expansion of capital stocks and (potential) productivity growth for the next periods. In other words, investment is not only an aggregate demand component, but also directly affects the supply of goods, by expanding goods' future potential supply frontier.

However, as Kalecki already knew, grasping investment's behavior is extremely challenging: investment decisions are pulverized amongst many decentralized firms, whose strategies are not normally public, and there is a crucial expectational component, linked to investment's volatility. Furthermore, to convert decisions taken at the micro level, for the aggregate (macro) level is not straightforward.

The conventional approach[1] often solves this issue by reducing the analysis to the study of a representative agent, who maximizes with rational expectations and complete information under perfect competition. It is also highlighted that a singular stable equilibrium will be necessarily reached. These assumptions, however, don't seem coherent with most empirical studies. Those studies display firms with imperfect information and competition, which invest in a decentralized and heterogeneous manner, using rules of thumb and adaptive expectations, for they are boundedly rational. Furthermore, mainstream models suffer from aggregation problems and lose a relevant dimension of analysis: the interaction between firms, which for investment analysis is critical, as it helps explain expectations' formation and opens a way to bring business' confidence into play.

Although after the last financial crisis some of these aspects have been incorporated in the newest DSGE models (Dynamic Stochastic General Equilibrium), they never appear as the model's heart: they are mere ad-hoc extensions to old models, typically adopted to allow them to fit better the data and improve their predictions. However, as could be expected, this agenda didn't solve the fundamental methodological problems inherent to the mainstream models.

Nevertheless, there is an approach which can provide a suitable framework for addressing nonlinearities, bounded rationality and the uncoordinated and decentralized interaction among heterogeneous agents, allowing non-equilibrium analysis. Using a highly inductive method, the complexity approach, when applied to economics, is an important alternative to study problems for which the mainstream analysis faces troubles inherent to the assumptions it takes for granted.

As we believe that many of the problems faced by the mainstream literature on investment are better addressed using an approach which allows for heterogeneous uncoordinated interaction among agents, we will develop an Agent Based Simulation Model (ABM) to study investment dynamics in a complex adaptive system. Our model is mainly inspired by Kaleckian contributions, but is also influenced by Neo-Schumpeterian insights and incorporates innovation as the main

[1] Not to mention a variety of models in which investment is a mere residue of consumption and production maximizations.

driver for growth. By combining these frameworks in an ABM we follow especially Possas et al. (2001), Dosi et al. (2010) and Caiani et al. (2016), which combine Keynes/Kalecki insights with a Neo-Schumpeterian view on innovation to build models that can match empirical regularities, with endogenous growth and business cycles.

The main contribution we intend to provide to this literature is the incorporation of an optimism rule in firms' expected demand (which leads its production and investment decisions), based on Lima and Freitas (2007), and a local interaction mechanism among firms. We understand that investment decisions are a crucial aspect of the above models (and of the economy itself) and the study of different specifications for these decisions can advance our understanding on how investment decisions affect and are affected by the economy.

Our main focus is to develop a model useful to study the influence a firm can have on its competitors, in the moment of investment and production, and how this interaction affects the economic aggregates and economy's "degree of monopoly". This effect does not integrate the main models of the literature, but was extremely relevant for Kalecki. Even though Kalecki (1971, pp.146) affirms that "capitalists do many things as a class but they certainly don't invest as a class", this does not mean that firms are not influenced by their competitors investment decisions.

Besides that, we think the complexity approach is an adequate methodology to study Kaleckian insights on investment, for its holistic understanding that is only through the study of the uncoordinated behavior of interactive parts that we can advance in the comprehension of the whole economy. We consider this belief extremely similar to Kalecki's ideas on investment motives; even the most famous Kaleckian fallacy of composition, for instance, teaches us that capitalist's decisions have different consequences for themselves individually and for them as a class, an idea that can be rigorously examined by the complexity approach. In addition to that, this framework puts, as Kalecki did before, heterogeneity, interaction and historical instead of logical time as major economic factors, and guarantees a rigorous logical coherence between our assumptions and the results we get.

The motivation for this work arose from the increasing application in different lines of related research of the Kaleckian concept of "Investment Strike". The discipline mechanisms imposed by the business on the government, using confidence crisis, are part of the explanations about themes like the 2008 crisis (Streeck, 2014), the current Brazilian crisis (Rugitsky, 2015) and the British austerity policies (Krugman, 2015). Noticing this recurrence, we looked for an adequate methodology to study, with clear assumptions, whether and under which conditions investment strikes could emerge in an economy. However, with the development of our research, we realized that our model could have different interesting uses.

We believe that a simulation model using plausible assumptions and parameters, when it provides plausible economic results, is interesting by itself. It often helps us understand how each specific variable can affect the economy, and clarify the different ways each behavior affects, often in unexpected ways, the aggregate. Besides that, given our initial motivation, we intend to carry on three different "experiments" to be implemented using our model: i) optimism shocks, ii) endogenous political motivation, and iii) Soros' (2013) concepts of Reflexivity and Fallibility. Each of these specifications will be better explained and justified below, and their simulation results will be compared with those of our base model.

This paper presents in section I a brief review of the relevant literature, in section II the model we've developed, trying to justify and compare its specifications to the main models we are following and the empirical literature, and in section III very preliminary results of our research. This work is an ongoing research for my master thesis, and this paper intends to present the work developed so far, so that our research benefits from criticisms and opinions.

Finally, before progressing to our review of the literature, we thank the support of São Paulo Research Foundation (FAPESP) grant #2016/17987-0. We also want to express our gratitude to the Institute of Economic Research Foundation (FIPE), which made my presence in Berlin possible by reimbursing my travel expenses.

Part I - Related Literature

Kalecki

Although Kalecki is frequently acknowledged for the clarity of his reasoning, accurate logic and the concern to keep transparent on which assumptions each of his conclusions depend on (López and Assous, 2010), a wide and deep theoretical debate in the history of economic thought persists on Kaleckian models. A good part of these controversies are explained by Kalecki (1971) himself in the introduction:

"It is interesting to notice that the theory of effective demand, already clearly formulated in the first papers, remains unchanged in all the relevant writings, as do my views on the distribution of national income. However, there is a continuous search for new solutions in the theory of investment decisions, where even the last paper represents – for better or for worse – a novel approach."

As our ambition in this paper is not either to take part on those controversies nor discuss Kalecki's different formulations on investment, our review should be understood as mere motivation, presenting the formulations which seem most convenient and coherent in the context of our model. In a way, the idea is to display the main insights which inspired the construction of our model, and directly influenced most of its structure and agents' behavior.

Already in 1933 we can find in Kalecki's theory of the business cycle many of his fundamental insights. He employs great effort in explaining the role played by the time dimension in his model, as investments have a maturation time, and it is exactly this lag which enables the emergence of business cycles. Assuming stable inventories, the author points out that investment orders depend on the net expected profitability, which would be forecasted using the current interest rate and profitability.

The cycles would emerge due to the alternation between moments when capital deliveries exceed depreciation, raising the capital stock, reducing new investment's profitability and diminishing new investment orders; and moments when the opposite occurr, leading investment's and economy's upswing. This "natural" business cycle's mechanism illustrates well the mismatch between investment as a demand element, and its supply dimension, and was considered by Kalecki (1971, pp.32) "one of the most remarkable paradoxes of the capitalist system" as "The expansion of the capital equipment, i. e., the increase in the national wealth, contains the seed of a

depression in the course of which the additional wealth proves to be only potential in character. For a considerable part of capital equipment is idle then (…)".

Still in 1933, Kalecki presented his insight that capitalists are "masters of their fate", for they dictate, as a class, the amount of their own profit. Assuming that workers can't save, Kalecki (1968, pp.45-46) demonstrates that profits would be as large as capitalist's consumption and investment, in the aggregate, and affirms that "it is clear that capitalists may decide to consume and to invest more in a given period than in the preceding one, but they cannot decide to earn more. It is, therefore, their investment and consumption decisions which determine profits, and not vice versa.".

In this matter, Kalecki presents us a fallacy of composition as the consequences of capitalist's choices are distinct for him and for his class – the paradox of thrift. Equally famous is Kalecki's (1971, chap.3) demonstration that a reduction in wages, even when it can benefit capitalists individually, leads in the aggregate to reductions in the output level and even in the profit rate, due to its effects on the demand side in an economy with two heterogeneous classes – the paradox of costs.

As advanced above, Kalecki also recognized in the data and incorporated in his theories the existence of idle capacity in firms. As exposed in Kalecki (1968, chap.1), the full utilization of productive capacity is an uncommon phenomenon, even during booms, being normally restricted to war or post-war times. López and Assous (2010) explain that in Kaleckian models the assumptions, which imply the prevalence of idle capacity, are the existence of cartels and imperfect competition in the economy. Anyway, it is thanks to the discard of mainstream's full utilization assumption that in Kalecki's understanding the output level depends on the effective demand, even though the labor force and the capital stock place an upper limit to the expansion of output.

In this vein, the level of investment would assume a central role in the determination of demand and nothing in a capitalist economy assures the achievement of full employment (Assous et al., 2017). Investment would be limited by firms' internal capital (retained profits or entrepreneurial capital) and the amount of credit they could access. These resources wouldn't be freely available, as small firms suffer from credit constraints and even large firms avoid borrowing money in large scale, due to Kalecki's "principle of increasing risk" (Kalecki, 1968, chap.8).

For Kalecki (1968, chap.9), in the beginning of each period firms would have already pushed their investment plans to their maximum, and new expenditures would be made only when/if changes in the determinants of investment had occurred. The factors capable of this would be i) the gross accumulation of capital out of firms' profits (improvement in internal capital relaxes credit constraints), ii) changes in the stocks of fixed capital (reduces the possibility of new equipments to be profitable) and iii) the expected rate of profit. The interest rate and technological innovations are also mentioned, but not included in this specific formulation.

As firms' decisions are capable of affecting by themselves capitalist economy's future developments, Kalecki thought that capitalists' profit expectations should take into account their competitors' plans (Assous et al. 2017). In the same way, Kalecki (1971, p.44) explains that "in fixing the price the firm takes into consideration its average prime costs and the prices of other firms producing similar products". Therefore, it is clear that the interaction among heterogeneous firms in the moment when they are making their most important decisions is explicitly present in the work of Kalecki.

Price formation would also be impacted by the “degree of monopoly”, which would be affected by such diverse factors as how concentrated a market is, the amount of resources spent on advertisement and unions’ strength. The great importance the degree of monopoly has for Kalecki is connected to its interpretation as a proxy for measuring the class struggle conditions. However, Kalecki (1971, chap.5) demonstrated that changing the degree of monopoly would not affect an economy’s amount of profit, given that those would already be determined by previous period’s investment decisions.

Nevertheless, Kalecki should not be understood as one who disregards the political dimension as fundamental to comprehend capitalism. Not only in the influence that the degree of monopoly has on the distribution of income we can note the importance of political aspects for his thought, but above all in the emblematic “Political aspects of full employment” (Kalecki (1971, chap.12)). There the author states that the best policies to reach and keep full employment had already been enough discussed, but capitalists would oppose to those for political reasons.

Kalecki affirms that despite capitalists’ knowledge that government interventions to reduce unemployment would increase output and even their profits, they are suspicious of any government intervention in the economy. That would be caused by i) a fear that government expenditures start to compete with private investments, ii) a fear of losing their control mechanisms on society, based on the employment dependence in business’ “state of confidence”, and iii) their understanding that full employment would affect factories’ discipline, and promote social changes. For him, business leaders would appreciate more political stability than profit.

Political motivation: Investment Strikes and Reflexivity

“business interests dislike Keynesian economics because it threatens their political bargaining power. Business leaders love the idea that the health of the economy depends on confidence, which in turn – or so they argue – requires making them happy.” - Paul Krugman (2015), following Mike Konczal, in article about the British austerity

The Kaleckian insight that capitalists would threaten economy’s confidence level to assure the maintenance of advantageous policies for their class has been increasingly adopted, explicitly or not, in the last few years. This growth is in line with Rugitsky’s (2013) idea that Kalecki’s article advanced a peculiar expression, which would be widely used only in the after-war, of an important Marxian conception: that capitalists throughout history would have continually tried to keep control of government policies, to use them in their own support.

This modern mechanism of control would be indirect: capitalists menace to diminish economy’s state of confidence – which drives their investment decisions - when the government tries to implement policies that are inconvenient (for them). This way, business leaders threaten the output level and, thus, the employment level.

In that scenario, “big business would most probably induce the Government to return to the orthodox policy of cutting down the budget deficit.” (Kalecki, 1971, pp.44).

This procedure, known in the literature as "Investment Strike"[2], is also a crucial aspect in the theory developed by Streeck (2014). According to him, the capitalist system would be subject to repeated legitimacy tests, judged by three categories: the working class, the State and the capital. Among these, the legitimacy before capital would be the most necessary, as the output and employment level depend on capital's marginal propensity to invest. In this sense, the emergence of crisis would be a sign of capital's dissatisfaction, whose demands to guarantee its "confidence" would vary according to each place and time.

In our model's world we understand that these "Kaleckian reactions" could appear in a consistent and logical way in two manners: i) if in a given moment something beyond our model's internal logic happens - as the approval of a specific union-friendly law or the election of a candidate perceived (correctly or not) to be against business-, we can have a negative optimism shock in some or all of our firms; or ii) if our firms have an endogenous political motivation, this motivation can be a permanent factor in their optimism level – inducing, for example, firms to be less optimistic whenever the government's budget deteriorate.

If the above experiments are either based on the psychological[3] insight that subjective factors can affect our firms, or on the Kaleckian insight that firms may on purpose damage the growth rate of the economy to maintain their power, there is, at least, a third possible explanation for why would business leaders confront the economic logic and invest using strategies, which does not bring them maximum financial return. Maybe they are trying to maximize profits, but they are mistaken on exactly how the economy works.

In order to understand the deepness behind this simple idea, highly neglected by mainstream economics, we need to be familiar with Soros' (2013) concepts of fallibility and reflexivity. According to Beinhocker (2013, pp.334):

"In any non-trivial setting of minimal complexity (…) the true underlying model will not be given a priori to agents, knowledge of initial conditions and parameters will be limited, data will be finite and noisy, computing power will be finite, and the agents doing the observing will also be parts in the system. This means that (…) the internal model of the agents *must* be fallible. And that fallibility is also part of the system that the agents are trying to understand."

Although agents are able to learn in complex evolutionary systems, it is very difficult for agents to learn successfully, because predicting the future path of such a system does not only require perfect knowledge of their own fallibility, but also of all other agents' fallibilities. This embeddedness of human beings - whose views on the world never correspond to the actual state of affairs- in the system they are trying to understand is responsible for the emergence of the reflexity principle, which in Soros' (2013, pp.310-11) words states that: "imperfect views can influence the situation to which they relate through the actions of the participants. (…) It is like a partnership where each partner's view of the other influences their behavior and vice-versa.".

If we take this insight seriously, we conclude that the study of the economy, in and of itself, is also capable of changing the nature of the system we are studying. And it is not only an economics phenomenon: Soros understands that, in opposition to the natural sciences, studying social

[2] For a brief historical account of the evolution in the use of this concept, we recommend Frase (2011).

[3] Actually, Keynes (1996, chap.12) also stated that investor's expectations may be very volatile and unpredictable events, even outside the economy, may abruptly affect their humor.

sciences is capable of modifying the objects we are studying. This would also put a major challenge to the belief that social and natural sciences can be unified in the future.

With that in mind, we believe that with our model we have developed an adequate methodology to test some consequences of Soros' insights. Even though government expenditure expands unemployed's demand for goods, we may test what will the effects in our economy be when the business leaders unjustifiably believe that government's deficits are harmful to the economy (via expected demand). Can their fallibility influence the economy, in a way that more expenditures really ruin the economy?

Complexity and related ABMs

"Economy is a complexity wonder. It wasn't created and isn't commanded by anyone." *Alberto Ajzental (2015, p.178)*

Still lacking a consensual definition, the "Complexity science can be seen as the study of the phenomena which emerge from a collection of interacting objects" (Johnson, 2007, p.3). Nevertheless, there is a certain agreement that a system to be considered complex must i) contain a collection of many interacting agents, ii) whose strategies and behavior should adapt depending on their history, iii) the system can be affected by its environment, iv) evolve in possibly surprising ways, v) exhibit emergent phenomena, that can be a vi) complicated mix of ordered and unordered behavior.

Inspired by phenomena observed in biology and physics, the complexity approach is gaining ground in economics. Considered as an alternative to traditional theories, this approach avoids the the straighjacket of several orthodox assumptions and is flexible to deal with problems involving behavioral contagion, interaction, heterogeneity, non-linearities, lack of equilibrium, bounded rationality, adaptive systems, and many other issues, which are troublesome to mainstream analyses.

As exposed by Ajzental (2015, p.258), one of the main techniques to "analyze systems in which the equilibrium or the dynamics can't be analytically determined" is the use of Agent Based Modeling (ABM). Using this method we can overcome the mathematical difficulties and model our agents' behavior individually, simulating their behavior and watching the results and properties which emerge.

Fagiolo and Roventini (2016) show that by following a truly dynamic bottom-up approach, the ABMs have been used to treat issues related to heterogeneity, evolving systems, non-linearities, interactions, feedbacks, bounded rationality and innovation, discussing several different themes. Therefore ABMs prove themselves as an appropriate method to study investment dynamics, for they involve heterogeneous interactive firms, which evolve and make decisions in non-linear ways with bounded rationality and imperfect information in an innovative context.

Possas et al. (2001) and Dosi et al. (2010) have been our main references in this work, for they are based on a Keynesian/Kaleckian framework, make good use of Neo-Schumpeterian insights for innovation, have concerns similar to ours, and have achieved great resemblance to empirical evidence.

Dosi et al. (2010) present an ABM with endogenous growth and business cycles to study i) the process under which the technological innovation affects their model's macroeconomy, ii) how endogenous variations in fundamentals of the economy interact with demand conditions, and iii) if the demand conditions have long-run effects, or technological innovation is capable of assuring growth by itself. In this framework, the authors have tried to build a model able to combine Keynes' and Schumpeter's contributions. They display their model's great explanatory capacity both for short (cycles and fluctuations) and for long-run (tendency) and test the robustness of their results – which recommend the importance of Keynesian and anti-trust policies in order to secure higher levels of employment and growth.

Similar contribution can be found in Possas et al. (2001). Their sectoral evolutionary model combines Neo-Schumpeterian and Post-Keynesian microfoundations, whose common ground would be the rejection to the maximizing rationality and the equilibrium between agents and markets. Understanding innovation as a cause of maladjustment and expansion, they apply a bounded rationality framework and are inspired by Kaleckian conceptions, to specify firms' price formation and investment decision mechanisms. Although they emphasize that their main contribution was building a groundwork for future research, not the precision of their results, the simulations suggest (among other results) that increments in productivity growth could lead to higher market concentration.

Part II - The model

The economy described by our simulation model is composed of various sectors populated by boundedly rational agents, which follow simple heuristics in a context of incomplete and asymmetric information. The model contains:

- A capital goods sector, composed by one single monopolistic firm. It employs workers to manufacture capital goods and work in R&D. In each period, the monopolist advertises, sells and produces homogeneous capital goods, using only labor. However, the research made in R&D can improve capital's productivity for the upcoming periods, ensuring that the capital goods held by consumption goods firms remain heterogeneous. Moreover, the monopolist pays taxes on their net profit.
- A consumption goods sector, composed by a collection of competing heterogeneous consumption goods firms. They produce a homogeneous consumption goods, using labor and capital goods manufactured in the capital goods sector. To decide how much to produce and invest, they interact with each other locally in a way that shapes their expectations, considering also their financial and technological constraints. When necessary, they borrow money from a monopolistic bank. After investing and producing the consumption goods firms pay taxes on their net profit.
- A banking sector, composed by one monopolistic bank. It lends money passively to the consumption goods sector, charging an increasing interest rate.
- The government, which collects taxes from the consumption and the capital goods firms and pays unemployment benefits to the unemployed households.
- A collection of households, who sell their labor to the consumption/capital goods firms in exchange for wages. Unemployed households receive a dole from the government, and spend (whenever it is possible) everything they receive in consumption goods. The households are

homogeneously productive, and can work both in the consumption sector and in the capital/R&D sector. However, they are heterogeneous in any other respect, asking and receiving different wages, and consuming different amounts of goods.

The different agents summarized above interact in our simulation during each period on four markets:

- A capital goods market: our monopolistic capital firm sells capital goods, on demand and with advanced payment, to the consumption firms.
- A consumption goods market: the consumption firms sell their homogeneous consumption goods to the households, under imperfect competition and according to their market shares.
- A labor market: the consumption and the capital firms hire, each sector following its own dynamics, workers to produce their goods and conduct R&D.
- A credit market: consumption firms borrow money from our monopolistic bank when their own cash flows are not enough to guarantee their chosen production and investment levels.

