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An Agent-Based software platform for European economic policy design with heterogeneous interacting agents: new insights from a bottom up approach to economic modelling and simulation

Instrument STREP

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Introduction

The aim of this document is to give an integrated vision of the EURACE project following the recommendation contained in the review report for the first year. The document has been conceived in order to outline the main objectives, distinctive features and expected insights of the project. It has been structured in such a way to give explicit answers to every question raised by the reviewers.
Chapter 1 gives a general perspective on the economics within EURACE, explaining the motivation of our choices and expected insights. Success criteria for the project and the indication of possible users for the software platform are also included in this chapter.
Chapter 2 points out the distinctive technological features that characterize the EURACE software platform. In particular, it is explained how the FLAME environment is specifically designed in order to perform computational experiments on parallel computer clusters which are needed to simulate large-scale agent-based models. The complexity of a software framework is addressed by means of agile methodologies using the EURAM development process. Furthermore, human machine interfaces are implemented in terms of adequate GUIs.
Finally, it has been considered useful to ad an appendix that gives a general perspective on the economic aspects of EURACE that have been so far developed.

Chapter 1

A general perspective on EURACE

1.1 The EURACE economic model compared to existing (agent-based) macro models

In terms of models designed for policy advice the EURACE model follows a fundamentally different approach from the dynamic stochastic general equilibrium models (DSGE) which are currently employed by the European Central Bank (ECB) or the European Commission on Economic and Financial Affairs (ECFIN). These models are typically not as rich in terms of their spatial structure, heterogeneity of firms and households, and institutional details explicitly modelled. For example, the ECFIN model on which many of the policy recommendations of the European Commission rests has only two countries and three sectors. It lacks a more appropriate spatial dimension and differentiated skills of workers just to name two additional features that the EURACE platform will provide (see Commission of the European Communities, Directorate General, Economic and Financial Affairs: The EU Economy, 2006 Review: Adjustment Dynamics in the EURO Area, Experiences and Challenges, Brussels, 22. November 1996, ECFIN (2006) REP.56908-EN, pp. 232). Thus, for many policy questions, on which we become more explicit in the following section, they are inappropriate tools to come up with satisfactory answers.

The EURACE approach also goes substantially beyond existing macroeconomic models (e.g. Chiarmonte and Dosi (1993,) Delli Gatti et al. (2005), Dosi et al. (2006)). EURACE is by far the largest and most complete agent-based model developed in the world to date. It is the only one explicitly aiming to capture features of the European economy. Its main distinctive and innovative features are:

- its closure: EURACE is one of the very rare fully-specified agent-based models of a complete economy. EURACE is dynamically complete, that is, it specifies all real and financial stocks and flows and will allow us to aggregate upward from the micro-specifications to the macroeconomic variables of interest;
- the encompassing types of real and financial markets and economic agents are taken into consideration;
- the wide use of empirically documented behavioural rules;
- the different levels of time and space granularity taken into account. Thus, it is possible to investigate the impact of real-life granularity on the economic outcomes, and to analyse the consequences of a modification of this granularity;
- the treatment of time: asynchronous decision-making across different agents;
- the explicit spatial structure, allowing to take into account not only regional and land-use aspects, but also more generally the fact that all human activities are localized in geographical space;
- the evolving social network structure linking the different agents;
- thanks to the detailed spatial and time modelling, and to the network structure, the possibility to investigate in finer detail more differentiated policy options;
- the very large number of agents, possibly allowing to discover emerging phenomena and/or rare events that would not occur with a smaller population;
- the use and development of innovative software frameworks, code parallelization in order to employ super-computers, allowing very large-scale simulations;

- the calibration on European economic data and the focus on European policy analysis.

1.2 Modelling choices and motivation

Number and types of agents

It is one of the main goals of EURACE to analyze how far qualitative properties of the phenomena arising in economies with (locally) interacting heterogeneous agents change as the number of involved agents goes up. A research topic that has been to a large extent ignored in previous work in agent-based computational economics. Based on this goal, the implementation of the EURACE platform is designed to be scalable to a large number of agents (up to millions).

Spatial structure and local interaction

The decision to give the model an explicit spatial structure and to let the agents locally interact within this structure was motivated by theoretical, empirical, and policy-related considerations.

- At the theoretical level, an explicit local interaction structure in space and time is arguably the most salient feature of an agent-based model.
- At the empirical level, we want at least to take into account the main elements of heterogeneity between the different regions in the EU - the distribution of economic activity and of wealth.
- At the policy level, many issues of major concern for the EU are of a spatial nature: how to distribute funds to poorer areas, in which regions to invest, what regional labour market policies to set, and what land use policy to promote, and so on.

Market interaction types

Casual empirical observation about how each market is functioning, rather than an in-depth empirical study, let us chose specific interaction patterns for the way agents interact on the different markets: local or global interaction, centralized or decentralized market mechanisms.

We started recently defining the appropriate interfaces needed to integrate the different markets. This work is based again, in addition to accounting constraints, on plausibility and practicability consideration.

Timing of decisions

The choice of time scales for the agents' decision making has been made in order to reflect the real time scales in economic activities. The agents' financial decisions are made on a shorter time scale (day) than the economic decision making, e.g., consumption and production, where the proper time horizon can be a week, a month, or a quarter.

Asynchronous interactions

In reality, most human decision-making and interaction is asynchronous, due to the autonomous decisions of the agents. We model this asynchronous decision making by letting agents have different activation days. This means that on a single market different agents are active on different days. Thus, who interacts with whom changes from day to day.

Some activities, however, are synchronized. This is in particular the case when they are institutionally initiated. Think, for example, of yearly tax payments, or monthly wage payments. We use synchronous decision-making/interactions whenever it reflects the reality.

Modelling (or lack of explicit modelling) of institutional details

Being the model a tool with which policy-makers can carry out policy-related experiments, the political and monetary institutions are not included as agents in the model. The institutions enter the model through the various policy parameters (tax rate, interest rate etc.) that can be tuned in order to carry out experiments to assess the effects on the economic system of different economic policies. For example, ECB need not be modelled as endogenous (that is as an X-agent itself), because EURACE does not aim to predict how ECB would behave, but aims to investigate how non-institutional agents react to policy changes. As described below market institutions are captured with differend levels of detail. Our approach is to be able to represent important types of transaction costs and to capture inter-regional differences in that respect rather than closely representing the variation in the details of the respective institutional frameworks (e.g. legal framework, social norms, etc.).

Market protocols

The modelling of the market protocols is empirically inspired by real-world markets.

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 form to model localized markets with potential rationing on both sides. In particular the market protocols used 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 two real-world market protocols: the clearinghouse and the limit-order book. There exists a third trading technology which is floor trading, but we will refrain from modelling it. The motivation for using these protocols is that most markets that use electronic trading use a limit-order book. In Europe, in particular, stock markets either use floor trading or a limit-order book for stock transactions. However, several illiquid stocks of small and midcap firms are sold by the clearinghouse mechanism. Government bonds are usually sold by auction.

For the credit market we use a firm-bank network interaction mechanism. Firms can apply for loans with at most n banks, where n is a parameter that can be set by the modeller. This reflects how real-world firms appear to manage their credit lines and will be compared to the empirical data that the Consortium has at its disposal concerning firm-bank network interactions.

Decision processes

In modelling agent decision processes, we 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. 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.

We also make use of experimental evidence from the psychological literature on decision making. For example, for the modelling of the households' portfolio decisions on the financial market we use Kahneman and Tversky's Prospect Theory.

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.

Relationship between EURACE modelling and the European economy

As described in the Economic Policy section, one of the main aims in building the EURACE platform is to derive an economic model which will ultimately deliver meaningful answers to a set of policy questions of particular interest in a European context. The selection of features and the degree of detail in the model are driven by these questions of particular importance for the European economy. One of these is for example the coexistence of a single central bank with several national governments (we do not model the EU as an agent but embody its redistributive and other relevant functions in the national governments). To obtain meaningful results we do not need to model all the European governments in detail, but governance heterogeneity among a few countries should suffice.

The model will be parameterized based on empirical studies for Europe whenever possible. The modelling choices in the various markets (worker mobility, debt equity ratio in firm capital structure, number of households active in the stock market, etc.), the spatial distribution of economic activities, will be Europe-driven. We will test whether our model delivers economically meaningful results against a selection of stylized facts for the European economy. In that way, our generic model will become distinctly European, and will serve to address European questions.

