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1.1 Introduction

The agent-based framework provides an useful computational facility for economics, where performing experiments on policy design issues in a realistic environment, characterized by non-clearing markets and bounded rational agents (see Tesfatsion and Judd (2006) for a recent survey). Under this respect, this study addresses both the issue of monetary policy design by the central bank, that operates by means of the interest rate setting, and the issue of fiscal policy design by the government, that decides among different taxation strategies.

A distinctive feature of our study is the endogenous modelling of agents financial decisions, e.g., portfolio allocation for households or dividend payment for firms, who make choices which are subject to the policy strategies by the Government and the Central Bank about taxation and interest rates.

A particular attention is devoted to the balance sheets, considering the dynamics of the financial flows among agents. Firms and bank's equity are divided into shares among households and traded in the financial market. Firms also recur to debt financing, asking for bank loans. The bank collects households deposit and accesses to the standing facilities of the central bank, that sets the interest rate. The government collect taxes and pays bonds coupons to bondholders.

Another important feature of the model concerns households beliefs formation mechanism and households financial preferences. The belief formation process on asset returns takes into account expected cash flows, establishing an endogenous integration between the financial side and the real side of the economy. The model of financial preferences applies some general concepts from *Prospect Theory* Kahneman and Tversky (1979); Tversky and Kahneman (1992), such as the endowment effect (i.e., agents derive utility not from wealth, but from gains and losses defined to some reference level), and loss aversion (i.e., a loss hurts more than an equally large gain produces joy).

Barberis et al. Barberis et al. (2001) recently proposed a model of agents financial decision making, according to *Prospect Theory's* psychological assumptions, following the standard consumption-based equilibrium asset pricing framework. In this respect, our approach is different and consists into the integration of a preference structure based on *Prospect Theory* in an agent-based model of a financial economy, in the lines of recent studies in the field, see e.g. Raberto et al. (2008). In particular, our work is based on the concepts of myopic loss aversion and mental accounting Benartzi and Thaler (1995).

The monetary policy of the central bank is based on an inflation targeting rule, and uses the interest rate as an operational instrument. On the other hand, firms take their dividends pay-out policy and investment decisions on the base of the central bank interest rate. The main idea is that firms will compare the debt cost with the equity capital cost, and will consequently decide their financing strategies, i.e., asking for bank credit or resorting to internal resources, if available.

The paper is organized as follows. The model is outlined in Section 1.2. Computational experiments and results are discussed in Section **??**. Section **??** provides some concluding remarks.

1.2 The model

The general pattern of the model is outlined in Figure 1.1, where the main interactions among agents are represented. It is worth noting that, with respect to the financial flows, the model is closed. Figure 1.1 shows that all the flows between agents are contained in the model: there are neither exogenous input flows nor output flows. All the decision making of the agents is also endogenous and depends on behavioral rules that will be explained in the sections of agents description with more detail. Lacking a labor market in the model, the wage level is determined exogenously by means of a stochastic process.

The time structure of the model is the following: two nested time units are considered, let say the day and the month. The month is indexed by τ; firms, the commercial bank, the Government and the central bank make decisions on a monthly basis. In order to fully take into account the interplay between the financial and real variables of the economy, a stylized credit and consumption goods market have been considered operating on a monthly basis besides the financial market. Even if firm profits and households wage income are exogenously give, a goods market with price setting firm has been considered necessary to study the effects of monetary policy. Besides, a stylized crdit market has been functional to address the problem of financing investments. Conversely, the financial market operates daily and the day, indexed by t, is the time unit considered by households for their financial investments. Each month is supposed to be subdivided into a given number of trading days. Monthly events are supposed to occur before the first day of the corresponding month.

1.2.1 Firms

The production sector is characterized by the M firms producing an homogeneous consumption goods, henceforth CGPs, and by a single monopolistic state-owned investment producing firm, henceforth IGP. Each CGP j is characterized by a variable endowment of

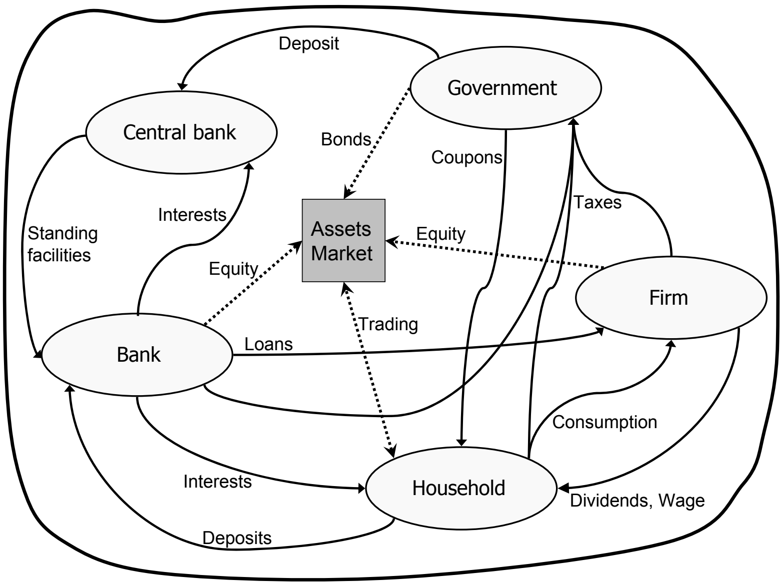

Figure 1.1: General scheme of the main interactions in the model. Financial flows between agents are represented, along with their interaction with the multi-asset financial market.

physical capital A^j_τ, and by a time-varying return on physical capital ξ^j_τ, modeled according to an exogenous autoregressive stochastic process; the quantity $\xi^j_\tau A^j_\tau$ sets the earnings before interests and taxes obtained by the CGP. The initial level of physical capital A^j_0 is determined by both equity capital E^j_0 and debt financing D^j_0, i.e., $A^j_0 = (E^j_0 + D^j_0)/P_0$, where P_0 is the initial value of the price level of both consumption and capital goods, and E^j_0 and D^j_0 are the initial amount of equity and loan in nominal terms. The equity of each CGP is divided into $\mathcal{N}^j$ shares among households and traded in the financial market. The initial price of each firm share s^j_0 is set to $E^j_0/\mathcal{N}^j$. The debt is a loan provided by the commercial bank.