Once presented the general framework in which each of our agents will interact, we need to describe more specifically their behaviors and exactly how they interact in our model. Our goal is to keep their behavior as close as possible to what empirical studies suggest it to be in reality. In this vein, we try to justify as much as possible the choices we made in building the model, using the empirical literature and Kaleckian insights. Furthermore, we expound which previous contributions (if any) in the ABM literature we are following, to model each behavior in our economy.

i) Capital goods sector

As we have anticipated, our capital goods sector is represented by one monopolistic firm. In the beginning of each period, it presents to the consumption firms the productivity and price of the capital goods it will produce in this period. All capital goods produced will have the same productivity and price.

The productivity of equipment manufactured in step *t* will be given by:

$$\text{Productivity}_t = \max\left(Productivity_{t-1}, Innovation_t\right)$$

where “Innovation” is the productivity developed in last period’s innovative process (if any).

Inspired by Kalecki, following Dosi et al. (2010), and consistent with the empirical evidence presented in Fabiani et al. (2006) – which shows that prices are usually determined using a markup rule – our monopolistic firm establishes the prices for which their capital goods will be sold by multiplying to their costs (wages) a variable referring to their markup.

This markup increases a bit every time the productivity of the equipment sold increases – which means that the monopolistic firm appropriates for itself a part of economy’s efficiency gains. Also, the R&D budget is not included in the costs used to establish prices, for it is a share of the net profits.

Once the capital goods have been advertised, the monopolistic firm receives its orders from the consumption goods sector, receiving the payments in advance. Although the main reason for our monopolist to produce and conduct R&D without any risk, receiving advanced payments for their goods, is to keep a sector that is not our model’s core as simple as possible, the empirical evidence presented in Bromiley (1986) suggests that it is usual for capital goods firms to have much

of its demand agreed and secured by long-term contracts. As a result, once the agreements are signed, they assure a kind of guaranteed demand, for which the firm invest and produce without risks – in a manner like the one of our model.

Following the literature (Possas et al. (2001), Dosi et al. (2010)), our monopolist splits the value collected by selling its goods into three parts. Firstly, it hires (the dynamics will be explained below) the workers needed to produce the amount of capital goods ordered by the consumption goods sector. Subsequently, it computes its revenue and the labor costs, to evaluate its gross profits. A share of the profits is spent developing R&D: the monopolistic firm hires more workers, now to work with innovation, trying to improve the manufactured equipment's productivity. Finally, the firm evaluates its net profits, pays a fraction of it in taxes to the government and adds the retained profits to its wealth, cumulated in previous periods.

For each period, once the monopolistic firm establishes the amount of resources available in its budget to R&D, this department tries to spend all its budget (and possible leftovers from last period) hiring workers to develop more efficient capital goods (labor-saving innovations). The specification under which the innovation will take place follows Dosi et al. (2010) and Possas et al. (2001), and, according to the analysis displayed in Possas (2008), has been proposed and evolving since the seminal work from Nelson and Winter (1982). However, in our model as we are dealing with a monopolist – which is always at the technological frontier- we discard any mechanisms for imitation among firms. That does not seem like a huge loss, considering that in Dosi et al.'s (2010) model this mechanism didn't provide great effects or changes in their model's main results.

Furthermore, to keep things more simple, in this version of the model the innovations developed only improve productivity in the consumption goods' sector. The equipment sold by the monopolistic firm can be upgraded in each period, but its own production requires the same amount of work (a parameter) in every period.

As precisely explained in Dosi et al. (2010): "We model innovation as a two steps process. The first one determines whether a firm obtains or not an access to innovation – irrespectively of whether it is ultimately a success or a failure- through a draw from a Bernoulli distribution", whose probability of success is given by:

$$P(SuccessInov_t) = 1 - (exp(-NumbWorkerInov))$$

which means that the access to innovative discoveries is more likely when the monopolistic firm hires more workers in its R&D sector. If it achieves success, the firm draws equipment's incremental productivity according to a normal distribution. As this draw may be a negative value, not every innovation is implemented in next step's capital goods advertisement and production. The idea behind this is to represent the fact that beyond the inherent difficulty to generate new knowledge, there is in innovative investment the risk that the innovation created fails to accomplish its goals – in this context, to be more productive than the old equipments.

Finally, in the end of each time step, our monopolistic firm delivers the capital goods ordered and previously paid by the consumption firms (there is not any costs or imperfections in these deliveries). Also, the capital producer evaluates its profits and pays proportional taxes to the government, following our main reference models in the literature.

ii) Consumption goods sector

Our collection of heterogeneous consumption goods firms start each period receiving from the capital sector advertisement containing the prices and productivity level of the machines the monopolistic capital firm will manufacture this period. Before the consumption firms order, they compute their financial constraints to invest and produce the amounts they desire.

The process which determines the consumption firms desire to produce and invest is our model's core. Here we find the main behaviors which we want to simulate, report the results, evaluate emerging properties of and with which we intend to give a contribution to the literature and the existing models. In order to assure the attention it deserves, we pause for a while the brief explanation of our model, to concentrate in this aspect.

Expectations

In our model, the desired production level in time step *t* depends on the expectations each firm has about the demand for its products in *t.* On the other hand, its investment expenditures depend on each firm's expectations about the demand for its products in *t+1*. That is because investment goods ordered in *t* will be delivered only in the end of each period. This lag is not just a Kaleckian inspiration[4], but it is also described by Bromiley (1986) as happening in reality. According to him, investments take time between being planned, implemented and then mature. Thus the firms are compelled to designate its maximum productive capacity always in advance.

As usual in the literature (Dosi et al. (2010), Possas et al (2001), Caiani et al. (2016)), our firms have adaptive expectations. Our choice for expectations which depend on past performance, in terms of effective demand that those firms received, rather than forward-looking expectations (rational expectations, usually adopted in mainstream literature) is based on a myriad of empirical evidence. As stated in Gennaioli et al. (2016), models using rational expectations have been proved empirically problematic and the behavior observed among investors has preliminary validated the adaptive expectations' hypothesis.

In the same way, Caballero (1999) maintains that sales' growth explains pretty well the level of investment and Davar and Gill (2007) demonstrate that investor's preferences are strongly related to to the performance of current investment. One possible explanation for this is described in Dreman et al. (2001). According to them, under uncertain conditions (as it is an investment decision) there is a propensity for choices to be leaded by the "representativeness heuristic". According to this heuristic, found in psychological studies, "forecasts are made to be similar to (…) salient features of the observed data. The recent performance of stocks *[in our model "sales"]* is much more salient than the historical performance, hence likely to become the representative standard by which future returns are forecasted.". Therefore, it is usual that sales' current performance dictate the standards which firms will base their choices on, extrapolating the present for the future[5].

[4] Here we are inspired by Kalecky (1971, cap1). Both in assuring a lag between investment decisions and their deliveries, which in Kalecki's model is crucial for the emergence of cycles, and in distinguishing between three stages in investment activity, as Kalecki explains: "Three stages should be distinguished (…): (i) investment orders, i.e., all types of orders for investment goods for the sake of reproduction and expansion of the capital equipment (…); (ii) production of investment goods (…); (iii) deliveries of finished equipment per unit of time".

[5] An extremely similar explanation is found in Keynes (1936, cap.12)"It is reasonable, therefore, to be guided to a considerable degree by the facts about which we feel somewhat confident, even though they may be less decisively relevant to the issue than other facts about which our knowledge is vague and scanty. For this reason the facts of the

However, as exposed in Gennaioli et al. (2016), expectations, beyond the factors that we can rationalize by looking at the data (as previous sales), also seem to rely on other – less rational-motives. For example, optimism with the national economy seems to be positively correlated with the firm's investment and "firm's expectations and sentiments appear to be a key driver of investment activities" (p.19). In this vein, there is a wide behavioral literature about how psychological aspects influence economic decisions, as in Kahneman and Tversky (1979), and about the various ways in which economics is connected with psychology, as described and summarized by Rabin (1998).

Even among more traditional methodological approaches the effort to add an interaction between psychological aspects and economic decision is becoming more popular. Just to mention one, Hermalin and Isen (2000), using a standard utility maximization approach build a model in which "the happiness or utility level at the time of decision making affects preferences, which then affects the decision made." (p.2). Also, they state that individuals' "affect" (understood as "mood" or "emotions") tend to be persistent – something we try to implement in our model.

Again, an explanation for this observed non-rational behavior can be found in Dreman et al. (2001). They present the importance of the "Affect Heuristic", according to which "images, associated with positive and negative affective feelings, guide judgment and decision-making.". As a consequence, the kind of news broadcasted by the media in the moment of an investment can affect disproportionately the investor's image and lead his decision-making. In other words, "in the process of making a judgment or decision, people are assumed to consciously consult or unconsciously sense an "affect pool" containing all the positive and negative feelings associated with the representations (images) of the object being judged."(p.129).

Yet, for our purposes, the reasons for which firms' "humor", which we shall call "optimism", affects their decisions are less important than their implications. The fundamental point we want to make here is that not only there is robust empirical evidence that each firm's optimism level influence its decisions to produce and invest, but also other firms' (and society's) optimism level affect the investor's confidence level - and, therefore, its investment and production.

For those reasons, we understand that it is relevant and can be fruitful to embody in the adaptive expectations used in the main models we are following from the literature an insight from Lima and Freitas (2007), and add a factor corresponding to the consumption firms' optimism level, when they are formulating their expectations. This means that in our baseline version of the simulation the demand firms expect to receive in *t* is given by:

$$ExpectDem_t = Optimism_t(Demand_{t-1} + (Demand_{t-1} - Demand_{t-2}))$$

and the demand they expect to receive in *t+1* is given by:

$$ExpectDem_{t+1} = Optimism_t(Demand_{t-1} + 2(Demand_{t-1} - Demand_{t-2}))$$

The optimism level, in turn, varies depending on the firm's profit in the last period and on its local interaction with other firms. Specifically, the optimism level in *t* is the level in *t-1* added (diminished) by a positive parameter, when the firm's profit in *t-1* was higher (smaller) than the firm's

existing situation enter, in a sense disproportionately, into the formation of our long-term expectations; our usual practice being to take the existing situation and to project it into the future, modified only to the extent that we have more or less definite reasons for expecting a change."

profit in *t-2* was. Furthermore, the optimism level is added (diminished) by another positive parameter when our firm's optimism in *t-1* was smaller (higher) than the average optimism level it observes from the three other firms with which it interacts locally. In behaving this way, our firms are affected both by the "affect heuristic" and the "representativeness heuristic" described in Dreman et al. (2001).

This interaction between firms in the determination of their confidence levels (which influence their expectations, consequently affecting their production and investment levels) is the main innovation proposed by our model. Inspired by Kalecki, we understand that including this dynamic is not just justified by the empirical and psychological evidence presented before, but also for rational reasons, which lead firms to base their choices in what they know about their competitors, in the moment they decide their production and investment levels.

Two approaches to understand how firms depend on each other can be found in Keynes' beauty contest metaphor[6] (1996, chap.12) and in Chamley et al. (1994). The latter adopts the idea that there is imperfect information among firms, to model a game with information externality. There, the herd effect emerges as a possible result, due to a dynamic in which the first firms to act have influence on the remaining.

Under imperfect information, we can also understand the higher investment a firm does - when it observes its competitors spending more- as an answer to what its competitors' expenditures reveal about the very evolution of the national economy itself. Moreover, the competitive motive and the idea, stated in Bromiley (1986), that firms are worried about keeping their market shares, can be pointed out as driving firms' reaction to their peers' investments.

Coming back to the description of the model

Now that we've explained the main reasons why we are using adaptive expectations, the way they will be affected by firms' own optimism and their interaction with each other, we can describe how firms' demand expectations are used to determine their production and investment levels – after the capital goods monopolistic firm's advertisement.

For that, we follow Possas et al. (2001), and specify that the desired level of production is the one which assures supply for the expected level of demand and the preservation of a fixed proportion (of the expected demand) of inventory. On the other hand, the desired level of investment in *t* is determined by the addition of the expected demand in *t+1*, and the desired inventory level in *t+1*. If this sum is larger than the firms' future installed maximum capacity (the current less depreciation), the firm's desired investment is the one which assures this desired maximum productive capacity in *t+1*. If that sum is smaller than the future maximum installed capacity, the firm chooses not to invest in *t*, because, as Kalecki (1968, cap.9) puts it, "at the beginning of this period the firms have pushed their investment plans up to a point where they cease to be profitable".

[6] Among many, another excerpt where Keynes explains how agents' decisions under uncertainty can be influenced by their peers can be found in Keynes (1937, p.214): "Knowing that our own individual judgement is worthless, we endeavour to fall back on the judgement of the rest of the world which is perhaps better informed.That is, we endeavour to conform with the behaviorof the majority or the average.".

At this point, it is worthy to point out that when we give priority to expectations, which reflect sales' growth, as investment's determinant in our model, we are in accordance with the data we found in our review of the empirical literature. Gennaioli et al. (2016) demonstrates that directors' expectations are better predictors both of expected investment and of real investment than other usual explanations, as Tobin's q, discount rates and measures of financial constraints and uncertainty. In this vein, Caballero (1999) states that business' cash-flows and sales' growth seem to be much more important to explain firms' investment decisions than Tobin's q. We are also following this same literature, when we assure that investment is a sunk cost, namely, that once firms buy machines there is not a secondary market available to resell them, if they need to recover a share of their investment.

The effective production and investment are restricted by technical and financial constraints. In the first place, each firm forecasts its wage costs, by multiplying the number of workers it needs to produce their desired amount, given the productivity of its equipments, by the average wage demanded in *t* by the workers. If the resources available (firm's reserves and bank credit) are smaller than the expected wage costs, the firm does not invest in this period. Otherwise, it orders and pays to the capital sector as many machines as it can pay, or as it desires (whatever is smaller). It is worth noticing that the expected wages can be a bad forecast, if when hiring the firm draws only workers demanding above average wages, and the firm may produce less than predicted for lack of money. The firm may also produce less than desired if its maximum productive capacity is smaller than the desired production level or if their demand for work is higher than the number of workers available.

As explained, the process of making desired production/investment (in Bromiley's (1986) terms, the reason for capital investment) and effective production/investment compatible is carried out starting with the evaluation of firm's available resources. Firms always prioritize the usage of internal resources, accumulated from previous periods. Only in case these resources are not enough to cover expected wage costs and the desired investment costs, the firm appeals to the monopolist bank, taking credit. When that happens, the firm takes credit until the first of the following facts occur: i) the maximum indebtedness tolerable by the firm's board is achieved, ii) the maximum indebtedness or minimum market share tolerable by the bank is achieved, or iii) the resources sufficient to finance the desired level of production and investment are obtained. In line with our exposition above, if i) or ii) happens the firm diminishes its resources committed with investment and, when this possibility is exhausted, it decreases its effective production level. This mechanism is in line with the evidence presented in Bromiley (1986), who mentions that investment tends to be the first component to be diminished in a firm under financial fragility.

Although our banking sector and its financial relations are as simple as possible, we believe that by modeling the dynamic exposed above we are following evidence presented, for instance, in Fazzari et al. (1988), according to which financial decisions are not the main determinants of investment in aggregate, but they matter for specific groups of firms (in our case, they matter for firms with small reserves). In addition, we follow Bromiley's (1986) idea that there is a maximum indebtedness that firms' boards allow their companies to take, and, as will be better explained in the description of the banking sector, that internal funds have a cost advantage, when compared to credit. Applying these mechanisms we intend to maintain our Kaleckian inspiration, emphasizing the necessity of firms' internal capital and the increasing cost of indebtedness.

After paying the capital sector, the consumption firms hire workers (the detailed process is described in the section about the households sector) and allocates them to produce using their equipments. The machines are sorted out by their productivity, ensuring that the more productive ones are employed first. The production then takes place, with every occupied machine producing as many goods as its productivity permits.

Once the production has taken place, we need to specify how firms define their prices, and how does the market interaction between consumers (buyers) and firms (sellers) develop. Here we follow Fabiani et al. (2006, pp.3), according to whom "firms operate in monopolistically competitive markets, where prices are mostly set following markup rules and where price discrimination is common.". Therefore we are inspired by Kalecki's (1971, chap.5) scheme for price determination to delineate a modified version of the replicator dynamics presented in Dosi et al. (2010) and Possas et al. (2001).

Under imperfect competition, our firms define each one its price, by which all available production will be potentially sold in this period. Each firm applies its own markup rule, multiplying it by their heterogeneous costs of production. The firms' cost for each good is given by:

$$UnitCost = \frac{Spread_{t-1} + Investment_t + Wages_t + Taxes_{t-1}}{NumberConsumptionGoodsProduced}$$

where the markup varies on each period for each firm, depending on whether the firm's market share expanded or shrunk in last period, as firms worry about maintaining their market shares. Therefore, firms determine their markup according to the following, and for now simple, equation:

$$MkUp_t = MkUp_{t-1} + \alpha_1(MktShare_{t-1} - MktShare_{t-2})$$

where α_1 is a positive parameter giving firm's sensitivity to the maintenance of their market share.

Given firm's heterogeneous prices, we can establish each firm's market share. In our replicator dynamics, the market share grows (shrinks) based on the difference between one firm's competitiveness and the weighted (by market share in *t-1*) average of all firms' competitiveness. In other words, when a firm is more competitive than the weighted average, it enlarges the portion of the total demand to which it can sell its products. In our model the firms' competitiveness is purely determined by the prices charged by each firm[7] – a firm enhance its productivity by lowering its prices. In Possas' et al. (2001, p.347) words:

"Firms with smaller costs take advantage of that to obtain higher profits in the short-run (…) and firms with larger costs sacrifice their desired markup in benefit of their market share. Another implication of this equation for firms' behavior is that, with the average price weighted by the market share, firms with larger market share will have more influence to determine the market price, playing the role of a price leader, while smaller firms can reduce significantly their prices without creating a big impact in the market price."

Following the determination of the firms' competitiveness, average competitiveness and the market shares, we compute the total demand value. It is given by the sum of everything all workers received, as they spend everything they earn:

[7] In our base model we won't include in the competitiveness level a factor related to deliveries' delays, as in Possas et al. (2001), nor a factor related to firms' lack of goods to sell, as in Dosi et al. (2010). We don't believe this choice will bring major consequences for the issues we want to analyze.

$$TotalDemand = TotalUnemploymentBenefits + TotalWagesEarned$$

We allocate this demand amongst firms, proportionally to their market shares. In this version of our model, when a firm can't satisfy all the orders it receives from its customers (for producing less goods than its market share demanded), these customers are left without those goods in this period, and no firm keeps this share of the demand[8]. The amount of money not spent by the households (when total demand is greater than firms' total revenue) is equally divided amongst all households, as an unsatisfied demand to be met in the next period.

After receiving payments for its sales, the consumption firms return the money they borrowed (except when they didn't borrow any money) to the monopolistic bank, adding the proper interest rate. Afterwards they evaluate their gross profits in this time step, and pay a proportion of it to the government. Finally, every simulation period ends when the consumption sector receives its new machines ordered from the capital sector monopolistic firm in the beginning of the period. Also, the oldest machines are discarded (their lifetime is defined by a parameter), as a depreciation mechanism.

iii) Banking sector

As earlier noticed, our banking sector will be as simple as possible. Composed by one monopolistic bank, which does not pay interest on deposits and grants credit passively, our bank lends money to the consumption firms which don't have enough internal financial capital to produce and invest their desired levels.

The interest rates charged increase based on the indebtedness level of the firm: the higher the (borrowed value/firm's revenue in *t-1)* ratio is, the more expensive is each money unit lent. The idea here is to reproduce a simplified proxy of the increasing risks and costs associated with borrowing money, as a proportion to firm's internal capital, as presented in Kalecki (1968, cap.8). With this mechanism we also want to reproduce the evidence presented in Bromiley (1986), who mentions that internal funds have cost advantages for firms, when compared to credit funds.

As done by the board of the firm, the bank also defines a maximum indebtedness level above which it does not lend additional money for firms. The idea is that above that level, banks are afraid of the firms' solvency, and stop taking the risk to lend. The credit risk is real in our model: while a firm does not have enough resources to pay their loans to the monopolistic bank, the missing money is a loss the bank needs to deal with. Our bank also prevents defaults by neither lending money for firms which didn't pay everything they owe in last period, nor for firms below a certain market share, which is in line with the credit constraints that small firms face.

Apart from that, the interaction between firms and bank is extremely simple: the monopolistic bank concedes the amount of money demanded by each consumption firm in the beginning of each period, and receives these resources added by the proper interest rate in the end of the same time step.

iv) Public sector

[8] In a latter version we intend to transfer the demand not met to the firm with the smallest price, and keep households' reserves individually (for now they are equally divided between all households for later use).

