FIRMS' FINANCE IN AN EXPERIMENTALLY MICROFOUNDED AGENT-BASED MACROECONOMIC MODEL

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ABSTRACT

The purpose of this work is twofold. First, we highlight the importance of the finance motive in Keynes and how it has affected the work of Augusto Graziani and Hyman Minsky. Second, we build an agent-based model where artificial agents replicate heterogeneous financial behavior induced from discovery driven economic experiments. The aggregate and disaggregate outcomes of the model are then investigated to identify the role of entrepreneurs' financial decisions in facing aggregate negative events or in generating endogenous business cycles.

1. INTRODUCTION

The onset of the ongoing Great Recession has pushed a number of economists on rethinking fundamentals of Keynesian thought. Although different interpretations of Keynes's General Theory (1936) have characterized the evolution of the economic analysis, it is interesting to observe how Keynes's ideas endure and open wide debates to the present day. One of the most common arguments deals with the widespread role of finance in our contemporary economy. A topic highlighted by Keynes during the Great Depression which proves to be more intriguing in the light of the current Great Recession.

In particular, we focus our analysis on the Keynesian argument regarding a 'monetary theory of production' which is at the core of our research. Our paper is motivated by highlighting the role that finance and uncertainty play in the background of Keynes's reasoning. In that regard, we move in the tradition of heterodox Keynesians Augusto

Graziani and Hyman Minsky whose investigations are clearly linked to a vision of capitalist economy where the finance motive is at the heart of their analysis.

Accounting for the traditional Keynesian perspective, it seems reasonable that a general macroeconomic theory has to encompass the reality of booms and slumps and it should turn the attention to the causes which led to periodical upheavals of the system.

According to Graziani's and Minsky's approaches, great recessions or depressions are endogenously generated by contemporary economic systems since they depend on individuals' behaviour and financial relationships which compose the system itself. Unfortunately, both the approaches have been overlooked by most of the economics profession because they are based on a task implying behavioural foundations and complex dynamics which cannot be handled by traditional quantitative models.

To cope with this task, we suggest a different methodological perspective grounded in the synergy between Experimental and Computational Economics as a new economic modelling tool which will prove to be valuable for the improvement of economic analysis.

After recalling the concept of Keynesian finance motive in Section 2, we show in Section 3 our experimental design focused, in this work, exclusively on firms' financial behaviour. Indeed, the design is precisely set up to highlight the role that finance and uncertainty as well as time irreversibility play at the root of entrepreneurs' behaviour. We perform some laboratory experimental sessions where subjects are asked to manage a virtual firm in an uncertain and risky environment. Production (assets) and liabilities (debt and equity) are the control variables with which subjects struggle against fluctuations of demand. In Section 4, we introduce how and why such experimental design could be fruitful to provide an alternative way to build macroeconomic models based on inductive microfoundations. Section 5 provides an evidence of such endeavour. We identify financial behavioural rules for selected experimental subjects by data mining techniques and, in Section 6, we build an agent-based model where artificial agents adopt the identified humans' behaviour. Section 7 concludes and gives directions for future research.

2. THE FINANCE MOTIVE

The Great Depression of 1929 is generally acknowledged in the literature as the event that characterized a deep rupture in the economic theory (Lekachman, 1959; Galbraith, 1987). In the boundaries of the philosophy of science, we think this period as the embryonic state that led to the ‘scientific revolution’ (Kuhn, 1962) stated by Keynes’s General Theory. The General Theory of Employment, Interest and Money (Keynes, 1936) has undoubtedly determined a shift in the way economists would have thought in relation to the evolution of a capitalist economy.

Keynes specified that the main problem concerning our understanding of crisis must be found in the lack of what he defined a ‘Monetary Theory of Production’:

> an Economy, which uses money but uses it merely as a neutral link between transaction in real things and real assets and does not allow it to enter into motives or decisions, might be called—for want of a better name—a Real Exchange Economy. The theory which I desiderate would deal, in contradistinction to this, with an Economy in which Money plays a part of its own and affects motives and decisions and is, in short, one of the operative factors in the situation, so that the course of events cannot be predicted, either in the long period or in the short, without a knowledge of the behaviour of money between the first state and the last. And it is this which we ought to mean when we speak of a Monetary Economy (Keynes, 1973, p. 408).

In that regard, Keynes developed a theory of the capitalist process that try to explain how financial, income and employment instability are the result of human behaviour in dealing with fundamental uncertainty where all events take place in an irreversible historical time (Kregel, 1976; Sawyer, 1988; Davidson, 2010). Booms and depressions are not treated as anomalies but as peculiar phenomena within an economy in which money is not neutral and strongly affects humans’ decisions and the behaviour of markets.

Keynes summarized the difference between the General Theory and the ‘tradition’ in two key concepts: uncertainty and effective demand. The concept of uncertainty and the relevant process of decision-making were longstanding interests of Keynes. With regard to the uncertainty, Keynes used a dialectics widely reported in the literature on the difference between fundamental uncertainty and risk (Keynes, 1921).

The uncertainty reveals the nature of money as a

> subtle device for linking the present to the future (Keynes, 1936, p. 294).

Keynes explains the use of money as a store of wealth to fight against fundamental uncertainty: ‘Because, partly on reasonable and partly on instinctive grounds, our desire to hold money as a store of wealth is a barometer of the degree of our distrust of our own calculations and conventions concerning the future. [. . .] The possession of money lulls our disquietude; and the premium which was require to make us part with money is the measure of the degree of our disquietude'. (Keynes, 1937b, p. 216).

Concerning the effective demand, Keynes specified that investments are the 'causa causans' of its fluctuations because they are prone to sudden and wide changes since they depend on two set of judgements about the future: the propensity to hoard and the subjective evaluation about prospective yields of capital assets.

In this respect, Minsky observed how Keynes's discussion on finance and portfolio decisions was quite vague (Minsky, 1975, 1982, 1986). In an important passage of the General Theory—chapter 17—Keynes decided to hide the price of capital assets and the terms of money loans from the liquidity preference function moving his analysis in terms of interest rates.[1]

According to Minsky, at a crucial juncture of the analysis, Keynes has turned from liabilities structure and cyclical perspective to stagnation by the assumption of a negatively sloped marginal efficiency-of-capital. The novelty of Minsky's insights is exactly to place the balance sheet at the background of cost and revenue curves (Minsky, 2004). For physical capital, Minsky shows as its return (q) is the cash flow that the asset will yield from operations. That is the quasi-rent, the Keynes's q. Discussing about carrying costs, the Keynes's c, Minsky believes that most economists underestimated the relevance of the Keynesian argument. In Minsky's view, the Keynes's c is mainly the cash flow set up by the liability structure. Adopting this perspective, Minsky introduces his theory of the firm in relation to business cycle theory, that was later to be at the heart of his analysis of financial fragility (Toporowski, 2008).

Each economic unit inevitably acts in a fundamental uncertain evolutionary complex open system in which a portfolio choice implies an irreversible decision since it depends on payment obligations assumed in the past as well as on the uncertainty that affects future cash flows: 'The fundamental speculative decision of a capitalist economy centers around how much, of the anticipated cash flow from normal operations, a firm, household, or financial institution pledges for the payment of interest and principal on

[1] On this point, Minsky argues that Keynes's (1937b) reply to a review on his work written by Viner (1936) is enlightening. Money and debts determine the interest rate. Long-term expectations determine the prospective yield of capital assets and current investments. This prospective yield and the interest rate determine the price of capital assets. Investments will be made until the supply price of investment is equal to the capitalized value of the yield. The vacuum of the General Theory is that it does not really explain how the investment is financed. Minsky's endeavour is to bring investment finance back into Keynes's analysis. He believed that Keynes developed an investment theory of fluctuations in real demand and a financial theory of fluctuations in real investment.

liabilities' (Minsky, 1975 pp. 86–87). Assets and liabilities involve cash-flows and payment commitments in a delayed future. Economic agents fulfil commitments on liabilities using the cash-flows that will be realized in a delayed term. Agents must decide the proper mix of assets and liabilities and how to manage their balance sheet structure according to their 'enjoyment' of risk. During expansions, the more leveraged firms are, the more they earn (Lavoie, 1986). In this framework, money becomes essential since it acts as a safety margin against bankruptcy (survival constraints) or as insurance against a malfunctioning of the financial markets. Cash-flows realized as well as optimistic expectations on future prospects will validate the rollover of debt.

In his critiques to Ohlin (1937) and Robertson (1937), Keynes specified as 'finance' is essentially a revolving fund which employs no savings and can be seen as a bookkeeping transaction: the credit required in the interval between planning and execution. In fact, Keynes observes: 'The ex-ante saver has no cash, but it is cash which the ex-ante investor requires' (Keynes, 1937c, pp. 665–666). Therefore, the supply of liquidity does not depend on the saving decisions but on the bankers' decisions and the credit market is mainly based on the relationship between banks and firms (Schumpeter, 1954). This vision of the economy is also clearly advocated by Minsky and Graziani.

The key difference between Minsky and Graziani is that, while the former integrates the finance motive as the demand for money 'reflecting the precautionary demand for cash balances because future payment commitments increase owing to the increase in investment activity' (Minsky, 1975, p.75), the latter identifies the finance motive as the initial finance which is the first prerequisite for the formation of income (Graziani, 1984, 1987).

Minsky argues that some financial instruments, namely near money—saving deposits and saving bonds—satisfy such precautionary demand for money. The introduction of near money is important because it focuses the analysis on the institutions whose liabilities are generally accepted as near money. Then, it is possible to highlight the endogenous determination of the effective quantity of money and the interest rate 'as being determined by the interplay of the terms on which the public desires to become more or less liquid (borrow) and those on which the banking system is ready to become more or less illiquid (lend)' (Keynes, 1937c, p. 666).

Conversely, Graziani argues that economists like Davidson (1965), Chick (1983) and Minsky (1975) are wrong to consider the finance motive strictly connected or included to the transactions motive. For those authors, the transactions motive explains the demand for money as a function of current income, while the finance motive explains an increase in the demand for money as a function of an increase in investment activity. Graziani strongly rejected this position as clearly emphasized in this sentence: ‘a constant level of output requires a constant amount of finance, while a growing level of output requires an increasing amount of finance. But in no way a stationary level of output can be considered to be self-financing. […] In fact, it cannot be claimed that the revolving fund be automatically renewed each time’. The very existence of a revolving fund requires a discretionary decision to be taken by banks again and again’ (Graziani, 1987, p. 35).

Focusing on Keynes's monetary vision from that of the Treatise on Money (Keynes, 1930), through the General Theory (Keynes, 1936) and until the articles between 1937 and 1939 (Keynes, 1937a,c, 1939), Graziani tries to build a rigorous approach. He argues that finance refers both to provide support for current production through an adequate supply of liquidity, and for future investment decisions through an adequate supply of saving.

In a nutshell, there are two separate moments that affect the production process and have profound implications for the economic analysis: (i) an initial finance which has the aim of providing a priori liquidity for the financing of production (short-term debt). An initial finance involves a relationship between banks and firms; (ii) a final finance which is based on a posteriori supply of saving to increase the production, i.e. investments (long-term funding). A final finance involves a relationship between firms and savers by issuing securities on the financial market (Fontana and Realfonzo, 2005).

Those premises led Graziani to move away from the neoclassical interpretation of Keynes's General Theory, refusing both the schema of equilibrium analysis and the exogenous nature of money in favour of a sequential schema that originates from finance to investment, income and saving (or consumption) in which money is created endogenously by the banking sector.

However, in our opinion, Minsky's and Graziani's different viewpoints can be seen as two sides of the same coin.[2] This difference mainly arises from the different angle of vision chosen by the authors to investigate the same core ideas. While Minsky focuses principally on the natural evolution of the economic system from financial robustness to financial fragility[3]

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[2] It is our belief that such coin may be considered, using an euphemism, a monetary vision of the economy in which the finance motive is at the heart of the analysis.

[3] In his well-known Financial Instability Hypothesis (FIH), Minsky emphasizes that the equilibrium-seeking rules characterizing Walrasian economies could fail to work. Centrifugal forces may originate and overcome centripetal ones in real life economies. Therefore, it is important to identify the dynamic laws governing this escape from equilibrium. The focus of FIH is on capitalistic economies that move in real calendar time, where the past, the present and the future are linked primarily by financial relationships. In particular, periods of

(Minsky, 1992), Graziani is mainly interested to elucidate the evolution of the capitalistic process from its initial to its final financial condition (Graziani, 2003; Cesaratto, 2016).

Nevertheless, if we look closely at the core of their analysis, i.e. the search for a dynamic model able to explain the endogenous generation of capitalistic process rather than the acceptance of a static Walrasian equilibrium approach, we are able to highlight several similarities in the ideas of the two authors: (i) the focus on complex dynamics rather than on simultaneous equilibrium of production and exchange; (ii) the refusal of traditional consumption/investment approach. The focus should be on firms and investment and its financing rather than on the identity between investment and saving; (iii) the opinion that money is created endogenously by the banking sector and business cycles are endogenously generated; (iv) the refusal of an atomistic representative agent; (v) the focus on a dialectical view of time rather than on a deterministic one; (vi) the priority given to cyclical patterns or circuitist sequences rather than to equilibrium analysis; (vii) the refusal of the neutrality of money; and (viii) the special attention to stock and flows analysis.

In our opinion, the approaches of the two authors under investigation are complementary. As stated by Fontana (2009), although the analysis of the monetary circuit is enlightening to elucidate the nature and origin of money, it lacks a rigorous analysis of the process of decision-making under uncertainty, what is well known in literature to represent the core of Minsky's analysis (see recent works by Dow, 2011; Keen, 2013).

Speaking of which, in the next sections, we show our experimentally micro-founded agent-based macroeconomic model which tries to integrate Graziani's and Minsky's approaches.[4] Essentially, we have built a Graphical User Interface with which subjects have to manage a virtual firm making production and financial decisions under risk and uncertainty. Accordingly, we use the experimental method following an inductive approach to explore

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prolonged prosperity foster optimistic expectations about the future. This phenomenon makes more leveraged financial positions acceptable to economic actors and excites stock market activity. In other words, agents' financial behaviours cause the economy to become progressively unstable and fragile.

[4] Simulations are also used in the stock-flow consistent approach (Goodley and Lavoie, 2007) which is also suitable to formalize the monetary circuit. It usually consists in building aggregative dynamic macroeconomic models where financial aspects, especially banking credit, has a crucial role. Recent works include Le Heron and Mouakil (2008); Caiani *et al.* (2014); Sawyer and Passarella (2015). The combination of agent-based models with stock-flow consistency is a topic of research which is currently under development (Caiani *et al.*, 2016).

experimental subjects' behaviours over the business cycle and to identify their behavioural rules rather than to test if they behave as they should according to a particular model. Although the experimentation in economics often takes its importance from its relation to theory, we point out that it may have a life of its own, independent of theory (see among others, Smith, 2002; Selten, 2003; Sugden, 2005; Akerlof, 2007; Schmidt, 2009). Then, we have endowed artificial agents with the identified behavioural rules. Finally, we have built an agent-based model in order to explore the phenomenon that emerges through the interactions of artificial agents at a macroscopic level.

3. THE EXPERIMENTAL DESIGN

In this section, we describe the theoretical background which underlies our experiment and the microeconomic model built in order to shape the experimental framework and its functioning.

3.1 The microeconomic framework

Our experimental design relies, in particular, on two specific features: the process of decision making under uncertainty and the analysis of the firm which in turn takes into account the balance sheet structure (Minsky, 2004).

Essentially, Minsky highlighted that the balance sheet structure of firms affects their costs. In addition to the conventional production costs, each business enterprise has to take into account financing costs which in turn depend on the 'mix' of liabilities which finance the assets. The mix basically reflects the entrepreneur's psychological attitude toward risk taking.

Accordingly, we design a framework where assets and liabilities involve cash-flows and payment commitments in a delayed future. Cash-flows depend on sales of the produced items which in turn depend on the level of inputs employed in the production process. In the environment, we set up, the value of production inputs is equal to the sum of the firm's balance sheet assets entries. Firms fulfil commitments on liabilities (interest and dividends payments) using the cash-flow that will be realized in a delayed term. Each firm must decide the 'proper mix' of assets and liabilities and how to manage their own capital structure according to their subjective perception of the demand volatility for the produced item.

The scenario submitted to the experimental subjects is described as follows. Subjects are asked to manage a virtual operating firm. Accounting for some preliminary information (a forecast on the future level of demand and past realizations of the same variable which are continuously updated), subjects are asked to set the level of their physical capital which in turn determines the optimal scale of production, i.e. the level of production which minimizes production costs. Once this choice has been made the software reveals the level of demand. The maximum profit is realized if a subject sets the optimal production scale equal to the received demand. Profit is a decreasing function of the gap between the chosen level of production scale and the level of demand realized. For high levels of the gap, production costs become progressively higher than revenues and the firm suffers an increasing loss.[5]

Beyond this production revenue/cost structure, financial burdens have to be accounted for. Subjects had to take decisions in a simplified context where there are two types of liabilities: debt and equity. The economic result of the firm activity is indeed obtained by subtracting production and financial costs from the sales influx; it can be either positive or negative. Concerning financial costs, following Myers and Majluf (1984) we set the cost of the equity base higher than the interest on the debt.

