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Credit Money and Macroeconomic Instability in the Agent-based Model and Simulator Eurace

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Abstract This paper investigates the interplay between monetary aggregates and the dynamics and variability of output and prices by considering both the money supplied by commercial banks as credit to firms and the fiat money created by the central bank through the quantitative easing monetary policy. The authors address this problem by means of an agent-based model and simulator, called Eurace, which is characterized by a complete set of interrelated markets and different types of interacting agents, modeled according to a rigorous balance-sheet approach. The dynamics of credit money is endogenous and depends on the supply of credit from the banking system, which is constrained by its equity base, and the demand of credit from firms in order to finance their production activity. Alternative dynamic paths for credit money have been produced by setting different firms' dividend policies. Results point out the strict dependence of output and prices dynamics on monetary aggregates, and show the emergence of endogenous business cycles which are mainly due to the interplay between the real economic activity and its financing through the credit market. In particular, the amplitude of the business cycles strongly rises when the fraction of earnings paid out by firms as dividends is higher, that is when firms are more constrained to borrow credit money to fund their activity. This interesting evidence can be explained by the fact that the level of firms leverage, defined as the debt-equity ratio, can be considered ad a proxy of the likelihood of bankruptcy, an event which causes mass layoffs and supply decrease.

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Keywords Macroconomic policy design; agent-based computational economics credit money; economic instability, quantitative easing

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Introduction

The paper presents a study on the interplay between monetary aggregates and macroeconomic performance in an artificial economy setting, based on the Eurace model and simulator.

This simulator is the outcome of a three years project started in September 2006, whose aim was to design an agent-based macroeconomic simulation platform integrating different sectors and markets. A description of the simulator and of its main features is given in section 1, while this introduction points out some general aspects that are relevant to the specific topic investigated in the paper.

The overall philosophy of the Eurace Project is part of the research program on a Generative Social Science (Epstein, 1999; Epstein and Axtell, 1996), which seeks to explain socio-economic phenomena by constructing artificial societies that generate possible explanations from the bottom-up. The field of agent-based computational economics (ACE) has been characterized by a great deal of development in recent years (see Tesfatsion and Judd (2006) for an comprehensive survey), but we think that the Eurace project has been the first successful effort to build a complete economy that integrates all the main markets and economic mechanisms which exist in the real world. In particular, the interactions between the real and the financial sides of the economy are essential to generate and to understand the results presented in this study.

In the last decade, in the ACE field, there have been many studies regarding finance (see LeBaron (2006) for a review), while others have focused on labour and goods market (Tassier, 2001; Tesfatsion, 2001) or industrial organization (Kutschinski et al., 2003). However, only a few partial attempts have been made to model a multiple-market economy as a whole (Basu et al., 1998; Bruun, 1999; Sallans et al., 2003). Compared to these models, the Eurace simulator is certainly more complete, incorporating many crucial connections between the real economy and the credit and financial markets. We think that, in order to understand the recent crisis, and in general the profound functioning of modern economies, it is not possible to ignore that connections any more. In this respect, the Eurace agent-based framework provides a powerful computational facility where experiments concerning policy design issues can be performed. It offers a realistic environment, characterized by non-clearing markets and bounded rational agents, well suited

for studying the out-of equilibrium transitory dynamics of the economy caused by policy parameters changes.

From a strictly macroeconomic point of view, we focus our analysis on the understanding of output and prices variabilities in the Eurace economic environment and their interplay with the amount of credit in the economy. This central topic has been addressed by Ben Bernanke in a well known speech at the Federal Reserve Board in 2004 (Bernanke, 2004), but after the crisis it surely needs to be revisited. The talk of Bernanke regarded the so called “Great Moderation", i.e., the decline in the variability of both output and inflation in the previous twenty years, and argued that it could be explained by the improved ability of the economy to absorb shocks. Shocks are considered, in line with the dynamic stochastic general equilibrium modeling approach, as the main source of economic instability. In this paper we show that instability can also endogenously arise as a consequence of agents decision making. The issue is of primary importance because, as Bernanke says, reducing macroeconomic volatility has numerous benefits. Lower volatility of inflation improves market functioning, makes economic planning easier, and reduces the resources devoted to hedging inflation risks. Lower volatility of output tends to imply more stable employment and a reduction in the extent of economic uncertainty confronting households and firms. Unfortunately, the recent crisis pointed out the times we are living are not so “moderate" as the FED chairman and many mainstream economists showed to think. Moreover, the effectiveness of monetary policies based on a “Taylor rule" structure is seriously in question.

This study investigates the interplay between monetary aggregates and the dynamics and variability of output and prices by considering both the money supplied by commercial banks as credit to firms and the fiat money created by the central bank through the quantitative easing monetary policy. Different amount of credit money have been produced in the system by setting different dividends payout policies and so different bank financing policies by firms. Quantitative easing has been implemented by letting the central bank intervening in the bond market. Quantitative easing is an extraordinary monetary policy measure that has

been largely used by the Federal Reserve and the Bank of England during the recent crisis [1], and has also been recently adopted by the European Central Bank.

In concrete terms, our experiments on the Eurace platform consist of different simulations for different parameter values. We take into consideration the effects of two critical parameters of the model.

