Doctoral Thesis

UNIVERSITY OF TRENTO

CIFREM

INTERDEPARTMENTAL CENTRE FOR RESEARCH TRAINING
IN ECONOMICS AND MANAGEMENT

DOCTORAL SCHOOL IN ECONOMICS AND MANAGEMENT

THREE ESSAYS
IN AGENT-BASED MACROECONOMICS

A DISSERTATION

SUBMITTED TO THE DOCTORAL SCHOOL OF ECONOMICS AND MANAGEMENT

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DOCTORAL DEGREE

(PH.D.)

IN ECONOMICS AND MANAGEMENT

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November 2009

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Per chi viaggia in direzione ostinata e contraria
Col suo marchio speciale di speciale disperazione
E fra il vomito dei respinti muove gli ultimi passi
Per consegnare alla morte una goccia
di splendore,
di umanità,
di verità.

F. DeAndrè

To Bruno and Celide
To my Family

Abstract

The dissertation is aimed at offering an insight into the agent-based methodology and its possible application to the macroeconomic analysis. Relying on this methodology, I deal with three different issues concerning heterogeneity of economic agents, bounded rationality and interaction.

Specifically, the first chapter is devoted to describe the distinctive characteristics of agent-based economics and its advantages-disadvantages. In the second chapter I propose a credit market framework characterized by the presence of asymmetric information between the banks and the entrepreneurs. I analyze how entrepreneurs' heterogeneity and the presence of Relationship Banking influences the macro properties of the designed system. In the third chapter I work to take the core of Keynes's macroeconomics into the computer laboratory, in the spirit of a counterfactual history of economic thought. In particular, I devote much effort in the behavioural characterization of the three pillars of Keynes's economics – namely the MEC, MPC and LP – relying on his clear refusal of perfect rationality in the decision making process. The last chapter adds to the literature that assesses the impact of monetary policy under the hypothesis of agent's bounded rationality. Indeed, I design a quasi rational process through which inflation expectations are updated, and then I analyze how this hypothesis interacts with the efficacy of different monetary policy regimes.

Keywords

Macroeconomics, Agent-based economics, Complex Adaptive System

Contents

Introduction

Introduction

> “The economy is an evolving, complex, adaptive dynamic system. Much progress has been made in the study of such systems in a wide variety of fields, such as medicine an brain research, ecology and biology, in recent years. To people from one of these fields who come to take an interest in ours, economists must seem in the grips of an entirely alien and certainly unpromising methodology. In these other fields, computer modelling and experimentation is accepted without much question as valuable tools. It was possible, already 15 years ago, to hope that economists would find them valuable as well [Leijonhufvud, 1993]. But the intervening years have not witnessed a stampede into agent-based economics.” (Leijonhufvud, 2006, pag.1627)

This dissertation is my personal first tentative to work towards what Leijonhufvud called “Agent Based Macroeconomics”. It is a tentative in the sense that the agent based methodology is both in its “technical infancy” (Lejionhufvud, 2006) and it is still considered controversial by the majority of the profession.

Nonetheless, I found particularly inspiring the previously cited Lejionhufvud’s article, and I decided to go deeper into the understanding of how agent-based modelling can help us in disentangling the inner characteristics of complex economic systems.

Which are the reasons to consider real economies as complex systems?

If I was to put it very briefly, I would highlight three interrelated points.

First, real people are heterogeneous. Probably we can bring back their economic behaviour to some reasonable and homogeneous macro behaviour, but this cannot overcome the fact that they are inherently different. The inner diversity makes them behave in a variety of manners at the very micro level.

Second, people are not unbounded rational. Real economic agents are neither able to perfectly forecast the future, nor they are able to perform very complex computation, so that it is quite controversial assuming them to choose through the resolution of optimizing processes. Indeed, bounded rational people are not necessarily irrational, in the sense that most people follow reasonable economic patterns, and most of the times they do not degenerate in some crazy conduct. Their bounded rationality can be traced back to the incapability of processing all the information they would need to take rational economic decisions.

Third, the former characteristics imply interaction. People interact because of their heterogeneity, and therefore because interacting they can overcome their lack of knowledge and their incapability of processing information. Interaction becomes a way through which coping with bounded rationality.

The three features taken together render any economic system complex, adaptive and dynamic.

Indeed, the chapters of this thesis try to assess the study of the economy as a complex system taking as reference point the latter issues.

Since traditional DSGE models perform poorly in tackling these problems, I am working in the spirit of Leijonhufuvd's words, that is, I aim at showing that agent based economics endows economists with the possibility of building models that better assess such complex systems. These models then present us with a better understanding of the macroeconomic dynamics resulting from micro behaviour characterization.

Chapter 1 offers an overview about what agent based models are and why they can be considered good alternatives to general equilibrium optimizing models, highlighting the differences between ABM and assumption-based economics. In particular, they will be presented both the advantages of this new methodology and the disadvantages of it. Finally, I will show why the older Classical Economics can be considered as a precursor of the principles on which agent based economic is built on.

The three subsequent chapters deal in different ways with the issues characterizing complex economies.

