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Carl Chiarella
Corrado Di Guilmi

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Monetary Policy and Debt Deflation: Some Computational Experiments

C. Chiarella and C. Di Guilmi*

University of Technology, Sydney

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Abstract

The paper presents an agent based model to study the possible effects of different fiscal and monetary policies in the context of debt deflation. We introduce a modified Taylor rule which includes the financial position of firms as a target. Monte Carlo simulations show that an excessive sensitivity of the central bank to inflation, the output gap and firms' debt can have undesired and destabilising effects on the system, while an active fiscal policy appears to be able to effectively stabilise the economy. The paper also addresses the puzzle of low inflation during stock market booms by testing different behavioural rules for the central bank. We find that, in a context of sticky prices and volatile expectations, endogenous credit can be identified as the main source of the divergent dynamics of prices in the real and financial sector.

Keywords: Financial fragility, monetary policy, debt deflation, agent based modelling, complex dynamics.

JEL classification: E12, E31, E44.

*Corresponding author: Corrado Di Guilmi. Economics Discipline Group - University of Technology, Sydney - PO Box 123, Broadway, NSW 2007, Australia. Ph.: +61 2 9514 4746, Fax: +61 2 9514 7722. E-mail: corrado.diguilmi@uts.edu.au.

1 Introduction

The chain of events that started with the Global Financial Crisis is leading academics and policy makers to rethink the tasks and the instruments of monetary policy. In fact, a definition of the range of tools to achieve non-standard goals, such as financial stability, has already occurred, at least with reference to the major world central banks. An interesting feature of the debate that these events provoked is that it involves elements typical of non-conventional thought that have now found a place in mainstream articles. Suggestions for a structured redefinition of monetary policy have been put forward from different perspectives. Gathering together some of these elements can provide a first list of the factors that an effective policy should take into account.

1. A growing number of mainstream authors have started to take an interest in the role of private debt in determining macroeconomic outcomes. The once dominant view that a debt deflation represents just a redistribution of wealth from borrowers to lenders, without a net effect in the aggregate (Bernanke, 1995) seems to have been definitely overturned. The aggregate level of private debt is now widely considered as a factor of fragility of the economic system (Minsky, 2008b). In particular Christiano and various co-authors[1] argue that monetary policy should also target the level of private debt.

2. The bankruptcy of an economic agent is not an isolated fact as every economic actor has financial liabilities and claims against a number of others (Stiglitz and Greenwald, 2003; Delli Gatti et al., 2010). Therefore policy makers should address the topology of the credit network and the possible effect of financial distress of single agents (Battiston et al., 2012; Di Guilmi et al., 2012).

3. While the heterogeneity and the interaction of economic agents (Gallegati and Kirman, 1999; Kirman and Zimmermann, 2001) are progressively gaining more attention, the fact that different agents can follow different behavioural rules is relatively less explored by the theory. In particular Koo (2008) illustrated, with reference to Japan, the risks that can arise when firms target their level of leverage, in order to survive, rather than adopting an optimising behaviour as conventionally represented in economic models.

4. The argument that the amount of credit, and consequently of broad money in the economy, cannot be effectively controlled by the central bank has been consolidated in the non-orthodox literature (see in particular Post-Keynesian authors such as Moore, 1998). Consequently the monetary authority can only influence the credit conditions through the interest rate but not the actual supply of credit.

[1] See for example Christiano et al. (2007), but also White (2009).

5. Inflation is typically low during stock market booms (Fama, 1981). As stressed by Christiano et al. (2007), this can mislead the central bank, pushing interest rates down and fuelling in this way a possible bubble.

In our opinion the investment theory developed by Hyman Minsky (2008a) provides an important reference to develop a model which can embody the elements mentioned above. According to this approach, business fluctuations are explained as the effect of the periodic changes in expectations in a context of less than perfect foresight. During an expansion, banks can reduce the risk premium for loans, both because of the optimistic expectations about future repayment and because of the high evaluation of collateral. The increase in the availability of credit fuels new investment by firms and the prices of shares, as investors increase borrowing to exploit cheap credit and the forecasted capital gains. Stock price inflation, in turn, provides for further new investment in the real economy. This positive feedback loop lasts until the growing debt commitments cause insolvencies of the weakest units in the economy and a consequent reduction of the amount of liquidity in the system. Expectations will then worsen, reducing the value of enterprises' collateral. This leads banks to apply higher interest rates for the perceived higher risk of default, further worsening the financial condition of borrowers. The growth phase is now reversed into a negative spiral which eventually leads to a downturn.

Chiarella and Di Guilmi (2011) microfound the aggregative models by Minsky (2008a) and Taylor and O'Connell (1985) by introducing firms that are different in size and financial conditions. The model is solved both numerically, through computer simulations, and analytically, by means of the techniques proposed in Aoki and Yoshikawa (2006) and Di Guilmi (2008). Chiarella and Di Guilmi (2012b) extend that work by introducing a government which uses fiscal policy to stabilise the economy, putting a floor to the decline in private spending.

This paper builds on Chiarella and Di Guilmi (2011, 2012a,b) and proposes an agent based model with a central bank and financially heterogeneous firms. The model adopts Minsky's perspective in modelling investment: firms do not optimise but follow the market mood, quantified by the latest variation in stock prices. Firms' responses to the market mood are asymmetric. In fact, firms are exposed to idiosyncratic stochastic shocks and their ability to fulfil debt commitments depends on their different degrees of financial fragility. The public sector is composed of the government and the central bank. Following Chiarella and Di Guilmi (2012b), the government collects taxes and decides the level of expenditure in order to stabilise the economy and to avoid or lessen depressions. In particular the government accumulates surpluses during expansions in order to have sufficient financial resources to counteract a downturn. The central bank adopts a modified Taylor rule which also includes the financial position of firms. By means of Monte Carlo simulation we show the effects on the main macroeconomic variables of changes in the sensitivity of the central bank to the inflation gap, the output gap and the level of firms' indebtedness.

The paper also analyses a different scenario in which the central bank handles directly the supply of money. The goal of this last experiment is to assess the effects of endogenous credit in the correlation between stock prices and inflation.