Our government will play only two roles in the baseline version of our model: collecting taxes and paying unemployment benefits. However, its presence is important for the experiments we want to conduct with our simulations, and to test hypotheses related to business' confidence levels.

Therefore, as in Dosi et al. (2010), in the end of each period our government interacts with the consumption and capital sectors, charging a proportion of their net profits as taxes given by an exogenous tax rate. In the next time step, these resources are employed to pay each unemployed a benefit. The government acts in an anti-cyclical manner, giving a proportion of the period's average wage as an unemployment dole to each unemployed, thus spending more when there are more unemployed and less in boom periods. Modeling this way we choose to have the government's budget as the variable which adjusts to the others; an alternative path would be using the unemployment dole's value as an adjustment – which makes our model more pro-cyclical, less stable and, in our view, less realistic.

v) Households

Our economy contains a fixed number of households (workers/customers), responsible for all productive activities in our economy and, also, for the entire demand for consumption goods. These agents are homogeneous in their productivity when working, but define, in the beginning of each period, heterogeneous wages, which they will demand for accepting a job in the consumption sector.

Our workers will establish their demanded wages using a similar, but modified, equation in relation to Dosi et al.'s (2010). The wage each worker will ask for will vary depending on i) the wage asked in *t-1*, ii) the growth of the unemployment rate between *t-1* and *t-2*, and iii) the evolution of productivity in machines produced in the capital sector (as suggested in Kalecki (1971, chap.6). As the number of workers is fixed, ii) may be understood as the fluctuation in the number of job opportunities, which put us in line with Barron's (1975) evidence that when the number of vacant jobs increases, the probability of a worker to accept a job decreases. Workers' wage demands are better understood by displaying the following equation:

$$DemandedWage_t = DemandedWage_{t-1} + \alpha_2(ProdK_{t-1} - ProdK_{t-2}) + \beta_2(UnempRate_{t-2} - UnempRate_{t-1})$$

where α_2 is a positive parameter measuring how much of economy's efficiency gains are appropriated by workers and β_2 is a positive parameter, which represents how much bargaining power the workers loose when the unemployment rate increases.

The first to hire workers is the capital goods sector. The capital monopolist hires first workers to manufacture equipments and, only after that, hires workers to do R&D. The monopolist receives the information about the average wage workers are demanding this period, and hires paying a markup above this average. It draws workers randomly and offers them this homogeneous payment[9]. In our simplified model, no worker denies the offer made by the capital firm, because they know it offers a better wage than they should expect to earn in the consumer's goods sector (although this worker may have demanded an even higher wage previously).

After hiring the workers it needs to produce every machine ordered by the consumption sector. The capital firm takes all workers not employed before and, again, draws randomly who will be their

[9] Of course, when hiring firms take care not to hire the same worker twice.

employees in R&D, paying them a markup above the average wages demanded in this time period. Even if this mechanism looks oversimplified, it is important for our goals that the capital firms send their advertisement in the beginning of each period knowing exactly how big their costs will be, so that there are not miscalculations and the consumption goods sector (the real core of our model) receives every machine it has demanded without any trouble.

The workers who weren't hired in the capital sector will take part in a matching protocol, as proposed in Riccetti et al. (2015) and followed in Caiani et al. (2016), to be employed in the consumption sector. What this means is that for every worker a consumption firm needs, it will draw three random workers still available (a metaphor for imperfect information) and compare their wage demands. Whoever among the three has asked the smaller wage will be hired by the consumption firm, which pays exactly the wage demanded by the worker. The protocol follows until every consumption firm has hired every worker it wants (or can pay), except when all workers have already been hired. However, as advocated in Kalecki (1971, chap.12) and differently from what is often the case in conventional models, the usual situation here is the existence of involuntary unemployment.

In the end of each period, the unemployed households receive from the government an unemployment benefit, while the employed receive their proper wage. Following one of Kalecki's main assumptions (e.g. Kalecki (1971, chap.15)), and also our reference models in the literature (Dosi et al. (2010) and Possas et al. (2001)), we suppose that workers try to spend all the money they earn in each period. That won't happen only when consumption firms don't produce enough goods, nor have enough inventories available to meet their total demand. In this situation, these funds are equally shared between all workers, and increase next period's total demand.

Sequence of events

Although the simulation in Laboratory for Simulation Development (LSD) in general does not require the programmer to establish an accurate sequence for the equation's execution, we think it is a fruitful way to summarize our model, now that we've carefully presented it, to offer a brief timeline of events occurring in each time step. It can also help us to have a broader and more intuitive view of its execution.

In any given period, the following microeconomic decisions take place in sequential order:

1) Households establish their desired wages for this period.
2) With the average wages, the capital firm can foresee its costs and decide its capital goods prices. The monopolistic firm advertises to the consumption sector this price and the productivity of the machines it will manufacture in this period.
3) With the capital goods prices, the consumption firms try to foresee their expenditures with wages and decide its desired levels of production and investment.
4) The consumption firms evaluate its financial constraints and take credit from the monopolistic bank, trying to make compatible its financial constraints to its desired production and investment levels.
5) The consumption sector orders from and pays for the investment goods to the capital sector.

6) The capital goods sector hires and pays wages to all workers it needs to manufacture every machine ordered by the consumption sector.

7) The capital sector monopolist calculates its profits and allocates a share of these resources to R&D. It hires and pays new workers to work in this innovative activity.

8) The consumption goods sector hires and pays workers, among the available households, to carry out its production.

9) The government spends the reserves from last period and pays an unemployment benefit to every unemployed.

10) Consumption firms establish the prices of their goods, using a markup above their costs.

11) All households spend their cash buying consumption goods. The consumption firms receive their revenues.

12) The consumption sector pays its debts to the banking sector.

13) Both the consumption sector and the capital sector evaluate their profits and pay the proper taxes to the government.

14) The capital sector delivers to the consumption sector the machines ordered in the beginning of this period. The oldest equipments in the consumption sector are discarded, for being excessively deteriorated.

15) The capital goods monopolist receives the results about its attempt to create more productive capital goods. When successful it replaces the old machines by the new, in next period's advertisement to the consumption firms.

Future improvements

As this model is just a baseline version, before our final master thesis, we are aware of some of its shortcomings, and intend to improve soon some of the mechanisms used in our simulation. In this section we want to briefly describe some of these ideas, so that our readers can make their own mind on if and how those imperfections are biasing our results, and anticipate how our final version will operate. In our opinion, however, those improvements are more designed to enrich our model's credibility and resemblance with reality, than to change significantly the main results presented in this paper. The average reader won't lose much skipping this section.

In the first place, we intend to make more complex the mechanism according to which our workers determine their wages. Their wages' demand won't depend only on economy's productivity and on the unemployment rate, but also on workers' own situation in the previous period, on the functional distribution of income (as a measure of bargaining power between workers and firms), and on the degree of monopoly of the economy (measured by a Herfindahl index for market shares). Therefore, we intend to follow an equation similar to:

$$DemandedWage_t = DemandedWage_{t-1} + \alpha_2(ProdK_{t-1} - ProdK_{t-2}) + \beta_2(UnempRate_{t-2} - UnempRate_{t-1}) + \gamma\,(Hired_{t-1}) + \Omega(WageShare_{t-1} - WageShare_{t-2}) + \theta(HerfInd_{t-2} - HerfInd_{t-1})$$

where $Hired_{t-1}$ assumes value (1) if the worker was employed in *t-1* and (-1) in case he was unemployed, γ is a positive parameter measuring how sensitive this worker is to spend a period

unemployed, Ω[10] and θ are positive parameters measuring workers' bargaining power and industry's rise in the degree of concentration, and α_2 and β_2 where already explained in our baseline model.

Also, the markup rate charged by consumption firms won't depend only on their market shares' evolution, but also on on i) the difference between the firm's price in *t-1* and the average of other firms's prices in *t-1* (the firm interacts locally to observe how much its competitors are charging), and ii) the firm's market share in *t-1*, as larger firms have more market power and can charge more. Therefore, our firms will probably determine their markup according to the following equation:

$$MkUp_t = MkUp_{t-1} + \beta_1\left(Price_{t-1} - AveragePrice_{t-1)}\right) + \alpha_1(MktShare_{t-1} - MktShare_{t-2}) + \pi(MktShare_{t-1} - \frac{1}{NumbFirms})$$

where α_1 and π are positive, and β_1 is negative.

We are also evaluating the possibility of adding a new constraint in the firms' process to take credit, avoiding money took by interest rates higher than their markups (which is rare in our current model). Two additional problems, which probably will be improved with the entrance of new firms, are bank's loss of importance (after some periods most of our firms are either deleted or have enough internal capital to invest and produce) and government's consecutive budget deficits with our current parameterization.

Beyond that, a more technical issue is to correct a minor imperfection in our matching protocol in the consumption firms' hiring process, since each firm is hiring all its workers, before the next starts to hire, and we think it would be better that each firm hires only one worker per time, thus avoiding biased results.

Another necessary improvement is to individualize each worker's consumption, and assure that when his demand for goods is not met, the remaining resources are kept in the hands of this worker, so that he can spend it in goods in the next period. As our reader will recall, in our baseline version all demand not met is equally shared among all workers, to demand goods in the next period.

Last, but not least, we intend to develop an entirely new dynamics for firms' bankruptcy and their replacement by newcomers. Firms' entrance and failure is a critical point in our kind of ABM model, because it is difficult that this won't develop into a distortion for the model, so here it is worthy of take a little longer in our discussion. For now, when our firms lose their entire market share, they are simply deleted from our model, without any replacement.

As argued in Caiani et al. (2016), a way to attenuate distortions is assure that our model is Stock-Flow-Consistent (SFC), as we are proposing here. However, we think that this is a necessary, but not sufficient condition to reduce the distortions, which can arise with the entrance of newcomers. And in this matter most of our reference models are not very helpful: while Possas et al. (2001) does the same as in our base model (firms can fail, but none supplant them), Dosi et. al (2010) does not look like SFC. On the other hand, Caiani et al. (2016) is SFC and has an entrance mechanism, but it depends on households' savings (which we don't have in our model inspired by Kalecki).

[10] There is a controversy on whether this effect is positive or negative. Although our base model will follow Kalecki's view (positive), we intend to test the robustness of this choice.

In view of this, we intend to look for a new solution, specific for our model, according to which when a firm goes bankrupt it is replaced by a new one, which will be a copy of one randomly chosen company. As newcomers tend to start their business smaller than the market's average firm, this random draw will be only among the 50% smaller firms.

In a SFC model, the resources to start this business need to come from our own model. That's why these costs are divided amongst other objects: the newcomer's first machines will have their costs covered by the capital firm (we see as a kind of entrepreneurship, made with the reserves our capital monopolist accumulated with no risk), and, for hiring workers in the first period, the newcomer will receive all retained profit from the crashed firm (if any) and credit free of interest rates for one period from the bank (we think that as a special line of credit for start-ups).

It is important to reaffirm that all those improvements probably won't change much the qualitative results we already had in our baseline model. However, they may enhance our model's precision, its resemblance with reality and contribute somehow to the literature.

Part III – Preliminary results and analysis

We simulate the baseline version of our model described above with one bank, one capital goods firm, 50 consumption goods firms and 5000 workers over 1000 periods. Most of our analysis is based on the average results of 20[11] simulated markets. Our consumption firms have identical initial values and parameters, except for their initial markup – which assumes random values between 1.1 and 1.5. Also, our workers follow the same parameters, except for their initial wage demand – which assumes random values between 50 and 60. The most important values in our initial setup are displayed in a table, at the end of this section.

As we are dealing with a non-ergodic system, in which the initial conditions play a critical role in determining our results, we choose to follow Caiani et al. (2016) and present our model's transition phase. Also, there is an inevitable arbitrariness in choosing which moment establishes our model's convergence to its quasi-steady-state configuration, and we prefer to give our readers the option to decide. However, we suggest the first 250 periods to be understood as a period of transition, and we will center our analysis below on the subsequent time steps.

Figures 1-3 show our markets' average values for nominal GDP[12], aggregate demand and unemployment. We achieve an economy with cyclical, and stable, employment level, which assures cyclical, but slowly increasing, demand and output. This increasing demand is the other face of the increasing total wages paid by consumption firms (figure 4) added to the, proportionally much more volatile but less important, stable wages paid to workers producing capital goods and slowly increasing wages paid to workers innovating (figures 5 and 6).

[11] We are aware that more markets are needed for a reliable Monte Carlo analysis, but for now that wasn't possible for computational constraints. However, as all our markets behave very similarly for every relevant variable, we don't believe this imperfection spoils our preliminary conclusions.

[12] As will be shown, consumption firms produce most of our economy's output, and their prices essentially converge to 1. Given that, the nominal and real GDP are very closely related.