A general description of our modelling guidelines and their motivation is given in the new release of Deliverable D2.1

1.3 Expected economic insights

Due to the descriptive nature and rich features of the EURACE model, we expect we will produce new results with respect to the design and experimentation with macroeconomic policies than representative agent models. Since we include heterogeneity along the spatio-temporal dimension, specific policies can be focussed on particular agent characteristics, regarding its behaviour and geographic location. Also interaction between different types of policy measures can be analyzed taking into account endogenously emerging dynamic phenomena (e.g. contagion effects).

The added value in adopting the agent-based computational approach is its ability to take into account the important issue of heterogeneity among agents. According to mainstream representative agent models, economic policy is by definition uniform across agents, but agents are heterogeneous and interact one with each other and this fact has far reaching implications, see e.g. the causal effect between the financial fragility of firms and business fluctuations or between herding behaviour of traders and booms and crashes in financial markets.

The major applications that will be considered are related to monetary policy design and to fiscal and Research and Development policies in the Euro area. In particular, attention will be devoted to the study of monetary policies able to control inflation without affecting growth. Besides, computational experiments will be focused on implementing Research and Development and industrial policies aimed at boosting innovation and the adoption of new technologies according to the prescriptions set in the Lisbon Strategy. Furthermore, macroeconomic stabilization policies for the European economy in the case of exogenous shocks such as energy shocks or financial crises will be designed.

From a complex systems perspective we expect insights related to specific research questions concerning large-scale agent-based models. The question can be studied concerning the impact of population size on agent-based simulations: Do the model results scale, or do we get qualitatively different outcomes if the population size is increased? Other questions concern the simulation technology, and how we improve efficiency for running large-scale ABMs. We hope to contribute to the technological know-how on distributed, parallel simulations.

1.4 Economic Policy Analysis in EURACE

1.4.1 General approach

The main objective of EURACE in terms of economic policy analysis can be summarized as follows:

- analyzing the effects of economic policy measures in a micro-founded model that encompasses many realistic features which the modelling framework, characterized by heterogeneous and interacting agents, is able to address. Among them, it is worth mentioning the bounded-rationality and asymmetric information of economic agents, the agency of decentralized economic transactions which occurs out of equilibrium and are costly, the cascade effects due to agents' interactions. A major problem arising in this setting is the problem of coordination of economic activity which is taken for granted in current mainstream rational expectations macroeconomic models but that indeed is crucial for business cycles dynamics and so in policy design.
- analyzing the effects of economic policy measures in an economy with spatial structure consisting of a number of regions where distributions of the characteristics of economic agents in general differ between regions and the spatial flow of goods and production factors have substantial real effects.
- analyzing the interaction effects of policy measures of different types that are typically studied in isolation in mainstream analytical models.
- deriving normative insights for European policy making by calibrating the model using European data and incorporating regional differences in the characteristics of the potential flow of goods and factors between regions.

The EURACE project aims at building a macroeconomic model which, with regard to policy analysis, complements existing dynamic macroeconomic models (e.g. dynamic general equilibrium models) by being much richer in the representation of economic interactions and the set of policy questions that can be addressed. The types of policy measures considered reflect to a large extent the policy analysis employed in standard macroeconomic models. However, the modelling environment where the policies are analyzed is challenging and new. We are developing an agent-based model that allows to consider measures from fiscal and monetary policy as well as policies influencing the educational and skill levels of the workforce. As pointed out above, the approach is a normative one in the sense that we try to determine the policy measures that yield optimal results in a spatial economy with heterogeneous agents, market frictions, transaction costs and cascade effects. A detailed consideration of how such policies can be optimally implemented within the institutional framework of the European Union and its member countries is outside the scope of this three-year project. The same holds true for considerations of institutional details and strategic considerations that influence the way policy decisions in this area are actually taken.

1.4.2 Foreseen Policy Experiments

Within the EURACE project several concrete policy issues will be addressed. The main topics of concern are:

Monetary policy

The design of a uniform monetary policy in a spatial economy with heterogeneities across regions will be one of the main issues, thus addressing a critical aspect of the Euro zone monetary policy. The current central banks' policy practice of inflation targeting monetary policy, employed among others by the ECB, will be considered. In this respect, the EURACE agent-based model should give new insights and more reliable results compared to the standard macroeconomic models currently employed. The new-Keynesian dynamic stochastic general equilibrium models, which are the workhorse of many central banks, are characterized by a time-dependent price stickiness and are usually studied in the log-linearized form around a zero-inflation steady state. Indeed, recent studies have shown that these models are able to capture only partially the effects of inflation on the growth rate of output and important stylized facts such as inflation persistence. Conversely, agent-based models are able to encompass important channels through which inflation may affect real activity, like adaptive expectations and coordination failures due to out-of-equilibrium transactions and heterogeneous and independent beliefs. Finally, an important point to be addressed will be the relationship between monetary policy and financial stability, and in particular the question of whether monetary policy should or should not target bubbles in the asset markets other than inflation.

Fiscal policy

The design of a suitable fiscal policy to support economic activity will be pursued. In particular, different types of fiscal stimuli will be taken into account, considering the different effect of moving taxation from income to consumption, or the other way around, and also, among income, the best allocation of the tax burden among labour and capital production factors. Both short and long term effects of fiscal stimuli will be considered with respect to the output level and the distribution of income among agents.

The issue of income and wealth distribution and related policies to mitigate economic inequalities will also be addressed. In this respect, a multi-agent model should be particularly suited to addressing this point from a realistic perspective.

Macroeconomic stabilization policies

Adequate monetary and fiscal stabilization policies will be considered with respect to different types of shocks hitting the economy. In particular, the main effort will be devoted to shocks due to financial asset bubbles bursting and due to inflation in the price of energy. The former shocks will be modelled endogenously in the system, while the latter will be treated as exogenously given. Besides, policies aimed at reducing financial volatility will be considered, such as taxation of speculative trading (the so-called Tobin tax). Preliminary studies [ref. Mannaro, K., Marchesi, M., Setzu, A., "Using an Artificial Financial Market for Assessing the Impact of Tobin-like Transaction Taxes", to be published on Journal of Economic Behavior and Organization] have already been performed on a dual-market model where a transaction tax can be levied on one of the markets. Market transition mechanisms have been tested, where agents choose the market in which to trade basing their choice on perceived risk and profitability, and it has been shown that they are influenced by a transaction tax. Futhermore an impact of Tobin Tax on price volatility which increases when the tax is levied has been observed.

Finally, great attention will be devoted to considering an important source of cascade effects of shocks to the economy, i.e., credit rationing. Agent-based modelling allows to address issues related to heterogeneity and interaction between agents not considered by analytical models. Thus, through ABM it is possible to develop stabilization policies directed towards subsets of agents or even to single agents which show particular individual characteristics. Secondly, this modelling technique allows to assess the effect of different stabilization policies on the structure of the interaction network. For instance, ABM permits to implement policies such as the rescue of a single bank characterized by a particularly relevant financial fragility or by a strategic position ("hub") in the banking system network. Note that this is impossible to evaluate in standard analytical models. We can also assess the effect on the trade-off between efficiency and stability of different antitrust policies. In fact, it is well known from network theory that networks with hubs, that is with few and very connected nodes, tend to be more efficient but also more fragile (bankruptcy cascades are more likely), whereas less concentrated networks (that is without hubs) are less efficient but also less vulnerable in case of failure of some bank. Hence, the EURACE model will allow to understand whether and when a strict antitrust policy can boost the overall economic performance.

Facilitation of technological change and international competitiveness

It is by now well established that the success of national or regional innovation systems is influenced by a large set of diverse aspects of the economy, among them the educational level of the work force, training activities of firms, firm willingness and ability to carry out R&D, availability of financing options for firms, producer-supplier relationships, producer-user relationships or consumer attitudes towards innovative products. Many of these aspects can potentially be influenced by economic policy measures from different areas like educational, industrial or fiscal policies. So far the literature in this area is almost entirely based on case-studies and qualitative reasoning. No model-based attempts have been made to analyse effects of the interplay of such measures. It is planned to provide first insights into interaction effects for some of the relevant policy measures. In particular, the following policies will be considered.

- Educational Policies influencing general skills of workers.
- Fiscal Policies determining funding of public research and subsidies for private R&D investments.

- Research Policies increasing public-private knowledge transfer.
- Labour Policies influencing volatility of the work-force and labour flows between firms.

