Deleveraging crises and deep recessions: a behavioural approach[*]

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Abstract: Macroeconomic dynamics are characterized by alternating patterns of periods of relative stability and large swings in economic activity. Standard micro-founded macro-economic models – such as DSGE models – account for these patterns through exogenous and persistent shocks. In this paper, we suggest to model these alternating patterns through a fully decentralized and micro-founded macro-economic agent-based model. We integrate an opinion model, which produces successive waves of pessimism and optimism, and feed back into firms' leverage and households' precautionary saving behaviour. One key emergent property of our framework is the complex successions of stable and unstable macro-economic regimes. The model is also able to account for a wide spectrum of macro- and micro empirical regularities. We further observe a series of macro-economic phenomena of key relevance in the current macro-economic debate, especially the occurrence of deleveraging crises and Fisherian debt-deflation recessions. Our analysis concludes that the relative dynamics of prices and wages and the resulting income distribution along a deflationary path are critical determinants of the severity of the recession, and the chances of recovery.

Keywords: Agent-based modelling, Deleveraging crisis, Opinion dynamics, Prices-Wages Dynamics.

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1 Introduction

Developed economies are characterized by alternating patterns of periods of relative stability and large swings in economic activity. The Great Moderation period, and the recession following the 2007-8 financial crisis are a good example of these patterns. Where these patterns stem from, which mechanisms drive and amplify economic downturns, and which conditions can allow for a recovery are the central issues at stake in this paper.

Standard micro-founded macro-economic models – such as DSGE models – account for fluctuations through (large) exogenous and persistent shocks added to the aggregate equations of the model. However, this explanation does not answer the question of what lies at the origin of these exogenous shocks. The reason for such an explanation has to be founded in the necessary assumptions to derive analytical solutions from these models. These assumptions include the representative agent hypothesis and the substantive rationality axiom. Assuming representative agents dramatically simplifies the mapping between the micro-foundations and aggregate dynamics but also rules out by construction interactions between potentially heterogeneous agents, and the resulting (mis)coordination that can be a core issue for the understanding of economic fluctuations and crises.[1] The assumption of substantive rationality and complete information disciplines agents' behaviour, and, unless some frictions are imposed, allows the model to settle down on a socially optimal path, along which markets clear and agents' (intertemporal) welfare is maximised.[2]

Several contributions have tried to provide a more convincing explanation to the origin of business cycles by relaxing (some of) these strong assumptions. This growing literature belongs to the field of behavioural (macro)economics. Among these contributions, the heterogeneous agent literature has given interesting insights into the emergence of booms and busts in a New Keynesian model (see De Grauwe (2011, 2012)). Agents switch between optimistic and pessimistic predictions of inflation and output gap according to how well these predictions perform. This switching creates endogenous waves of pessimism and optimism, which feed back into the actual macro-economic dynamics. While promising, this literature relies on general equilibrium frameworks, which are derived by making use of the assumption of maximising representative agents.

The growing agent-based literature takes a different view.[3] Agent-based models (ABMs) are the representation of a decentralized market economy as a *complex system*. Such a picture of the economy can be described as follows: "*Large numbers of micro agents engage repeatedly in local interactions, giving rise to macro regularities such as employment and growth rates, income distributions, [...] These macro regularities in turn feed back into the determination of local interactions. The result is an intricate system of interdependent feedback loops connecting micro behaviour, interaction patterns, and global regularities*", (Tesfatsion (2006, p.191)). Two main ingredients play a crucial role to allow for such a representation of the economy. First, ABMs provide a comprehensive way to model *heterogeneity*. Based on that heterogeneity, agents are engaged in dispersed interactions, without being able to *see the whole picture of the economy*. They instead make economic decisions only on the basis of local observations. The overall context is characterized by an endogenous uncertainty (Delli Gatti et al. (2010)), in the sense that this uncertainty is generated by agents' own actions. In such a context, agents cannot hold model-consistent expectations, and cannot identify optimal plans given the whole relevant information. The second corollary ingredient is then *procedural rationality* (Simon (1962)): agents aim at simplifying their decision making by adopting simple rules – or heuristics, which allow them to cope with the overwhelming complexity of their en-

vironment. ABMs have therefore the significant advantage of providing more realistic micro-foundations to macroeconomic models, avoiding the assumption of optimizing and representative agents. As a macroeconomic consequence of heterogeneity and procedural rationality, agents' decisions are not necessarily mutually consistent, consumption and production plans are not necessarily feasible, and rationing in the markets (in particular involuntary unemployment) may prevail.

The purpose of ABMs is to study how patterns form in the economy. The resulting model can be used as a virtual laboratory, in which a wide range of economic configurations can be simulated, policies can be implemented and assumptions can be tested *in silico*. Accordingly, a significant part of the ABMs has shown how these models are able to interestingly account for the endogenous emergence of coordination between agents in markets[4], and business cycles[5]. Some ABMs put an emphasis on the empirical exercise, and show how an ABM is successful at reproducing a broad range of observed regularities.[6]

This paper aims at making a bridge between the behavioural macro literature *à la* De Grauwe (2011) and the ABM macro literature. In order to do so, we elaborate on the macroeconomic ABM of Seppecher (2012*a*), which exhibits several interesting features, both compared to standard DSGE models, and existing ABMs. In particular, our ABM represents a fully decentralized and disaggregate economy, and is stock-flow consistent. This allows to model and keep track of all real and monetary links between heterogeneous agents in the economic system, and, therefore, to account for key elements to explain business cycles and crises, in particular debt and leverage of firms, saving and consumption decisions of households, income distribution and wages and prices dynamics. This feature of our model stands in sharp contrast with standard DSGE models.[7] We extend the ABM by introducing an opinion dynamics model among the agents, in tune with the so-called concept of *animal spirits*. This model is inspired both by simple heuristic switching models (see De Grauwe (2011)) and herding behaviour representations in finance (see, e.g., Lux (1995), Tedeschi et al. (2012)). One key emergent property of our ABM is the complex interactions between agents' market sentiment, their individual financial behaviour, and the resulting aggregate dynamics. We also perform an extensive empirical validation exercise, and conclude that this ABM is strongly in line with a large spectrum of macro empirical regularities and micro stylized facts concerning firms' and households' distributions.

Furthermore, the type of crisis we observe in our model echoes the *deleveraging crisis* as discussed in Eggertsson & Krugman (2012). In a nutshell, an extended period of economic stability encourages relaxed views about what level of debt (leverage) is acceptable. However, at some point, some borrowers' attitude changes, as some firms and households become pessimistic. As a result, they engage in a sudden deleveraging and saving process. This translates into a decrease in consumption expenses, debt and dividends. This in turn leads to a slow down in aggregate activity and a debt-driven slump, so that the pessimistic views turn out to be self-validating. This reinforces the wave of pessimism, and the economy is driven towards a deep recession. This phenomenon is known as the Fischerian debt-deflation dynamics (Fischer (1933)). Unlike Eggertsson & Krugman (2012), in our framework, the deleveraging shock arises endogenously, as a product of the positive feed-back system formed by the trio market sentiment/financial behaviour/aggregate dynamics.

Last but not least, we address the question of the drivers of the recovery along a deflationary path. Our model strongly suggests that the end of the recession critically depends on the way the debt-deflation spiral affects income distribution and the relative dynamics of prices and nominal wages. If prices fall quicker than nominal wages do,

real wages end up increasing, so that a demand-driven recovery is made possible. This recovery occurs well before the deleveraging process of firms is completed, or households' precautionary savings objective is reached. On the contrary, if nominal wages fall faster than prices do, real wages decrease along a debt-deflation path, and a demand-driven recovery is no longer possible. The relative rise in profits repairs firms' balance sheets, and allows them to get closer to their deleveraging objective, which may create the conditions of a recovery. However, in that case, the recession appears much deeper and longer-lasting than in the case where a demand-driven recovery is made possible. We think that this type of emergent dynamics is of particular relevance regarding the current economic debates in the wake of the 2007-8 financial crisis and the Great Recession which has followed.

The rest of the paper is organized as follows: Section 2 introduces our ABM – the `Jamel` model, numerical simulation results are reported in Section 3 and Section 4 concludes.

2   The `Jamel` model

In this section, we describe the general characteristics of the model, the behavioural rules of the agents and their interactions. An earlier version of the `Jamel` model (*Java Agent-based Macro-Economic Laboratory*) is fully described in Seppecher (2012*b*), to which we also refer.[8]

2.1   General features

The economy is populated by a collection of n heterogeneous households, indexed by $i = 1, ..., n$, m heterogeneous firms, indexed by j, $j = 1, ..., m$, and one single bank. The firms produce an homogeneous consumption goods by using capital (assumed to be fixed) and labour. Labour is supplied by the households, who also consume the goods. The bank provides loans to the firms to finance their production (wage bill), and hosts households' savings (as cash deposits). The firms and the bank are assumed to be owned by households, who then receive dividends.[9]

The `Jamel` model exhibits several original features, to be contrasted with existing macroeconomic frameworks, both in the DSGE literature and in the ABM literature.

