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LEVERAGE, LIQUIDITY AND CRISIS: A SIMULATION STUDY

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Abstract

We study the interactions of banks and firms within a leverage cycle to understand how capacity utilisation and capital investment interact with funding costs, leverage by banks and firms, and liquidity. We show in a simulation study that when firms can grow and die by becoming insolvent, and when banks can grow and die as their bad debts increase to unsustainable levels, the real economy cycles around a leverage cycle.

Keywords: Leverage, capital investment, capacity utilization, simulation modeling.

JEL Codes: E22, E32, E37.

1 How do banks and firms interact within a leverage cycle?

The goal of this paper is to study the interaction of firms and banks throughout a leverage cycle when liquidity constraints are present. There are many studies of firm size and investment, and a growing literature on leverage and liquidity constraints in banking, but few studies look carefully at the interaction between banks and firms throughout a leverage cycle.

In this paper we simulate the behavior of firms attempting to maximise growth relative to their capacity utilization and the unit costs they face. We simulate the behavior of banks attempting to increase their net worth through loans, and the interactions between them.

We allow firms and banks to interact in a simulated trading environment. Our simulation replicates the empirical findings of Schularick and Taylor (2009), Fagiolo and Luzzi (2006), and Audretsch and Elston (2002). We show that when firms can grow and die by becoming insolvent, and when banks can grow and die as their bad debts increase to unsustainable levels, the economy itself cycles around the leverage cycle.

The leverage cycle is an old concept in economics (Bagehot, 2006), (Minsky, 1986). In its modern incarnation, the leverage cycle as described by Fostel and Geanakoplos (2008) is a procyclical phenomenon where, the absence of intervention, leverage becomes too high in boom times, and too low in bad times.

Fostel and Geanakopolos define ‘leverage’ as a ratio of collateral values to the downpayment that must be made to buy them. This definition is clearly different to the usual definition of leverage as the ratio of (debt+equity)/equity. They argue this definition is misleading because equity is wiped out during crisis. Maximum leverage according to Fostel and Geanakoplos (2008) is the inverse of margin where margin of an asset is the shortfall from its borrowing to price ratio from a hundred percent, so margin = $\frac{\text{price}-\text{borrowing capacity}}{\text{price}}$.

If we assume that the price of a firm is equal to its capital stock (k) and that its borrowing capacity is measured by the capital it has already borrowed (k_b), then its margin is $margin = \frac{k-k_b}{k} = 1 - \frac{k_b}{k}$. The definition of leverage ratio used in this paper ($\lambda = \frac{k_b}{k}$) thus follows the same cycle as the leverage defined in Fostel and Geanakoplos (2008): $\lambda^f = \frac{1}{margin} = \frac{1}{1-\lambda}$. When one goes up, the other has to go up and vice-versa.

With fully rational agents, as long as there are differential attitudes to the holding of debt, then because of leverage, in boom times, asset prices are too high, and in crisis times they are too low. Agents react to ‘news’–good or bad–by changing their expectations and hence their preferences for leverage. The resulting cycle in asset prices, leverage, and real output follows naturally.

The role of the financial intermediary in the transmission of the leverage cycle is already well studied in this growing literature by Coricelli et al. (2010), Denis and Sibilkov (2010), and Devereux and Yetman (2010). The extent of leverage levels internationally has been measured recently by Kalemli-Ozcan et al. (2011) who find that debt levels at present are at historic highs. The connection between liquidity and leverage has been made recently by Adrian and Shin (2010), Oliveira and Fortunato (2006), and earlier by Kiyotaki and Moore (1997) and Whited (1992). Evidence on firm growth and development in the presence of constraints to investment from Germany (Audretsch and Elston, 2002), Canada (Aivazian et al., 2005), Italy (Fagiolo and Luzzi, 2006) and a panel of emerging economies (Coricelli et al., 2010) has also been well documented. Each study shows to a greater or lesser extent that excess leverage leads to a boom-bust cycle within firms, with the consequent default and firm deaths.

Importantly, we allow firms to plan for excess capacity. Both Labini (1971) and Spence (1977) point out that under imperfect competition, the existence of excess capacity allows incumbent firms to deter new entrants to the market, and for this reason, excess capacity is desired. Robinson (1969) notes that firms are usually incorrect in their estimation of demand growth, creating unwanted excess capacity as a result of incorrect planning, while Steindl (1952) indicates that firms utilise excess capacity the same way households hold cash–as a buffer agains an unknown future. Pasinetti (1981) uses uncertainty both on the distribution of demand and on new consumption when income grows to justify the existence of excess capacity.

Lavoie (1992) notes that new production capacities usually requires time to be build. Investments have thus to be planned ahead and productive capacities increase largely at once while demand increase slowly. Lavoie (1992) also points out that firms do not want to frustrate customers by not being able to respond to demand explaining why they have to plan investments ahead of demand growth

Our focus in this paper is on the connections between leverage, liquidity, and firm growth, which we feel have not been well explored in the literature on leverage cycles to date. We will study the interaction of firms and banks throughout a leverage cycle when liquidity constraints are present.

The main results of the paper are that the leverage cycle is enough to generate business cycle-like fluctuations in the model, with the firm birth and death rate changing in line with the leverage cycle over time. Banks require regulation of their reserves and lending to avoid a financial meltdown.

1.1 A brief sketch of the model

A brief sketch may aid intuition.

The model evolves in historical time. We describe the piecewise linear functions each firm and bank uses to make their decisions at any point in the leverage cycle. We allow capital accumulation and borrowing to be a piecewise linear function of capacity utilitsation in each firm. Unit costs are a decreasing linear function of output for a given stock of capital. Firms choose to invest (or not) in a given period according to their level of retained earnings, capital accumulation to date, and other factors. Firms are assumed to go bankrupt as soon as the price level does not allow them to pay labor unit costs and to service their debts.