Capital is the only factor of production. The supply of consumption goods by each firm, $Q^{s,j}_\tau$, is then a linear function of physical capital as follows:

$$Q^{s,j}_\tau = a\,\kappa^j_\tau A^j_\tau; \tag{1.1}$$

where a is a constant and κ^j_τ represents exogenous productivity shocks modeled according to a lognormal distribution with given variance and unitary mean. The consumption goods market is a posted price market, where CGPs are price setters and each household is given a random priority to buy at the lower available price. Each CGP set its selling price p^j_τ and production target $Q^{t,j}_\tau$ according to an adaptive behavioral rule which take into account past firm sales and past firm price relative to the past price level. Past firm sales are considered as a proxy of future demand at the posted price, while the comparison with the price level is taken as an indicator the firm pricing policy with respect to competitors. In particular, four nested distinct cases are considered. First, we distinguish the case if the firm has been rationed or not in the goods market in the previous period. If the firm was able to sell all production and its price was lower than price level, then it finds better to increase revenues by increasing the price, which was lower than its average competitors, with the confidence to able to sell again the entire production. Its present production target is then set at the previous supply, with the constraint of a minimum level of supply, corresponding to a zero profit scenario.

Net earnings π^j_τ for each firm are given by:

$$\pi^j_\tau = \xi^j_{\tau-1} A^j_{\tau-1} - r^L_{\tau-1} D^j_{\tau-1} - T^j_\tau \,, \tag{1.2}$$

where T^j_τ are taxes paid to the Government on gross earnings, after deducing interest payment, and r^L is the commercial bank lending rate. Net earnings can be paid to shareholders by means of dividends d^j_τ or partially retained to reduce the loan. New investment in physical capital I^j_τ is financed by additional bank loan; however, firms may be rationed in the credit market and so may be unable to fulfill their entire investment plan $I^{d,j}_\tau$, i.e. $I^j_\tau \leq I^{d,j}_\tau$.

Firm dividends payout policy is based on the comparison between the return on equity (ROE), i.e., the cost of equity, computed at market value, and the cost of debt. Basically, if the debt cost is higher than ROE, the firm decreases dividends payout in order to reduce its debt burden; whereas, in the opposite case, the firm has an incentive to became free of its excess costly capital by rising its dividends payout. Higher dividends should increase the share price and so reduce the ROE. Given the stock market capitalization of the firm $\mathcal{E}^|_\tau = \mathcal{N}^j s^j_\tau$, the ROE at month τ is defined as $\pi^j_\tau / \mathcal{E}^|_{\tau-\infty}$, then the payout policy is determined by the percentage θ^j_τ of net earnings, if positive, distributed to shareholders in form of dividends, as follows:

$$\begin{cases} \theta^j_\tau = \theta^j_{\tau-1} + \hat{\theta} & \text{if} \quad (ROE - r^L_\tau) \ > \ \bar{\theta}^j, , \\ \theta^j_\tau = \theta^j_{\tau-1} - \hat{\theta} & \text{if} \quad (ROE - r^L_\tau) \ < -\bar{\theta}^j, , \end{cases} \tag{1.3}$$

$\hat{\theta}$ is the adjusting step, and $\bar{\theta}^j$ is a sensitivity factor relative to firm j.

Let us note retained earnings with $\widehat{\pi}^j$, i.e., $\widehat{\pi}^j_\tau = \pi^j_\tau - \mathcal{N}^j d^j_\tau$, where d^j_τ is the per share dividend. The dynamics of firms assets and liabilities is thus given by:

$$\begin{cases} A^j_\tau = (1-\gamma) A^j_{\tau-1} + I^j_\tau \,, \\ D^j_\tau = D^j_{\tau-1} + P_\tau I^j_\tau - \widehat{\pi}^j_\tau \,, \\ E^j_\tau = P_\tau A^j_\tau - D^j_\tau \,, \end{cases} \tag{1.4}$$

where γ is the rate of capital depreciation and P_τ is the price level at month τ determined in the goods market. Investment in new physical capital is paid at the current price level. For the sake of simplicity it is supposed that investment goods are provided by a single state-owned monopolistic firm with no production capacity constraint at the current price level, and no production costs. Investment costs of the consumption goods producing firms are then the profits of the investment goods producing firm; the profits are taken into account in the monthly Government financial budget. P_τ is also used to evaluate the current stock of physical capital, and then to compute the book value of equity E^j_τ, which in principle can be very different from the stock market capitalization of the firm $\mathcal{E}^|_\tau$.

1.2.2 Households

Households are simultaneously taking the roles of workers, consumers and market traders. They receive a labor income from the firm at a common wage, if employed, and an unemployment subsidy from the government, if unemployed.

