Агентная макроэкономическая модель с согласованными реальными и финансовыми потоками

А.В. Леонидов

ФИАН, МФТИ, УДП

1A. Caiani et al., "Agent-based stock-flow consistent macroeconomics: Towards a benchmark model" Journal of Economic Dynamics & Control 69 (2016), 375-408
A collection $\Phi_H$ of households selling their labor to firms in exchange for wages, consuming and saving in the form of banks' deposits. Households own firms and banks proportionally to their wealth, and receive a share of firms' and banks' profits as dividends. Unemployed workers receive a dole from the government. Finally, households pay taxes on their gross income.

- **Two collections of firms**: consumption ($\Phi_C$) and capital ($\Phi_K$) firms. Consumption firms produce a homogeneous consumption good using labor and capital goods manufactured by capital firms. Capital firms produce a homogeneous capital good characterized by the binary $\{\mu_k, l_k\}$, indicating respectively the capital productivity and the capital-labor ratio. Firms may apply for loans to banks in order to finance production and investment. Retained profits are held in the form of banks' deposits.

- A collection $\Phi_B$ of banks, collecting deposits from households and firms, granting loans to firms, and buying bonds issued by the Government. Mandatory capital and liquidity ratios constraints apply. Banks may ask for cash advances to the Central Bank in order to restore the mandatory liquidity ratio.

- A Government sector, which hires public workers (a constant share of the workforce) and pay unemployment benefits to households. The government holds an account at the Central Bank, collects taxes, and issues bonds to cover its deficits.

- A Central Bank, which issues legal currency, holds banks' reserve accounts and the government account, accommodates banks' demand for cash advances at a fixed discount rate, and possibly buy government bonds which have not been purchased by banks.
• A consumption goods market: households interact with consumption firms;
• A capital goods market: consumption firms interacts with capital firms;
• A labor market: households interact with government and both types of firms;
• A credit market: firms interact with banks;
• A deposit market: households and firms interact with banks.

Following Riccetti et al. (2014), we explicitly model agents' dispersed interactions by assuming that agents on the demand and supply sides of each market interact through a common matching protocol. In each period of the simulation, 'demand' agents are allowed to observe the prices or interest rates charged by a random subset (whose size depends on a parameter χ proxying the degree of imperfect information) of potential suppliers. They choose the 'best': the cheapest counterparty for goods, labor, or credit markets, or the bank offering the highest interest rate for the deposit market. Each agent then has a probability of switching (Prs) from the previous supplier to the new one as defined by (3.1).

For the consumption, capital, and credit markets, where prices (or interest rates) express a disbursement from the demander, the probability of switching to the new partner is decreasing (in a non-linear way) with the difference between pold and pnew:

\[ Prs = \begin{cases} 
1 - e^{\epsilon \frac{(p_{\text{new}} - p_{\text{old}})}{p_{\text{new}}}} & \text{if } p_{\text{new}} < p_{\text{old}} \\
0 & \text{otherwise} 
\end{cases} \]  (3.1)

On the deposit market, interest rates generate an income for the depositor, the probability of switching is thus:

\[ Prs = \begin{cases} 
1 - e^{\epsilon \frac{(p_{\text{old}} - p_{\text{new}})}{p_{\text{old}}}} & \text{if } p_{\text{new}} > p_{\text{old}} \\
0 & \text{otherwise} 
\end{cases} \]  (3.2)

where \( \epsilon > 0 \) is an exogenous parameter.

In some cases, some suppliers exhaust inventories available for sale, possibly leaving some customers with a positive residual demand. We then allow demand agents to look for other suppliers within the original random subset of potential partners in order to fulfill it. Markets interactions are 'closed' when demand agents have fulfilled their demand, when there are no supply agents willing or able to satisfy their demand, or if demanders run out of deposits to pay for demanded goods.

3.2 Sequence of events
In each period of the simulation, the following sequence of events takes place:

1. Production planning: consumption and capital firms compute their desired output level based on their sales expectations (sec: 4.1.1).
2. Firms' labor demand: firms evaluate the number of workers needed to produce the desired level of output (sec: 4.1.1).
3. Prices, interest, and Wages: consumption and capital firms set the price of their output while banks determine the interest rate on loans and deposits (sec: 4.1.2 and 4.2). Workers adaptively revise their reservation wages (sec: 4.4).
4. Investment in capital accumulation: consumption firms' determine their desired rate of capacity growth and, as a consequence, their real demand for capital goods.
5. Capital good market - first interaction: consumption firms interact with capital firms and choose their preferred supplier.
flexibility in creating money through loans should be limited by the need to remain profitable in a competitive banking system.

In addition, the model presents a fully disaggregated—fully decentralized economy in which all transactions between private agents occur through local interactions based on matching protocols, rather than aggregating some sector (as for example in Seppecher, 2012; Assenza et al., 2015), or assuming replicator equations as usual in the evolutionary literature (see for example [and later works] Saviotti and Pyka, 2004; Verspagen, 2002; Dosi et al., 2010). This allows not only to analyze the microeconomic distributions of several important variables, but to generate them as an emergent properties of agents' disperse interaction rather than the reflection of a behavioral assumption.

Finally, the model also presents several aspects on novelty in the definition of agents' heuristics, in particular related to firms' investment and funding behavior, banks' interest and lending (and rationing) strategies, and the management of firms' and banks' bankruptcies. To avoid repetitions, we postpone the discussion of these aspects to the dedicated sections.

2. The model

The economy described by the flow diagram of Fig. 1 is composed of:

- A collection $\Phi_H$ of households selling their labor to firms in exchange for wages, consuming and saving in the form of banks' deposits. Households own firms and banks proportionally to their wealth, and receive a share of firms' and banks' profits as dividends. Unemployed workers receive a dole from the government. Finally, households pay taxes on their gross income.
- Two collections of firms: consumption ($\Phi_C$) and capital ($\Phi_K$) firms. Consumption firms produce a homogeneous consumption good using labor and capital goods manufactured by capital firms. Capital firms produce a homogeneous capital good characterized by the binary $\mu_k; l_k$, indicating respectively the capital productivity and the capital-labor ratio. Firms may apply for loans to banks in order to finance production and investment. Retained profits are held in the form of banks' deposits.
- A collection $\Phi_B$ of banks, collecting deposits from households and firms, granting loans to firms, and buying bonds issued by the Government. Mandatory capital and liquidity ratios constraints apply. Banks may ask for cash advances to the Central Bank in order to restore the mandatory liquidity ratio.
- A Government sector, which hires public workers (a constant share of the workforce) and pay unemployment benefits to households. The government holds an account at the Central Bank, collects taxes, and issues bonds to cover its deficits.
- A Central Bank, which issues legal currency, holds banks' reserve accounts and the government account, accommodates banks' demand for cash advances at a fixed discount rate, and possibly buy government bonds which have not been purchased by banks.