Chapter 2 tries to shed light on the implications of having heterogeneous entrepreneurs in an asymmetric information framework regulated by Relationship Banking. On one hand, the Financial Fragility literature points at demonstrating that economic fluctuations can be traced back to the presence of asymmetric information in the credit market although neither considering heterogeneous entrepreneurs, nor differentiating the possible contractual arrangements that regulate bank-firm interactions. On the other hand, both the theoretical and the empirical literature about Relationship Banking do not consider heterogeneous agents and do not study the macroeconomic impact of such credit relationship. Aiming at overcoming these limitations, I build a model in which the economy is populated by entrepreneurs who are heterogeneous both in their productive capacity and in their opportunistic attitude. In order to produce they have to ask for credit to a bank, which is not able to distinguish good entrepreneurs ex-ante. Then, I envision two treatments. In the first one, the bank faces asymmetric information by charging each entrepreneur with the same interest rate since it is not able to discriminate among them. In the second one, the bank has the possibility of discriminating entrepreneurs ex-post upon their being good long term clients or not: in the former case, the bank charge entrepreneurs with a lower interest rate. The two situations will be separately analyzed in order to assess which situation is better in terms of aggregate efficiency and macro dynamics.

Chapter 3 offers an interpretation of Keynes's intuitions in the spirit of conducting a counterfactual history of economic thought. In particular, the agent based model deals with one of the most controversial and neglected issues of the *General Theory*, namely, agents' bounded rationality in the form of limited information processing. The economy is designed such that all economic decisions are mediated by the Market Sentiment, that is, they are taken not through optimization processes but through heuristics based on personal feelings and common sense. The three pillars of the General Theory are modelled in light of this assumption: the Marginal Efficiency of Capital, the Marginal Propensity to Consume and the Liquidity Preference change along with the Market Sentiment and in turn impact over the economy. Simulations are conducted in order to study whether the framework is able to produce a coherent aggregate dynamics resembling the principal characteristics that Keynes highlighted.

Chapter 4 wants to analyze the implications of assuming bounded rational agents for the design of monetary policy. Indeed, the theoretical framework upon which monetary policy has been designed in the last years still results unsatisfactory in considering agents' bounded rationality. The learning literature has offered some developments with respect to traditional DSGE models, but its principle of cognitive consistency remains controversial; not only, a part from expectations formation, the learning literature assumes the rest of economic decisions to be regulated by optimization processes. My contribution goes in the direction of taking seriously into account bounded rationality in the design of a framework over which monetary policies are to be tested. Indeed, I stay with the model developed in the previous chapter, and complement it with the additional hypothesis that agents form inflation expectations basing upon Market Sentiment; therefore, I let the Market Sentiment to be in turn influenced by inflation dynamics. In this way the system envisions a mechanism for the macro regularities to feed back into the micro behaviour.

References

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Chapter 1

An insight into Agent-Based Economics

In the following I will offer a brief and general overview about agent-based economics.

In particular, in section 1, I will introduce what an agent-based model is describing its principal characteristics as a tool through which many different issues in different fields can be tackled. The second section is twofold: first I present the principal features and the main drawbacks that have characterized macroeconomics in the last 40 years, and second I will show how it appears natural to use ABM to overcome these inconsistencies.

Finally, in the last section, the validity of the complexity approach in using agent-based techniques is reinforced by looking back to Classical economics: it will result how the seed of it was already present in the pioneer works of the British School, and in particular in Keynes' and Marshall's way of thinking about economics.

1. What are Agent Based Models?

Let me introduce the topic presenting the definition of agent-based economics offered by Tesfatsion (2006):

> "Agent Based Economics is the computational study of economic processes modelled as dynamic systems of interacting agents"

Indeed, it is worth noting that agent-based models are not an exclusively prerogative of economic theory, but of the social science in general and the natural science too.

Coming them from a social scientist or a natural one, agent-based models share some general basic characteristics.

The protagonists on stage are agents, which are nothing but pieces of software endowed with data and behavioural rules. Agents can be anything able to interact with other agents, so that we can have agents as biological entities, physical entities, individuals or groups of individuals or institutions too.

Agents are moved by a specific goal determined by the modeller, and they have *to try* to reach the goal given the data, the behavioural rules and the institutional constraints they are confronted with. Therefore neither they are guided by the modeller in their search nor they are compelled to be successful in it, that is, they are not compelled to pursue optimality.

Agents' behavioural rules are algorithms that govern the way in which they react to external stimulus as well as to interaction. In this sense, they are methods following which decisions are taken, given the particular characteristics the modeller decided to give the agent.

Accordingly, whatever agents' identification the modeller chooses, the essential feature to have an agent-based model is the fully specification of actors on stage: agents are able to interact only if they are fully specified, that is, only if they are endowed with all the rules and initial resources they need.

This is not as assuming perfectly rational, or fully informed, agents, being them individuals or biological entities: it just means that agents should know how to react to stimuli. They are not compelled to be rational, or to choose the best reaction to the stimulus, but rather to choose *a reaction* and not to remain deadpan. Or, the agent can rests deadpan, only if his behavioural rule tells him that to a particular stimulus he has to react by doing nothing.

Therefore, the ultimate goal of specifying behavioural rules is to let agents interact independently on the modeller's influence.

Having fully specified and interacting agents gives rise to the most important characteristic of agent-based models, i.e., they are "*dynamically complete:* the modelled system must be able to develop over time solely on the basis of agent interactions, without further intervention from the modeller". (Tesfatsion, 2006)

The previous features can be summarized in the *bottom-up approach*, that translates into modelling entities from the bottom (behavioural rules) , making them interact and analyzing the aggregate properties that arise.

This aggregate properties share the characteristic of being *self emerging*, that is, the aggregate behaviour cannot be inferred from the conduct of the particular entity: aggregate emergent regularities finally influence the individual's decisions through a feed-back mechanism, resulting in a "downward causation" (Gallegati, Richiardi 2008).