The paper provides three main contributions. First, it fits into the debate for a reformulation of economic policy that is urgent in the current macro-economic climate. In this agent based framework, consistently with the paradigm of complexity, the business cycle does not originate from external shocks but rather it is an emergent property due to the interaction of heterogeneous agents. The dynamics of macroeconomic variables is determined by the behaviour of economic units. The latter adjust their balance sheets as a consequence of the macroeconomic climate in a chain of feedback effects between the micro- and the macro-level of the economy. The reactions are different across the different units and different times, given the different pre-shock conditions. This setting can therefore provide further insights on the macroeconomic outcomes of policy interventions than do aggregative and representative agent models. Moreover, these chains of dynamic feedback can also be helpful in studying the effect of interactions, which are difficult to consider in Dynamic Stochastic General Equilibrium (DSGE) models, even when they involve the heterogeneity of agents. This paper is not the first attempt to use agent based modelling for monetary policy (see for example Delli Gatti et al., 2005), but, to the best of our knowledge, it is the first to use this modelling methodology to frame a study of central banking within the Financial Instability Hypothesis.

Second, by pursuing the first goal, this paper represents a step in building an agent based representation of the whole economic systems. Indeed while agent based models for single markets and sectors have been proposed, this literature still lacks a systematic representation comparable to the one provided by DSGE models. This paper still leaves out the foreign sector and only partially accounts for the job market, but presents a framework which is flexible enough to be extended to include other subsystems.

The third contribution is in that the paper attempts to offer an explanation for the evidence of low or declining inflation during stock market booms. In our opinion an analysis of this phenomenon cannot ignore the effects of endogenous credit. Some of the existing treatments (see Christiano et al., 2007) do not consider this feature and need to resort to, in our view, quite audacious hypotheses to explain this feature, as illustrated in section 6 below.

The paper is organised as follows. Sections 2 and 3 introduce the assumptions relative to the productive and the public sectors of the economy. The public sector is composed of the government and the central bank. The hypothesis regarding the financial sector and the equilibrium conditions in the credit and stock market are presented in section 4. The results of the simulations are analysed in section 5. Section 6 presents the alternative scenario in which the central bank handles the supply of money; this section also presents and comments on the results of the simulations for this alternative setting. Section 7 offers some concluding remarks.

2 Firms

This section introduces the productive sector of the economy that is composed of heterogeneous firms. The variables referring to firms are indicated with a superscript i while the variables without any superscript refer to aggregate variables. The behavioural rules are listed below.

- In every period t the i-th firm targets an amount of investment I_t^i. The new level of capital then determines the demand for labour and output. The investment is decided on the basis of the *shadow-price* of capital P_k^i (Tobin, 1969; Minsky, 2008a), such that

$$I_t^i = a P_{k,t}^i, \tag{1}$$

  where a is a parameter measuring the sensitivity of firms to the shadow price. The variable P_k is determined according to

$$P_{k,t}^i = \frac{\rho_{t-1}^i P_t}{r_{t-1}}. \tag{2}$$

  The variable ρ_{t-1}^i measures the market sentiment (or *animal spirit* in Keynes' words) and the variable r_{t-1} measures the interest rate, both referred to the previous unit of time. As detailed in section 4, ρ^i depends on the performance of the stock market, leading firms to invest more during bull market period and less during bear market phases.

- Capital depreciates in each period at a constant rate σ. The variation in the physical units of capital is then given by

$$\Delta K_t = I_t / P_t - \sigma K_{t-1} \tag{3}$$

- Firms produce a good that can be used either for consumption or investment. Assuming that the firms adopt a technology with constant coefficients, the amount of labour requested is residually determined once the optimal level of investment, and hence of capital, is quantified. The supply of labour is infinitely elastic. The production function for all firms is written as

$$X_t^i = min(K_t^i, L_t^i) \tag{4}$$

  The constant capital to labour ratio is equal for all firms and is indicated by $v = K_t^i / L_t^i$. A firm will demand the amount of workforce needed to operate its capital, so that the demand for labour will be equal to

$$L_t^i = K_t^i / v. \tag{5}$$

  Assuming a perfectly elastic supply of labour and no technological progress, we can define the production function as[2]

$$X_t^i = \varphi\, K_t^i, \tag{6}$$

[2]We are able to use a linear production function as the accumulation of debt and the bankruptcy mechanism put a ceiling on production.

where the output/capital ratio φ is a parameter that is constant across firms and in time.

- The selling price of the final good and investment is the same across firms and is a mark-up price on the cost of labour, hence

$$P_t = (1+\mu)w_{t-1}b \tag{7}$$

where $0 < \mu < 1$ is the mark-up, w_t is the nominal salary at time t and b is the labour-output ratio. Since all firms use the same technology the price is equal for all of them.

- The aggregate demand is given by

$$P_t X_t^d = w_{t-1}L_t + I_t + G_t \tag{8}$$

where $L_t = bX_t$ is the demand for labour, X_t is the total output (consumption + investment goods) and G_t is the government expenditure. We allocate aggregate demand among firms according to their sizes, so that

$$X_t^{id} = \frac{X_t^d}{K_t} K_t^i. \tag{9}$$

- The level of the nominal salary w is set in order to partially accommodate the difference between demand and supply. If we set $X_t = X_t^d$, consider that $X_t = bL_t$ and substitute (7) into (8) we have that, in order to match demand and production in each period, the salary in the previous unit of time should be equal to

$$w_{t-1} = \frac{I_t + G_t}{b\mu X_t}. \tag{10}$$

We assume that the salary is determined by two factors: one that tends to accomodate the demand to the supply according to (10), with a one period lag, and a second that represents the nominal rigidity. Consequently, we can write

$$w_t = \eta w_{t-1} + (1-\eta)\frac{I_t + G_t}{b\mu X_t}, \tag{11}$$

where $\eta \in (0,1)$ is a parameter quantifying the stickiness of salaries.

The goods are assumed to be non perishable, therefore they can be stored as inventories whenever $X_t^i > X_t^{id}$. Inventories are used when current production is not sufficient to meet the demand. A control is introduced to make sure that inventories plus current production are always bigger than or equal to current demand. For this reason the model is only partially demand-driven.

- Profits are given by

$$\pi_t^i = P_t X_t^{di} - wbX_t^i - r_t D_t^i, \tag{12}$$

where w is the nominal wage, X_t^i is the output and D_t^i the outstanding stock of firms' debt. The government imposes a tax rate τ on gross profits. All the salaries are consumed.

- Firms are classified into the three categories of Minsky (1963). In particular, a firm is defined as hedge if it is able to generate enough profit to repay its debt, speculative if the profit is enough at least to repay the service of debt and Ponzi if the firm needs to roll over also the interest on the outstanding debt.