During each period of the simulation agents interact on five markets:

- A consumption goods market: households interact with consumption firms;
- A capital goods market: consumption firms interacts with capital firms;
- A labor market: households sell their labor to firms in exchange for wages;
- A bond market: banks buy bonds from the Government;
- A money market: banks and households interact through deposits.

To our knowledge, the only model sharing these features is the Eurace/Eurace-UniBi model (Raberto et al., 2012; van der Hoog and Dawid, 2015).
Deposit transfers: If agents involved hold their deposits at the same bank, payer's deposit is decreased and receiver's increased. Otherwise, also a reserve transfer for the same amount from the payer’s bank to the receiver's bank takes place. The same occurs when an agent decides to move its deposits to a new bank.

Dividends and deposits interests: Firms pay dividends through deposit transfers. Interests on deposits are paid by simply increasing customers' deposits by the required amount. The same occurs for dividends, when the receiver holds a deposit at the paying bank. Otherwise, also a reserve transfer for the dividend amount from the paying bank to the receiver's bank takes place.

Private workers' wages: wages of private workers by firms are paid via a deposit transfer, as explained above.

Public servants' wages and dole: public workers' wages and unemployment benefits give rise to the same type of transfers. The receiver's deposit is increased while reserves are subtracted to the government account at the Central Bank and transferred to the receiver's bank.

Taxes: firms' and households pay taxes using their deposits. Accordingly, the payer's bank transfers reserves for the same amount to the government account at the Central Bank. Banks pay taxes by transferring reserves to the government account at the Central Bank.

Purchases of real goods: transactions in real goods are cleared via a deposit transfer. Contextually, also real goods motivating the transaction are transferred from the seller's to the buyer's asset side.

Purchases of bonds, repayment, and interests: Bonds are a liability for the government and an asset for banks and the Central Bank. Central Bank's purchases increases its liabilities (i.e. reserves, that is legal money) while also increasing the government account at the Central Bank. Interests on bonds are immediately re-distributed to the government. Commercial banks purchases of bonds are cleared via a transfer of reserves from banks to the government current account at the Central Bank. Bonds repayments and bonds interest payments give rise to the opposite flows.

Loans creation, repayment, and interests: Loans and matching deposits are created endogenously and ex-nihilo as explained above. Interest payments and principal repayments (reducing the stock of loans) give rise to the same type of transfers. If borrower's deposit bank coincides with the lending bank, the payment is realized by lowering the borrower's deposit. If the borrower's moved his deposits to another bank, also a corresponding reserves transfer from the borrower's bank to the lending bank takes place.

Cash advances creation, repayment, and interests: Cash advances are a loan extended by the Central Bank to commercial banks which is matched by a temporary increase of banks' reserves (a liability for the Central Bank). Conversely, cash advances repayments extinguished the loan while reducing commercial banks' reserve accordingly. Interest payments give rise to the same type of transfer, reducing private banks' reserves. Interests on cash advances are distributed to the government by increasing its deposit account at the Central Bank.
1. Production planning: consumption and capital firms compute their desired output level.
2. Firms' labor demand: firms evaluate the number of workers needed to produce.
3. Prices, interest, and Wages: consumption and capital firms set the price of their output; banks determine the interest rate on loans and deposits. Workers adaptively revise their reservation wages.
4. Investment in capital accumulation: consumption firms' determine their desired rate of capacity growth and, as a consequence, their real demand for capital goods.
6. Credit demand: Firms assess their demand for credit and select the lending bank.
7. Credit supply: Banks evaluate loan requests and supply credit accordingly.
8. Labor market: unemployed workers interact with firms on the labor market.
9. Production: capital and consumption firms produce their output.
10. Capital goods market (2): consumption firms purchase capital from their supplier. New machineries are employed in the production process starting from the next period.
11. Consumption goods market: households interact with consumption firms and consume.
12. Interest, bonds and loans repayment: firms pay interests on loans and repay a (constant) share of each loan principal. The government repays bonds and interest to bonds' holders. Banks pay interest on deposits. Cash advances and related interests, when present, are repaid.
13. Wages and dole: wages are paid. Unemployed workers receive a dole from the government.
14. Taxes: taxes on profits and income are paid to the government.
15. Dividends: dividends are distributed to households.
16. Deposit market interaction: households and firms select their deposit bank.
17. Bond purchases: banks and the Central Bank purchase newly issued bonds.
Фирмы: ожидания, выпуск и труд

- Ожидаемые величины:

\[ z_t^e = z_{t-1}^e + \lambda(z_{t-1} - z_{t-1}^e) \]

- Capital goods

\[ y_{k,t}^D = s_{k,t}^e(1 + \nu) - \text{inv}_{k,t-1} \]
\[ N_{k,t}^D = \frac{y_{k,t}^D}{\mu N} \]

- Consumption goods

\[ y_{c,t}^D = s_{c,t}^e(1 + \nu) - \text{inv}_{c,t-1} \]
\[ N_{c,t}^D = \frac{y_{c,t}^D}{k_{c,t}^D}, \quad u_{c,t}^D = \min \left( 1, \frac{y_{c,t}^D}{k_{c,t}^D / \mu K} \right) \]
Фирмы: ценообразование и доход

- Ценообразование

\[ p_{x,t} = (1 + mu_{x,t}) \frac{W_{x,t}^e N_{x,t}^D}{y_{x,t}^D} \]

\[ mu_{x,t} = \begin{cases} 
\mu_{x,t-1}(1 + FN), & \frac{inv_{x,t-1}}{s_{x,t-1}} \leq \nu \\
\mu_{x,t-1}(1 - FN), & \frac{inv_{x,t-1}}{s_{x,t-1}} > \nu
\end{cases} \]