Decentralized market interactions and endogenous price/wage dynamics   The `Jamel` model is a *fully disaggregated* market economy. This is a major feature of ABMs, as they precisely aim at replacing the representative agent hypothesis by a large number of heterogeneous and interacting agents (firms, households). Every market interaction between these heterogeneous agents has therefore to be modelled, and every macroeconomic variable results from the aggregation of individual ones. Importantly, we do not assume that firms apply a fixed mark-up to set their prices, because this would exogenously dictate the price/wage dynamics. In our model, prices and wages come out of local interactions in the labour and the goods markets, and the resulting income distribution is endogenous. It should be noted that existing ABMs often focus on disaggregating one sector (usually firms and/or banks), leaving one side of the markets (usually households) to be determined as an aggregate component, and, hence, leaving the determination of at least some variables as an aggregate process.[10]

Stock-flow consistency   The `Jamel` model is *stock-flow consistent*. This feature has been emphasized as a major one in macroeconomic settings in general (see, e.g., Caverzasi

& Godin (2013)), and in ABMs in particular (see, e.g., Deissenberg et al. (2008), Kinsella (2011)). This means that we are able to keep track of all monetary flows, each unit of money spent by one agent goes to another agent. There is no leakage, nor exogenous inflow of money in the model. As a result, all agents' balance sheets are linked together. This general interdependence must be summarized at the aggregate level in a balance sheet matrix (see Godley & Lavoie (2007)). As the purpose of illustration, Table 1 displays such a matrix for a typical period of the model.

[Table 1 about here.]

Credit dynamics and money In modern economies, money is essentially a credit money, created when a loan is granted by banks to an economic agent, and destroyed when this agent pays back the loan – see McLeay et al. (2014). At the aggregate level, the money dynamics correspond to the credit dynamics, and these dynamics emerge from local interactions between firms and the banking system. In the `Jamel` economy, firms have to borrow to pay the wage bill because production requires time, and credit dynamics originate from this source.

Micro and macro consistency We cope with the "wilderness of bounded rational-ity"[11] in a twofold way. On the one hand, we ensure the consistency of the micro be-havioural rules by applying a common pattern for *most* agents' decisions in the model. This common pattern is designed to be fully in line with the behavioural literature. For-mally, the general decision rule for period t and agent j is as follows:

$$
\delta_{j,t} = \begin{cases} \alpha_{j,t}\nu_F & \text{if } \alpha_{j,t}\beta_{j,t} < \frac{X^*_{j,t}-X_{j,t}}{X^*_{j,t}} \\ -\alpha_{j,t}\nu_F & \text{if } \alpha_{j,t}\beta_{j,t} < \frac{X_{j,t}-X^*_{j,t}}{X^*_{j,t}} \\ 0 & \text{else.} \end{cases} \tag{1}
$$

where $\delta_{j,t}$ is the scale of adjustment of the behaviour, $X^*_{j,t}$ is agent j's targeted level of variable X, $\alpha_{j,t}$, $\beta_{j,t}$ are $\mathcal{U}(0,1)$ and $\nu_F > 0$ is a constant.

Behaviour rule (1) follows three guidelines:

- Adjustments and *satisfycing* (Simon (1955)): agents successively adjust their eco-nomic decisions observing unbalances between the actual and the targeted level of their objectives. These targeted levels are exogenously defined, and correspond to satisfying levels.

- Reaction to stress and conservative principle (see also Cyert & March (1963)): the probability of agents to adjust their economic behaviour increases when observed unbalances increase (i.e. the higher α, the stronger the adjustment and the less likely to be adopted), and decreases when the level of the required adjustment increases (i.e. the higher the observed disequilibrium between $X_{j,t}$ and $X^*_{j,t}$, the more likely the adjustment to be adopted).

- Heterogeneity: the behavioural rule (1) involves individual stochastic components, resulting in heterogeneous reactions, even between agents facing the same situation.

On the other hand, we successfully perform an extensive exercise of *empirical validation* (see Subsection 3.1). This exercise aims at showing that the micro behavioural ingredients of the model allow for the emergence of both micro and macro patterns, that are fully in line with stylized facts highlighted by the empirical micro and macro literature.

Market sentiment and animal spirits Finally, we assume that firms' and households' behaviour is also influenced by their perception of the state of the affairs – the so-called *market sentiment*, in a way similar to *animal spirits*.[12] Depending on their market sentiment, which depends both on their own individual situation and the one of their neighbours, agents are either pessimistic or optimistic. Accordingly, they switch between two different heuristics, corresponding to optimism and pessimism. Therefore, agents adjust their behaviour as a function of the economic context.

2.2   Timing of the events

As ABMs are sequential models, we have to make the timing of events explicit. One period t corresponds to a month, as wages are usually monthly payments. For each period, the following steps prevail:

1. Households who own the firms and the bank receive dividends.

2. The firms set up their production *plan* (labour to hire, quantity to produce, price to set, wage to offer, and financial needs), and borrow money from the bank accordingly, in order to finance their wage bill.

3. The labour market opens, and matches firms' labour demands and households' labour supplies. This process yields the households' labour incomes and the firms' production plan is implemented.

4. Households adjust their saving/consumption plan.

5. The goods market opens, and matches households' demand and firms' supply for the goods. This process gives the updated level of firms' inventories and their profits.

6. The firms pay back part of their loans and the interests to the bank.

7. The firms and the bank decide the amount of the dividends to pay to their owners.

8. This process starts all over again for a given length of T periods.

We now fully describe the behaviour of each category of agents.

2.3   The households

The households provide labour to the firms and consume the goods.

Labour supply and wage Each household is endowed with a one-unit labour supply. Households' decision variable in the labour market is the reservation wage. If an household is employed, his reservation wage equals the wage that he is currently receiving. If household i is unemployed, his reservation wage is adjusted downward, depending on the number of periods since his last job, $d_{i,t}^u$ and his resistance d^w. The percentage size of the downward adjustment $\delta_{i,t}^w$ is then given by:

$$\delta_{i,t}^w = \begin{cases} \beta_{i,t} \cdot \eta_H & \text{if } \alpha_{i,t} < \frac{d_{i,t}^u}{d^w} \\ 0 & \text{else.} \end{cases} \tag{2}$$

where $\alpha_{i,t}$, $\beta_{i,t}$ are $\mathcal{U}(0,1)$ and $\eta_H > 0$ is a parameter. Accordingly, the probability of decreasing the reservation wage increases with the unemployment duration. After d^w periods being unemployed, the adjustment is systematic.[13]

Consumption   The second decision of the households concern consumption and savings. We assume that households cannot borrow, and follow a buffer-stock rule: they build precautionary savings (at a zero-interest rate) to smooth consumption in face of unanticipated variations in their labour income.[14] Each household computes his targeted savings level as a fraction κ_S of his average monthly income over the last ρ_S months/periods. If his effective savings at time t are lower than the targeted level, the household intends to spend only a fraction κ_S of his current income, and saves the rest. If his effective savings are higher than the targeted level, the household intends to spend all his income and a fraction μ_H of his excess savings in the goods market.

Market sentiment   As underlined below, the market sentiment also influences households' behaviour. Each household can be either optimistic or pessimistic about the state of the affairs in the economy. The market sentiment model relies on two main assumptions. First, unemployment influences consumer sentiment. Several empirical studies document this relationship.[15] Second, more pessimistic views about future economic developments refrain consumption, and incite households to build up more precautionary savings.[16] Accordingly, optimistic households have a low savings target ($\underline{\kappa_S}$), and pessimistic households have a high savings target ($\bar{\kappa_S} > \underline{\kappa_S}$). They switch between these two targets depending on their market sentiment. Market sentiment evolves according to an opinion dynamics model which allows to account for both the effective state of each household and an "animal spirit" component, through which the household is influenced by some other households in his "neighbourhood". Precisely, the market sentiment of each household is updated for each period as follows:

- With a probability p, the household's market sentiment depends on his employment situation: if he is unemployed, he is pessimistic, and if he is employed, he is optimistic.

- With a probability $1 - p$, the household adopts the majority opinion among h other households.

This behavioural model is consistent with the fully decentralized feature of the ABM, as the households only rely on their individual opinion, or the one of a small neighbourhood.[17]

2.4   The firms

Within each period, in a sequential order, each firm borrows money from the bank, hires and fires workers, produces and sells goods to households, pays back loans to the bank and pays dividends to its owner.

Production function   Each firm is endowed with K units of capital (each unit can be understood as a machine), which remains fixed for the whole simulation. Hence, there is no capital accumulation dynamics through investment in this current version of the model[18]. Each machine has the same productivity, equal to pr_k. Firms combine labour with machines in order to produce, and production factors are assumed to be complementary. Production is also explicitly modelled as a time-consuming process, and spread out over several successive periods (Keynes (1979)). Accordingly, for each period, each worker can only work on a machine, and increment its production process by one step. The maximum labour force that a firm can hire for each period is then given by the number of machines, $K_j = K, \forall j$, which also defines the capacity production of each firm.