  Accordingly, for *hedge* firms the internal finance evolves according to

  $$A_t^i = A_{t-1}^i + \pi_t^i(1-\tau), \tag{13}$$

  where where A_t^i is the cumulated past profit and τ is the tax rate on positive profit. For *speculative* firms net profits are first used to repay the debt and then accumulated for the remaining part. Thus, denoting the amount of cumulated past profits by A_t, we have that

  $$A_t^i = \pi_t^i(1-\tau) - D_{t-1}^i \text{ if } \pi_t^i(1-\tau) > D_{t-1}^i, \tag{14}$$

  $$D_t^i = D_{t-1}^i - \pi_t^i(1-\tau) \text{ if } \pi_t^i(1-\tau) \leq D_{t-1}^i. \tag{15}$$

  In the first case the firm becomes hedge, while in the second it is speculative.

  Finally, for *Ponzi* units we have that

  $$D_t^i = D_{t-1}^i - \pi_t. \tag{16}$$

  As a consequence we can write the classification criteria for the firms as follows[3]:

  - hedge if $A_t^i > 0$;
  - speculative if $D_t^i > 0$ and $\pi_t^i \geq 0$;
  - Ponzi if $D_t^i > 0$ and $\pi_t^i < 0$.

- Firms finance investment first with internal funding A and then, for the remaining part, by a fraction ϕr_t with equities, where $\phi > 0$ is a parameter, and then the rest with debt. The dependence on the interest rate reflects the fact that in periods with a high interest rate equities would be preferred. The price of the new capital goods is assumed to be equal to the final goods price P_t. So for each enterprise the number of shares evolves according to

[3] The consideration of A, which is a stock, forces a difference between this classification and the original one by Minsky (1963), which is specified in terms of flows. In particular, in Minsky a firm i is speculative if $\pi_t^i < I_t^i$ and Ponzi if $D_t^i > I_t^i$.

$$\Delta E_t^i = \phi r_{t-1}(I_t^i - A_t^i)/P_{e,t-1}^i. \tag{17}$$

As for the dynamics of debt, equations (15) and (16) should be accordingly redefined as

$$\Delta D_t^i = (1 - \phi r_{t-1})(A_t^i - P_t I_t^i) - \pi_t^i (1 - \tau), \tag{18}$$

$$\Delta D_t^i = (1 - \phi r_{t-1})(A_t^i - P_t I_t^i) - \pi_t^i. \tag{19}$$

- The bankruptcy of a firm occurs when

$$K_t^i P_t < \gamma D_t^i, \tag{20}$$

where $\gamma > 1$. A failed firm can be replaced or not, depending on the macroeconomic conditions. More precisely, the probability of a new firm entering is directly proportional to the variation in the aggregate production with respect to the previous period. The capital of bankrupted firms is acquired at no cost by the surviving ones in proportion to their size.

3 The public sector

We consider a public sector composed of the government and the central bank. Fiscal policy is modelled as in Chiarella and Di Guilmi (2012b).

3.1 Fiscal policy

The government decides the amount of the public expenditure countercyclically. For simplicity, during expansions the public expenditure is assumed equal to 0. During recessions, the government supports private demand by filling the gap in investment and consumption. It finances with bonds the part of public expenditure that exceeds taxes.

The reaction of the government to business fluctuations is quantified by the parameter $\theta \in [0, 1]$. It determines the strength of fiscal intervention in two ways. First, in case of a negative variation of private expenditure, the government brings the level of public expenditure to a fraction θ of the loss, so that $G_t = \theta|\Delta X_{t-1}^d|$, where ΔX_{t-1}^d is the negative variation in aggregate demand at time $t - 1$. We assume a lag of one period for the government intervention. With regards to the second way, once the cycle hits its trough and the economy starts to recover, the government keeps supporting aggregate demand until it is equal to at least a fraction θ of the peak before the recession.

The tax is levied on profit and it is defined as a fixed and constant share τ of positive firms' profits. The total amount of fiscal revenue is therefore equal to

$$T_t = \sum_{i=1}^{N} \tau \pi_t^i. \tag{21}$$

When taxes are not sufficient to cover the expenditure, the government issues bonds while surpluses are used to pay out existing bonds.

3.2 The central bank

The central bank determines the reference interest rate r_B by applying a Taylor rule of the type

$$r_B = \theta_p(p_t - p_t^*) + \theta_x(X_t - X_t^*) + \theta_d(PS_t - PS_t^*), \tag{22}$$

where θ_p, θ_x and θ_d quantify the sensitivity of the central bank to, respectively, the inflation gap, the output gap and the to the ratio of speculative plus Ponzi firms over the total number of firms, indicated by PS[4]. The target values p^*, X^* and PS^* are calculated as a moving average on the past t_{MA} periods. As shown in section 4, the market interest rate is determined by the financial sector by applying a mark-up h on the official interest rate (as proposed by Rousseas, 1985), so that

$$r_t = (1 + h_t)r_B. \tag{23}$$

4 Capital market

The capital market is modelled along the lines of Chiarella and Di Guilmi (2011). The most relevant difference is that in this treatment, the variable ρ does not depend on an external stochastic shock but it is determined within the system. In particular this variable, which embodies the expectations of firms and determines their level of investment according to (1), is assumed to be dependent on the performance of the stock market[5].

4.1 The stock market and the expectations

Expectations are influenced by fluctuations in the stock market. For this reason we consider the variable ρ as dependent on the latest variation in the stock market index. Hence ρ is quantified by

$$\rho_t = 1/\left(1 + \alpha exp(-\Delta P_{e,t}/P_{e,t-1})\right) \ , \tag{24}$$

where $\alpha > 1$ is a parameter. Each unit in the system is subject to an idiosyncratic shock which affects both its expected profitability ρ^i and its share price P_e^i, so that

$$\rho_t^i = \tilde{u}_t^i \rho_t, \tag{25}$$

$$P_{e,t}^i = \tilde{u}_t^i P_{e,t}. \tag{26}$$

The idiosyncratic shock $\tilde{u}_t^i$ is uniformly distributed.

[4]We make the heroic assumption that the monetary authority is able to compute the shares of the different types of firms. This permits a quantification of the effect of the inclusion of microeconomic factors in the central bank's behavioural rule.

[5]The dependence of firms' investment on stock price has been extensively investigated in the empirical literature. See for example Barro (1990).