When a firm dies, banks owed debt by that firm try to liquidate the firm by selling the firm's capital stock at a discount rate. Following Fostel and Geanakoplos (2008), at each period good or bad news is received and this affects –positively or negatively– the targeted leverage level of firms. When a firm has excess capacity, and if it needs to decrease its leverage level, it may try to sell part of its excess capital at a discounted rate to other firms.

Banks provide loans to make profits in the usual fashion. We assume banks charge an interest rate which is a function of the leverage level of the firm(s) trying to borrow from it, the reserve ratio of the bank, its targeted reserve ratio, and a parameter which reflects the desired profit rate of the bank, following Delli-Gatti et al. (2010). Profits are then determined as the sum of interest received minus non performing loans. All profits are kept as retained earnings, and increase banks' reserves. If the reserves of a bank go negative in a period, the bank is assumed insolvent and goes bankrupt. At first, banks are randomly assigned to firms, but then firms try to minimize the interest rate charged to them, and banks try to optimize their customers and avoid non performing loans. When a firm needs to finance part of its investment, it applies to all banks with a preference for low interest banks. Banks then accept or reject loans applied for by firms according to their targeted reserve ratio and according to their own preferences over customers (those having a lower leverage ratio being preferred over those with a higher lever ratio). If a firm does not find a bank willing to finance its investments, it cannot invest unless it uses its own retained earnings.

The rest of the paper is laid out as follows. Section 2 introduces the main facets of the model. We relegate details of the model to an appendix. Section 3 describes the results of the simulation, and three exercises using the model: changing the dividend policy in firms, changing interest rates and changing the rate of 'good news' received in the economy from period to period. Section 4 concludes.

2 The model-proper

We assume a large population of firms typically 1000 in each period, the model runs for 500 periods. We assume 10 banks initially, each servicing the firms with loans made from their reserves. Banks are free to set interest rates, and firms are free to move from one bank to another for the funding of a particular project in the next period. The structure of the decisions taken by banks and firms in the model is shown in figure 1.

In each period news enters the model as a positive or negative quantity which firms and banks must react to. We assume households consume everything firms produce. Firms can also choose to increase or decrease employment, and to invest in productive capacity, or not. We assume an elastic labour supply.

Figure 2 traces out the flows of money within the model, including the rest of the world. Firms can pay a dividend to shareholding households in each period, or not, as well as wages. Firms can choose to take loans or not from banks, and to repay those loans plus interest in that period. This model is not stock-flow

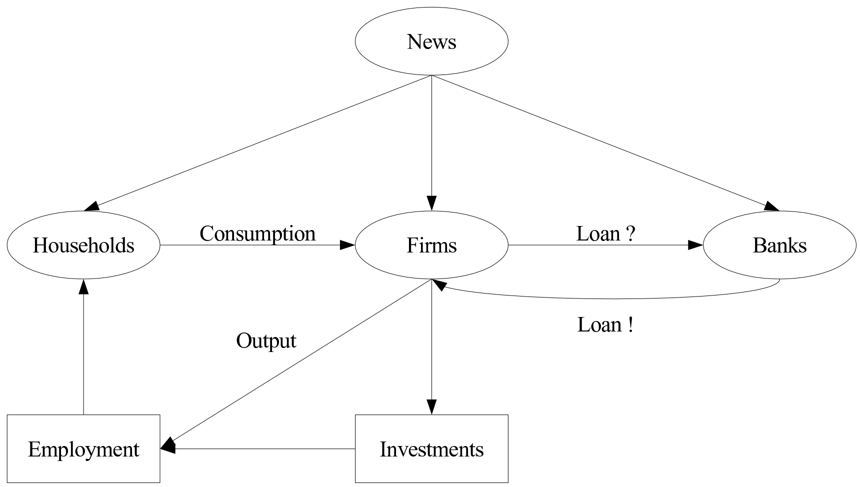


Figure 1: Decision diagram. Firms choose to take loans or not, to invest, or not, and to react to news as it comes in. Households can buy all that firms make, and firms choose to employ based on the output of households.

consistent, so we include a 'rest of the world' term to capture the 'leaks' from investments and income in figure 2.

The model is really a description of the interaction between firms' and banks' liquidity and solvency across a leverage cycle. We have several variables of interest, and we show their behavior in the panels in figure 3 below.

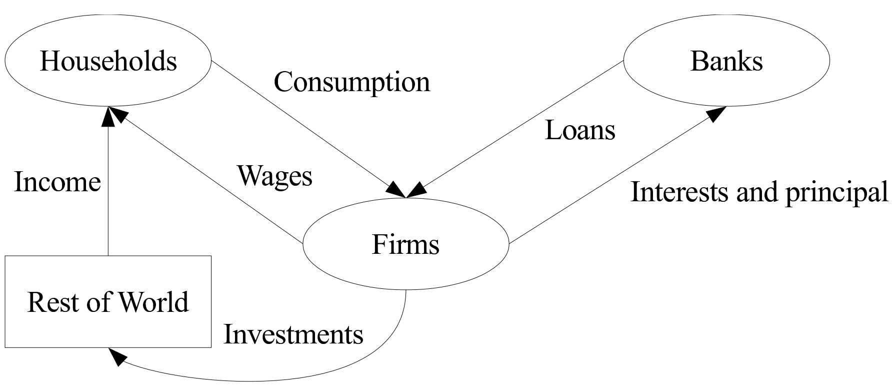


Figure 2: Money flow diagram. Firms borrow from and (normally) repay banks, households consume products and receive wages from firms and the rest of the world.

2.1 Firms

We use a formulation of the piecewise rate of change of capital from Goodwin (1951), depending on capacity utilization (u) and its targeted range ($u_{MIN} \leq u \leq u_{MAX}$)[1]:

$$\Delta k = \begin{cases} I - \delta k & \text{if } u > u_{MAX} \\ 0 & \text{if } u_{MIN} \leq u \leq u_{MAX} \\ -\delta k & \text{if } u < u_{MIN} \end{cases} \tag{1}$$

where δ is the rate of capital depreciation and I is investment[2]. We assume that firms invest as much as they can get when they decide to invest[3].