Each machine needs d^m steps to complete the production process, so that it takes at least d^m periods for a machine to deliver an output, and after completion, this output is given by $y_k = pr_k \times d^m$ units of goods. When hiring workers, the machines whose production process are most advanced are prioritized. Each time a production process of a machine of firm j comes to the end, the resulting output $y_{k,j}$ is added to firm j's inventories level in_j.

Production plan decisions For each period, the whole production plan is decided by successive adjustments, following the general guidelines given in Sub-section 2.1. We assume that firms take variations in the level of their inventories as a proxy for variations for their demand. They maintain stock as a buffer to cope with unexpected variations in their environment. The targeted level of inventory is a proportion in_F^* of the full capacity of production of the firm – which is the same across all firms as the number of machines embedded in each firm is the same. If the effective level of inventories $in_{j,t}$ is higher that the targeted one, this may be a sign of excess demand, and firms are likely to increase production, and, hence, the number of vacancies. Conversely, if effective inventories are less than the targeted level, firms fire workers, the latest hired being the first fired. Therefore, for each period t, the labour demand of each firm is adjusted (within the lower bound 0 and the upper bound K, the number of machines) by a percentage $\delta_{j,t}$ through the general scheme (1), where variable $X_{j,t}$ corresponds to the level of inventories of firm j at time t, and the target X_j^* is in_F^*.

The offered wage is also adjusted according to the general rule (1), but the guide variable X is the vacancy rate, whose targeted level is exogenously fixed to ρ_F^* for all firms. A lower-than-targeted vacancy rate is interpreted as a sign of an excess labour supply over demand, and leads to a decrease in the offered wage, and vice-versa. The duration of the offered contract is $d^w > 1$ periods, and the wage remains fixed for the whole period.

Prices may be increased in reaction to a lower-than-targeted level of inventories, and vice-versa. Precisely, a firm gradually *increases* her price if her inventories are lower than the targeted level *and* she was able to sell all her production during the last period. Similarly, a firm gradually *decreases* her price if her inventories are higher than the target *and* she got unsold quantities after the matching process in the goods market. Otherwise, the firm leaves her price unchanged. We further assume that each firm can only adjust her price every d^p periods. This allows to control for price stickiness in the model, through a process similar to a Calvo (1983) process. We show below how this parameter influences real effects of shocks (see Figure 3).

The firms then estimate their wage bill in case all the vacancies will be filled. The firm has a targeted level of net wealth (i.e. excess of assets on liabilities), expressed in terms of a leverage target κ_F (i.e. a fraction of her total assets[19]). In case the deposit of a firm in not enough to finance the expected wage bill, taking into account her leverage target, the firm borrows from the bank the missing cash-on-hand (see Sub-section 2.5 how the loans are granted).

It should be noticed that those behavioural rules imply rigidities in the adjustment of price, nominal wage and quantities.

Payment of dividends Dividends are distributed only if the observed level of net wealth is higher than the targeted one. In that case, the excess amount is distributed.

Market sentiment   In the exact same way as the households, the firms can be either pessimistic or optimistic regarding the state of the affairs in the economy, and switch between two targeted levels of net wealth: one high, $\bar{\kappa_F}$, corresponding to a pessimistic behaviour, and one low, $\underline{\kappa_F} < \bar{\kappa_F}$, corresponding to an optimistic behaviour.[20]   What drives optimism and pessimism is the evolution of the anticipated demand, that we compute as the average of past sales (see Dosi et al. (2010, 2013) for a similar assumption). More precisely, if the past level of the sales exceeds $s_f\%$ of the total market capacity of the firm, a firm is optimistic. Otherwise, she is pessimistic. For the sake of consistency and simplicity, we assume the same opinion dynamic model as for the households. In particular, probability p and the size of the neighbourhood h are the same (see Sub-section 2.3).

Bankruptcies and entry mechanism   Firms may not be able to pay back their loans in due terms (see Sub-section 2.5 for the exact procedure of the bank). In that case, the failed firm exits the market, and a new firm is created t_f periods later, in order to avoid a mechanical concentration in the goods market.

2.5   The bank

The main role of the bank is to provide loans to the firms to finance the production. As this role is essentially passive, the banking sector is summarized by a single bank.

At a first step, the bank is fully accommodative, and satisfies all the demands for credit from the firms. Loans are granted for a period of d_l months, at a fixed interest rate r. However, when a firm is not able to pay off a loan in due terms, the due period is extended to d_l', the interest rate is set at a higher level r', and the debt is downgraded to *doubtful* debt, reflecting the increasing risk of the firm's loan. When a firm cannot pay off a doubtful debt, she goes bankrupt, and the bank absorbs the failing firm' debt through its own resource. The bank then uses its resources (interest-payments made by firms) in order to recapitalize up to the targeted level. In the exact same way as the firms, this targeted level is a proportion κ_B of the total assets of the bank, and excess is distributed as dividends to its owner.

2.6   Markets and dynamics

The local interactions in the markets are based on a tournament selection procedure: each seeker only consults a subset of offers, and selects the one which fulfils the most his objectives. This is a rationing mechanism consistent with the design of a decentralized economy (see e.g. Riccetti et al. (2012)).

In the labour market,   firms post offers with a given number of jobs at a given wage. Each unemployed household consults g offers, and selects the one with the highest wage, provided that this wage is at least as high as his reservation wage. Otherwise, he stays unemployed.

In the goods market,   firms post offers with a given quantity and price, and households enter with a budget, that they intend to spend entirely. Each household selects a subset of g firms, and chooses to buy to the cheapest one. This process is repeated until the total budget of all consumers or the total quantity of good are exhausted.

We now turn to the numerical simulations of the model.

3 Numerical simulations

We proceed as follows. We first define a `baseline` scenario which serves as a benchmark. This scenario is obtained following empirical validation criteria. We then analyse the different phases of business cycles in the model. We finally perform sensitivity analyses on the probability p, i.e. the strength of the "animal spirits" in the model.

3.1 Empirical validation: a `baseline` scenario

The model involves many parameters, whose values cannot necessary be set based on empirical estimations. Following recent developments in macro ABM (see Windrum et al. (2007)), we perform an empirical validation exercise. We first select parameter values so as to target realistic order of magnitude for the main macro variables (notably inflation, unemployment, wage share). We then analyse the resulting dynamics under the selected calibration. If the model is able to capture a reasonably wide set of stylized facts, both at the macro and at the micro levels, we define this calibration as the `baseline` scenario. The purpose is not to exactly replicate empirical figures, which vary widely across sectors, countries and time periods. The empirical exercise is more qualitative, and aims at obtaining from the model empirical patterns and statistical properties of macro and microeconomic time series, e.g. correlation structure or distributions. Table 2 gives the chosen parameter values of the baseline. As a purpose of illustration, Figure 1 displays the main time series of a baseline simulation.

[Figure 1 about here.]

[Table 2 about here.]

Business cycles and macroeconomic regularities We first check that the values of the main aggregate variables display a realistic order of magnitude. Table 3 reports statistics from 30 replications of the `baseline` scenario, and shows that the resulting values are in line with empirical observations in developed countries. These values concern the unemployment rate, the inflation rate, the unemployment duration, the mark-up of firms over costs, the profit share and the velocity of money.[21] Moreover, the low values of standard deviation across the 30 replications demonstrate that the aggregate behaviour of the model is quite stable, and qualitatively insensitive to stochastic elements.

[Table 3 about here.]

Our model is also able to reproduce empirical findings on business cycles (see, notably, Stock & Watson (1999)). In particular, consumption and output time series are strongly and positively correlated, both display an alternate of smooth phases and strong fluctuations (a so-called "roller-coaster" pattern, see Figure 2a), while consumption being less volatile than output (see Table 3).[22]

[Figure 2 about here.]

Furthermore, consumption, employment, changes in inventories, inflation, the vacancy rate and the velocity of money appear pro-cyclical, while the unemployment rate, the unemployment duration and the share of doubtful debts are contra-cyclical (see Figure 2b and Figure 2c, Figure 1 below provides an illustration from one run). Inflation is

therefore demand-driven, which is consistent with the main ingredients of the `Jamel` model. There is indeed no exogenous element akin to a cost-push shock which could lead inflation and output to move in opposite direction. Having a closer look at Figure 2b, and consistent with this statement, consumption is leading, and employment is lagging, so that we can conclude that the economic dynamics is mostly demand-driven in the model. The share of doubtful debt is also lagging, which shows that a drop in output at time t leads to an increase in financial difficulties of firms in the future. The vacancy rate being procyclical and the unemployment rate being contra-cyclical implies that the Beveridge curve becomes flatter in periods of economic downturns. Our model is able to fully account for this stylized fact.

The order of magnitude of output autocorrelation is close to 0.9, which is very close to empirical evidence in G7 countries (see Figure 2d). In line with further empirical evidence (see Gallegati et al. (2003)), we observe that the ratio between the firms' and the bank' capital is broadly constant throughout time (cf. Figure 2e). The model is also able to generate a significantly downward-sloping Phillips curve and Beveridge curve (see Figures 4a and 4b, and Table 3). It should be noted that the slope of the Phillips curve strongly depends on price rigidity. The more flexible the prices, the more vertical the Phillips curve. This is strongly in line with common knowledge in macroeconomics.