Figure 1: Nominal GDP

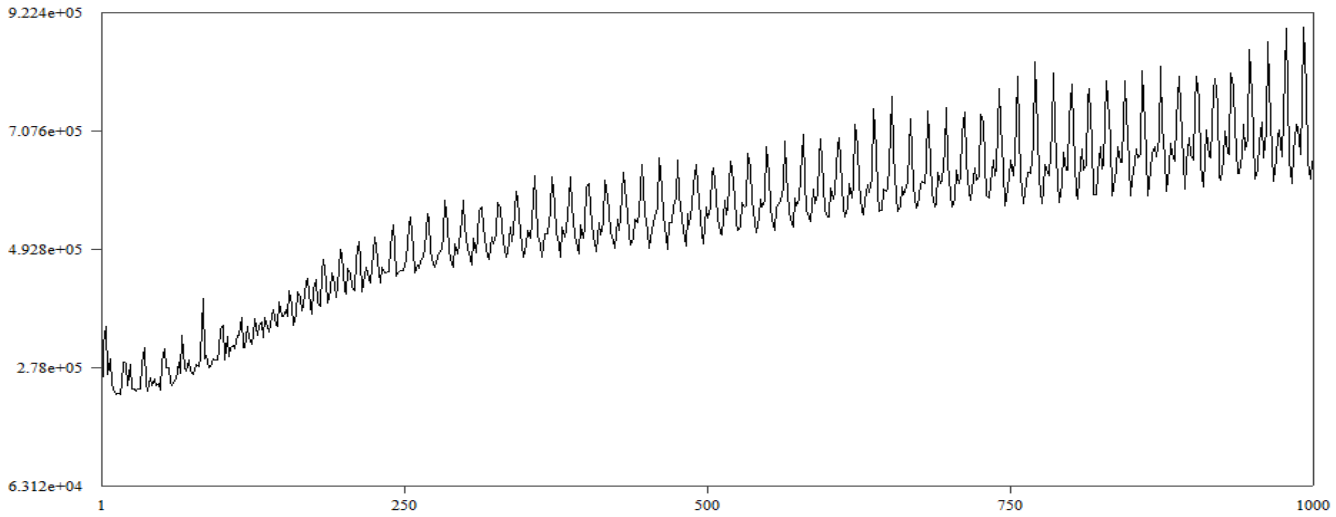


Figure 2: Aggregate Demand

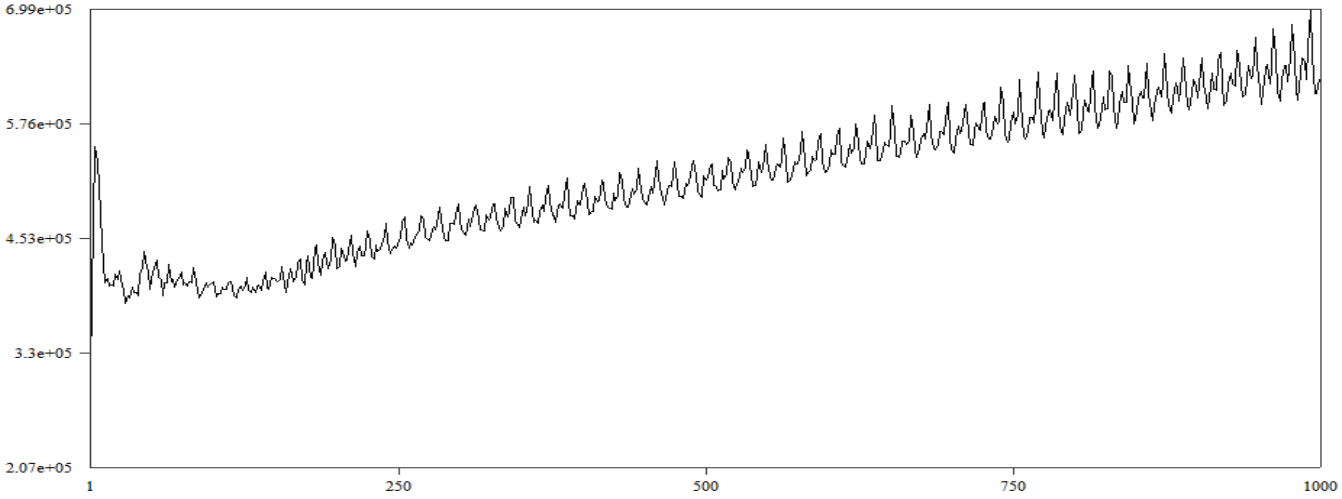


Figure 3: Number of Unemployed

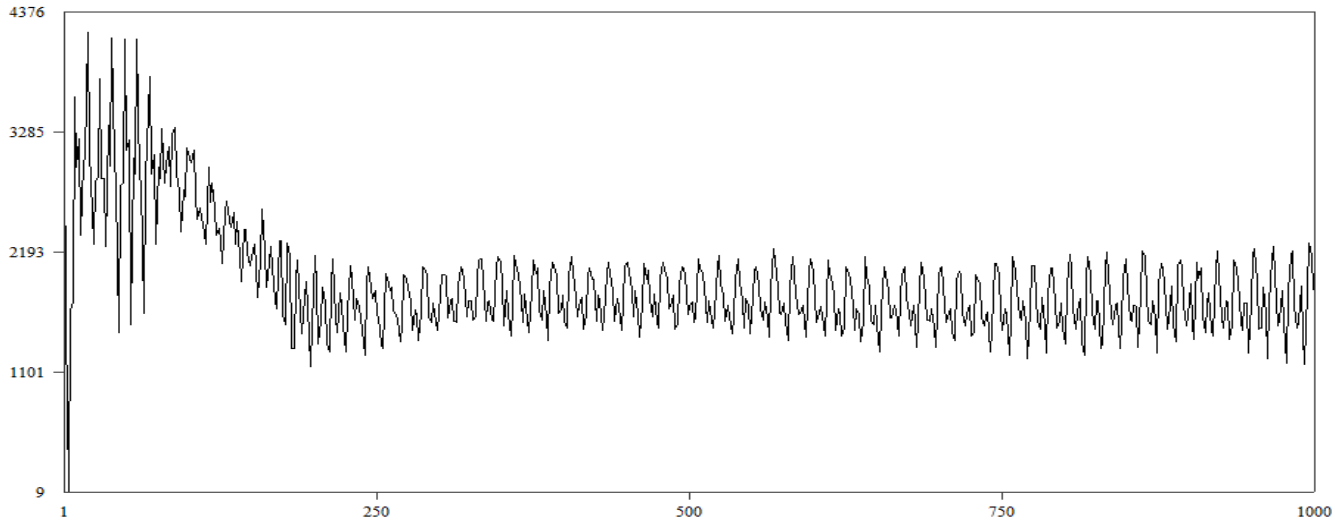


Figure 4: Total Wages paid by Consumption Firms

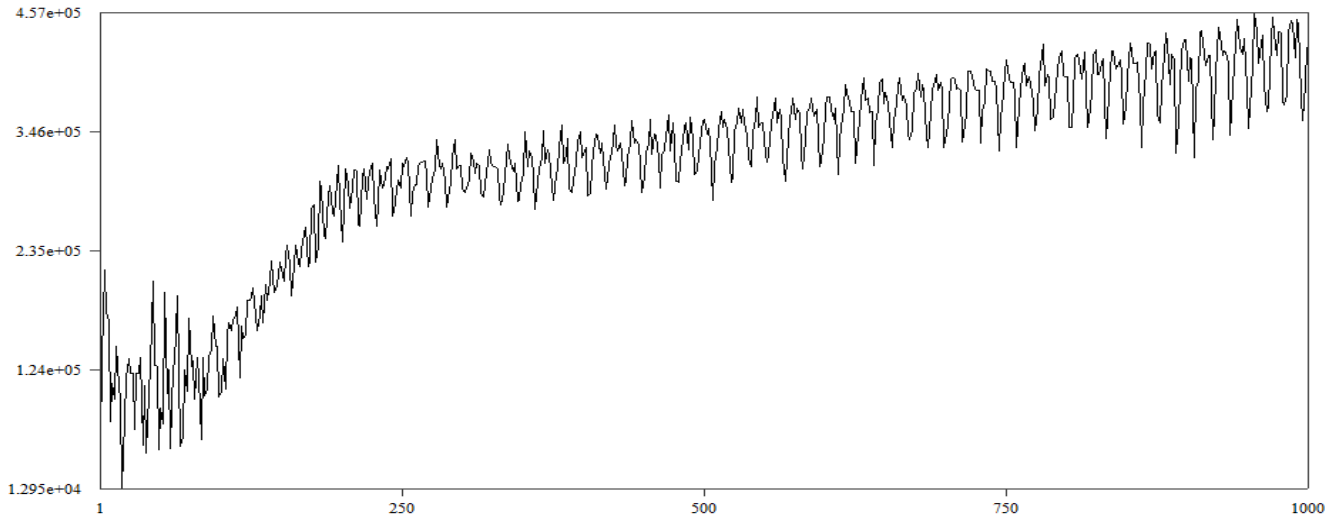


Figure 5: Total Wages paid to produce equipment

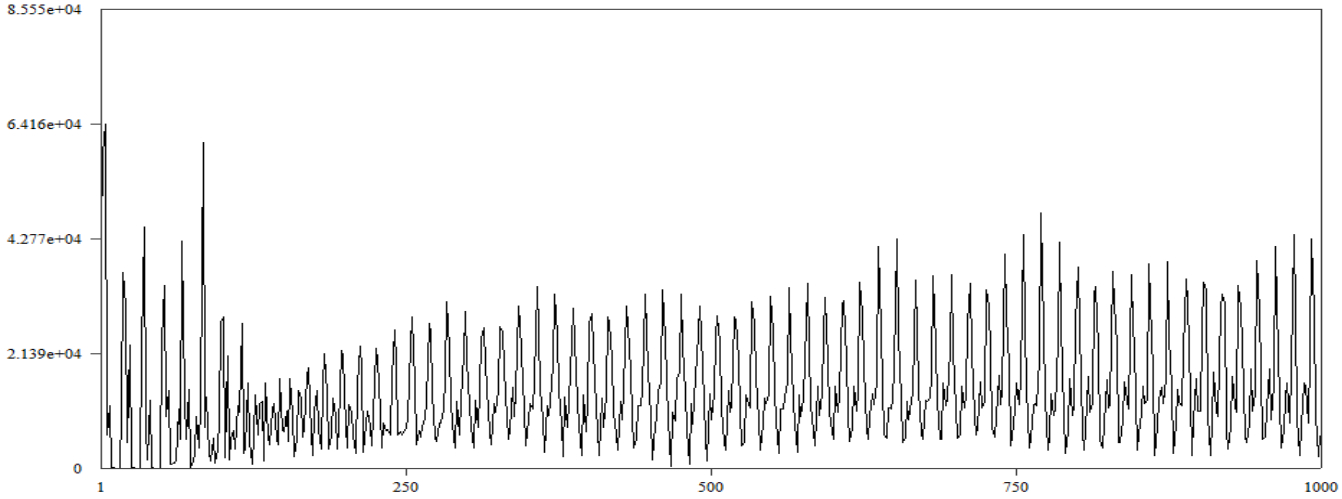
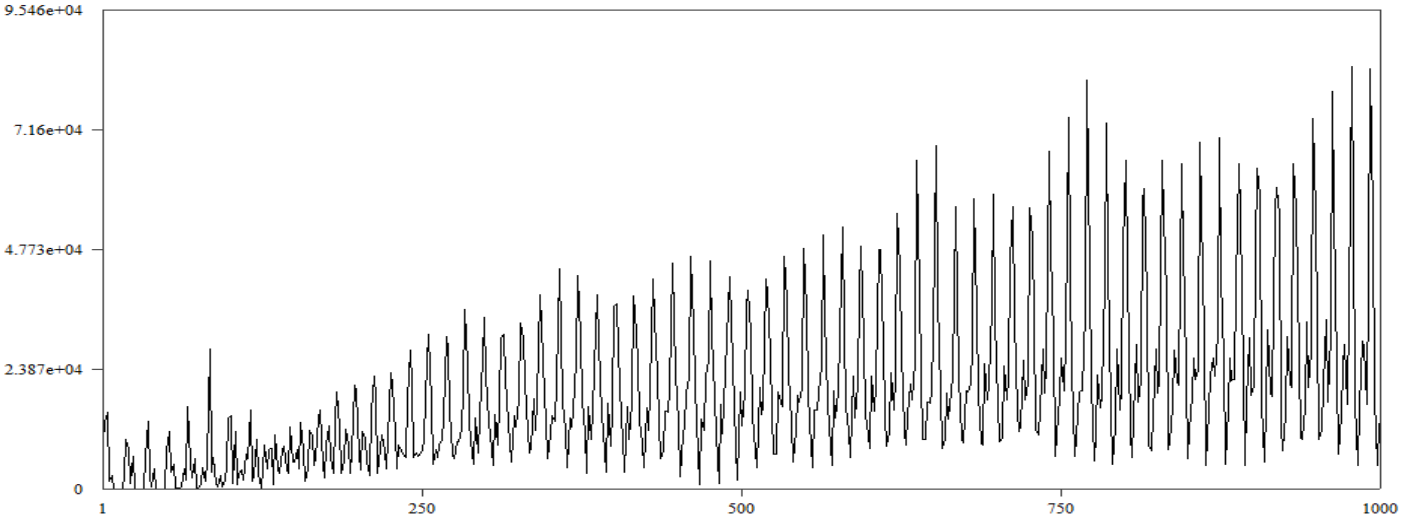


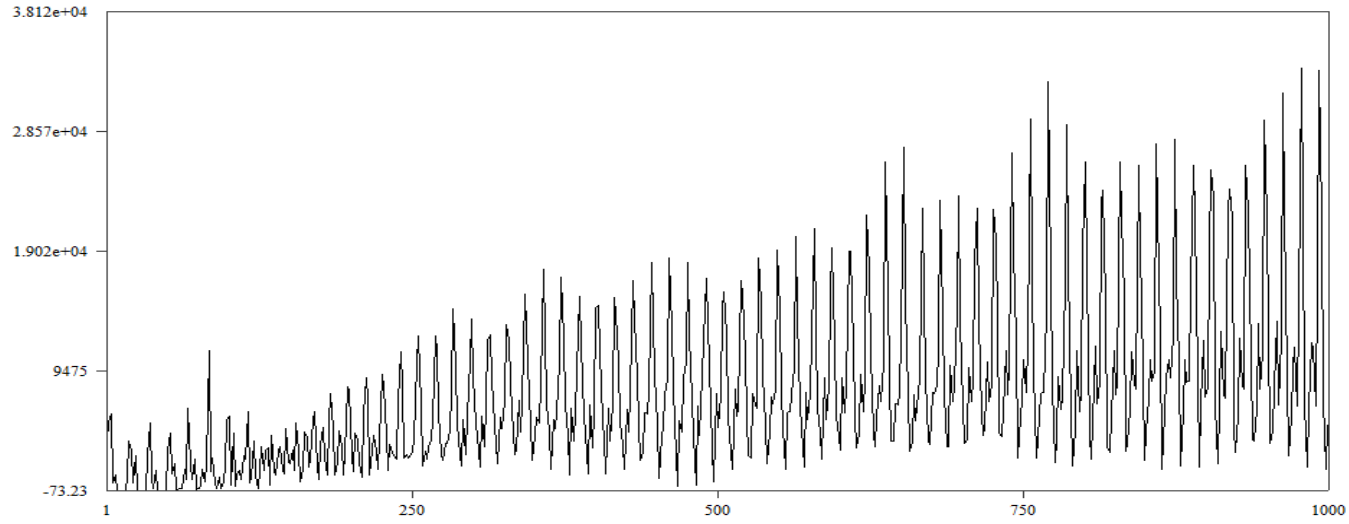
Figure 6: Total Wages paid in R&D sector



The contrasting trends observed between the two kinds of wages paid by the capital goods monopolist reflect that its profit rate is increasing. As our monopolist appropriates a part of the capital goods' efficiency gains, charging increasing prices while its costs of production remain

stable, its total profits increase (figure 7). As the innovative budget is a fixed proportion of profits, and entirely spent, its growth implies higher wages paid to the R&D sector.

Figure 7: Capital Firm's Net Profit



Of course, higher revenues to our capital firm means higher investment levels done by the consumption firms. Also, we can observe in figure 8, that our investment goes in line with the empirical literature and is more volatile than our economy's output and consumption (Danthine and Donaldson (1993)). In addition to that, in line with Caballero (1999) and Doms and Dunne (1998), we can see that investment is not a steady and consistent phenomenon. Quite the opposite: observing the total number of machines in one singular market, we can see that firms invest in jumps when their capital level is below a certain limit (figure 9).

Figure 8: Aggregate Investment

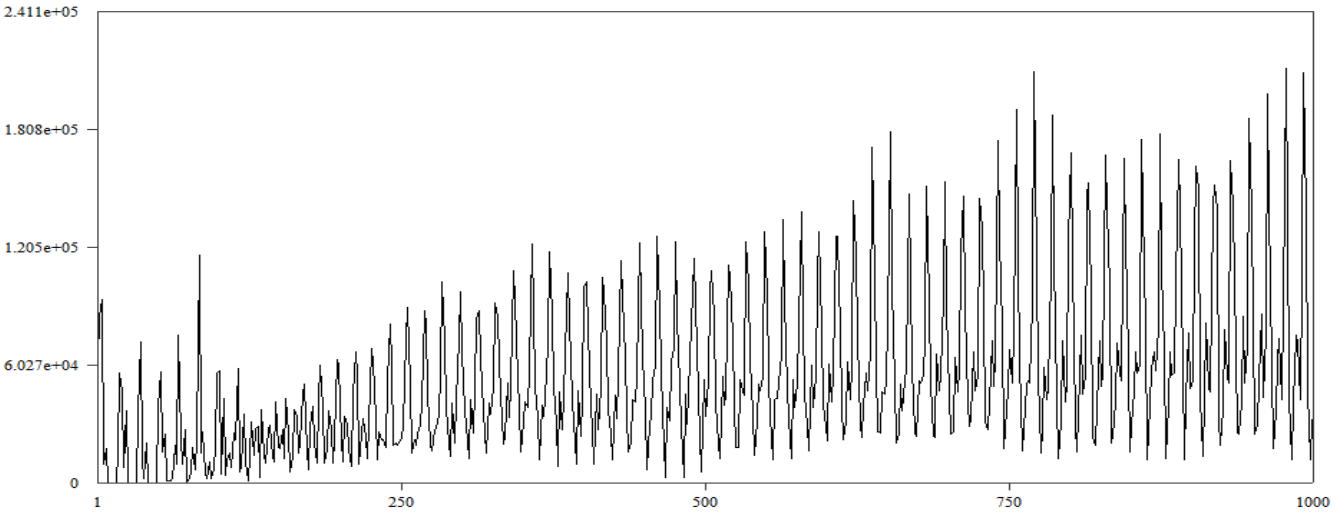
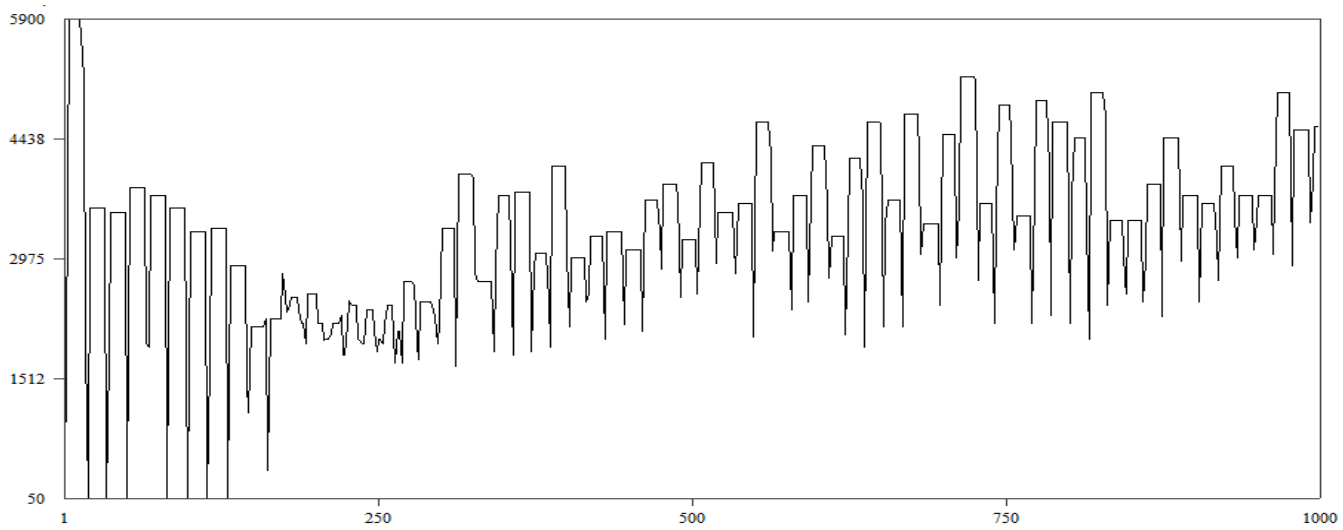


Figure 9: Total number of machines available (example of one single market)



Following investment, we can see in figure 10 that our productivity increases slowly and in small jumps. As workers appropriate a part of this growth, we can see in figure 11 that the average wage demanded by our workers grows following the productivity level.

Figure 10: Productivity of the machine advertised (black) and of the average machine available (red)

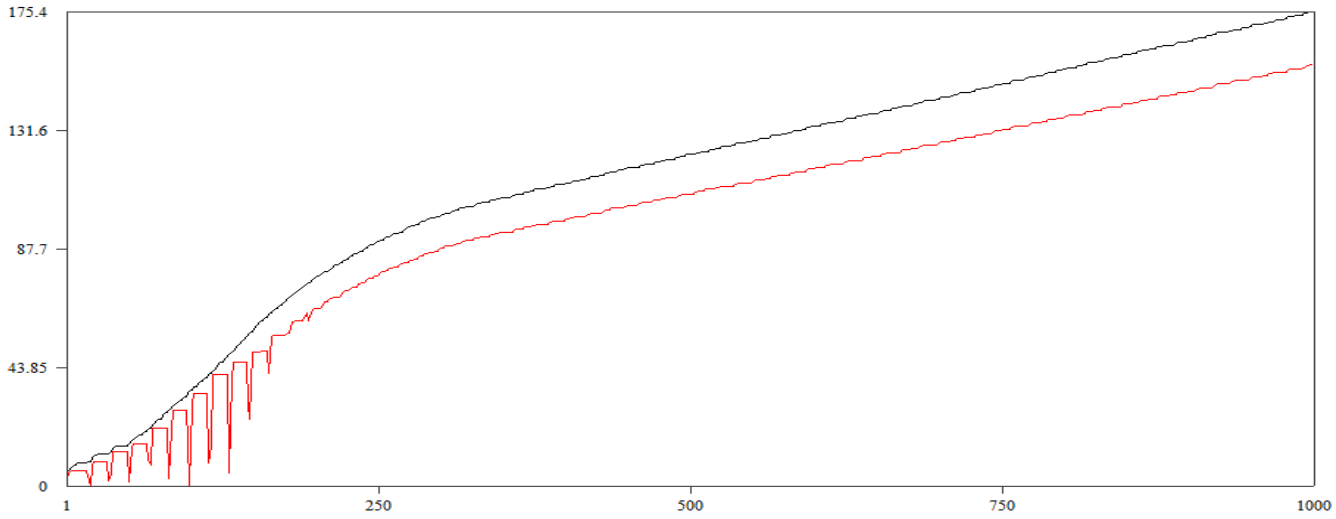
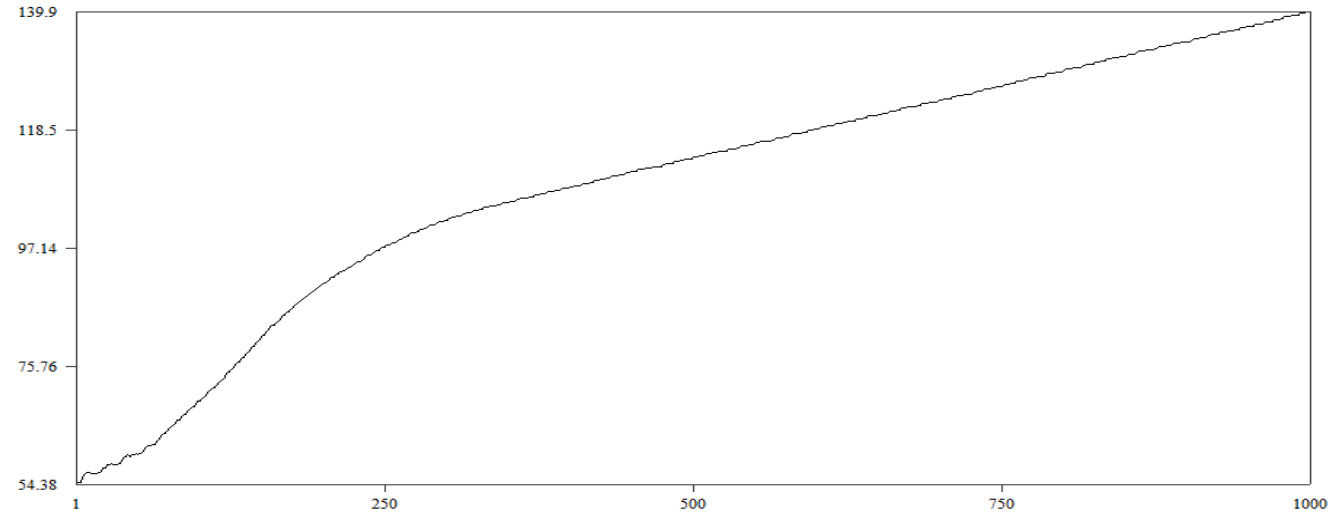


Figure 11: Average wage demanded by workers



Another crucial aspect of our model that deserves attention is demand's expectations. We can see in figure 12 that expectations grow cyclically, as does effective demand, but are much more volatile than effective demand. Our main contribution to the literature, the optimism level (figure 13) that affects expectations is fairly stable, though does not have well behaved cycles.

Figure 12: Demand Expectations for t

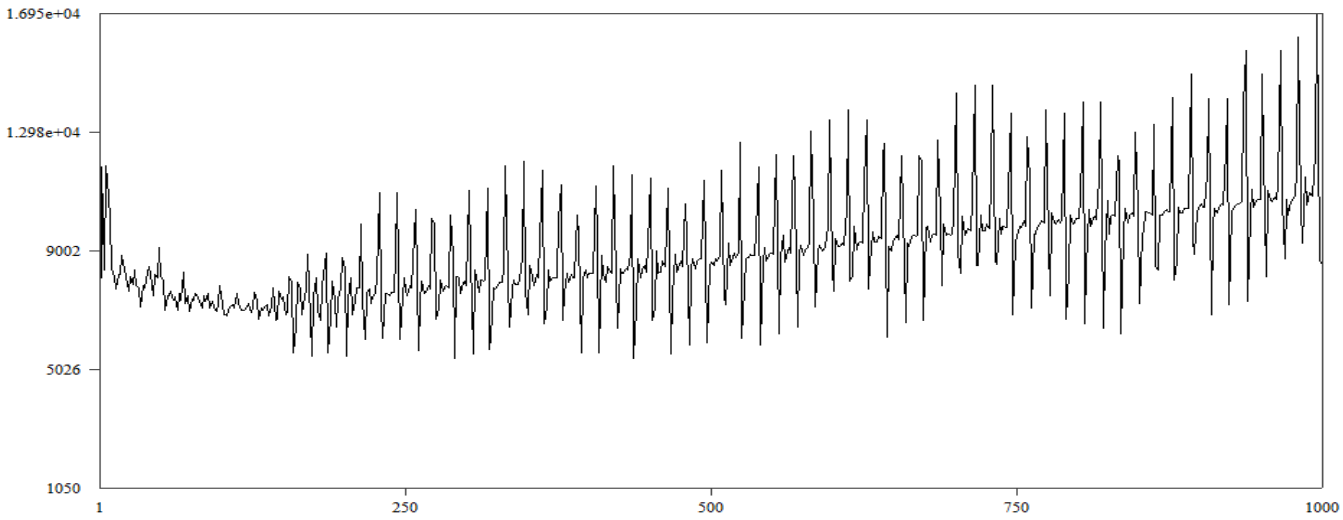
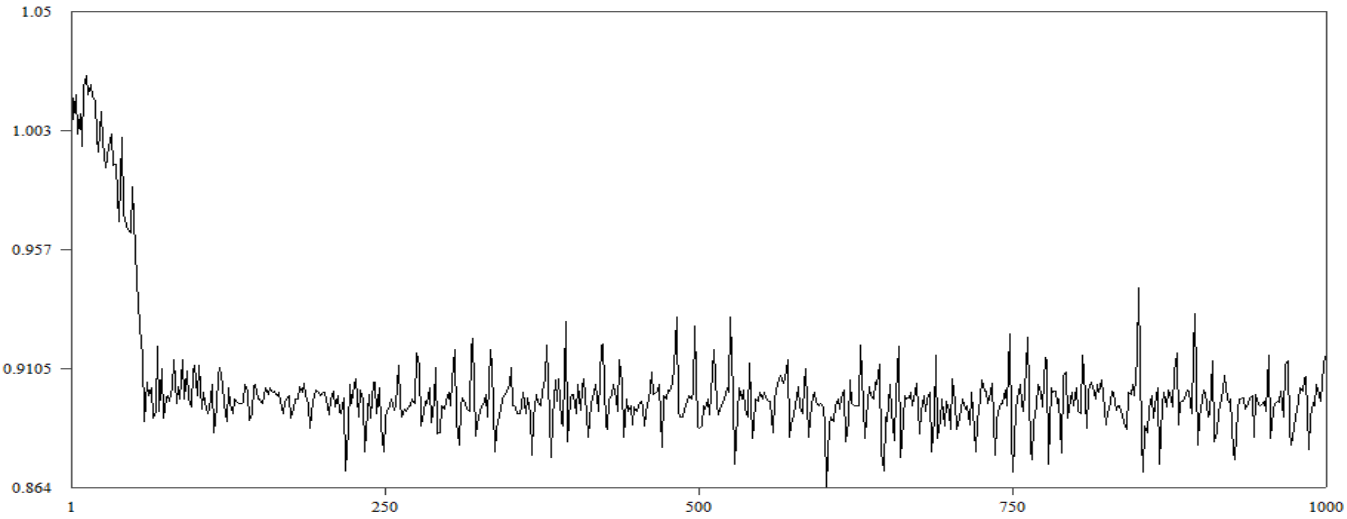


Figure 13: Average Optimism Level



Furthermore, it is worthy to observe whether the consumption firms[13], the monopolistic bank or the government are cumulating reserves. Here we can see (figure 14) that our bank suffer losses in our economy's transition phase (as some firms fail), but quickly recovers, receiving spreads from the survivor consumption firms – until they have enough reserves to use only internal resources. As we can see in figure 15, those firms normally have positive profits, but use to suffer a loss in cycle's descending stage. The government, on the other hand, is suffering repeated deficits – which is probably our baseline model's greater flaw, and will deserve further attention in the future.