1.5 Users of the EURACE model

The platform will have two different kinds of users: researchers and policy makers. Researchers will continue to develop the system, and will perform computational experiments in order to gain new insights from the emergence of aggregate economic features. Policy makers will mainly use the platform, which will be endowed with an appropriate high level user GUI, as an instrument to support their policy decisions. The European Central Bank as well as the national central banks may particularly be interested in conducting policy experiments related to monetary policies. Researchers providing direct input to policymakers at national treasury ministries and the European Commission on Financial Affairs may have an additional tool for analyzing the effects of various fiscal policies. Banks and insurance companies, and financial market authorities may want to apply this agent-based model with a focus on financial market issues and their interaction with firm and household behaviour. Furthermore, the option to analyze regionally differentiated policy measures will make the EURACE platform an attractive tool for regional policy makers (e.g. on a state level) to develop policies that are tailored to regions with specific characteristics. In particular we intend to approach policy makers concerned with growth oriented technology and educational policy to allow them to coordinate these types of policies on a quantitative model basis. For this reason growth and technological change are among the main issues in EURACE.

Going beyond the group of people who will work directly with the EURACE platform the project will be valuable to the scientific community and policy makers by pushing forward the level of sophistication of agent-based models for policy advice. In particular, EURACE will generate:

- Fundamental advances in computational methodology, allowing for the treatment of very large models, for a flexible and realistic treatment of time, for the easy inclusion of spatial and evolving network features. These advances will profit the whole scientific community concerned with agent-based simulation, within and outside of economics.

- Specific advances in the modelling of a concrete complete (supra) national economy, important for future work by the EURACE team and other researchers.
- Experience and guidelines on how to model specific markets.
- Experience and guidelines on how to integrate these markets.
- Experience and guidelines on how to validate a large model.
- Experience and guidelines on how to treat the data generated by the model.

1.6 Success criteria

We will consider our endeavour a success if we realize the following:

- a software platform able to run on parallel machines;
- an economic model able to replicate diverse stylized facts of the European economy;
- a credible demonstration that the model can be used to address various important policy questions.

Chapter 2

EURACE distinctive technological features

2.1 The FLAME framework for modeling economic systems

The initial FLAME framework was based around the needs of biological systems modelling, specifically tissue models where agents are biological cells. The agents were quite simple needing only a list of variables for memory that are single fundamental data types. The agents functions could be defined as a simple list and agent communication was restricted by Cartesian space.

Economic models for EURACE require more complex agents with multidimensional memory and functions that depend on a magnitude of other functions either via communication or the change of agent memory. For this purpose, a number of additional features have been designed and added to the FLAME framework to make it more friendly for economic modellers. These have been listed below:

- Additional features for economic systems includes the use of abstract data types and arrays in agent memory.

- Agent functions are not just linear but are dependent on numerous markets and different types of agents. This has required the use of function dependencies to order the execution of functions and the timing of communication synchronisation to make the execution of a simulation as efficient as possible.

- Communication is no longer restricted to Cartesian space but can be dependent on the relationship between any message variable and any other variable, possibly agent memory variables. This allows communication to be restricted to specific markets and networks of regions.

Each agent function has defined input and output messages. Any input to a function is dependent on the output coming from other functions, this is called a communication dependency. Whenever there is a communication dependency between functions there needs to be a synchronisation across the agents so the that message boards are fully updated. In the parallel implementation this is a very complex task and is discuss in a later section.

2.2 The FLAME framework compared to existing software platforms

FLAME is specifically designed to provide a formal and very flexible approach to agent-based modelling. Also the use of high performance computing was an integral part of the design as the goal was to perform simulations contain many millions of agents.

No other currently available platform is designed to utilise high performance computing. Some platforms like A-Globe, ABLE, Cougaar, and Zeus, use common network protocols to send communication between computers and are written in Java. Although this is a very portable approach Java implementation are not very efficient. EcoLab provides a way for users to try and implement HPC routines themselves using the MPI library.

FLAME introduces formal methods and mark-up language for models to be written, allowing these applications to be automatically created to work on both serial and parallel systems through the FLAME Xparser. Echo, Swarm, and Repast don't obey these principles. Indeed, Echo was for ecological modelling and is now obsolete. Repast and the most recent versions of Swarm are platforms based on Java language, which is an interpreted language.

The models we are developing need much more computer power to perform realistic simulations, of up to hundreds thousand, or millions, agents. FLAME, being based on C language can exploit the computation efficiency of the language and can easily ported on most target machines.

2.3 The FLAME framework and High Performance Computing

In the design of FLAME it was recognised that the computation power and memory requirements for large scale simulations would be significant. For problems involving millions of agents and many message types, the processing power and memory size of a single processor not be sufficient. Thus the initial design included an approach to exploit distributed memory parallel computing.

There are four main difficulties to be overcome in the parallel implementation of the FLAME framework:

- the initial distribution of agents to processors to provide an adequate load balance
- the efficient distribution and management of message board data
- the maintenance of good a load balance during the simulation
- the minimisation of the communication overheads between processors during the simulation.

In the initial applications of FLAME - biological systems - an essential attribute that can enable effective parallelisation, locality, is inherent in the models. Cells and molecules have position and a limited range of influence within the model. These attributes enable the definition of geometric domains that can be used for parallelisation and also aid the distribution and maintenance of message data.

This approach to agent simulations and parallel implementations is very different from existing agent-based simulation packages.

However EURACE is aiming to use more complex and more flexible agents. The essential attribute of locality is not as simple although location maybe defined in the agents. The size and complexity of the model - the number of agents, the type of communication and the number of message board types - will require a more flexible parallel implementation. This additional flexibility will impact the efficiency of the implementation however it will enable us to simulate larger complex systems.

The four objectives above still apply in the design but there complexity and difficulty will be greater. Even the task of generating an initial distribution of agents distributed over the processor becomes very difficult as a balance needs to be achieved between meeting the message board memory requirements and the communication costs.

FLAME and the formal model definitions can provide a source of information that can aid the parallelisation of a particular model. By exploring the combined use of function dependencies and message filters it should be possible the generate an initial distribution of agents and to guide the FLAME algorithm to minimise the waiting time agents when requiring certain information from other agents.

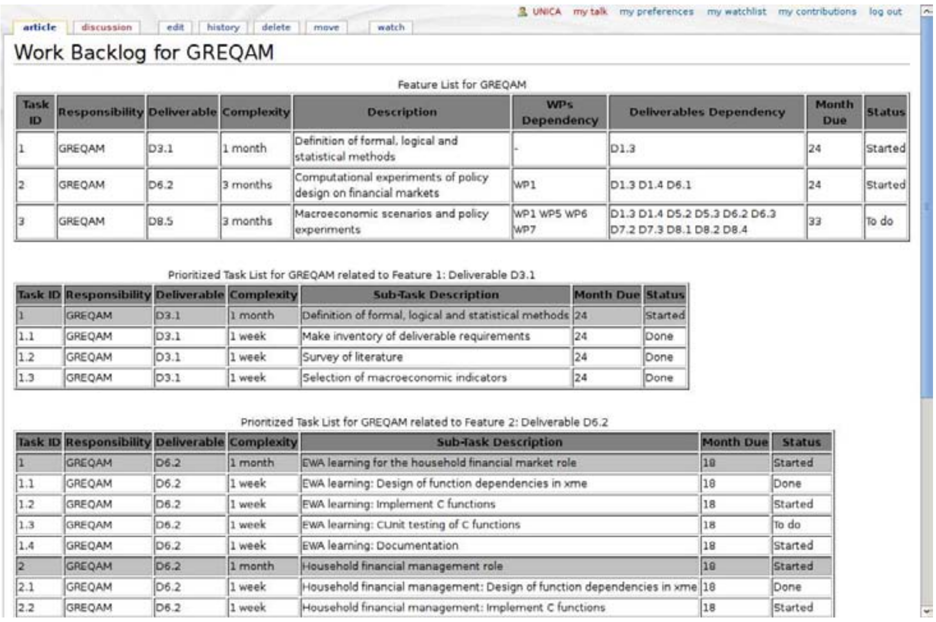
During the simulation message board management is the most important task. Not all agents need to receive all the messages sent out, for example exclusive markets within regions. Pre-defined function input filters are used by the framework to limit the number of messages that need to be sent on a HPC and it is possible for the framework to pre-filter a subset of messages for each agent.

A second significant problem in a parallel implementation is that of communication deadlocks - situations in which all agents find themselves waiting for information. Although the function sequencing inherent in the framework reduces the possibilities for this occurring, in a simulation containing millions of agents with many communication requirements, unforeseen deadlocks may appear.

