Production and Finance in EURACE

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Abstract EURACE is a major FP6 STREP project aiming at constructing an exhaustive agent-based model of the European economy, populated by a very large number of sophisticated, autonomous agents. The EURACE model, which has an explicit spatial structure, includes all the major markets considered in quantitative macroeconomic modelling (consumer goods, investment goods, labour, credit and finance). It offers a unique opportunity for studying, from a new perspective, the empirically observed but theoretically poorly understood link between the real and the financial sphere of a modern economy. After summarily presenting the main features of EURACE, this paper describes in more detail the newly developed *financial management module* that intermediates between the real and the financial spheres in EURACE. In a nutshell, this module defines the link between the hiring and investment behavior of the firms as a function of the revenues they obtain by selling their products, of the money they can raise on the credit and financial markets, of their dividend policy, and other major aspects of financial decision-making.[1]

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1 Introduction

An important question in economics is to explain the link between the real and financial sphere of the economy. Empirically speaking, the macroeconomic and financial variables are correlated along the business cycle. The existing theoretical models, however, have difficulty explaining the observed correlations.

This paper documents recent work carried out to address this problem from an agent-based perspective. This work is part of a major FP6 STREP project, EURACE, that aims at developing a comprehensive agent-based model of the European economy. In this paper, we sketch the broad structure of the EURACE model and present in more detail the model of financial policy decisions by the firm that links the real and the financial spheres within the model.

This paper is organized as follows. In the second section, we succinctly present the EURACE project. The third section presents the financial management module. A final fourth section concludes.

2 The EURACE project

Most of the existing agent-based models cover only a single industry, one restricted geographical area, or a unique market, and involve relatively small populations of agents. In contrast, EURACE aims at creating an integrated agent-based model of the European Union, linking all the various markets one typically encounters e.g. in a large dynamic CGE model of a multi-national economy. The thus defined artificial economy is to be populated with a very large number (possibly tens of millions) of fairly sophisticated agents.

The model has an explicit spatial structure mimicking the regional statistical units used by Eurostat. It includes various (typically, regional) artificial markets for real commodities (that is, consumption goods, investment goods and labour), and markets for financial assets (such as loans, bonds and stocks). For a general overview of the EURACE model, see Deissenberg et al. (forthcoming).

The three-years EURACE Project started in September 2006. It includes economists and computer scientists from eight research centres in Italy, France, Germany, the UK, and Turkey, as well as the 2001 Nobel laureate in economics, Joseph Stiglitz. More institutional and scientific details can be found on the project's web page: `www.eurace.org`.

By its scope and complexity, the effort is unsurpassed and needs to cover much terra incognita, among others concerning the conceptual and computational architecture of the model, its numerical implementation, its validation, and the exploitation of the simulation results. In particular, running such a large model will necessitate using massively parallel computing clusters, using pioneering software such as the *Flexible Large-scale Agent Modelling Environment* (FLAME).

2.1 FLAME

Developed by Simon Coakley, Mike Holcombe, and others at the University of Sheffield (see `www.flame.ac.uk` for a more complete presentation and references), FLAME provides a computational framework allowing modellers to easily create, exchange, include and couple models written in a high-level modelling language. Other important aspects include the development of parallelisation techniques, the distribution of agents over many processors, and the inclusion of testing methods to verify developed models. All these elements are vital to agent-based models in general and to EURACE in particular. The framework has been adapted to enable it to run on parallel computing platforms. It has been previously used to study the behavior of a number of biological systems - at the molecular, cellular, tissue and social levels - and has been instrumental in uncovering a number of new biological properties that have been confirmed experimentally by Coakley et al. (2006).

The approach followed in FLAME is to define each agent as a so-called *Stream X-Machine* (Laycock, 1993). That is in a nutshell: as an automaton described by a finite number of states, transitions between those states, and actions, and endowed with both an internal memory and the ability to interact by sending and receiving *messages*.

In the FLAME framework, agents act within *contexts*, that is preeminently, within markets. The agents can have different *roles* in different contexts, e.g., an agent can be a buyer on one market, a seller on another. Table 1 lists the main classes of agents in EURACE, the contexts in which they operate and the main messages they exchange.