[Figure 3 about here.]

Micro-regularities, firms' and households' distributions   We now compare the distributions that are generated by the model to recurrent statistical patterns in industrial data and households' income distributions.

Empirical evidence tend to show that firms are heterogeneous. More precisely, Fujiwara (2003) finds that the distribution of firms' size is power law and right-skewed. Table 4 reports that the estimated shape parameter of the distributions of firms' size, both measured through their profits and capital, is significantly lower than 2 (the shape of the normal distribution), and that those distributions display significantly positive skewness. The Shapiro normality test confirms that firms' sizes are not normally distributed.

[Figure 4 about here.]

As for households' income distribution, empirical data are generally characterized by a Pareto distribution, especially for the upper tail (see, e.g., Reed (2003)). Following the method proposed by Clauset et al. (2009), we estimate a Pareto distribution on the upper tail of the income distribution.among the households at the end of the simulations, and replicate this estimation for 30 runs. Results are reported in Table 4. The average p-value indicates that a Pareto distribution nicely fits the income distribution of the 2% wealthiest households. This is in line with empirical findings, see e.g. Clementi & Gallegati (2005).

Table 3 also gives the average value of the Gini coefficient computed with households' wealth. The value of the Gini coefficient measures the inequality of wealth between households, and is broadly in line with empirical observations in developed countries.

[Table 4 about here.]

From this empirical validation exercise, we conclude that our ABM is able to produce statistical properties which account for a wide spectrum of macro- and micro-economic empirical regularities. The `Jamel` model is therefore able to catch-up with the state-of-the-art ABMs[23], and to go a step further by replicating some income distribution patterns among households. We now turn to a more detailed analysis of business cycles in the baseline simulation.

3.2 Deleveraging crisis, debt-deflation and business cycles

Figure 6 depicts the dynamics of a baseline simulation in the 3-dimensional plan representing unemployment, profits and wages, and inflation. This allows us to clearly distinguish the successive phases of the business cycles that emerge *endogenously* from the ABM.

[Figure 5 about here.]

The "corridor of stability" The top right part of the figure, where the ratio of the profit over the wage share equals 50% (i.e. roughly 1/3 over 2/3), inflation is low and positive and unemployment is around 9% depicts the area of stability of the model. As a reference to Leijonhufvud (2009), we call this area the *corridor of the stability* of the model. In this corridor, the behaviour of the model resembles the behaviour obtained with fixed behaviour[24], i.e. under the assumption that the households' savings rate and the firms' leverage objectives are the same for pessimistic and for optimistic agents. We can say that the model has reached a form of *steady state*. The density of points is this area shows that a significant number of periods within the whole simulation fall into this corridor of stability. This situation can be therefore described as "normal times" situation. However, the dynamics of the model sometimes exits this corridor of stability, and economic dynamics then follow a typical business cycles path. Each of these business cycles is depicted by a (clockwise) loop in the figure (5 in this simulation). The wider the loop, the stronger the swing along the business cycle.

Successive phases of a business cycle Along a typical business cycle in the model, we successively observe the following six phases. i) The economy lies in the corridor of stability; ii) an economic downturn takes place (red points), in which profits decrease, unemployment rises and inflation slows down until deflation; iii) the economy then bottoms out (see the bottom left part of the figure), deflation and unemployment are at a maximum level, and the profit share is at a minimum level; iv) the economy starts to recover (see blue part of the loops), inflation becomes positive again, unemployment decreases, and profits start increasing again; v) the recovery goes on, and the economy experiences a boom with high inflation and low unemployment, and profits go back at their "normal times" level; vi) finally, the economic activity starts slowing down, inflation decreases, and the economy settles down back in the corridor of stability.

The deleveraging crisis The key to understand the driver of the downturns in the model is the negative shock that pushes the economy towards a deflation and a drop in employment and profits (step ii)). Eggertsson & Krugman (2012) describe this shock as a *deleveraging shock*: an extended period of economic stability (step i)) encourages relaxed views about what level of debt (leverage) is acceptable. In our model, this translates into a wave of optimism, during which firms have a high objective in terms of leverage. However, at some point, borrowers' attitude changes, and they engage in a sudden deleveraging process, i.e. a reduction of the share of their debt. This sudden change recalls the "Minsky moment", in reference to H. Minsky, who extensively discussed the key role of subjective views about leverage and debt dynamics in the recurring cycles of economic instability (see Minsky (1986)). In our model, this change comes from an abrupt change (avalanche) in firms' market sentiment, which leads to a wave of pessimism. This is clear from Figure 1b.

A key point of our framework is that these abrupt changes from optimism and pessimism arise endogenously, as the result of the *complex interactions* between firms' and households' market sentiment, their interplay with their individual financial behaviour, and the resulting aggregate dynamics. The contagion phenomenon of pessimistic views through "animal spirits" alone cannot explain the economic downturn without a retroaction of pessimism on financial behaviour. What happens is that a small fraction of firms and households becomes pessimistic, and, as a result, adjusts its saving and debt behaviour. This translates into a decrease in consumption expenses, debt and dividends. The velocity of circulation slows down, as bank loans are paid off and consumption expenditures decrease, and this causes a fall in prices and profits of firms. This in turn contributes to slow down aggregate activity, so that the pessimistic views turn out to be self-validating. This aggregate slowdown further propagates pessimistic views and reinforces the wave of pessimism, and this self-reinforcing loop drives the economy towards a deep recession (step iii)). *The trio market sentiment/financial behaviour/aggregate dynamics forms a positive feedback system.*

Interestingly, what follows such a crisis closely echoes what was first described as the *debt-deflation theory of Great Depressions* by Fischer (1933).[25] Paradoxically, a stronger effort of deleveraging increases the burden of the debt (i.e. the amount of debt in real terms). This is because, if some firms try to deleverage, the aggregate effect of such a deleveraging process is an economic downturn, and a fall in prices, so that deflation actually sharpens the debt burden of these firms. This is illustrated in Figure 7, which displays a typical simulation run where a deleveraging crisis occurs around period 225, as the graph of firms' leverage clearly shows (bottom panel). GDP drops, and so does inflation (expressed here in monthly rate, see middle panel). The debt' burden increases, and picks around period 260, which corresponds to a sustained period of deflation. The second peak around period 320 also corresponds to a severe drop in prices. When the economy recovers, after period 320, inflation stabilizes at low and positive values, and the debt' burden falls back to its pre-crisis level.

We observe a similar effect, known as the "paradox of thrift", among households. Indeed, if some households become pessimistic, they try to increase their precautionary savings. However, the aggregate effect of such an increase in individual precautionary savings is a decrease in aggregate demand. As a consequence, firms' sales, employment, and, hence, households' labour income decrease, so that households' actual savings rate does not increase, even if they try to build a higher level of precautionary savings. We can observe the saving paradox in Figure 1b: the actual saving rate of households is barely affected by households' market sentiment and the phases of the business cycles. These types of phenomena obviously underline the interest of the complex system approach to macroeconomic dynamics, and the key role of heterogeneous agents and interactions in driving aggregate dynamics.

[Figure 6 about here.]

What drives the recovery   As shown above, the economy bottoms out (see step iii)), and then starts to recover (step iv)). To complete our analysis, an important point is to identify the main factors behind this recovery process. Koo (2011) provides an explanation of the recovery after a debt-deflation cycle: "*the economy enters a deflationary spiral because, in the absence of people borrowing and spending money, the economy continuously loses demand equal to the sum of savings and net debt repayments. This process will*

continue until either private sector balance sheets are repaired or the private sector has become too poor to save " (Koo (2011, pp. 21-22)). However, a close look at Figure 8g demonstrates that, in our model, the recovery starts before the firms have achieved their objective of decrease of leverage and households have achieved their objective of savings. What actually drives the recovery is the increase in real wages up to the point it offsets the effect of the rise in unemployment on aggregate demand. Indeed, our ABM allows for both prices and nominal wages rigidities, but, under our baseline calibration, nominal wages appear less flexible than prices, so that prices fall quicker than nominal wages do, and the real wage increases. This is clearly illustrated by Figures 1f and 8g. Once the economy starts recovering, some firms and households turn optimistic and, as a result, consumption expenditures, dividends and debt start increasing again. A virtuous circle through optimism initiates in exactly a symmetric way to the spiral down along a recession.

This result is of particular interest as it clearly demonstrates that nominal wages rigidity in face of deflationary pressure can stop a debt-deflation cycle stemming from a deleveraging shock. If, in real economies, private consumption is not strong enough, or nominal wages are not rigid enough to allow for such an increase in real wage and a recovery from such a crisis, this suggests that there is room for counter-cyclical fiscal and monetary policies in sustaining aggregate demand. This element is absent from our framework, but constitutes one of its potential immediate extensions to be explored.