4.2 Equilibrium in the capital market

The wealth of investors is given by the value of the stock ($P_{e,t}E_t$), private and public bonds ($Bon_t = B_t + D_t$) and money (M_t), such that

$$W_t = P_{e,t}E_t + Bon_t + M_t. \tag{27}$$

We assume that investors do not distinguish between private and public bonds. The equilibrium conditions in the capital market is set by a Tobinian asset portfolio that quantifies the price of equities, the interest rate, the amount of money and the amount of total wealth. In order to allocate their wealth between bonds and equities, investors look at the performance of the equity market, quantified by ρ, and at the return from bonds, given by the market interest rate. The financial sector provides all the credit demanded by firms and liquidity demanded by investors by generating them endogenously. Investors have a constant propensity to keep part of their wealth in liquid assets. This propensity is quantified by the parameter ψ. The allocation of assets and the determination of stock price and interest rate follow the same procedure as in Chiarella and Di Guilmi (2011). As in that paper, the parameter ψ plays an important role: since the demand for credit is always accommodated (even though with a variable interest rate), a larger ψ implies a larger M and, as a consequence, aggregate wealth W. As shown by Chiarella and Di Guilmi (2011) this factor amplifies the magnitude of business cycle fluctuations.

Accordingly, the equilibrium conditions in the capital market can be expressed by the following system of equations

$$\begin{cases} P_{e,t}E_t = \dfrac{W_t}{1+e^{r_t+\psi-\rho_t}}, \\ Bon_t = \dfrac{W_t}{1+e^{\rho_t+\psi-r_t}}, \\ M_t = \dfrac{W_t}{1+e^{r_t+\rho_t-\psi}}, \\ W_t = P_{e,t}E_t + Bon_t + M_t. \end{cases} \tag{28}$$

5 Results

We performed single run simulations and Monte Carlo simulations of 1,000 replications. The results of the single runs are shown in order to appreciate the dynamics of business cycle that are generated by the model, the impact of fiscal policy and the pattern of evolution of the different types of firms across the cycle. The set of parameters used in the simulations are reported in table 1. The parameters are calibrated in order to match the statistical regularities detailed below and therefore to allow for a comparison with a real system. A more refined study of the calibration is part of our future research agenda.

The model is able to replicate some empirical evidence, in particular with reference to the business cycle. The firm size distribution, using capital as the dimensional variable, displays fat tails and can be approximated by a Pareto distribution as empirically observed (Axtell, 2001, among others). Figure 1 illustrates this result for a representative simulation and shows that the distribution shifts to the right during expansions due to the average larger size of firms. The figure also displays the fact that the distribution is more skewed during upturns, as shown by Gaffeo et al. (2003) for real data. This micro-evidence causes a macro-pattern compatible with the empirical evidence. As shown by figure 2, the distribution of variations in aggregate demand follow a Weibull distribution, matching the evidence reported by Di Guilmi et al. (2005) for GDP data in industrialised coutries.

Figure 3 shows the typical results of a single run simulation. It is possible to detect a growth trend for aggregate demand with irregular cycles around it. The contrast between aggregate demand and private demand (net of government expenditure) reveals that fiscal policy prevents the negative phases from becoming serious depressions. The sudden drops that are observable are due to the one-period lag in the implementation of fiscal policy.

An examination of figure 3 illustrates how micro-financial variables are at the root of macro-economic fluctuations. Expansion phases are accompanied by the transformation of most of the speculative firms into Ponzi. After a few periods the over-leveraged firms begin to fail, causing a reduction in total demand and a downturn. This pattern is illustrated by the dramatic drop in the share of Ponzi firms. The less leveraged Ponzi firms become speculative and the cycle restarts. The share of hedge firms is relatively stable and it increases, together with the proportion of Ponzi firms, during an upturn. This pattern can be explained by the fact that relatively sounder firms can profit from the increasing demand. Therefore the boom consolidates the financial position of sounder firms and, at the same time, compromises the position of the most leveraged ones. This can also be the reason for the right-skewed distribution observed for firm size and its modifications during the cycle.

The correlation between the share of Ponzi firms with the detrended series of private demand is about 0.5, while it becomes close to 0 if we consider the total demand (inclusive of fiscal expenditure). Therefore, active fiscal policy proves to be effective in decoupling the business cycle from its micro-financial determinants.

5.1 Monte Carlo simulations

In order to study the effect of changes in the sensitivity parameters of the Taylor rule (22), we performed Monte Carlo simulations for different values of the parameters. We run 1,000 replications for each value of a parameter within a given interval, keeping the other constant. We study the effect on the following variables: average and variance of total demand, average price, average ratio of Ponzi firms, average government deficit, average interest rate, correlation between asset price inflation and good price inflation and the average bankruptcy ratio.

Figure 4 shows the result for the parameter measuring the sensitivity to inflation, θ_P. Below a threshold of 0.1, an increase in the sensitivity of the central bank to inflation has a stabilising effect: a lower variance of demand, inflation and a lower ratio of Ponzi firms and bankruptcies. As expected, also the effect on the average aggregate demand is negative. For values of θ_p above 0.1, further increments of θ_p fail to contain inflation while there are no appreciable effects on variance and proportion of Ponzi firms, the bankruptcy ratio nevertheless increases. Not surprisingly the surplus in the government budget reduces as an effect of the weaker private demand. A relatively high value of this parameter with respect to θ_x (the sensitivity to the output gap) and θ_d (the sensitivity to the share of Ponzi plus speculative firms) is comparable to an inflation targeting policy, with emphasis on the stability of prices. This policy proves to be inadequate in this context, not achieving the intended goal on the price and undermining the general stability of the system. A higher sensitivity to inflation also contributes to an increase in the negative correlation of asset and goods prices, and so possibly misguides the reaction of the central bank. As shown in the bottom-left panel, the correlation between the two takes larger negative values as θ_p increases.

Figure 5 displays the effect of higher sensitivity of the central bank to the ratio of speculative plus Ponzi units, θ_d. An automatic reaction of the central bank to an increase in the ratio of Ponzi firms and speculative firms does not cause a stabilising effect on the system. An increase in the sensitivity parameter θ_d reduces mean and variance of aggregate demand but brings about larger ratio of Ponzi firms and bankruptcies. An automatic response of monetary policy to a perceived growing debt bubble does not appear to be able to halt it. On the contrary, an increase in the interest rate due to a proportion of distressed firms that is deemed to be too large can push more firms towards an unsound financial condition and bankruptcy.

The effects of changes in the sensitivity to the level of demand are displayed by figure 6. For θ_x lower than 0.1, the effect of changes in the parameter on most of the variables under examination is not quite clear. Above this threshold, further increments bring about higher averages of the demand and variance of demand. The government budget does not appear to be affected by variations in this parameter while the correlation between asset and goods prices reduces. Higher values of θ_x also cause an increase in the ratio of Ponzi firms and bankruptcies, together with a decrease in the market interest rate. A more accommodating monetary policy therefore can have the side effect of making the system more unstable and financially fragile.