Table 1 Main agents, contexts, roles, and messages in the model.

Agent	Context	Role	Messages
Household	Consumption goods market	Buyer	units demanded
	Labour market	Worker	application, accept/reject job
	Credit market	Depositor	cash holdings
	Financial market	Investor	stock/bond orders
Firm	Investment goods market	Buyer	units demanded
	Consumption goods market	Seller	price, quality
	Labour market	Employer	vacancy, job offer
	Credit market	Borrower	loan request
	Financial market	Issuer	stock/bond orders
Investment Goods Firm	Investment goods market	Seller	price, productivity
	Labour market	Employer	vacancy, job offer
Bank	Credit market	Lender	credit conditions
Government	Financial transactions		tax payments
Central Bank	Credit market	Regulator	

2.2 The real sector

Somewhat simplifying, the real sector is composed of an investment goods sector, a consumption goods sector, and a labour market. The investment goods sector, however, is not agent-based, but modelled as a passive entity whose behavior is determined by simple rules. In a nutshell, it provides an infinite supply of investment goods at exogenously given prices. The productivity of the investment goods increases over time according to a stochastic process. The amounts paid for the investment goods are channeled back into the economy.

Together with labour, the investment goods are used in the consumption goods sector to produce consumption goods. These goods are sold to the households. The consumption goods firms (the firms thereafter) follow plausible, to the largest possible extend empirically grounded rules for investment, production, stocking, pricing, hiring and firing, dividend payment and/or debt making. Likewise, the households follow plausible rules for saving, consuming different types of products, looking for another job while being employed or trying to find a job while unemployed.

The workers are characterized by (i) a general skill level; and (ii) specific skills. The specific skills are acquired on the job to fully exploit the technological potential of the physical capital being used in the production process. The general skill level is obtained through schooling. The higher the worker's general skill level, the faster it acquires the specific skills associated with a given job.

To capture spatial effects, the economy is divided into regions. Consumption occurs locally within each of these regions. The firms send the goods they produce to diverse local outlet malls. The local prices may differ from one outlet mall to the next, i.e. from region to region. Households and firms are distributed across the regions and are allowed to migrate. Workers can apply for jobs in any region, but working outside of their own region of residence is associated with commuting costs that have to be subtracted from the wage.

2.3 The real-financial interaction

Figure 1 sketches the place of the financial management in the interaction between the real and financial spheres.

The financial management module serves to reconcile the production and investment goals of the firm with its payout policy and other financial commitments. The firms receive revenues from the sales on the consumption goods market. This income is used to remunerate the workers they hire on the labour market and to buy investment goods. It is also used to pay the firm's prior financial commitments, i.e. to service the debt (interest and debt installment payments) and to pay taxes. Part of it may also be used to pay out dividends or to repurchase shares on the financial market. Alternatively, the firm can borrow on the credit market and/or issue stocks on the financial market to raise financial capital.