The first one, as said above, regards the financial management decision making of the firms, and corresponds to the fraction of net earnings paid by the firm to shareholders in form of dividends. The dividends decision impacts on many sectors of the model. In the financial market, for instance, agents beliefs on asset returns take into account corporate equity and expected cash flows, establishing an endogenous integration between the financial side and the real side of the economy. In particular, fundamentalist trading behavior is based on the difference between stock market capitalization and the book value of equity, therefore generating an interaction between the equity of the firm and the price of its asset in the financial market. Concerning the credit market, the dividends payment is strongly correlated with the request of loans by firms and consequently influences the amount of credit created by commercial banks; as our results show in section 2, the credit amount proves to be decisive for its effects on the variability of output and prices.

The second parameter of our study is a binary flag that activates the possibility for the central bank to buy treasury bills in the financial market, when a government asks for it. In practical terms, the central bank expands its balance sheet by purchasing government bonds. This form of monetary policy, widely adopted during the global financial and economic crisis of the years 2007–2010, which is used to stimulate an economy where interest rates are close to zero, is called quantitative easing. The money creation channel through quantitative easing is intended to facilitate the funding of the government budget deficit in a situation of depressed economy, when a raise of taxes should be avoided. In synthesis, the paper analyzes two alternative ways to finance government budget deficit: fiscal tightening (FT) and quantitative easing (QE).

[1] See, for instance, Willem Buiter blog at FT for a report on Bank of England balance sheet explosion (http://blogs.ft.com/maverecon/2009/09/what-can-be-done-to-enhance-qe-and-ce-in-the-uk-and-who-decides/).

From a theoretical point of view, the interplay between monetary factors and the real economy is not new and has been extensively investigated by many economists. However, both in the old (Hicks, 1937) and in the new Keynesian economics (Clarida et al., 1999), as well as in the monetarist tradition (Friedman, 1953), the attention has been mainly devoted to monetary aggregates and interest rates set exogenously by central banks, disregarding the important role of the credit sector in setting the overall money supply by the endogenous creation of credit money. Notable exceptions in this respect have been Fisher (1933) during the Great Depression era, the circuitist school of economics, represented e.g. by Graziani (2003), and the now celebrated Hyman Minsky (1986). They pointed out the importance of the endogenous nature of credit money, and of the nominal level of debts as opposed to the price level of real assets, in originating business cycles and depressions.

In the agent-based literature, a few attempts have been made to study the interplay between monetary policy, credit and business fluctuations. Raberto et al. (2006) show the long-run monetary neutrality of an agent-based Walrasian-like macro-model characterized by price-taking agents subject to changes in the money supply. Raberto et al. (2008) study a Taylor-like monetary policy rule in an agent-based integrated model of a real, financial, and monetary economy with price, wage and interest setting agents and show the effectiveness of the policy in limiting inflation and increasing welfare. Delli Gatti et al. (2009) show the emergence of business cycles from the complex interaction of agents heterogeneous financial conditions in a three-sector network economy characterized by credit relationships.

The EURACE model is by far more complete and realistic than the ones outline above. It encompasses price-making agents, a heterogenous production sector instead of the monopolistic firm considered in Raberto et al. (2008), and an explicit modelling of the households consumption behavior instead of the passive final consumers considered in Delli Gatti et al. (2009). Therefore the EURACE model and simulator promises to deliver more meaningful and precise results for any of the computational experiments considered.

The paper is organized as follows. In section 1 an overall description of the model is given, with particular attention to the features that are relevant to this article. Section 2 presents the computational results of our study and a related discussion. Conclusions are drawn in Section 3.

1 The Model

1.1 The Eurace Simulator

The EURACE model is probably by far the largest and most complete agent-based model developed in the world to date. It represents a fully integrated macroeconomy consisting of three economic spheres: the real sphere (consumption goods, investment goods, and labour market), the financial sphere (credit and financial markets), and the public sector (Government, Central Bank and Eurostat).

Given the complexity of the underlying technological framework and given the considerable extension of the Eurace model, it is not possible to present within this paper an exhaustive explanation of the economic modelling choices, together with a related mathematical or algorithmic description. Consequently, we will limit our approach to a general qualitative explanation of the main key features of the model, treating in a concise way each different market, and giving prominence to those modelling aspects that attain to the argument of the specific analysis we are presenting in this paper. In particular, we will explain in details the so-called balance-sheet approach followed in the Eurace modeling, an approach we think is very important for our purposes and in the agent-based modeling in general.

If the reader will need general information as well as more details on Eurace model and implementation, he will find a quite exhaustive summary in the Eurace (2009).

Before proceeding with the description of agents and markets of Eurace, we introduce some general aspects of the model.

1.2 General Features

The choice of time scales for the agents' decision making in Eurace has been made in order to reflect the real time scales in economic activities, and interactions among households are generally asynchronous. This means that different agents are active on the same markets on different days. Synchronous decision making or synchronous interactions are used whenever they reflects what happens in reality.

Both the modelling of agents behaviors and the modelling of markets protocols are empirically inspired by the real world.

Agent decision processes follow the usual and realistic assumptions of agent-based economics about bounded rationality, limited information gathering and storage capacities, and limited computational capabilities of the economic agents; see e.g. Tesfatsion and Judd (2006) for a comprehensive survey on this approach. These assumptions lead us to use simple heuristics to model the agents' behaviour, derived from the management literature for firms, and from experimental and behavioural economics for consumers/investors (Deaton, 1992; Benartzi and Thaler, 1995). We also make use of experimental evidence from the psychological literature on decision making. For example, the modelling of households' portfolio decisions on the financial market is based on Prospect Theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992).