More formally, each firm has a simple balance sheet in which two liabilities, namely debt ($B_{j,t}$) and equity ($A_{j,t}$) finance the only asset that consists in the production capital endowment ($K_{j,t}$). Economic features of the firm are in line with the microeconomic perfect competition according to which an optimal scale of production ($\bar{y}_{j,t}$) can be identified. In our framework, the existence of an optimal scale of production is ensured by considering adjustment costs of capital (see Koeva, 2009). The firm realizes an economic result (profit or loss) given by:

$$\pi_{j,t} = y_{j,t} - c^{p}_{j,t} - c^{ad}_{j,t} - c^{f}_{j,t} \tag{1}$$

where $y_{j,t}$ is the production carried out by the entrepreneur j at time t and $c^{p}_{j,t}$, $c^{ad}_{j,t}$ and $c^{f}_{j,t}$ denote production, adjustment and financing costs, respectively. These costs are modelled as follows:

$$c^{p}_{j,t} = wy \tag{2}$$

[5] At this stage, we use rising marginal costs of production and constant financial costs in order to have control of our experimental environment. We intend to adopt alternative solutions in future studies. The L-shaped average cost curve (Blinder, 1998; Lee, 1998) and Kalecki's principle of increasing risk (Kalecky, 1937) are two favourite candidates for our future analysis.

$$c^{ad}_{j,t} = \beta y_{j,t} \left(\frac{y_{j,t} - \bar{y}_{j,t}}{\bar{y}_{j,t}} \right)^2 \quad (3)$$

$$c^{f}_{j,t} = r_B B_{j,t} + r_A A_{j,t} \quad (4)$$

where w is the variable cost for each unit of production capacity, β is a parameter which regulates the significance of adjustment costs, r_B the interest rate charged by the bank and r_A the reward for shareholders. The parameters are set as follow: $r_B = 0.01$, $r_A = 0.05$, $w = 0.9$, $\beta = 9$.

In order to ease the experimental subject's task of monitoring the financial aspects, we use a very simple production function $y_{j,t} = K_{j,t}$. By doing so, according to the balance sheet identity $K_{j,t} = B_{j,t} + A_{j,t}$, a change in the production capacity implies changes in the liabilities structure.

In our simplified framework, the balance sheet items are modified in two occasions: when the optimal scale of production is set (i.e. when the entrepreneur modifies $K_{j,t}$ in order to adapt the production to the demand s/he will receive) and when the economic result is computed. The equity base does not change when $K_{j,t}$ is updated so that at this stage $\Delta K_{j,t} = \Delta B_{j,t}$. On the contrary, we assume $K_{j,t}$ to be out of the entrepreneur control when the economic result is realized. If a profit is realized, the experimental subject is asked to decide how much of it s/he will use to reduce debt. In this case, we have $0 < \Delta A_{j,t} = -\Delta B_{j,t} \leq \pi_{j,t}$. If a loss is suffered the experimental subject has no choice: the loss wears away both assets and equity base: $\Delta A_{j,t} = \Delta K_{j,t} = \pi_{j,t} < 0$.

We think it is useful to describe how the above presented framework relates to the standard textbook microeconomic framework. We start from considering that in our economic context the demand can significantly change over time. To account for this, we make the uniperiodal microeconomic scheme 'scale free'. In fact, the model presented above can be formulated by using exclusively intensive variables. As specified below, the goal assigned to subjects is to maximize the average economic result, i.e. the difference between average revenue and average costs. These quantities are obtained from (2)-(4) and depend exclusively on intensive variables. It is straightforward to see that the average production cost is constant and the average adjustment cost depends on the percentage deviation between demand and the optimal production scale. The average financing cost deserves a little more reasoning. Starting from (4) we can write:

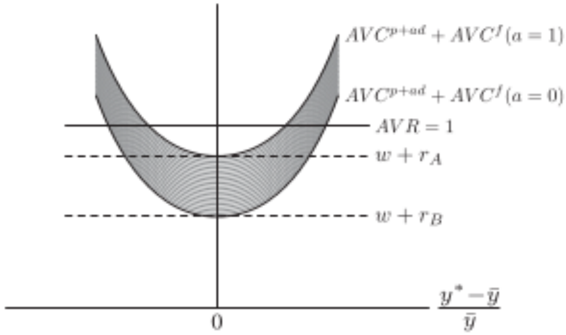


Figure 1. The uniperiodal microeconomic framework. AVR is the average revenue, AVC^{p+ad} is the average production plus average adjustment costs, AVC^{f} is the average financing cost. y^* is the production (realized according to the demand) and $\bar{y}$ is the optimal production scale set by the entrepreneur before knowing the level of demand.

$$\frac{c^f_{j,t}}{y_t} = r_B \frac{B_{j,t}}{y_t} + r_A \frac{A_{j,t}}{y_t}$$

Using the production function in the balance sheet identity we have $B_{j,t} + A_{j,t} = y_t$, so that the average financing cost can be expressed as follows:

$$\frac{c^f_{j,t}}{y_t} = r_B(1 - a_{j,t}) + r_A a_{j,t}$$

which depends on the intensive variable $a_{j,t} := A_{j,t}/K_{j,t}$ (i.e. the equity ratio).

Summing up, both objective function and constraints depend on intensive variables and, consequently, the uniperiodal microeconomic model is scale free.

Figure 1 gives a graphical representation of average revenues and costs in terms of the percentage deviation between production scale and demand.

Note how the adoption of the pecking order theory makes the position of the average cost curve depending on the balance sheet liabilities structure which is represented by the equity ratio. The average cost curve (*AVC*) falls between the two black lines which locate the two boundary cases of an all equity (*a* = *0*) and an all debt (*a* = *1*) liability structure. Figure 1, reports in gray a bundle of them obtained at different levels of *a*. The *AVC* shifts upward (downward) when the entrepreneur moves the firm's financial condition towards a safer (more fragile) situation. We also highlight how the economic result depends on the possibility to set the production capacity ($\bar{y}$) close enough to the level of demand which will be received by the firm (y^*).

Because the return on investments (roi, denoted with ρ) will play an important role in our study, it is convenient to give its formal definition. It is given by the profit minus assets ratio, but in our simplified setting, assets are equal to production, so we can write:

$$\rho_{j,t} = \frac{\pi_{j,t}}{K_{j,t}} = \frac{\pi_{j,t}}{y_{j,t}} = 1 - w - \beta\left(\frac{y_{j,t} - \bar{y}_{j,t}}{\bar{y}_{j,t}}\right)^2 - [r_B(1-a_{j,t}) + r_A a_{j,t}] \tag{5}$$

In this setting, experimental subjects have to take a basic speculative decision: a high level of the equity base ensures them against prospective losses but at the same time it reduces the rate of return of the entrepreneurial activity. In our framework, the realization of several consecutive negative economic results can affect the 'health' of the firm. The equity base may indeed reach low values so that a further loss could lead the equity base to negative levels. In this case, subjects have to activate a solvency procedure (i.e. bailout) which has a cost and implies a penalty.

The experimental subjects' performance is evaluated according to a score computed by the software (for a detailed description see next subsection) as the average return on investment minus the bailouts penalties.

3.2 *The graphical user interface*

In this section, we introduce the Graphical User Interface (GUI) underlying the microeconomic structure described in the previous sub-section.

Experimental subjects are endowed with a forecasting service whose reliability can change and must be assessed by them over each round. Basically, this means that experimental subjects should evaluate when and whether the forecasting service helps in 'neutralizing' the uncertainty we introduced into the settings by asking subjects to set the production $y_{j,t}$ before the demand $y^*_{j,t}$ is known.

Subjects are asked to maximize a score which is computed as follows:

$$score_{j,t} = \langle\rho\rangle_{j,t} - O_{j,t}c^O \tag{6}$$

where $\langle\rho\rangle_{j,t}$ denotes the average roi up to time t, $O_{j,t}$ is the number of bailouts until time t and c^O is a parameter representing the bailout cost.[6]

[6] The parameter is set to 0.01.

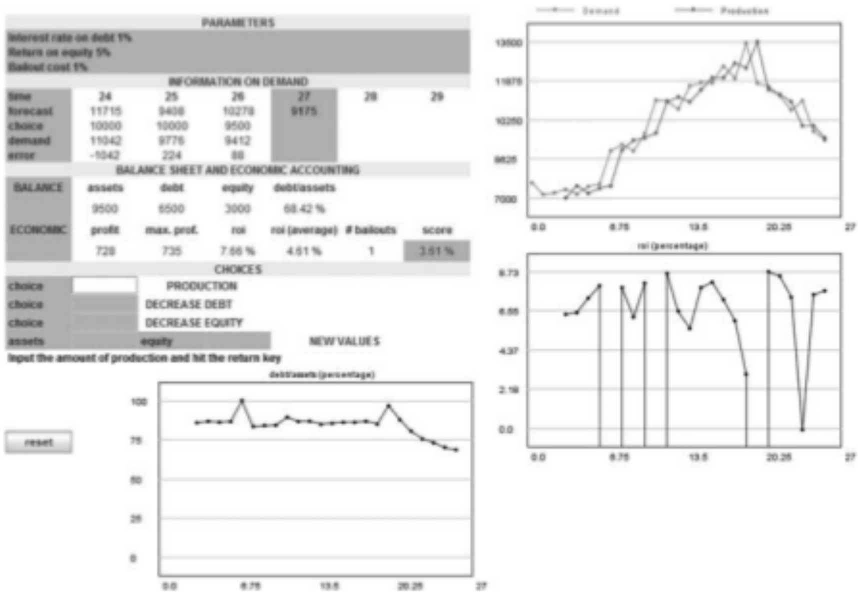


Figure 2. The graphical user interface used by the experimental subjects.

Subjects receive a proportional payment according to their score (see the Appendix). The goal of maximizing the score predisposes subjects to take care of two aspects: (i) the maximization of their reward and (ii) the minimization of the number of bailouts. Therefore, in this specific framework the equity ratio plays a key role. In fact, a high level of the ratio helps in the achievement of (ii), while it makes harder the achievement of (i) because equity base is more expensive than debt.

Figure 2 shows the GUI managed by the subjects during the experimental sessions they were involved in. The GUI is divided into two parts. In the first one, information on demand and financial position is given and continuously updated in real time. In the second one, the experimental subjects are asked to take decisions.

In Figure 2, the GUI is prompting for the production choice at period 27. Some useful information for this choice is available in the report on demand section. Looking at this part for example, the experimental subject knows the level of demand received in the previous three periods (10,663 in $t = 24$, 11,042 in $t = 25$ and 9776 in $t = 26$). The demand forecast is 9175. Comparing the values in the forecast and demand lines, the experimental subject can infer the reliability of forecasts. The error line gives information about the past values of the difference $y_{j,t} - y^*_{j,t}$. Taking into account this information, the experimental subject sets the level of production trying to guess the future level of demand. Once the input value is entered and the return key is pressed, the GUI reveals the realization of demand and, simultaneously, it computes the economic result and activates the appropriate choice input field. If a profit is realized, the debt reduction choice input field is first activated; once the value has been entered, the equity reduction choice input field is activated and finally the prompt jumps to run the production choice for the next period. If a loss is suffered, but the equity base is enough to cover it, the prompt jumps to the equity reduction choice input field and successively to the production choice input field of the next period. When the loss is higher than equity base, decisions on debt and equity reduction are skipped and the prompt jumps to the bailout section before going to the next period.

Information is updated after each decision. Experimental subjects are also endowed with graphs displaying the whole past history of demand, choices, debt percentage and roi.

3.3 *The experimental settings*

3.3.1 The benchmark pattern of demand

A benchmark pattern of demand is denoted by $\hat{y}_t$. It consists of a time series which is used to obtain the series of demand provided to the experimental subjects in the various sessions. We scheduled different paths which are associated to the different experimental sessions. In the training phase, the series of demand are obtained as different realizations of the following process:

$$\hat{y}_t = 1.001\hat{y}_{t-1}(1+u_t) \qquad \text{where} \qquad u_t \sim U[-0.05, 0.05] \tag{7}$$

These series are different in each experiment and among subjects. This generating process is denoted as $\hat{y}_t^{(r)}$.

In order to gain insights on subjects' behaviour over the business cycle, we generate a very regular sequence of demand according to the following expression:

$$\hat{y}_t = (1+\cos(0.2t)0.25)\,10000 \qquad t \in \{0, 1, 2, \ldots\}.$$

This benchmark demand pattern is shown in Figure 3 and is identified with $\hat{y}_t^{(1)}$.

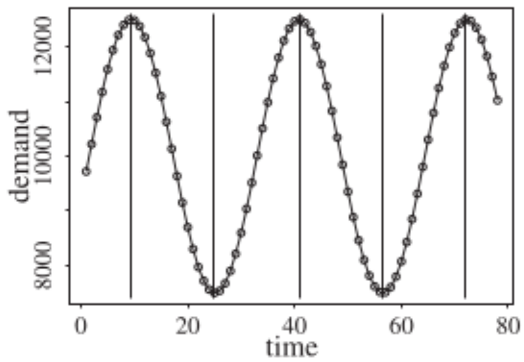


Figure 3. The benchmark pattern of demand.

Starting from the benchmark, each experiment (lower script e) is characterized by a demand time series generated as follows:

$$y^*_{e,t} = \hat{y}^{(1)}_{e,t}(1 + x_{e,t}\sigma_{e,t})$$

where $x_{e,t}$ is the realization of a standard Gaussian distribution and $\sigma_{e,t}$ denotes the standard deviation; $\hat{y}$ is indexed by e since in each experimental session we extract sub-series of $\hat{y}$ having different starting points and length in order to diversify the experimental environment.

The resulting series represents the demand received by the firm in a given experiment. Starting from $y^*_{e,t}$, we generate the forecast series as

$$\tilde{y}_{e,t} = y^*_{e,t}(1 + \tilde{x}_{e,t}\tilde{\sigma}_{e,t}),$$

where $\tilde{x}_{e,t}$ is the realization of a standard Gaussian distribution. The standard deviation $\tilde{\sigma}_{e,t}$ regulates the accuracy of the forecast and is a crucial parameter for the subjects' performance in the laboratory. If $\tilde{\sigma}_{e,t} = 0 \forall t$, the experimental subjects are expected to set the production at the same level of the forecast. In this way, they will always achieve the maximum profit and the bailout procedure will never be activated. At high levels of $\tilde{\sigma}_{e,t}$, the standard deviation of demand ($\sigma_{e,t}$) is a key factor. In fact, if $\sigma_{e,t}$ is low, fairly good 'guesses' on the future level of production could still be obtained extrapolating the trend from past levels of demand. When both $\tilde{\sigma}_{e,t}$ and $\sigma_{e,t}$ are high, it becomes troublesome to set the production because both the forward looking and the backward looking behaviours are not reliable.

Table 1. The experimental plan

e	*Type*	$\hat{y}$	σ	$\tilde{\sigma}$	*Time periods*	*Date (2011)*
At	Training[a]	$\hat{y}_t^{(r)}$	0	0	30	26 Sept
*B*1*a*	Experiment	$\hat{y}_t^{(1)}$	0.02	0.03	30	28 Sept
*B*1*b*	Experiment	$\hat{y}_t^{(1)}$	0.02	0.05	60	28 Sept
*B*1*c*	Experiment	$\hat{y}_t^{(1)}$	0.02	0.10	60	28 Sept
*B*2*a*	Experiment	$\hat{y}_t^{(1)}$	0.03	0.04	60	29 Sept
*B*2*b*	Experiment	$\hat{y}_t^{(1)}$	0.04	0.05	60	29 Sept
*B*2*c*	Experiment	$\hat{y}_t^{(1)}$	0.05	0.06	60	29 Sept
*B*3	Experiment	$\hat{y}_t^{(1)}$	0.05	t.d.	100	30 Sept

Source: the letter e identifies experimental sessions; $\hat{y}$ refers to the patterns of demand provided to the experimental subjects; σ is the standard deviation of demand and $\tilde{\sigma}$ is the standard deviation of forecasts; time periods refers to the number of sequential choices that experimental subjects have to perform

[a]It can be repeated.

3.3.2 Description of treatments and sessions

The whole experimental plan is reported in Table 1. It is composed of four sessions.

The first session of the experimental plan (labelled *At*) was completely dedicated to training. In this session, subjects were able to repeat sequences of 30 time periods as many times as desired, with a minimum number of three exercises. At the beginning of each sequence, the software generates a time series of demand that is a new realization of the process in (7). In session *At*, subjects familiarized themselves with the model and were expected to discover the mechanisms at work in the microeconomic structure. To this end, we removed the forecast uncertainty by setting $\tilde{\sigma}=0$. In this case, an optimal strategy exists. After a few periods, subjects learn that forecasts are fully reliable and always realize a profit by setting production equal to the forecast.