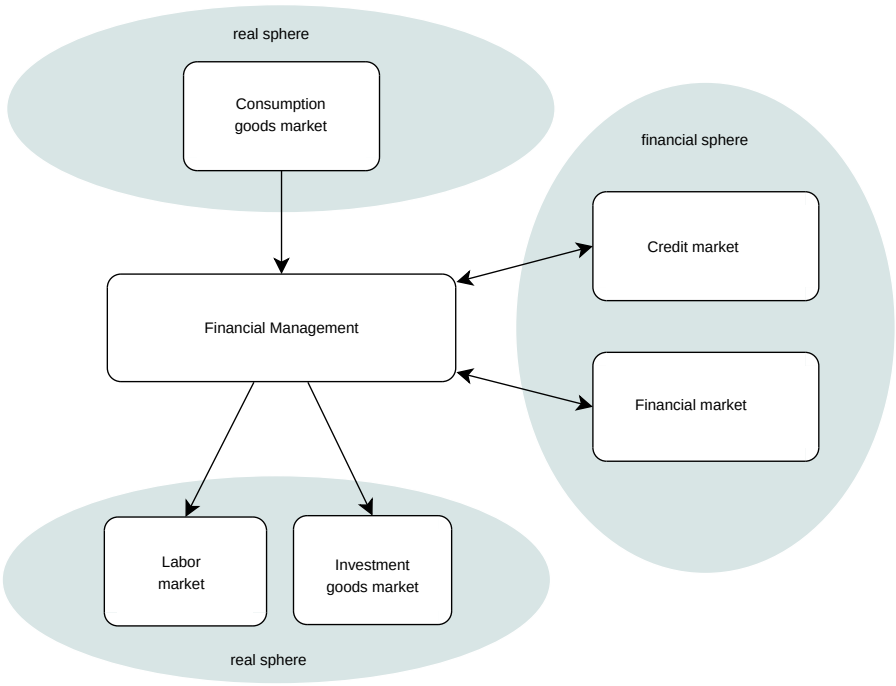

Fig. 1 Financial management as intermediary between the real and financial spheres.

3 The financial management module

All firms in EURACE are corporations. Therefore we use insights from corporate finance and capital management theory to model their financial decision-making. The behavioral rules are kept as close as possible to those used in reality. We define them based, among others, on the seminal contribution by Cyert and March (1963/92) on a Behavioral Theory of the Firm and the work of Myers (1984) on Pecking Order Theory, a behavioral theory of corporate finance. We also draw information from Tirole (2006, Ch.2), Allen and Michaely (2004), and Brav et al. (2005), who report empirical evidence on payout policies.

General assumptions

The following general assumptions are captured by the financial management module.

- The firm's production plan is chosen before the financial policy is decided on. Thus, in the case of newly issued equity, the new shareholders do not influence the production decision for the current period. Hence, preferred stocks and com-

mon stocks are indistinguishable and the price of equity is the same on the primary and secondary equity markets.
- All dividend payments are made in cash, not in stocks. Thus, there is no dilution of the stock value.
- Firms can repurchase their own stocks, but cannot buy stocks of other firms.
- Clearing of the equity- and bond markets occurs through a clearinghouse or a limit-order book mechanism.
- The credit and capital markets are imperfect and subject to transaction costs. Thus, a non-trivial trade-off exists between different financing instruments.
- Firms can be credit rationed on the credit market and consequently may need to resort to corporate bonds or equity for financing.
- In accordance to the Pecking Order Theory, the firm prefers internal financing since it is the least risky. This is followed by debt financing, corporate bonds and, finally, equity financing.
- The wages and investment costs are paid before production takes place, see Dawid et al. (2007); Gallegati et al. (2007).
- Firms pay dividends at the beginning of each operating cycle, based on the results of the previous operating cycle. The total dividend payout may vary, but there is an effort to maintain a constant dividend to earnings ratio (see, e.g. the survey by Brav et al., 2005).

Over the course of the business day (one iteration) the markets open and close in the following sequence:

- Credit market
- Financial market
- Labour market
- Investment goods market
- Consumption goods market

Each firm is active on the first four markets during one day every month. This activation day varies from firm to firm and is chosen randomly at the start of the simulation. During their activation day, the active firms complete a so-called operating cycle, as described below. The selling of output however occurs over the course of the entire month that follows the activation day.

3.1 The operating cycle

During its operating cycle, the firm executes four main routines:

1. Production planning routine
2. Financial planning routine
3. Production routine
4. Accounting routine

It also checks at different points whether or not it is bankrupt, as explained in more detail later on.

Production planning routine

The operating cycle starts with production planning: the firm calculates the production level it would like to realize, the workforce it would like to hire, and the investments in new physical capital it would like to purchase in the absence of financial constraints. It computes the corresponding estimated costs. It also decides upon the dividends to be paid. However, it does not contractually commit to hire respectively to buy or to pay dividends since at this point of its decision-making process it is not sure that the required financing will be available.

Since, as previously assumed, the wages and investment costs are paid before the production takes place, the firm may need to obtain a bank loan or other external capital before being able to start producing.

Financial planning routine

After completing the production planning routine, the firm computes all financial commitments from the previous period: interest payments, debt installment payments. These, together with the production and investment costs and the dividend payout previously calculated, determinate the total liquidity needs for the current operating cycle. These needs are to be financed by internal and external means before production starts.