We perform Monte Carlo simulations also for the the parameter θ which measures the extent of the intervention of fiscal policy in downturns. The results are illustrated by figure 7. The simulations show that a "moderately" interventionist government (with θ below 0.3 circa) increases the average demand but, at the same time, can generate instability, as testified by the increase in the variance of aggregate demand, price, negative correlation of asset and goods price inflation and the bankruptcy ratio. A more active fiscal policy ($\theta > 0.4$), despite not having noticeable influence on the average demand, can actually have positive systemic effects, as displayed in particular by the lower ratios of Ponzi units and bankruptcies. Apparently there is no crowding-out effect since the interest rate shows a decreasing pattern for higher values of θ.

6 Endogenous money, inflation and the stock price

It is noticeable that, at least to the best of our knowledge, the explanations provided by the literature for the negative correlation between asset and goods price inflation do not involve the mechanism of the creation of credit. In this section our computational experiment focuses on identifying the effect of the endogenous creation of credit in the presence of over-investment and sticky salaries. The assumptions for the productive sector and the government are the same as in sections 2 and 3, while the behaviour of the central bank is modified.

6.1 Behavioural rules of the central bank

In this treatment, in order to study the effect of the endogenous money, we define a new behavioural rule for the central bank. The monetary authority targets the price level and the financial stability of the economy by handling the quantity of money. The supply of money is set according to the following rule

$$M_t = (\beta_t - \zeta Pon_t)(B_t + D_t), \tag{29}$$

where ζ is a parameter, Pon_t is the share of Ponzi firms and

$$\beta_t = \frac{1}{1 + e^{\lambda \Delta P_t / P_{t-1}}}. \tag{30}$$

In equation (30) λ is a parameter and ΔP_t is the variation in price at time t. Therefore λ measures the sensitivity of the monetary authority to inflation while ζ quantifies the sensitivity to the systemic financial fragility, proxied by the share of Ponzi firms. According to the rule (29), the central bank buys on the secondary market an amount of private and public bonds that is inversely related to goods price inflation and the share of Ponzi firms, and injects an equivalent amount of currency into the economy. The intended effect is to reduce liquidity in the presence of growing inflation or an excessive level of indebtedness in the business sector, in order to prevent or deflate a possible speculative bubble.

In the first scenario, the actual supply of money in the system is defined by the central bank according to (29). In other words, the financial sector is unable to generate liquidity. The equilibrium value of the interest rate is therefore determined in a more Wicksellian setting by equating demand and supply of credit. It is determined simultaneously to the stock price by the Tobinian portfolio

$$\begin{cases} P_{e,t} E_t = \dfrac{(W_t + M_t)}{1 + e^{\varpi r_t - \rho_t}}, \\ D_t + B_t = \dfrac{(W_t + M_t)}{1 + e^{-\varpi r_t + \rho_t}}, \\ W_t + M_t = P_{e,t} E_t + D_t + B_t. \end{cases} \tag{31}$$

Since the supply of money M is exogenous in this setting, the system (31) presents only three equations[6]. The amount of wealth W is dependent on the stock price and therefore is quantified as well within the system (31).

In the second scenario, the assumption of endogenous money is reinstated. We use the behavioural rules (29) and (30) but assume that the private sector is able to provide a perfectly elastic supply of liquidity, as in section 4. The central bank buys a share of public and private bonds in an attempt to regulate the supply of money, but this latter is endogenously determined within the system, so that the only effect is to reduce the quantity of bonds in the market. The equilibrium values of the stock price, interest rate, wealth and amount of liquid assets are therefore calculated according to (28).

6.2 Results of the simulations

Figures 8 and 9 present the results for a single run for the two different settings. The correlations between share of Ponzi firms with the detrended series of aggregate private demand and total demand are both about 20% in the case of endogenous money. When the money can be controlled by the central bank, fiscal policy is more effective in breaking this causal chain and the correlation between the share of Ponzi firms and total demand is close to 0, even though still significant.

The correlation between asset price and goods price inflation is, on average, higher in the case of endogenous money. Monte Carlo simulations return an average correlation of -0.61 for the endogenous money compared to -0.04 in the exogenous money case. The explanation of this statistical regularity involves the mechanisms of formation of the two prices. Equation (7) quantifies the goods price as salary plus a constant mark-up. According to equation (11), the salary is directly related to the autonomous component of the expenditure (investment plus government expenditure) and inversely to the production level. The reaction of salaries to the increase in investment and employment is delayed by the sluggishness in the adjustment of salary, quantified by η. In the endogenous money scenario, the dynamics of equity prices and, consequently, of investment and production, are accelerated by the increase in wealth and liquidity that brings about a reduction in the interest rate. This liquidity effect further pushes investment up through equation (1) and drives more wealth into equities due to (28). During a recession, the reduction in liquidity, due to the unredeemed bonds and the destruction of equities, reduces wealth and increases the interest rate, depressing investment. The joint effect of public expenditure (which makes up for the reduction in investment) and sluggish salaries contributes to the divergent dynamics of asset and good prices also during the depression phase.

In the exogenous money scenario the contraction in the supply of money during the building up of a bubble hampers this causal chain reducing the

[6]The supply of money appears on the left hand side in the last equation because it is used by the central bank to buy bonds, decreasing their amount in the market.

availability of wealth to purchase equities and increasing the interest rate. In this second scenario, large stock market bubbles do not always accompany the expansionary phase of the cycle.

The model therefore explains the low inflation during stock market booms as the consequence of self-reinforcing positive expectations in the financial market that increase the availability of credit for the purchase of investment and financial assets. This in turn determines an increase in the induced expenditure larger than the increase in autonomous expenditure and, hence, a divergent dynamics of asset and good prices.

In both settings this correlation is typically higher (in absolute value) for a low λ and high ζ, as demonstrated by the Monte Carlo simulations (illustrated by figures 10 to 13 and further discussed below). One possible explanation is that a policy that tries to burst the bubble by targeting the level of debt (the proportion of Ponzi firms) can possibly worsen the overall condition of firms, pushing them to demand more debt financing as a perverse effect.

To complete the presentation of the results, figures 10 to 13 present Monte Carlo simulations for different values of λ and ζ. The plots are analogous to the ones discussed in section 5. The comparison between figures 10 and 12 shows that the consequences of an increase in λ are different between the exogenous and the endogenous money scenario. The most interesting finding is that, in the former case, a high sensitivity of the central bank to inflation has a positive effect only on the share of Ponzi firms and the bankruptcy ratio, whereas in the latter it also reduces the variance of fluctuations.