Following Kalecki, we assume a fraction ρ of retained earnings (RE) can be borrowed to finance total investment.

$$I = (1 + \rho)RE \tag{2}$$

According to Lavoie (1992), retained earnings are:

$$RE = rk - i_s k_s - i_b k_b \tag{3}$$

where r is the expected return on capital k, i_s is the dividend rate on net worth k_s and i_b is the interest rate on loans k_b. We have that total capital is composed of net worth plus loans $k = k_s + k_b$. Furthermore, we assume that shareholders are willing to accept a dividend rate equal to a $(1-\epsilon)$ percentage of the prevailing interest rate, leading to:

$$RE = k(r - i_b) + \epsilon(k - k_b) \tag{4}$$

Unit costs are a decreasing linear function of output, for a given stock of capital, up to the level of practical[4] full capacity output $x_{fc} = \mu k$, where μ is capital productivity. After that point, unit costs are a quadratic increasing function of output x until full capacity[5].

$$UC(x) = \begin{cases} \omega + \frac{\delta k}{x} & \text{if } u \leq 1 \\ \beta + \alpha(x - x_{fc})^2 & \text{if } u > 1 \end{cases} \tag{5}$$

Where ω are the labour unit costs. From 1, we observe that when $u = \frac{x}{x_{fc}} < u_{MIN}$, firms are not replacing depreciated capital. The unit cost function is

[1] In this paper, we follow Robinson (1969) in that firms might make mistakes in their estimation of growth creating unwanted excess capacity; and Lavoie (1992) as firms also plan some excess capacity in order to avoid to constrain demand in case of large growth in demand.

[2] For simplicity and without loss of generality we assume that price of capital is equal to 1.

[3] Intuitively, this could be either because investments are big machinery, or because firms think that demand will keep on increasing.

[4] *Practical* or *engineer-rated* full capacity is the maximum level of production such that it allows normal maintenance and renovation of machinery to take place without impeding production Eichner (1976), Steindl (1952).

[5] Such a function of piecewise unit costs is based on constant marginal costs up to practical full capacity. When maintenance cannot be performed and when workers work overtime, marginal costs increase drastically implying the increasing quadratic unit costs function.

thus modified in order to reflect this choice:

$$UC(x) = \begin{cases} \omega & \text{if } u < u_{MIN} \\ \omega + \frac{\delta k}{x} & \text{if } u_{MIN} < u < 1 \\ \beta + \alpha(x - x_{fc})^2 & \text{if } u > 1 \end{cases} \tag{6}$$

Figure 3 shows an example of unit costs as a function of capacity utilisation.

According to the price level p prevailing and output x, firms' profits are defined as:

$$\Pi = px - UC(x) - i_b k_b \tag{7}$$

Out of these profits, firms distribute dividends (8) and use the remaining amount to invest, repay loans or pay extra dividends.

$$i_s k_s = (1 - \epsilon) i_b (k - k_b) \tag{8}$$

2.1.1 Behavioral equations

Each firm has some characteristics: ϵ, the discount on dividends that shareholders are willing to accept, λ^T, the targeted leverage level, δ, the depreciation rate of capital, ω, the unit cost of labor, and μ, the rate of capital productivity. Given these parameters, and two endogenous variable i_b, the interest rate charged by banks, and u, their current level of capacity utilisation, firms decide how much they want to invest (1). We assume that firms decide to invest in order to reach u_{MAX} (11).

$$k^T = \frac{y^e}{u_{MAX} pr_k} \tag{9}$$

$$k^T = k_{-1}(1 - \delta) + i \tag{10}$$

$$I = p_k \left[\frac{y^e}{u_{MAX}} - k_{-1}(1 - \delta) \right] \tag{11}$$

Based on (2), firms know what is their targeted retained earnings in order to finance their desired investments. The value of ρ is computed using their current level of leverage and their targeted one (12). Expected sales growth is inversely proportional to price inflation (13). Finally, the mark-up on unit costs[6] is computed through expected sales and targeted retained earnings (14) and (4). Figure 3 displays how the *Kaleckian* function ρ, the mark-up and amount of requested loans respond to capacity utilisation and desired increase in leverage.

$$\rho = \frac{\lambda^T (k + RE^e) - kb}{(1 - \lambda^T) RE^e} \tag{12}$$

$$y^e = y_{-1}(1 - \hat{p}) \tag{13}$$

$$p = (1 + \phi) UC(y^e) \tag{14}$$

$$RE^e = \phi UC(y^e) - i_b \left[(1 - \epsilon)k - \epsilon k_b \right] \tag{15}$$

[6] We assume Kaleckian mark-up prices on normal unit costs.

When firms decide not to invest and if they need to de-leverage, they repay their loans up to their targeted level of leverage. In order to repay their loans, they use retained earnings. Their targeted earning is thus computed through (16) where Δk is determined through (1).

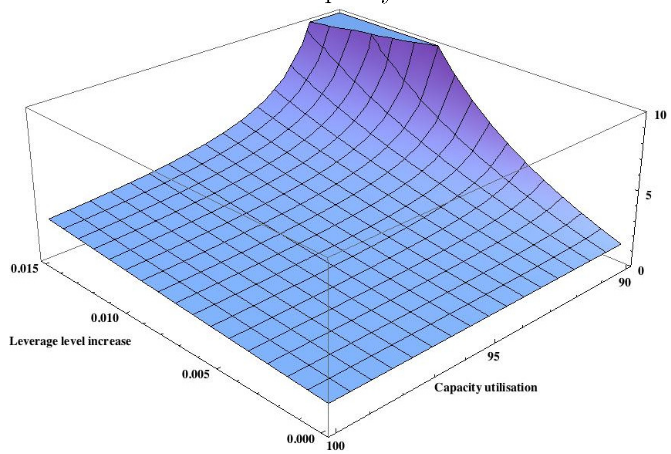
$$RE^e = k_b - (k_{-1} + \Delta k)\,\lambda^T \tag{16}$$