As previously stated, the firm's first attempt is to use internal financing since this is the least risky alternative. If the current internal financial resources are insufficient they try to complete them on the credit market by applying for bank loans with individual banks. If successful, the firm implements its current production plan. If it fails, it tries to obtain the remaining external financing it needs from the financial market. This starts the firm's financial market routine.

Financial market routine

Here, the firm tries to raise financial capital through the emission of new equity (stocks, bonds) on the primary equity market. If successful, all external financing needs are satisfied and the firm can continue with the actual production routine. Otherwise, the firm needs to revise its production and investment plans. It re-runs the production planning routine subject to the total financial resources available. The new production plan automatically satisfies the budget constraint of the firm, which therefore does not have to run again the financial planning routine. See figure 2 for a decision flowchart.

Production routine

After the production planning routine and the financial planning routine have been completed, the firm starts with the actual production cycle. It first visits the labour market, then the investment goods market, in order to obtain the required factor inputs. At this stage the firm solidifies its production plans, i.e. labour and investments are contracted.

If there is rationing on the labour or investment goods market, the firm spends less than planned and thus has unneeded cash after fulfilling all its contractual obligations. These involuntary savings are deposited in an account at a given bank (different firms can have accounts at different banks). It is deposited there at the end of the firm's operating cycle, i.e., at the end of the day when the firm is active, and will be available for the next production cycle. In that way, all money remains in the system and is available to the banks for making loans to other firms. This prevents inefficiencies due to improductive cash holdings. Incidentally, a similar mechanism is used for modelling the households' left-over consumption budget: all unused cash holdings flow back to the banks immediately in the form of deposits.

The same holds when prices turn out lower than expected: the savings are deposited. If prices turn out higher than expected the firm is rationed in its labour and/or investment demand as well, but there are no savings. The quantity of factor inputs is lower than planned, so also the actual production output will be lower than planned.

After going to the labour market and the investment goods market, the firm starts the actual production process. The output is assumed to be available instantaneously once the financing and factor inputs have been contracted.

The firm distributes the output from a central inventory to the local outlet malls where it tries to sell its merchandise. As previously stated, the selling of output occurs over the course of an entire month, starting from the activation day of the firm. The local outlet malls record and transmit the regional sales revenues. This signals the end of the production cycle, and starts the accounting routine.

Accounting routine

The firm compiles an income statement and a balance sheet after each production cycle.

The *income statement* includes the monthly cumulative revenues from the sales of goods and services and the total costs: costs of sales, operating expenses, taxes, service of the debt, dividends, etc. (see Table 2).

The *balance sheet* lists the total assets and total liabilities (see Table 3). The new balance sheet is computed by updating the current cash holdings with the incoming and outgoing cash flows as listed in Table 4.

After the balance sheet has been updated, but before executing any payments, the firm first checks if it is financially solvable by checking a bankruptcy condition. If financially solvable, the firm executes its payments and this signals the end of the

Table 2 Firm income statement.

revenues from sales of goods and services
– cost of sales
– operating expenses
earnings before interest and taxes
– interest payments
earnings before taxes
– tax payments
net earnings
– debt installment payments
– total dividend payment
– share repurchases
retained earnings

Table 3 Firm balance sheet.

Assets	Liabilities
cash holdings	total debt
total value physical capital stock	shareholders' equity
total value local inventory stocks	

Table 4 Firm cash flow.

Positive cash flows	Negative cash flows
revenues from sales	cost of sales
	interests
	tax payments
	debt installments
	total dividends
	share repurchases
total income	total costs and expenses

operating cycle. Otherwise bankruptcy is declared. The precise modelling of events when a bankruptcy occurs is discussed below.

Bankruptcy conditions

In order to closely mimick managerial practice, the firm checks for bankruptcy at several places during the operating cycle. The first check occurs directly after the balance sheet computation, in order to verify whether the firm can keep its financial commitments from the previous period and pay for the production costs of the upcoming period.

The liquidity needs of the firm are defined as follows:

Financial liquidity needs: FLN = interests + installments + taxes,
Production liquidity needs: PLN = labour costs + investment costs,
Total liquidity needs: TLN = FLN + PLN + dividends.