Although a goal is to allow modellers freedom in defining their models, the use of parallel computing systems will influence the way in which models are designed. EURACE will explore ways of minimising these restrictions but it can be expected that there will be some if effective use of high performance system is to be made.

2.4 Agile software management method

The agile software methodology EURAM has been introduced for managing Eurace software development and is fully described in deliverable No 1.2 (D1.2). After a slow start, it is now working well, and all computer software units are taking advantage of it. UNICA unit is acting as Process Manager, responsible for enforcing the rules of the process, helping to remove impediments and ensuring that the process is used as intended. USFD is acting as Project Manager, as far as FLAME development is concerned, while UNICA is the Project Manager for all the activities related to the integration of the different modules (WP 8). The process artifacts and the software deliver-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Work Backlog for GREQAM

Feature List for GREQAM

Task ID	Responsibility	Deliverable	Complexity	Description	WPs Dependency	Deliverables Dependency	Month Due	Status
1	GREQAM	D3.1	1 month	Definition of formal, logical and statistical methods	-	D1.3	24	Started
2	GREQAM	D6.2	3 months	Computational experiments of policy design on financial markets	WP1	D1.3 D1.4 D6.1	24	Started
3	GREQAM	D8.5	3 months	Macroeconomic scenarios and policy experiments	WP1 WP5 WP6 WP7	D1.3 D1.4 D5.2 D5.3 D6.2 D6.3 D7.2 D7.3 D8.1 D8.2 D8.4	33	To do

Prioritized Task List for GREQAM related to Feature 1: Deliverable D3.1

Task ID	Responsibility	Deliverable	Complexity	Sub-Task Description	Month Due	Status
1	GREQAM	D3.1	1 month	Definition of formal, logical and statistical methods	24	Started
1.1	GREQAM	D3.1	1 week	Make inventory of deliverable requirements	24	Done
1.2	GREQAM	D3.1	1 week	Survey of literature	24	Done
1.3	GREQAM	D3.1	1 week	Selection of macroeconomic indicators	24	Done

Prioritized Task List for GREQAM related to Feature 2: Deliverable D6.2

Task ID	Responsibility	Deliverable	Complexity	Sub-Task Description	Month Due	Status
1	GREQAM	D6.2	1 month	EWA learning for the household financial market role	18	Started
1.1	GREQAM	D6.2	1 week	EWA learning: Design of function dependencies in xme	18	Done
1.2	GREQAM	D6.2	1 week	EWA learning: Implement C functions	18	Started
1.3	GREQAM	D6.2	1 week	EWA learning: CUnit testing of C functions	18	To do
1.4	GREQAM	D6.2	1 week	EWA learning: Documentation	18	Started
2	GREQAM	D6.2	1 month	Household financial management role	18	Started
2.1	GREQAM	D6.2	1 week	Household financial management: Design of function dependencies in xme	18	Done
2.2	GREQAM	D6.2	1 week	Household financial management: Implement C functions	18	Started

Figure 2.1: Feature list and task lists of various iterations of GREQAM research unit

ables of the project are kept in Eurace Wiki. Fig. 2.1 shows a list of features a research unit is responsible for, followed by the task lists pertinent to the various iterations. Note that the task lists extend down the Web page shown. Presently, EURAM repository is being ported to the CCPForge repository to take advantage of the task-management features of CCPForge, featuring automated tracking of task dependencies and reporting capabilities.

2.5 The Graphical User Interface

One of the software tools to be implemented as part of the EURACE project is a graphical user interface (GUI) and its library to build and develop complex agent-based models in economics. GUI design follows generally accepted conceptualizations and terminology in computational economy while at the same time it ensures that the design can be represented in canonical form in the XMML format of FLAME. Currently we have implemented the GUI component for agent design. However, over all GUI software platform, addi-

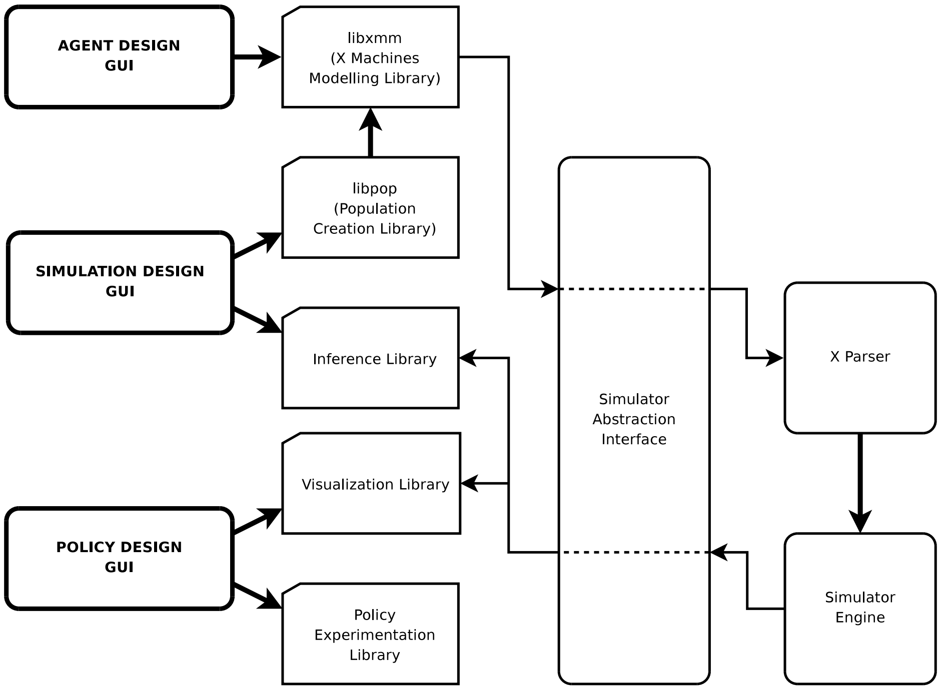

Figure 2.2: EURACE Software Architecture

tionally, as it is discussed in Deliverable No 1.3 (D1.3) will be used to create population of agents and their relations, and will also provide tools to allow policy designers to run what-if analysis they need. Currently adopted GUI architecture, as shown in Figure 2.2, reflects such three types of uses and users for which the complete software platform is targeted for. The functionality that is used in several places was organized into several libraries to allow for code reuse and parallel implementation. Implementation of software tools has started from pieces that are at the top of the illustration and proceeds downwards. Our GUI design approach allow us to improve/add new features when new requests and necessities emerge.

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Appendix A

Present EURACE model specifications

This part of the document gives an overview of the integrated macroeconomic model that has been developed so far. Reviewers correctly pointed out that the various economic models are interesting but the interaction and the integration between different models does not clearly emerge by considering each particular deliverable. Here the integration between the models will be clarified, which are the inputs and the outputs for each model, and which are the different roles of the agents when acting in different markets. These issues were discussed along with other topics at a recent project meeting in Istanbul.

The integrated model presented here is the first operative version of the EURACE model and is being entirely implemented in the FLAME framework, using some instruments developed within the project, like the Graphical User Interface (GUI). We plan that the first operative results of the model should be available within two or three months.

A.1 The model

The model is populated by three main types of agents: households, firms and banks. These agents are not the only ones in the model but they are the only ones that have active and relevant roles in every market. Other agents have more technical and specific tasks, like the Eurostat agent, that retains useful information for other agents, or the Clearing House agent, that simply calculates the asset prices in the financial market, or the malls, that are intermediaries between firms and households.

There are four markets in the model: the goods, the labour, the credit and the financial market. Each agent acts in a particular market according to some behavioural rules that have been specified in detail in the corresponding deliverable (D5.1, D6.1, D7.1). What is missing in the deliverables is an overall description of the system that shows the interactions between the markets, and the different roles that agents play when acting in different markets. In order to give a broad-spectrum vision of the integrated model, some flowcharts and some graphs have been prepared. Three of them refer to the agents and summarize the roles that each agent plays in a different market, describing an input/output scheme where it is specified which variables are needed to perform a particular role and which variables are generated as output. The other plots refer to the markets, describing the mechanism of integration, i.e., which are the exogenous variables (produced by other markets) that a specific market needs, and which are the outputs that it sends to other markets. It is worth noting that markets are simply a form of interaction among agents and that, when we talk about input and output variables between markets, it is only a shortcut, because the only ones who are able to send and receive information are the agents. In the following table the presented flowcharts are summarized and briefly explained:

Household diagram	Fig. A.1	Interaction and roles of the household
Firm diagram	Fig. A.2, A.3, A.4	Interaction and roles of the firm
Bank diagram	Fig. A.5	Interaction and roles of the bank
EURACE interface	Fig. A.6	Interactions inside EURACE

Some acronyms are used in the diagrams, a short list follows:

ALM: Artificial Labour Market
CGM: Consumption Goods Market
AFM: Artificial Financial Market
ACM: Artificial Credit Market

A.1.1 Agents

This section provides a general description of what happens in the model from each agents point of view. Combining these descriptions and referring to the flowcharts, this should give a general vision of the most recent version of the model.