Following Fostel and Geanakoplos (2008), the targeted leverage level (λ^T) is a function of news. At each period, news is received, and according to whether it is good or not, it affects positively (or negatively) the targeted leverage level of firms. Each firm responds more or less to the news according to their optimistic or pessimistic natures encapsulated by the parameter ψ:

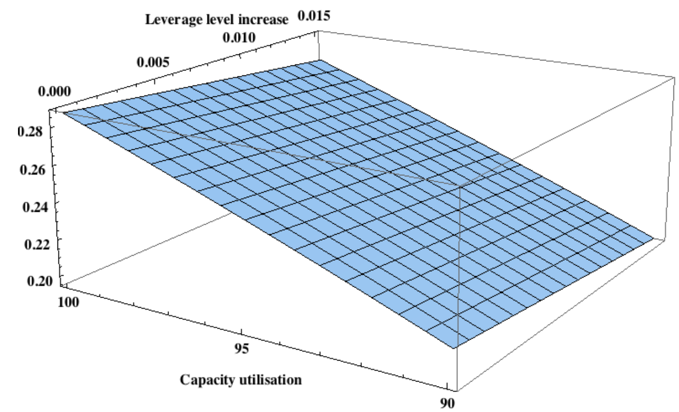
$$\lambda^T = 1 - (1 - \lambda)^{1+news\psi} \tag{17}$$

where $news = \pm 1$, $0.1 \leq \lambda^T$.

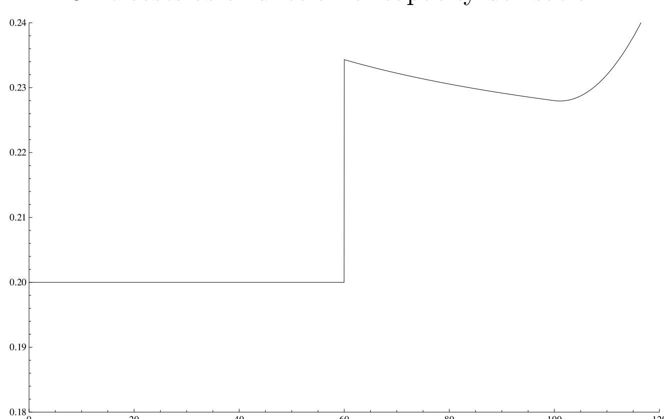
The Kalecki function, ρ, as a function of desired leverage increase and capacity utilisation.



The Markup, ϕ, as a function of desired leverage increase and capacity utilisation.



Unit costs as a function of capacity utilisation.



Loans requested as a function of desired leverage increase and capacity utilisation.

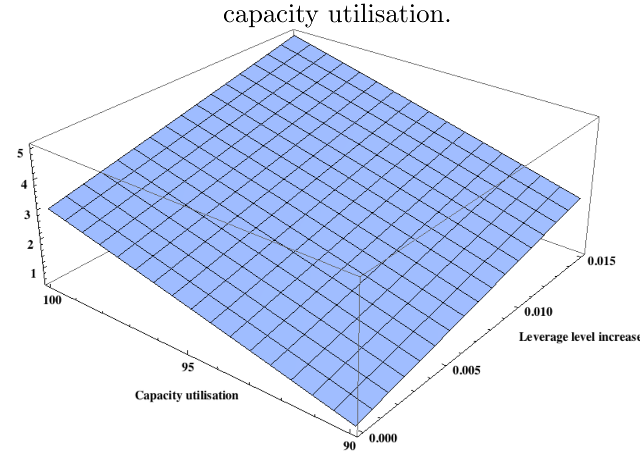


Figure 3: When investments are not important, ρ needs to be very high, in order to meet the desired level of leverage. The higher the amount of investments (the higher the current level of capacity utilisation), the lower the share of borrowed funds for a given increase in desired leverage.

2.2 Demand

We assume that produced goods are differentiated. Demand is distributed according to a linear expenditure system

$$y_i = \beta_i \frac{(1-s)Y}{p_i} \tag{18}$$

where y_i, p_i and β_i are the real demand, price and preference for good i, s is the saving rate of households and Y is income. Assuming that preferences are constant, the differentiation of (18) is given by

$$\Delta y_i = \frac{\beta_i}{p_i} \left((1-s)\Delta Y - Y \Delta s - \frac{(1-s)Y}{p_i} \Delta p_i \right) \tag{19}$$

Dividing (19) by (18) gives us the equation for demand growth:

$$\hat{y}_i = \hat{Y} - \hat{s}\frac{s}{1-s} - \hat{p}_i \tag{20}$$

Demand growth can then be determined once the growth of income, propensity to save and prices are known. We assume that s varies according to news[7] (21). Furthermore, income is composed of wage bills from firms and the rest of world. Increases in the wage bill from rest of world is approximated by a variation in aggregated capital, ($\hat{k}$), as increased investment implies higher employment in that sector. An increase in consumers' incomes might come from increases in the aggregate wage bill of the firms. This growth might be due either to an increase in the nominal wage, or to an increase in employment (due to an increase in output), or both (22).

$$\hat{s} = -\gamma news \tag{21}$$

$$\hat{Y} = \hat{k} + x\hat{\omega} + \omega\hat{x} \tag{22}$$

This leads to the following demand growth function

$$\hat{y}_i = \nu_i(\hat{k} + x\hat{\omega} + \omega\hat{x} + \gamma news\frac{s}{1-s} - \hat{p}_i) \tag{23}$$

$$\nu_i = 1 - \frac{y_{i,-1} - x_{i,-1}}{y_{i,-1}} \text{ if } y_{i,-1} > x_{i,-1} \tag{24}$$

where ν_i is a parameter which captures the fact that when a firm operates at full capacity, it constrains demand by an amount equal to $y_i - x_i$. The firm thus has a lower demand growth as consumers are turned away.