However, a further strategy to increase the score may be approached by observing that debt is cheaper than equity and, if the possibility of suffering a loss is excluded, one may fully exploit financial leverage. In other words, subjects are expected to set their equity base always to zero after having discovered this more subtle mechanism. This behaviour informs the experimenter that the subject is aware of financial leverage, which is an essential component of the experiment. With this concept in their hand, we believe that subjects are capable to manage the three following sessions (labelled *B1, B2* and *B3*) characterized by uncertainty. Two of these sessions are divided into sub-sessions (i.e. the second session is composed of sub-sessions $B1a$, $B1b$, $B1c$; the third session is divided in sub-sessions $B2a$, $B2b$, $B2c$). Each sub-session lasted about 30 minutes depending on the number of time periods it was composed, whereas the average length of a session was approximatively 2 hours.

The entire experiment was run during a 4-day period in within-person format, randomly recruiting 23 undergraduate students at the Faculty of Economics and Management of the University of Chieti-Pescara. 20 of them have performed all sessions.

4. TOWARDS INDUCTIVE MICROFOUNDATIONS

In this section, our aim is to explain how the experimental design previously discussed can be used to provide alternative microfoundations to a macroeconomic model. In our opinion, the experimental design can be fruitful in exploring the management decision at individual level (i.e. case by case studies). This allows us to discover behavioural rules used by individuals and gives more details to the microfoundation process of an Agent-based model, wherein artificial agents have a dynamic behaviour similar to that induced from experimental results.

Although agent-based models (Tesfatsion and Judd, 2006) have been receiving growing attention as an alternative to the standard approach in macroeconomics (see Colander *et al.*, 2008; Gallegati and Kirman, 2012, among others), they are still experiencing difficulties in gaining general consent among economists. One of the main point of contention concerns the problem of how to endow artificial agents with the ‘proper’ behaviour (Fagiolo *et al.*, 2007).[7] In our opinion, the combination between Experimental Economics and Agent-based modelling may be useful: by mining the data from each experimental subject, researchers can get insights into the rules that subjects use when taking decisions.[8] The outcomes of the experiment may exhibit some statistical regularities and, hence, they could be used to estimate and validate an agent-based model where artificial agents mimic humans’ behaviour. On the other hand, the agent-based model enables to increase the number of agents to a level that makes comparisons with real macroeconomic data reasonable.

[7] The topic of microfoundations of agent-based macroeconomic models has been addressed by Gaffeo *et al.* (2008); Dosi *et al.* (2008); Dawid *et al.* (2016) among others.

[8] An attempt in this direction is provided by Anufriev *et al.* (2013) who show how the use of genetic algorithms generates forecasting behaviours which resemble those observed in experimental subjects.

Summing up, we maintain that the process towards an experimentally microfounded agent-based macroeconomics should be based on the following steps:

(1) inducting and calibrating microeconomic behavioural rules by using 'real world' microeconomic data (i.e. running experiments);
(2) building an artificial agent for each identified behavioural rule;
(3) building an Agent-based model using the artificial agents designed in the previous step;
(4) validating and calibrating the macroeconomic outcome of the artificial economy by using 'real world' macroeconomic data.

This process provides the advantage of performing a double validation-calibration exercise (both at the micro- and macro-level dimensions) which in turn has the potentialities to increases the reliability of the model.

It behooves to point out that several difficulties have to be overcome for this approach to be successful. Probably, the most important of them is that experimental economics has been mainly used, and thus it developed methods, for testing the predictions of theoretical microeconomic models. The approach we propose needs instead an inversion of the casual link: experiments are used to find out behavioural rules. Fortunately, the usefulness of this inversion has been claimed by a number of economists who talk about 'exhibit': a phenomenon produced only by a specific experimental design (Sugden, 2008; Bardsley *et al*., 2010). They highlight how often experiments that discover such exhibit are motivated mainly by untheorized hunches. Furthermore, this shift from pre-existing theory to experimentally observed regularities has also been claimed by a number of philosophers who coined the new term 'exploratory experiment': a kind of experimentation in which no well-formed conceptual framework is readily available and driven by the scientific desire to obtain new empirical regularities (Hacking, 1983; Galison, 1987; Steinle, 1997; Cartwright, 2005; Franklin, 2005). However, this literature is limited, and protocols and methods to carry on the analysis in a proper way are currently under development. Bearing this in mind, the rest of the paper has to be interpreted as the implementation of the above described microfoundation process that, despite susceptible of improvements in some specific aspects (such as the selection of experimental subjects to be included in the analysis discussed in the following section), leads to meaningful results.

In this paper, we focus on steps 1, 2 and 3 of the list outlined above, leaving step 4 for future research.

Table 2. Ranked average scores

rank	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
j	11	13	14	19	9	17	4	12	20	2
ρ	6.92	6.92	6.54	6.42	6.32	6.30	6.24	6.21	6.09	5.83

5. DATA ANALYSIS AT MICROSCOPIC LEVEL

In this section, we provide the description of the experimental data analysis in order to search for models which better approximate the experimental subjects' behaviour.

5.1 Selection of experimental subjects

The main concern in experimental economics is perhaps the one known as external validity of experiments, i.e. one wonders if experimental subjects' behaviour may or may not be replicated and generalized in the real world. Within this debated question is the more subtle issue concerning whether students' behaviour that emerges in the laboratory may be generalized in the reality. The answer changes a case-by-case mainly depending on the experimental topic under investigation, as well as its abstraction level. In our experimental sessions, the entrepreneurial activity is involved and pursued. Differently from other social activities, the entrepreneurial ability is not a general aptitude easily found among the population. Hence, taking randomly a set of students only few of them may become entrepreneurs in the future. This means that letting a group of students play the entrepreneurial role, the majority of them are forced in a role they probably will never have. The scenario completely changes if instead of students the experimental subjects were real-life entrepreneurs. In this case, all the behaviours would have been meaningful and thus considered. Because our experimental subjects were students, we were extremely careful in the selection standards, accounting for two criteria: (1) the experimental subjects' performance and (2) the variety of their behaviour. Our intent was to minimize the distortion generated by forcing all the subjects to play the entrepreneurial role.

It is easy to have an idea of performances achieved by experimental subjects by ranking them according to their average score. Table 2 reports the average scores of the 10 best performing experimental subjects (see table A1 and A2 in the Appendix for the whole set of subjects).

A more tricky task is to overview the second aspect taken into account for the selection to evaluate the variety of subjects' behaviour. In looking for their

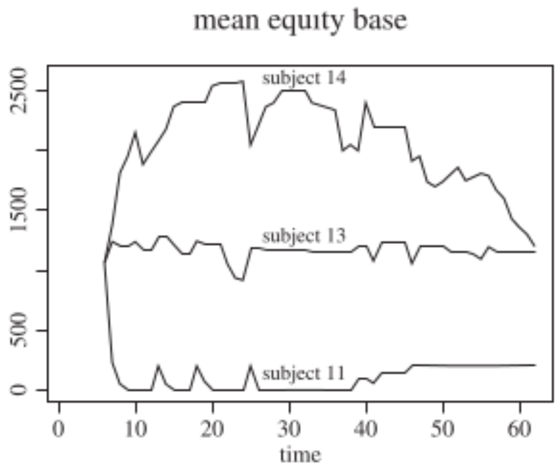


Figure 4. Series obtained by averaging the equity base in each period chosen in experiments B1b, B1c, B2a, B2b and B2c by the experimental subjects 11, 13 and 14.

behavioural rules, we first check for rules which are economically grounded. As an example, on the one hand we can imagine the more sophisticated subjects estimate the degree of risk by evaluating the volatility of past levels of the return on investments, or on the other hand we can conceive that they use an s-S rule on the level of equity ratio. To this aim, we produce a set of charts reporting on the dynamics of the key variables (a large number of them are reported in the Appendix). We delve deeper into these charts to identify the financial variables targeted by the subjects and the conditions which triggers the change in these variables. The countercyclical dynamics of the equity ratio detected in the data show that the experimental subjects do not target the equity ratio and this hints at a stable dynamics of the equity base. This insight is confirmed by the time path of the equity base that we noted while analysing the individual data. After these observations, we take the equity base as the variable on which to evaluate the variety of behaviours.

Pondering the just reported elements according to the two selection criteria, we were able to select the experimental subjects 11, 13 and 14 so that to be the base of our study. In fact, they all have good performances and present a good variety of behaviour. This can be deduced by looking jointly at Table 2 and Figure 4.

In order to ease the reading of the paper, we will hereafter refer to

- subject 14 as the high equity-type;
- subject 13 as the mid equity-type;
- subject 11 as the low equity-type.

5.2 Looking for behavioural rules

The main effort is to identify the level of a variable (or that of a set of variables) which triggers the change in the production and liability structures.

With the aim of finding out the equity base behavioural rules, we have identified the following common features of the decision process. In our experiments, subjects were asked to manage a simple balance sheet having two liabilities (debt, B, and equity, A). Once the economic result (profit or loss) is computed, each experimental subject was allowed to move the liability structure towards the desired level. The attention is in particular pointed to the movement of the equity base (ΔA_t). The equity adjustment is affected by the economic result: the upward adjustment is possible only when a profit is realized and its amount is bounded by the level of it; equity base reductions occur when a loss is suffered. In addition, the equity base can always be withdrawn by the experimental subjects. Before taking any decision about the movement of the equity base, each subject has to perform the following two-steps evaluation:

- setting a target level of equity base ($\hat{A}$);
- deciding whether to move towards the target level.

Concerning the first point, we made an effort to identify rules and parameters governing the choice for the three subjects. The reason for considering the second step is given by possible delays in moving towards the target level. Delays can be due either to the presence of adjustment costs—which make small adjustments not convenient—or just to the waiting behaviour for a consolidation of a new detected tendency. In order to account for this eventuality, in the next section we will let the artificial agents start the downward adjustment when

$$A_{j,t} > \hat{A}_{j,t}(1+d_j^-) \tag{8}$$

and the upward adjustment when

$$A_{j,t} < \hat{A}_{j,t}(1-d_j^+) \tag{9}$$

where d_j^- and d_j^+ are parameters to be estimated.

Once the adjustment starts, the equity base is moved as fast as possible towards the target level. This means that the equity base moves as follows:

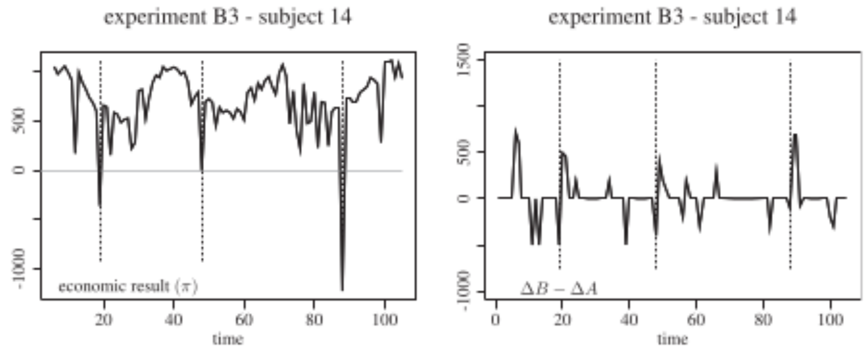


Figure 5. ΔA and π of experimental subject 14 in experiment B3.

$$A_{j,t} = \hat{A}_{j,t} \quad \text{if condition (8) holds}$$
$$A_{j,t} = A_{j,t-1} + \pi_t \quad \text{if condition (9) holds}$$

Once a model has been set up, the goodness of the behavioural rules and parameters is evaluated by using the differential evolution algorithm (Storn and Price, 1997). We implement a feedback loop between model fitting and model design and we consequently select the model which best fit experimental data. In the next sections, we describe the microeconomic calibration of the financial behaviour of the selected experimental subjects.

5.3 Experimental subject 14

5.3.1 Identification of behavioural rules

The examination of the charts reported in the Appendix (figures A1, A2 and A3) allows to identify some empirical regularities. We highlight some of them by focusing on some charts in particular. Figure 5 shows the time series of the economic result (π_t) and that of the variation of equity (ΔA_t) obtained from the choices made by the experimental subject 14 in experiment *B3*, also included in Figure A2. The left chart in Figure 5 shows that this subject suffered three losses highlighted by the vertical dashed lines. Looking at the right chart of the figure, we can infer how this subject reacts to losses. We recall that after a loss the software reduces the equity base by the loss amount and gives the possibility to perform further reduction of the equity base whenever it is still positive. The right chart on Figure 5 shows that this subject takes advantage of this possibility and withdraws additional financial resources from the firm after a loss. In fact, the ΔB–ΔA line has troughs at the vertical dashed lines. A possible explanation of this counter intuitive behaviour is that after a loss, the subject chooses more risky positions to fully exploit the leverage effect in an attempt to catch up his previous financial position. In other words, in this subject's behaviour we can observe the 'reflection effect' described in Kahneman and Tversky (1979).

After observing this regularity, we conclude that a pronounced fall in the economic result, below a threshold π^-, decreases this subject's target level of equity and we model this behaviour using the following rule:

$$\hat{A}_t = \hat{A}_{t-1}(1 - g_{\hat{A}}^-) \qquad \text{if} \qquad \pi_t < \pi^-$$

Figure 5 shows that following an equity base reduction, the subject cumulates equity in a few of the following periods in order to reach a level of equity comparable to that observed before the loss. In addition, we can observe in Figure A2 that except in the described negative occurrences, the subjects often moves the level of equity base, but it basically fluctuates around a reference value that we will denote with $\tilde{A}$.

Summing up, the rules proposed for this subject's financial behaviour are as follows:

$$\begin{aligned} \hat{A}_t &= \hat{A}_{t-1}(1 - g_{\hat{A}}^-) && \text{if} \quad \pi_t < \pi^- \\ \hat{A}_t &= \tilde{A} && \text{if} \quad \pi_t \geq \pi^- \end{aligned}$$

5.3.2 Estimation of parameters

The estimation of the parameters d^+, d^-, π^-, $g_{\hat{A}}^-$ and $\tilde{A}$ complete the identification of the behavioural rules.

We set the parameters by running the differential evolution algorithm. The algorithm was set up in order to minimize the distance between the equity base time series generated by using the rules previously identified and the equity base chosen by the experimental subject. Several Monte-Carlo exercises have been performed in order to investigate the robustness of the estimation.

After studying the results, we set the parameters as follows:

$$d^+ = 0.35,\ d^- = 0.7,\ \pi^- = 179,\ g_{\hat{A}}^- = 0.375 \text{ and } \tilde{A} = 2000$$

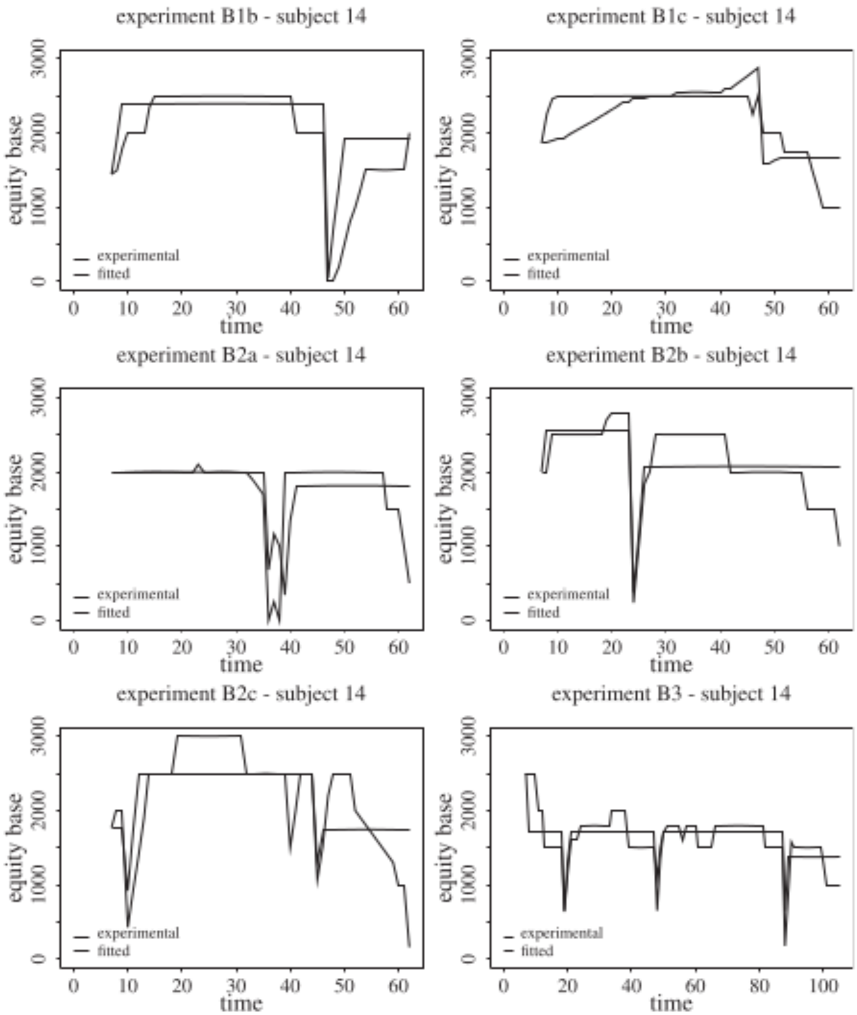


Figure 6. Observed and fitted values of the equity base of experimental subject 14 in experiments B1b, B1c, B2a, B2b, B2c and B3.