Households A scheme of household activities can be found in figure A.1.

On the labour market the households search for vacancies (Household Labour Market Role). The households can search-on-the-job if they are unemployed. They apply for a job at several firms if the wage offer of these firms are higher than the reservation wage of the household. After applying they receive zero, one or more job offers and rank these offers with respect to the wage offer: highest wage offer first. If two or more wage offers are equal then these are ordered randomly. The households accept the highest ranked job offer and update their reservation wage which is the new wage. If households are still unemployed they decrease their reservation wage.

The household takes its savings/consumption decision according to a rule-of-thumb inspired by Deaton, where the target is smoothing consumption over time (see D6.1 and D7.1). Then the household plays the role of consumer, where it buys goods according to its consumption budget, and the role of investor in the Financial market, where it takes decisions about asset trading. The household splits the consumption budget, determined once a month, into four equal shares which are used for purchasing goods when a household goes shopping once a week. The commodities are offered in geographically distributed outlet malls, where it is assumed that a household can select the mall to visit out of a set of malls located nearby. The mall decision is based on rough price and quality information in conjunction with a certain degree of loyalty. After choosing a mall, the household gets detailed price and quality information about the range of provided goods, and makes then the decision on what good to purchase by taking this price and quality information into account. The household tries to spend the whole weekly budget for the intended good, although there is the possibility of rationing. In this case the household has a single opportunity to select another good. If the budget is then not completely spent, the remaining amount is rolled over to the following week. In the financial market the household decides how to invest its savings, choosing among stocks, government bonds (corporate bonds are not present in the model) and a savings account, withdrawing some money from the bank deposit, if needed. The decision is taken according to a behavioural rule that makes reference to prospect theory (see D7.1) and takes into account some important psychological aspects. After the clearing house price setting and rationing process, the household updates its portfolio and sends its new deposits to the bank (each household owns deposits only in one bank).

Firms A scheme of firm activities can be found in figure A.2.

After determining the required workforce during the calculation of production inputs the firms either post vacancies or fire workers depending on whether additional workers are needed or not (Firm Labour Market Role). If the firms have to dismiss workers they fire the workers with the lowest specific skills (specific skills depend on the technology of the firm) until the needed number of workers is reached.

Otherwise the firms post vacancies together with a wage offer. Firms calculate one wage offer for each of the five general skill levels depending on the average specific skills of each general skill group in one firm. The incoming applications are ranked with respect to the general skill level: applicants with the highest general skill level first. If two or more applicants have the same general skill level they are ranked by chance. The firms send as many job offers as they have vacancies to the highest ranked applicants. If the firms then receive only job acceptances from the applicants the firms have filled their vacancies and have to pay the accordant wages. Otherwise there are still vacancies and the firms increase the job offers.

Current considerations for the implementation of the firm financial management role The firm has to take financial decisions (Firm Financial Management Role) that are summarized by the flowchart A.3. Basically the firm has to finance its production plan. First it verifies the availability of internal resources, then, if needed, the firm turns to banks in order to be financed, sending a message with the requested quantity. If the firm manages to receive all the required amount it can go further with he production plan, if not it has to turn to the financial market, raising new capital by issuing stocks. If the firm gets sufficient money in the financial market to go on with the initial production plan, it starts it, if not the firm needs to re-plan according to its limited resources.

In the current implementation we make the following set of assumptions (the order of decisions is reflected in the diagram A.3 and the decision flowchart A.4):

- Firms pay wages at the beginning of their production cycle (this may not be the 1st of the month, so households might receive wage payments in the middle of the month).

- Firms pay dividends at the end of their production cycle when they have determined their earnings and have made their financial planning for the upcoming production cycle. The dividends are paid out of the earnings, so they belong on the balance sheet of the production cycle that has just ended.

- What is not included in the financial planning are the forecasted earnings for the upcoming production cycle and the forecasted dividend payments. These are simply calculated after the earnings have been determined at the end of the production cycle.

- The total dividend payout may vary, but in general CFO's try to maintain a constant dividend to earnings ratio. If earnings increase, total dividend payout also increases accordingly. However, CFOs are very conservative about increasing the level of dividends per share since this implies a payout commitment for the indefinite future. According to survey data, CFOs prefer to keep dividends per share constant and certainly not increase them in the absence of any structural increase in earnings. Decreasing the dividend per share is also not a good signal, and may even cause a sell-off of the firm's stock. Therefore, the best guide for setting the dividend payout level is to leave it as in the previous period. In fact, the choice variable to determine the dividend payout is not the level but the percentage change of the dividends per share. By default this is kept at zero percent.

- The share repurchase decision has been postponed to a future implementation.

- At the end of each production cycle an end-of-period accounting routine is run consisting of the computation of an income statement and a balance sheet. The income statement consists of a computation of the cumulative revenues from sales of goods and services, and the total costs that include the costs of sales and operating and administrative expenses.

- The balance sheet consists of computing the EBIT (earnings before interest and taxes), then subtracting interest payments to obtain earnings before taxes (EBT). After subtracting the taxes net earnings are obtained, and after subtracting the debt installment payments and the dividend payout, the total freely disposable financial resources is what is left.

- After all pre-determined commitments have been met – interest payments, taxes, debt installment payments and the total dividend payout – the firm looks at its balance sheet. The balance sheet computation ends with the computation of the total assets and liabilities of the firm.

- Assets consist of cash holdings, property of plant and equipment (the total value of the capital stock), inventories (the total value of local inventory stocks).

- Liabilities consist of all borrowings, investment contracts, shareholder's equity.

- Next, the firm enters its financial planning routine. This starts with production planning, to determine the total planned production quantity, the planned workforce, and planned investments in new capital stock. The output of the production planning function is the planned demand for labour (and its total costs) and the planned demand for investments (and its total costs). These quantities still remain non-fixed since it has still to be determined whether there are sufficient financial resources available, or if additional external financing is required. If this is the case, it might turn out that a re-planning of the production quantity and planned investments is needed before actual production can begin.

- After the initial production planning stage, the financial planning routine continues with a computation of the (planned) interest payments, debt installment payments, total dividend payout, and total production costs (i.e., total costs of investments and labour costs). These costs will partly have to be paid already before the production starts (investment and labour costs), and partly out of next period earnings (interest payments, debt installment payments, total dividend payment).

- The sum of all payouts equals the total financial needs for the firm. Next, the total financial needs are split into internal financing and external financing. Following the Pecking Order Theory, if the current internal financial resources (the payment account, or cash holdings of the firm) are sufficient, the total financial needs are financed using internal financing only (`external_financial_needs=0`). Otherwise, the remainder is to be financed using external financing, and the firm starts the credit market routine (this requires a conditional function dependency, where the condition is given by `(external_financial_needs==0)`.

- On the credit market the firm tries to obtain all external financing. If it succeeds, it can continue with the actual production routine. If it fails, the remaining external financing needs should be obtained from the financial market. This starts the financial market routine (this again requires a conditional function dependency, given by the condition `(external_financial_needs==0)`.

- If the financial market routine ends with success, all external financing needs are satisfied and the firm can continue with the actual production routine. If it fails, the firm was unable to obtain the required financial resources to start actual production, and subsequently needs to replan production. This starts a production re-planing phase, in which the firm re-computed its planned production quantity, planned labour force, and planned investments. This means the production planning routine is re-run from the start, given the total financial resources available. The new production plan automatically satisfies the budget constraint of the firm. It is not necessary to re-run the financial planning routine again since the plan that now exists is consistent and exhausts all financial resources available.

- After the production planning routine and financial planning routine have finished, the firm can start with actual production. This starts with a visit to the labour market, followed by the investment goods market, in order to obtain the factor inputs for production.

- If there is rationing on the labour market, the firm's labour market role sets an internal memory variable `retained_cash_holdings`. These are the cash holdings that remain idle during the current production cycle but which can be used in the next production cycle. If the firm is rationed on the investment goods market the involuntary savings are also retained as idle cash holdings for the next cycle. In the simplified version of the model rationing of the the investment good cannot occur since it is always in infinite supply.