- Доход

\[ \pi_{c,t} = s_{c,t} p_{c,t} + i_{b,t-1}^d D_{c,t-1} + (inv_{c,t} uc_{c,t} - inv_{c,t-1} uc_{c,t-1}) \]

\[ - \sum_{n \in N_{\alpha}} w_{n,t} - \sum_{j=t-\eta}^{t-1} i_j^l L_{c,j} \frac{\eta - [(t - 1) - j]}{\eta} - \sum_{k \in K_{c,t-1}} (k^k p_k)^\frac{1}{k} \]
Фирмы: налоги, дивиденды, инвестиции

- Налоги

\[ T_{x,t} = \max(\tau_{\pi} \pi_{x,t}, 0) \]

- Дивиденды

\[ \text{Div}_{x,t} = \max(0, \rho_{x} \pi_{x,t}(1 - \tau_{\pi}), 0) \]

- Инвестиции

  - Определяем желательный рост производительности \( g_{c,t}^{D} \):

\[
g_{c,t}^{D} = \gamma_{1} \frac{r_{c,t-1} - \bar{r}}{\bar{r}} + \gamma_{2} \frac{u_{c,t}^{D} - \bar{u}}{\bar{u}}
\]

\[
r_{c,t} = \frac{OCF_{c,t}}{\sum_{k \in K_{c,t-1}} k^{k} p^{k} (1 - \frac{\text{age}_{k,t-1}}{\kappa})}
\]

  - Определяем желаемые номинальные инвестиции \( l_{c,t}^{D} \):

\[
g_{c,t}^{D} \rightarrow i_{c,t}^{D} \rightarrow l_{c,t}^{D} = p_{k,t} i_{c,t}^{D}
\]
Фирмы: спрос на кредиты

Для несовершенных финансовых рынков заемное финансирование дороже, чем собственное - в противоречии с теоремой Модильяни-Миллера

Кредитный спрос $L_{x,t}^D$:

$$L_{c,t}^D = l_{c,t}^D + \sigma W_{e,t}^c N_{c,t}^D - OCF_{c,t}^e$$

$$L_{k,t}^D = \sigma W_{e,t}^k N_{k,t}^D - OCF_{k,t}^e$$
Механизм кредитного рационаирования:

Обслуживание долга характеризуется величиной

\[ ds^{L_d} = \left( i_{b,t}^{L} + \frac{1}{\eta} \right) L^d \]

Вероятность дефолта \( pr_x^D \) оценивается по формуле

\[ pr_x^D = \frac{1}{1 + \exp \left( \frac{OCE_x,t - \zeta_x ds^{L_d}}{ds^{L_d}} \right)} \]
Оценка возможных траекторий плательщика:

Кредит выдается в объеме, обеспечивающем положительную среднюю доходность
Домашние хозяйства

\[
 w_{i}^{d,t} = \begin{cases} 
 w_{h,t-1}^{D}(1 - FN), & \sum_{n=1}^{4} u_{h,t-n} > 2 \\
 w_{h,t-1}^{D}(1 + FN), & \sum_{n=1}^{4} u_{h,t-n} \leq 2, \quad u_{t-1} \leq v 
\end{cases}
\]

Спрос на потребление:

\[
 c_{h,t}^{D} = \alpha_{1} \frac{NI_{h,t}}{p_{h,t}^{e}} + \alpha_{2} \frac{NW_{h,t}}{p_{h,t}^{e}}
\]

Доход домохозяйств:

\[
 w_{h,t} + i_{b,t-1}^{d} D_{h,t-1} + Div_{ht}
\]

А.В. Леонидов (ФИАН, МФТИ, УДП) Семинар ЛМЭ ЦЭМИ ЦЭМИ 20.03.2018 13 / 31
The government hires a constant share of households. Public servants are also subject to a turnover $\theta$. Furthermore the government pays unemployment benefits ($d_t$) to unemployed people ($U_t$). The state collects taxes on income and profits (with constant rates $\tau_i$ and $\tau_p$) from households, firms and banks and issues bonds $b_t$ (at fixed price $\bar{p}_b^b$ and interest $\bar{i}_b^b$) which are assumed to last 1 period for simplicity reasons:

$$\bar{p}_b^b \Delta b_t = T_t + \pi_{CBr} - \sum_{n \in N_{gt}} w_n - U_t d_t - \bar{i}_b^b b_{t-1},$$

where $T_t = T_{Ht} + T_{Ct} + T_{Kt} + T_{Bt}$ are total taxes, $\pi_{CBr}$ are Central Bank profits, $N_{gt}$ is the collection of public workers.

The Central Bank buys bonds not purchased by commercial banks and accommodates banks’ request for cash advances. Cash advances are assumed to be repaid after one period and their constant interest rate represents the upper bound for interest paid by banks on customers’ deposits. For simplicity reasons, we assume the Central Bank pay no interest on private banks' reserves account. Finally, Central Bank earns a profit equal to the flow of interest coming from bonds and cash advances: $\pi_{CBr} = \bar{i}_b^b B_{t-1} + \bar{i}_CB^a CA_{cbt}$. Central Bank’s profits are distributed to the government.
1. We derive an aggregate version of the model.

2. We constrain the aggregate model\textsuperscript{15} to be in a real stationary state associated with a nominal steady growth equal to $g_{ss}$. This imply that while all real quantities are constant, all prices and wages are growing at the same rate $g_{ss}$\textsuperscript{16}.

3. We numerically solve the constrained model by setting exogenously reasonable values for the parameters for which some empirical information is available\textsuperscript{17} (e.g. unemployment rate, mark-ups, interest rates, income and profit tax rates, etc.) or that we want to control (e.g. technological coefficients, number of agents in each sector, distribution of workers across sectors, loans and capital durations). We thereby obtain initial values for each stock and flow variable of the aggregate steady state, as well as for some behavioral parameters coherent with the steady/stationary state (e.g. propensity to consume out of income, target capacity utilization and profit rates, initial capital and liquidity ratio targets for banks).

4. We distribute each sector’s aggregate values uniformly across agents’ in that sector. In this way we derive the total value of each type of stock held by agents (e.g. households’ and firms’ deposits, total outstanding loans and real capital for each firm, total loans, reserves and bonds for individual banks etc.) and agents’ past values to be used for expectations (e.g. past sales, past wages, past profits, etc.).