It is worth noting that even if I defined agents as pieces of software, agent-based models do not need to be computational. One of the first and most famous agent-based model ever designed, Schelling's Segregation, was born as a pencil and paper model, and just subsequently was translated into a computer code.

2. Why Agent Based Models and not DSGE for a modern macroeconomics?

The previous section has contributed to outline the essential components of agent-based models. Even it has be remarked that they are not a prerogative of economics, their use in the profession can help in assessing some on the Neo Classical economics most controversial aspects.

Indeed, the latter are briefly documented in the following.

- The economy is organized on the basis of decentralized markets populated by a fixed number of price-taking firms and a fixed number of price-takers consumers. There exists a coordinating price mechanism, the so called auctioneer, which determines the vector of prices so that all markets instantaneously clear. The auctioneer offers different price vectors until he finds the one for which buyers' and sellers' plans are consistent and markets clear. All this happens in a meta time, that is, there is no timing in the *tatonnement* process.
  All agents interactions are passively regulated by the price mechanism, and the possibility for strategic behaviour is not contemplated.
- Agents are globally rational, that is, they are able to rationally deal with the complexity of the economy: they can instantaneously process all the information they receive so that the aggregate equilibrium reflects all their intentions and desires. They are endowed with perfect foresight about future states of the world, and they always hold correct future variables' expectations. Given their rationality, the decision making process translates into solving optimization problems, being them intertemporal or not, in which the only guideline is self-interest, and in which the dependence of one's own choice on others' behaviour does not play any role.
  It is assumed the existence of a Representative Agent (Representative Consumer or Representative Firm) who incorporate all the relevant characteristics of the population. Indeed, aggregate behaviour is then derived as the simple summation of the Representative Agent allocations.
- The equilibrium consists in a vector of fully flexible prices and a list of individual plans such that at those prices, all the individual plans are consistent, and therefore all

markets clear. Moreover, the same is true in an intertemporal fashion, that is, the price vector is such that, given the existence of Arrow-Debreu securities and agents' perfect foresight, all future individual plans are mutually consistent; this equilibrium is unique and stable, unaffected by dynamic adjustments. Moreover, all equilibrium are Pareto efficient in that they maximize a well defined social welfare function.

The framework constituted the core of all the macroeconomics done over the past 40 years. It has gone under various extensions and tentative revisions, nonetheless the really grounding hypothesis have not been questioned.

Although problematic in some sense, as we will see, this conceptualization is mathematically simple enough to be easily handled and to give easily understanding policy implications.

However, nowadays it appears to many economists that representing the economy in such a way is simplistic rather than simple, and it is at odds with real economies, that is to say, the principal criticisms against the traditional approach concerns "the intuitive foundations of the abstractions being made" (Colander, 1996).

What are in details the major objections against the traditional framework?

One of the most important concerns regards the role of the Auctioneer. Following the *tatonnement* process it happens that, quite unrealistically, the configuration of the equilibrium price vector comes before any kind of transaction, exchange or trade: there is no reason in the economy to have exchanges, since all the relevant intermediations are done by the "Benevolent Dictator". For the same reason, there is no means of considering the timing of these transactions because they are all regulated at the same time by the Auctioneer[1].

The models that incorporate the Auctioneer are not able to develop over time solely upon agents' interactions because there is no interaction at all. The framework performs well as long as the Benevolent Dictator moves the pieces, but in case he disappeared, the economy would collapse because there would not be any vector of price regulating the markets.

The absence of interaction is therefore a consequence of the Representative Agent hypothesis: if we assume the existence of a super natural agent who encompass all the relevant characteristics of the population, then it is simply impossible to have interaction. Truly, heterogeneity is the normality in real world, and it is unrealistic thinking of resuming all the characteristic features of a society into a single agent.

The origin for this hypothesis come from Reductionism, for which a complex system is nothing but the sum of its part, and an account of it can be reduced to accounts of the individual constituents. Upon this view, the Representative Agent assumption took place and flourished. In-

[1] See Mehrling (2006)

deed, the hypothesis gives the opportunity to extremely simplify the analysis, since most of the aggregation problems of choices of different individuals can be overcome. “Macroeconomists (and many applied microeconomists and econometricians) routinely assume the existence of one [agent], seeing it as a necessary (though acceptable) evil required for the sake of tractability.[…] Representative consumer models are typically employed when one wants to ignore the complications caused by aggregation”(Lewbel, 1989).

As Kirman (1992) pointed out, there are several inconsistencies about the RA assumption. First, referring to the works by Jerison (1984, 1997), it can be shown that individual maximizing choices are not necessarily consistent with the maximizing choice of a RA endowed with the simple sum of individuals initial budget constraints and similar preferences.

Second, the RA hypothesis is not suitable for the analysis of distributional problems. It is plausible that changes in the income policy will affect differently the components of the society; on the contrary, in the RA world, it is assumed that income changes affect all individuals in the same way, so that the analysis boils down to the static comparison of the RA’s choice before and after the policy implementation, evaluating the policy in terms of the best option for the RA. Then, using such models to drawn policy implications may lead to misleading conclusions.

Finally, there are also some problems concerning the empirical validation of the models using the RA assumption since what the researcher is testing is a double hypothesis. On one side he is testing one particular economic assumption, but on the other side, he is also implicitly testing the hypothesis that the aggregate dynamics analyzed can be summarized as the result of the behaviour of one single Representative Agent. This should explain why in some cases RA models are not able to replicate or even come to reject some stylized facts.