- After the visits to the labour market and the investment goods market, the actual production routine is started; This is followed by the selling of the goods. The selling role of the firm is handled by the outlet malls that transmit all the cumulative revenues from sales to the firm headquarters. After the selling, the production cycle has ended and the end-of-period accounting routine is run again.

Banks A scheme of banks activities can be found in figure A.5.

For firms, bank credit is the first of external financial sources. For each applicant firm, banks decide how much credit to supply and the corresponding interest rate. The amount of supplied credit depends on bank's credit availability (affected by bank's capital, Basel II parameter and already supplied credit) and by the Value-at-Risk (VaR) related to the applicant firm. VaR depends on the amount of credit demanded and on the probability of default: the latter is an exponential function of firm's financial soundness computed by the bank. If the sum of the VaRs does not exceed the Basel II threshold, the bank supplies to firms all the credit they required, otherwise firms are credit rationed. If banks experience a shortage of cash due to withdrawals by households, they can take liquid resources from the Central Bank at a minimum interest rate, but they cannot supply additional credit until the debt towards the Central Bank has been repaid.

As far as the interest rate is concerned, it is an increasing function of Central Bank's minimum interest rate and of actually supplied credit. The sensitivity of interest rates to the latter is a behavioural parameter which the bank updates adaptively according to past profits.

Periodically, banks receive the payment of interest and loan instalments from firms.

A.1.2 Markets

In figure A.6 a very general sketch of the current EURACE model is represented. In each box is schematically represented the activity related to a particular market. Each agent can be found inside a box, playing the specific roles in the corresponding market, that have already been described in section A.1.1 and shown in figures A.2, A.1 and A.5. These boxes could eventually be replaced with the more detailed interface diagrams, resulting in a very detailed overall picture of the integrated EURACE model. Here we only show the basic flows between the markets; a brief description of each market is given below.

Goods market The goods market, described in D7.1, consists of two submarkets that are the investment goods and consumption goods market. The agents acting on the investment goods market are the investment good producer (IGP) as producer and provider of capital goods, and the consumption good producer (CGP) as demander.

An IGP uses two input factors in the production process, labour (link to the labour market) and energy, where energy is an exogenous parameter. An important feature of the technology produced by the IGP is its quality or, respectively, its technological productivity. To increase the quality, the IGP undertakes research and development, where it is assumed that solely high skilled workers can be deployed for R&D.

The demand for investment goods is determined by the capital and investment decision made by the consumption goods producer in combination with CGP's financing opportunities obtained at the financial market.

Capital goods are used by the CGP as one input factor to produce the consumer goods, which are traded on the consumption goods market. The other input is labour, where it is assumed that labour is differentiated among general as well as specific skills. General skills can stand for the education or other abilities that are not directly linked to the production process, and (technology) specific skills are abilities and experiences built up by using a single technology. A critical assumption is that the general skill level of a worker influences the formation of specific skills in a way that higher educated worker are able to build up specific skills faster than less educated worker.

Firm's average specific skill level of its labour force and the productivity of its capital technology stock are complementarily related so that the firm cannot exploit the full feasible productivity if worker's specific skills are not high enough, and vice versa. The input factors labour and capital however are substitutes.

The commodities are vertically differentiated in terms of quality, and the CGP can improve the quality by investing in R&D. The goods are traded on local markets, these local markets are represented by outlet malls where firms as providers can store and offer their goods, and households as consumers can go in order to purchase. There are no restrictions on malls that a firm may deliver to, but the ability of a firm to serve a certain region may depend on expected profits derived from market research activities.

Labour market The labour market, described in D7.1 (some minor changes, like wage offer determination, have been done from the first year review date of the EURACE project), interacts with other markets as shown in the flowchart of figure A.6. In the labour market firms and households behave according to their labour market roles defined in A.1.1.

Each firm reviews once a year whether to post vacancies for R&D jobs and consumption goods producers also review once a month whether to post vacancies for production workers. In the case where a firm posts vacancies for R&D and for production workers on the same day transactions for the two vacancies are processed independently from each other. Vacancies stay posted only for a single day and all transactions associated with a vacancy take place on that day. Job seekers check for vacancies every day. The matching between vacancies and job seekers works in the following way (This is a short version. For the long version see D7.1 or compare to A.1.1):

Step 1: The firms post vacancies for R&D or for production jobs including wage offers for each general skill level.

Step 2: Every job seeker extracts from the list of vacancies those postings to which he fits in terms of his reservation wage. Job seekers rank the suitable vacancies and send applications.

Step 3: Every firm ranks the applicants. Every applicant on the application list for R&D jobs has the general skill level b^{gen}_{max}. Hence the applicants with skill level b^{gen}_{max} are distributed to the lists by chance. Firms send job offers to as many applicants going down their ranked application list as they have vacancies to fill.

Step 4: Each worker ranks the incoming job offers corresponding to his preference list. Each worker accepts the highest ranked job offer at the advertised wage rate and refuses the other job offers.

Step 5: Vacancies' lists and applications' lists are adjusted for filled jobs. If a firm received refusals, these applicants are dropped from the list of applicants. If all vacancies (R&D and/or production) of a firm have been filled the firm refuses the other applicants and the algorithm for this firm ends.

Step 6: If a firm has more vacancies after the hiring process than a certain threshold it raises the wage offer. If an unemployed job seeker did not find a job he reduces his reservation wage. If a worker finds a job then his new reservation wage is the actual wage. Go to step 1.

This cycle is aborted after n-times even if not all firms may have satisfied their demand for labour. As discussed above this might lead to rationing of firms on the labour market and therefore to deviations of actual output quantities in a period from the planned quantities.

Features of the labour market are the existence of vacancies and unemployed at the same time. Furthermore workers with higher general skills receive a higher wage and have a lower unemployment rate than workers with lower general skills.

Financial market The financial market, described in D6.1 (some minor changes have been done from the first year review date of the EURACE project), interacts with other markets as shown in the flowchart of figure A.6. In the financial market firms and households behave according to their financial roles defined before. As exogenous variables it requires the EBIT (Earnings before interests and taxes) from the firms, which have been calculated in the goods market (see D7.1). It also requires the wages, that have been set in the labour market (D7.1) and the interest rate on deposits fixed by the bank (D5.1). These variables are the only inputs that the financial market needs from the other markets in order to perform its task. In the computational results shown in D6.1 these variables have been considered as generated by exogenous stochastic processes.

As shown in A.6, the EBIT enters the financial market and is used by the firm in order to decide its dividends payment policy. The wages, defined in the labour market, and the interest rate on deposits defined by the bank, are used by the household in order to take its portfolio decision.

Credit market The credit market, described in D5.1 (some minor changes have been done from the first year review date of the EURACE project), interacts with other markets as shown in the flowchart of figure A.5. This market is entered by the cash-flows (in and out) of households, by the minimum interest rate and Basel II parameter of Central Banks, and by loan demand and financial conditions of firms. All of these variables are used by banks in order to put out credit supply and interest rates charged to applicant firms.

From the banks' point of view, the market works on a daily basis. Periodically (monthly for firms) banks get the payment of interest and loan instalment payments.