[13] There is not any doubt about the capital goods firm: it receives in advance for each machine produced and always cumulates profit.

Figure 14: Bank's retained profits

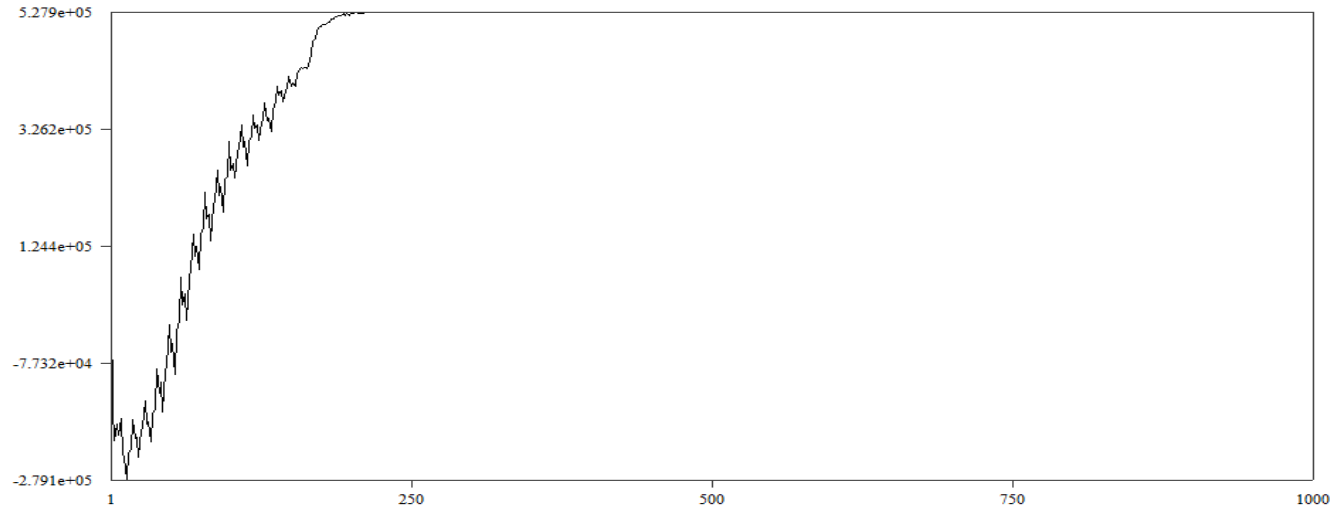


Figure 15: Consumption Firms' Net Profit

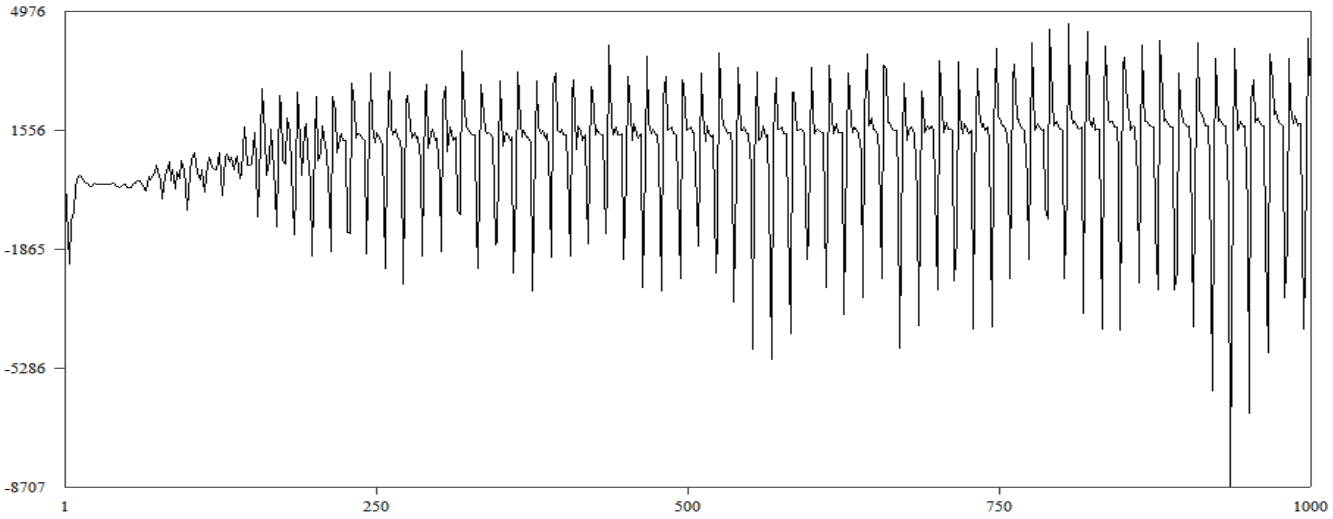
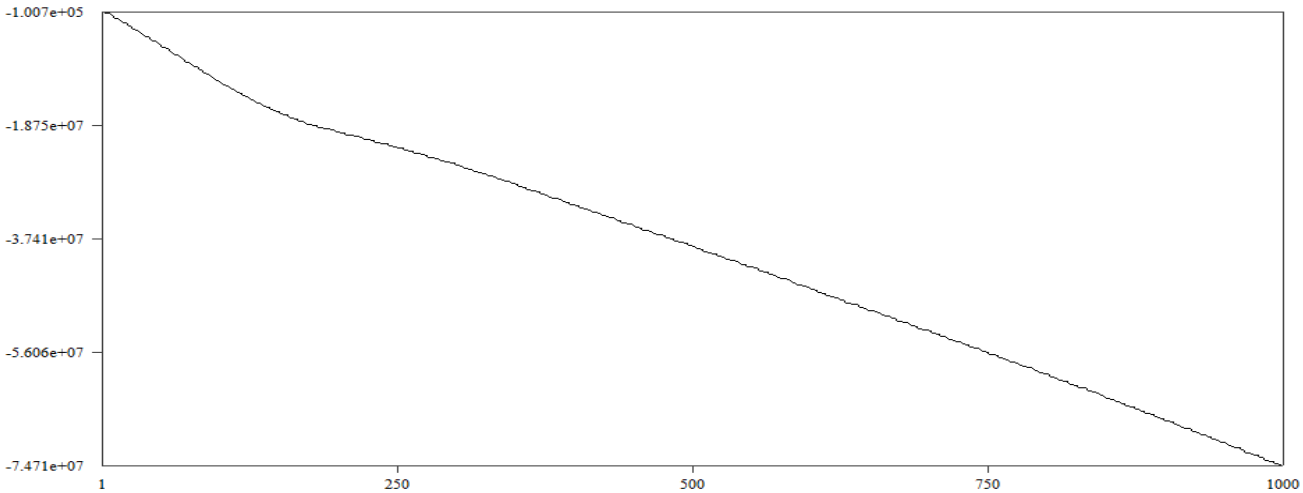


Figure 16: Government's Reserves



When discussing our monopolistic bank's wealth, we've mentioned that some firms fail in our transition phase. As we think this growing concentration in consumption market as problematic, and intend to introduce newcomers in a future version of this model, it is worthy to understand how firms'

market share evolve (figure 17), a measure of the growing concentration (figure 18 is a Herfindal Index) and to observe that prices converge with spikes to 1 (figure 19), as firms try to appropriate via competitiveness the maximum market share possible.

Figure 17: Market Share evolution (example of one single market)

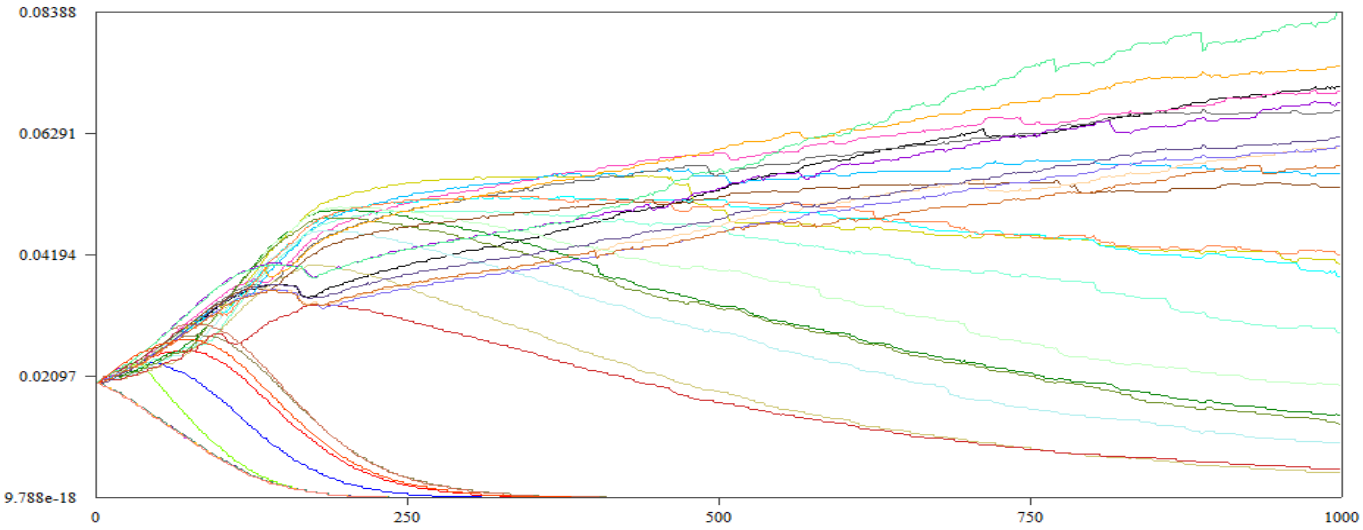


Figure 18: Concentration Index (Degree of Monopoly)

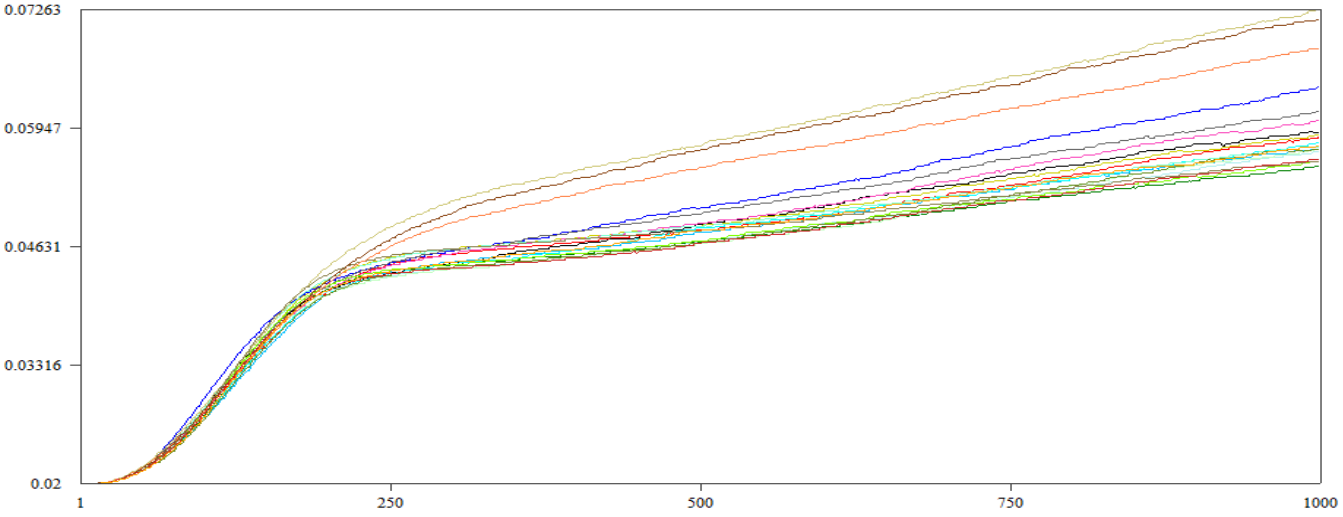
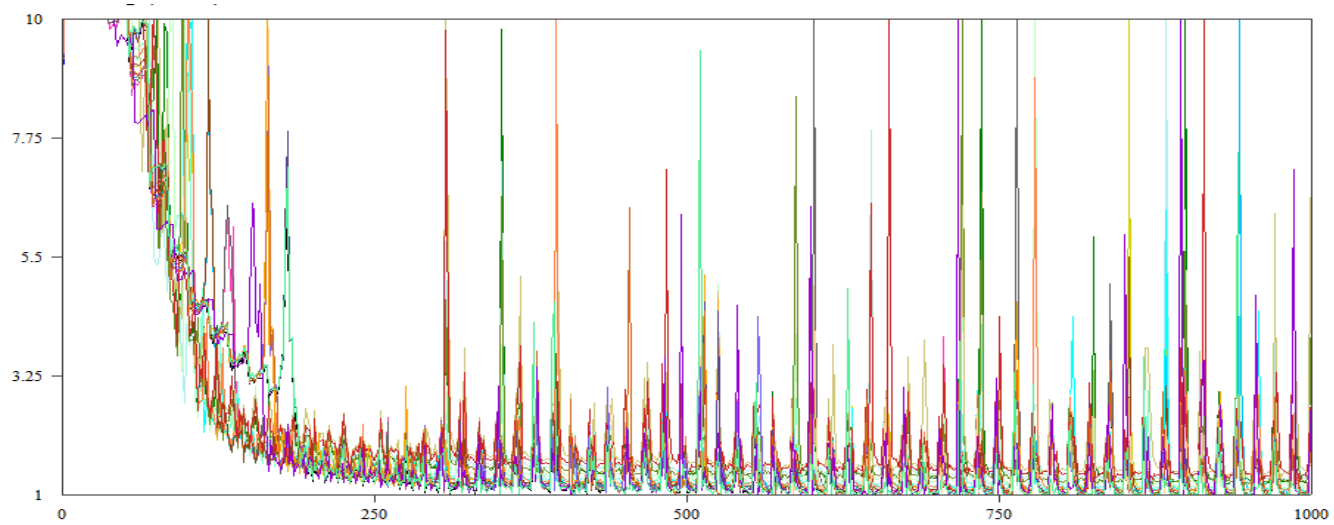
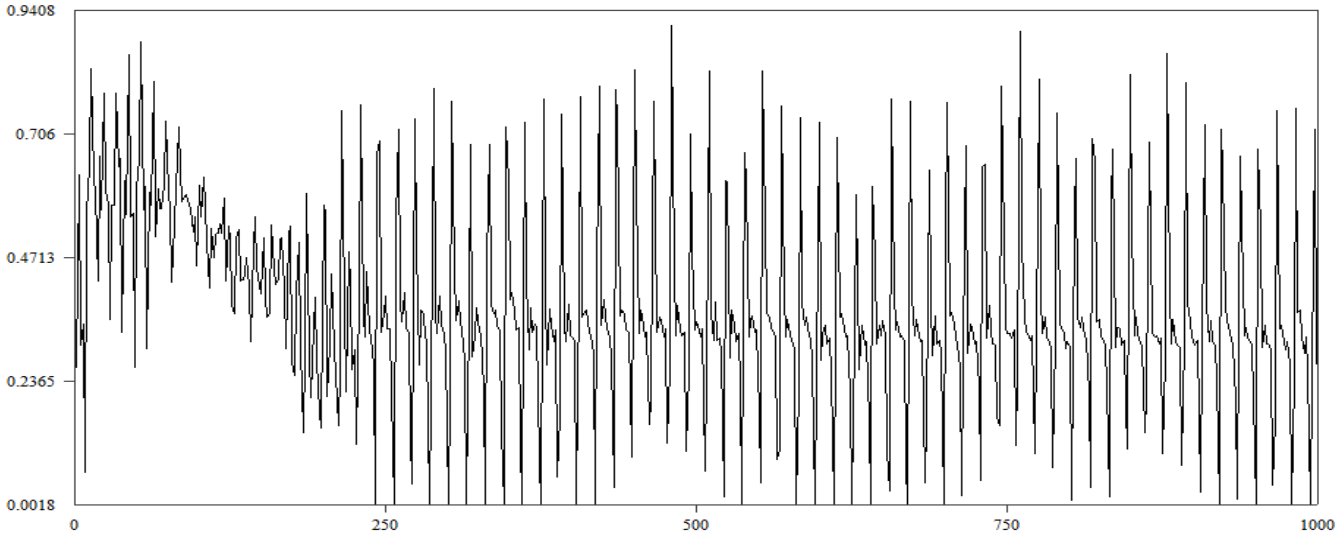


Figure 19: Price Evolution (example of one single market)



Finally, one last relevant fact to notice is that averaging the results achieved by a number of different markets may, sometimes, hide the real volatility achieved by each variable in each of the simulated economies. With the examples taken from one single market, and the figure 20 below, we intend to make clear the volatility achieved by each market, as it is surely higher than the reported in the averaged statistics.

Figure 20: Unemployment Rate (example of one single market)



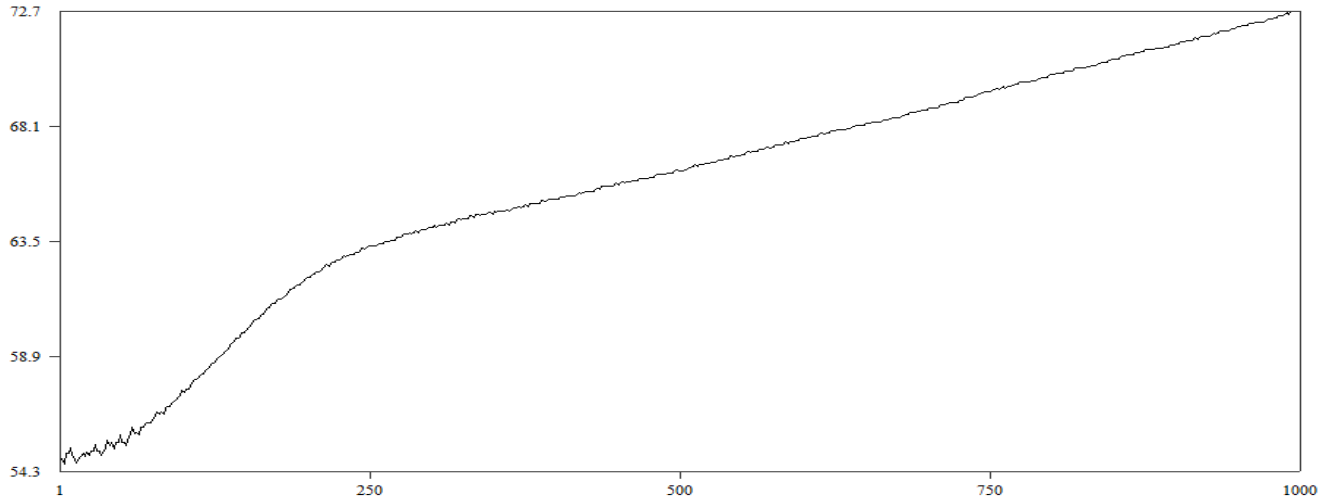
The Paradox of Costs

Along this work we have claimed our inspiration in Kaleckian features to base each of our agent's micro behavior. An interesting question which follows is whether these Kaleckian microfoundations result in macro behaviors alike those suggested by Kalecki.