Based on these definitions, we define a bankruptcy state, a financial crisis state, and a normal state of affairs:

$\text{Cash} < \text{FLN}$: bankruptcy state
$\text{FLN} \leq \text{Cash} < \text{TLN}$: financial crisis state
$\text{Cash} \geq \text{TLN}$: normal state of affairs

In the bankruptcy state, the firm cannot keep its prior financial commitments. Its equity is negative and it has not been able to raise sufficient amounts of financial capital. It sends a bankruptcy message to all the banks with which it has outstanding loans, with content: the credit that is refunded, the bad debt that will not be refunded, and the residual value-at-risk. This information allows the bank to update its balance sheet, which will affect its future lending activities.

In the financial crisis state, the firm did not raise sufficient funds to pay for its total liquidity needs, but can possibly salvage the situation by down-scaling the dividends (in a worst-case scenario, to zero). The down-scaled dividend is given by:

$$\text{Div} = \max\{0, \text{Cash - FLN - PLN}\}. \tag{1}$$

This leads to two possible two sub-states:

1. $\text{Cash} \geq \text{FLN + PLN}$ and $\text{Div} \geq 0$.
   The payment account is sufficient to pay for the financial commitments and production costs. In this case the equity of the firm is positive and the financial crisis is resolved. The firm respects its financial commitments and starts the production cycle.
2. $\text{Cash} < \text{FLN + PLN}$ and $\text{Div} = 0$.
   The payment account is sufficient to pay for the financial commitments, but not for the production costs. The equity of the firm remains negative, even after decreasing the dividends to zero. The firm has not yet resolved the financial crisis. It needs to down-scale its production before proceeding further. We assume that the firm pays the financial payments *before* recalculating production costs. Thus, the firm first pays its financial commitments from its current liquidities. It then recalculates the production quantity such that the corresponding production costs are equal to the remaining liquidities:

   $$\text{Set prod. costs s.t. PLN} \leq \text{Cash - FLN}. \tag{2}$$

   If the firm succeeds in lowering production costs sufficiently, it has resolved the financial crisis and produces the decreased quantity. In a worst-case scenario, production costs have to be lowered to zero. The firm does not produce anything in the current period.

In the normal state of affairs the equity of the firm is positive. The firm can respect its financial commitments and pay for the production costs as planned. There is no need for a down-scaling of dividends or production. Business as usual continues with the firm entering the labour market and the investment goods market and producing as planned.

4 Conclusion

Together with its financial management module, EURACE offers a powerful tool to investigate the yet little understood interaction between real and financial phenomena, including timely questions such as the real impact of credit shortening in a heterogenous, spatially differentiated world. The ability it provides to track the micro-macro interaction and the dynamics into the finest detail may lead to the discovery of transmission mechanisms and phenomena that are obscured by the more traditional representative agent approach. The first simulations we conducted using the financial module indicate that, indeed, the harvest is likely to be rich.

References

Allen, F., Michaely, R., 2004. Corporate finance: Handbook of the Economics of Finance. Amsterdam: North-Holland, Ch. Payout policy, pp. 337 – 429.

Brav, A., Graham, J. R., Harvey, C. R., Michaely, R., 2005. Payout policy in the 21^{st} century. Journal of Financial Economics 77 (3), 483 – 527.

Coakley, S., Smallwood, R., Holcombe, M., 2006. From molecules to insect communities - how formal agent-based computational modelling is uncovering new biological facts. Scientiae Mathematicae Japonicae Online e-2006, 765–778.

Cyert, R. M., March, J. G., 1963/92. A Behavioral Theory of the Firm. Blackwell.

Dawid, H., Gemkow, S., Harting, P., Kabus, K., Neugart, M., Wersching, K., 2007. Agent-based Models of Skill Dynamics and Innovation. EURACE Report D7.1, Bielefeld University.

Deissenberg, C., van der Hoog, S., Dawid, H., forthcoming. EURACE: A Massively Parallel Agent-Based Model of the European Economy. Applied Mathematics and Computation.

