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Financial instability and debt deflation dynamics in a bottom-up approach

Carl Chiarella
Finance Discipline Group - University of Technology, Sydney

Corrado Di Guilmi
Economics Discipline Group - University of Technology, Sydney

Abstract

In this paper we expand the agent based model introduced by Chiarella and Di Guilmi (Chiarella, C. and Di Guilmi, C., The financial instability hypothesis: A stochastic microfoundation framework. Journal of Economic Dynamics and Control, 35(8):1151 – 1171, 2011) in which the business cycle originates by the modifications in firms' balance sheets induced by their investment decisions. During periods of market euphoria, firms increase their capital stock and their level of debt. At the same time the increasing availability of liquidity for investors causes inflation in asset price. When firms' debt reaches an unsustainable level the virtuous cycle is reversed in a depression. We modify the original model in order to study the impact of the dependence of firms' expectations on the stock market performance and of the rise in the proportion of Ponzi firms. We also run a further computational experiment to assess the effect of the buy-back of firms' shares.

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Contact: Carl Chiarella - carl.chiarella@uts.edu.au, Corrado Di Guilmi - corrado.diguilmi@uts.edu.au.
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1 Introduction

Chiarella and Di Guilmi (2011) (CDG from now on) contribute to the literature that aims to formalize Minsky's idea of a financial origin of the business cycle due to the increase in leverage during an expansion. Minsky (1982, 2008) presented a systematic approach to the analysis of how a financial crisis can lead to a downturn. According to his theory, instability is unavoidable in a capitalist economy due to its dependence on credit. Firms can be distinguished, on the basis of their short-term financial structure, as being of hedge, speculative and Ponzi type. The hedge firms are the soundest ones and can repay their obligations with their cash flow, speculative firms can pay the service on debt while Ponzi firms must refinance it. During expansions, banks grant credits with growing facility, since the rise in the level of economic activity spreads a sort of contagious optimism. The level of debt considered as acceptable grows, as the expansion makes bank confident about repayment. This confidence leads to a boom in economic activity, that contains in itself the germ of the crisis since the proportion of Ponzi firms has increased in the meantime. When the Ponzi firms begin to fail, liquidity declines and banks start to reduce lending, causing a stagnation that becomes a depression as financial distress extends to other firms.

CDG model Minsky's theory using an agent based model, with two classes of firms (grouping together Ponzi and speculative firms) and solve the model both numerically and analytically. The model is able to reproduce some features of the business cycle in the US. CDG show that financial innovation, that is the capacity of the financial system to create liquidity to satisfy the demand for credit, is a key variable in creating instability in the system.

In this paper we extend the model in two directions. First, we endogenize the key variable for firms' decisions about investment, which was stochastic in CDG, modeling it as functionally dependent on the recent stock market performance. The second extension is the reinstatement of the original Minsky's classification of firms into three categories, in order to better appreciate the evolution of systemic financial fragility (intended as the proportion of distressed firms over the total population) during the cycle. We also run a further computational experiment by allowing firms to buy back their shares. As stressed by Ryoo (2010), the level of buy-back rises before crashes and decreases afterward. From this perspective it is interesting to assess its actual destabilizing power. Furthermore, this model is entirely demand driven which makes it more consistent with Minsky's theory than CDG, whose model is only partially demand driven. The model is solved numerically and we leave the analytical solution to the future developments of this work.

The paper is organized as follows: section 2 presents the theoretical model, section 3 illustrates the results of the numerical simulations and, finally, section 4 provides some concluding remarks.

2 The model

The model is developed along the lines of CDG. Some assumptions are adapted to make the model more consistent with the Keynesian background of Minsky and to run additional computational experiments. We refer the reader to that paper for a more detailed explanation of the content and the rationale of the assumptions. Firms' variables are identified by the superscript j.

2.1 The firms sector

- Every period the j-th firm targets an amount of investment I^j. The new level of capital then determines the demand for labor and output. The investment is decided on the basis of the difference between the shadow-price of capital P_k^j (Minsky, 2008) and the price of acquisition of capital goods P, so that

$$P_t I_t^j = a(P_{k,t}^j - P_t), \tag{1}$$

where $a > 0$ is a constant parameter. The shadow price of capital P_k^j is determined according to

$$P_{k,t}^j = \frac{\rho_t^j P_t}{r_t}, \tag{2}$$

where ρ is a parameter that expresses firms' expectations, as defined in subsection 2.2 below, and r is the interest rate.