All these remarks point to the fact that “the representative consumer [agent] is a purely mathematical result and need not have economic content” (Lewbel, 1989), so that as Kirman asserted “the representative agent approach is fatally flawed because it attempts to impose order on the economy through the concept of an omniscient individual.” (Kirman, 1992)

The Representative Agent is a super-rational individual who has access to all the information he needs to make his decision, and in this way he is able to perfectly foresight every possible future state of the world. This assumption is extremely important for traditional models to exist. Nonetheless, even considering the literature about asymmetric information, it appears clear that the models are inconsistent if agents are not fully rational, since they solve the problem of arising uncertainty due to limited information by assuming agents to be able to calculate exactly the probability of occurrence of every possible alternative.

Indeed, the fully rationality assumption appears inconsistent with real world economic functioning. As Leijonhufvud (1996) asserted, traditional economics describes “the behaviour of incredibly smart people in unbelievably simple situation", rather far away from the complexity of modern economies.

Along this line of reasoning, many psychologists and experimental economists have presented evidence about the inconsistencies of the rationality axioms that guide individuals' decision making. In particular, most of the developments came from the criticism about expected utility theory, for which agents, when facing uncertainty, make their decision considering each alternative's utility and their probability.

Nevertheless, various paradoxes have been offered that can refute the theory, such as the famous Allais's paradox. If you ask people to make a choice in two different experiments each of which consisting in the choice over two predetermined gambles[2], most people will first choose a particular option, say 1A, and then a different option, say 2B, but this is inconsistent with the tenets of expected utility theory, since the theory predicts people should be indifferent between the two situations because they give the same expected utility. This paradox together with other examples[3] and lot of experimental evidence, starting with the pioneering work by Kahneman and Tversky (1979, 1981), demonstrate that people do make choices under uncertainty not relying on exact calculations but rather on heuristics and personal rules of thumb.

According to Epstein (2006), we can distinguish two components of bounded rationality, namely, bounded information and bounded computing power. Nevertheless, since the calculations involved in the Allais' gambles are not that difficult, these paradoxes show that we do not need to confront people with very difficult calculations to have them behaving not in a fully rationality fashion.

This is not as saying that people are irrational, but simply that they act following a different type of rationality, that is, there is room to dismiss the "homo economicus" in favour of the "algorithmic man" (Leijonhufvud, 1996).

The "algorithmic man" idea has been originally brought to life by Herbert Simon (1955, 1978) who firstly introduced the notion of "procedural rationality" as opposed to "global rationality" with which the RA is endowed. He asserted that we can define the behaviour of an agent as *rational* when it is the result of a correct reasoning. When confronted with new situations agents collect all the possible information at which they have access and analyze it in order to find a reasonable guideline that could lead them to the final solution. In such a framework, it is natural to have an algorithmic representation of both the decision rule and the behaviour of the agents.

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[2] Let imagine in the first experiment people have to choose between gamble 1A "Win 1 million with 100% probability" and gamble 1B "Win 1 million with 89% probability, Win nothing with 1% probability, Win 5 million with 10% probability"; in the second experiment they have to choose between gamble 2A "Win nothing with 89% probability, Win 1 million with 11% probability" and gamble 2B "Win nothing with 90% probability, Win 5 million with 10% probability".

[3] See for example the Saint Petersburg Paradox or the Ellsberg Paradox

Moreover, it appears natural to describe individuals as inductive agents rather than deductive as all RAs are. If they had to be deductive units, agents should have been supplied with all the necessary information needed to deduct the optimal course of action. Instead, if we admit economic agents to be "simple people [that] cope with incredibly complex situations", we have to "build" them as inductive units, that cope with the system making inference on the basis of bounded rationality and limited information (Leijonhufvud, 1996).

This view is at odds with the previously presented tenets: the focus here is on the *way* in which agents make their decision, and not on the final equilibrium solution.

Recalling Simon, it can be that the final solution would not be globally optimal, but only *individually* optimal, since it satisfies the agent rather than maximizes his utility. This is counterintuitive for the RA, but it is not for real people who have to take decisions in extremely uncertain environments and who are most of the time prevented from the access to relevant information. In the real world as a complex system, procedural rationality *is* a rational way of thinking because it avoids immobility, so that agents are at least able to act in a way that satisfies their needs.

Finally, advocates of traditional economics could argue that their models have been successful for long time because they do are able to replicate economic stylized facts and to give answers to political economic questions. Indeed, it can be recognized that "standard economic theory is useful in a myriad of ways, despite its unrealistic assumptions about people cognitive capabilities, *because* the interaction of ordinary people in markets very often does produce the incredibly smart result" (Leijonhfvud, 1996).

Nonetheless, some problems arise for the analysis when real economic systems do not display the "incredibly smart result" and the models fail in explaining those episodes.

Episodes of hyperinflation cannot find an explanation in the traditional models since they are the result, among other factors, of having bounded rational and limited informed agents coping with a growing complex environment, feeding in turn the complexity with their interaction (Leijonhfvud, 1997).

Departing from the inconsistencies just discussed, recent years have witnessed the development of the complexity approach[4], which main tenet is that "An economy is an evolving, complex, adaptive dynamic system" (Leijonhufvud, 2006).

Treating the economy as a complex adaptive system means assuming that the system is composed by heterogeneous interacting units, which exhibit emergent properties at the aggregate

[4] To have an overview of the way in which the complexity approach challenges Neoclassical economics, see Gaffeo et al. (2007).

level; a system which includes “reactive units, i.e., units capable of exhibiting systematically different attributes in reaction to changed environmental conditions” (Tesfatsion, 2006).