5.3.3 Evaluation of the model

Once the parameters were set, the identified behavioural rules were used within the same experimental setting provided to the subject.

Charts in Figure 6 compare the subject's choices with the equity base obtained by using the optimized rule in each experiment. The identified model makes a good job in fitting the subject's choices.

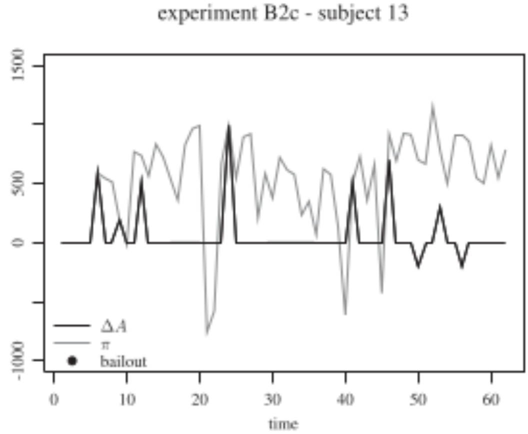


Figure 7. ΔA and π of experimental subject 13 in experiment B2c.

5.4 Experimental subject 13

5.4.1 Identification of behavioural rules

The examination of the charts reported in the Appendix (figures A4, A5 and A6) allows to identify some regularities. We highlight some of them by focusing some charts in particular. Figure 7 shows the time series of the economic result (π_t) and that of ΔA_t obtained from the choices of the experimental subject 13 in experiment *B2c* even included in Figure A5. By observing the figure one can see that financial resources are retained (the black line has a peak) after a loss is suffered (the gray line enters the negative portion of the plane). This behaviour can be seen in other experimental sessions (see Figure A5).

After observing this regularity, we conclude that suffering a loss increases this subject's target level of equity. Thus, the following rule:

$$\hat{A}_t = \hat{A}_{t-1}(1 + g_{\hat{A}}^{+}) \qquad \text{if} \qquad \pi_t < \pi^{-}$$

grasps subject's 13 behaviour concerning financial resources retention. The parameter $g_{\hat{A}}^{+}$ has to be estimated.

In order to have the 'complete picture' for this subject's financial behaviour, it is worth finding out her/his financial resource withdrawal rule. The simultaneous analysis of the ΔA_t, ρ and equity base (A_t) time series suggests a candidate model for this decision. Figure 8 is an enriched version of

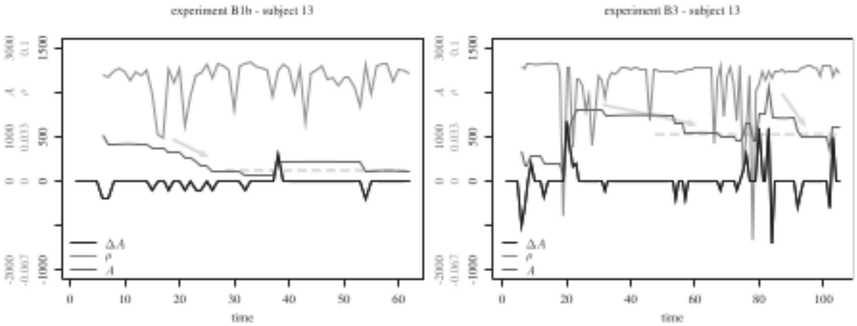


Figure 8. ΔA, ρ and A of experimental subject 13 in experiment B1b and B3.

those charts already included in Figure A6. These charts report the three mentioned time series concerning experiments *B1b* and *B3*. Data gathered from experiment *B1b* suggest that roi (and consequently the profit) never reached the 'safety mark'. This subject became more and more confident in the management of the firm and her/his equity base follows a sort of 'landing' trajectory between period 15 and 25. The remaining time span presents fluctuations around a positive benchmark value ($\tilde{A}$). The 'landing' behaviour of the equity base can be observed also in the two 'low risky' time spans which characterize experiment *B3*. In the right chart of Figure 8, one can observe how the equity base tends to approach a benchmark level of equity base in the time spans 30–70 and 85–100. In these periods, the roi is stable around a high level and occasional troughs (such as the one present in time span 30–70) do not affect the behaviour. From these observations, we induce that the roi is the triggering variable for the decision on the reduction of the equity base. However, to account for missed responses to single episodes we use a moving average as the variable which determines financial resources withdrawals. More formally, if we denote the roi moving average as

$$\rho_t^m = \frac{1}{m}\sum_{i=1}^{m} \rho_{t-i}$$

we can determine the target level as

$$\hat{A}_t = \hat{A}_{t-1} - g_{\hat{A}}^{-}(\hat{A}_{t-1} - \tilde{A}) \qquad \text{if} \qquad \rho_t^m > \rho^+$$

where $g_{\hat{A}}^{-}$, $\tilde{A}$ and ρ^+ are parameters to be estimated.

Summing up, the rules proposed for this subject's financial behaviour are as follows:

$$
\begin{aligned}
\hat{A}_t &= \hat{A}_{t-1}(1+g_{\hat{A}}^{+}) && \text{if} \quad \rho_t < \rho^{-} \\
\hat{A}_t &= \hat{A}_{t-1} - g_{\hat{A}}^{-}(\hat{A}_{t-1} - \tilde{A}) && \text{if} \quad \rho_t^m > \rho^{+} \\
\hat{A}_t &= \hat{A}_{t-1} && \text{otherwise}
\end{aligned}
$$

5.4.2 Estimation of parameters

The estimation of the parameters m, $g_{\hat{A}}^{+}$, ρ^{+}, d^{+}, $g_{\hat{A}}^{-}$, ρ^{-}, d^{-} and $\tilde{A}$ complete the identification of the behavioural rules. The initial level of the target equity base ($\hat{A}_0$) has been added to the set of variables in order to account for the initial transient behaviour.

We set the parameters by running the differential evolution algorithm. The algorithm was set up in order to minimize the distance between the equity base time series generated by using the rules previously identified and the equity base chosen by the experimental subject. Several Monte-Carlo exercises have been performed in order to investigate the robustness of the estimation.

After studying the results, we set the parameters as follows:

$$g_{\hat{A}}^{+}=0.1, \rho^{+}=0.066, g_{\hat{A}}^{-}=0.25, \rho^{-}=0, m=10, d^{+}=0.3, d^{-}=0.3 \text{ and } \tilde{A}=500.$$

5.4.3 Evaluation of the model

Once the parameters were set, the identified rules were used within the same experimental setting provided to the subject.

Charts in Figure 9 compare the subject's choices with the equity base obtained by using the optimized rule in each experiment. The identified model makes a good job in fitting the subject's choices.

5.5 *Experimental subject 11*

5.5.1 Identification of behavioural rules

The whose set of chats reported in the Appendix (Figures A7, A8 and A9) help us in modeling This subject's financial behavior. S/he was extremely

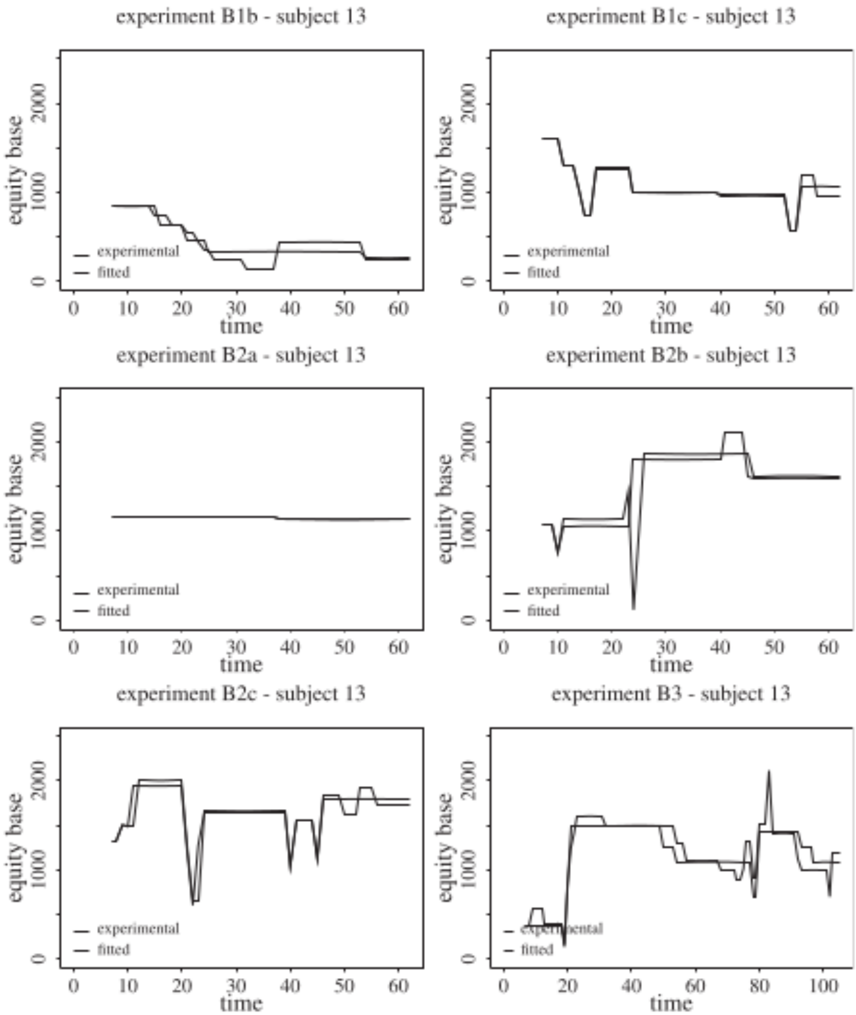


Figure 9. Observed and fitted values of the equity base of experimental subject 13 in experiments B1b, B1c, B2a, B2b, B2c and B3.

careful in keeping the equity base at a low level. In fact, by watching Figure A9 it is possible to see how s/he set the equity base to zero unless an 'alarm bell' is perceived. Figure A8 shows how this behaviour brings her/him to activate several bailout procedures. The equity base is set at a positive value, but rapidly brought back to zero after these bailouts. This behaviour signals that the bailout is not a triggering event of the equity base increase.

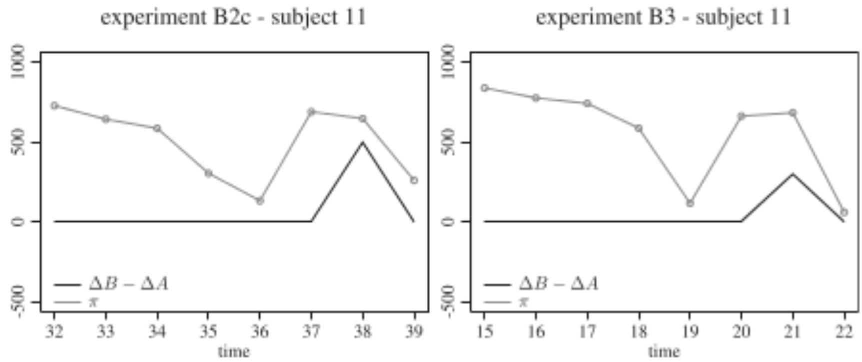


Figure 10. Zoom on the periods before an increase of financial resources.

A close observation of the dynamics of the profit in the periods preceding the first equity base increase in both experiments *B2c* and *B3* shed some light on the triggering event. Looking at Figure 10, one can see how the two patterns of profit are basically the same and they presents a number of consecutive reductions of profit.

However, there are episodes in which the equity base is increased while the event just identified does not occur (the second episode of the equity base increase in both experiments *B2c* and *B3*). This shows the existence of an additional trigger event which was found in the equity ratio time series: both episodes are indeed preceded by a fall in the equity ratio (see Figure A9).

Another example of the financial position management is a resource withdrawal in experiment *B3* which can be justified by the levels of profit and roi which are kept high for a long period. Note how the resource withdrawal causes a trough in the equity ratio which in turn falls below the 'safety level'. The subject decided to 'correct' her/his situation after a couple of periods by means of resources retention.

To sum up, there are two triggering events for financial resource retention: a persistent decreasing pattern of profit and a downward threshold of equity ratio. The withdrawal of financial resources is triggered by a long period of high roi.

To put this subject's rule more formally let us introduce the variable

$$\xi_t^{m_\xi} := \sum_{i=1}^{m_\xi} \operatorname{sign}(\pi_{t-i} - \pi_{t-i-1}),$$

so that we can express this subject's rule as follows:

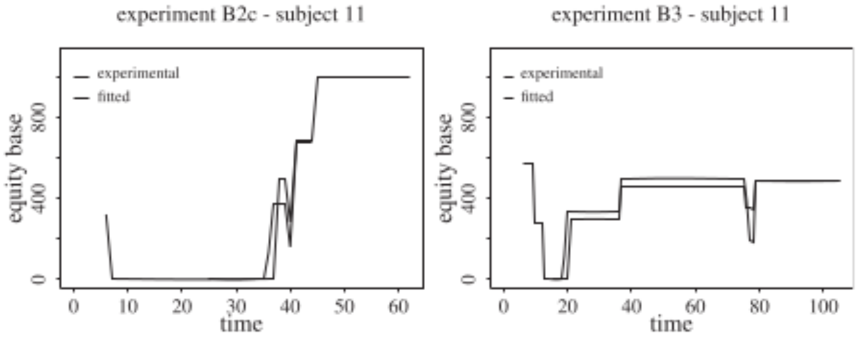


Figure 11. Observed and fitted values of the equity base of experimental subject 11 in experiments B2c and B3.

$$\hat{A}_t = \hat{A}_{t-1} + \Delta\hat{A}^+ \begin{cases} \text{if } \xi_t^{m_\xi} = -m_\xi \\ \text{or } (a_t < a^- \\ \text{and } a_{t-1} > a_t) \end{cases}$$
$$\hat{A}_t = \hat{A}_{t-1} - \Delta\hat{A}^- \quad \text{if } \rho_t^{m_\rho} > \rho^+$$
$$\hat{A}_t = \hat{A}_{t-1} \qquad \text{otherwise}$$

5.5.2 Estimation of parameters

To make these rules working, the parameters m_ρ, m_ξ, $\Delta\hat{A}^+$, ρ^+, $\Delta\hat{A}^-$, a^-, d^+ and d^- are estimated. For this subject, we have informative movements of the financial position in the time span 25–44 of experiment *B2c* and in the whole experiment *B3*. The estimates of the parameters are as follow:

$$m_\rho = 20,\ m_\xi = 5,\ \Delta\hat{A}^+ = 200,\ \rho^+ = 0.086,\ \Delta\hat{A}^- = 50,\ a^- = 0.03,\ d^+ = 0.3 \text{ and } d^- = 0.3$$

5.5.3 Evaluation of the model

The fitted equity base is displayed in Figure 11. Even in this case, the behavioural rules we found make a good job in fitting this subject's choices.

6. THE INDUCED AGENT-BASED MACROECONOMIC MODEL

6.1 Simulation setup

In the previous section, we have identified the behavioural rules and parameters which regulate the three categories of entrepreneurial behaviour we have studied. By using the object-oriented programming,[9] we build a class for each type of entrepreneur and we populate the economy with a large number of instances of these classes.

At each simulation step, each artificial agent is involved in the following process:

- s/he determines the level of production by using a one-step-ahead forecasting module (see Giulioni *et al*. (2012) for details on this module);
- the level of demand ($y_{j,t}$) gets known;
- the economic result is computed;
- the financial position is managed by using the rules identified in the previous section.

To close the model, we have to establish how the level of demand ($y_{j,t}$) and the level of bank credit ($B_{j,t}$) are set for each entrepreneur.

In our context, the 'natural' way to deal with this issue would be the creation of consumer and banker avatars. Since this phase of our research is still in progress, we use the following adaptation.

6.1.1 The level of demand for each artificial agent

To determine the level of demand for each artificial agent, we follow Giulioni (2011). First, demand depends on households' income. Second, income is equal to the value of production.

Let us start from the previous period aggregate production Y_{t-1}. On the one hand, when a firm's asset becomes lower than debt due to losses, agents are allowed to activate a bailout procedure which generates an income loss (because for example a number of workers are dismissed).[10] The aggregate income loss (Y_t^-) is endogenously determined as a percentage (θ) of assets of firms which activates the bailout.

On the other hand, firms' profits increase the income of the whole economy. The aggregate income gain (Y_t^+) is given by a percentage (η) of alive firms' profits.