The rules used by the agents are simple but not necessarily fixed. Their parameters can be subject to learning, and thus adapted to a changing economic environment. Here we can make a distinction between adaptive agents and learning agents: the first use simple stimulus-response behaviour to only adapt their response to their environment, while the last use a conscious effort to learn about the underlying structure of their environment.

Different market protocols characterize the markets of the Eurace model. For the consumption goods market all consumer-firm interactions go through the local outlet malls. Households go shopping on a weekly basis. This closely mimics reality and is a simple way to model localized markets with potential rationing on both sides. In particular the used market protocols capture important market frictions based on problems of search, matching and expectation formation in turbulent environments that are present in real world labour and goods markets. The labour market functions by way of a local search-and-matching protocol that likewise resembles a real world job search by unemployed workers. For the artificial financial market we model a clearinghouse. For the credit market we use a firm-bank network interaction mechanism where firms can apply for loans with at most n banks, where n is a parameter that can be set by the modeler.

1.3 The Balance Sheet Approach

In this section we stress the importance of using a balance sheet approach as a modelling paradigm.

Assets	Liabilities
M^h: liquidity deposited at a given *bank* n_g^h: government bonds holdings n_f^h, n_b^h: equity shares holdings of firm f and bank b	(none)

Table 1: Household (H): balance sheet overview

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

Table 2: Firm (f): balance sheet overview

In the Eurace model, 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, e.g. market transactions, determine the period by period balance sheet dynamics. Stock-flow consistency checks have then been done at the aggregate level to verify 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.

In order to explain our approach, let us consider the balance sheets of the different agents of the model.

Household's balance sheet is reported in Table 1. Its financial wealth W^h is given by

$$W^h = M^h + \sum_{f \in \{firms\}} n_f^h p_f + \sum_{b \in \{banks\}} n_b^h p_b + \sum_{g \in \{governments\}} n_g^h p_g$$

where p_f, p_b are the daily prices of equity shares issued by firm f and bank b, respectively; while p_g is the daily price of the bond issued by government g.

Firm's balance sheet is shown in Table 2. M^f and I_m^f are updated daily following firms' cash flows and sales, while K^f and D_b^f are updated monthly following

Assets	Liabilities
M^b: liquidity (reserves) 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

Table 3: Bank (b): balance sheet overview

capital investments and financing decisions. The equity E^f is also updated monthly according to the usual accounting rule:

$$E^f = M^f + p_C \sum_{m\in\{malls\}} I_m^f + p_K K^f - \sum_{b\in\{banks\}} D_b^f$$

where p_C is the average price level of consumption goods and p_K is the price of capital goods.

Table 3 reports the balance sheet of the bank. M_h^b, M_f^b, L_f^b are updated daily following the private sector deposits changes and the credit market outcomes. M^b and E^b are updated daily following banks cash flows. First M^b is updated according to the equation:

$$M^b = D^b + \sum_{h\in\{households\}} M_h^b + \sum_{f\in\{firms\}} M_f^b + E^b - \sum_{f\in\{firms\}} L_f^b,$$

then E^b is updated considering bank profits (the difference between interest revenues and expenses), dividends and taxes. If M^b becomes negative, D^b, i.e., the standing facility with the Central Bank, is increased to set $M^b = 0$. If M^b is positive and the bank has a debt with central bank, i.e. $D^b > 0$, D^b is partially or totally repaid for a maximum amount equal to M^b.

In order to understand the functioning of money creation, circulation and destruction in EURACE, as a starting point we need to have clear in mind how the bank's balance sheet looks like. Let's start with the money creation issue: four channels of money formation are open. The most important is, as explained

Assets	Liabilities
M^g: liquidity deposited at the central bank	n^g: number of outstanding bonds

Table 4: Government (g): balance sheet overview

Assets	Liabilities
n_g^c: Government bonds (QE)	M^{QE}: fiat money outstanding due to QE
M^c: liquidity	M_g^c: Governments liquidity
L_b^c: loans to banks	M_b^c: banks liquidity
	E^c: equity

Table 5: Central Bank (c): balance sheet overview

above, when banks grant loans to firms, and new money appears in the form of firm's increased payment account M^f (and, thus, increased deposits). The second channel operates when the central bank is financing banks through lending of last resort, and money creation (Fiat money) translates in augmented bank's liabilities. Government Bond purchasing constitutes the third channel: it is at work whenever the quantitative easing (QE) feature is active and thus the CB is forced to buy government bonds in the financial market. Finally, the fourth and last channel, not considered in our simulation, is represented by bailouts of commercial banks by the CB.

So far we have dealt with money creation, but money's story has other two chapters: circulation and destruction. Since there is not currency, that is no money is present outside the banking system, when agents (firms, households or Government) use their liquid assets to settle in favor of other agents, money should simply flow from payer's bank account to taker's bank account, obviously keeping itself constant (such cash movements are accounted at the end of the day, when agents communicate to banks all their payments). On the contrary, whenever a debt is repaid, money stock has to decrease accordingly. For technical details and a more exhaustive discussion on these issues, see Eurace (2009).

Finally, the balance sheets of the government and of the central bank are reported in Tables 4 and 5, respectively.

The government budget is composed by taxes on corporate profits, household labor and capital income, as revenues, and unemployment benefits, transfer and subsidies, as expenses.