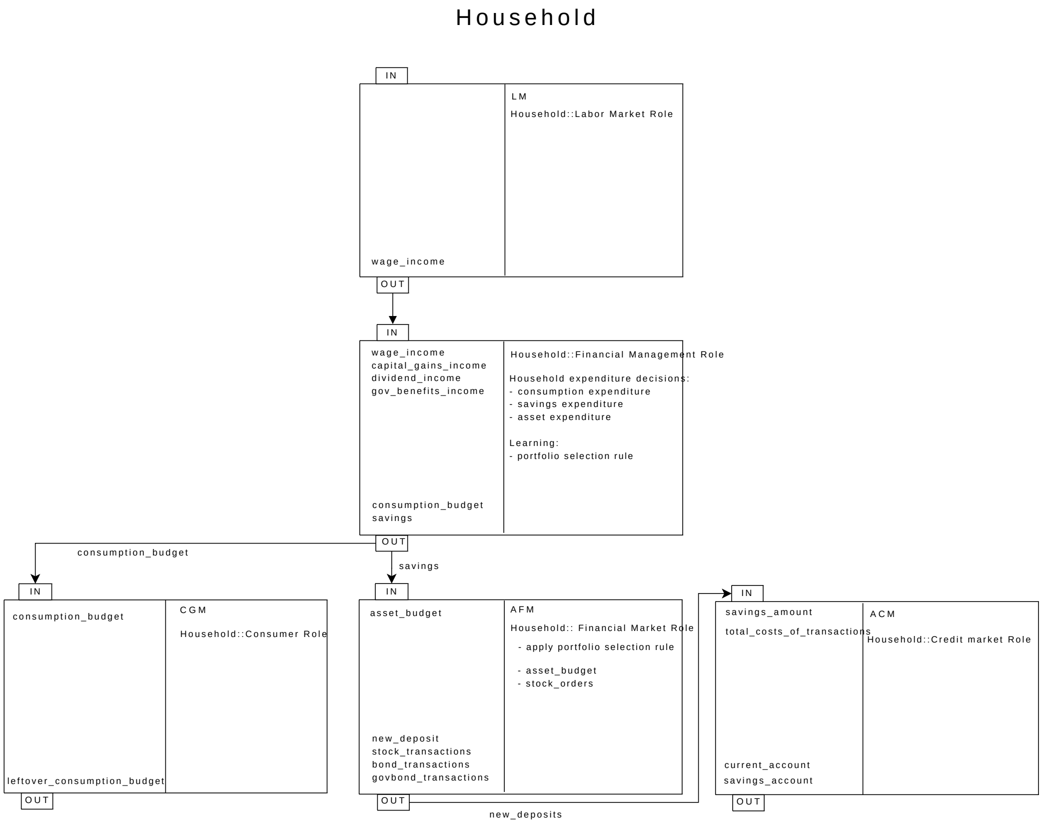

Figure A.1: Household interface diagram

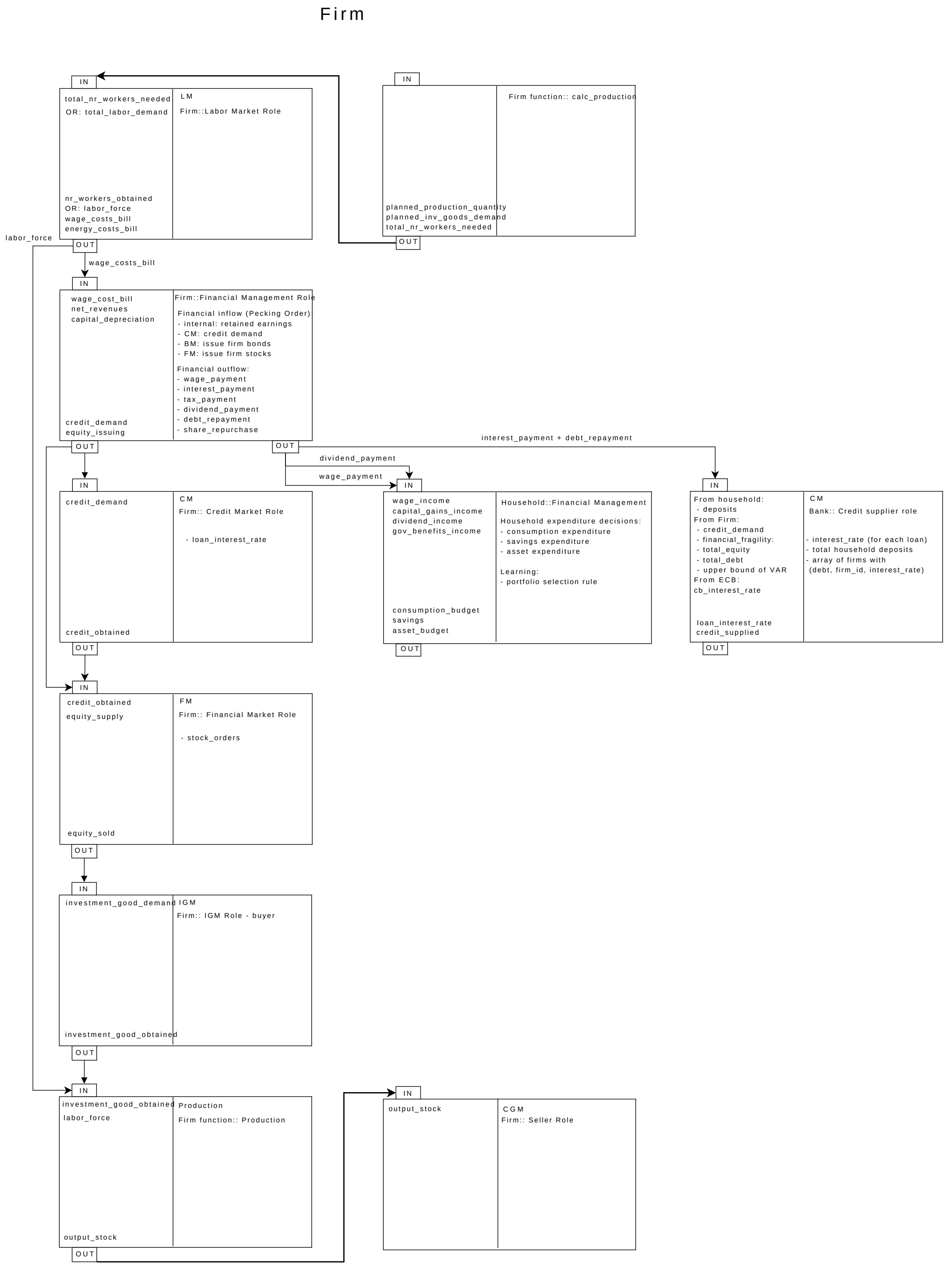

Figure A.2: Firm interface diagram

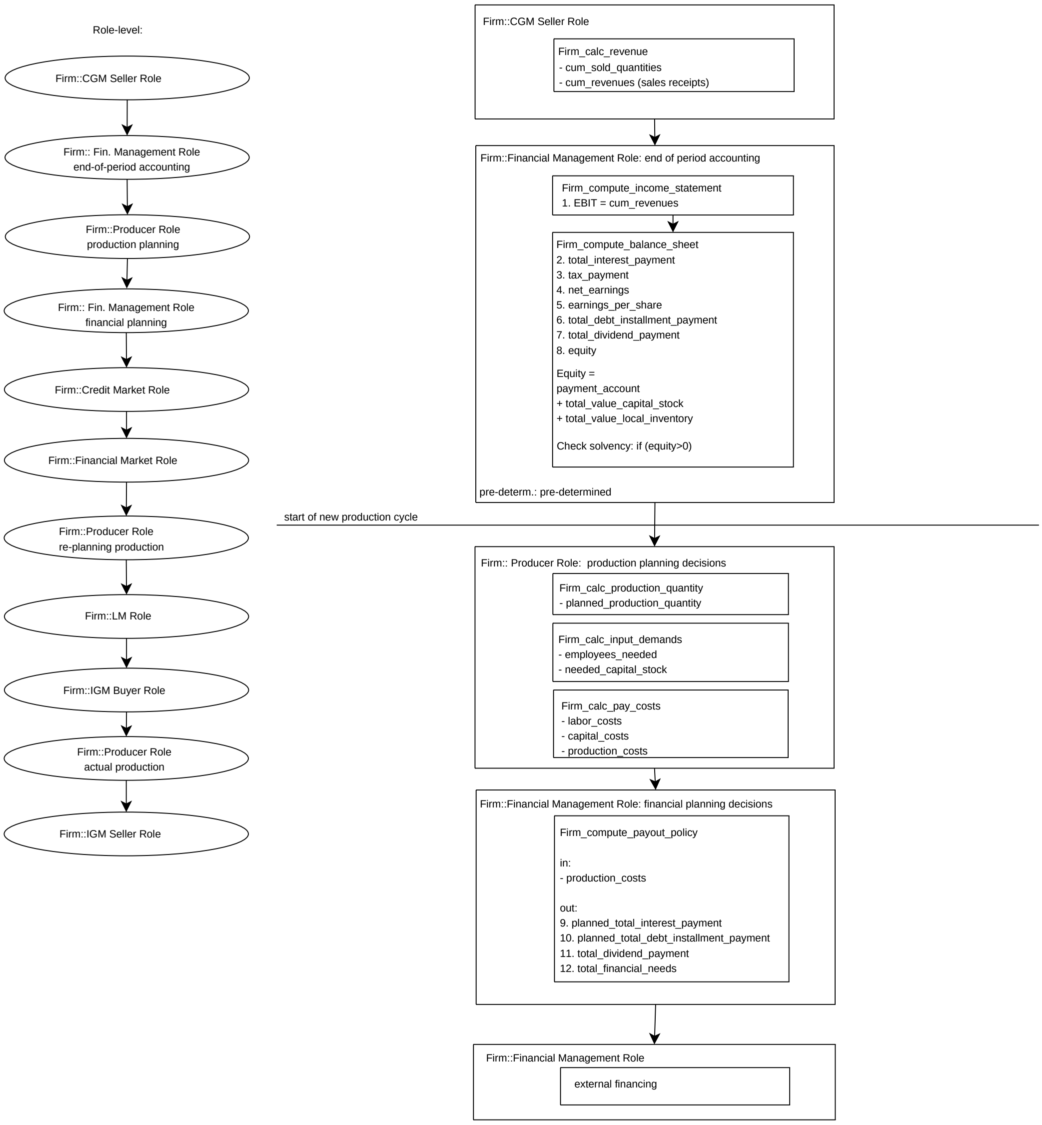

Figure A.3: Firm financial management role. The chart shows the accounting process at the end of the production cycle, computing the balance of payments and the balance sheet of the firm. After the accounting, the firm proceeds with the production planning.