[9] We are developing in Java taking advantage of the RepastJ 3.1 classes.

[10] Note that the presence of the bailout procedure implies that firms do not exit the model. For those firms having a negative equity base, the software resets the balance sheet assets to the level of demand received in the latest period and the equity base to 5% of assets. The equity base will be adjusted for each financial firm restructuring by using the behavioural rules that characterize each type of firm. A consequence of adopting a bailout procedure is that the number of firms in the model is constant over time.

The aggregate demand has the following dynamics:

$$Y_t = Y_{t-1} - Y^-_{t-1} + Y^+_{t-1}.$$

The final step is to obtain the firm-level demand ($y_{j,t}$) from the aggregate level (Y_t). Having no product differentiation, each unit of the aggregate demand is randomly allocated to each of the existing firms.

6.1.2 The level of bank credit for each artificial agents

At this stage, to determine the level of finance ($B_{j,t}$) for each artificial agent we follow a simplification based on the horizontalist view (Moore, 1988). We assume that the credit volume is demand determined, so that the bank accommodates the demand for credit in each time period.

6.1.3 Setting Macroeconomic Parameters

In this section, we aim at showing the macroeconomic result of the precise calibration of parameters done at the microeconomic level. To do this, we proceed by performing Monte Carlo runs of the macroeconomic agent based model in order to provide an overview of different macroeconomic parametrizations. The baseline model is composed of 300 firms (100 firms for each type of financial behaviour we have found in Section 5). For them, we set assets at the beginning (K_0) to 10,000, and the initial equity ratio (a_0) to 10% for high equity level firms, to 5% for middle equity firms and to 2.5% for low equity firms. The macroeconomic behaviour depends crucially on the difference between the two parameters η and θ. To show how the model behaves under different levels of this difference, we set $\theta = 0.05$ and perform simulations at various levels of η. The macroeconomic results for $\eta = 0.13$ and $\eta = 0.15$ are those reported hereafter.

6.2 Simulation results

In this section, we present the simulation outcomes. We start from the analysis of the long-term average dynamics of the model. To do that, we pool results from several simulation runs and compute averages across runs. Although averaging washes out the effects of idiosyncratic events, the analysis of sub-section 6.2.1 will give us a precise idea of the overall behaviour of the model.

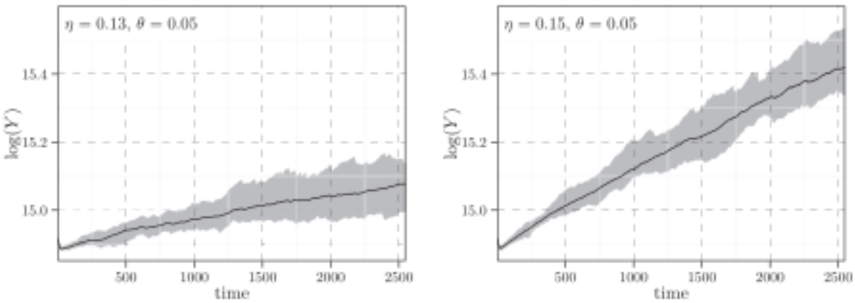


Figure 12. Aggregate production of the economy at different revenue rates η. Shadowed: area covered by 10 runs of the model. Solid line: average production of the 10 runs.

In the following sub-sections, we analyse the effects of events that perturb agents position. As mentioned above, since averaging over several runs smooths out the events perturbing single runs, we make each run being perturbed in the same manner, i.e. we account for aggregate perturbing events. In sub-section 6.2.2, we analyse the overall effect of a negative aggregate event such as a period of price deflation.

Finally, in sub-section 6.2.3, we leave the 'average' analysis to investigate the fluctuations observed in the individual runs of the model. This perspective allows us to study the presence of endogenous business fluctuations.

6.2.1 The average behaviour over time

Figures 12–15 report the simulation results where each run goes on up to 2500 time steps. As expected, the average aggregate growth of the economy increases with the parameter governing the revenue from sale η and,

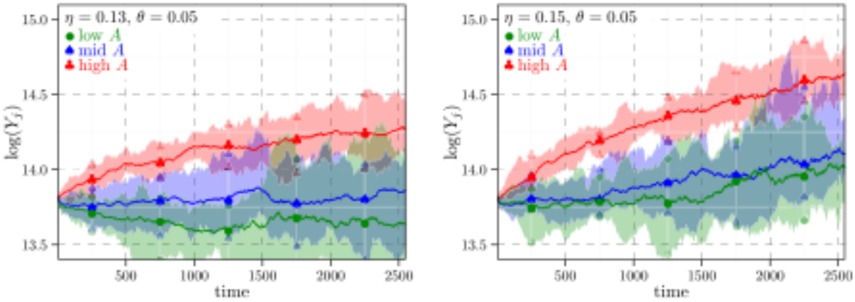


Figure 13. Production of the three types of firms at different revenue rates η. Shadowed: area covered by 10 runs of the model. Solid line: average production of the 10 runs.

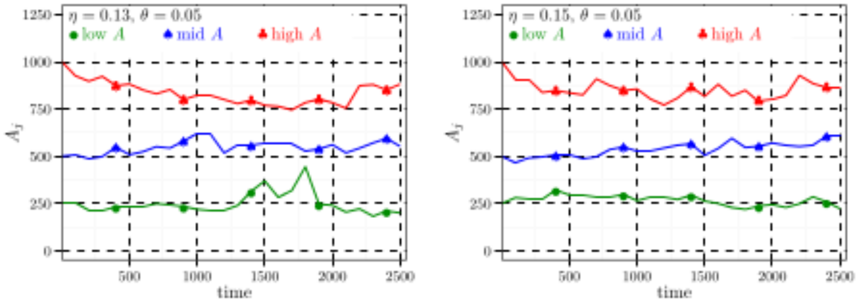


Figure 14. Average equity over 10 runs of the model of the three types of firms at different revenue rates η.

consequently, firms profits (see Figure 12). Figures 13–15 allow the evaluation of key variables dynamics of the three groups of firms. In particular they show the contribution to the aggregate production (Figure 13), the average equity base (Figure 14) and the number of defaults (Figure 15) of each of the three types of firms.

Figure 13 shows that the financial position is a key determinant of the contribution to the aggregate production. The left chart of the Figure shows that firms with high equity base (red line with clubs) produce more than firms with middle level equity base (blue line with spades) which in turn have a production higher than firms with low equity base (green line with bullets). An increase of the return on sales (η) improves the growth rate of all the three types of firms (see the right chart of Figure 13). However, firms with low level equity base benefit more of this improvements and the level of their production gets closer to firms with middle equity base.

The dynamics of the average level of equity are in line with what is expected from the microscopic framework presented in the first part of this

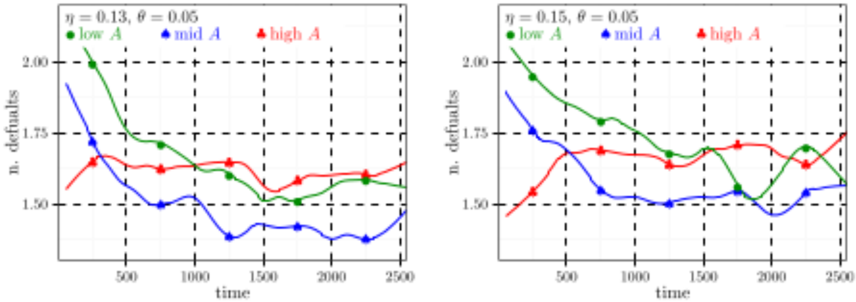


Figure 15. Average number of defaults over 10 runs of the three types of firms at different revenue rates η.

paper. Figure 14 shows a slightly increasing trend for firms with middle level equity base for both levels of η, while the decreasing trend observed in the left chart for the type with high level equity is not confirmed in the right chart. Firms with low level of equity keep their equity constant in the two charts.

The dynamics of the number of defaults displayed in Figure 15 presents some unexpected features. The three time series fulfil our expectations in the initial part where firms with high level equity have a lower number of defaults than firms with middle level ones that in turn have a lower number of defaults than firms with low level equity. However, the three series become ruffled when time progresses. A rationale for this can be found observing that while equity base keeps constant, the level of production changes. These changes impact on the equity ratio of the three types of firms. Indeed, intuition suggests that the default probability depends inversely on the equity ratio. The higher default rates observed in the right chart of Figure 15 are explained by our observation: a higher production with the same equity base implies a lower equity ratio and a higher default rate. This fact is in line with Minsky's thought: prolonged periods of economic growth cause an increase of financial fragility.

6.2.2 Aggregate negative events

In this section, we evaluate the effects of an aggregate negative events such as a deflation period. To this aim we include a price index (p_t) in our microeconomic context. It is easily done modifying equation (1) as follows:

$$\pi_{j,t} = p_t y_{j,t} - c^{p}_{j,t} - c^{ad}_{j,t} - c^{f}_{j,t}$$

This also modify equation (5):

$$\rho_{j,t} = p_t - w - \beta\left(\frac{y_{j,t} - \bar{y}_{j,t}}{\bar{y}_{j,t}}\right)^2 - [r_B(1 - a_{j,t}) + r_A a_{j,t}]$$

While the analysis of the previous section implicitly assumes $p_t = 1$ for all t, in this section we include a deflation by letting our simulations go on with $p_t = 1$ for a while. Then, we make p_t gradually reduce until the price index reach 0.8 and going back to unity in a subsequent time span. A visual representation of the exogenously given dynamics of p_t is given in the left chart of Figure 16 (even though the chart is aimed to a different goal). To ease the evaluation of the deflation effects, the periods with price movements

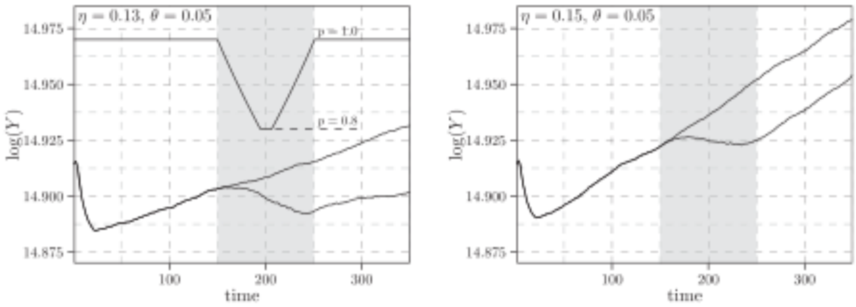


Figure 16. Comparison of aggregate production dynamics with and without deflation at different revenue rates η. Shadowed: price change period. Solid line: average of 10 runs.

are highlighted in gray in Figures 16–19. These figures let us assess the effect of the deflation because they report the simulation outcomes as term of comparison in the absence of the deflation period. Since the simulations are initialized exactly in the same way (including the random seeds), the two outcomes are exactly the same before the beginning of the deflation period.

According to the two charts in Figure 16, at the aggregate level, the deflation causes a deep recession for $\eta = 0.13$ while the reduction of the aggregate production is milder when $\eta = 0.15$. Both the timing and intensity of the deflation effects on the production level of the three types of firms are different. Looking at Figure 17, we can observe how significant deviations from the unperturbed time series can be observed in the final part of the deflation period for firms with high equity base. Firms with middle equity base are heavily and quickly affected by the lower price level, while

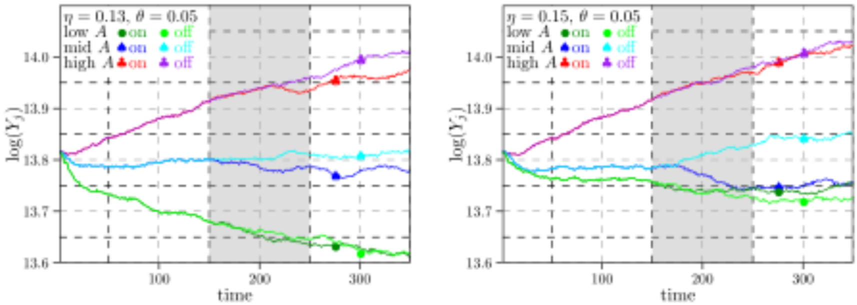


Figure 17. Production of the three types of firms at different revenue rates η with (on) and without (off) deflation. Shadowed: price change period. Solid line: average production of 10 runs.

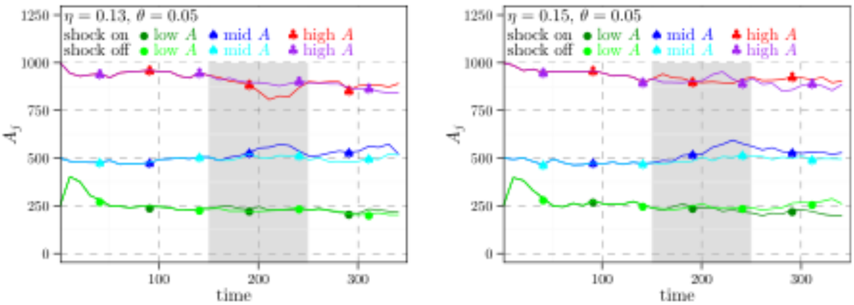


Figure 18. Equity base of the three types of firms at different revenue rates η with (on) and without (off) deflation. Shadowed: price change period. Solid line: average equity base of 10 runs.

the effect on firms with low equity base is small. Differently from the $\eta = 0.13$ scenario, the deflation does not affect the production of firms with high equity base when $\eta = 0.15$. At this level of η, the decrease of revenue affects heavily those firms with middle level of equity base. This happens despite those firms are the only type to increase their equity levels (see Figure 18).

The effect of deflation on the number of defaults can be observed in Figure 19. All the unperturbed series present a negative trend. These trends are reverted by the deflation for all firm types. A robust regularity observed for both levels of ηs concerns the sequence of time series peaks. Firms with low equity base reach the maximum number of default first (green line with bullets) and then, firms with middle equity base (blue line with spades).

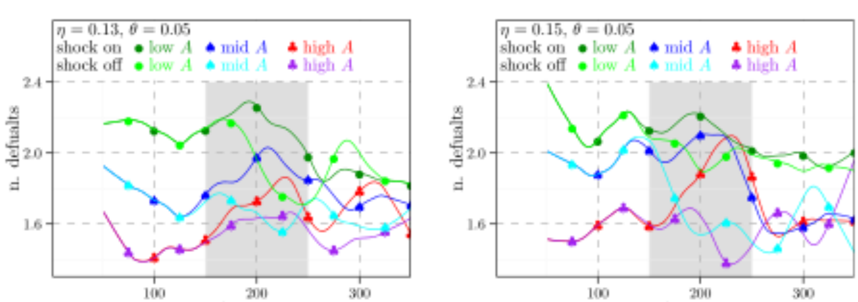


Figure 19. Number of defaults of the three types of firms at different revenue rates η with (on) and without (off) deflation. Shadowed: price change period. Solid line: average number of defaults of 10 runs.

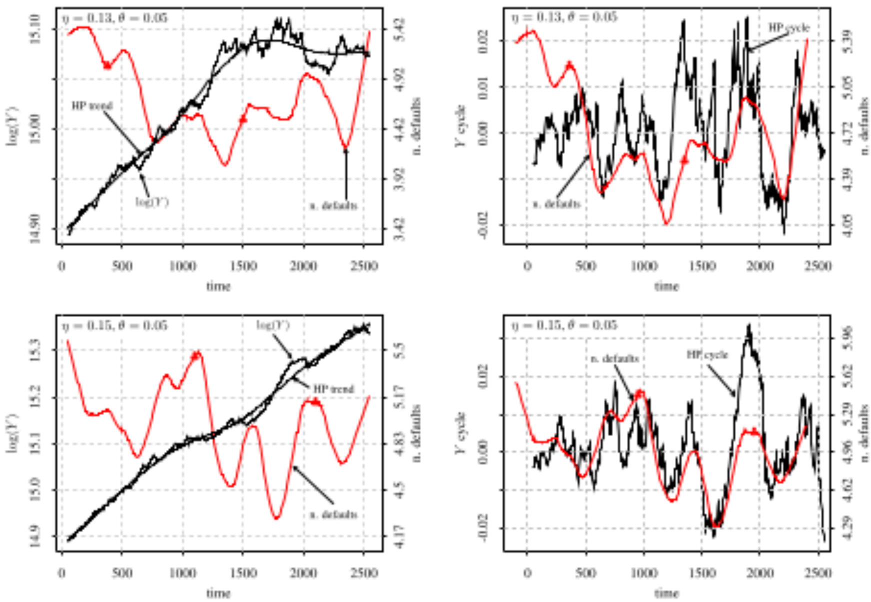


Figure 20. Left charts: aggregate production (fluctuating black line), trend component obtained with Hodrick-Prescott (HP) decomposition of aggregate production (smooth black line) and non-parametric regression of the number of bailouts (red line with clubs). Right charts: cyclical components obtained with HP decomposition of aggregate production (black line) and non-parametric regression of the number of bailouts (red line with clubs).

The number of defaults of firms with high equity base reaches a maximum in the final phase of the deflation.