Since the Central Bank is not allowed to make a profit, its revenues from government bonds and bank advances are distributed to the government in the form of a dividend. In case of multiple governments, the total dividend payment is equally divided among the different governments.

These modelling hypotheses lead to the definition of a precise “EURACE time invariant" feature, consisting in a fundamental macroeconomic flows accounting identity:

$$\underbrace{\Delta\Big(\sum_h M^h + \sum_f M^f\Big)}_{\text{private sector deposits}} + \underbrace{\Delta\Big(\sum_b E^b\Big)}_{\text{banks' equity}} + \underbrace{\Delta\Big(\sum_g M^g + M^c\Big)}_{\text{public sector deposits}}$$

$$=$$

$$\underbrace{\Delta\Big(\sum_g n_g^c p_g^* + \sum_b L_b^c\Big)}_{\text{fiat money}} + \underbrace{\Delta\Big(\sum_b \sum_f L_f^b\Big)}_{\text{credit money}},$$

where the symbol $\Delta(.)$ is used to represents the variation of the quantity inside the brackets and p_g^* is the purchasing price of government bonds by the central bank. The interpretation of the above identity is that the variation of monetary assets held by both the private sector (households, firms and banks) and the public sector (governments and the central bank) must be equal to the variation of the money supplied by both the central bank (fiat money) and by the banking sector (credit money). The identity above regards variation of monetary stocks, then is referred to flows. An analogue identity could be derived regarding monetary stocks provided that the initial condition concerning monetary assets and outstanding monetary liabilities of the central bank would be properly set. The meeting of the above equation is a necessary condition to validate the aggregate stock-flow consistency of EURACE model.

For policy considerations, it is clearly important to consider the monetary endowment of agents in the private sector, i.e.,

$$\sum_h M^h + \sum_f M^f + \sum_b E^b .$$

An higher monetary endowment due, e.g., to a loose fiscal policy and QE, leads to a higher nominal demand that translates into a higher real demand in the short and in the long run depending on the behavior of prices.

1.4 The Goods Market

For detailed information about the economic modelling choices characterizing the goods and the labor markets, see D7.1 (2007); D7.2 (2008). See also Dawid et al. (2008) and Dawid et al. (2009) for additional explanations and for some discussion and analysis of computational experiments directly involving the two markets. What follows is a qualitative description of the main aspects that are relevant to the paper.

The goods markets are populated by IGFirms (investment goods firms) that sell capital goods to CGfirms, that produce the final consumption good. Stocks of firms product are kept in regional malls that sell them directly to households. A standard inventory rule is employed for managing the stock holding. Standard results from inventory theory suggest that the firm should choose its desired replenishment quantity for a mall according to its expectations on demand, calculated by means of a linear regression based on previous sales.

Consumption good producers need physical capital and labor to produce. The production technology in the consumption goods sector is represented by a Cobb-Douglas type production function with complementarities between the quality of the investment good and the specific skills of employees for using that type of technology. Factor productivity is determined by the minimum of the average quality of physical capital and the average level of relevant specific skills of the workers. Capital and labor input is substitutable with a constant elasticity and we assume constant returns to scale. The monthly realized profit of a consumption goods producer is the difference of sales revenues achieved in the malls during the previous period and costs as well as investments (i.e. labor costs and capital good

investments) borne for production in the current period. Wages for the full month are paid to all workers at the day when the firm updates its labor force. Investment goods are paid at the day when they are delivered. Pricing is based on a fixed mark-up rule.

Once a month households receive their income. Depending on the available cash, that is the current income from factor markets (i.e. labor income and dividends distributed by capital and consumption goods producers) plus assets carried over from the previous period, the household sets the budget which it will spend for consumption and consequently determines the remaining part which is saved. This decision is taken according to the buffer-stock saving theory (Deaton, 1992; Carroll, 2001).

At the weekly visit to the mall in his region, each consumer collects information about the range of goods provided and about the prices and inventories of the different goods. In the marketing literature it is standard to describe individual consumption decisions using logit models. These models represent the stochastic influence of factors not explicitly modelled on consumption.We assume that a consumer's decision about which good to buy is random, where purchasing probabilities are based on the values he attaches to the different choices he is aware of. Since in our setup there are no quality differences between consumer goods and we also do not take account of horizontal product differentiation, choice probabilities depend solely on prices. Once the consumer has selected a good, he spends his entire budget for that good if the stock at the mall is sufficiently large. In case the consumer cannot spend all his budget on the product selected first, he spends as much as possible, removes that product from its list, and selects another product to spend the remaining consumption budget there. If he is rationed again, he spends as much as possible on the second selected product and rolls over the remaining budget to the following week.

1.5 The Labor Market

The labor market is governed by a matching procedure that relates directly workers looking for a job and firms looking for labor force. On the demand side, firms post vacancies with corresponding wage offers. On the supply side, unemployed workers or workers seeking for a better job, compare the wage offers with their

actual reservation wages. Then the matching algorithm operates by means of ranking procedures on the side both of firms and households (see Eurace (2009) for more details).

The algorithm might lead to rationing of firms on the labor market and therefore to deviations of actual output quantities from the planned quantities. In such a case the quantities delivered by the consumption good producer to the malls is reduced proportionally. This results in lower stock levels and therefore it generally increases the expected planned production quantities in the following period.

1.6 The Financial Market

For more detailed information on the financial market, see D6.1 (2007) and D6.2 (2008). Teglio et al. (2009) shows also economic results obtained by means of computational experiments in the financial market, mainly regarding the problem of the equity premium puzzle.