5. We assume that, in each of the periods before the simulation starts, firms have obtained a loan and consumption firms have also invested in new capital to maintain their productive capacity constant. We further assume that the real value (i.e. corrected for inflation) of the new loan or of the new capital goods was constant in each of these periods. Knowing the constant inflation rate $g_{ss}$ and the amortization schedules for capital goods and loans, we can then derive the outstanding value for each of these stocks, so that their total value sums up to the amount determined in the previous step.\textsuperscript{18}

6. In order to set the network structure, we randomly assign a previous period supplier (required for the matching mechanism) to each demand agent on each market, ensuring that each supplier has the same number of customers. Similarly, we assign to each single financial stock in households’ and firms’ balance sheets, the asset or liability counterpart by randomly selecting a bank. Again, we impose that each bank has the same number (and amount) of deposits and loans with the same number of agents.
N_k = \frac{y_k}{\mu_N} \tag{A.1}

\text{uc}_k = \frac{WN_k}{y_k} = \frac{W}{\mu_N} \tag{A.2}

\begin{align*}
\rho_k &= (1 + mu_k)\text{uc}_k \tag{A.3} \\
D_k &= \sigma WN_k \tag{A.4} \\
y_k &= (i_c = )\frac{k}{\kappa} \tag{A.5} \\
\text{inv}_k &= \nu y_k \tag{A.6} \\
\pi_k &= \rho_k y_k + \frac{iD_k}{1 + g_{SS}} + \text{inv}_k \frac{g_{SS}}{1 + g_{SS}} \text{uc}_k - WN_k - \frac{iL_k}{1 + g_{SS}} \tag{A.7} \\
T_k &= \pi_k \tau_k \tag{A.8} \\
\text{Div}_k &= \rho_k[\pi_k(1 - \tau_k)] \tag{A.9} \\
L_k \left( \frac{g_{SS}}{1 + g_{SS}} \right) &= \left( \text{inv}_k \frac{g_{SS}}{1 + g_{SS}} \text{uc}_k \right) + \left( D_k \frac{g_{SS}}{1 + g_{SS}} \right) - (\pi_k - T_k - \text{Div}_k) \tag{A.10}
\end{align*}
Калибровка модели: consumption firms

\[ N_c = \frac{y_c}{\mu_k I_k} \]  
(A.11)

\[ uvc_c = \frac{WN_c}{y_c} \]  
(A.12)

\[ uc_c = \frac{WN_c + p_k k}{\kappa^2} \sum_{j=1}^{\kappa} \frac{1}{(1 + g_{SS})^j} \]  
(A.13)

\[ K_c = \frac{p_k k}{\kappa^2} \sum_{j=1}^{\kappa} \frac{j}{(1 + g_{SS})^{\omega_l-j}} \]  
(A.14)

\[ p_c = (1 + m u_c) uvc_c \]  
(A.15)

\[ D_c = \sigma WN_c \]  
(A.16)

\[ y_c = ku\mu_k \]  
(A.17)

\[ inv_c = \nu y_c \]  
(A.18)

\[ \pi_c = p_c y_c + \frac{i^d D_c}{1 + g_{SS}} + inv_c \frac{g_{SS}}{1 + g_{SS}} uc_c - WN_c - \frac{i^d L_c}{1 + g_{SS}} - \frac{p_k k}{\kappa^2} \sum_{j=1}^{\kappa} \frac{1}{(1 + g_{SS})^j} \]  
(A.19)

\[ T_c = \pi_c \tau_c \]  
(A.20)

\[ Div_c = \rho_c [\pi_c (1 - \tau_c)] \]  
(A.21)

\[ L_c \left( \frac{g_{SS}}{1 + g_{SS}} \right) = (i_c p_k) \left( inv_c \frac{g_{SS}}{1 + g_{SS}} uc_c \right) + \left( D_c \frac{g_{SS}}{1 + g_{SS}} \right) - (\pi_c - T_c - Div_c) - \frac{p_k k}{\kappa^2} \sum_{j=1}^{\kappa} \frac{1}{(1 + g_{SS})^j} \]  
(A.22)
\[ N_{\text{tot}} = N_c + N_k + N_g \]  

(A.23)

\[ NI_h = \left( WN_{\text{tot}} + \frac{i^d D_h}{1 + g_{ss}} + \frac{Div_c + Div_k + Div_b}{1 + g_{ss}} \right) (1 - \tau_h) - \omega W (size_{\phi} - N_{\text{tot}}) \]  

(A.24)

\[ T_h = \left( WN_{\text{tot}} + \frac{i^d D_h}{1 + g_{ss}} + \left( \frac{Div_c + Div_k + Div_b}{1 + g_{ss}} \right) \right) \tau_h \]  

(A.25)

\[ c_h = \alpha_1 \frac{NI_h}{p_c} + \alpha_2 \frac{NW_h}{(1 + g_{ss})p_c} \]  

(A.26)

\[ c_h = y_c \]  

(A.27)

\[ C_h = c_h p_c \]  

(A.28)

\[ NW_h \left( \frac{g_{ss}}{1 + g_{ss}} \right) = NI_h - C_h - \frac{(Div_c + Div_k + Div_b)}{1 + g_{ss}} + (Div_c + Div_k + Div_b) \]  

(A.29)

\[ NW_h = D_h \]  

(A.30)
Калибровка модели: государство и замыкание

\[ \pi_b = i^b L_c + L_k + \frac{B_b}{1 + g_{SS}} - \frac{i^b D_h + D_c + D_k}{1 + g_{SS}} \]  
(A.31)

\[ T_b = \pi_b \tau_b \]  
(A.32)

\[ \text{Div}_b = \rho_b[\pi_b (1 - \tau_b)] \]  
(A.33)

\[ NW_b = L_c + L_k + B_b + R_b - D_h - D_c - D_k \]  
(A.34)

\[ R_b = B_{CB} \]  
(A.35)

\[ B_{CB} = B - B_b \]  
(A.36)

\[ B \left( \frac{g_{SS}}{1 + g_{SS}} \right) = WN_g + \omega W (\text{size}_{ph} - N_{tot}) + \frac{i^b B}{1 + g_{SS}} - (T_h + T_b + T_c + T_k) - \pi_{CB} \]  
(A.37)

\[ \pi_{CB} = \frac{i^b B_{CB}}{1 + g_{SS}} \]  
(A.38)

\[ u = \frac{\text{size}_{ph} - N_{tot}}{N_{tot}} \]  
(A.39)
### Table 1
Aggregate balance sheet (initial situation).