As already explained in our review of the literature, the paradox of costs states that higher (smaller) wages would lead to higher (smaller) profits. Although when a single firm reduces its costs related to wages it can improve its profits, Kalecki explains that when all firms make this decision together, the demand shrinks and their profits are reduced.

In order to test if this behavior may happen in our model, we simulate 5 markets with exactly the same parameters and initial values as our baseline model, except for the parameter measuring workers' sensitivity to productivity improvements, when they demand wages. While in our baseline model workers demand 0.5 higher wages for each additional good produced by the machines advertised, in this version we reduce this parameter to 0.1. The idea is to test how our economy develops when workers appropriate a smaller part of the economy efficiency gains.

Figure 21: Average Wage Demanded by Workers (Paradox of costs' experiment)



As we can observe in figure 21, applying this change really shrinks workers' actual demand for wages after some periods. While in our baseline model they demand 139.9 after 1000 time steps, now they demand only 72.7 (the consumption goods' prices didn't change relevantly). The effects of this variation on the economy are evident: even with productivity improvements the GDP stops growing after the transition phase and demand expectations converge to a value smaller than its initial – leading to stable investment and production decisions.

Figure 22: Nominal GDP (Paradox of costs' experiment)

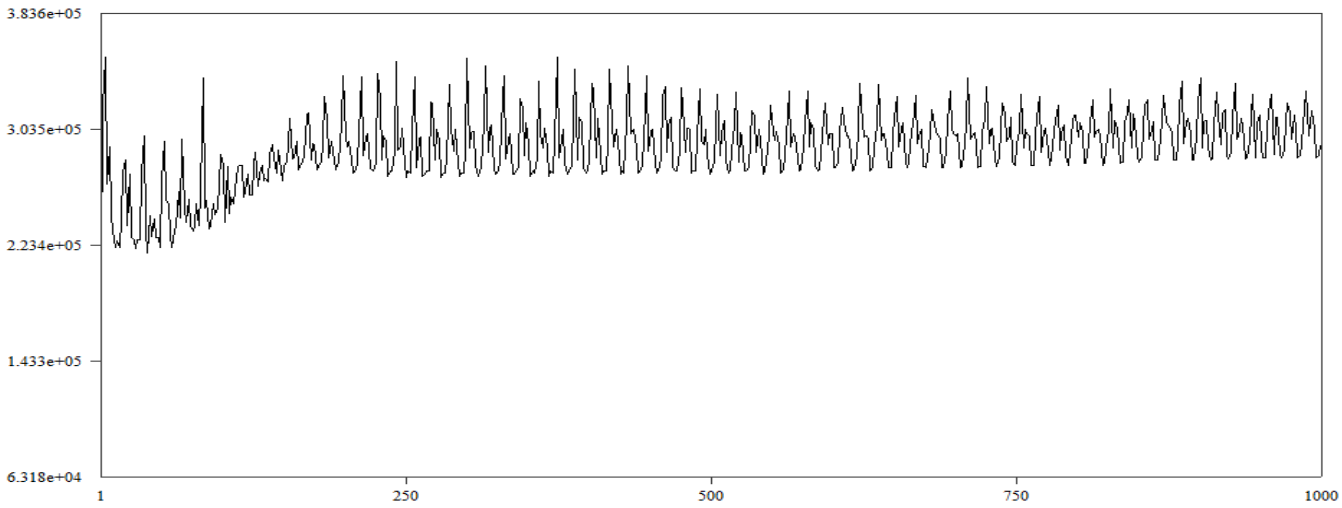


Figure 23: Demand Expectations for t (Paradox of costs' experiment)

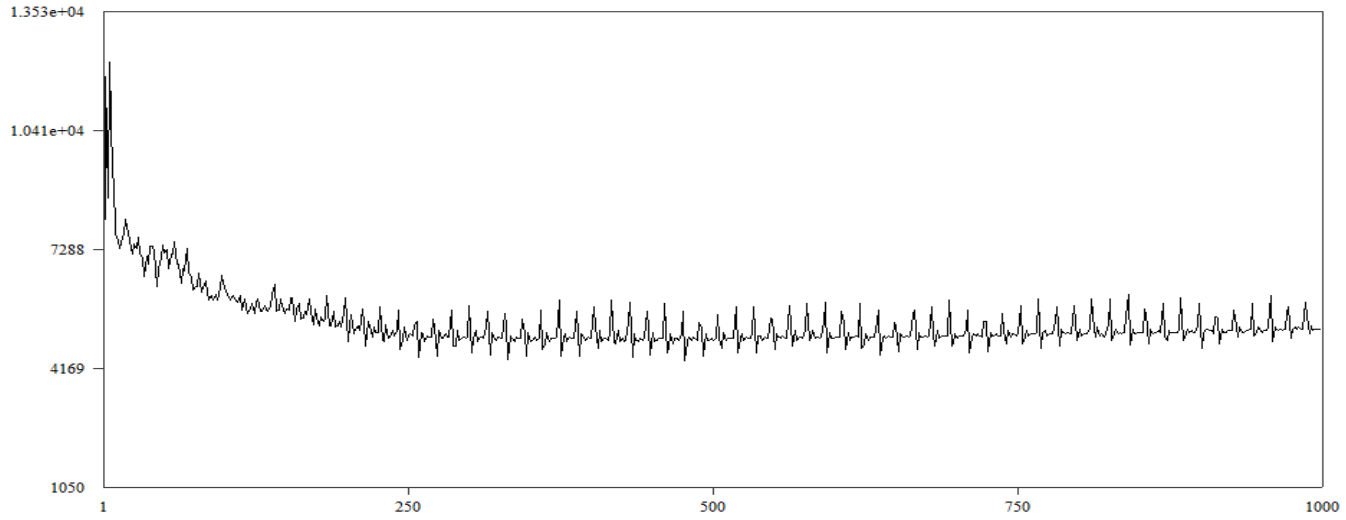
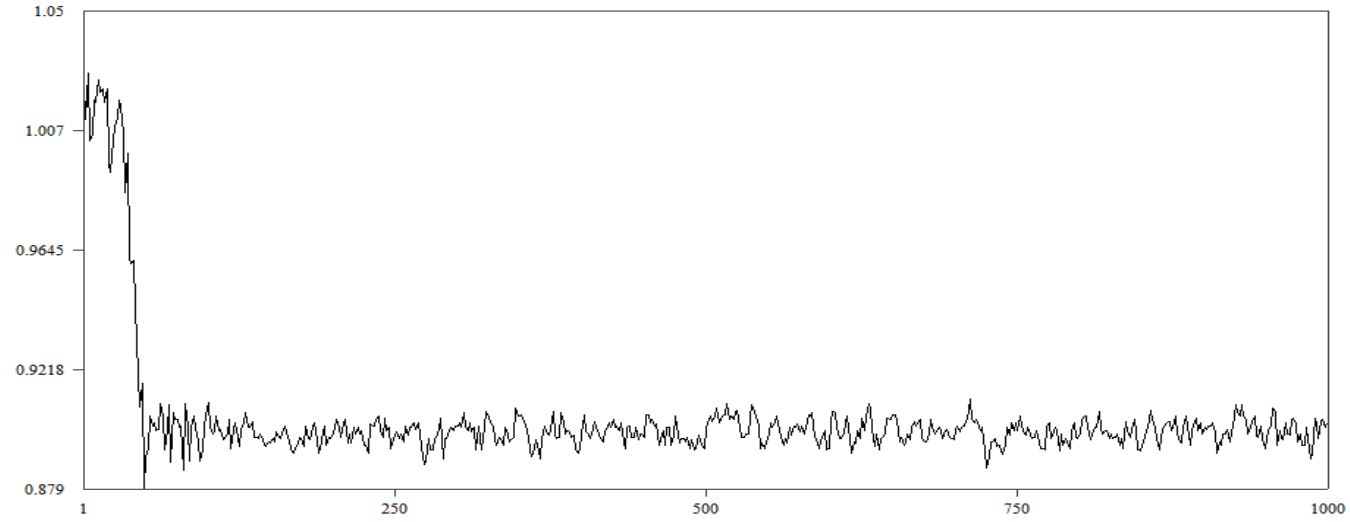


Figure 23: Optimism (Paradox of costs' experiment)



The behavior observed in firms' profits is less obvious. While consumption firms (which had stable profits in the baseline model) experience increasing profits, reaching after 1000 periods a level approximately 700 higher than in the initial version; the capital monopolist (which had increasing profits in our baseline model) experience stable profits, approximately 7500 smaller than in the initial version after 1000 time steps. This means that, though living in a stagnate economy, the consumption firms manage to improve a little their profits, when workers appropriate a smaller part of economy's efficiency gains.

However, when we think of all capitalists as a class, including in analysis the capital goods' monopolist profit, we can see that both the workers and the capitalists are harmed by our parameter change, and smaller wages mean smaller profits, in line with Kalecki's paradox of costs.

Figure 23: Consumption Firms Net Profits (Paradox of costs' experiment)

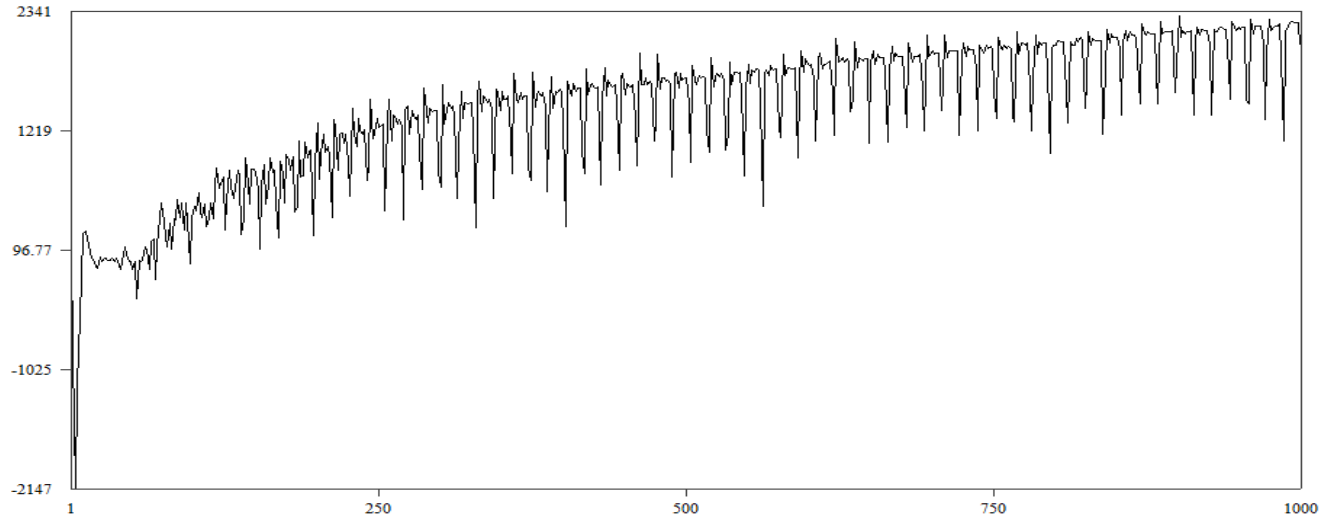
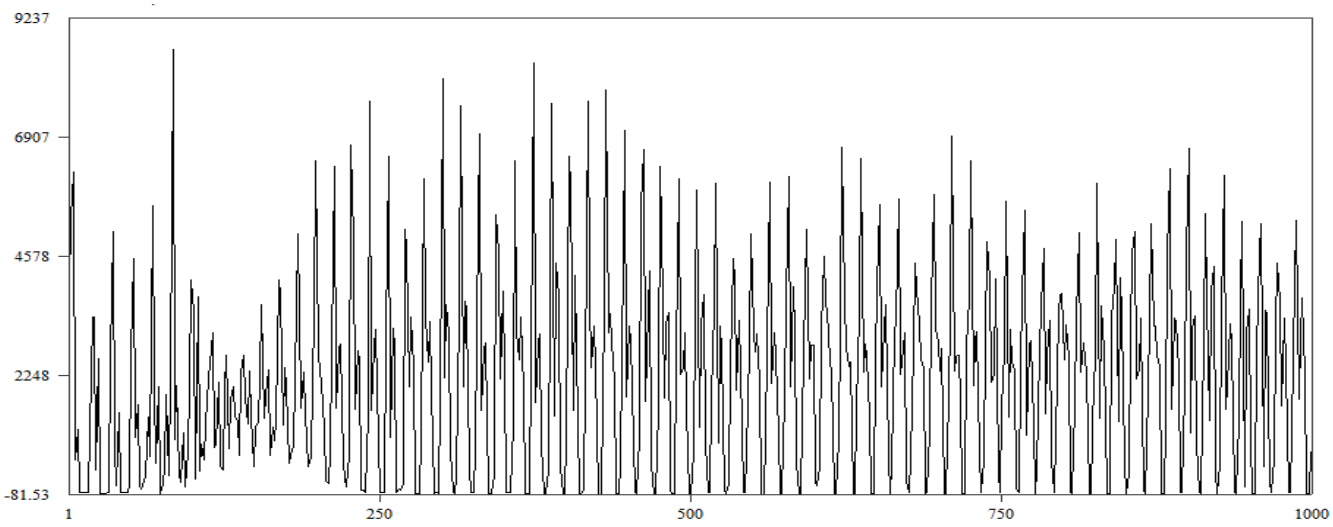


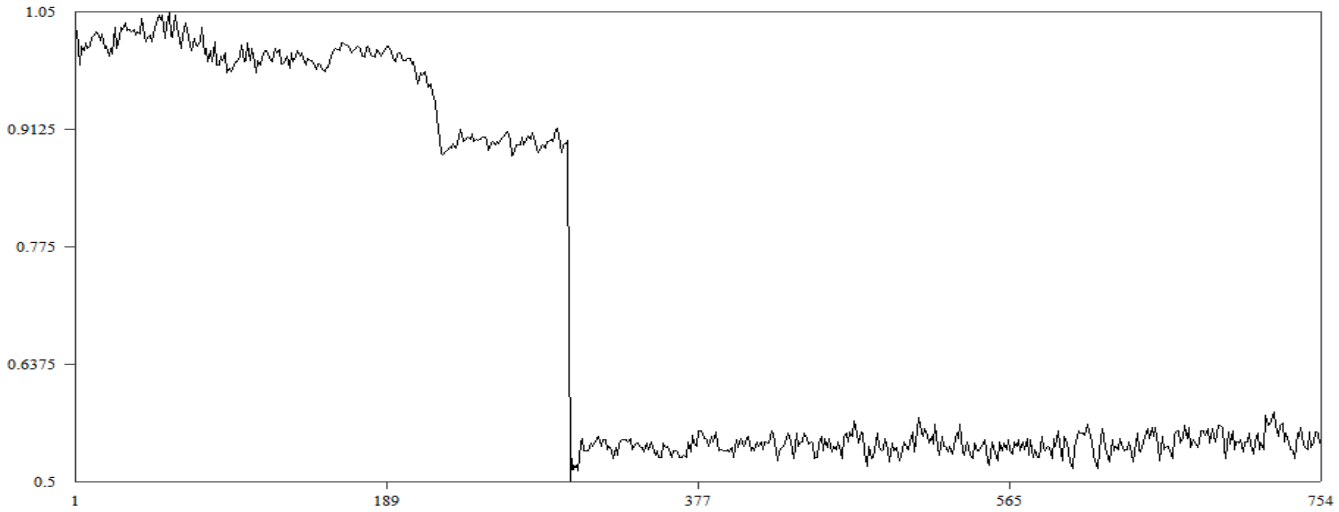
Figure 24: Capital Monopolist Net Profits (Paradox of costs' experiment)



Optimism shock

Both in our literature review and our introduction to this work we've claimed that inflicting an optimism shock in our economy could be an interesting experiment to study phenomena as investment strikes and exogenous psychological causes, which could affect firms' confidence to invest and produce. To test what happens in our economy when firms suffer a singular shock in this subjective factor, we simulate 20 markets with exactly the same parameters and initial values as our baseline model for 750 periods. Nevertheless, in period 300 every consumption firm suffer an abrupt confidence loss (optimism goes to 0.5 for one period), as can be seen in figure 25.

Figure 25: Consumption Firms' Average Optimism (Optimism Shock experiment)



As the confidence level have an inertial component, our optimism cyclically stabilizes in a lower level. While some of the other variables, as economy's productivity and average wages, look only a bit lagged in relation to our baseline model – which is expected, because in the period immediately after our shock unemployment explodes and investment is reduced- another unexpected and persistent result emerge.

We can clearly observe in the most different variables in our model a permanent change in the cycle shape, after the shock in period 300. Either in unemployment (figure 26), GDP (figure 27), demand for goods (figure 28), and others, the shock immediately depress the economy, but in the long-run the trend seems to be maintained. The cycle, however, looks to have its "half period" – the time it takes between the highest and the lowest point in a cycle- permanently diminished. Our figure 29 presents an example of one of our economies' total expenditure in consumption goods around period 300, to clarify this unexpected phenomenon.