6.2.3 A single run

The study of a single unperturbed run allows an assessment of endogenous dynamic properties of the model. The presence of significant aggregate fluctuations in absence of aggregate shocks will come out in favour of the presence of mechanism which magnifies idiosyncratic shocks. In these conditions, the model under investigation generates an endogenous business cycle. The black fluctuating line in the left charts of Figure 20 shows the logarithm of the aggregate production of our multi-avatar economy for the two different parametrizations analyzed above. The time series have a ‘real like’ pattern with expansions and recessions showing different length and intensity. The charts also allow for a comparison of the aggregate output with the dynamics of the number of bankruptcies (red line with clubs; this line is obtained by applying nonparametric smoothing techniques). It can be observed that the number of bailouts increases during the expansion period. When the business cycle reverts, firms' financial position keeps worsening for a while before reverting its slope.

To make this observation more evident, we refine our investigation. In particular, we perform the Hodrick-Prescott decomposition[11] of the aggregate production and compare the smoothed series of the number of defaults with the cyclical component. The trend component is reported in the left charts of Figure 20 as the black smooth line. Right charts of the same Figure report the cyclic component as the black line and the smoothed number of defaults as the red line with clubs. In the right charts of Figure 20, the red line with clubs is shifted to the right by 150 time ticks to provide a better visual assessment of the number of defaults procyclically. Taking account of this movement, we can assess that the trend in firms' financial position goes on for a while after the inversion points of the aggregate production.

The analysis of the data at firm types level is much more demanding and is currently under investigation. However, the regularities found at the aggregate level show how the movements of firms' financial position are strictly related to the business cycle and this makes the economy to exhibit persistent fluctuations without imposing any relevant exogenous shocks.

7. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

In this paper, we provided new insights on a different possible approach to microfound agents' behaviour which mainly relies on the vision of the economy as a credit production system. On this point, it may be useful to recall two intriguing and hopeful sentences by Augusto Graziani and Hyman P. Minsky who were aware of the difficulties to model the aforementioned vision:

> It would seem reasonable to conclude that the idea of the economy as a simultaneous exchange is an idea not only immortal but also paranormal, as capable to give in to any alternative vision.
>
> (Graziani, 1977, 129, authors' translation)
>
> The short durations of crises means that the smoothing operations that go into data generations as well as econometric analysis will tend to minimize the

[11] Following the insights in Ravn and Uhlig (2002), we use a smoothing parameter $\lambda=1600\times30^4$.

> importance of crises. Because of such factors, it might be that the most meaningful way to test propositions as to the cause and effect of financial instability will be through simulation studies, where the simulation models are designed to reflect alternative ways that financial instability can be induced.
>
> (Minsky, 1970, p. 4)

These sentences, which perhaps do not sound particularly special considering the nowadays economic research frontier, turn to be impressive by thinking that computational techniques become workable only two decades after they were written.

Indeed, computational techniques make it possible to put into action what we have found in Section 5.

In our opinion, the combination between Experimental and Computational Economics may be very useful: by mining experimental data, researchers can get insights into the rules that experimental subjects use when taking decisions. This information could be eventually used to build a more 'lifelike' agent-based model which allows to increase the number of agents to a level that enables to make acceptable comparisons with real macroeconomic data.

In this paper, we focus in particular on firms' financial behaviour. By doing so, we also give a novel contribution to Keynesian economics by inducing its main insights by means of the experimental method and agent-based approach. In future research, we intend to tackle the issue of providing different microfoundations for macro models by combining two approaches, i.e. Experimental and Computational Economics. More specifically, the future goal of our research will be (i) the assessment and enrichment of the behavioural rules adopted in this paper by performing additional experimental exhibits and (ii) the development of a comprehensive experimentally microfounded agent-based macroeconomic model made up of a large number of different types of artificial agents (entrepreneurs, households and banks) all interacting with each other. In other words, by using exploratory experiments we aim at discovering an ecology of behavioural rules that mirror those of real life economic agents so that the resulting artificial macro economy is thoroughly microfounded. According to this conception, we believe that modeling the economy as a complex adaptive system proves to be useful in order to help understanding and managing the abrupt changes sometimes observed (especially during big recessions or depressions) in macroeconomic variables.

In line with the recent studies on emergent processes or behaviours, this kind of new macroeconomic model which will rely on inductive microfoundations may foster to progress Macroeconomics and may be helpful to explain the real dynamics observed in our modern capitalist economies. Moreover, improving the rigor of the model selection at the microeconomic level will provide a microscopic validation that coupled with the macroscopic calibration will become the solid roots for building more reliable agent-based models to be used for policy making.

APPENDIX

Table A1. Ranked average scores

Subjects	*Average score*
$j = 11$	6.92
$j = 13$	6.92
$j = 14$	6.54
$j = 19$	6.42
$j = 9$	6.32
$j = 17$	6.30
$j = 4$	6.24
$j = 12$	6.21
$j = 20$	6.09
$j = 2$	5.83
$j = 5$	5.74
$j = 8$	5.67
$j = 3$	4.81
$j = 15$	4.47
$j = 6$	4.35
$j = 18$	3.97
$j = 7$	3.79
$j = 1$	3.08
$j = 10$	3.00
$j = 16$	2.25

A1. Subjects' average score

Table A2. Subjects' total scores (roi and bailouts)

	B1a		*B1b*		*B1c*		*B2a*		*B2b*		*B2c*		*B3*	
e	$\langle\rho\rangle$	O	$\langle\rho\rangle$	O	$\langle\rho\rangle$	O	$\langle\rho\rangle$	O	$\langle\rho\rangle$	O	$\langle\rho\rangle$	O	$\langle\rho\rangle$	O
$j=1$	8.06	0	6.05	1	0.89	3	4.19	2	3.74	0	2.04	2	4.56	0
$j=2$	7.76	0	7.73	0	7.26	0	6.00	1	5.69	2	5.91	0	6.43	3
$j=3$	7.16	1	7.15	1	7.15	2	6.27	0	4.88	3	4.58	1	6.50	2
$j=4$	8.08	0	7.20	0	6.17	1	7.08	0	5.97	2	5.67	1	7.51	0
$j=5$	7.03	0	5.31	0	5.76	0	5.34	0	5.96	0	5.02	0	6.79	1
$j=6$	6.41	1	6.50	1	6.41	2	6.17	3	5.49	1	5.25	1	6.23	3
$j=7$	8.36	0	3.22	1	−3.83	4	7.19	0	6.06	0	4.30	1	7.23	0
$j=8$	8.67	0	6.58	3	7.03	3	7.67	0	6.70	2	5.25	2	7.76	0
$j=9$	8.34	0	7.34	0	7.37	0	6.96	0	4.89	3	5.35	0	7.00	0
$j=10$	7.80	0	6.60	0	−0.88	9	6.41	0	5.05	2	2.32	1	6.71	1
$j=11$	8.42	0	7.60	0	7.28	0	7.72	0	7.03	1	5.78	2	7.64	0
$j=12$	8.26	0	6.90	0	7.40	0	6.58	1	6.01	2	5.41	1	6.89	0
$j=13$	8.37	0	7.82	0	6.55	0	7.54	0	6.49	1	5.14	0	7.51	0
$j=14$	7.99	0	6.66	0	6.75	0	6.35	1	6.12	0	6.07	0	6.83	0
$j=15$	8.23	0	5.41	0	−2.57	4	6.04	0	5.85	0	4.88	0	7.47	0
$j=16$	7.98	0	−4.02	4	−0.96	2	4.38	0	6.12	0	2.76	1	6.46	0
$j=17$	7.13	0	5.80	0	5.82	0	6.57	0	5.76	0	5.38	0	7.61	0
$j=18$	8.46	0	6.76	1	4.21	8	7.33	1	5.44	5	6.29	0	6.32	2
$j=19$	8.50	0	7.84	0	6.91	1	7.65	1	6.25	1	5.27	2	7.55	0
$j=20$	8.60	0	7.38	0	7.57	0	6.65	2	6.02	2	4.89	0	7.50	2

A2. Software instructions

(1) This experiment gives you the opportunity to test your intuition and your ability as a manager.

(2) You are leading a production firm having a simple balance sheet: production capital is the only item in the assets section and debt and equity are the items in the liabilities section. The table below shows an example:

ASSETS	*LIABILITIES*
	Debt 9,000
Production capital 10,000	
	Equity 1,000

(3) During the test your goals are:

- to limit the number of bailouts;
- to maximize the performance of the firm. The return on investment in percentage (ROI = profit(loss)/assets*100) is taken as measure of performance.

These two aspects are summarized by the score which is calculated as follows:

score = average ROI − number of bailouts.

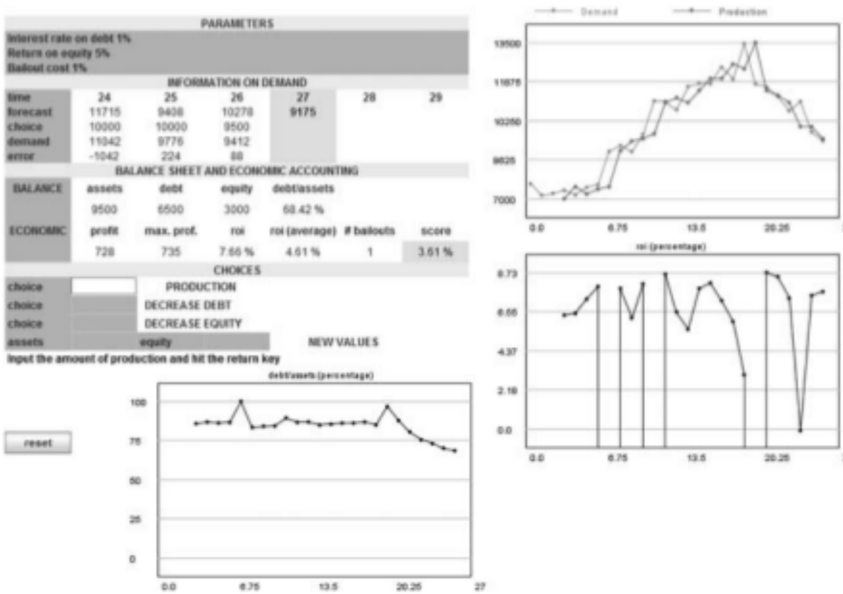
(4) High scores can be achieved:

- by setting production as close as possible to the demand which will be observed on the market (a demand forecast is given to you at this stage);
- by taking the appropriate decisions regarding the financial structure of the firm.

(5) In each period you have the following information set:

- the report on demand:
  - the demand forecasts you had in the three last periods and the demand forecast for the current period;
  - the demand obtained by your firm in the three last periods;
  - the production choices you made in the three last periods;
  - the gaps between demand and production in the three last periods;
- the report on financial and economic situation:
  - the data of your balance sheet (assets, debt and equity) and the percentage of assets financed by debt. These figures are updated after each decision;
  - the data on your performance (the obtained profit, the maximum achievable profit, the ROI of the current period, the average ROI, the number of bailouts and your score);
- charts showing the whole history of:
  - the demand (green line with bullets) and of your choice of production (red line);
  - the percentage of debt (debt/liabilities*100);
  - the Return on Investment (profit (or loss)/assets).

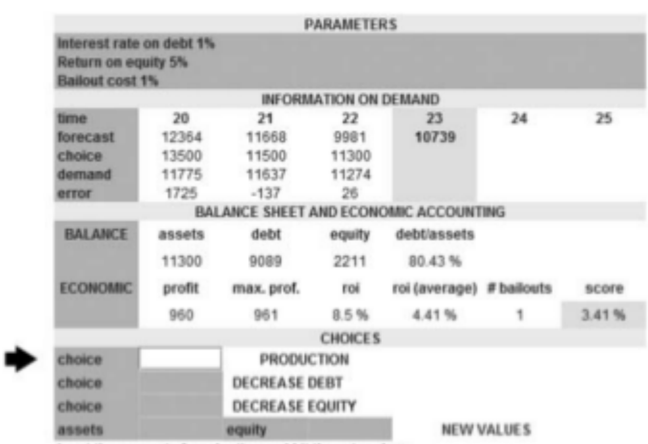
This information is displayed in the computer screen by the window reported hereafter.



In each period, you are asked to make the following choices.

(6) PRODUCTION CHOICE

CHOICE: choose the production (your goal is to rightly guess the demand which will be received by your firm). This choice modifies the levels of assets and debt in your balance sheet (equity does not change).



(6.1) The production capacity can be adjusted by changing assets in the balance sheet (you get one product per unit of assets: in the example given at point 2 of this appendix, your firm makes 10,000 products).

(6.2) Inventories cannot be carried over the subsequent period (think of highly perishable products).

(6.3) Once you have made your choice, the demand is revealed and the economic result (profit or loss) is computed as the difference between revenue, production costs and financing costs. Financing costs are as follows: the interest rate on debt is 1 percentage; the cost of equity is 5 percentage.

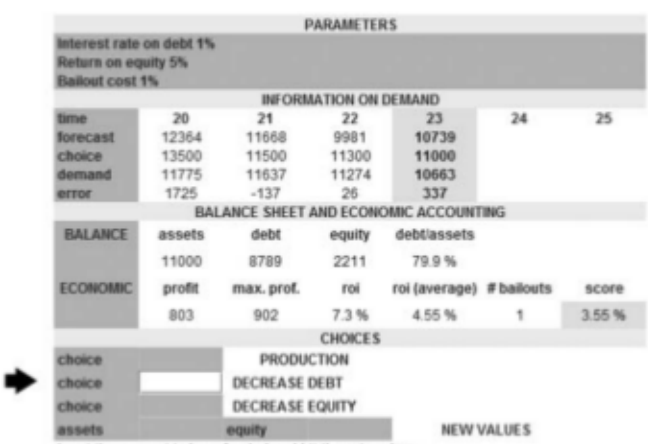
(6.4) The information on the maximum achievable profit is given beside the economic result realized in the current period.

(6.5) Given the financial structure, the maximum profit is achieved when the demand is equal to production: the larger is the gap the lower is your economic result. You can suffer a loss in either cases of excesses and shortages of production.

(6.6) The ROI of the current period, the average ROI up to the current period, the number of bailouts (see point 8.1 of this appendix) and the score (average ROI minus bailouts) are updated after the production choice is made.

(7) IF YOU HAVE A PROFIT:

CHOICE: choose any amount of debt to be repaid to the bank. You cannot repay an amount higher than the profit of the current period. If you choose a positive amount, debt and equity are modified, but assets remain unchanged in your balance sheet.



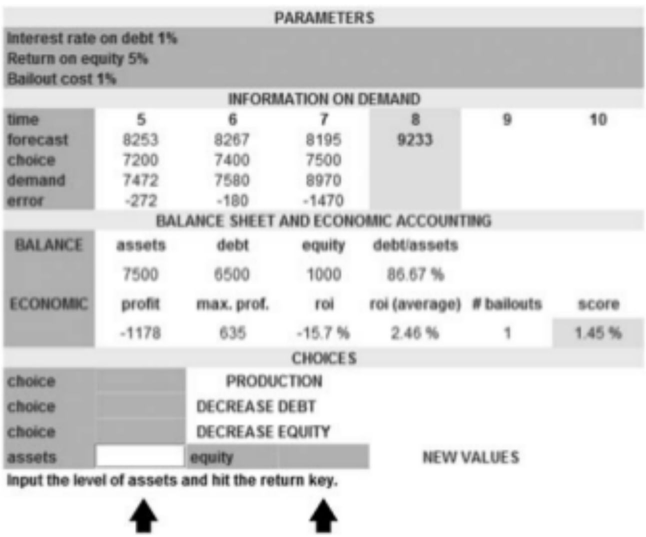
PARAMETERS						
Interest rate on debt 1% Return on equity 5% Bailout cost 1%						
INFORMATION ON DEMAND						
time	20	21	22	23	24	25
forecast	12364	11668	9981	**10739**		
choice	13500	11500	11300	**11000**		
demand	11775	11637	11274	**10663**		
error	1725	-137	26	**337**		
BALANCE SHEET AND ECONOMIC ACCOUNTING						
BALANCE	assets	debt	equity	debt/assets		
	11000	8789	2211	79.9 %		
ECONOMIC	profit	max. prof.	roi	roi (average)	# bailouts	score
	803	902	7.3 %	4.55 %	1	3.55 %
CHOICES						
choice		PRODUCTION				
choice		DECREASE DEBT				
choice		DECREASE EQUITY				
assets		equity			NEW VALUES	

Input the amount to be refunded and hit the return key.

(7.1) Profits unused to reduce debt are your management reward and they cannot be used in the next steps of the experiment.