<table>
<thead>
<tr>
<th></th>
<th>Households</th>
<th>Cons. firms</th>
<th>Cap. firms</th>
<th>Banks</th>
<th>Govt.</th>
<th>Central bank</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposits</td>
<td>+80 704.1</td>
<td>+25 000</td>
<td>+5000</td>
<td>−110 704</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Loans</td>
<td>0</td>
<td>−52 194.4</td>
<td>−1298</td>
<td>+53 492.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cons. goods</td>
<td>0</td>
<td>+2997.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+2997.4</td>
</tr>
<tr>
<td>Cap. goods</td>
<td>0</td>
<td>+53 863.6</td>
<td>+500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+54 363.6</td>
</tr>
<tr>
<td>Bonds</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+38 273.5</td>
<td>−66 838.1</td>
<td>+28 564.6</td>
<td>0</td>
</tr>
<tr>
<td>Reserves</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+28 564.6</td>
<td>0</td>
<td>−28 564.6</td>
<td>0</td>
</tr>
<tr>
<td>Advances</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Net worth</td>
<td>+80 704.1</td>
<td>+29 666.6</td>
<td>+4202</td>
<td>+9626.4</td>
<td>−66 838.1</td>
<td>0</td>
<td>+57 361</td>
</tr>
</tbody>
</table>
Table 2
Aggregate transaction flow matrix (initial situation).