In order to further investigate the conditions of the recovery, we conduct an experiment allowing for more flexible nominal wages. In this simulation, we set η_H, the parameter of wage adjustment of the households, equal to 0.25, instead of 0.05 in the baseline scenario. Nominal wages are therefore adjusted downward in a faster way in face of rising unemployment. Figure 8h displays the outcomes of such a simulation. It is clear that nominal wages fall more quickly than prices do, so that a recovery driven by a rise in private consumption is ruled out. With more flexible nominal wages, the crisis alters the income distribution in favour of profits. This in turn improves firms' financial health, and allows them to finally reach their leverage objective. However, not all firms succeed and, during this process, an increasing number of them goes bankrupt, so that, paradoxically, the share of doubtful debt increases even though the total amount of debt decreases. In our ABM, the high number of bankruptcies leads to the bank's bankruptcy, and the simulation breaks off due to a systemic crisis (therefore the simulation displayed in Figure 8h stops around period 600).[26]

The above analysis suggests that deleveraging crises lead to much deeper recessions if the crises last until private balance-sheets are repaired than in the case of a recovery driven by aggregate demand. The outcome of such a crisis seems therefore to depend on the way the crisis affects prices relatively to nominal wages. This result stresses the interest of combining fully decentralized frameworks with heterogeneous agents and stock-flow consistency.

[Figure 7 about here.]

3.3 Animal spirits and business cycles: sensitivity analyses

We now contrast the model's dynamics of the same simulation assuming different probabilities p in order to highlight the role of animal spirits in the origin and propagation of the business cycles in the model. Figure 9 indicates the macroeconomic volatility over 30 replications of the simulations with each of the following scenarios: fixed behaviour (i.e. a

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15% savings rate objective for households, and a 20% of leverage target for firms, whether pessimistic or optimistic) with $p = 0.7$, and different values of p, i.e. $p \in [0, 0.1, ..., 0.9, 1]$ with specific pessimistic and optimistic objectives (baseline calibration). For the purpose of illustration, Figure 10 shows the simulation outputs with fixed behaviour. This figure has to be compared with Figure 1 above, which shows the baseline simulation with animal spirits dynamics ($p = 0.7$), as analysed so far.

[Figure 8 about here.]

[Figure 9 about here.]

Several observations are in order. First, we see that the model with fixed behaviour displays a stable pattern, which resembles a *steady state* or a *corridor of stability*, as discussed in the previous sub-section.

Second, the introduction of market sentiment but without animal spirits ($p = 0$), and differentiated objectives for optimistic or pessimistic agents, gives raise to (limited) fluctuations around this steady state. As it is clear from the Figure 9, the reaction of the agents to their perception of the business climate offers a straightforward explanation of the emergence of these fluctuations. This is especially salient for inflation. These fluctuations are not the result of exogenous shocks as this is the case in standard micro-founded models.

Third, Figure 9 shows that the "animal spirits" are at the roots of the stability and crisis dynamics observed in the baseline simulation. The opinion dynamics model creates contagion effects between optimistic and pessimistic agents. These contagion phenomena create endogenous waves of pessimism and optimism (see Figure 1a), and amplify these small fluctuations, turning them into deep recessions (see Figure 1c). The stronger these contagion phenomena (i.e. the higher p), the more volatile output and inflation (see Figure 9). Nonetheless, as discussed above, it should be recalled that the positive feedbacks from market sentiment to financial behaviour and aggregate activity are necessary to allow for the emergence of waves of pessimism and optimism. Without these positive feedbacks, the contagion model alone is not able to create such waves (see Figure 10).

Fourth, as discussed above, the endogenous switches between optimism and pessimism, resulting in endogenous switches between stability and downturns, result from the *complex interactions* between firms' and households' market sentiment, their individual financial behaviour, and the resulting aggregate dynamics. Even if the alternating pattern of stability and recessions is a regular and robust feature of the model, different simulations (i.e. with different seeds of the RNG) exhibit switches between these different regimes at different times, and with different orders of magnitudes.

Eventually, our explanation of business cycles is perfectly in line with the one provided by behavioural macroeconomics, see notably De Grauwe (2011, 2012). However, the endogenous waves of pessimism and optimism are rooted in the micro behaviour of heterogeneous agents. This provides an answer to one of the main methodological shortcomings of the heterogeneous agent literature in macro models (usually New Keynesian model). Namely, we do not have to plug *ex post* behavioural heterogeneity in the aggregate equations, which yet remain derived under the assumption of representative and fully optimizing agents.

4 Conclusion

Macroeconomic dynamics are characterized by alternating patterns of periods of relative stability and large swings in economic activity. Several attempts of explaining the origin of business cycles have been proposed by behavioural macroeconomics. In line with this literature, we introduce a macroeconomic agent-based model which exhibits several interesting features, both compared to standard DSGE models, and existing ABMs. First, our model represents a *fully decentralized* economy, in which prices and wages, and the resulting income distribution are endogenous, and result from local market interactions. Second, our model is *stock-flow consistent*, and allows to track every monetary flow in the model and to ensure that there is no leakage. Third, our model explicitly accounts for credit dynamics. Finally, we address the issue of the "wilderness of bounded rationality" in a twofold way: we apply a common pattern of behavioural rules to obtain micro consistency, and we successfully perform an extensive exercise of micro and macro empirical validation.

One key emergent property of our framework is the complex interactions between agents' market sentiment, their individual financial behaviour, and the resulting aggregate dynamics. Economic downturns arise endogenously, as a product of the positive feed-back system formed by the trio *market sentiment/financial behaviour/aggregate dynamics*. Our results clearly underline the interest of a complex system approach to macroeconomic dynamics. Indeed, micro-foundations rooted in heterogeneous and interacting agents show how the interplay of individual behaviour can lead to non-trivial aggregate results. We discuss a series of phenomena that are of particular relevance for the macroeconomic debate which has followed the 2008 financial crisis and the Great recession in western economies. We also provide extensive sensitivity analyses.

Importantly, our model strongly suggests that the end of the recession critically depends on the way the debt-deflation spiral affects income distribution and the dynamics of prices and nominal wages. If prices fall quicker than nominal wages do, real wages end up increasing, so that a demand-driven recovery is made possible. This recovery occurs well before the deleveraging process of firms is completed. On the contrary, if nominal wages fall faster than prices do, real wages decrease along a debt-deflation path, and a demand-driven recovery is no longer possible. The relative rise in profits improves firms' margins, and allows them to get closer to their deleveraging objective, which may create the conditions of a recovery. However, the recession appears much deeper in comparison to the demand-driven recovery. This analysis claims for further efforts to model wage and price dynamics in order to highlight the mechanisms of transmission of crises to income distribution. This analysis also suggests that there could be significant room for counter-cyclical monetary and fiscal policies to dampen the effects of such crises. This constitutes an immediate extension of the model, that is left for future research.

Notes

[1]This point has been risen by, *inter alia*, Delli Gatti et al. (2010), De Grauwe (2012), Howitt (2012).

[2]Other scientific fields, such as psychology, cognitive science or experimental economics, have been questioning the plausibility of such a sophisticated degree of rationality in agents' behaviour; see, e.g., Simon (1996).

[3]The interested reader can consult Prof. Leigh Tesfatsion's website at `http://econ2.econ.iastate.edu/tesfatsi/amulmark.htm`, which offers a rich library of the models which have been developed in this literature.

[4]See, e.g. Howitt & Clower (2000), Gintis (2007).

[5]See, *inter alia*, Brunn (1997), Gaffeo et al. (2008), Dosi et al. (2010), Riccetti et al. (2012).

[6]See, e.g., Delli Gatti et al. (2007), Dosi et al. (2010, 2013), Cirillo & Gallegati (2012) and Lengnick (2013).

[7]Some DSGE models account for financial frictions, within "financial accelerator" models, see Bernanke & Gertler (1995) for an overview. However, these frictions generally operate through the supply side, whereas our ABM is demand-driven. One exception, which is closely related to our paper is Eggertsson & Krugman (2012), and is discussed further below.

[8]The model is implemented as a `Java` application, that is executable at `http://p.seppecher.free.fr/jamel/`

[9]The owners are randomly drawn among households at the beginning of each simulation, and remain the same for the whole simulation.

[10]Notable exceptions include the `Eurace` project (Deissenberg et al. (2008)), Riccetti et al. (2012) and Lengnick (2013).

[11]The expression is due to C. Sims, and refers to the fact that modelling non-optimizing agents can be done in a multitude of ways, by contrast to optimization.

[12]For a general treatment, see Keynes (1979). See De Grauwe (2011, 2012) for a recent application in the New Keynesian model, and Eggertsson & Krugman (2012) in a DSGE model. Our modelling assumption is close in spirit to probability choice models à la Brock & Hommes (1997), and to contagion models of herding behaviour and opinion dynamics in the financial literature, see notably Lux (1995, 1998), Sornette (2003), Tedeschi et al. (2012), Bouchaud (2013).

[13]This behavioural rule finds support in empirical micro studies, see, notably, Burdett & Vishwanath (1988).