An essential aspect of the model is defining agents' behavior while facing their savings-consumption decision, that have been modeled within the framework of the buffer-stock theory of consumption Carroll (2001); Deaton (1992). The dynamics of cash on hand X^i_τ is given by:

$$X^i_{\tau+1} = R^i_\tau\left(X^i_\tau - C^i_\tau\right) + \varsigma^i_{\tau+1} w_{\tau+1}\,, \tag{1.5}$$

where R^i represents the gross total return of savings at time t, thus incorporating price returns, assets' cash flows and interests on the saving account. The term $\varsigma^i_{\tau+1} w_{\tau+1}$ refers to labor income at time $\tau + 1$, which will be equal to zero if the household is unemployed, i.e., $\varsigma^i_{\tau+1} = 0$. Let us consider the ratio x^i_τ between cash on hand and permanent labor income, i.e.,

$$x^i_\tau = X^i_\tau / w_\tau \quad \forall t. \tag{1.6}$$

The main attractive feature of the buffer-stock theory of saving is that optimal consumption behavior can be articulated in very simple and intuitive terms. Consumers have a target level of cash on hand to income ratio $\bar{x}^i$, i.e., a target buffer stock of liquid assets with respect to permanent income, that they use to smooth consumption in the face of an uncertain income stream. If their buffer stock falls below target, their consumption level C^i_τ will be lower than their expected income and liquid assets will rise, while if they have assets in excess of their target they will spend freely and assets will fall.

Households can either invest their savings in the asset market, by trading stocks or bonds, or can put them in a saving account that pays a fixed, risk-free interest rate. They form beliefs about assets future returns considering a common forward horizon of three months. The implied idea is that households are able to foresee assets trends only for short periods of time, also if they plan to hold their assets for a longer period of time. Besides, each household i is characterized by an evaluation period ϵ_i which is a multiple of the forward horizon and is used to compute preferences and evaluate investments Benartzi and Thaler (1995). Beliefs are formed according to three stylized behavior, i.e., random, chartist and fundamental. In particular, expected asset returns for each asset j, issued by the j-th firm, are given by a linear combination of three terms: a scalar random component $\rho^r_{j,i}$, a set of past returns $\rho^c_{j,i}$ computed in a backward time window, and a fundamentalist scalar term $\rho^f_{j,i}$. In order to compute the fundamental return, each household estimates a fundamental price

$$p_{j,i} = (E^j_\tau + \widehat{\pi}^j)/\mathcal{N}^j \tag{1.7}$$

taking into account the equity capital of firm j and the expected retained earnings in the forward horizon. Given the fundamental price and considering the last market price, the household derives the expected fundamental return $\rho^f_{j,i}$. Composing the three terms and adding expected cash flow yields $y^e_{j,i}$ (i.e., dividends for stocks and coupons for bonds), households determines a set of total expected returns $\rho_{j,i}$ as

$$\rho_{j,i} = \alpha_i^r \rho_{j,i}^r + \alpha_i^c \rho_{j,i}^c + \alpha_i^f \rho_{j,i}^f + y_{j,i}^e \tag{1.8}$$

where α_i^r, α_i^c and α_i^f are household's weights that sum to one. Then households build a normalized histogram $H[\rho_{j,i}]$ where the set of total expected returns is grouped in M_i bins. It is worth noting that a large number of bins M_i means that the household is more careful when examining the asset's past performance, taking into account more elements (it uses a higher resolution to build the histogram).

The histogram $H[\rho_{j,i}]$ can be seen as a prospect $\mathcal{P} = [\rho_{j,i}^H, p_{j,i}^H]$ where $\rho_{j,i}^H$ are the bins center values of the expected total returns histogram and $p_{j,i}^H$ are the associated probabilities, i.e., the level of the normalized histogram. If the evaluation period of the household is longer than the forward horizon used in the beliefs formation, it means that the prospect should be iterated accordingly. To this aim, we modelled how the structure of a prospect varies when the evaluation period changes. Following the concepts of myopic loss aversion, we introduce a new prospect $\mathcal{P}^n$ that represents the mental accounting (see Benartzi and Thaler (1995)) of the agent when considering the risky investment, that means an n times iteration of prospect $\mathcal{P}$. Accordingly, the number of elements of the iterated prospect $\mathcal{P}^n$ will pass from M_i to $\mathcal{M}_i$. Thus, each household will face a new prospect $\mathcal{P}^n = [\rho_{j,i}^{H_n}, p_{j,i}^{H_n}]$ depending on its evaluation period.

Prospect theory utility is defined over gains and losses, i.e., returns ρ^{H_n}, rather than levels of wealth. The value function for the ith household has the following form:

$$v_i(\rho_{j,i}^{H_n}) = \begin{cases} (\rho_{j,i}^{H_n})^\alpha & \text{if} \quad \rho_{j,i}^{H_n} \geq 0\,, \\ -\lambda_i(-\rho_{j,i}^{H_n})^\beta & \text{if} \quad \rho_{j,i}^{H_n} < 0\,, \end{cases} \tag{1.9}$$

where λ_i is the coefficient of loss aversion of household i. By means of behavioral experiments Kahneman and Tversky estimated α and β to be equal to 0.88 and λ to be equal to 2.25 Kahneman and Tversky (1979).

Given the histogram of composed expected returns, the ith household may calculate the utility of asset j as,

$$U_{j,i} = \sum_{\mathcal{M}_i} p_{j,i}^{H_n}\ v(\rho_{j,i}^{H_n}), \tag{1.10}$$

where $p_{j,i}^{H_n}$ are the probabilities associated to $\rho_{j,i}^{H_n}$. These utilities are finally normalized and mapped into assets weights by means of a linear transformation. Once the assets weights are available, the household can build its desired portfolio and emit orders consequently. Orders are therefore submitted to a clearing house that determines assets new prices.