<table>
<thead>
<tr>
<th></th>
<th>Households</th>
<th>Cons. Firms</th>
<th>Cap. Firms</th>
<th>Banks</th>
<th>Govt.</th>
<th>Central Bank</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CA KA</td>
<td>CA KA</td>
<td>CA KA</td>
<td>CA KA</td>
<td>CA KA</td>
<td>CA KA</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>-32,971.4</td>
<td>+32,971.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wages</td>
<td>+36,800</td>
<td>-25,000</td>
<td>-5000</td>
<td>0</td>
<td>0</td>
<td>-6800</td>
<td>0</td>
</tr>
<tr>
<td>Dole</td>
<td>+1,280</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-1,280</td>
<td>0</td>
</tr>
<tr>
<td>CG on inventories</td>
<td>0</td>
<td>+22.3</td>
<td>-22.3</td>
<td>+3.7</td>
<td>-3.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Investments</td>
<td>0</td>
<td>0</td>
<td>-5375</td>
<td>+5375</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Capital amortization</td>
<td>0</td>
<td>-4,974</td>
<td>+4,974</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Taxes</td>
<td>-7084.7</td>
<td>-484.8</td>
<td>-68.7</td>
<td>-39.3</td>
<td>0</td>
<td>+7,677.4</td>
<td>0</td>
</tr>
<tr>
<td>Dep. interest</td>
<td>+200.3</td>
<td>+62</td>
<td>+12.4</td>
<td>-274.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bonds interest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+95</td>
<td>0</td>
<td>-165.9</td>
<td>0</td>
</tr>
<tr>
<td>Loans interest</td>
<td>0</td>
<td>-388.5</td>
<td>0</td>
<td>-9.7</td>
<td>0</td>
<td>+398.2</td>
<td>0</td>
</tr>
<tr>
<td>Advances interest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Profits</td>
<td>+2,367.6</td>
<td>-220.8</td>
<td>+220.8</td>
<td>-312.8</td>
<td>+31.3</td>
<td>-179.1</td>
<td>0</td>
</tr>
<tr>
<td>Δ Deposits</td>
<td>-600.8</td>
<td>0</td>
<td>-186.1</td>
<td>0</td>
<td>-37.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Δ Advances</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+824.1</td>
<td>0</td>
</tr>
<tr>
<td>Δ Reserves</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-212.6</td>
<td>0</td>
</tr>
<tr>
<td>Δ Gov. bonds</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-284.9</td>
<td>+497.6</td>
<td>0</td>
</tr>
<tr>
<td>Δ Loans</td>
<td>0</td>
<td>0</td>
<td>+388.5</td>
<td>0</td>
<td>-398.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Δ Total</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
**Table 3**
Parameters.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Baseline</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>gss: pre-SS</td>
<td>Nominal rate of growth in the SS</td>
<td>0.0075</td>
<td>Same</td>
</tr>
<tr>
<td>size⁢ηi : pre-SS</td>
<td>Number of households</td>
<td>8000</td>
<td>Same</td>
</tr>
<tr>
<td>size⁢ηc : pre-SS</td>
<td>Number of consumption firms</td>
<td>100</td>
<td>Same</td>
</tr>
<tr>
<td>size⁢μi : pre-SS</td>
<td>Number of capital firms</td>
<td>20</td>
<td>Same</td>
</tr>
<tr>
<td>N⁢μi : pre-SS</td>
<td>Number of banks</td>
<td>1360</td>
<td>Same</td>
</tr>
<tr>
<td>N⁢μo : pre-SS</td>
<td>Consumption firms' initial workers</td>
<td>4000</td>
<td>Same</td>
</tr>
<tr>
<td>νo : pre-SS</td>
<td>Capital firms' initial workers</td>
<td>1000</td>
<td>Same</td>
</tr>
<tr>
<td>μo: pre-SS</td>
<td>Initial unemployment</td>
<td>0.08</td>
<td>Same</td>
</tr>
<tr>
<td>μN: SS-given</td>
<td>Productivity of labor in K sector</td>
<td>2</td>
<td>Same</td>
</tr>
<tr>
<td>χ⁢μi,κ : pre-SS and SS-given</td>
<td>Productivity and capital/labor ratios of K</td>
<td>(1.6,4)</td>
<td>Same</td>
</tr>
<tr>
<td>(χ_\epsilon = \chi_\nu ): free</td>
<td>Number of potential partners on C and K goods mkts</td>
<td>5</td>
<td>Same</td>
</tr>
<tr>
<td>(\chi_\mu ): free</td>
<td>Number of potential partners on deposit-credit mkts</td>
<td>3</td>
<td>Same</td>
</tr>
<tr>
<td>(\chi_\nu ): free</td>
<td>Number of potential partners on labor mkt (for each vacant job)</td>
<td>10</td>
<td>Same</td>
</tr>
<tr>
<td>(\phi^\nu = \phi^\lambda ): free</td>
<td>Intensity of choice in deposit-credit mkts</td>
<td>4.62098</td>
<td>Same</td>
</tr>
<tr>
<td>(\phi^\epsilon = \phi^\lambda ): free</td>
<td>Intensity of choice in C and K goods mkts</td>
<td>3.46574</td>
<td>Same</td>
</tr>
<tr>
<td>(\nu: pre-SS)</td>
<td>Firms' inventories target share</td>
<td>0.1</td>
<td>Same</td>
</tr>
<tr>
<td>λ: free</td>
<td>Adaptive expectations parameter</td>
<td>0.25</td>
<td>Same</td>
</tr>
<tr>
<td>(\beta: pre-SS)</td>
<td>Labor turnover ratio</td>
<td>0.05</td>
<td>Same</td>
</tr>
<tr>
<td>(\mu_\omega: pre-SS)</td>
<td>Initial mark-up on ULC for C firms</td>
<td>0.31857</td>
<td>Same</td>
</tr>
<tr>
<td>(\mu_\mu: pre-SS)</td>
<td>Initial mark-up on ULC for K firms</td>
<td>0.075</td>
<td>Same</td>
</tr>
<tr>
<td>(\mu_m,\sigma_m): free</td>
<td>Folded Normal Distribution parameters</td>
<td>(0,0.0094)</td>
<td>Same</td>
</tr>
<tr>
<td>(\tau_\epsilon = \tau_\nu ): pre-SS</td>
<td>Profit and Income tax rates</td>
<td>0.18</td>
<td>Same</td>
</tr>
<tr>
<td>(\eta: pre-SS)</td>
<td>Loans duration</td>
<td>20</td>
<td>Same</td>
</tr>
<tr>
<td>(\kappa: pre-SS)</td>
<td>Capital goods duration</td>
<td>20</td>
<td>Same</td>
</tr>
<tr>
<td>(\gamma: SS-given)</td>
<td>Target profit rate (Investment function)</td>
<td>0.0435</td>
<td>Same</td>
</tr>
<tr>
<td>(\tau: SS-given)</td>
<td>Target capacity utilization (Investment function)</td>
<td>0.8</td>
<td>Same</td>
</tr>
<tr>
<td>(\gamma_\nu ): free</td>
<td>Profit rate weight (Investment function)</td>
<td>0.01</td>
<td>0.000: 0.005: 0.040</td>
</tr>
<tr>
<td>(\gamma_\omega ): free</td>
<td>Capacity utilization rate weight (Investment function)</td>
<td>0.02</td>
<td>0.000: 0.005: 0.040</td>
</tr>
<tr>
<td>(\sigma: pre-SS)</td>
<td>Firms' precautionary deposits as share of WB</td>
<td>1</td>
<td>0.5: 0.1: 1.5</td>
</tr>
<tr>
<td>(\rho^\epsilon = \rho^\lambda ): pre-SS</td>
<td>Firms' profits' share distributed as dividends</td>
<td>0.9</td>
<td>Same</td>
</tr>
<tr>
<td>(\rho^\omega ): pre-SS :</td>
<td>Banks' profit share distributed as dividends</td>
<td>0.6</td>
<td>Same</td>
</tr>
<tr>
<td>(\rho^\nu ): pre-SS :</td>
<td>Initial interest rate on loans</td>
<td>0.0075</td>
<td>Same</td>
</tr>
<tr>
<td>(\rho^\nu ): pre-SS :</td>
<td>Initial interest rate on deposits</td>
<td>0.0025</td>
<td>Same</td>
</tr>
<tr>
<td>(\gamma_\epsilon ): SS-given</td>
<td>Initial banks' target capital ratio</td>
<td>0.17996</td>
<td>Same</td>
</tr>
<tr>
<td>(\gamma_\omega ): SS-given</td>
<td>Initial banks' target liquidity ratio</td>
<td>0.258026342</td>
<td>Same</td>
</tr>
<tr>
<td>(\gamma_\nu ): SS-given</td>
<td>Initial banks' target liquidity ratio</td>
<td>3.92245</td>
<td>1.0: 1.0: 10.0</td>
</tr>
<tr>
<td>(\gamma_\omega ): SS-given</td>
<td>CB interest rates on advances</td>
<td>21.51335</td>
<td>5.0: 5.0: 40.0</td>
</tr>
<tr>
<td>(\gamma_\nu ): SS-given</td>
<td>CB interest rates on advances</td>
<td>0.005</td>
<td>Same</td>
</tr>
<tr>
<td>(\nu: pre-SS)</td>
<td>Haircut on defaulted firms' capital value</td>
<td>0.5</td>
<td>Same</td>
</tr>
<tr>
<td>(\omega_n: pre-SS)</td>
<td>Initial wages</td>
<td>5</td>
<td>Same</td>
</tr>
<tr>
<td>(\alpha_\gamma ): pre-SS</td>
<td>Dole (share of average wages)</td>
<td>0.4</td>
<td>Same</td>
</tr>
<tr>
<td>(\nu: free)</td>
<td>Unemployment threshold in wage revision function</td>
<td>0.08</td>
<td>Same</td>
</tr>
<tr>
<td>(\omega: SS-given)</td>
<td>Propensity to consume out of income</td>
<td>0.38581</td>
<td>Same</td>
</tr>
<tr>
<td>(\omega_\epsilon ): SS-given</td>
<td>Propensity to consume out of wealth</td>
<td>0.25</td>
<td>Same</td>
</tr>
<tr>
<td>(\omega^\nu ): pre-SS</td>
<td>Bonds interest rate</td>
<td>0.0025</td>
<td>Same</td>
</tr>
<tr>
<td>(\pi: pre-SS)</td>
<td>Bonds price</td>
<td>1</td>
<td>Same</td>
</tr>
</tbody>
</table>
The analysis of variables trends highlights that the model first experiences a succession of expansionary and recessionary phases. This behavior is driven by the interaction of real and nominal variables, such as consumption prices, net-income, and capital prices. Growth rates of prices and wages, as well as capacity utilization rates, are key indicators that help in understanding the economic dynamics.