Demand growth in each firm is affected both by the firm's situation (i.e. individual price inflation, constrained demand, unit cost inflation) and the aggregate situation (aggregate capital growth, aggregate output growth, news).

[7] We assume that news affect the animal spirits of consumers: bad (resp. good) news increase (resp. decrease) propensity to save.

2.3 Banks

We assume, as in Delli-Gatti et al. (2010), that banks charge an interest rate which is a function of the leverage level λ of the firm at hand, the reserve ratio κ of the bank. Due to asymmetric information, banks charge a risk premium based on the risk of default of firms. The higher the leverage level of firms, the higher the risk of default. Furthermore, banks have an "agressive" market policy: they decrease their interest rate in order to attract customers. This reduction of interest rate is based on their reserve ratio, the higher it is, the lower the interest rate. In our model, the reserve ratio of a bank is equal to the inverse of its leverage level. Each bank has a targeted reserve ratio κ^T and a parameter σ which reflects the desire for high or low profit rate:

$$i_b = \begin{cases} \sigma\kappa^{-\sigma} + \sigma\lambda^{\sigma} + \sigma(\kappa^T - \kappa)^{\sigma} & \text{if } \kappa < \kappa^T \\ \sigma\kappa^{-\sigma} + \sigma\lambda^{\sigma} & \text{if } \kappa \geq \kappa^T \end{cases} \tag{25}$$

When the actual reserve ratio is below its targeted level, we assume that banks increase the interest rate they charge by $\sigma(\kappa^T - \kappa)^{\sigma}$ in order to increase their profits and thus increase their reserves.

Profits are then determined as the sum of interest received minus the non performing loans. Profits are partly distributed as dividends for shareholders and partly kept as retained earning to increase reserves. If the reserves of a bank attain a negative value, the bank goes bankrupt. A new bank is then created. Each bank is characterized by two parameters; σ reflecting its desired profit rate and ψ showing how the banks responds to news by updating its reserve ratio.

$$\kappa^T = (1-\eta)\kappa + \eta\kappa^T_{-1}(1 - \psi\, news) \tag{26}$$

where $0.08 \leq \kappa^T$ to reflect Basel III rules.

At first, banks are randomly assigned to firm but then firms try to minimize they interest rate they are exposed to in a particular period, and banks try to optimize their customers and avoid non performing loans in order to grow. When a firm needs to finance part of its investment, it applies to all banks with a preference for low interest banks. Banks then choose to accept or reject the loans according to their targeted reserve ratio and to their own preferences over customers (those having a lower leverage ratio being preferred over those with a higher one). If a firm does not find a bank willing to finance its investments, it can only invest using its retained earnings.

3 Simulations

3.1 Baseline

The baseline scenario is composed of a population of a thousand firms and ten banks in each period and runs for 500 periods. Each firm is randomnly allocated an initial stock of capital, a leverage level and a set of parameters[8].

[8] Details of the parameters can be found in appendix A.1, A.2 and A.3.

The probability of bad news in each period is equal to 30% in the baseline scenario.

Figure 5 presents the results of the baseline scenario and of the first two scenarios. The solid lines are the baseline scenario results, dotted and dashed lines are respectively scenario 1 and 2. The two lower figures represents the difference in firms' bankruptcies from scenario 1 or 2 with respect to the baseline scenario. Positive (or negative) numbers indicate more (or less) bankruptcies in scenario 1 or 2 with respect to the baseline scenario.

We observe a peak of leverage level in the first hundred periods indicating that firms increase massively their productive capacity in order to meet demand (initial capacity utilisation is around 75%). After a few bankruptcies (about 500 in the first 100 periods), firms settle to a less risky leverage level. The leverage level nonetheless shifts according to news fluctuations.

Capital stock growth also follows news cycle as shown by figure 4. During span of good news, capital is growing while during bad news period, capital grows at a lower pace or even decreases. Capital growth does not follow perfectly the news cycle as it also depends on capacity utilisation. This explains the variation in growth during good news periods.

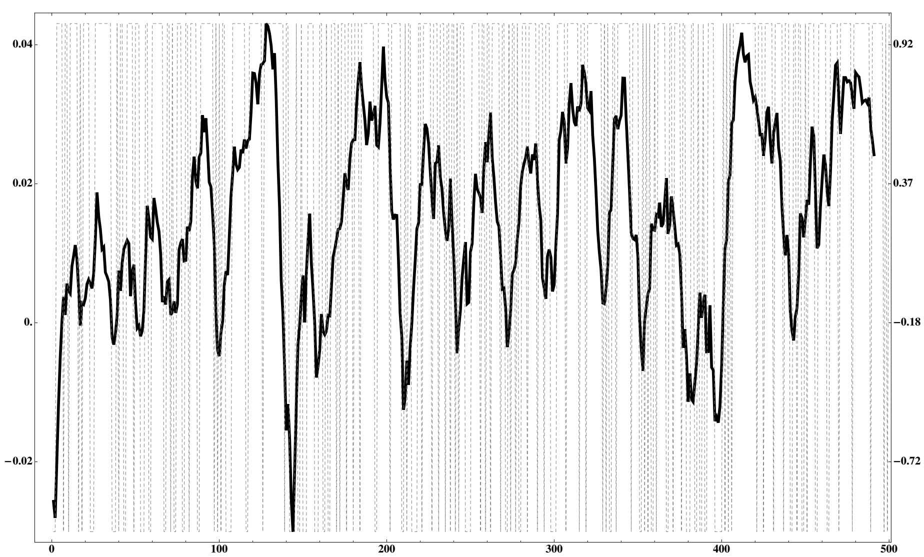


Figure 4: Capital growth (thick line, left scale) follows the news cycle (dashed grey line, right scale). During spans of good news, capital grows while when bad news are observed, capital growth either decreases or goes negative.

3.2 Scenario 1: Changing dividend policies in firms

The first scenario simulates a change in dividend policies in firms. Shareholders accepted discount is decreased by 10 percent ($\epsilon' = 0.9\epsilon$) for each firm. Prices and news (the two exogenous variables) remain as in the baseline scenario. Firms and banks start with same capital stock, leverage ratio and parameters than in the baseline scenario.