In particular, the greatest departure from the traditional economics lays in admitting a role for emerging properties. If we remove the reductionist idea that the dynamics of the whole can be described as the dynamics of the individual element, then we have to confront ourselves with the question of where the macro dynamic comes from, if it reflects the micro behaviour functional form and if not, how this macro dynamics can be derived (Gallegati, Richiardi, 2008).

Indeed, emergence comes into play only if we discard the idea of the RA and the absence of interaction. The very notion of emergence implies that “The whole is more than the sum of its parts” (Aristotele) because it is assumed that at the very bottom level there is some heterogeneity, being it in agents’ characteristics or in the parameters’ distribution, and that this heterogeneity makes agents interact among them and with the environment they live in. The final result of this interaction is the macro dynamics.

Taking emergence seriously means to revolutionize the way in which economic models should be constructed. Since there is no more room for models that deductively prove the existence of an equilibrium price vector upon a set of very strong assumptions, we should look for economic models capable of inductively *constructing* an equilibrium from the micro behaviour of agents (Axtell, 2000). What is needed is a bottom-up approach through which the model’s building starts from the lowest level and then “climbs” the macro dynamic mountain.

Recalling the initial presentation about what Agent-Based models are, now it appears natural to use such devices in assessing the issues raised by the complexity approach.

Agent-based modelling can be considered as the necessary tools through which developing theories of complex worlds since they do not discard complexity in favour of simplification, but rather they seek for the abstractions to maintain a close association to real world agents. In this respect lays the major departing point from previous models. Traditional models can be considered “abstraction-based” (Miller, Page, 2008), that is, they rely on strong assumptions about the agents that populate them; on the contrary, agent-based models entail the idea that these assumptions are no longer necessary, since the modelling begins with the observation of real agents’ behaviour and terminates into the translation of such behaviour into computational codes.

Following, “The ACE methodology is a culture dish to the study of economic systems viewed as complex adaptive systems [...] . As in a culture dish laboratory experiment the ACE modeller starts by computationally constructing an economic world comprising multiple interacting agents. The modeller then steps back to observe the development of the world over time” (Tesfatsion, 2006). Then, the regularities observed are emergent since they are the result of having agents interacting, and are not derived from the imposition of some driving forces such as equilibrium seeking condition.

This corresponds to apply the bottom-up approach to economics, that is, describe the behaviour of each single agent and then let agents interact together, in contrast with the Neoclassical top down approach consisting in imposing high levels rules and discussing the implications of these impositions.

ABMs enable economists to construct models in which economic agents interact among them and with the environment. They are purposive in the sense that they are goal directed but they do not necessarily are fully rational. They can be heterogeneous in their personal characteristics or in their initial endowments, or it can also be that endowments' heterogeneity comes in as an emergent property due to heterogeneity in agents' behavioural rules.

Moreover, ABMs permit the understanding of the feedback mechanism through which the macrostructure influences the micro behaviour of agents: they are essentially microeconomic models, that looks for macro regularities and enables the macro level to step in into the determination of micro behaviours.

The economic agents that populate ABMs are "algorithmic men": they are assumed to act in a complex environment and they come to some decision analyzing the limited information they have access to and following very simple behavioural rules, most of the time consisting in rules of thumb or heuristics.

Indeed, ABMs agents do not necessarily need to be bounded rational because it can be possible to have emergent regularities just by letting different individuals interact.

ACE is still a developing methodology, nonetheless some of its advantages are well recognized.

The possibility to represent agents as interactive goal-oriented entities is considered of great importance since it enables the study of the behaviour of an economic system in the presence of cooperation or competition among its components, or its behaviour under specific hypothesis about the market structure or the institutional arrangement that would be impossible in a traditional framework. Along this line, another great advantage is the possibility to deeply model institutions and social structure: in this regard, ABMs help "evaluating whether designs proposed for economic policies, institutions, and processes will result in socially desirable system performance over time" (Tesfatsion, 2006).

Therefore, having agents interacting means that the designer does not have to intervene anymore in the model, since the interaction is the unique responsible for the autonomous development of it, once initial conditions have been specified.

The independency of ABMs is principally due to the fact that agents can be endowed with a greater degree of autonomy than traditional consumers/firms. “An autonomous agent is a system situated within and part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future” (Franklin, 1996): according to this definition both traditional consumers and ABM agents are autonomous, but the latter, equipped with behavioural rules as well as initial conditions, have the capability of acting without any further external intervention, while the former do need the Auctioneer to take over their business.

Therefore, computational agents are not only autonomous referring to traditional ones but also referring to all the other agents in the same model, since each decision process is private and agents are let alone in taking their decisions.

While computational agents are far from being considered human replications, it is true that this new methodology “[...] allows a flexible design of how individual entities behave and interact, since the results are computed and need not be solved analytically ” (Leombruni,Richiardi, 2005) so that it is possible to accurately design cognitive processes, learning rules and social behaviours.

Then, using ABM is quite easy to study the evolution of an economic system in which agents are interacting upon a well characterized network, or in a well defined physical space, as well with the possibility of having agents belonging to different spaces interacting, that is, there is the possibility of constructing models with more than two real countries involved in the economic activity.

ACE modelling permits the focus on the path followed by the economic system rather than its equilibrium configuration, so that it is no longer necessary to limit the economic analysis to models for which an equilibrium can be derived. On the contrary, through ABMs it is possible to construct and analyze models that do not possess analitically tractable equilibrium: “since the model is “solved” merely by executing it, there results an entire dynamical history of the process under study. That is, one need not focus exclusively on the equilibria, should they exist, for the dynamics are an inescapable part of running the agent model ” (Axtell, 2000).