1.2.3 The banking sector

The commercial bank collects households deposits B_τ, provides loans L_τ to firms, and holds a buffer account C_τ at the central bank, which can be positive or negative. The commercial bank sets the lending rate r^L to firms according to a mark-up rule on the central bank policy rate r, i.e., $r^L = \mu_L r$, where $\mu_L > 1$ is the mark-up. The rate on households deposits

r^B is determined by $r^B = \mu_B r$ where μ_B is lesser than one. Net earnings are given by

$$\pi^b_\tau = r_{\tau-1} C_{\tau-1} + r^L_{\tau-1} L_{\tau-1} - r^B_{\tau-1} B_{\tau-1} - T^j_\tau \tag{1.11}$$

where T^j_τ are taxes as a fraction of gross earnings paid to the Government. The capital structure of the bank is composed by both equity capital E^b and debt financing, i.e., the Central Bank account and households deposits. The bank equity is divided into shares among households and traded in the financial market. Given the amount of L and B set by firms and households, respectively, and the dynamics of equity $E^b_\tau = E^b_{\tau-1} + \widehat{\pi}^b_\tau$, where $\widehat{\pi}^b$ are the retained earnings, the bank adjusts C according to the budget constraint $C_\tau = E^b_\tau + B_\tau - L_\tau$.

The central bank implements monetary policy decisions by means of a policy rate r which is used both as a borrowing or lending rate for the commercial bank account.

1.2.4 The government

The Government runs a financial budget. Income is given by a mixture of different taxation policies, that include taxes on households wages, on corporate earnings, and on capital income. Expenditures depend on unemployment benefits b, that are expressed as a percentage of the current wage level, and on the interest rates on government debt. Taxation is adjusted adaptively in order to finance expenditures, running a zero budget target. The government may issue both short-term or long-term bonds in order to finance the budget deficit. Bonds have a face value which is paid at the maturity date, and pay fixed coupons to bondholders anchored to the central bank policy rate. The goal of both the Government and the central bank policies is the pursuit of low volatility in the asset market and of long-run growth in the economy by means of accumulation of physical capital by firms.

Chapter 2

Behavioral Experiments

Portfolio preferences are a key issue while designing artificial models of financial markets. The standard preference structures with constant risk aversion, based on CRRA utility functions, are not able to explain many features of the financial markets. In particular, there are some well known puzzles in finance, which the modern portfolio theory can not solve. Among them, there are the equity premium puzzle (Mehra and Prescott (1985)), the equity home bias puzzle (French and Poterba (1991)), and the stock market participation puzzle (Mankiw and Zeldes (1991) and Haliassos and Bertaut (1995)); for complete surveys see Kocherlakota (1996), Campbell (2000) and Campbell (2003). As explained with more detail in section 1.2.2, in order to overcome the limits of the standard risk aversion approach, we designed a solution that takes into consideration the results of prospect theory concerning human decisions under risky conditions. We developed a preference structure that allows agents to take decisions about their portfolio allocation in a multi asset environment, keeping into consideration the main psychological features emphasized by prospect theory, such as *loss aversion* and *endowment effect*(agents draw utility not from wealth, but from gains and losses defined with respect to some reference level). Many other psychological characteristics, as the *certainty effect* (people underweight outcomes that are merely probable in comparison with outcomes that are obtained with certainty), or the fact that agents weight low probability states too much and high probability states too little, can be easily implemented the future versions of the model, testing their specific effects on the financial market.

In this chapter we present some computational results showing the impact of the main psychological features of the agents on the financial market dynamics. In particular, we investigate the effects of variations in the loss aversion and in the evaluation period, i.e., the the length of time over which an agent aggregates and evaluates returns. In order to facilitate the analysis of results, let us remind that the agents have three different solution available for their financial investment: a bank account (risk free), government bonds (lower risk), and stocks (higher risk). A second important aspect that the reader should keep in mind is that, in the computational experiments presented in this chapter, there is no issuing of new bonds by the government. This means that the total number of assets in

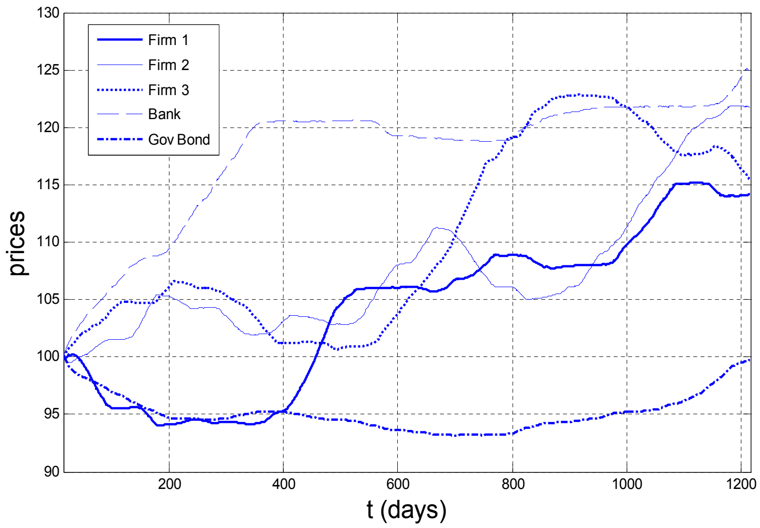

Figure 2.1: Reference simulation. It shows the trajectories of the five assets that are traded in the financial market. Four stocks (issued by three firms and the bank) and a government bond

the market is constant, and that, in average, the percentage of a specific asset in households portfolio is predetermined by this total number of assets. This consideration is relevant in order to explain the method underlying the proposed simulations, inspired by the work of Benartzi and Thaler (1995), that is based on the following principle: keeping fixed a given ratio between stocks and bonds in households portfolio (determined by the total number of assets), we change one of the households psychological parameters, and we observe how the other variables of the system (mainly assets prices) are compelled to vary in order to support that given ratio. This approach, that will be explained in more detail in section 2.1.4, permits us to draw some interesting conclusions on the interpretation of the equity premium puzzle.

2.1 Computational experiments

In this section we present some computational experiments that show the effects of loss aversion on the financial market model. We first introduce in section 2.1.1 a representative simulation of the assets prices evolution in the system, performed with a standard value of loss aversion ($\lambda = 2$), in order to comment the main features of the model. Then we will vary the loss aversion value, checking the effects on the financial market.