The EURACE artificial financial market operates on a daily basis and is characterized by a clearing house mechanism for price formation which is based on the matching of the demand and supply curves. The trading activity regards both stock and government bonds, while market participants are households, firms and the governments. Both firms and governments may occasionally participate to the market as sellers, with the purpose to raise funds by the issue of new shares or governments bonds. Households provide most of the trading activity in the market, to which they participate both for saving and speculation opportunities. Household preferences are designed taking into account the psychological findings emerged in the framework of behavioral finance and in particular of prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). Households portfolio allocation is then modeled according to a preference structure based on a key prospect theory insight, i.e., the myopic loss aversion, which depends on the limited foresight capabilities characterizing humans when forming beliefs about financial returns (see Benartzi and Thaler (1995)).

A very relevant aspect with respect to the presented analysis, is the fraction of earning d that firms pay to shareholders in form of dividends. In this paper it is treated as a constant and varied in the different computational experiments.

1.7 The Credit Market

Concerning the credit market of Eurace, in the project deliverables D5.1 (2007); D5.2 (2008) the modelling philosophy and the technical details can be found.

Firms finance investments and production plans preferably with internal resources. When these funds are not sufficient, firms rely on external financing, applying for loans to the banks in the credit market. The decision about firms loan request is taken by the bank to which the firm applies and depends on the total amount of risk the bank is exposed to, as increased by the risk generated by the additional loan. If a firm is credit-rationed in the credit market, then it has other possibilities of financing, i.e. issuing new equity on the financial market.

Commercial banks have two roles: one consists in financing the production activities of the firms, operating under a Basel II-like regulatory regime. The other role is to ensure the functioning of the payment system among trading agents. Finally, firms and households deposit entirely their liquid assets in the banks.

In the model banks are at the core of the system of payments: each transaction passes through the bank channel. Firms and households do not hold money as currency but under the form of bank deposits. Hence, the sum of payment accounts of bank's clients is equal to bank's deposits. As a consequence, every transaction (payment) between two non-financial agents translates into a transaction between two banks. At the end of every day, agents communicate the consistency of their liquid assets to their banks; then each bank can account for the net difference between inflows and outflows of money from and to the other banks and, if its reserves are negative, a compensating lending of last resort by the central bank is always granted. Thus, a sort of Deferred Net Settlement System has been implemented.

The Central Bank has several function in the Eurace model. It helps banks by providing them with liquidity when they are in short supply. It has the role of monitoring the banking sector setting the maximum level of leverage each bank can afford. It decides the lowest level of the interest rate, which is a reference value for the banking sector. If the quantitative easing feature is active, the central bank expands its balance sheet by purchasing government bonds in the financial market.

2 Computational Experiments

A number of computational experiments has been performed in order to study the interplay between the stock of liquidity (credit money + fiat money) and the performance of the economy, measured by the dynamics of the gross domestic product (GDP), the unemployment level, the dynamics of prices and the accumulation of physical capital in the economy.

The dynamics of credit money is fully endogenous and depends on the supply of credit from the banking system, which is constrained by its equity base, and on the amount of loans demanded by firms to finance their activity. Alternative dynamic paths for credit money have been produced by setting different firms' dividend policies. The ratio d of net earnings that firms pay out as dividends has been exogenously set to five different values, namely, 0.5, 0.6, 0.7, 0.8, and 0.9. It is clear that for higher values of d, firms' investments and hiring of new labor force must be financed more by new loans than by retained earnings, thus determining a higher amount of credit money in the economy.

The dynamics of fiat money depends on the central bank monetary policy. In particular, the non conventional monetary policy practice called quantitative easing is considered. The central bank policy rate is kept fixed at low levels, however, if the quantitative easing (QE) policy is active, the central bank may buy government bonds directly on the market, thus increasing the overall amount of fiat money in the economy. Under quantitative easing, we set that the government budget deficit is funded just by the issue and sale of bonds on the market. In this case, the intervention of the central bank is finalized to sustain bond prices and thus to facilitate the financing of government debt. If quantitative easing is not active, we set that the government budget deficit is funded both by the issue of new bonds in the market and by an increase of tax rates. This second policy case has been named as FT, an acronym that refers to "fiscal tightening".

Each parameters' setting is then characterized by one of the five values of d and by a flag which denotes whether the quantitative monetary (QE) policy or the fiscal tightening (FT) one has been adopted. The total number of parameters settings then sums up to 10. In order to corroborate the significance of results, for each parameters setting, 10 different simulation runs have been considered, where

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 6: 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.

each run is characterized by a proper seed of the pseudorandom numbers generator. The same set of 10 random seeds has been employed for all parameters' settings.

The agents' population is constituted by 1000 households, 10 consumption goods producing firms, 1 investment goods producing firms, 2 banks, 1 government and 1 central bank. The duration of each simulation is set to 240 months (20 years).

