Endogenous credit dynamics as source of business cycles in the EURACE model

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Main objectives of EURACE

▶ Scientific objectives:
   ▶ Establishing an innovative framework for the study of the macroeconomy according to the agent-based computational approach.
   ▶ Providing new insights on the emergence of global regularities in the aggregation of heterogeneous interacting agents.

▶ Technological objective:
   ▶ Development of new software methodologies for implementing, designing and validating large-scale agent-based economic simulations.

▶ Societal objective:
   ▶ Development of an agent-based software platform to perform simulation experiments on economic policy design for the European Union.
The current financial and banking crisis and the subsequent severe economic recessions have caused a crisis of confidence in the science of Economics.

Most economists have been unable to forecast timely the crisis and even to devise helpful policies at its beginning.

The Nobel Laureate Paul Krugman recently feared that most macroeconomics of the past 30 years was “spectacularly useless at best, and positively harmful at worst” (The Economist, July 16th 2009).

“Economics needs a scientific revolution” by J.-P. Bouchaud (Nature, October 30th, 2008)
The EURACE model represents a fully integrated macroeconomy consisting of:

- the **real sector** (production of consumption and capital goods with labor, capital goods and energy as factors of production and relative markets; technological innovation);
- the **credit sector** (financing production plans of firms);
- the **financial sector** (exchange of claims on the equity capital of producers as well as of governments liabilities);
- the **public sector** (policy making, i.e., fiscal policy made by Governments and monetary policy set by the Central Bank).
Key features of EURACE

▶ Technology (FLAME, GUIs, parallelization).

▶ Spatial structure and local interactions.

▶ Realistic time scales and asynchronous interactions.

▶ Decentralized markets (Walrasian auctioneer banned except for the financial market):
  ▶ market clearing is not for granted
  ▶ no law of one price

▶ Adaptive and empirically grounded behavioral rules (optimization banned).

▶ Balance sheet approach in modeling agents.

▶ Validation based on the reproducibility of well-known empirical regularities and the consistency of balance sheets.
Agents (I)

The EURACE model is characterized by a set of agents’ typologies with proper balance sheets and behavioral features:

- Households
- Consumption goods producing firms
- Investment goods producing firms
- Commercial Banks
- Governments
- Central bank
Besides the agents presented before, the simulator is populated by a number of agents for the purpose of facilitating market exchanges and statistical computation:

- Malls
- Eurostat
- Clearing House
Markets

- Consumption goods market
- Investment goods market
- Credit market
- Financial market (stock and government bonds)
- Labor market

Except for the financial market, the other markets are all decentralized.
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Examples of decision rules

- Firms and Households act rule-based using backward looking expectations

- Households decisions in the financial market are based on prospect theory

- Operational decisions of firms are modelled using standard decision rules from the Operations Management literature:
  - Pricing (markup)
  - Inventory and Production Planning

- Savings/consumption decisions of households are based on empirically-founded rules derived from the buffer-stock theory of consumption, see Deaton (1991) and Carrol (1993)

- Purchasing decisions of households are modelled using standard logit-models from the Marketing literature
A double-entry balance sheet with a detailed account of all monetary and real assets as well as monetary liabilities is defined for each agent.

Monetary and real flows given by agents’ behaviors and interactions determine the period by period balance sheet dynamics.

A stock-flow model is then created and used to check that all monetary and real flows are accounted for, and that all changes to stock variables are consistent with these flows.

This provides us with a solid and economically well-founded methodology to test the consistency of the model and it increases the credibility of model’s results.
Monetary and financial assets

- cash holdings in the form of commercial bank or central bank deposits. There is no cash hoarding since all money is held inside the banking sector;
- bank loans
- central bank standing facility
- government bonds
- equity shares (issued by firms and banks)
Real assets

- firms inventories
- physical capital
- human capital
Household (H): balance sheet overview

| Assets                                      | Liabilities |
|---------------------------------------------|-------------|
| $M^h$: liquidity deposited at a given bank  | (none)      |
| $n^h_g$: government bonds holdings          |             |
| $n^h_f$, $n^h_b$: equity shares holdings of |             |
| firm $f$ and bank $b$                       |             |

- Financial wealth:

$$W = M^h + \sum_{f \in \{\text{firms}\}} n^h_f p_f + \sum_{b \in \{\text{banks}\}} n^h_b p_b + \sum_{g \in \{\text{governments}\}} n^h_g p_g$$