Gallegati, M., Richiardi, M., Clementi, F., 2007. Agent-Based Models of Goods, Labour and Credit Markets. EURACE Report D5.1. Department of Economics, Università Politecnica delle Marche.

Laycock, G., 1993. The theory and practice of specification based software testing. Ph.D. thesis, University of Sheffield, Dept. of Computer Science.

Myers, S. C., 1984. The capital structure puzzle. Journal of Finance 39 (3), 575 – 592.

Tirole, J., 2006. The Theory of Corporate Finance. Princeton University Press.

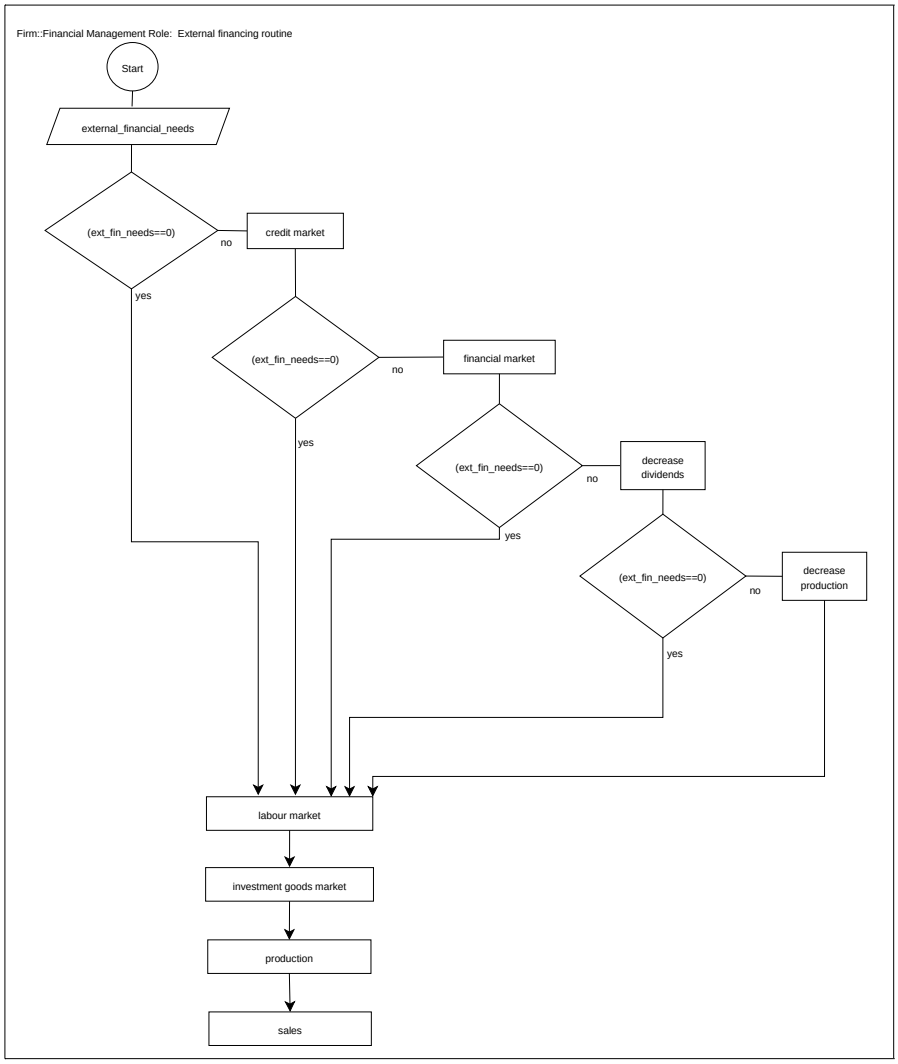

Fig. 2 Interface diagram between the firm's financial management role and its credit market and financial market roles. This flowchart shows the conditional functions that need to run to execute the firm's external financing decisions. It first runs the credit market routine and then the financial market routine. If the firm cannot satisfy all its external financing needs, it decreases its dividends (possibly to zero). If it then still cannot satisfy all its liquidity needs, it should re-run the production planning routine to re-optimize the planned production quantity such that the total production costs (i.e., the costs for labour and capital) can be financed.