Tables 6 and 7 report the simulation results for the main real and nominal variables of the economy, respectively, obtained with the 10 parameters' settings considered. Figures from 1 to 4 in the appendix show two representative time paths, respectively for $d = 0.6$ and $d = 0.9$, for the main real and nominal variables, both in the FT and the QE policy cases. A clear and important empirical evidence that emerges from the path of GDP is that the EURACE model is able to exhibit endogenous short term fluctuations, i.e., business cycles, as well as endogenous long-run growth.

d	policy	physical capital growth rate (%)	real GDP growth rate (%)	unemployment rate (%)
0.5	FT	0.140 (0.006)	0.023 (0.006)	20.3 (0.5)
	QE	0.19 (0.01)	0.052 (0.008)	10.68 (0.08)
0.6	FT	0.135 (0.006)	0.007 (0.01)	20.5 (0.8)
	QE	0.25 (0.02)	0.07 (0.02)	10.7 (0.1)
0.7	FT	0.157 (0.006)	0.036 (0.005)	19 (1)
	QE	0.25 (0.02)	0.07 (0.01)	10.4 (0.1)
0.8	FT	0.20 (0.01)	0.04 (0.01)	15.4 (0.6)
	QE	0.24 (0.02)	0.04 (0.02)	10.0 (0.1)
0.9	FT	0.28 (0.02)	0.06 (0.01)	13.2 (0.7)
	QE	0.29 (0.02)	0.05 (0.01)	8.5 (0.2)

Table 7: 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.

The main cause of long-run economic growth is the positive growth rate of aggregate physical capital that is present in the economy, despite the existence of a capital depreciation rate, see the first column of Table 7. Endogenous investment decisions in physical capital by firms are responsible of the growth of physical capital in the economy. The increase of labor productivity due to the improvement of the skills of workers is the other reason which explains the long-run growth.

Main reasons explaining business cycles are the coordination failure between demand and supply of consumption goods, strong fluctuations in the investment in physical capital, and disruptions in the supply chain as well as mass layoffs due to firms bankruptcies. In particular, investment decisions as well as firms bankruptcies strongly depend on the availability of internal liquidity or bank credit. Therefore, there is a strict relation between real economic activity and its financing through the credit sector. The following analysis of simulation results will outline in details this relationship. Simulation results will be interpreted with respect to the different values of d and the two policies, namely FT and QE, considered.

Nominal variables, as shown in Table 6, exhibit similar qualitative behavior with respect to the value of d in the two policy cases considered. However, the QE case is characterized by a more pronounced increase of nominal variables as d increases. The table shows that as the value of d increases, i.e., firms raise their dividends payout ratio, then the growth rate of the private sector money endowment also increases in the two policy cases considered. It is worth noting that 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 in the demand for bank credit by firms then increases the amount of liquid resources in the economy as a whole, and consequently the private sector's liquidity. The higher growth rates of nominal variables in the QE case, can indeed be explained by the additional contribution of the increase of fiat money in this case.

The effects of different parametrization of d on nominal variables is also evident from the Figures 1 and 2 in the appendix, where the simulation paths for two different values of d, i.e., $d = 0.6$ and $d = 0.9$ are reported. The paths are in fact diverging over time in any of the four panels considered.

Table 6 also shows that higher inflation and wage rates are associated to higher values of d. It is worth noting, however, that higher inflation rates for higher values of d can not be directly explained in this framework according to the quantity theory of money, i.e., referring 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 they 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. Higher credit money induces also higher wage inflation, and thus again higher price inflation through the cost channel. The wage inflation can be explained by the labor market conditions, i.e., the level of unemployment, as it will be clear in the following.

Finally, Table 8 reports the cross-correlation between the percentages variations of the private sector money endowment and the ones of the price level, respectively. Reported values, which are higher than the 95 % noise band set at 0.13, indicates positive meaningful cross-correlation. In particular, changes in the monetary

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 8: 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 al lag 1 are an indication that percentage variations of the private sector money endowment lead percentage variations of the price level.

aggregates seems to lead changes in the price level, thus indicating a clear influence of money on prices.

Table 7 presents the outcomes of the simulation concerning the real variables of the economy, i.e., the unemployment level and the growth rates of physical capital and of real GDP. In the FT policy case, a clear indication emerges for a better macroeconomic performance, i.e., lower unemployment, and higher growth rate of real GDP and physical capital, related to higher levels of credit money in the economy, i.e., higher values of d. On the contrary, no clear indication in this respect emerges in the QE policy case, where the performance of real variables is very similar irrespective of the value of d. Another possible way to read the results is to compare the outcomes of the FT policy with the ones of the QE for each value of d. In this respect, results shows that the QE policy provides better macroeconomic performance for low values of d, while it gives results similar to the FT policy, except for lower unemployment records, for values of d equal or close to 0.9. A possible explanation of these findings is that for low values of d, the QE policy outperforms the FT policy because of the injection of fiat money created by the central bank, as also testified by the higher level of private sector monetary

d	policy	lag -1	lag 0	lag 1
0.5	FT	0.21 (0.02)	0.20 (0.01)	0.06 (0.01)
	QE	0.22 (0.02)	0.01 (0.02)	0.15 (0.02)
0.6	FT	0.27 (0.02)	0.25 (0.01)	0.07 (0.01)
	QE	0.38 (0.04)	0.27 (0.03)	0.27 (0.05)
0.7	FT	0.28 (0.01)	0.27 (0.01)	0.10 (0.02)
	QE	0.38 (0.04)	0.29 (0.03)	0.26 (0.03)
0.8	FT	0.35 (0.02)	0.27 (0.02)	0.13 (0.02)
	QE	0.34 (0.04)	0.27 (0.03)	0.17 (0.03)
0.9	FT	0.34 (0.03)	0.31 (0.02)	0.14 (0.02)
	QE	0.31 (0.03)	0.26 (0.03)	0.10 (0.02)

Table 9: 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 GDP, respectively. High values al lag -1 are an indication that percentage variations of GDP lead percentage variations of the private sector money endowment.

endowment shown in Table 6, while for high values of d the higher amount of credit money supplied by commercial banks results to be a close substitute of the fiat money created by the central bank, then providing comparable outcomes for the real variables.