- $p_f$, $p_b$: daily price of equity shares issued by firm $f$ and bank $b$, respectively
- $p_g$: daily price of the bond issued by government $g$
### Firm (f): balance sheet overview

| Assets                      | Liabilities               |
|-----------------------------|---------------------------|
| $M^f$: liquidity deposited at a given bank | $D_b^f$: debts to banks |
| $I_m^f$: inventories at malls | $E^f$: equity             |
| $K^f$: physical capital     |                           |

- $M^f$, $I_m^f$ updated daily following firms’ cash flows and sales
- $K^f$, and $D_b^f$ updated monthly (at the first day of the month to act)
### Bank (b): balance sheet overview

| **Assets** | **Liabilities** |
|------------|-----------------|
| $M^b$: liquidity deposited at the *central bank* | $D^b$: standing facility (debts to the *central bank*) |
| $L_f^b$: loans to firms | $M_h^b$: households’ deposits at the bank |
|             | $M_f^b$: firms’ deposits at the bank |
|             | $E^b$: equity |

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Government (g)

| Assets                      | Liabilities                                                   |
|-----------------------------|---------------------------------------------------------------|
| $M^g$: liquidity deposited at the central bank | $D^g$: standing facility with the central bank |
|                             | $n^g$: number of outstanding bonds                            |

Government budget:

- Revenues: taxes on corporate profits and household labor and capital income;
- Expenses: unemployment benefits, transfer and subsidies.
Central Bank (c): balance sheet overview

| Assets                                      | Liabilities                      |
|---------------------------------------------|----------------------------------|
| \( n_g^c \): Government bonds (QE)         | outstanding fiat money           |
| \( M^c \): liquidity                       | \( M_g^c \): Governments liquidity |
| \( L_b^c \): loans to banks (standing facility) | \( M_b^c \): banks reserves      |
|                                             | \( E^c \): equity                |

With quantitative easing (QE), the central bank purchases government bonds using money it creates from nothing (fiat money), and so expands its balance sheets.
Validation rules

- Balance sheet accounting identities can be devised across agents and used to validate the model.

- Examples:

\[
\sum_{f} \sum_{b} L_f^b = \sum_{f} \sum_{b} D_f^b
\]

\[
\sum_{h} M_h^b = \sum_{b} \sum_{h} M_h^b
\]

\[
n_g^h = \sum_{h} n_g^h
\]
In the EURACE model we have a key monetary invariant:

$$\Delta \left( \sum_h M_h + \sum_f M_f \right) + \Delta \left( \sum_b E^b \right) + \Delta \left( \sum_g M^g + M^c \right)$$

private sector deposits + banks’ equity + public sector deposits

$$= \Delta \left( M^c + \sum_b L^c_b + QE \right) + \Delta \left( \sum_b \sum_f L^b_f \right)$$

fiat money + credit money
The computational experiments aims to investigate the overall performance of the EURACE economy with respect to two different and alternative fiscal and monetary policies:

- fiscal tightening policy (FT)
- quantitative easing policy (QE)

The results may provide insights for designing suitable policies in the European economic scenario, where monetary authorities are implementing quantitative easing monetary policies.
Overview of the two policies

- **Fiscal tightening policy (FT)**
  - It pursues a zero government budget deficit objective by increasing tax rates if necessary.
  - The budget deficit, if any, is funded by both the increase of taxes and the issue of new government bonds which are sold in the market.

- **Quantitative easing policy (QE)**
  - The zero government budget deficit is NOT an issue. Tax rates are then maintained at a low constant level.
  - The budget deficit, if any, is funded just by the issue of new government bonds which are sold directly in the secondary market.
  - The Central Bank participate in the secondary bond market to buy an amount of gov bonds equal to the new issue.
Computational setting

- 1000 households, 10 firms, 2 banks
- 20 years of simulation
- Different levels of firms financial fragility have been considered by fixing exogenously the ratio \((d)\) of earnings that firms pay out as dividends
| $d$ | policy | Private sector money endowment growth rate (%) | price inflation rate (%) | wage inflation rate (%) |
|-----|--------|---------------------------------------------|--------------------------|------------------------|
| 0.5 | FT     | -0.47 (0.03)                                | -0.052 (0.004)           | 0.012 (0.001)          |
|     | QE     | -0.39 (0.02)                                | -0.020 (0.007)           | 0.052 (0.009)          |
| 0.6 | FT     | -0.37 (0.02)                                | -0.048 (0.004)           | 0.008 (0.001)          |
|     | QE     | -0.33 (0.03)                                | 0.02 (0.01)              | 0.11 (0.02)            |
| 0.7 | FT     | -0.29 (0.02)                                | -0.038 (0.004)           | 0.016 (0.004)          |
|     | QE     | -0.24 (0.03)                                | 0.02 (0.01)              | 0.10 (0.02)            |
| 0.8 | FT     | -0.14 (0.03)                                | -0.011 (0.008)           | 0.036 (0.008)          |
|     | QE     | -0.10 (0.03)                                | 0.03 (0.01)              | 0.07 (0.02)            |
| 0.9 | FT     | 0.16 (0.03)                                 | 0.11 (0.02)              | 0.13 (0.02)            |
|     | QE     | 0.18 (0.03)                                 | 0.14 (0.02)              | 0.16 (0.02)            |