Figure 26: Number of Unemployed (Optimism Shock Experiment)

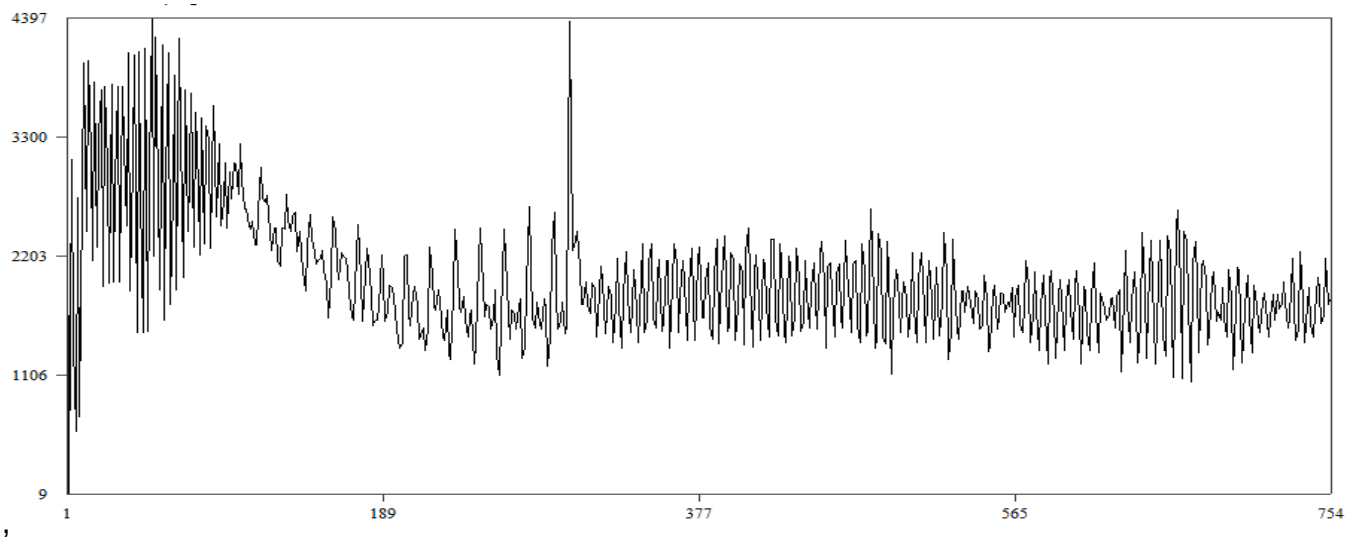


Figure 27: Nominal GDP (Optimism Shock Experiment)

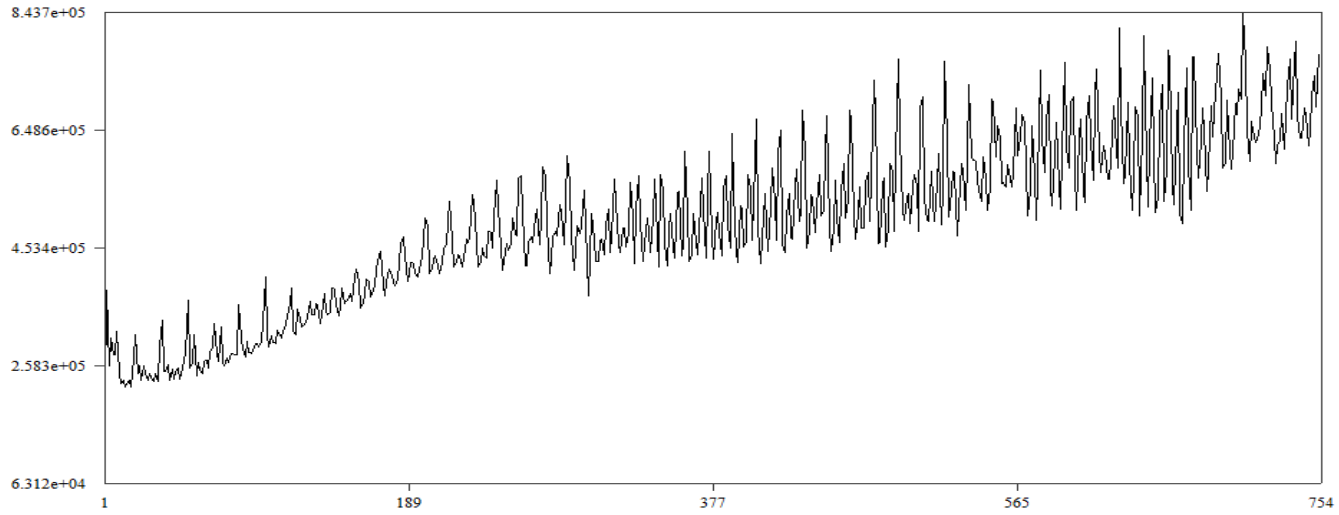


Figure 28: Total Demand (Optimism Shock Experiment)

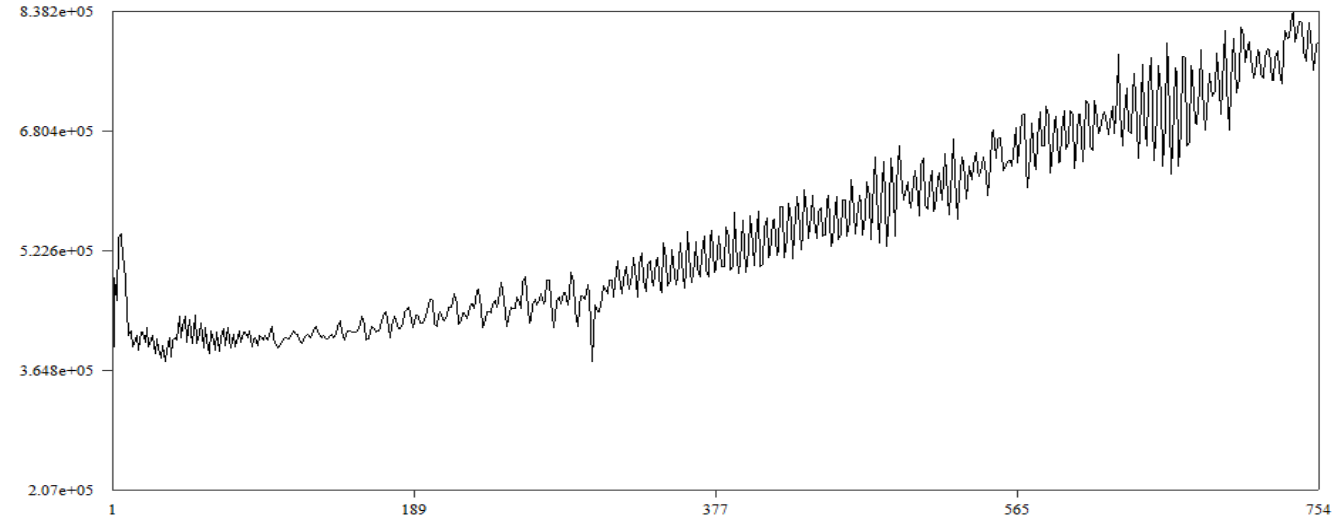
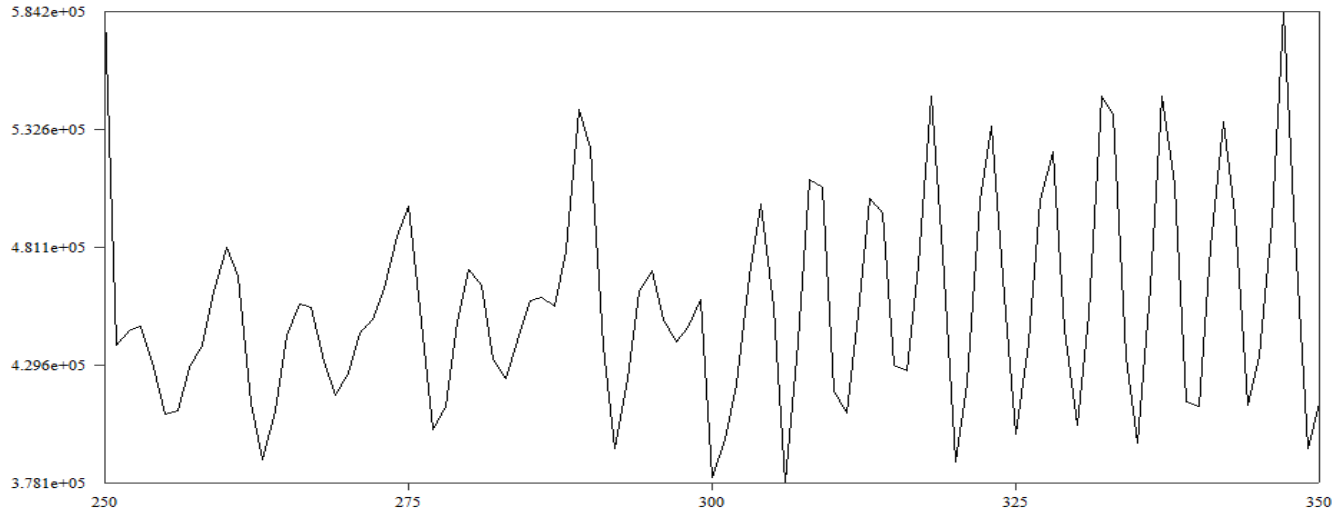


Figure 29: Total Expenditure in Goods (Around our Optimism Shock Experiment - example)



Other variable where a permanent effect can be observed is the average inventory stored by the firms. Even after the expected demand (which also stays in a level below its position before the

shock for at least 400 periods) recovers, firms keep their inventories much below their “standard” levels.

Figure 30: Expected Demand (Optimism Shock Experiment)

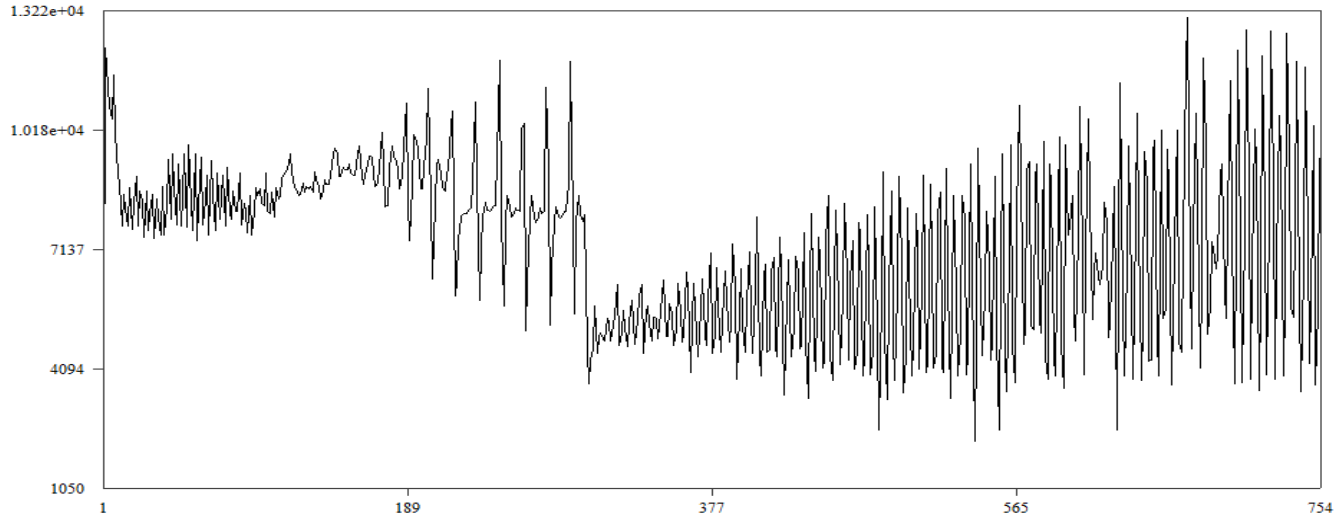
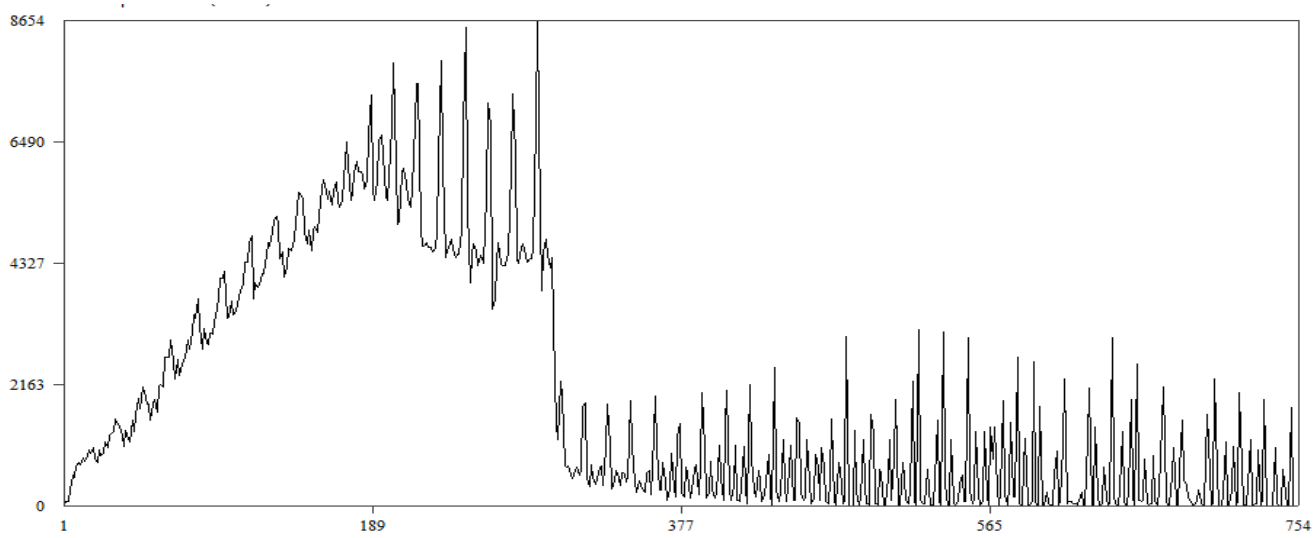
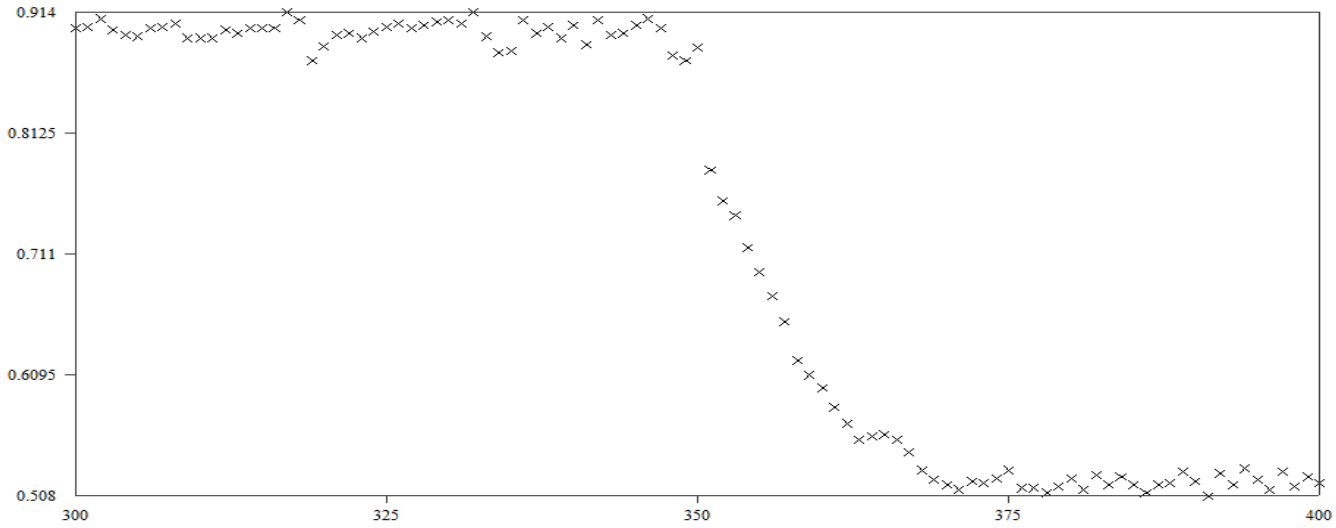


Figure 31: Consumption Inventory (Optimism Shock Experiment)



In addition to that, we’ve got interesting results in a second experiment, in which we try to observe how one firm affects others’ optimism. This time, we simulated 5 markets, with exactly the same parameters and initial values as our baseline model, but in period 350 fifteen out of our fifty firms get for some psychological or political reason pessimistic. As we can see in figure 32, those fifteen firms manage after some periods to infect their competitors, bringing the whole economy to converge to a low optimism level.

Figure 32: Consumption Firms' Average Optimism (Optimism Shock 2nd experiment)



The unexpected result which emerges is that our simulation with 15 pessimistic firms presents after period 350 exactly the same characteristics as our economy in the widespread singular shock tested above. It is unnecessary to reproduce the graphs here, but we observe exactly the same change in cycle's shape, and higher volatilities, but without huge changes in variables' level – except for expected demand and inventories, which also are consistently depressed.

Endogenous political motivation

We have argued in our literature review that firms' mistrust in government intervention may be understood in our model as a subjective political factor, which affects firms' confidence. To test this idea we simulate 5 markets with exactly the same parameters and initial values as our baseline model, except for an additional factor in firms' optimism, which diminishes it when our government has deficits (what usually happens in our model).

Here most of our main variables don't vary significantly, in relation to our baseline model, but we've got some counterintuitive results. Although firms' optimism (figure 33) converge to a very low level, GDP (figure 34) and employment (figure 35) are not affected in level; the only relevant effect is in their volatility, as their half-period diminishes and cycle's shape change.

Figure 33: Consumption Firms' Avg Optimism (Endogenous Political Motivation experiment)

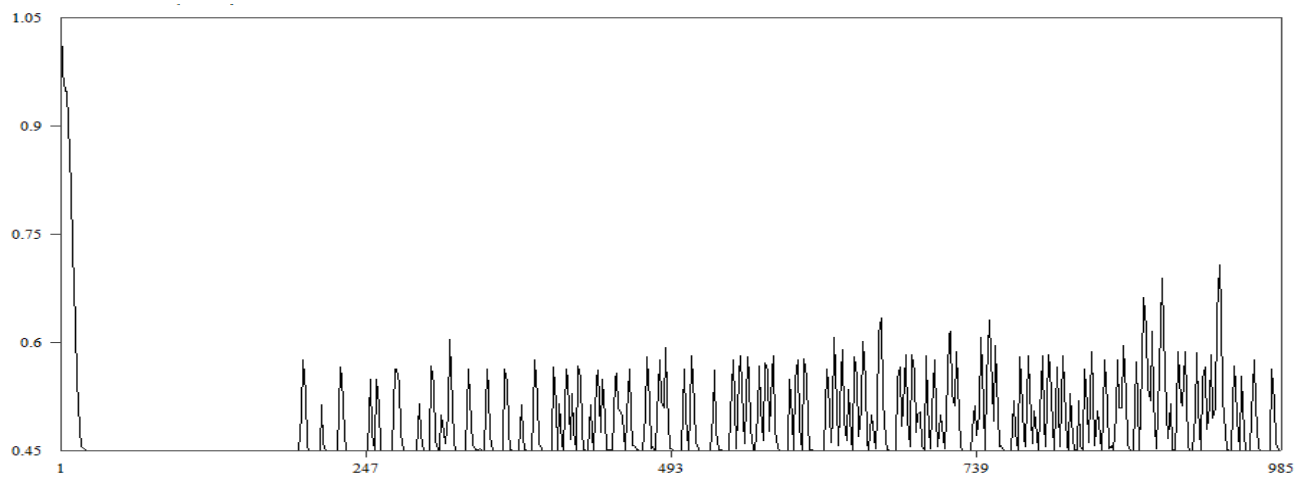


Figure 34: Nominal GDP (Endogenous Political Motivation experiment)

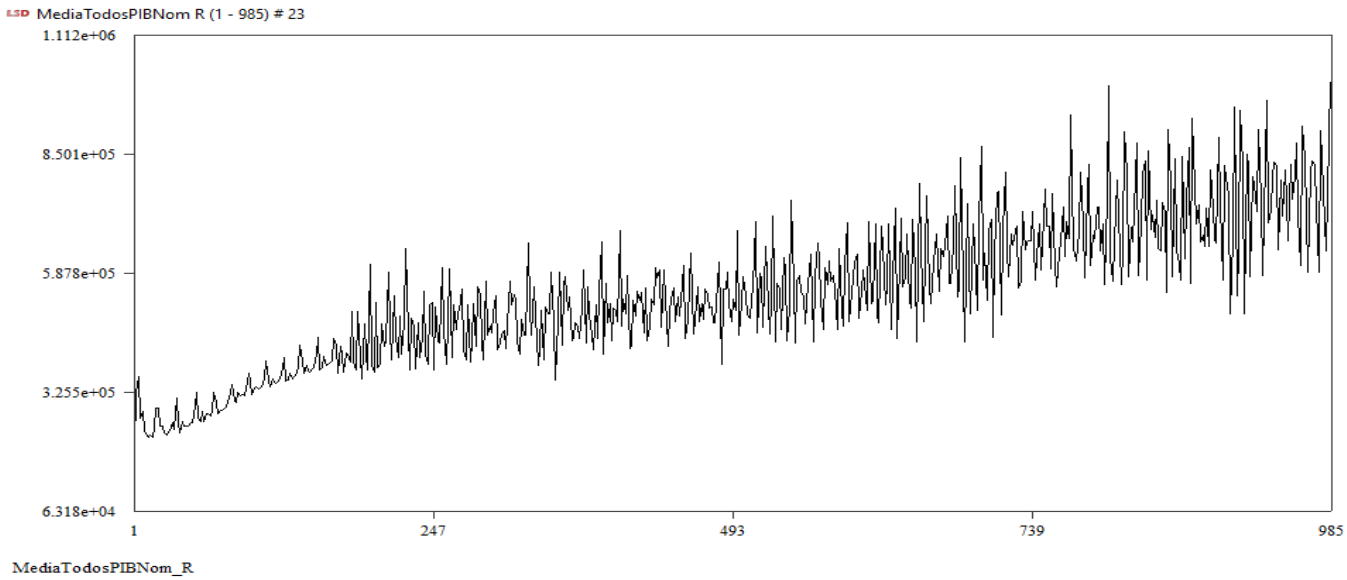
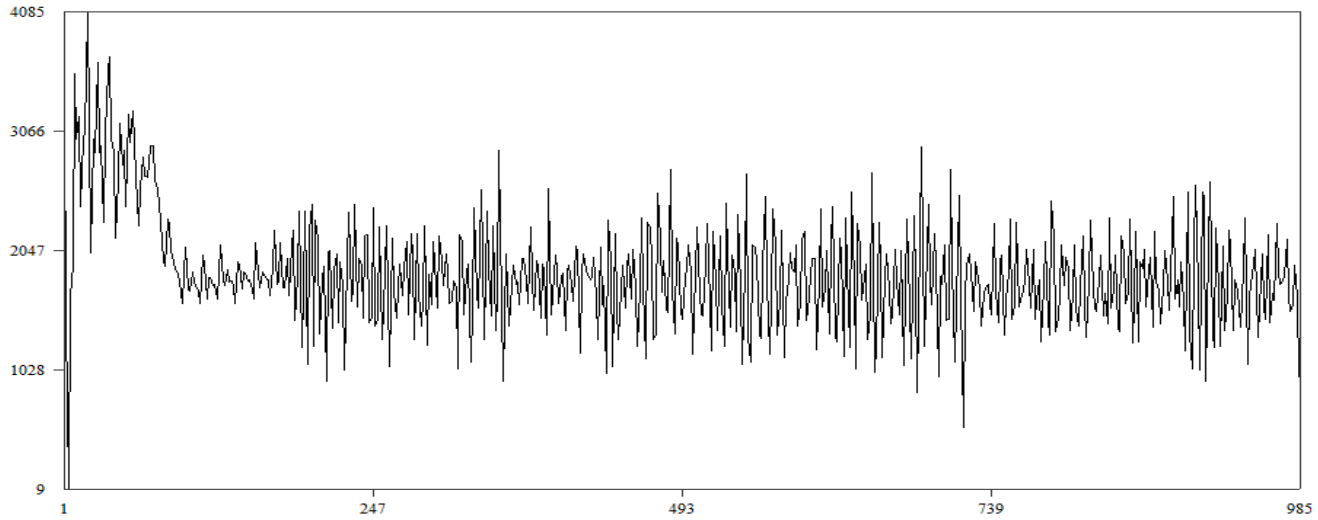


Figure 35: Number of Unemployed (Endogenous Political Motivation experiment)



The most unexpected result is probably found in workers' average wage, as it is a bit higher than in our baseine model (figure 36). It reflects another counterintuitive result: the machines produced in this alternative economy are more productive (figure 37). The robustness of these results require further studies and analysis, but they are probably related to government's larger cumulated debt.