Consumption (real units) experiences a growth process that leads to higher employment, which further stimulates demand, also through the wages in consumption prices. The increased mark-ups, however, increase production costs, reducing profit margins and causing an overall loss of purchasing power.

For expectations to catch up with actual values, it is required that rates of growth stabilize. Whenever wages growth accelerates, firms revise upwardly the prices of their output whereas only employed workers can increase their reservation wage, thus making their dynamics strongly path-dependent. This implies that the properties of the economy in its quasi-steady state configuration are affected by the symmetric condition imposed on agents' within each sector, which generates a rapid increase in unemployment, followed by an equally rapid recovery.

The time between periods 10 and 45 display a self-fuelling real growth process driven by real consumption: higher consumption prices result in higher production costs, which in turn lead to higher wages, causing an overall loss of purchasing power. The increased mark-ups however increase production costs, reducing profit margins and causing an overall loss of purchasing power. The increased mark-ups however increase production costs, reducing profit margins and causing an overall loss of purchasing power.

The model is employed for policy purposes, providing useful insights on the mechanisms that generate price and wage dynamics, capacity utilization rates, and investment. Third, agent based models are normally characterized by path-dependent dynamics, thereby helping to attain a deeper understanding of the inherent behavior of the model. Second, the analysis of the transient phase, for the very fact of being characterized by more pronounced (possibly extreme) fluctuations, can compensate the effect on capacity utilizations margins helping to compensate the effect on capacity utilization.

Average Firms' Bankruptcies
The reduction of profit margins reduces the amount of internal funding available to finance production and investment. A. Caiani et al. / Journal of Economic Dynamics & Control 69 (2016) 375–408

Capacity unaltered. After some period, real investment also stabilizes around the level required to keep consumption and capacity unaltered. Real consumption hits the ground around period 130, whereas the rise of wages, employment, and capital prices increases expenses. On average, consumption keeps rising, fostering a process of increasing concentration on real markets.

Simulations. Dashed lines are trends standard deviations across Monte Carlo runs. The situation at the micro level is far more variegated. Some firms outperform and experience increasing profitability, while an increasing number of firms undergo a dramatic drain of liquid resources.

Validation

A. Caiani et al. / Journal of Economic Dynamics & Control 69 (2016) 375–408

Phase 2

Recovery and convergence to the quasi steady-state

Trend inversion and great recession

Fig. 3.
The model also reproduces several other important macroeconomic stylized facts observed in reality. Fig. 6 (left panel) highlights that, in accordance with the empirical evidence on business cycles, inflation is pro-cyclical and lagging (tending to build up during an expansion and fall after the cyclical peak), whereas mark-ups are counter-cyclical and lagging, see Bils (1987) and, for a survey of the literature on business cycles and countercyclical markups, Rotemberg and Woodford (1999).

In addition, the model assumption that firms revise adaptively their prices every period of the simulation (i.e. a quarter) is fairly in line with the evidence provided in Klenow and Kryvtsov (2005) that find a monthly frequency of price changes of 29.3% (implying a pseudo-average duration of 3.4 months). Their paper also highlights that, despite moderate inflation, there is no evidence of prices downward rigidity at the microeconomic level, as price decreases account for 45% of total price changes. Price decreases in a context of moderate inflation (see below) are not uncommon (though less frequent) in our model as well, where the frequency of price-decreases ranges between 0.30 and 0.40 approximately across the baseline Monte Carlo runs.

Fig. 7 shows that changes in inventories are pro-cyclical whereas the inventories/sales ratio is counter-cyclical as we would expect by looking at the empirical literature (see Bils and Kahn, 2000). Usually, during a business downturn, firms let...
other, which is captured by the underlying correlation structure of macroeconomic variables, is kept unaltered in its main properties.

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Fig. 7 shows that changes in inventories are pro-cyclical whereas the inventories/sales ratio is counter-cyclical as we would expect by looking at the empirical literature (see Bils and Kahn, 2000). Usually, during a business downturn, firms let

This is consistent with economic reality where, despite the changes in agents' habits and 'animal spirits', the properties of the correlation structure of macroeconomic aggregates is fairly stable, thus justifying their adoption as a criteria to validate macroeconomic models.

The pro-cyclicality of inflation is explained by the fact that firms change adaptively their desired mark-up according to their sales performance, so during upturns they increases (on average) prices, and vice-versa. However, the markup is then applied on expected unit labor costs. If wages keep rising as a consequence of lower unemployment, realized unit labor costs will be higher than expected ones, more than compensating the increase in desired markups. The opposite happens during downturns, thus explaining the counter-cyclical behavior of markups.
their inventories decline producing less. In the model, a drop in real sales reduces the desired amount of inventories which is defined as a constant share of sales. However, since unsold inventories are accumulated, the drop is less than proportional with respect to sales, explaining the counter cyclical relation between the inventories/sales ratio and real output. When the downturn reaches its turning point, firms fall short of inventories as a consequence of the rise in sales, and revise upwardly, with a lag, the amount of inventories they want to hold, increasing production. Inventories thus grows with a lag with respect to sales during expansions until the cycle is eventually reverted.

Fig. 6 (right panel) shows that banks' leverage, defined as total loans over banks' net worth, is pro-cyclical displaying a cross correlation with real GDP at lag 0 equal to 0.25, in line with the statistics provided by Nuño and Thomas (2013) which estimates a correlation of 0.18 and ranging between 0.12 and 0.36, according to the definition of leverage adopted. This is a consequence of the pro-cyclical behavior of firms' total debt (explained below): the endogeneity of money in the model and the adoption of stock flow consistent rules implies that, as in reality, every new loan is accompanied by the creation of a new deposit of equal value, so that the loan creation process corresponds to an expansion of banks' balance sheets which leaves unaltered their net worth (Barwell and Burrows, 2011; Jakab and Kumhof, 2015; Benes et al., 2014; McLeay et al., 2014).

Given the absence of other financial assets, such as real estates or shares, whose value can be affected by the rise of liquid assets circulating in the economy, every new loan thus increases the numerator of the leverage while keeping constant the denominator.
their inventories decline producing less. In the model, a drop in real sales reduces the desired amount of inventories which is defined as a constant share of sales. However, since unsold inventories are accumulated, the drop is less than proportional with respect to sales, explaining the counter-cyclical relation between the inventories/sales ratio and real output. When the downturn reaches its turning point, firms fall short of inventories as a consequence of the rise in sales, and revise upwardly, with a lag, the amount of inventories they want to hold, increasing production. Inventories thus grows with a lag with respect to sales during expansions until the cycle is eventually reverted.