**Table:** Ensemble averages (standard errors are in brackets) over 10 different simulation runs of mean monthly rates. Each run is characterized by a different random seed. FT and QE cases are characterized by the same seeds. For each simulation run, mean monthly rates are computed over the entire simulation period, except for the first 12 months which have been considered as a transient and discarded.
| d  | policy | lag -1  | lag 0  | lag 1  |
|----|--------|--------|--------|--------|
| 0.5| FT     | 0.00 (0.02) | 0.50 (0.02) | 0.42 (0.02) |
|    | QE     | 0.24 (0.02) | 0.30 (0.02) | 0.37 (0.03) |
| 0.6| FT     | 0.39 (0.02) | 0.52 (0.01) | 0.43 (0.01) |
|    | QE     | 0.32 (0.02) | 0.41 (0.02) | 0.48 (0.03) |
| 0.7| FT     | 0.39 (0.01) | 0.52 (0.02) | 0.45 (0.02) |
|    | QE     | 0.31 (0.02) | 0.43 (0.02) | 0.49 (0.02) |
| 0.8| FT     | 0.40 (0.02) | 0.53 (0.02) | 0.50 (0.03) |
|    | QE     | 0.34 (0.03) | 0.45 (0.03) | 0.47 (0.05) |
| 0.9| FT     | 0.19 (0.03) | 0.30 (0.03) | 0.39 (0.02) |
|    | QE     | 0.18 (0.05) | 0.27 (0.06) | 0.36 (0.04) |

**Table:** Ensemble averages (standard errors are in brackets) over 10 different simulation runs of cross-correlations between percentages variations of the private sector money endowment and of the price level, respectively. High values at lag 1 are an indication that percentage variations of the private sector money endowment lead percentage variations of the price level.
Private sector money endowment and price level (FT)

Figure: Dividends payout: $d = 0.6$ (thick line) and $d = 0.9$ (thin line)
Private sector money endowment and price level (QE)

Figure: Dividends payout: $d = 0.6$ (thick line) and $d = 0.9$ (thin line)
The credit money supplied by the banking system is the source, together with the fiat money supplied by the central bank, of the endowment of liquid resources held by both the private sector (households, firms and banks) and the public sector (government and central bank).

An increase (higher $d$) in the demand for credit by firms, if supplied by banks, then increases the amount of liquid resources in the economy.
Higher inflation and wage rates are associated to higher values of $d$.

Higher inflation rates for higher values of $d$ can not be directly explained according to the quantity theory of money, i.e. due to the higher amount of liquidity in the economy. This because prices are not set by a fictitious Walrasian auctioneer at the cross between demand and supply, but are set by firms, based on their costs, which are labor costs, capital costs and debt financing costs.

Higher credit money means higher debt and higher debt financing costs, thus again higher price inflation through the cost channel.
| $d$ | policy | physical capital growth rate (%) | real GDP growth rate (%) | unemployment rate (%) |
|-----|--------|---------------------------------|-------------------------|-----------------------|
| 0.5 | FT     | 0.140 (0.006) 0.19 (0.01) | 0.023 (0.006) 0.052 (0.008) | 20.3 (0.5) 10.68 (0.08) |
|     | QE     |                                 |                         |                       |
| 0.6 | FT     | 0.135 (0.006) 0.25 (0.02) | 0.007 (0.01) 0.07 (0.02) | 20.5 (0.8) 10.7 (0.1) |
|     | QE     |                                 |                         |                       |
| 0.7 | FT     | 0.157 (0.006) 0.25 (0.02) | 0.036 (0.005) 0.07 (0.01) | 19 (1) 10.4 (0.1) |
|     | QE     |                                 |                         |                       |
| 0.8 | FT     | 0.20 (0.01) 0.24 (0.02) | 0.04 (0.01) 0.04 (0.02) | 15.4 (0.6) 10.0 (0.1) |
|     | QE     |                                 |                         |                       |
| 0.9 | FT     | 0.28 (0.02) 0.29 (0.02) | 0.06 (0.01) 0.05 (0.01) | 13.2 (0.7) 8.5 (0.2) |
|     | QE     |                                 |                         |                       |