2.1.1 Basic simulation

The simulations we present refer to a model populated by 2,000 households and 3 firms. Five assets are traded in the financial market: three firms stocks, the bank stock, and a long term government bond. Firms are endowed with a constant physical capital and make no new investments. The return on physical capital ξ is modeled by means of an

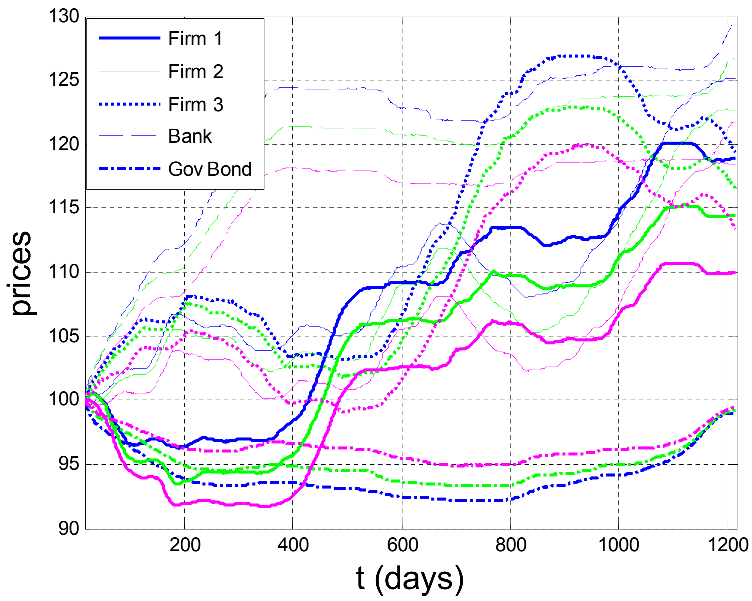

Figure 2.2: Assets prices trajectories depending on different values of loss aversion. The blues line refers to $\lambda = 1.5$, the green line to $\lambda = 2$, and the magenta line to $\lambda = 2.5$.

autoregressive process of order 1 with mean 0.06 and memory parameter 0.9. Firms are characterized by different dividends pay-out strategy; firm 1 pays 80% of its net earnings to shareholders, while firm 2 and firm 3 pay 90% and 100%, respectively. Retained earnings are used to increase the equity base of each firm. Among traders, fundamentalists and chartists are 10% each, while the rest are random traders. The commercial bank mark-up μ_L is 1.3, while μ_B is set equal to 0.9. The bank dividend policy is to pay 100% of its net earnings. The government applies a fixed tax rate of 15% both on capital income for households and on corporate earnings of firms and bank. The government bond maturity date is set at the end of the simulation. Finally, each month is considered to be subdivided in five trading days.

Firms and bank balance sheets have been initialized in order to characterize all stocks by the same initial fundamental price, which have been set to 100. In particular, the initial equity for each of the three firms is equal to 10,000,000, while the bank equity has been set to 6,000,000; besides, the number of shares outstanding is 100,000 for each firm, and 60,000 for the commercial bank. Currency units are arbitrary. Each firm is endowed with an initial debt of 20,000,000 , so that the aggregate amount of loans by the commercial bank to firms is 60,000,000, which, given the bank equity, corresponds to a core tier 1 ratio of 0.1. Households are initially endowed with an equal number of shares for each asset and a bank account of 5,000.

Figures 2.1 presents the assets price levels of the reference simulation. The central bank interest rate is $r = 0.05$, loss aversion λ is set to 2 for all households, and households evaluation period corresponds to 2 times the forward looking window, i.e., $\epsilon_i = 6$ months. A clear and relevant evidence of the basic simulation is that the bond price trajectory

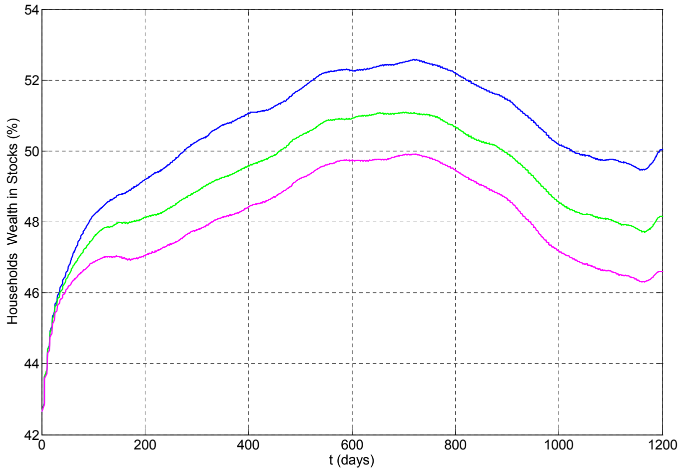

Figure 2.3: The percentage of the aggregated wealth of households invested in stocks. The blue line refers to a loss aversion $\lambda = 1.5$, the green line to $\lambda = 2$, and the magenta line to $\lambda = 2.5$.

exhibits a lower volatility with respect to stocks prices trajectories. It is worth noting that this is an endogenous emerging feature which has not been modeled in advance, but mainly depends on two factors: first, the face value, which is a strong anchoring to the expectations of price dynamics, and second, the bond cash flow which is characterized by constant coupons. On the other hand, stocks pay varying dividends whose value is a fixed fraction of the stochastic process of earnings. The price trajectories are affected by the cash flows of different assets, in particular the commercial bank, which pays the highest dividends, generally results to be the best performing stock. If we limit the analysis to firms stocks, it is worth noting that stock 1 shows an initial significant loss up to day 400, while Firm 2 and Firm 3 show a much better performance. This is due, again, to the higher percentage of profits that Firm 2 and Firm 3 distribute as dividends, that increases the expected total returns of the respective stocks. However, after day 400, the stock price of Firm 1 starts raising, reaching a level that is comparable to the one of Firm 3 and Firm 2 stocks at the end of the simulation. This second effect is due to the retained earnings that increase the equity level of Firm 1, influencing the beliefs of the fundamentalist traders that see a higher fundamental price, according to eq. 1.7, and consequently try to buy it. This mechanism clearly leads to a growth of Firm 1 stock price. Finally, it is worth remarking that the shape of the price processes exhibit jumps, crashing and periods of low volatility, realistic features which clearly depend on the interplay of random, chartist and fundamental strategies.