Figure 11 illustrates that, in the exogenous money scenario, a stronger reaction of the central bank to the ratio of Ponzi firms reduces it but this effect is obtained through the increment of the bankruptcy ratio. In the second scenario, the effect of a larger ζ is noticeable only for high values of the parameter (about 0.7), in particular for the share of Ponzi firms, as shown by figure 13. In this case the reduction does not involve a significant rise of the bankruptcy ratio.

Finally, the correlation between the share of Ponzi firms and the final demand is higher in the endogenous money setting (0.36 against 0.18 of the opposite case). This can be an effect of the higher interest rates, which push more firms into the Ponzi state during an expansion.

7 Concluding remarks

This paper presents an agent based model to test the effects of monetary policy when the swings in the business cycle are caused by over-investment and excessive leveraging. The aim is to contribute to the current debate about the redefinition and a broadening of monetary policy objectives in a financialised economic system.

The analysis mainly considers the systemic effects of variations in the parameters of a modified Taylor rule, which includes the ratio of financially unsound firms among the target variables. In the benchmark scenario, the parameters that quantify the sensitivity to inflation, the output gap and the ratio of Ponzi and speculative firms have the same value. The simulations reveal that a major focus on inflation can have destabilising effects on the system, without clear benefits in terms of lower prices. Also increases in the other parameters can generate unwanted, or even perverse, outcomes. We also performed the same experiment varying the fiscal policy parameter, finding that a more active fiscal policy appears to be the most suitable instrument to achieve growth and stabilise the economy. Interestingly, the higher levels of income reduce the demand for credit and push down the interest rate.

Summarising, our computational experiment reveals that fiscal policy proves to be the best option to stabilise an unstable economy, where the financial markets drive expectations of firms and, consequently, the whole system dynamics. Even a monetary policy with a broader range of targets does not seem adequate in this context. The cycle in our artificial economy shares some statistical features with real data, but a more comprehensive effort at calibration is needed in order to provide more detailed policy implications. This represents the next extension of this model together with a less mechanical definition of the central bank's responses.

An interesting general result of the paper is that, in a representation of the economy as a complex system, in which small idiosyncratic shocks cause the transitions in the cycle, the effects of an intervention on aggregate expenditure are more predictable than in the case of a manipulation of the choice variable of agents (such as the interest rate). Agent based models offer a perspective to investigate the mechanism of transmission that is radically different from the spontaneous adjustment to the equilibrium postulated by standard representative agent models. For this reason they can provide a relevant integration for the theoretical frameworks currently used in defining economic policies.

A further experiment sheds some light on the puzzle of low inflation during stock market booms. In this second set of simulations, the central bank controls the supply of money. Within this setting, we define two different scenarios depending on whether the financial system is able or not to generate endogenous credit. With endogenous credit, the correlation between asset and goods prices is always largely negative, in contrast with the alternative scenario. In a context of sticky wages, the fact that the financial system always accommodates the demand for credit can create a boom with growth in aggregate demand, mainly driven by firms investment, and declining salary. These dynamics will be investigated further in the future, in particular with the introduction of a labour market and a variable price mark-up.

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$\eta = 0.5$	stickiness of salary.
$\theta = 0.75$	sensitivity of the government to negative variations in demand.
$\theta_x = 0.01$	sensitivity to the output gap in the Taylor rule.
$\theta_p = 0.01$	sensitivity to inflation in the Taylor rule.
$\theta_d = 0.01$	sensitivity to the share of Ponzi plus speculative firms in the Taylor's rule.
$\alpha = 0.5$	Sensitivity of ρ_t to variations in asset price.
$\tilde{u} \in [0.1; 1.9]$	idiosyncratic shock affecting ρ and P_k.
$\tau = 0.2$	share of tax on profit.
$a = .25$	sensitivity of firms investment to ρ_t.
$b = 2.8$	labour-output ratio.
$\mu = 0.3$	price mark-up.
$v = 1.1$	constant capital to labour ratio.
$\varrho = (b * v)^{-1}$	output-capital ratio.
$\phi = 5$	parameter for firms decision between equity and debt.
$\psi = 0.5$	propensity of investors to liquid assets.
$\sigma = .05$	rate of capital depreciation.
$\gamma = 9$	Bankruptcy parameter.
$t_{ma} = 5$	period to calculate the moving average for the Taylor rule.
$\lambda = 1.3$	sensitivity of the central bank to inflation when it targets the supply of money.
$\zeta = 0.1$	sensitivity of the central bank to the share of Ponzi firms when it targets the supply of money.

Table 1: Parameters and values used in the simulation

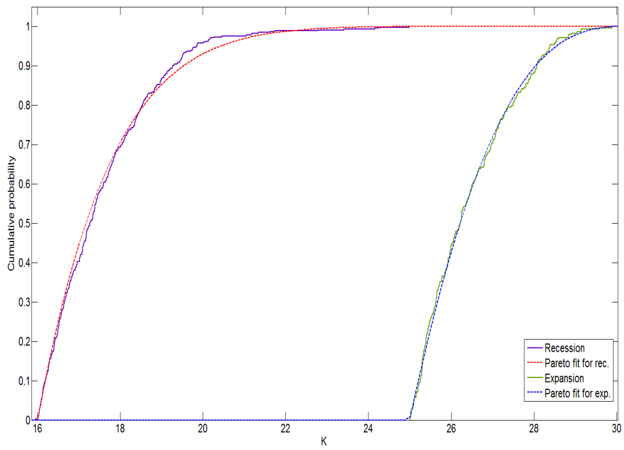

Figure 1: Cumulative distribution for firms size during recessions and expansions with Pareto fit.

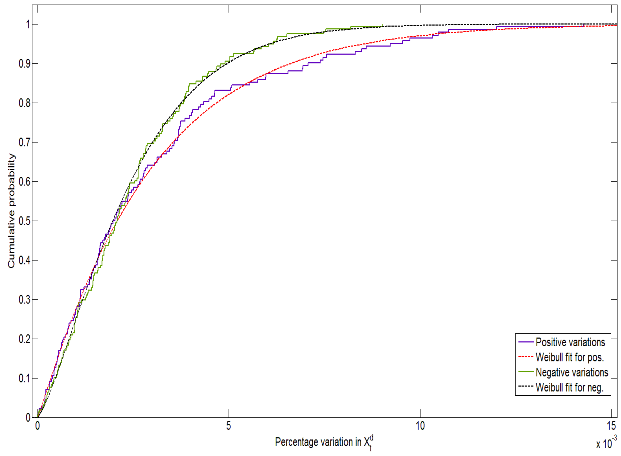

Figure 2: Cumulative distribution for positive and negative variations of aggregate demand with Weibull fit.