From a technical point of view, there is no complete agreement about how simple is to build an ABM model in computational terms. To write down the code of such a model call for some knowledge about the programming language, and sometimes the complexity of the behavioural rules is not so easily translated into the lines of the code. Nonetheless, compared to other computational models, the writing of an ABM is not so complicated since what one really needs is to write agents’ behavioural methods and then he is done with most of the work. Agents will be different but they will share the same behavioural rule, so that it is necessary to write it down just once: this results in a code composed by not so many lines and in a model in which there could be a multitude of agents.

Two principal critiques are presented against ABMs: first, it is claimed that simulations' results are difficult to interpret since a clear and explicit structural form for the agent-based model lacks. That is, what is claimed is that, given the difficulty in traducing behavioural rules into a mathematical model, it is quite impossible to recover the input-output implicit transformation function and clearly identifies the sources of the emergent regularities.

Indeed, as Leombruni and Richiardi (2005) show, simulations models can be described by a well defined set of mathematical functions, even if the resulting structural functions describing the macro regularities are quite impossible to manipulate algebraically.

Therefore, it is possible to analyze the behaviour of the structural function by simulating the set of equations composing the model for different parameters and initial conditions. Upon the artificial data set created, we can end up specifying a particular reduced form for the model to be fitted on the artificial data for which we can estimate parameters. Having recovered the meta model, it is then easily possible to interpret simulated data.

Another concern is directly related to this interpreting procedure, namely that simulations results are not representative of all the outcomes the model can produce, that is, they are very sensitive to model specification since as we move from the initial set of parameters, results can change dramatically leading sometimes to the appearance of singularities. Indeed, the same concern applies to the true model of the economy: being itself unknown, it is possible that at a point in time the model generates unexpected outcome, so that stylized facts change. Moreover, we should not worry too much about extreme results generated by some "evil" combinations of parameters since these combinations in the real world remains extremely rare (Leombruni, Richiardi 2005).

Once the artificial dataset is created, the simulated model can be calibrated, that is, it is possible to keep comparing the simulated outcome with the real data changing the structural parameters until the distance between simulated data and real ones is minimized. This is the same as the structural estimation offered by econometric literature.

Second, ABM opponents claim that the richer specifications of agent based models often leads to underidentification. Indeed, simulations models are used to represent complex economies, so that it would be meaningless to build an agent based model posing much restrictions. In this regard, the problem of underidentification in ABMs is often unavoidable and it could be that "analytical models that claim to be immune are sometimes only poor models" (Richiardi, 2003).

3. The agent–based nature of this dissertation

In the previous paragraphs I have offered some kind of “canonical” definition of what agent-based models are.

Nonetheless, there is no clear consensus about what agent-based models should be and in which occasion the agent-based label should be preferred to other definitions.

Within this discussion, I endorse the view of Joshua Epstein when defining agent-based modelling as

> “a new computational technique for modeling social systems in which we populate landscapes with artificial people. We basically build artificial societies where people differ from one another…they can be connected in networks, but they’re very diverse. They can have partial or even bad information (what we call bounded rationality); they use simple local rules in deciding how to behave. They move around and interact with neighbors, and the basic idea is that if we’re interested in some social phenomenon - like an epidemic or distribution of wealth or a settlement pattern - we try to grow it in an artificial society composed of individual agents. They can be young ones, old ones, sick ones, healthy ones, rich ones, poor ones. We can make this society look as realistic as we like and try to generate from the bottom up the large-scale, macroscopic phenomena that we care about.” (Epstein, 2008)

Not entirely artificial societies developing within a well defined landscape, the models developed in the following chapters try to capture the inner characteristic of artificial economies. In particular, great attention is devoted to the description of agents and their micro behavioural rules.

As it will be noted, such rules are mostly expressed in terms of differential equations. Though, they still can be labelled agent-based for two main reasons. First, I exerted much effort in behaviourally characterizing the agents and the rules that they follow, rather than assuming perfectly rational individuals. Second, the aim of my models is to explain and describe the emergence of macro regularities rather than only explaining them. The latter could be obtained by solving the equations, finding the equilibrium and asserting that a particular dynamics is the result of that particular equation. Nonetheless, what is going to be lost in this procedure is the descriptive power of the model. Then, the model and its description is interesting in itself, since it describes how and why solving the model we obtain a given dynamics (Epstein, 2006).

The agent-based characteristic does not reside in the mathematical intractability of the model, but rather on the focus of the analysis, being it in the description of how particular agents’ micro behavioural rules give rise to emergent properties.

Indeed, the spirit that characterizes the agent-based approach is the experimental attitude. That is, in Epstein words:

> “Consider biology. No one would fault a “theoremless” laboratory biologist for claiming to understand population dynamics in beetles when he reports a regularity observed over a large number of experiments. But when agent-based model-

> lers show such results there's a demand for equations and proofs. These would be valuable, and we should endeavour to produce them. Meanwhile, one can do perfectly legitimate "laboratory" science with computers, sweeping the parameters space of one's model, and conducting extensive sensitivity analysis, and claiming substantial understanding of the relationships between model inputs and outputs, just as in any other empirical science for which general laws are not yet in hand " (Epstein, 2006, pg.28)

The aim of the following chapters is to conduct "laboratory science", in order to describe and explain how the presence of heterogeneity, bounded rationality and interaction in rather simple macro models give rises to emergent properties.