2.1.2 The role of loss aversion

In this section we present some computational experiments with the aim of clarifying the role of loss aversion in households psychology, and its effect on asset prices and on other

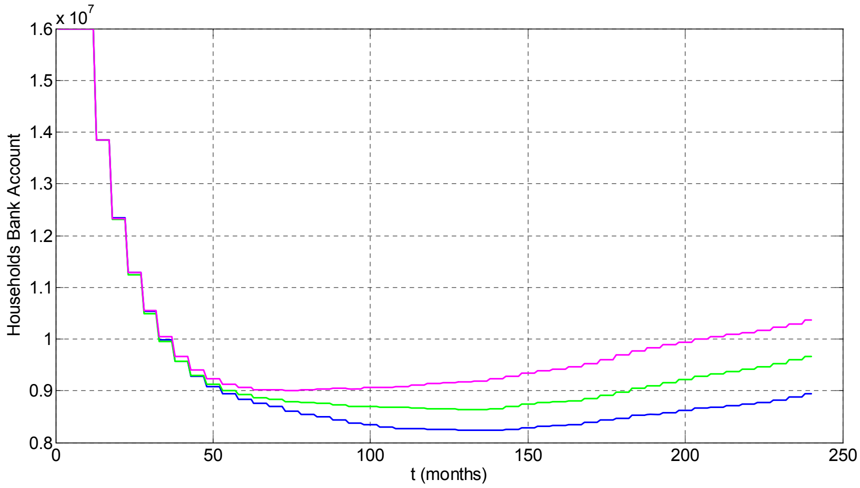

Figure 2.4: The aggregated households bank account depending on different loss aversion. The blue line refers to a loss aversion $\lambda = 1.5$, the green line to $\lambda = 2$, and the magenta line to $\lambda = 2.5$.

variables of the model. Figure 2.2 shows the assets prices trajectories for different values of the loss aversion parameter. In particular, the green line corresponds to a value of $\lambda = 2$, that represents a standard value for loss aversion according to prospect theory, while the blue and magenta lines show the same experiment with a higher (magenta) or lower (blue) value of loss aversion. It can be noticed that a loss aversion growth clearly reduces the stocks price level, increasing on the other hand the price of the government bond. The higher volatility of stocks determines such effect, because households tend to overestimate the risk of loosing money, when $\lambda = 2.5$, with respect to the standard case of $\lambda = 2$. The higher volatility of stocks with respect to bonds, combined with a higher loss aversion, actually determines a stronger perception of future possible losses, inducing investors to opt for safer assets, or to keep money in their bank account. Moreover, the fact that the price reduction happens systematically for every stock, included the bank stock, proves that loss aversion is a key aspect for the investigation of the relative performances between high-risk or low-risk assets, and in particular of the equity premium. Figure 2.2 shows that for lower values of loss aversions we obviously obtain the opposite effect. As the magenta line points out, the level of stocks prices for $\lambda = 1.5$ is higher, reflecting that the households are not as worried by future losses as they were for superior values of λ.

Figure 2.3 confirms the previous results, showing that the aggregated percentage of wealth invested in stocks by households strongly depends on their loss aversion. An evident effect is that for higher values of λ, households keep a lower fraction of stocks in their portfolio. However, it should be remarked that also the global fraction of households wealth invested in the financial market (considering both stocks and bonds) becomes lower when loss aversion increases. This is attested by figure 2.4, representing the dynamics of the aggregated quantity of money deposited in households bank accounts. After a first

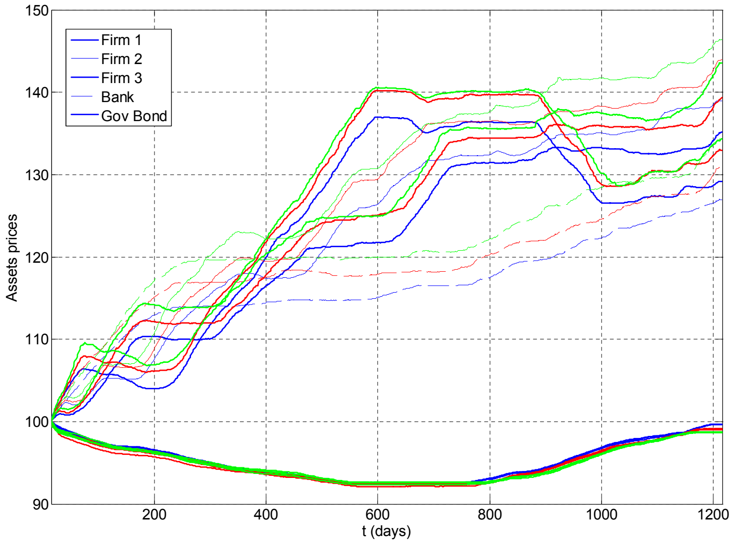

Figure 2.5: Assets monthly cash flows, i.e., dividends for stocks and fixed coupons for the government bond. Currency units are arbitrary.

period of negative trend, due to a settlement from the initial condition, the bank accounts dynamics clearly shows that households with higher loss aversion (magenta line) prefer to keep their money in the bank account rather then buying financial assets.