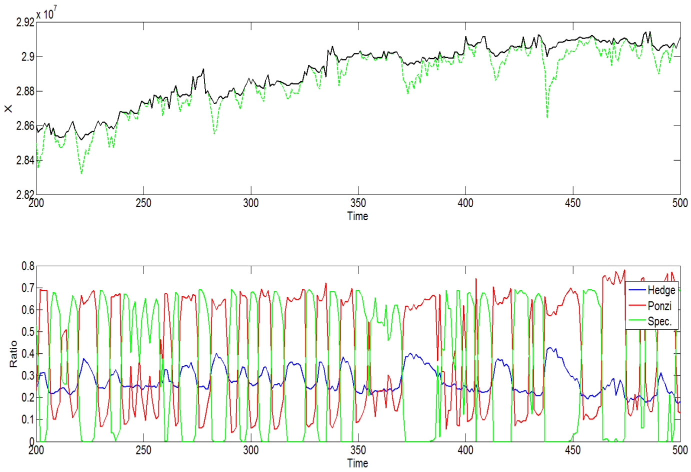

Figure 3: Aggregate and private demand (upper panel) and proportion of hedge, speculative and Ponzi firms (bottom panel).

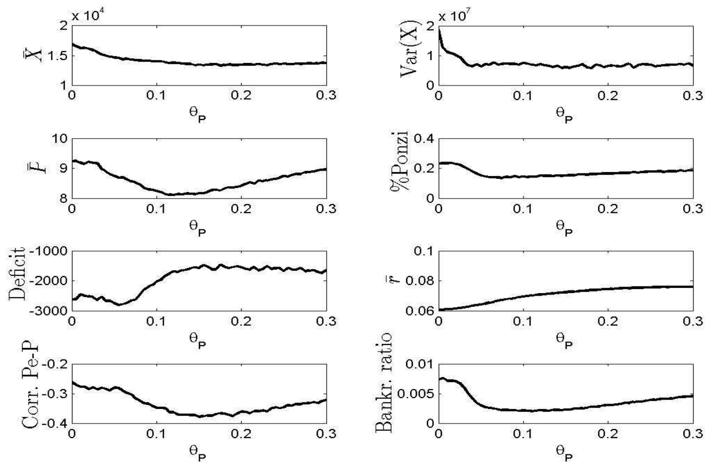

Figure 4: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of θ_p.

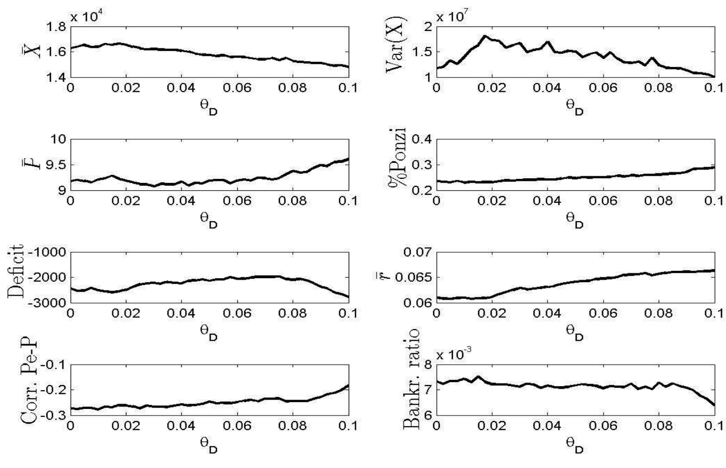

Figure 5: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of θ_d.

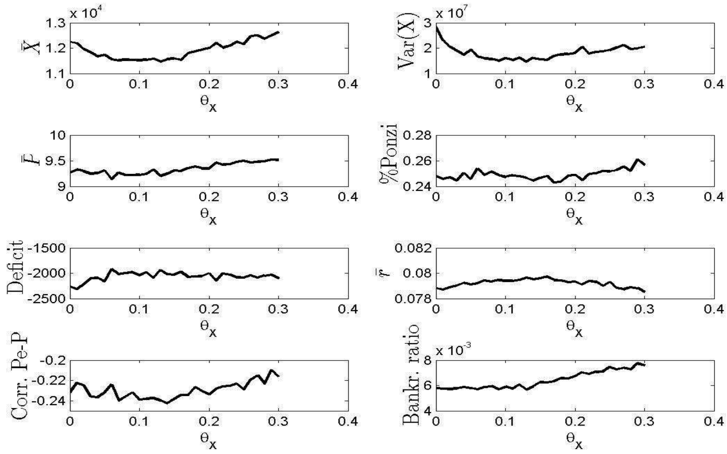

Figure 6: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of θ_x.

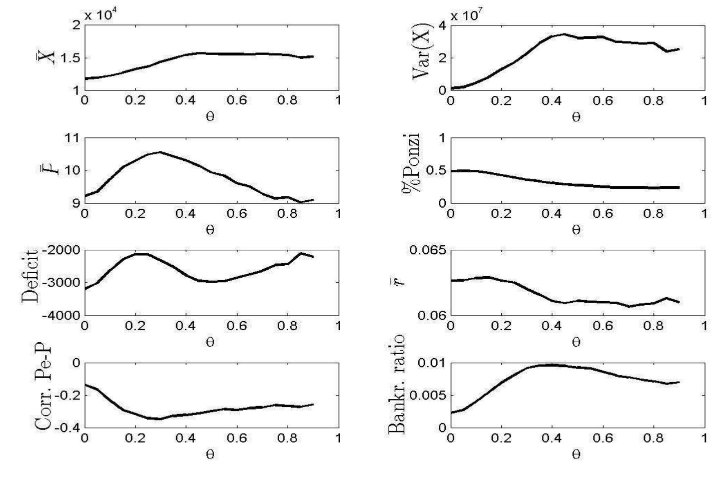

Figure 7: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of θ.