(8) IF YOU HAVE A LOSS:

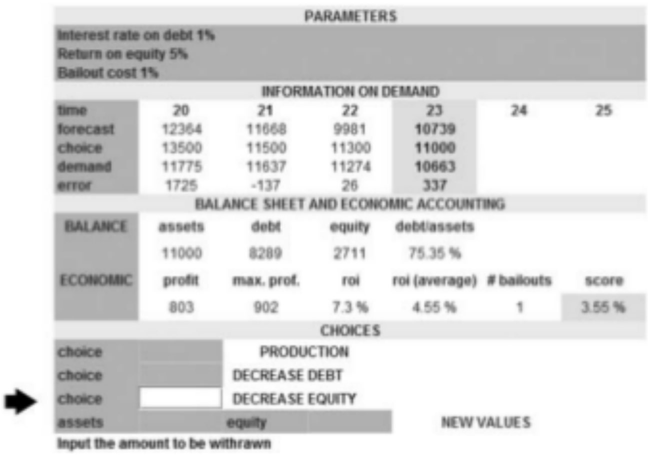
(8.1) A loss reduces assets in the balance sheet, and if the new level of assets is lower than debt you must bailout your firm. The bailout procedure asks you to reset your balance sheet: new levels of assets and equity have to be chosen. In the case of bailout, a penalty of 1 percentage is charged to your average ROI (as specified at point 3 of this appendix, each bailout reduces your score by 1 percentage).



(9) IF THE BAILOUT PROCEDURE IS NOT ACTIVATED (LOSS LOWER THAN EQUITY OR PROFIT):

You can reduce your equity if it is deemed too high.

CHOICE: choose to reduce the amount of capital if it is deemed too high. If a positive value is chosen, debt and equity are modified, but assets remain unchanged in your balance sheet.



A3. Informed consent information

Please review the information below before confirming your agreement to this policy at the bottom.

Registered subjects are invited to participate in research studies at University of Chieti-Pescara. The research studies help social scientists better understand decision-making by human subjects. Information that could identify you will remain confidential and will disclosed only with your permission or as required by law.

You may sign up to participate in specific experiment sessions from 26 September 2011 to 30 September 2011. If you chose to participate, you will be asked to make decisions for which you will be paid. At the beginning of the session, you will receive detailed and accurate instructions describing how payments will depend on decisions made by you and other participants. The rules and the payments may vary across sessions and may differ between participants. Interaction takes place over a computer network, and your personal identity is not revealed to other participants. Should you choose to withdraw after listening to the instructions, or if we cannot use you in the session for any reason, you are entitled to a show up payment and are under no further obligation to us. If you choose to stay for the decision making portion of the session, you are entitled to the show-up payment plus whatever money you have earned during the course of the session. Payment is made following the last session in cash. Only those participants who have attended and completed all sessions will be paid. Payment is made in private and you will be asked to sign a payment receipt. The receipt is for accounting purposes only and will not be linked to your responses.

Participants do not waive any legal rights through their participation. Your participation is voluntary. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty. Your decision whether or not to participate will not affect your relationship with University of Chieti- Pescara or any other organization. The use of deception at University of Chieti-Pescara is prohibited. If you have any questions about experimental economics laboratory, the research conducted at University of Chieti- Pescara, or if you wish to remove your registration information from our database, or if you have any questions regarding your rights as a research subject, you may contact Professor Gianfranco Giulioni or Professor Edgardo Bucciarelli: g.giulioni@unich.it or e.bucciarelli@unich.it.

By ticking 'YES' at the bottom of this document, you are indicating that you have read and agreed with this information. Once registered, we may contact you in the future by e-mail to let you know of forthcoming sessions. You are welcome to print out a copy of this page for your records.

PRIVACY POLICY

Participant database

All participant information will not be passed on to a third party. We use the data only for the following purposes:

- to inform and send invitations to potential participants about new laboratory and/or internet experiments;
- to accomplish a scientifically motivated selection of participants for certain experiment participant requirements;
- examine and track the participants experiment session history within our laboratory.

There is no published record connecting the identity or personal data gathered in the experimental economics laboratory and a participants experiment data gathered during an experiment session.

A participant can determine at any time that they do not want to receive further invitations to any future experiments. A registered participant can request at any time to have us delete without reservation all personal information about them gathered in our recruitment database. To initiate this request, an informal written and signed request for deletion is to be send to: Edgardo Bucciarelli, DMQTE, Viale Pindaro n. 42, 65,127 Pescara (Italy).

LABORATORY EXPERIMENTS

Data are generated by the decisions that the participants make at any given experiment session. This data are evaluated scientifically by a computer system using an application designed for each type of experiment. The decision data will essentially be made anonymous, and will not used in such a way as to allow the data to be tracked back to any specific participant. The generated anonymous data are used for the production by scientific research and lectures.

Do you agree with the informed consent information and the privacy policy?

YES - NO

References data of the participant in the lab experiment:
Last name……………………………………………
first name……………………………………………
place of residence……………………………………
Current academic studies……………………………
Phone and e-mail……………………………………
Signature……………………………………………

A4. Subjects' rewards

Our initiative was advertised among students registered at the Masters degree of the Faculty of Economics and Management. Twenty three students responded to the call. Due to our intention to compare results (especially of the same subject in different situations), we stressed the importance to attend all the four sessions since we met them for the first time.

The incentive to progress in the experimental project was represented by cash payments. In each session, a subject received five Euro just to showing up and an additional amount proportional to the score achieved in the session (the additional amount has a maximum of five Euro). Subjects were informed the day after each experimental session about their reward in a sealed envelope.

We informed that the first session would have been more generous because of the existence of an additional premium to be awarded to the subject (or split among the subjects) having the best performance (it was an additional expedient to prevent that the time of discovering the optimal rule could be biased by accidental communication among subjects).

Twenty one of the subjects 23 subjects who responded to the call attended the first session; 20 of them completed the whole experimental project.

	26 Sept	28 Sept	29 Sept	30 Sept
$j = 1$	9	10	6	8
$j = 2$	11.5	10	8	7.5
$j = 3$	11.5	9	8	7.5
$j = 4$	8	9.5	9	10
$j = 5$	11.5	8.5	10	9
$j = 6$	11.5	8.5	7	7.5
$j = 7$	6	6.5	9.5	8
$j = 8$	11.5	9	8.5	9.5
$j = 9$	9	9.5	8.5	9
$j = 10$	6	6	8.5	6
$j = 11$	11.5	10	9	9.5
$j = 12$	8	9.5	8.5	8.5
$j = 13$	11.5	9.5	9.5	10
$j = 14$	11.5	9.5	9.5	9.5
$j = 15$	11.5	9.5	9.5	9
$j = 16$	11.5	7	7	8.5
$j = 17$	11.5	9	10	8
$j = 18$	9	9	8	7.5
$j = 19$	9	9.5	8.5	8
$j = 20$	8	9.5	8	7.5

A5. Experimental subject 14: Describing the subject's dynamic behaviour with charts

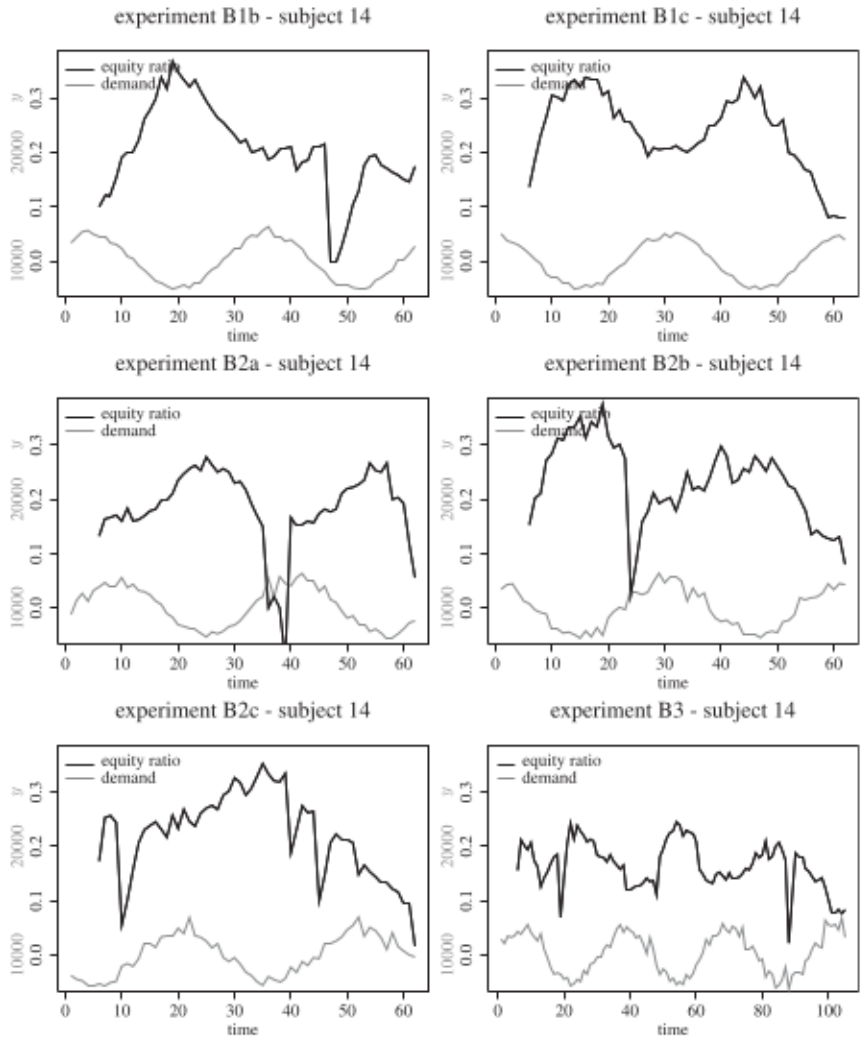


Figure A1. Equity ratio and demand of experimental subject 13 in experiments B1b, B1c, B2a, B2b, B2c and B3.

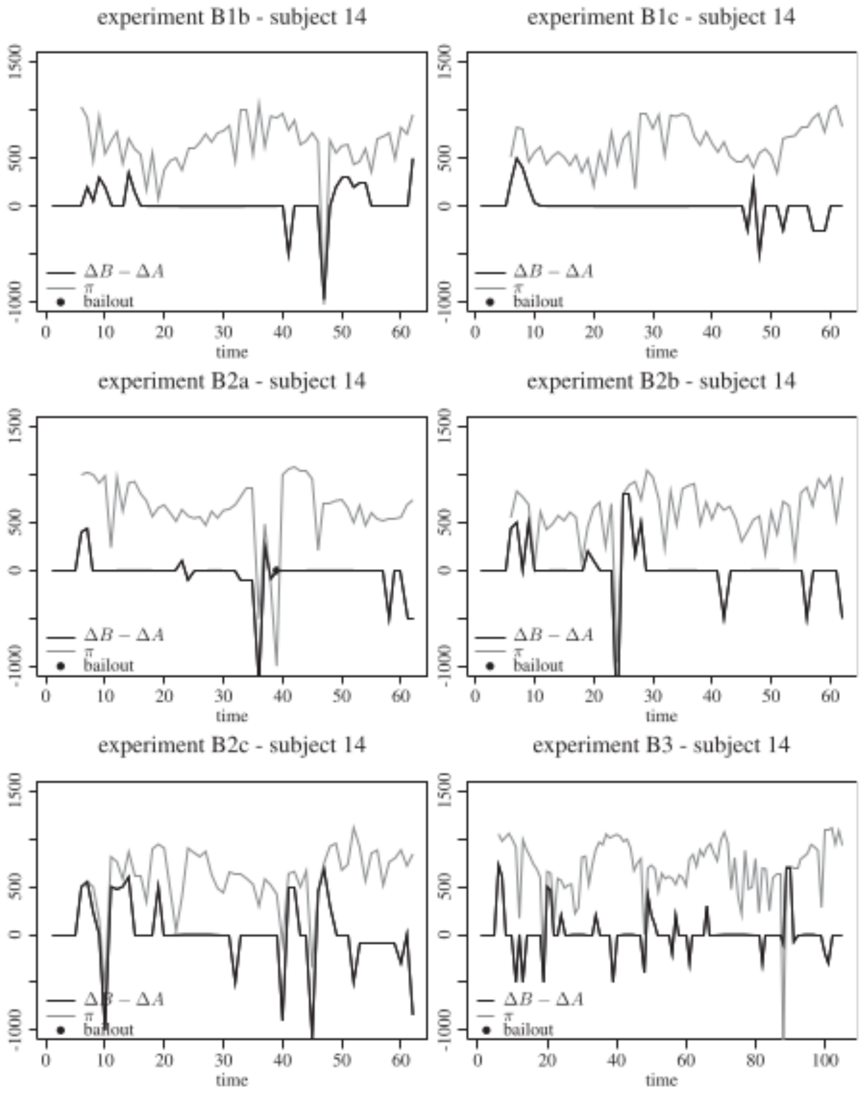


Figure A2. π_t *and* $\Delta B_t - \Delta A_t$ *of experimental subject 14 in experiments B1b, B1c, B2a, B2b, B2c and B3.*

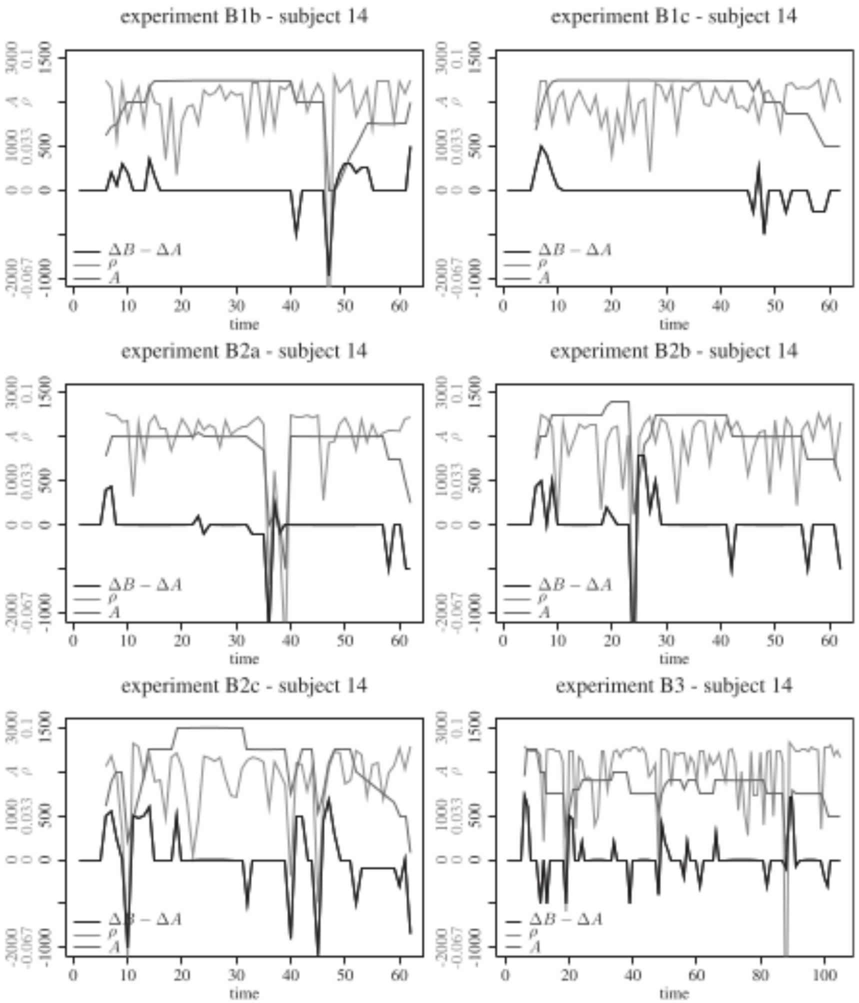


Figure A3. $\Delta B_t - \Delta A_t$, *ρ and A of experimental subject 14 in experiments B1b, B1c, B2a, B2b, B2c and B3.*

A6. Experimental subject 13: Describing the subject's dynamic behaviour with charts

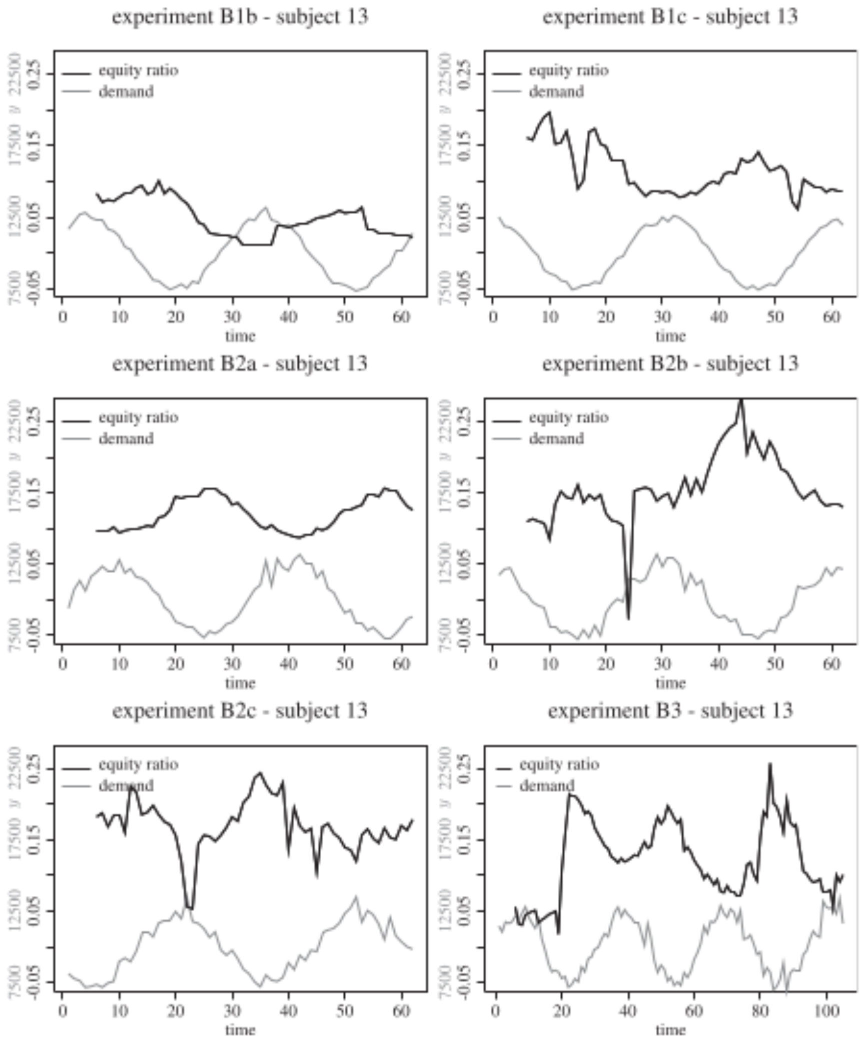


Figure A4. Equity ratio and demand of experimental subject 13 in experiments B1b, B1c, B2a, B2b, B2c and B3.