[14]This behaviour finds strong empirical support (see, e.g., Allen & Carroll (2001)).

[15]See, for instance, Artus (2013) for a comparative analysis between pessimism and the state of economy in France and other European countries.

[16]This assumption is consistent with the buffer-stock consumption rule assumed in the model, and is in line with both theoretical and empirical studies on precautionary savings and uncertainty. This kind of behaviour has been characterized as *prudence*, see e.g. Kimball (1990).

[17]Probability p could depend on the state of the economy: in adverse states, uncertainty is stronger, and the probability of relying on peers opinion may be higher (and p may be lower). However, while appealing, such an assumption would considerably complicate the design of the behavioural model, without bringing much deeper qualitative insights.

[18]This assumption is intended to be relaxed in future versions of the model, but is not essential to our research question in this paper. For ABMs designed to investigate issues pertaining to innovation, capital accumulation and economic growth, see notably Dosi et al. (2010, 2013).

[19]Total assets correspond to the sum of her inventories (finished and unfinished goods) and deposits.

[20]As a consequence, leverage is made pro-cyclical in our model. We discuss this in more details in Section 3; see Sharpe (1994), Geanakoplos (2010) for general discussion and empirical support, see, more specifically, Eggertsson & Krugman (2012) for a discussion about the link between confidence, leverage and opinion dynamics.

[21]In developed countries, the profit share is close to one third of the income. We obtain about 10 weeks for the average unemployment duration, which roughly matches the OECD data in the 2000's. The average mark-up varies across sectors, but we obtain around 30%, which falls into the range of usual estimations in the related literature.

[22]Following standard practices in macro time series analysis, all time series have been bandpass filtered, and represent deviations from a long term average value, see Baxter & King (1999). Plots correspond to one run of the model, and statistical significance of the results is systematically established using 30 replications of this run with different seeds of the random number generator.

[23]A non-exhaustive list includes Gaffeo et al. (2008), Dosi et al. (2010, 2013), Riccetti et al. (2012) and Lengnick (2013).

[24]See Figure 10 below, we comment further on that point in the following sub-section.

[25]Nonetheless, in our framework, indebtedness, which is the main ingredient in Fischerian debt-deflation theory, does not come from new investment opportunities, but from a wave of optimism during a stable economic period. To that respect, our model is more closely related to Eggertsson & Krugman (2012), originated from the idea of Minsky (1986).

[26]This is due to the simple modelling of the banking sector in the current version of the ABM, which abstracts, notably, from governments or central bank's intervention. These elements are left for future developments of the model.

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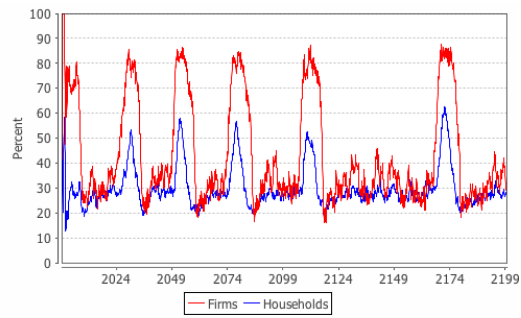
(a) Animal spirits
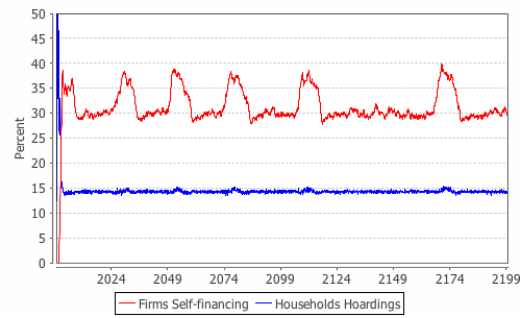
(b) Precautionary behaviour

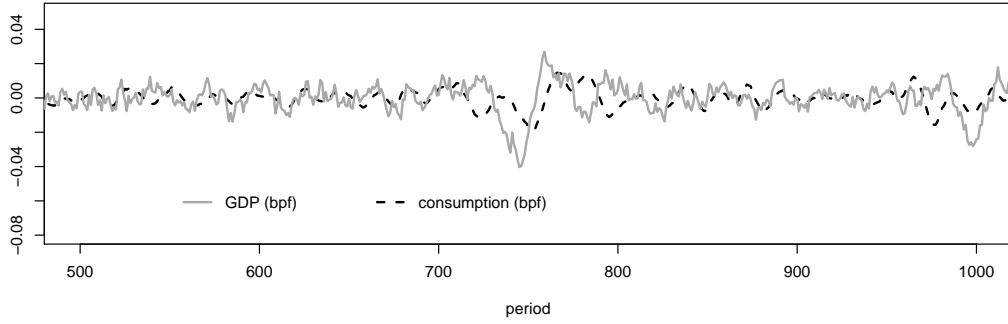(c) Real GDP and consumption
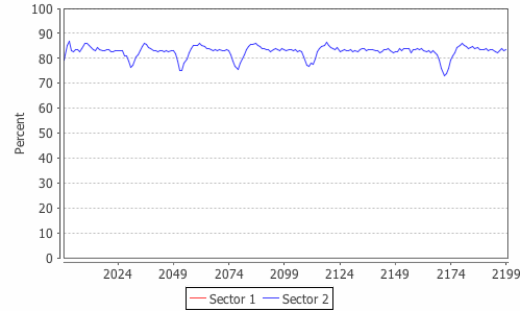
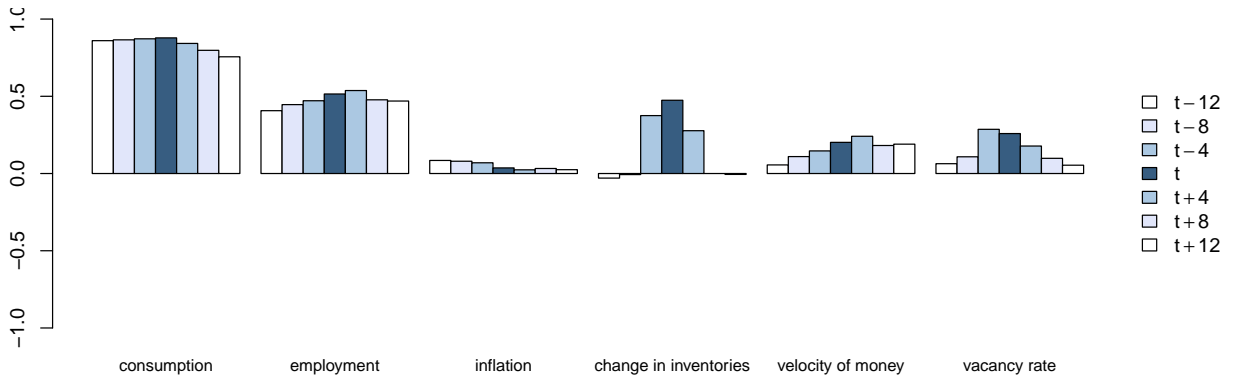(d) Capacity utilization
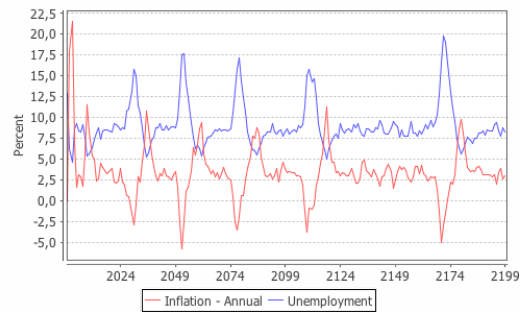
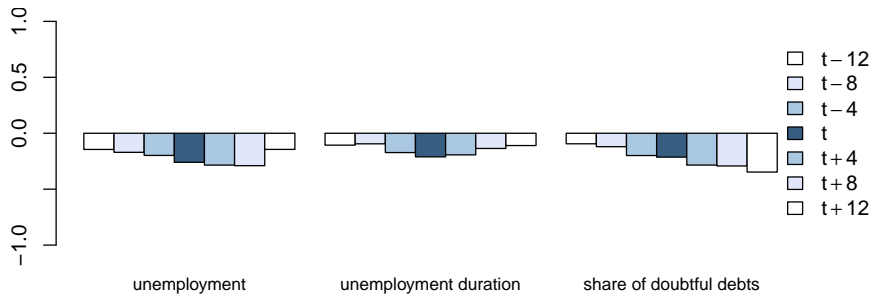(e) Inflation and unemployment rates
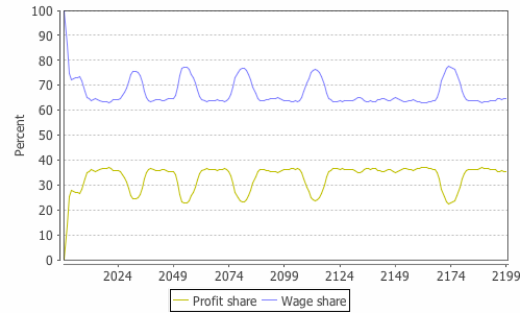
(f) Income distribution