It seems that when firms dislike government deficits, they cause higher unemployment volatility (and also a little higher average unemployment), implying in larger government deficits. On the other hand, those deficits may be maintaining firms' demand, and their demand for capital goods – bringing results even better than our baseline model for some variables.

Figure 36: Average Wage Demanded (Endogenous Political Motivation experiment)

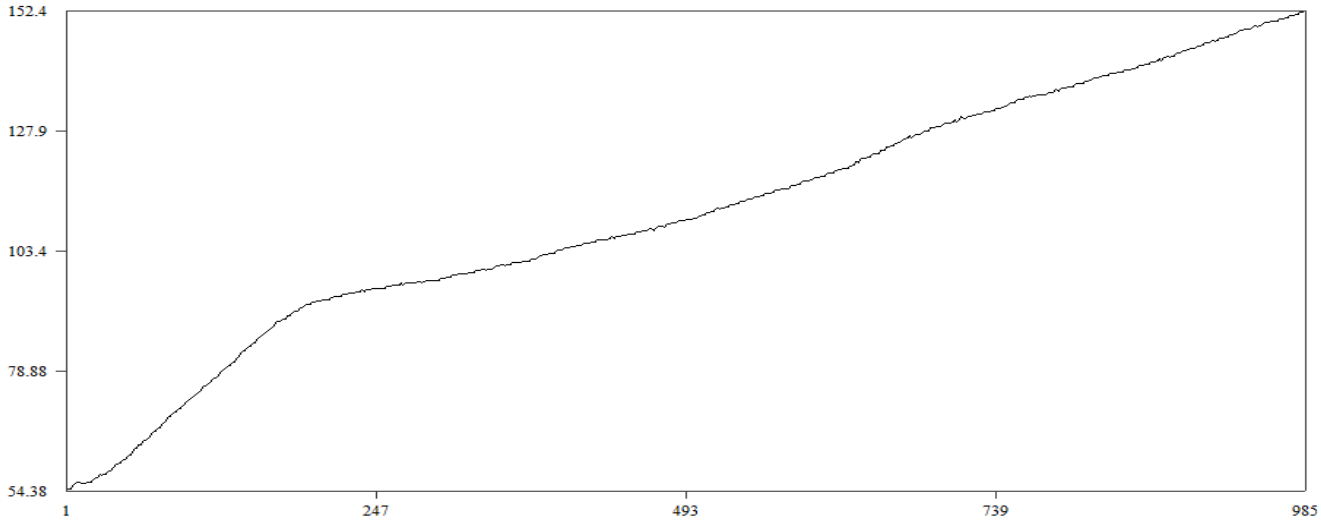
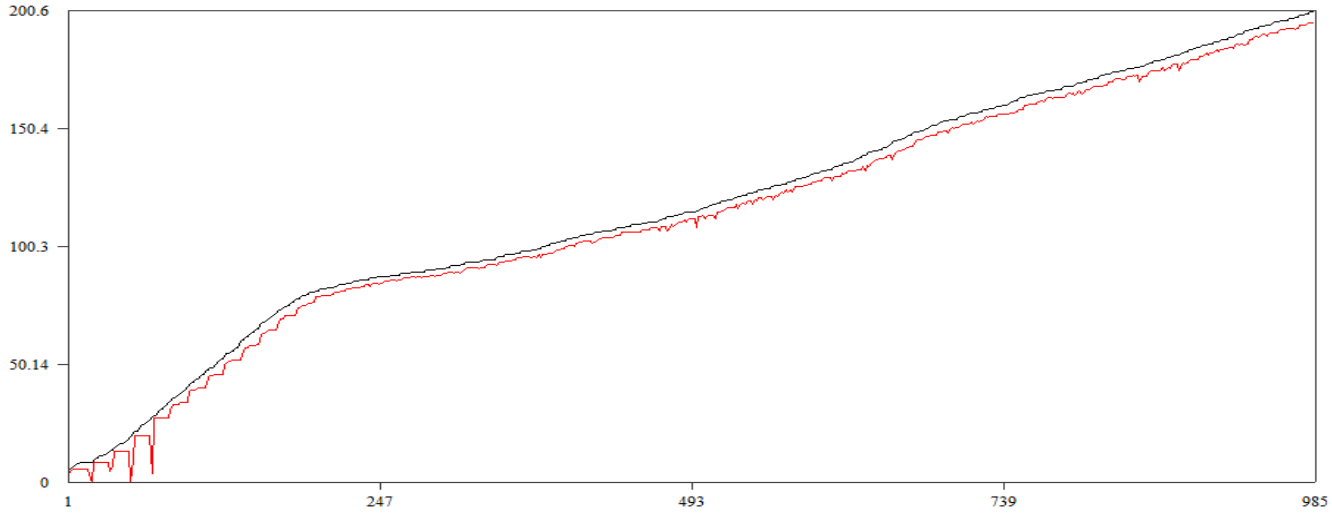


Figure 37: Productivity of the machine advertised (black) and of the average machine available (red) (Endogenous Political Motivation experiment)



Reflexivity

We've ended our review of the literature about political motivation asking whether it is possible that when firms are wrong about the effects of government's spending, they can change the real direction in which those expenditures influence our economy. At this point of our research, we don't think we have enough evidence to answer conclusively this question. However, maybe we can contribute with evidence for a less ambitious one: Can Soros' theory occur effectively? In which way firms' ideas about the economy can influence macroeconomic aggregates?

In a preliminary experience to test this, we simulate 5 markets with exactly the same parameters and initial values as our baseline model, except for an additional factor in firms' expected demand. When governments contract deficits, firms expect their demand to be (0.01*DeficitValue) lower.

As expected, this causes our economy's expected demand to be permanently lower than in our baseline version (figure 38). This leads to smaller production levels, and firms choosing to buy fewer

machines when they invest. The results can be observed in figures 39 to 41 below: lower GDP, productivity and average wage levels.

Figure 38: Expected Demand (Reflexivity Experiment)

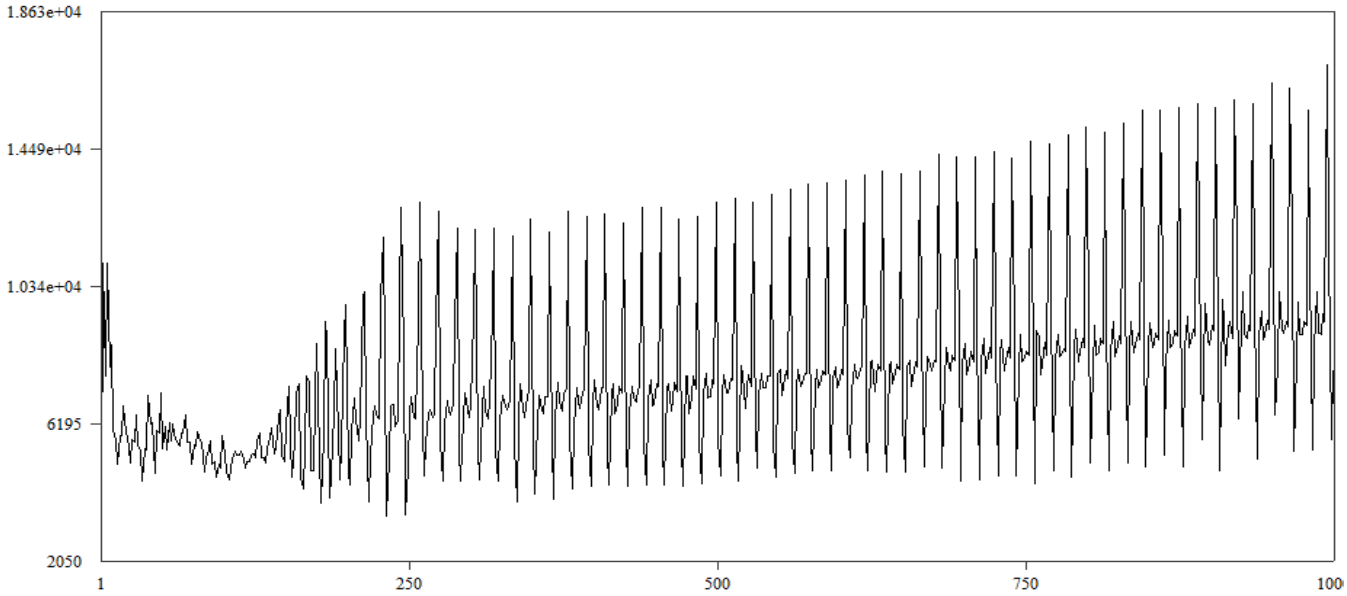


Figure 39: Nominal GDP (Reflexivity Experiment)

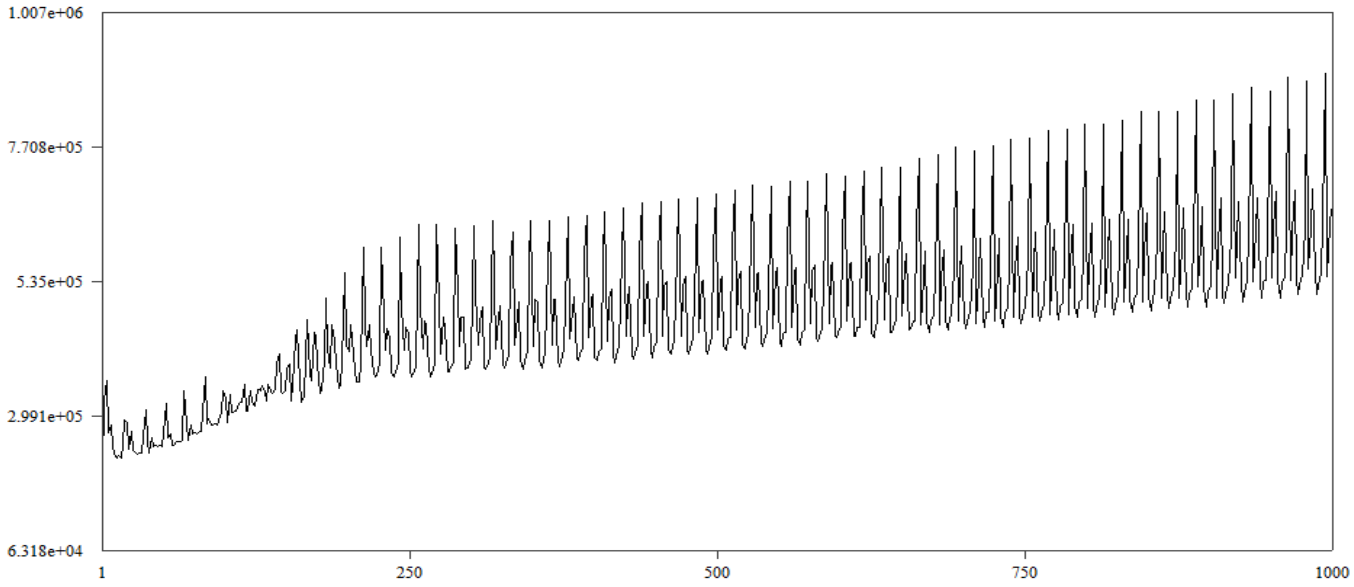


Figure 40: Productivity of the machine advertised (black) and of the average machine available (red) (Reflexivity Experiment)

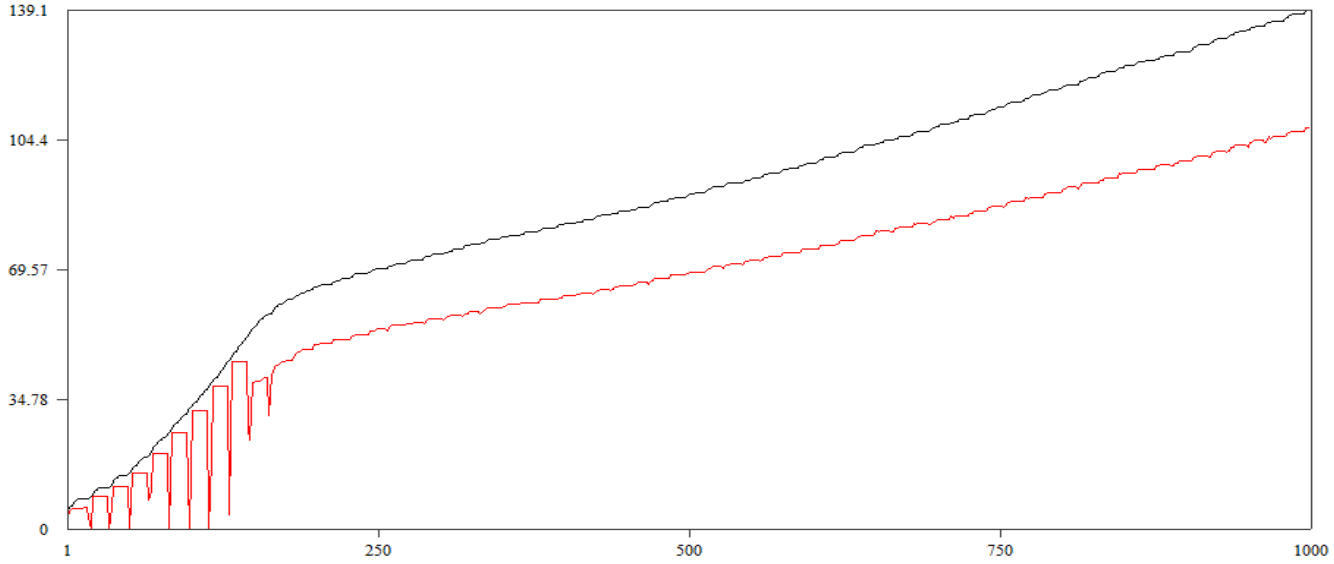
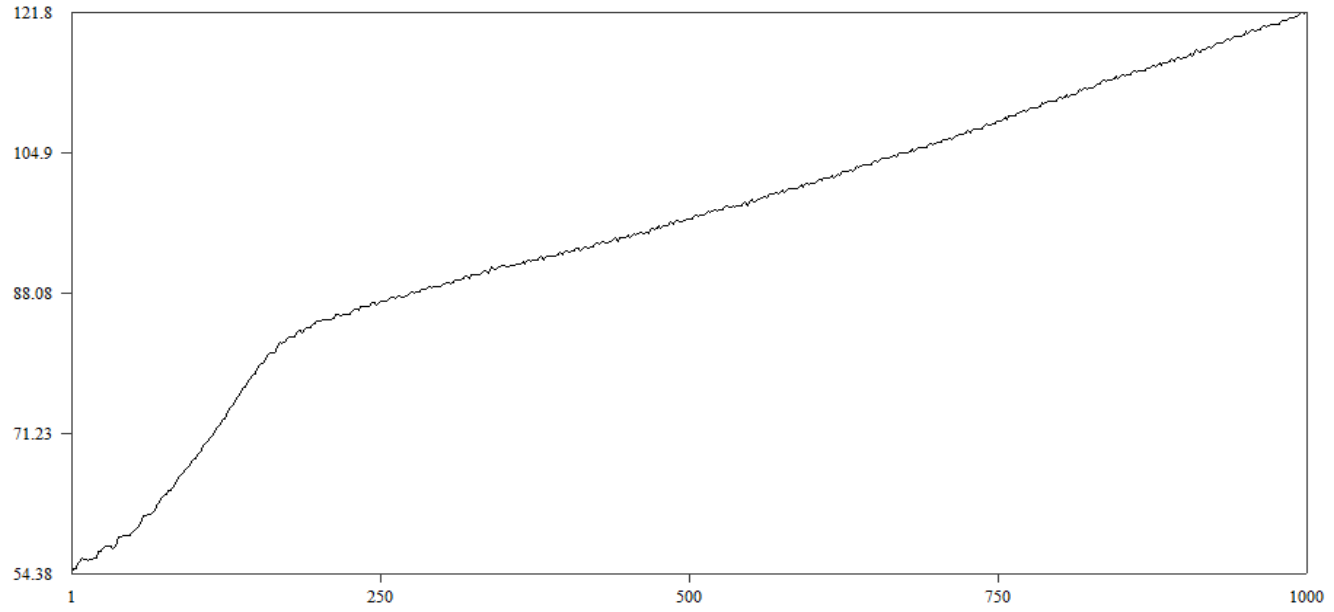


Figure 41: Average Wage Demanded (Reflexivity Experiment)



Parameter values and initial setup

Firms	Workers	Numb. of Machines$_0$	MkUpK$_0$	MktShare Speed of Adjustment	Mkt Share$_0$	Share profits to Innovation	Numb Worker for K$_{good}$
50	5000	4	1.45	0.01	0.02	0.5	1
Extra W$_k$	Extra W$_{innov}$	Capital$_{tax}$	Cons$_{tax}$	Machine Validity	Unempl. Benefit	Inventory Proport.	Extra Optimism
1.4	1.5	0.6	0.4	14	0.7*(avgW)	0.3	0.05
Max. Accept. Indebtd.	MkUp Cons$_0$	Sensitiv. Unempl.	Sensitiv. Prodtv K	Sensitiv. Δ Mkt Share	Workers Per machine	Max. Accept. Indebtd. Bank	Reflexivity Paremeter
2	1.1-1.4	1	0.5	0.15	5	2	0.01

Concluding Remarks

In this work we've studied the properties of an Agent Based Model in line with Dosei et al. (2010) and Possas et al. (2001), and inspired by Kaleckian and Neo-Schumpeterian insights. The main contribution we sought to make was incorporating in firms' expected demand - which leads their production and investment decisions- an optimism rule, based on Lima and Freitas (2007), and a local interaction mechanism.

We still recognize in our model some problems, as is expected in an ongoing research, and have already suggested some expected improvements in Part II. Nevertheless, by now we've managed to gather some interesting results, besides reaching plausible results using reasonable assumptions and parameters – which was by itself one of our goals, and is an evidence in favor of our model.

In addition to that, we were able to use a Kaleckian framework in a microfounded model and reproduce results coherent to his theories. Particularly, we managed to obtain a microfounded version of his famous "Paradox of Costs", and reproduced some stylized facts.

Beyond that, more important than our specific results about how each variable fluctuated in each of our experiments, is the progress we have already achieved about some general conceptions.

With our optimism shocks we verified that, in our model, shocks in a single moment of time are capable of bringing unexpected permanent effects to aggregate variables. These shocks were able to cause alterations as diverse as changes in cycles' shapes for most aggregate variables and permanent reductions in stocks and expectations.

Similar results were obtained in a version of our model in which 15 firms turn "pessimistic" in a given period. This proves that the behavior of an outnumbered group of firms may spread, strongly affecting the aggregate, and causing results similar to those achieved when all firms coordinate.

In our experiment of an endogenous political motivation, we could observe that when firms reject (for psychological or political reasons) governments' deficits, this rejection may, by itself, exacerbate governments' debt position.

In the same line, we've produced evidence, in our reflexivity experiment, that firms' ideas about economy may, by way of a reflexivity component in firms' expectations, disturb the real economy. Specifically, even in a model where higher government expenditure means only higher demand and output, we've shown that when firms believe that government deficits diminish their demand, our economy's aggregates are worse than in our baseline model.

In our understanding, all these results are evidence in favor of expectations' importance. Only a factor so crucial to our economy could with small shocks or parameter changes, even when momentary or applied only to a fraction of our agents, generate far-reaching results in aggregate, as those presented in this work.

That goes in line with our motivation to add an interaction in firms' investment and points a promising way to our future research: to test other particular forms to our expectations' dynamics, apart from improving our current model and add the features presented in Part II.

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