Higher dividend rate implies lower retained earnings to finance investments. Lower retained earnings has two impacts. Either it reduces the quantity of investments that can be made for a given level of leverage or it increases the quantity of loans to be made in order to invest. Both of these cases increase leverage[9]. This increase implies a Firms more difficulties to stay alive, and this can be observed from the increase in bankruptcies showed in the third panel of figure 5.

Furthermore, increased leverage levels imply higher interest rates, and thus even lower retained earnings due to an increase in the cost of servicing the debt, which futher hinders capital growth. This accelerates the difference of capital stock during time.

It is interesting to note is that total dividends distributed during the entire scenario 1 is equal to 94% of total dividends distributed during the baseline scenario. Higher short-run dividends yields lower aggregate dividends. In order to maximise dividends in the long run, firms have to maximise growth rather than trying to ask as much as possible for dividends in each period.

3.3 Scenario 2: Changing interest rates by banks

The second scenario simulates a change on the interest rates charged by banks. The desire for high interest rate is decreased by 10 percent ($\sigma' = 0.9\sigma$). As for scenario 1, prices change and news (the two exogenous variables) are identical than in the baseline scenario. Firms and banks are initially the same than in the baseline scenario.

From figure 5, we observe that a lower interest rate impacts the leverage level strongly, as well as the capital stocks and bankruptcies of firms. In the short run, firms' increased retained earnings due to lower debt costs allow them a lower leverage level and implies less bankruptcies. However, the peak of the leverage level occurs later than in the baseline scenario and is longer implying that more firms to go bankrupt. This hampers strongly capital growth.

Not surprisingly, total interest paid to bank during scenario 2 is lower than those paid in baseline scenario. However the magnitude is of the difference is large (73% difference), not only due to lower interest rate but also to lower aggregate growth.

[9]Lower investments imply a lower stock of capital and thus a smaller denominator. Higher debt impact the numerator part of leverage

3.4 Scenario 3: All news is bad news

The third scenario simulates a change in the frequencies of bad news. 10 percent of the good news of baseline scenario are changed into bad news. Prices are also changed as they depend on news. Firms and banks are initially the same than in the baseline scenario.

Figure 6 shows the result from scenario 3 (dashed) compared with baseline scenario (solid). We observe that more frequent bad news implies a higher leverage level both in the short run and in the long run. The peak of leverage is observed as in the baseline scenario but is wider. This larger peak is due to the fact that firms have more trouble paying back their loans. Indeed, more bad news implies lower retained earnings. These retained earnings are used either to invest or to repay loans when capacity utilisation is on target.

Furthermore, firms need more time to settle to an acceptable level of leverage and that level remains higher than in the baseline scenario. This long run effect is also explained by lower retained earnings and lower demand growth. What is more is that lower retained has a strong impact both on capital growth (and thus capital stock) and on firms' bankruptcies. Growth is also impacted by lower targeted leverage level (due to bad news) influencing firms in their investment decision.

4 Conclusion

This paper has shown that a simple leverage cycle in an otherwise deterministic model is enough to generate business cycle-like fluctuations in an economy with many connected firms and banks. The model studies the interactions of banks and firms within a leverage cycle and studies how capacity utilisation and capital investment interact with funding costs, leverage by banks and firms, and liquidity.

Our paper replicates the findings of Schularick and Taylor (2009), Fagiolo and Luzzi (2006), and Audretsch and Elston (2002) on firm and bank birth and deaths, levels of investment in the capital stock, and the importance of reserve ratios in calming leverage cycles.

There are several limitations to the present work. The model is not stock flow consistent. There is no central bank. There are too many parameters, these do need to be slimmed down to create a tighter control. The possibility of 'too big to fail' in bank size and their pricing behaviors should be modeled. Finally, the set of assumptions upon which the model sits is drawn from many schools–neoclassical, post-Keynesian, and more generally, heterodox. This is done deliberately to model the phenomena under study, but a lack of a unified theoretical framework underpinning the simulation is of course a limitation.

Further work includes the possibility for firm to engage in fire sales as refinements to the theory as well as a more elaborated pricing theory. Finally, banks' distribution of profits between retained earnings and dividends could be more explicitly modeled.