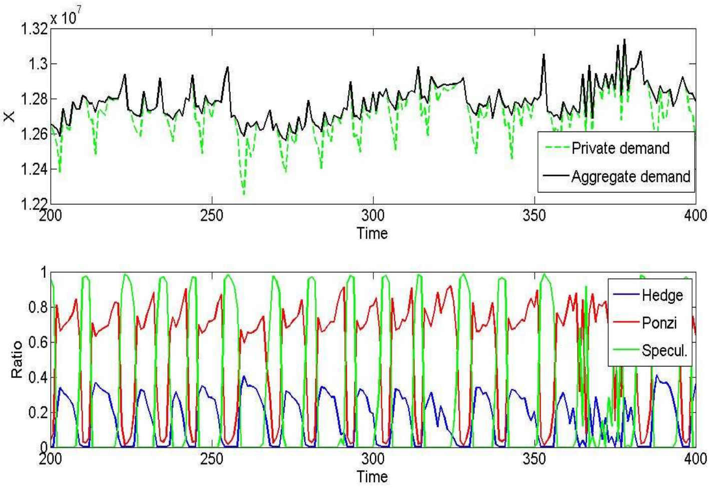

Figure 8: Aggregate and private demand (upper panel) and proportion of hedge, speculative and Ponzi firms (bottom panel). Simulation with exogenous money.

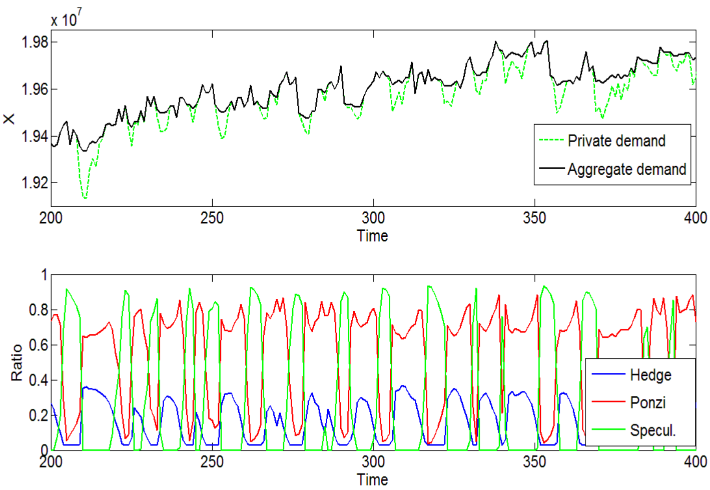

Figure 9: Aggregate and private demand (upper panel) and proportion of hedge, speculative and Ponzi firms (bottom panel). Simulation with exogenous money.

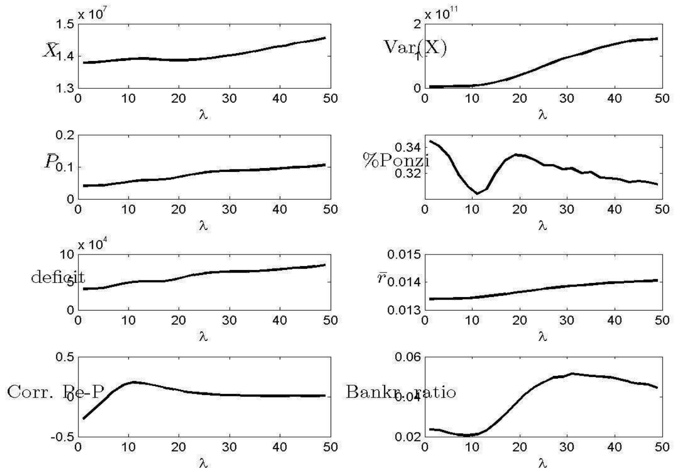

Figure 10: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of λ (exogenous money).

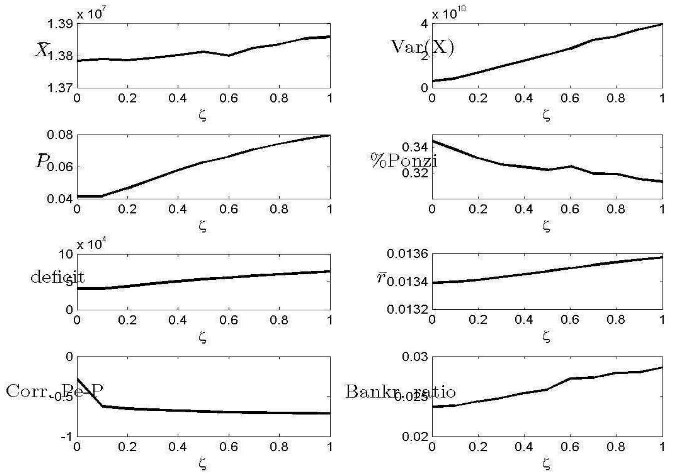

Figure 11: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of ζ (exogenous money).

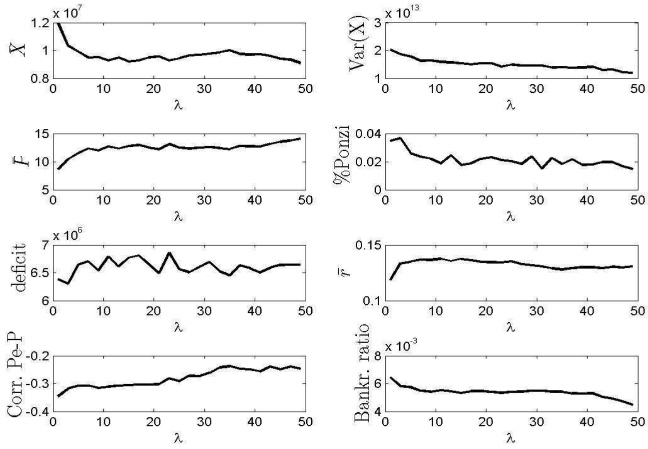

Figure 12: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of λ (endogenous money).

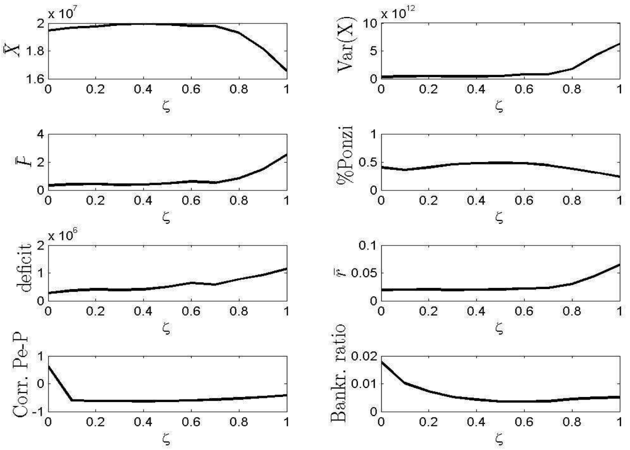

Figure 13: Aggregate production, variance of fluctuations, final goods price and share of Ponzi firms, public deficit, interest rate, equity price-goods price correlation and bankruptcy ratio over 1000 Monte Carlo replications for different values of ζ (endogenous money).