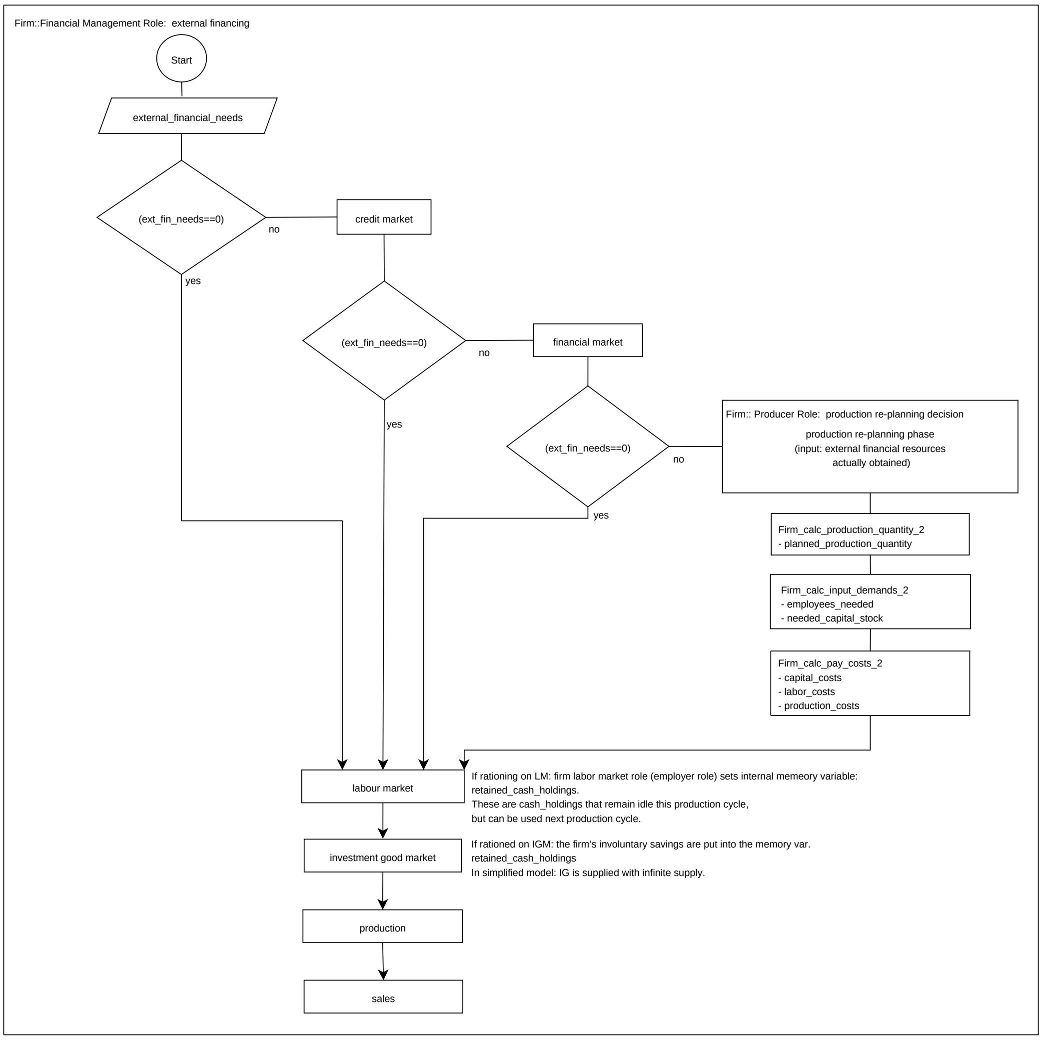

Figure A.4: Firm financial management role. The chart shows the external financing decisions and the interaction between the firm's financial role with its credit and financial market roles.

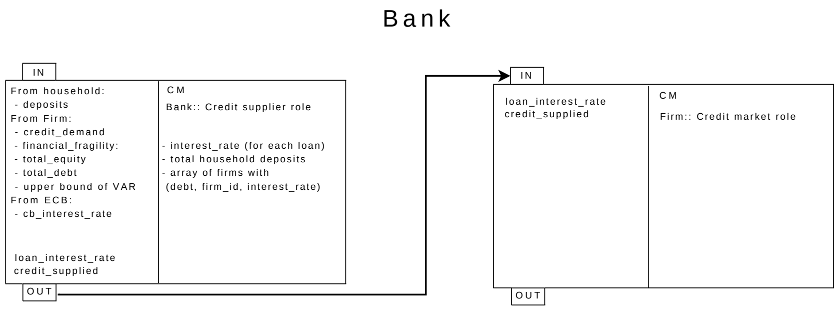

Figure A.5: Bank interface diagram

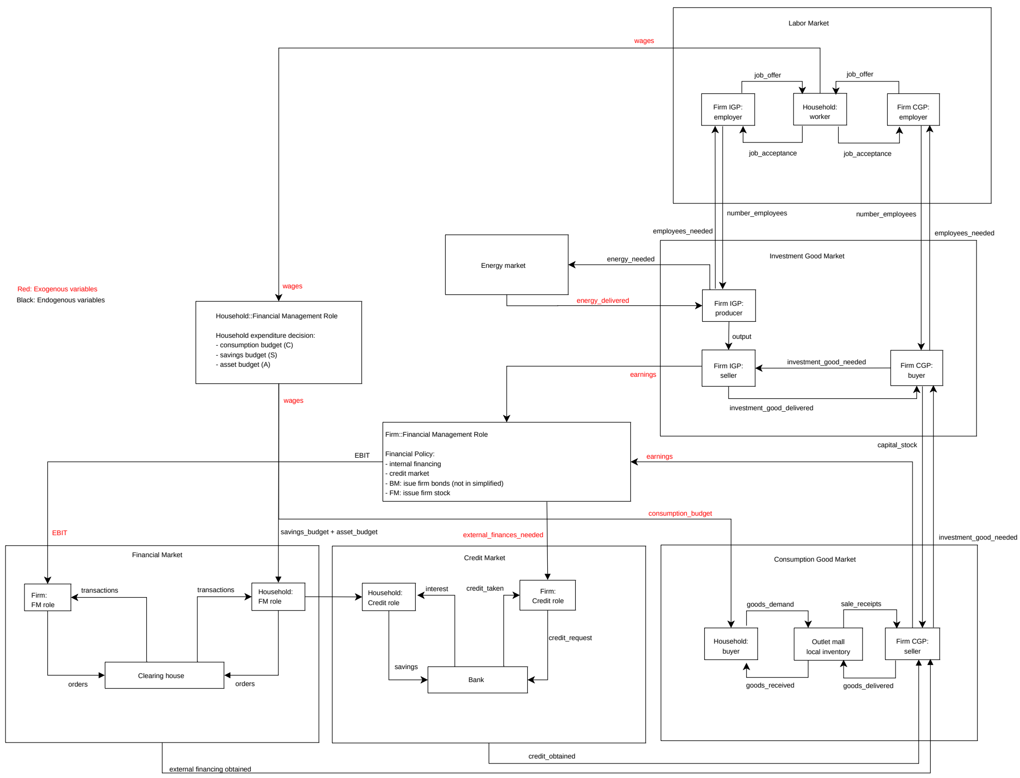

Figure A.6: EURACE interface diagram