- The selling price of the final good and investment is a mark-up price μ on the cost of labor

$$P_t = (1+\mu)w_t b, \tag{3}$$

where w_t is the salary and b the labor-output ratio.

- Firms produce a good that can be used either for consumption or investment. They produce upon order, therefore their production always matches the demand (there are no stocks). Assuming that the firms adopt a technology with constant coefficients, the amount of labor requested is residually determined once the optimal level of investment, and hence of capital, is quantified. The supply of labor is infinitely elastic. The production function for all firms is written as

$$X^j(t) = G(K^j(t), L^j(t)), \tag{4}$$

with K and L representing, respectively, physical capital and labor. Given that the supply of labor is infinitely elastic and the output/labor ratio is constant, it is possible to define the production function just as a function of capital

$$X^j(t) = \varphi\, K^j(t), \tag{5}$$

where the output/capital ratio φ is assumed to be a constant parameter.

- The aggregate demand is given by

$$X_t^d = w_t L_t + P_t I_t + c\Pi_t, \tag{6}$$

where c is the propensity to consume of capitalists and Π_t is the sum of the firms profits. It is allocated among firms according to their stock of capital, according to the rule[1] $X^{j,d} = \frac{X_t^d}{K_t} K_t^j$.

[1] Since production always matches demand we have that $X_t^{j,d} = X_t$.

- In order to model the inflationary pressure that may arise during expansions, the salary is assumed to be dependent on the past variation in the demand for work

$$w_t = w_{t-1}\left(1+\eta\Delta L_t^d\right), \tag{7}$$

with $\eta > 0$.

- Firms finance the part of investment that cannot be covered with internal funds by a fraction ϕ of equities and then the rest with debt, according to the rule

$$\phi_t = \frac{1}{1+e^{(h-r_{t-1})}}, \tag{8}$$

where h is the cost of issuing of new equity shares. The cost is due to technical costs of issuing (Myers, 1984). 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. The variation in the outstanding debt and in the stock of equities for each firm are equal, respectively, to $\Delta D_t^j = P_t I_t^j(1-\phi_t)$ and $\frac{\Delta E^j}{P_e^j} = P_t I_t^j \phi_t$.

- Capital depreciates in each period at a constant rate v. Consequently, the variation in the physical units of capital is given by

$$\Delta K_t^j = I_t^j - vK_{t-1}^j. \tag{9}$$

- Profits π are given by

$$\pi_t^j = P_t X_t^j - wP_t bX_t^j - r_t D_t^j - h\Delta E_t^j = P_t X_t^j(1-wb) - r_t D_t^j - h\Delta E_t^j. \tag{10}$$

Accordingly, firms can be classified into the three categories defined by Minsky (1982) in the following way:

  - hedge: $\pi_t > D_t$;
  - speculative: $D_t > \pi_t > 0$;
  - Ponzi: $\pi_t < 0$.

- A firm fails if its debt level exceeds some multiple of its capital stock, that is if

$$D_t^j > \gamma P_t K_t^j, \tag{11}$$

with $\gamma > 1$ as a constant parameter. The probability of a new firm entering is directly proportional to the variation in the aggregate production with respect to the previous period.

2.2 The capital market

While in CDG ρ is a random variable, here we consider it as dependent on the last variation in the stock market index, with a multiplicative shock that represents the influence of extra-economic and institutional factors (political, environmental, international, etc...). Hence ρ is quantified by

$$\rho_t = e^{\left(\frac{\Delta P_{e,t}}{P_{e,t-1}}\right)}\tilde{\beta}. \tag{12}$$

with $\tilde{\beta}$ randomly drawn from a uniform distribution with support $[0.1,\ 0.9]$. Besides this common shock, each firm is subject to an idiosyncratic shock which affects both its expectations ρ^j and its share price P_e^j, so that

$$\rho_t^j = \tilde{u}_t^j \rho_t, \tag{13}$$

$$P_{e,t}^j = \tilde{u}_t^j P_{e,t}. \tag{14}$$

Also the idiosyncratic shock $\tilde{u}$ is uniformly distributed in the interval $[0.1,\ 1.9]$.