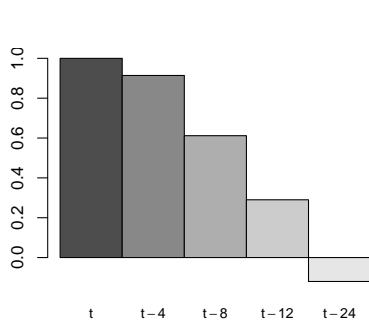Figure 1: `Baseline` scenario – Main macroeconomic variables

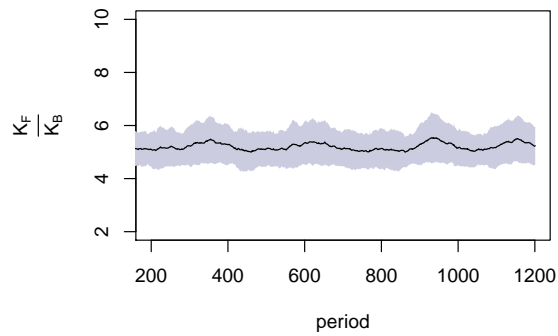(a) Output gap and aggregate consumption gap fluctuations (i.e. as deviations from long-run average)

(b) Cross-correlation with GDP at time t (pro-cyclical variables)

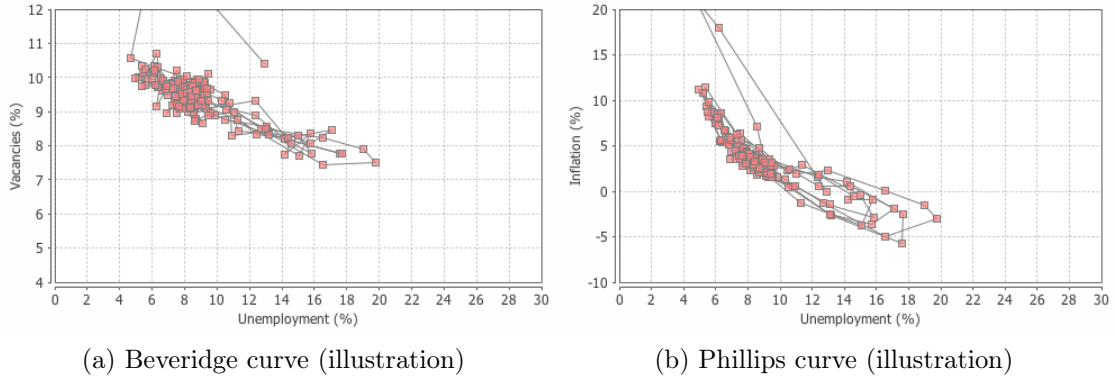(c) Cross-correlation with GDP at time t (contra-cyclical variables)

(d) GDP autocorrelation function

(e) Capital ratio (bank over firms)

Figure 2: Macroeconomic statistical features (average over 30 replications).

	slope of the Phillips curve			slope of the	Variance ratio
flexible prices $(d^p = 1)$	sticky prices $(d^p \hookrightarrow \mathcal{U}[1,2])$	sticky prices $(d^p \hookrightarrow \mathcal{U}[1,3])$	sticky prices $(d^p \hookrightarrow \mathcal{U}[1,4])$ (baseline)	Beveridge curve (baseline)	consumption/ output (baseline)
-1.6192	-1.673	-1.055	-0.7035	-0.1313	0.8432
(0.1573)	(0.131)	(0.1211)	(0.0308)	(0.0835)	(0.0501)

Figure 3: Average over 30 runs, standard deviations in brackets.

(a) Beveridge curve (illustration)

(b) Phillips curve (illustration)

	Estimated shape parameter	skewness	p-value (Shapiro test)
Firms' capital	1.2342	1.2103	0
	(0.0476)	(0.033)	(0)
Firms' profits	1.1112	1.6902	0
	(0.0356)	(0.355)	(0)

Figure 4: Estimations over 30 runs of the `baseline` scenario.

(a) Firms' size distribution (capital)

(b) Firms' size distribution (profits)
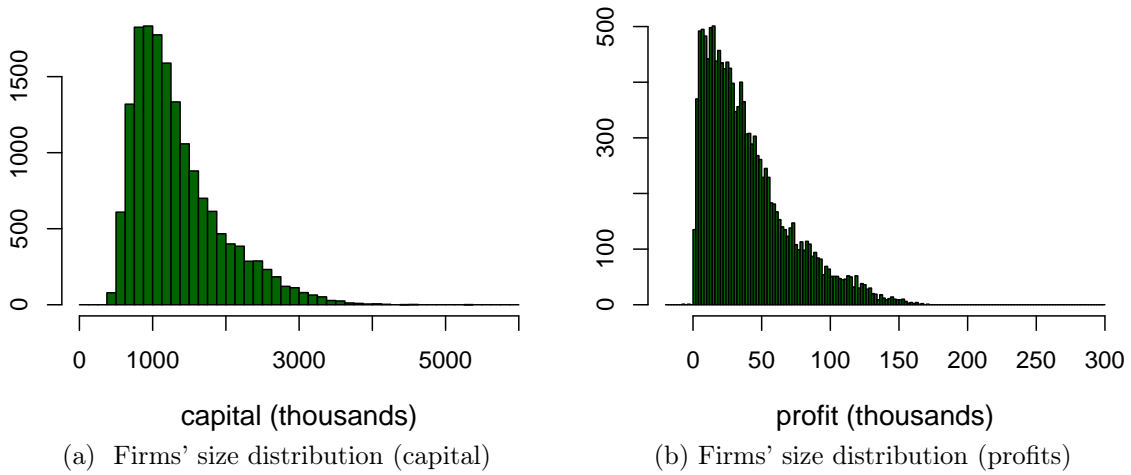
Figure 5: Non-normal and right-skewed firms' size distribution.
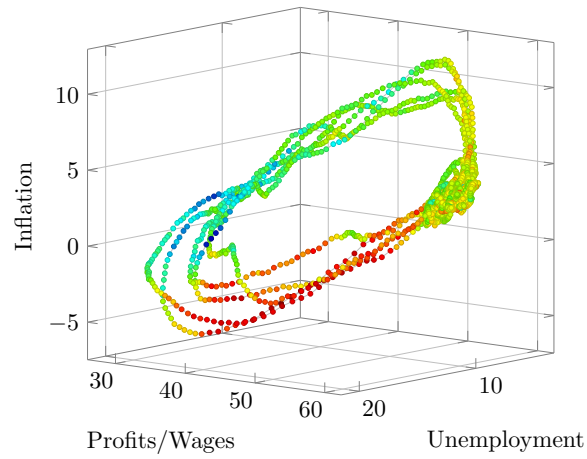
Figure 6: Co-evolution of unemployment, the ratio between the profit share and the wage share (Profits/Wages) and inflation during the business cycle in the model with the `baseline` simulation. Each point represents a period during a simulation. Numbers are percentages.
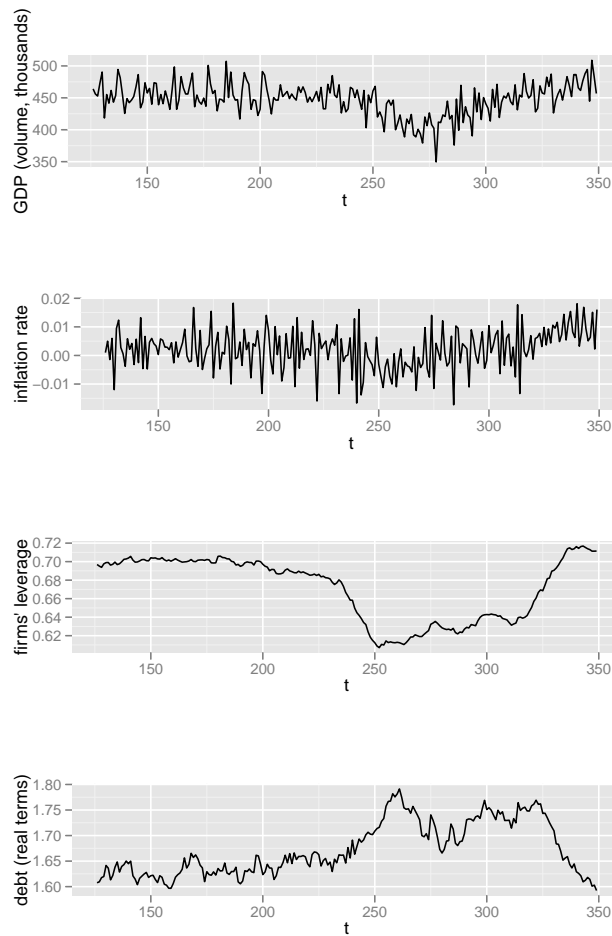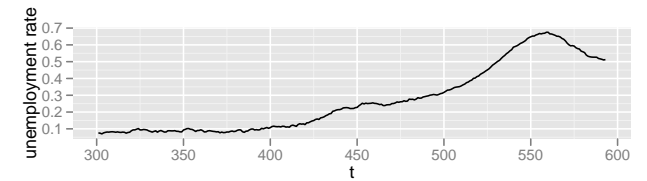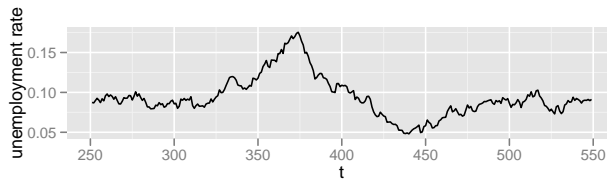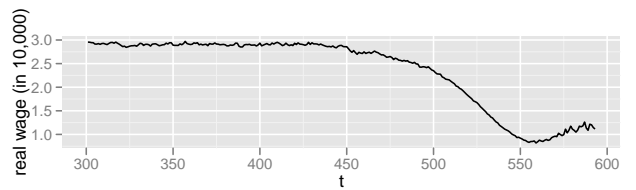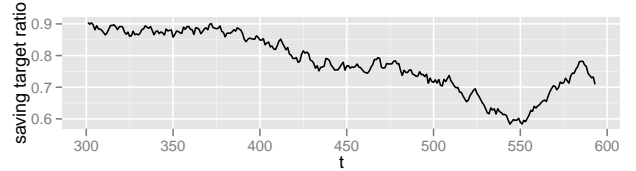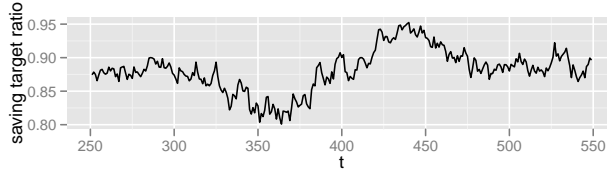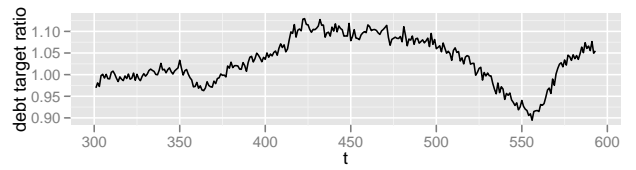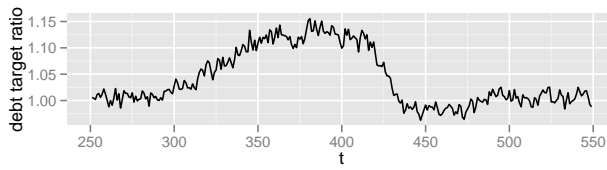