Let's now going deeper into the agent-based nature of the essays forming this dissertation.

Chapter 2 could be appropriately defined as an equation based model. It takes over from some robust theoretical presumptions concerning the economics of information, and the implications of asymmetric information in the credit market.

Though, I label the model agent-based because of two distinctive features. First of all, agents/firms that populate my economy are heterogeneous, and even if they do not directly interact, they follow simple behavioural rules determined by their inner characteristics. Second, the final objective of the analysis is not to find an equilibrium solution, but better to describe the static and dynamic properties of the two modelled treatments. In this sense, chapter 2 constitutes a laboratory exercise through which I want to assess the distributional properties of the series under study, rather than their equilibrium values.

Chapter 3 and chapter 4 are constructed upon the classical IS-LM building, so it could be argue that these chapters too are equation based and not agent-based. Nonetheless, they are agent-based because the micro engine that feeds the macro equations is not derive through stringent economic hypothesis – such as the Representative Agent one – but rather inspired by real agents behaviour. In this fashion, agents who populate the two economies are heterogeneous and bounded rational, and they cope with their bounded rationality through the interaction within the environment they live in.

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Chapter 2

Firm-bank relationship and the macroeconomy: some computational experiments

1. Introduction

An important development in economic theory[5], has been to demonstrate that the presence of asymmetric information influences the access to credit and its costs, since the information set that pertains to the borrower is different from the lender's one.

From a macroeconomic point of view, by the end of the 80s, these insights have been introduced in macroeconomic models - the so called Financial Fragility literature – that assume the presence of asymmetric information to be the responsible for spreading economic fluctuations.

The very first motivation for this chapter comes from two considerations about the previous general frameworks.

On one hand, the analysis of microeconomic models based on the assumption of Asymmetric Information is puzzling for what concerns how information is treated. Indeed, these models give extreme importance to the way in which information is distributed among agents – and the very basic problem lies in having information non homogenously distributed between principal and agent – but they pay little attention to the fundamental question about the inner heterogeneity of information. Not only is information heterogeneous between two types of individuals, but also across all individuals.

Departing from this point of view means assuming that it is no longer possible to use the Representative Agents hypothesis, as most of the traditional models of AI assume, but instead to give heterogeneity of agents an important role.

[5] The first reference that always come to mind is Stiglitz, Weiss (1981)

On the other hand, macroeconomic analysis regarding asymmetric information and economic fluctuations concentrates attention on general contractual arrangements, without taking into considerations the possible alternatives through which the problem can be tackled. This to say that the macro impact of asymmetric information is neither differentiated nor compared through different contractual arrangements.

Upon these considerations, the motivation for this chapter resides in assessing the macro behaviour of a credit system in which agents are heterogeneous and in which credit relations are regulated by different micro contractual rules. My research question then is evaluating the macro performance of two contractual arrangements, under the hypothesis of agents' heterogeneity.

Though, to keep the analysis as simple as possible, I do not adopt a General Equilibrium perspective but rather a Partial Equilibrium one, for, the focus will be on the dynamics of firms' distinctive magnitudes (output, wealth and the bankruptcy rate), disregarding the banking side.

Therefore, I conduct the analysis using agent-based modelling techniques. Indeed, as highlighted in the first chapter, ABM is a methodological instrument flexible enough to account for heterogeneity and interactions. In this chapter, heterogeneity acquires particular importance, since the different individuals characteristics determine how the banking relationship will develop. As for interactions, I assume them to be determined by the rule adopted by the bank to cope with unknown firms: though rather mechanical, this way of regulate banking relationships differentiates my model from previous ones, in which the bank was not allowed to discriminate entrepreneurs ex post.

The chapter is divided into six sections.

Sections 2 and 3 review the general framework of the Financial Fragility approach, referring to two particular literature contributions, and present the contractual arrangement I have decided to take into consideration, namely Relationship Banking. Moreover, in these initial sections, the motivations and the aim of the chapter will be made explicit.

The fourth section describes the agent-based model of the economy, and section 5 present the results of the simulation exercise. Section 6 concludes.

2. Finance and the economy

In spite of Milton Friedman's theory of money and Modigliani-Miller theorem, the idea that the financial system plays a crucial role in determining the macroeconomic dynamics of an economic system has found many estimators among which Fisher (1933) and Keynes (1937).

In the 50s, the work by Gurley and Shaw (1955) revitalized Fisher's and Keynes' emphasis on financial variables by shedding light on the relationship between these variables and economic development.

Since then, many authors have shown a general interest about the role of financial markets in the determination of aggregate real variables, and in particular in the role of financial intermediation in influencing economic fluctuations. Eventually, this growing interest has given rise to a complete strand of literature, the so called "credit view" whose main idea is that "the way in which agents finance their activities, have access to financial markets and choose contractual arrangements is mostly relevant to understand the business cycle" (Reichlin, 2001).

Most of the credit view literature has focused on the role of bank credit to analyze the effects of monetary policies[6], but not only. A growing debate about the analysis of the so called financial propagators has involved many scholars. The resulting financial fragility models attempt to develop a theory about the interaction between financial markets and the business cycle largely independent of monetary policy behaviour. The main idea behind these models is that imperfections in the financial markets aggravate the consequences and the persistence of shocks originated in the real economy.

For instance, Bernanke and Gertler (1989) analyzed the role of firm's balance sheet conditions in determining the business cycle.