The wealth W of investors is the sum of shares, bonds and money, so that

$$W_t = P_{e,t}E_t + D_t + M_t, \tag{15}$$

where M_t is the demand for money. Wealth evolves over time according to[2]

$$\Delta W_t = \psi\left(\Delta P_{e,t}E_t + s\Pi_t\right), \tag{16}$$

so that $W_t = W_{t-1} + \Delta W_t$. An initial endowment of money is assumed. Variations in total wealth are then due to capital gains plus saved profits, multiplied by a factor ψ that measures the degree of financial intermediation (or financial innovation).

Investors allocate their wealth among equities, firms' bonds and money. The proportion of wealth invested in each of the three assets is positively dependent, respectively, on ρ, the interest rate r and a fixed parameter ω. We assume that the government expenses are for non productive services and are financed by issuing money. For simplicity the supply of money grows at a constant rate[3]. Therefore, the equilibrium conditions in the capital market can be expressed as

$$\begin{cases} P_{e,t}E_t = \dfrac{W_t}{1+e^{r_t+\omega-\rho_t}}, \\ M_t = \dfrac{W_t}{1+e^{r_t+\rho_t-\omega}}. \end{cases} \tag{17}$$

The system (17) may be solved for the value of asset prices and the interest rate[4].

3 Results

The baseline configuration of the parameters is the following $b = 0.8; \varphi = 0.3; a = 1; \omega = 0.2; c = 0.3; h = 0.4; \Psi = 1.5; v = 0.1$. Figure 1 shows a positive correlation of the aggregate output with

[2] This assumption is different from CDG since, in that paper, wealth was endogenously determined.

[3] The companion papers Chiarella and Di Guilmi (2012b), Chiarella and Di Guilmi (2012a) and Chiarella and Di Guilmi (2013) explicitly focus on fiscal and monetary policy.

[4] We refer the reader to CDG for a detailed presentation of the dynamical system (17).

the share of Ponzi and speculative firms. Their proportions rise during expansions and fall during a recession. It is also possible to note that the most relevant recessions follow the sharpest increases in the share of Ponzi firms. When the expansion is accompanied by a transformation of a sizeable proportion of speculative firms into Ponzi firms, the subsequent recession is considerably more severe. The correlations between aggregate output and shares of hedge, speculative and Ponzi firms are, respectively, -0.94, 0.57 and 0.94, confirming this pattern.

The upswings and downswings are driven by a speculative motive: the difference between the shadow price of capital goods and their market price follows closely the trend of aggregate production (despite being significantly more volatile). Another feature of the model is the endogenous emergence of Goodwin cycle, with the share of salaries increasing during expansions. Consistently with the assumptions of the model, the capacity utilization is pro-cyclical.

We run some tests in order to evaluate the effects of changes in the benchmark setting. Analogously to what has been already shown by CDG, the capacity of the system to accommodate the demand for liquidity[5] is a crucial factor for the stability/instability of the system. That paper showed that increasing this parameter and therefore making the supply of credit more elastic, the variance of the fluctuations and the size of the financial sector are larger as well. In this paper, the introduction of the Ponzi category with a given supply of external finance can lead the system to the collapse as shown by figure 2. In particular, fluctuations are progressively wilder with an increasingly larger spike in the share of Ponzi firms during expansions. When all firms become Ponzi the economy can collapse if all the firms are bankrupted.

Another additional experiment that we run on the original framework is the introduction of the possibility for firms to use a fraction of their profits to buy back their shares, a phenomenon that has seen a significant growth during the recent years. The simulations show that firms' buy-back of shares pushes up the demand for them, raising their price and, consequently, the capital gain of investors and the shadow price of capital. These effects, in turn, drive up the shares price and the level of investment in an upward spiral. The burst of the bubble is triggered by the bankruptcy of the Ponzi firms, which leads to a decrease in the demand for equities that exacerbates the downturn. As figure 3 shows, the introduction of the buy-back amplifies the cycles, with growing proportion of Ponzi, until the system collapses when all firms are bankrupted.

4 Concluding remarks

This paper presents additional computational experiments on the model introduced by CDG by linking firms' expectations to the stock market performance, introducing the Ponzi category of firms and assessing the effect of the buy-back of shares by firms. The simulations confirm the findings of the original paper and show that the capacity of the financial system to accommodate the demand for credit by the productive sector (financial innovation) has a destabilizing impact on the macroeconomy as it contributes to rapidly increasing leverage above the sustainable level. The buy-back of shares also has a destabilizing effect as it amplifies the speculative bubbles that drive the expansions. The simulations also show that during expansions the share of salaries on the total output grows. The model is therefore able to generate Goodwin-type cycles. The results

[5] CDG broadly refer to financial innovation to define an institutional reference for the parameter Ψ. From this perspective a larger Ψ can be interpreted as a laxer financial regulation that allows the financial system to produce a greater quantity of liquid financial assets and therefore to facilitate credit expansion.

presented in this paper will be verified against empirical evidence and should be embedded in a framework aimed to provide some policy implications. As done in CDG the analytical devices for the solution of model with heterogeneous agents will be employed to provide more insights in the causal relationships among variables that are the origin of the cycles of booms and busts.