Figure 7: Illustration of the evolution of debt and GDP during a deleveraging crisis
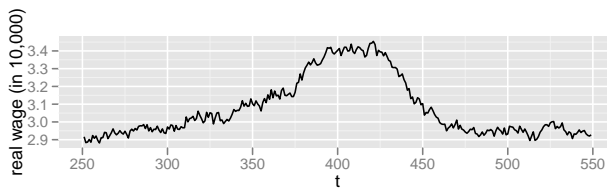
(g) baseline scenario   (h) flexible wages ($\eta_H = 0.25$)

Figure 8: Illustration of the evolution of firms' debt and households' savings (both expressed as a ratio over the targeted level) and real wage during a crisis.
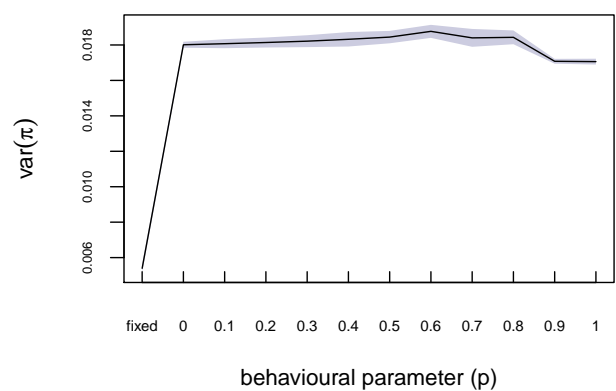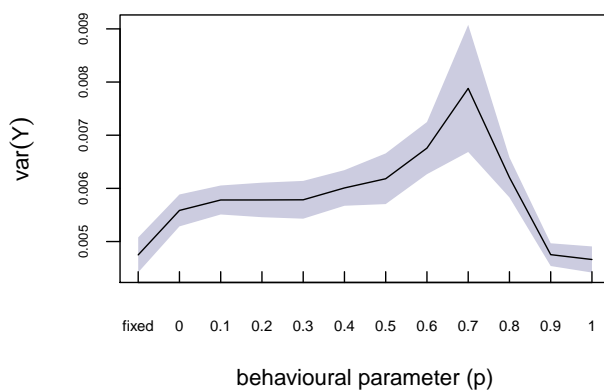

Figure 9: Average volatility of output gap (left panel) and inflation (right panel) over 30 replications of the simulations, $1,400$ periods (the grey bands give the standard deviation), for different behavioural assumptions ("fixed" corresponds to the model with fixed behaviour illustrated in Figure 10)

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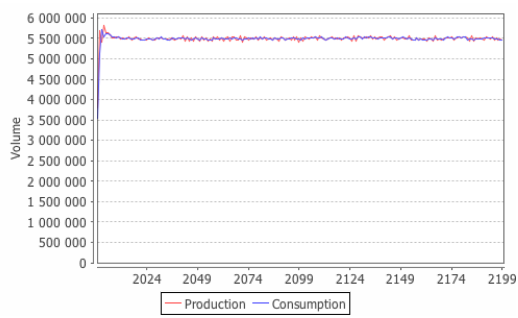
(a) Real GDP and consumption
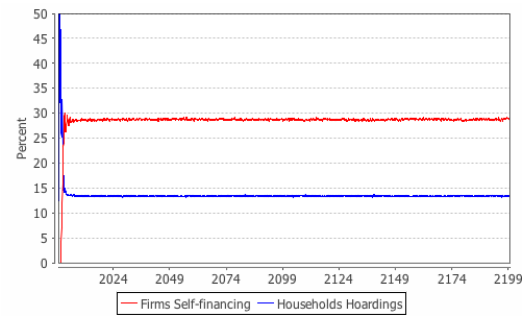
(b) Financial behaviour

Figure 10: Output series of the `Jamel` model with fixed behaviour and $p = 0.7$

	Households	Firms	Bank	Σ
Inventories		+1590161		+1590161
Money deposits	+752541	+697894	−1450434	0
Loans		−1592759	+1592759	0
Capital	+837621	−695296	−142325	0
Balance (net worth)	−1590161	0	0	+1590161
Σ	0	0	0	0

Table 1: Illustration: balance sheet matrix at a typical period of the `Jamel` model, values are expressed in real terms.

Parameter	Description	Baseline value
Parameters of the households' behaviour		
n	number of households	5000
d^w	wage resistance	12 (months)
η_H	wage adjustment parameter	0.05
κ_S^o	targeted savings rate (optimistic households)	0.15
κ_S^p	targeted savings rate (pessimistic households)	0.2
ρ_S	past saving window	
μ_H	rate of consumption of excess savings	0.5
Parameters of the firms' behaviour		
m	number of firms	550
K	number of machines per firm	10
pr^k	productivity of the machines	100
g	size of the market selection	10
d^m	length of the production process	8 (months)
in^*	targeted proportion of inventories	2 (months of production)
v_F	adjustment parameter	0.05
d^p	price rigidity parameter	$\mathcal{U}[1,4]$ (months)
ρ_F	targeted level of vacancies	0.03
d^w	length of employment contracts	$\mathcal{U}[6,18]$ (months)
κ_F^o	targeted level of capital (optimistic firms)	0.2
κ_F^p	targeted level of capital (pessimistic firms)	0.5
s_F	targeted sales ratio	0.85
t_f	regeneration time (min)	$\mathcal{U}[12,36]$ (months)
Parameters of the bank's behaviour		
r	interest rate	0.05
r'	premium interest rate	0.1
d_l	credit length	12 (months)
d_l'	extended credit length	12 (months)
κ_B	targeted level of capital	0.1
Parameter of opinion dynamics		
p	animal spirits probability	0.7
h	size of the neighbourhood	3

Table 2: Calibration of the `baseline` scenario. Random draws are performed at each period and for each agent.

unemployment rate	inflation (yearly rate)	unemployment duration (months)	mark-up	profit share	velocity of money	Gini coefficient (income)
0.0909	0.0308	2.2188	0.333	0.33	3.64	0.36
(0.002)	(0.0006)	(0.0155)	(0.0092)	(0.0091)	(0.0276)	(0.0311)

Table 3: Average over 30 runs, standard deviation in brackets.

Estimated shape parameter of the Pareto distribution	Size of the upper tail (% of households)	p-value of the K-S test (significant fit if above 0.05, see Clauset et al. (2009))
4.3573	1.966	0.3956
(1.162)	(0.0142)	(0.0338)

Table 4: Fit of a Pareto distribution on households' income, average over 30 runs, standard deviation in brackets.