As expected, loss aversion plays an important role in determining the trends of assets prices. A role that is in some way similar to the one that risk aversion plays in the modern portfolio theory. However, the concept of loss aversion seems more suitable for two main reasons. First because, according to many behavioral economics experiments carried on by economists and psychologists Tversky and Kahneman (1992); **?**, loss aversion captures in a more realistic way the human attitude in front of risky circumstances. Second because the concept of risk seems unfit to explain some important financial phenomena as the high empirical values of the equity premium.

2.1.3 The evaluation period

In this section we present the same type of experiment of section 2.1.2, with the difference that we now vary the evaluation period of households instead of the loss aversion, and we will show that the effect on assets prices is similar in the two cases.

Figure 2.5 shows three series of assets prices trajectories for three different values of the ratio ϵ between households evaluation period and forward horizon, ($\epsilon = 2, 4, 6$). Keeping fixed the forward horizon to 3 months, the evaluation period turns out to be 6 (blue line), 12 (green line) and 18 months (red line). A first glance to figure 2.5 shows that assets prices tend to growth for longer evaluation periods. We remind that here the evaluation period coincides with the holding period, i.e., the planned period for holding an asset. This means that if households intend to keep their assets for a longer period of time, they also

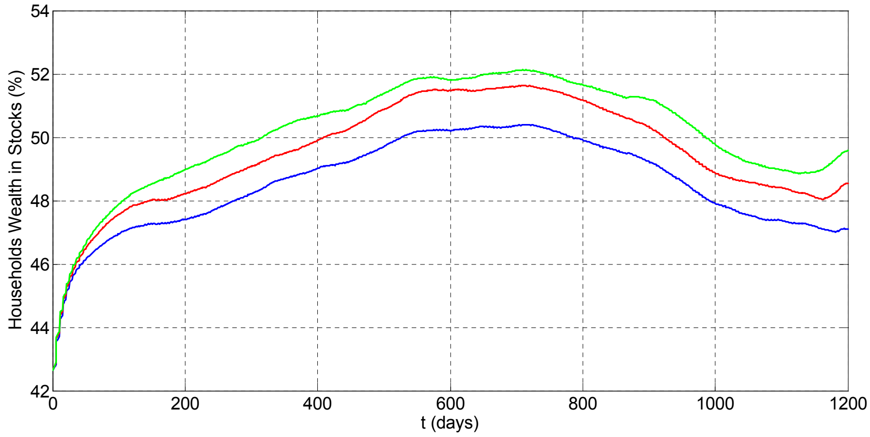

Figure 2.6: The percentage of the aggregated wealth of households invested in stocks. The blue line refers to an evaluation period of 6 moths, the red to a period of12 months, and the green line to period of 18 months.

evaluate that the asset will give higher returns in the long run, therefore increasing the demand for that asset, and its price. This is due to the combined effect of loss aversion and the mechanism of iteration of the beliefs of households, that are formed in shorter horizon (3 months). If the stock returns are, in average, positive, the effect of iterations will modify the basic prospect raising the utility of the the stock, and therefore raising its demand. To clarify this aspect we show one iteration of a belief structure where the household expects a negative return of 1% with 50% probabilities and a positive return of 2% with 50% probabilities.

Initial Prospect: $\big[$(-0.01,0.5) , (0.02,0.5)$\big]$
Utility: $U = 0$ ($\lambda = 2$)
Iterated Prospect: $\big[$(-0.02,0.25) , (0.01,0.5) , (0.04,0.25)$\big]$
Utility: $U = 0.005$ ($\lambda = 2$)

The price variation on government bonds does not seem so clear as in the case of loss aversion variations (see Figure 2.2). This is probably due to the sum of two contrasting effects. For higher evaluation periods, on one side households prefer stocks to bonds, but on the other side they prefer bonds to their bank account. For lower evaluation periods, they prefer bonds to stock, but they also prefer to leave their money in the bank account rather than buying assets. This two combined aspect are probably the reason of the apparent neutrality of bonds prices with respect to the length of the evaluation period. The evidence that households with lower evaluation periods leave their money on bank accounts is presented in figure 2.7. Figure 2.6 clearly shows that increasing the evaluation period, the percentage of households wealth invested in stock raises, confirming that, in the model, households believe that stocks could give better returns in the longer run.

In the next section we show how the loss aversion, combined with a short evaluation

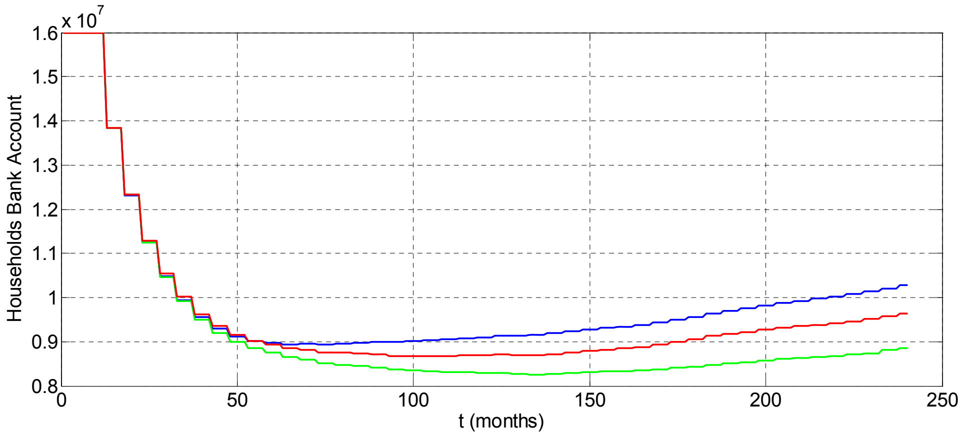

Figure 2.7: The aggregated households bank account depending on different evaluation periods. The blue line refers to an evaluation period of 6 moths, the red to a period of12 months, and the green line to period of 18 months.

period (called myopic loss aversion by Benartzi and Thaler (1995)), can be able to explain the equity premium puzzle, according to the computational results of this model.