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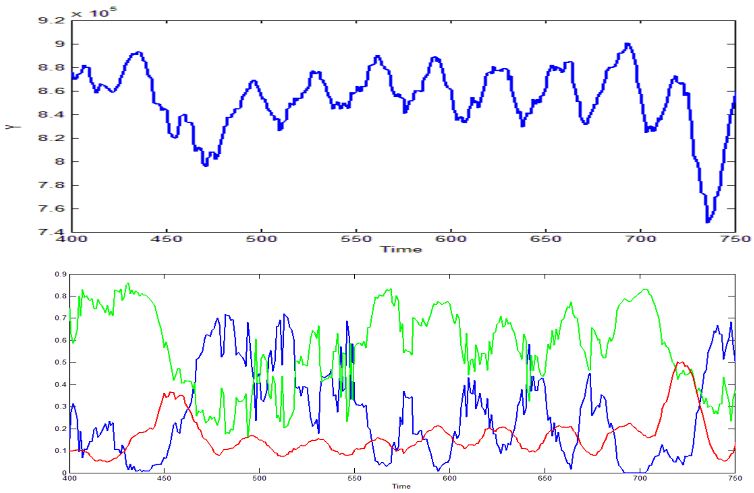

Figure 1: Top panel: time series of aggregate output. Bottom panel: proportion of hedge (blue), speculative (green) and Ponzi (red) firms. $\psi = 1.5$.

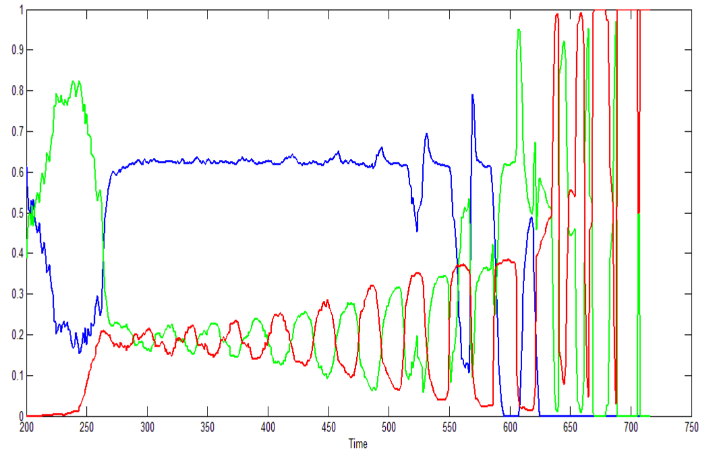

Figure 2: Proportion of hedge (blue), speculative (green) and Ponzi (red) firms. $\psi = 2$.

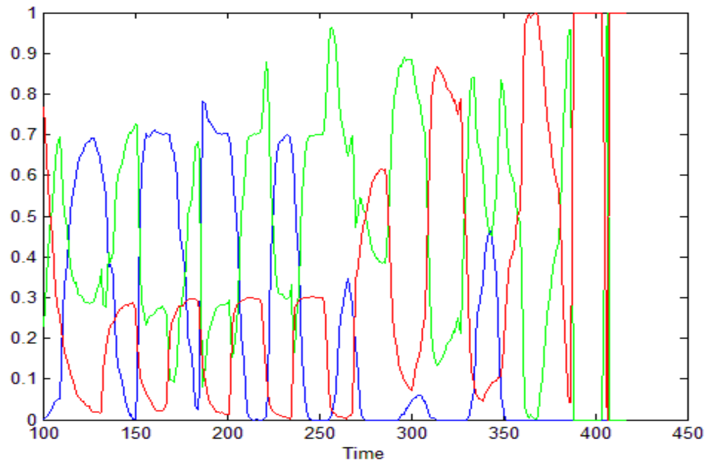

Figure 3: Proportion of hedge (blue), speculative (green) and Ponzi (red) firms. $\psi = 1.5$ and buy back of shares.