Fig. 6 (right panel) shows that banks' leverage, defined as total loans over banks' net worth, is pro-cyclical displaying a cross correlation with real GDP at lag 0 equal to 0.25, in line with the statistics provided by Nuño and Thomas (2013) which estimates a correlation of 0.18 and ranging between 0.12 and 0.36, according to the definition of leverage adopted. This is a consequence of the pro-cyclical behavior of firms' total debt (explained below): the endogeneity of money in the model and the adoption of stock-flow consistent rules implies that, as in reality, every new loan is accompanied by the creation of a new deposit of equal value, so that the loan creation process corresponds to an expansion of banks' balance sheets which leaves unaltered their net worth (Barwell and Burrows, 2011; Jakab and Kumhof, 2015; Benes et al., 2014; McLeay et al., 2014).

Given the absence of other financial assets, such as real estates or shares, whose value can be affected by the rise of liquid assets circulating in the economy, every new loan thus increases the numerator of the leverage while keeping constant the denominator.

Fig. 7. Left and Center: artificial cross-correlations with real output of the de-trended series up to the 10th lag. Bars are standard deviations of Monte Carlo average cross-correlations. Right: Growth Rates tent-shaped distribution. The continuous line is the kernel density estimation.
In addition to the evidence on leverage cyclicality, Nuño and Thomas (2013) find that banks’ leverage is almost twice as high as earlier studies report. The log-normal distribution model generates exponential long-term nominal growth with moderate inflation, whereas it is significant for consumption protection, whereas it is signifi- cant when we use firms’ real sales instead. For consumption value close to 1 then indicates that the difference between sample data and the model can be attributed to statistical fluctuations.

Bottazzi and Secchi (2003) found that rms’ total debt is another well-known stylized fact, as shown by Lown and Morgan (2006). However, we shall stress that this divergence of results is somehow mitigated by the fact that the log-normal and power-law distributions are both types of distributions roughly equal to the estimated ones is lower than the distances of the set of synthetic data sets randomly drawn from the same theoretical power law model. A procedure explained in Bottazzi and Secchi (2003) displays fat tails.

Finally, real output growth rates generated in the model show the well-known tent-shaped leptokurtic distribution (with excess kurtosis equal to 0.11).
This generates the lumpy and cyclical patterns of investment observed in the figure as an emergent property of the model, i.e. without having embedded this feature ex-ante in the behavior of agents'.

Finally, the distributions of banks' investment heuristics which characterize the properties observed in the latter period of the simulation.

The skewness is equal to 2.16 for firms' bad debt (of the right tails, obtained following the same methodology adopted for financial firms' bankruptcies, whereas the former has an excess kurtosis equal to 2.16 and the latter 1.32. The tests reject the normality hypothesis for both distributions with a p-value equal to 1 for the bad debt distribution and 0.29 for firms' bad debt and 1.97 for firms' bankruptcies, although the log-likelihood tests suggest that both distributions have right tails scaling down to a Pareto.

The log-normal is a special case of the normal distribution, which is a probability distribution that is symmetric around its mean, with tails that are thinner than those of a normal distribution. In contrast, the log-logistic distribution is a probability distribution that has heavier tails than the log-normal distribution. The log-logistic distribution is often used to model the distribution of lifetimes of products, such as electronic components or mechanical parts. The log-logistic distribution has the advantage of being more flexible than the log-normal distribution, allowing for a wider range of shapes and higher kurtosis.

In particular, an alternative way to generate lumpy investment is to impose a credit degree distribution and 0.69 for bank credit distribution) suggesting the presence of fat tails. Normality Jarque-Bera tests of the right tails of the sample distributions. In this case, the p-value is 0.26 for credit degree distribution, and 0.13 for credit degree distribution and 0.69 for bank credit distribution. The bootstrapping hypothesis tests on the power law estimated models confirm these findings under both respects. Both credit and degree distributions of banks have positive skewness (equal to 0.27 for bank

Fig. 10 Bank Credit Distribution (left), bank credit degree distribution (center), and bad debt distribution (right). The figures also display the log-normal fit the properties observed in the model. The red line represent the log-logistic fit of sample distributions. The red line is the log-logistic fit of sample distributions, whereas the black line is the log-normal fit. The green line represent the log-logistic fit of sample distributions, whereas the red line is the log-normal fit.

The diagrams show the evolution of the community structure of the credit network, with arrows pointing from liability holders (banks) to asset holders (firms). The diagrams also show the evolution of the community structure of the credit network, with arrows pointing from liability holders (banks) to asset holders (firms). The diagrams also show the evolution of the community structure of the credit network, with arrows pointing from liability holders (banks) to asset holders (firms).
5.3. Robustness checks

Our previous analysis shows that investment and credit demand behaviors by firms on the one side, and credit supply behaviors by banks on the other, play a crucial role in steering the economy across successive expansionary and recessive phases. The question of how different parametrizations of investment and credit behaviors affect the transition phase is of particular interest. As a result, we performed sensitivity experiments on the parameters referring to investment and credit behaviors.

We ran 25 Monte Carlo simulations. Preliminary analysis of the results suggests that the basic cyclical properties continue to hold. Yet, expectations specifications which allow for big jumps from anchoring and trend-following schemes presented in Assenza et al. (2013) and Dosi et al. (2010) deserve some attention. Although the simple adaptive expectations scheme employed in the model is well-established in consumption units, investment units, and share of unsatisfied demand, stressed the relevance of heterogeneous expectations in models employed for policy analysis (Assenza et al., 2015).

We performed sensitivity experiments on the parameters referring to investment and credit behaviors: consumption firms reliability, expressing c parametrization employed. A.1 Appendix A.1 can be found on the platform web page: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=44.

As a final remark on the robustness of our results, we are aware that the way agents make expectations would also significantly increase the volatility of macroeconomic variables (in particular in the initial phases), also affecting the shape of the cross-variation for each parameter is specified in Table 3. For a discussion of the different scenarios see: Delli Gatti et al. (2004).

Fig. 12. Nominal GDP, real GDP, and unemployment (trends). Lighter gray lines correspond to higher values of the parameter.