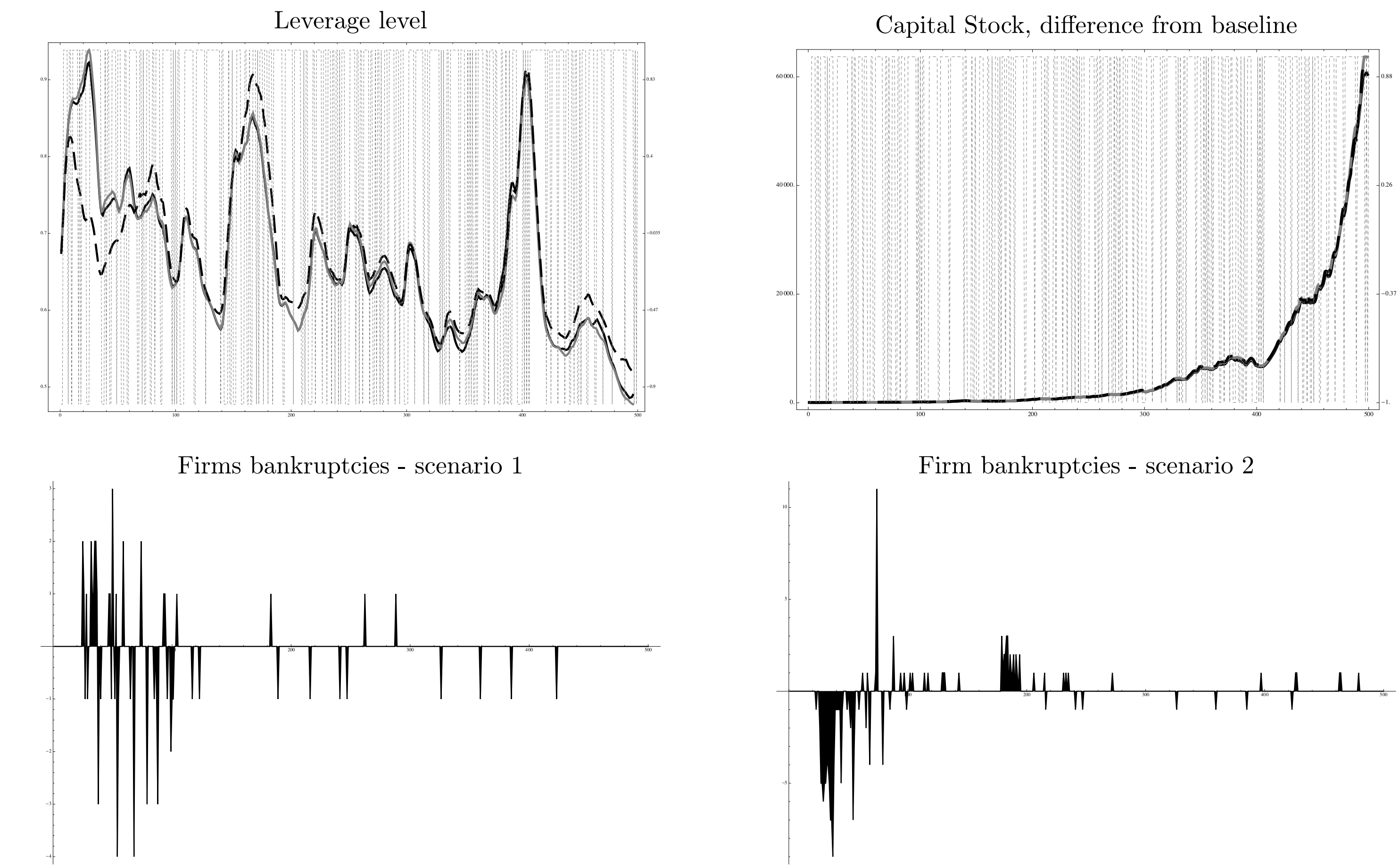


Figure 5: Scenario 1 (gray) has little effect on leverage level and a slight positive on capital stock and firms' bankruptcies while Scenario 2 (dashed) has a stronger effect on leverage level, capital stock and firm's bankruptcy.

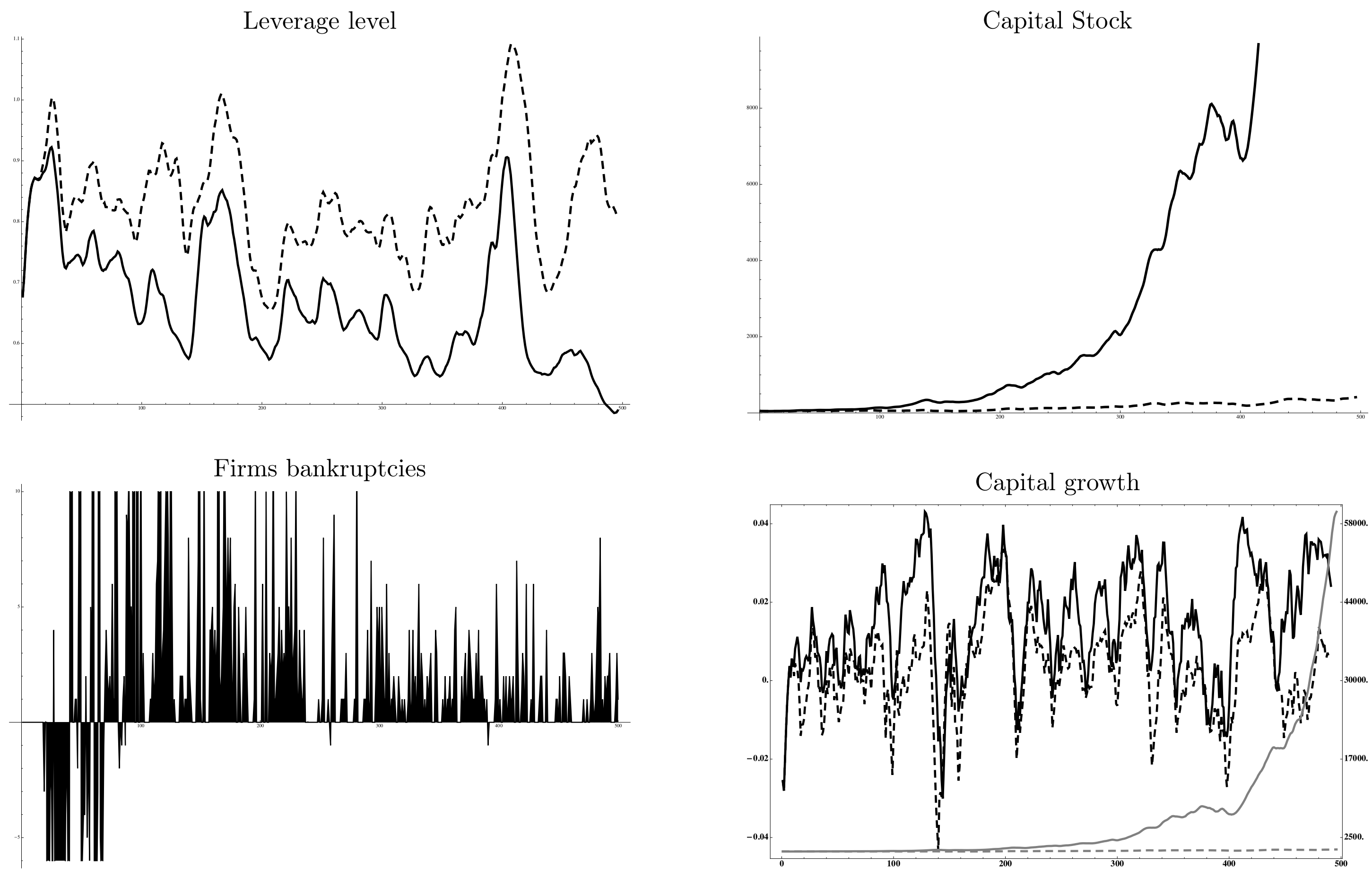


Figure 6: Scenario 3 (dashed) has strong positive effect on leverage level and a strong negative on capital stock and firms bankruptcies. Furthermore, capital growth is always lower in scenario 3 than in the baseline scenario.