**Table:** Ensemble averages (standard errors are in brackets) over 10 different simulation runs of mean monthly rates. Each run is characterized by a different random seed. FT and QE cases are characterized by the same seeds. For each simulation run, mean monthly rates are computed over the entire simulation period, except for the first 12 months which have been considered as a transient and discarded.
Figure: Dividends payout: $d = 0.6$ (thick line) and $d = 0.9$ (thin line)
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Remarks

- The EURACE economy is able to reproduce endogenous short-term fluctuations (business cycles) as well as long-run growth.

- Short-term fluctuations are caused by:
  - coordination failure between demand and supply of consumption goods.
  - fluctuations in investment in physical capital.
  - firms bankruptcies, i.e. disruptions in the supply chain.

- Long-run growth is given by the growth of physical capital as well as labor productivity.

- In the FT case, higher firms financial (higher $d$) clearly foster growth, while this is not so evident in the QE case.

- QE outperforms FT for low $d$, not for high $d$.
  - credit money close substitute of fiat money.
| d  | policy | GDP (first half) | GDP (second half) | Bankruptcies (first half) | Bankruptcies (second half) |
|----|--------|-----------------|------------------|--------------------------|---------------------------|
| 0.5| FT     | -16.1 (0.004)   | -16.1 (0.005)    | 0 (0)                    | 0.3 (0.3)                 |
|    | QE     | -14.0 (0.006)   | -16.8 (0.009)    | 0 (0)                    | 0 (0)                     |
| 0.6| FT     | -17.1 (0.003)   | -16.4 (0.005)    | 0.6 (0.4)                | 0.7 (0.4)                 |
|    | QE     | -14.5 (0.005)   | -24.9 (0.021)    | 0 (0)                    | 0.3 (0.3)                 |
| 0.7| FT     | -18.5 (0.003)   | -19.3 (0.006)    | 1.3 (0.5)                | 4.5 (0.7)                 |
|    | QE     | -15.3 (0.008)   | -22.8 (0.018)    | 0 (0)                    | 1 (0.5)                   |
| 0.8| FT     | -18.8 (0.003)   | -19.4 (0.011)    | 2.9 (0.4)                | 9.3 (1.5)                 |
|    | QE     | -14.2 (0.005)   | -19.9 (0.019)    | 1.1 (0.4)                | 6.6 (1)                   |
| 0.9| FT     | -20.3 (0.006)   | -20.3 (0.011)    | 4.9 (0.9)                | 22.4 (1.5)                |
|    | QE     | -13.6 (0.005)   | -18.0 (0.011)    | 1.9 (0.5)                | 20.6 (1)                  |

**Table:** Values in the first two columns report the ensemble average (standard errors are in brackets) over 10 different simulations runs of the maximum percentage variability over a moving window of 36 months (3 years) of the real GDP. Values in last two columns report the average number of bankruptcies.
Output variability

- The raising of output variability for higher $d$ values is related to the higher debt load of firms (more bankruptcies).

- In the first half of the simulation a QE policy seems to stabilize the economy, probably because firms are not subject to a strong fiscal pressure and can afford to pay their debts.

- In the long run: the high amount of money tends to increment the economic fluctuations in the case of QE, while fluctuations don’t change in the case of FT.
  - The higher inflation rate is probably the cause of the increase of economic instability in the case of QE.

- Under QE, the number of bankruptcies raises to a level comparable to FT in the long run for high values of $d$.
  - For high levels of firms debt, QE policy may not be effective in the long run.
  - Credit money is close substitute of fiat money.
Conclusions

▶ The EURACE economy shows endogenous business cycles and long-run growth

▶ Interdependence between real and nominal variables even in the long-run

▶ Firms financial fragility, firms bankruptcies and the credit channel are at the heart of this interdependence

▶ Policy outcomes:
  ▶ low values of $d$ (financial fragility of firms is low given that they mostly use internal funding to finance their investments) QE policy seems able to improve real economic performance
  ▶ high values of $d$
    QE and FT policies give indistinguishable real outcomes
    This probably because of the high level of credit money in the economy that may act as a substitute of the central bank fiat money of the QE case
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