This indication is also graphically evident by inspecting Figures 3 and 4 in the appendix, where two simulation paths for the real GDP and the unemployment levels are reported in both the FT and the QE policy cases for different values of d, i.e., $d = 0.6$ and $d = 0.9$. Finally, Table 9 reports the cross-correlation between the percentages variations of the private sector money endowment and the ones of GDP, respectively. Reported values, which are higher than the 95 % noise band set at 0.13, indicates positive meaningful cross-correlation, thus confirming the non-neutrality of money in the EURACE framework. In particular, changes in GDP seems to lead changes in the money endowment of the private sector.

Table 10 shows the maximum percentage variability over a moving window of 36 months (calculated as $(min - max)/mean$) of the real GDP. Let us point out some evident features related to this table. In the case of fiscal tightening policy, the output variability clearly depends on dividends pay-out, rising when d is

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 10: 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.

higher; this is no more true when the quantitative easing mechanism is active. GDP variability is constant along time (first and second half) in the case of FT, while in the case of QE the economy seems to become much more instable in the second half of the simulation: in fact, in the first part of the simulation, GDP variability values under QE policy are always higher than in the case of FT policy, while in the second part they are lower.

How can we interpret the information of the table? We can easily argument that the raising of output variability for higher d values is mainly due to the higher debt load of firms that produces more bankruptcies (see the last two columns of Table 10). 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. However, in the long run the effect is the opposite: the high amount of credit money injected in the system in the case of QE policy tends to increment the economic fluctuations, while fluctuations don't change in the case of fiscal policy. This phenomenon is probably due to the higher money supply that generates in the long run a higher price inflation rate (as shown in Table 6). This

higher inflation rate is probably the cause of the increase of economic instability in the case of QE. It is also worth noting that, when the QE policy is active, the number of bankruptcies in the first half is quite low but in the second half it raises to a level comparable to FT, especially for high values of d. This shows that for high levels of firms debt a QE policy may not be effective in the long run. The reason probably relies on the fact that for high values of firms dividends payout, a strong money supply is already guaranteed by commercial banks and therefore, the effect of quantitative easing is significantly weakened.

We could argue that Table 10 is warning about an extended use of quantitative easing. It shows us that QE can be used with the purpose of economic stabilization but in the long run the excess of money in the economy could also produce some counter reaction probably through the inflation channel.

3 Concluding Remarks

The paper presented a set of results provided by the agent-based model and simulator Eurace. In particular, results point out the strict dependence of output and prices dynamics on monetary aggregates. Credit money supplied by commercial banks as loans to firms and fiat money created by the central bank through quantitative easing determine the dynamics of monetary aggregates. The dynamics of credit money is endogenous, different dynamic paths can be obtained by exogenously setting different firms dividend policies. Results show the emergence of endogenous business cycles which are mainly due to the interplay between the real economic activity and its financing through the credit market. In particular, the amplitude of the business cycles strongly raises when the fraction of earnings paid out by firms as dividends is higher, that is when firms are more constrained to borrow credit money to fund their activity. This interesting evidence can be explained by the fact that the level of firms leverage, defined as the debt-equity ratio, can be considered ad a proxy of the likelihood of bankruptcy, an event which causes mass layoffs and decrease in supply. A quantity easing monetary policy coupled with a loose fiscal policy has been shown to generally provide better macroeconomic performance with respect to a tight fiscal policy and no central bank intervention in the bond

market. However, the QE policy causes more inflation both in the short and in the long run and seems responsible in the long run of a higher variability of output.

Finally, from a more general perspective, the results show the possibility to explain the emerge of business cycles based on the complex internal functioning of the economy, without considering any ad-hoc exogenous shocks. The adopted agent-based framework has been able to address this complexity, and these results reinforce the validity of the Eurace model and simulator for future research in economics.

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Appendix

Figure 1: Results of a simulation path for the private sector money endowment and the price level in the FT case. Two values of d are considered, i.e., $d = 0.6$ (thick line) and $d = 0.9$ (thin line).

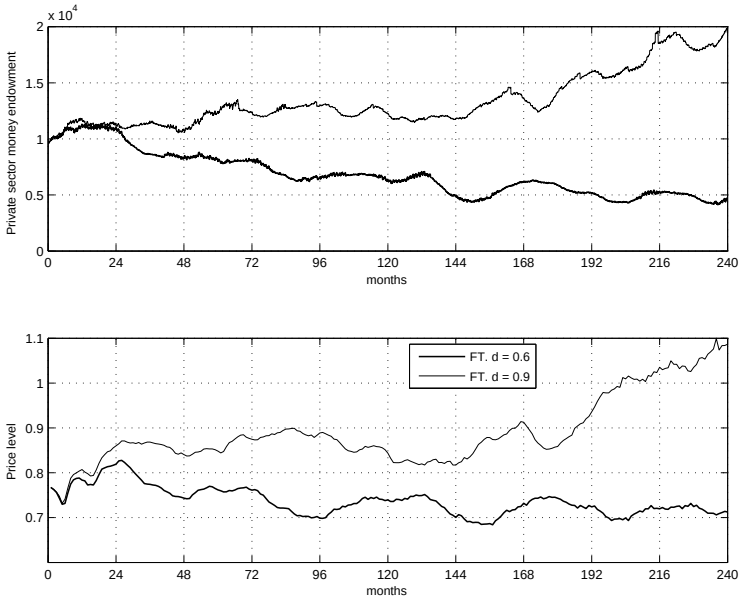


Figure 2: Results of a simulation path for the private sector money endowment and the price level in the QE case. Two values of d are considered, i.e., $d = 0.6$ (thick line) and $d = 0.9$ (thin line).