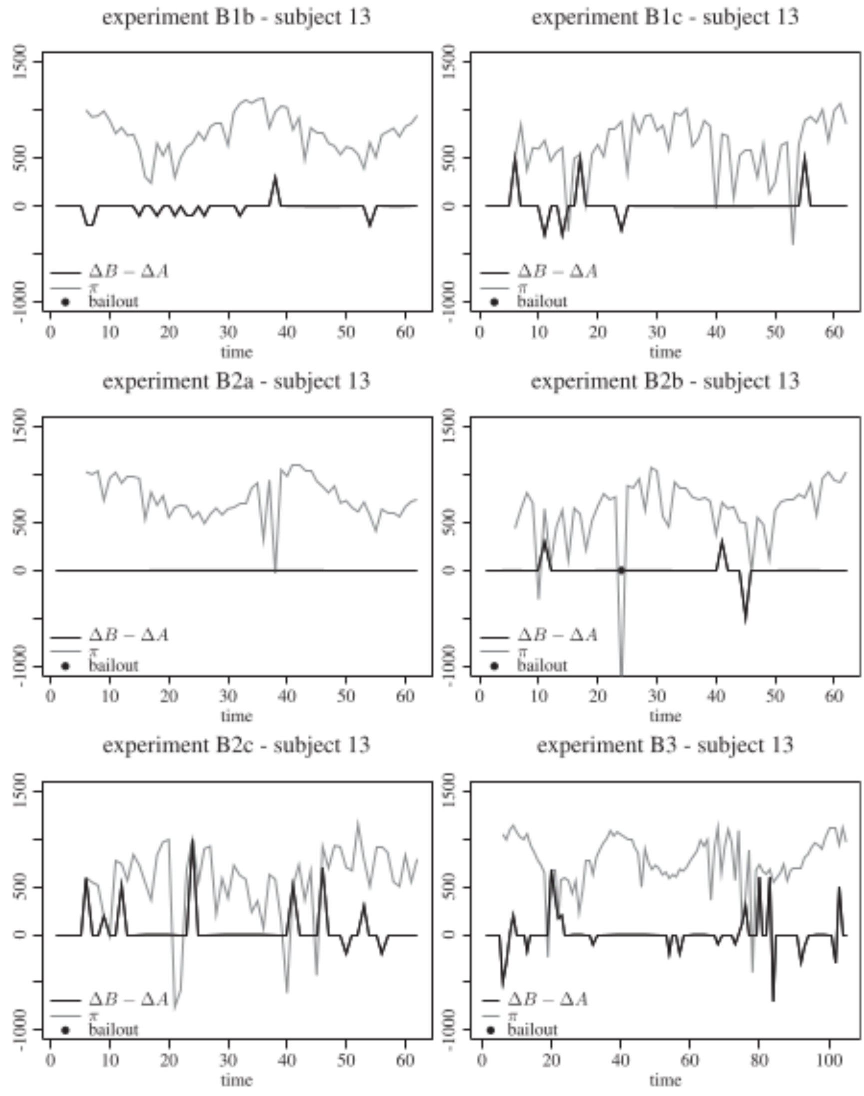


Figure A5. π_t *and* $\Delta B_t - \Delta A_t$ *of experimental subject 13 in experiments B1b, B1c, B2a, B2b, B2c and B3.*

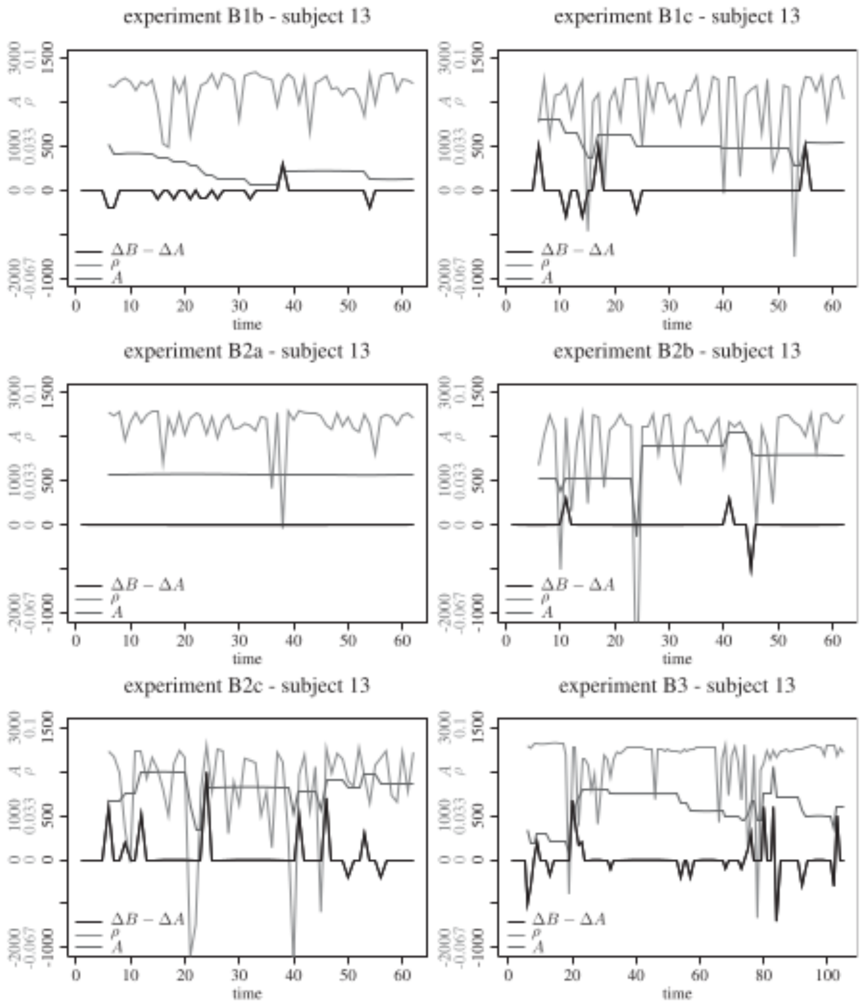


Figure A6. $\Delta B_t - \Delta A_t$, ρ *and* A *of experimental subject 13 in experiments B1b, B1c, B2a, B2b, B2c and B3.*

A7. Experimental subject 11: Describing the subject's dynamic behaviour with charts

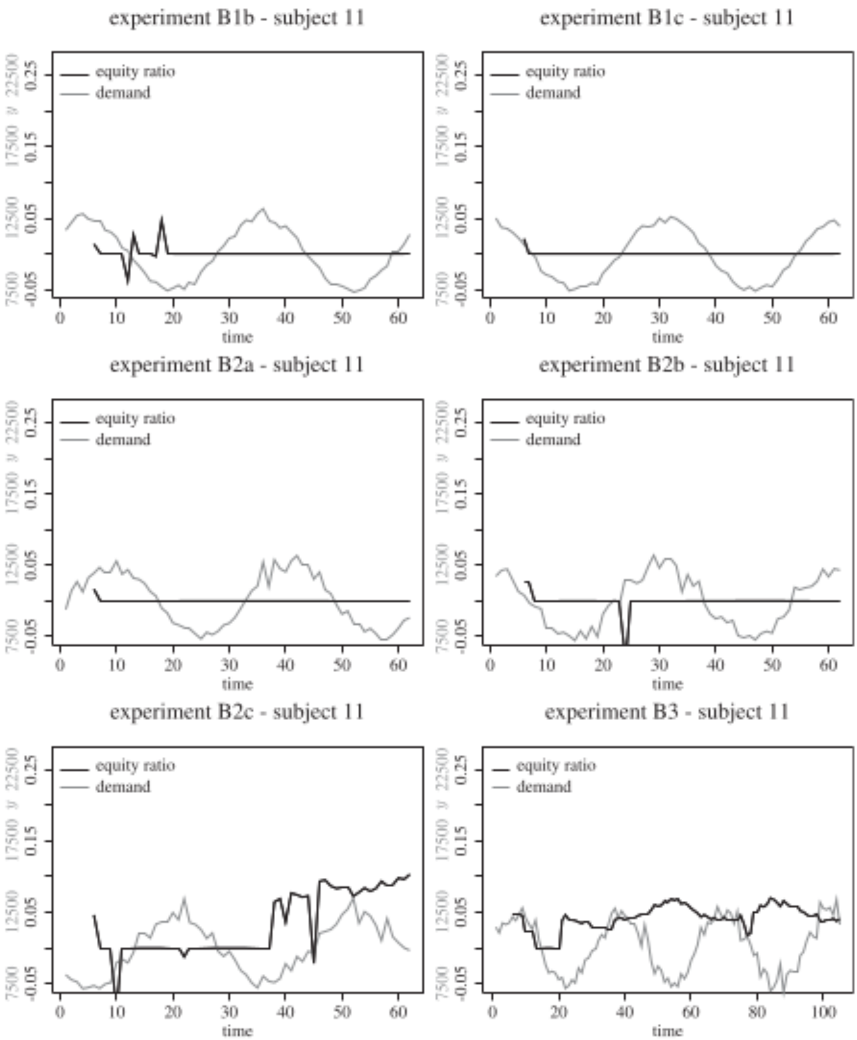


Figure A7. Equity ratio and demand of experimental subject 11 in experiments B1b, B1c, B2a, B2b, B2c and B3.

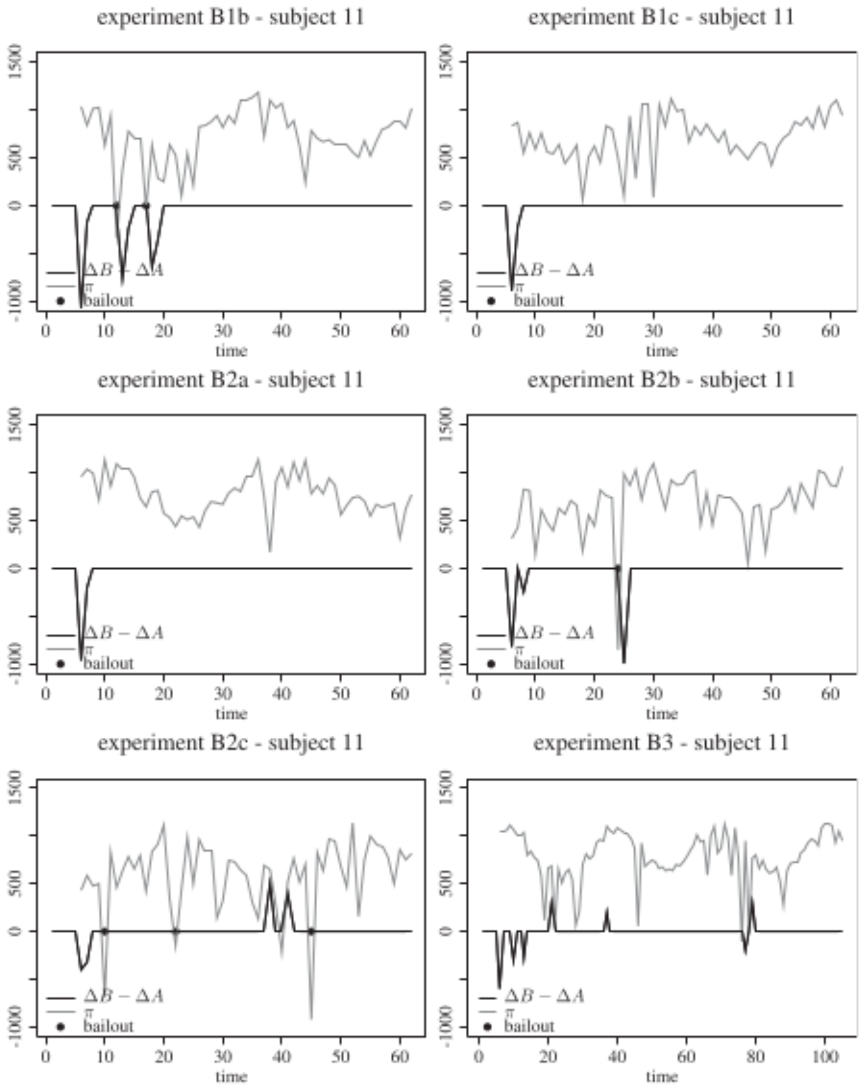


Figure A8. π_t *and* $\Delta B_t - \Delta A_t$ *of experimental subject 11 in experiments B1b, B1c, B2a, B2b, B2c and B3.*

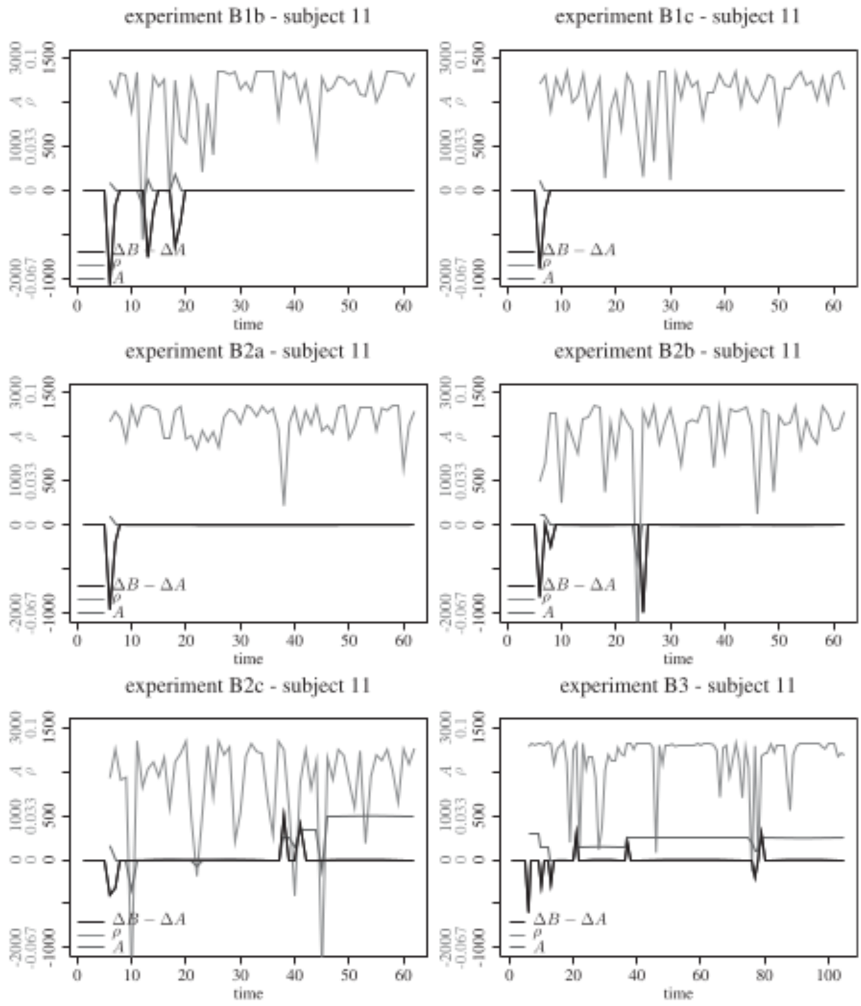


Figure A9. $\Delta B_t - \Delta A_t$, ρ *and* A *of experimental subject 11 in experiments B1b, B1c, B2a, B2b, B2c and B3.*

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