References

Tobias Adrian and Hyun Song Shin. Liquidity and leverage. *Journal of Financial Intermediation*, 19(3):418 – 437, 2010.

Varouj A. Aivazian, Ying Ge, and Jiaping Qiu. The impact of leverage on firm investment: Canadian evidence. *Journal of Corporate Finance*, 11(1-2):277 – 291, 2005.

David B. Audretsch and Julie Ann Elston. Does firm size matter? evidence on the impact of liquidity constraints on firm investment behavior in germany. *International Journal of Industrial Organization*, 20(1):1–17, January 2002.

Walter Bagehot. *Lombard Street: A Description of the Money Market*. Cosimo Classics, 2006.

Fabrizio Coricelli, Nigel Driffield, Sarmistha Pal, and Isabelle Roland. Excess leverage and productivity growth in emerging economies: Is there a threshold effect? Working Paper 4834, Institute for the Study of Labor, 2010.

D. Delli-Gatti, M. Gallegati, G. Greenwald, A. Russo, and J.E. Stiglitz. The financial accelerator in an evolving credit network. *Journal of Economic Dynamics & Control*, 34(3):1627–1650, 2010.

David J. Denis and Valeriy Sibilkov. Financial constraints, investment, and the value of cash holdings. *Review of Financial Studies*, 23(1):247–269, 2010.

Michael B. Devereux and James Yetman. Leverage constraints and the international transmission of shocks. *Journal of Money, Credit and Banking*, 42: 71–105, 2010.

Alfred S. Eichner. *The Megacorp and Oligopoly: Micro Foundations of Macro Dynamics*. Cambridge University Press, 1976.

Giorgio Fagiolo and Alessandra Luzzi. Do liquidity constraints matter in explaining firm size and growth? some evidence from the italian manufacturing industry. *Industrial and Corporate Change*, 15(1):1–39, 2006.

A. Fostel and J. Geanakoplos. Leverage cycles and the anxious economy. *American Economic Review*, 98(4):1211–1244, 2008.

R. M. Goodwin. The nonlinear accelerator and the persistence of business cycles. *Econometrica*, 19(1):1–17, January 1951.

Sebnem Kalemli-Ozcan, Bent Sorensen, and Sevcan Yesiltas. Leverage across firms, banks, and countries. Working Paper 17354, National Bureau of Economic Research, 2011.

N. Kiyotaki and J. Moore. Credit cycles. *Journal of Political Economy*, 105(2): 211–248, 1997.

Sylos Labini. La théorie des prix en régime d'oligopole et la théorie du développement. *Revue d'Economie Politique*, 81(2):244–272, 1971.

Marc Lavoie. *Foundations of Post-Keynesian Economics*. Edward Elgar, Cheltenham, 1992.

Hyman P. Minsky. *Stabilising an Unstable Economy*. McGraw-Hill, New York, 1986.

Blandina Oliveira and Adelino Fortunato. Firm growth and liquidity constraints: A dynamic analysis. *Small Business Economics*, 27(2/3):139–156, October 2006.

Luigi L. Pasinetti. *Structural change and economic growth: A theoretical essay on the dynamics of the wealth of nations*. Cambridge University Press., 1981.

Joan Robinson. A further note. *The Review of Economic Studies*, 36(2):260–262, 1969.

Moritz Schularick and Alan M. Taylor. Credit booms gone bust: Monetary policy, leverage cycles and financial crises, 1870–2008. Working Paper 15512, National Bureau of Economic Research, November 2009.

A. Michael Spence. Entry, capacity, investment and oligopolistic pricing. *The RAND Journal of Economics*, 8(2):534–544, 1977.

Josef Steindl. *Maturity and stagnation in American capitalism*. Blackwell, 1952.

Toni M. Whited. Debt, liquidity constraints, and corporate investment: Evidence from panel data. *The Journal of Finance*, 47(4):1425–1460, 1992.

A Appendix

A.1 Firms-related parameters for baseline scenario

Parameter	description	value
δ	Capital depreciation rate	$\sim Uniform(0.05, 0.1)$
ϵ	Percentage discount of dividend rate	$\sim Uniform(0.1, 0.3)$
ω	labour unit costs	$\sim Normal(1.07, 0.05)$
μ	Capital productivity	$\sim Normal(0.23, 0.05)$
ξ	Discount rate for used capital sales	$\sim Uniform(0.1, 0.3)$
ϕ	Response to news nature	$\sim Weibull(1.2, 0.1)$
η	Weight parameter for targeted leverage	0.5
$nFirms$	Number of firms	1000
k_0	Initial stock	$\sim Pareto(50, 1.1)$
λ_0	Initial leverage level	$\sim Uniform(0.6, 0.7)$

A.2 Demand-related parameters for baseline scenario

Parameter	description	value
γ_1	Weight parameter for demand growth	0.5
γ_2	Weight parameter for demand growth	0.02

A.3 Banks-related parameters for baseline scenario

Symbol	description	value
κ	Reserve ratio	$(0.08; 0.18)$
σ	Interest rate parameter	$\sim Uniform(0.005, 0.025)$
ϕ	Response to news nature	$\sim Weibull(1.2, 0.1)$
η	Weight parameter for target reserve ratio	0.5
$nBanks$	Number of banks	10
Res_0	Initial reserve	$\sim Pareto(100, 1.1)$