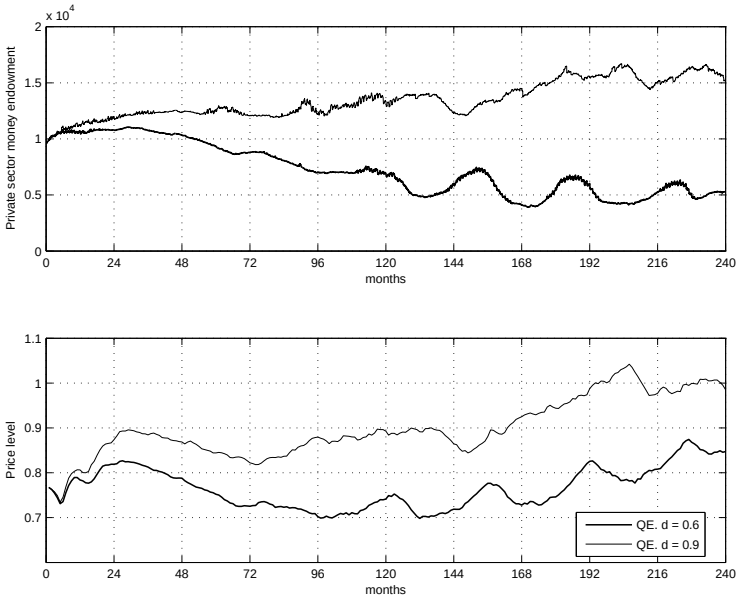


Figure 3: Results of a simulation path for the real gross domestic product (GDP) and the unemployment rate in the FT case. Two values of d are considered, i.e., $d = 0.6$ (thick line) and $d = 0.9$ (thin line).

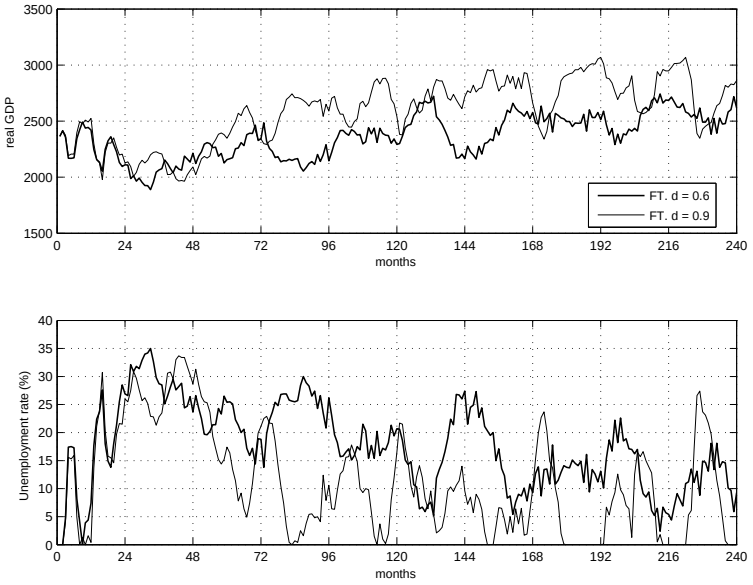
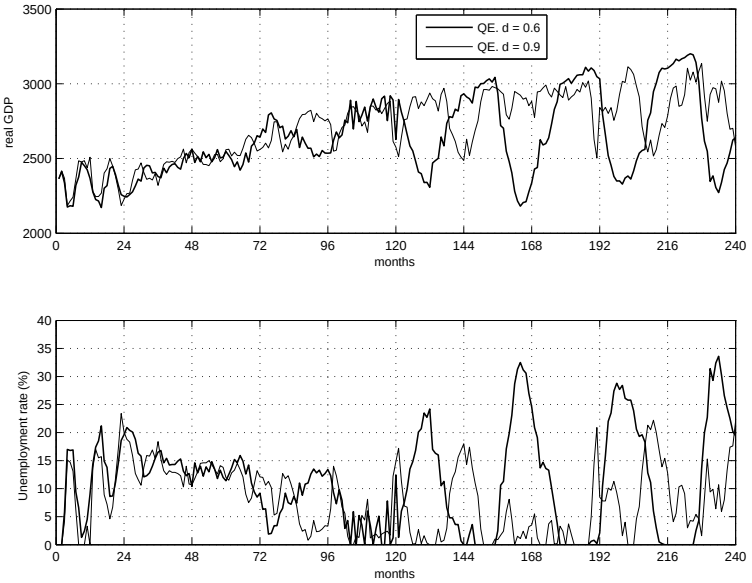


Figure 4: Results of a simulation path for the real gross domestic product (GDP) and the unemployment rate in the QE case. Two values of d are considered, i.e., $d = 0.6$ (thick line) and $d = 0.9$ (thin line).



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The Editor

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