2.1.4 The equity premium

Recently Mehra and Prescott wrote (see Mehra and Prescott (2003)): *More than two decades ago, we demonstrated that the equity premium (the return earned by a risky security in excess of that earned by a relatively risk-free T-bill), was an order of magnitude greater than could be rationalized in the context of the standard neoclassical paradigms of financial economics as a premium for bearing risk. We dubbed this historical regularity the "equity premium puzzle".*

In this section we show how our model deals with the equity premium puzzle, presenting the results of some computational experiments. Our perspective strictly follows the approach of Benartzi and Tahler, supposing that agents are characterized by narrow framing, loss aversion, and a specific evaluation period. What we show in this section is that the magnitude of the equity premium strongly depends on the evaluation period. Of course other variables like the interest rate, or the loss aversion, contribute to set the equity premium, but this could have been easily foreseen. On the other hand, the dependence on the evaluation period is more subtle and interesting, because, given certain standard values of the interest rate and the loss aversion, it is possible to deduct the evaluation period that identifies the correct empirical value of the equity premium. Using a similar approach Benartzi and Tahler find that, in order to justify the historical value of the equity premium, households should have an evaluation period of one year (see Benartzi and Thaler (1995)).

In order to interpret the plot of figure 2.8, it should be remarked again that the number of total assets in the system is fixed. This implies that, in average, the ratio between

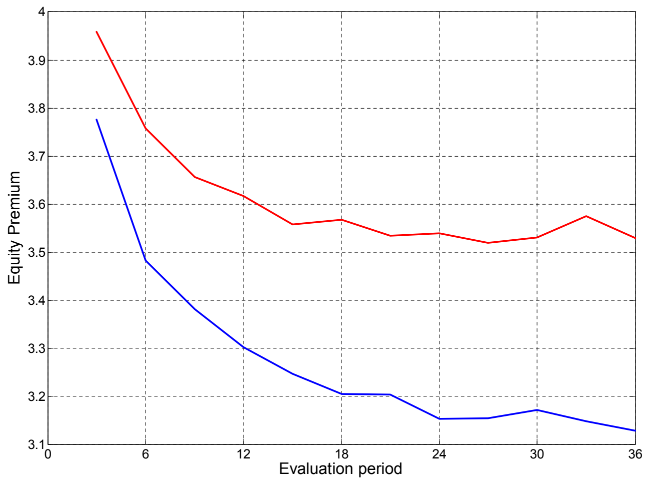

Figure 2.8: The equity premium for different values of the evaluation period. The blue line makes reference to a stock/bonds ratio of 50%. The red line makes reference to a stock/bonds ratio of 66%.

stocks and bonds in households portfolio is constant. Therefore, the question figure 2.8 is answering is: given a stocks/bonds ratio and an evaluation period, what is the equity premium in the system ? Or, turning it upside down, what equity premium do we need in order to justify a specific stock/bonds ratio, supposing a certain evaluation period ?

Figure 2.8 shows a blue line, referred to a stock/bonds ratio of 50% and a red one referred to a ratio of 66%. What distinctly emerges is the following concept: if we suppose that households have a shorter evaluation period, we should expect a higher equity premium in order to justify a given stocks/bonds ratio. This supports the thesis of myopic loss aversion as a determinant of a very high level of equity premium, because if a short evaluation is supposed, a high equity premium should be expected.

The red line (66% ratio) exhibits the same trend of the blue (50% ratio) but for higher values of the equity premium. Obviously, if we suppose that households hold more stocks, we should also expect the presence of higher stock returns attracting them.

Figure 2.9 simply adds to figure 2.8, a green line (66% ratio) corresponding to a policy rate (central bank interest rate) that decreases from 4% to 3%. The increase of the equity premium is evident but it also should be remarked that this increase is less that the reduction of the policy rate (corresponding to 1%) due to second order effects that still has to be investigated. Actually, the impact of the interest rate on the equity premium is probably a sensitive policy issue that we will take in more exhaustive consideration during the third year of the project.

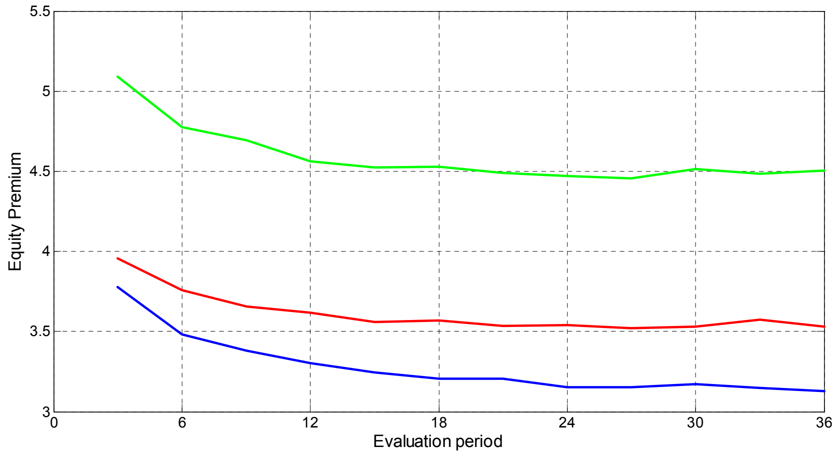

Figure 2.9: The equity premium for different values of the evaluation period, as in figure 2.8. The green line makes reference to a stock/bonds ratio of 66% and to a policy rate of 3%

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