Following their view, financial markets imperfections entail some costs. Managers have private information about their investment technology returns, so that lenders should undertake costly state verification to observe those returns. The presence of the asymmetry makes external funding more expensive then internal funding for firms.

In such a context net worth plays an important role: the greater the level of net worth of the potential borrower, the less the expected agency costs. Then, since net worth is likely to be procyclical, there will be a decline in agency costs in periods of economic booms and a rise in recessions.

Bernanke and Gertler show that the presence of this inverse relation under the assumption of asymmetric information is sufficient to introduce persistent fluctuations in investment and output into an economy that would present constant investment and serially independent fluctuations when agency costs are not considered.

Upon the same premises, Kiyotaki and Moore (1997) focus their attention on how the presence of collateralizable assets can influence aggregate output and finally determine the business cycle. They analyze an economy in which credit constraints arise because lenders cannot force borrowers to repay their debt unless they are secured, so that real assets do not serve just as productive factors but also as collateral for loans. Then, access to the credit market is influenced by the prices of the collateralized assets; in turn, it results that these prices are affected by the size of credit limits.

[6] See e.g. Bernanke, Gertler (1995), King (1986)

So, the dynamic interaction between credit limits and asset prices results in a transmission mechanism by which the effects of shocks persist, amplify and spread out.

Both the previous works share the common idea that macroeconomic volatility is a function of agency costs associated to the implementation of a particular contractual arrangement in the presence of imperfect information.

Nevertheless, even admitting a role for asymmetric information, the models belonging to the credit view literature, strongly rely on the traditional assumptions of the Representative Agent and the absence of interaction between the agents.

Hence, starting from the same idea about the sources of economic volatility, my aim is to go further into the understanding of the relationship between the credit market and the macroeconomic dynamics by constructing an agent-based model able to take into account heterogeneity of agents and some particular contractual agreements through which they can regulate credit relationships.

In particular, my main concern is to analyze firms' performance under the hypothesis that bank-firm interactions are driven by the mutual capacity of creating credible incentives/threats to keep the relationship going on, rather than by the presence of net worth or collateralizable assets.

The credit market I have in mind is still characterized by asymmetric information, but entails the possibility for the banks to discriminate entrepreneurs ex-post upon their being good long term clients or not, that is, their financing method is inspired to relationship banking. Then, I want to study what happens at the aggregate level when banks has to deal with many different clients in a situation of asymmetric information, and decide to cope with this problem relying on relationship banking rather than on a pure asymmetric information arrangement.

The economy is populated by a large number of heterogeneous entrepreneurs that are differentiated by their productive capacity and their opportunistic attitude, allowing them to be either opportunistic or honest: the former will use the amount of credit obtained to private purposes and will not give back the loan to the bank, while the latter will always meet their obligations in case they obtain positive end period profits.

As usual, the bank is not able to discriminate ex-ante between the two types of entrepreneurs the first time it meets them, but is able to recognize honest entrepreneurs as long as the relationship continues.

Then, the bank is willing to offer these entrepreneurs better financing conditions: in this way entrepreneurs are given the incentive to stay with the same bank for long time, since any rate they will be offered from "outside" banks will be greater than the one they are receiving. For those entrepreneurs, the relationship with the bank will break up only in case they achieve negative profits and exit the market.

The reason for modelling the credit market following the relationship banking rationale comes from the recognition of the increasing interest in both the empirical and theoretical literature regarding such financing choice.

Nonetheless, the models that theoretically analyze RB rely on the RA assumption and limit their scope to the understanding of the micro mechanisms that govern the framework instead of complementing the analysis studying the macroeconomic effects of it. In particular, the efforts in studying the macroeconomic effect of RB can be mainly reported to the credit view literature – the consequences of monetary policy on banks' lending activity and consequently on the financial structure of the firms – or can be confined into works analyzing the impact of bank defaults on the economy and in particular on the stability of firms involved in a Relationship Banking with those banks.

3. An overview about Relationship Banking

Relationship Banking can be defined as "an implicit long term contract between a bank and its debtor" (Elsas, 2005): the uniqueness of such an agreement comes from some critical dimensions.

The relationship lending contract implies *repeated interactions* between agents, through which the bank is able to conduct investment monitoring.

Therefore, investment monitoring translate into the *achievement of customer-specific information*, which is not publicly available.

Long term interactions combined with private information in turn implies the possibility of benefit from intertemporal informational reusability (Boot 2000). Indeed, Relationship Banking can be interpreted as a particular agreement in which both parties' knowledge comes from interaction, and such a knowledge cannot be purchased or achieved in any different external way.

For, all these elements result in a close and tight relationship, peculiar for its *implicitness*: the enforcement of loan terms is endogenous rather than exogenous , that is, the threat of termination and the consequent benefits' loss is sufficient to make both parties keeping their promises and making the relationship long lasting, not involving any external form of regulation.

As pointed out by Rajan (1992) these kind of relationships "may evolve in situations where explicit contracts are inadequate, but a long term interaction between two parties is mutually beneficial"; moreover, the agreement on the mutual benefits arising make firms and banks willing to make some sacrifices to obtain future benefits (Ongena, Smith 2000).

In the credit market, Relationship Banking is important since it facilitates the information exchange between banks and borrowers, and it consequently eases the resolution of asymmetric information problems.

Having superior information that others financiers cannot have, the bank is able to easily face each period adverse selection difficulties, and mitigate moral hazard problem through continuous monitoring.

Further, thanks to banks' informational competitive advantage, firms involved in relationship lending have facilitated access to credit, since the close interaction implies reputation building (Petersen, Rajan (1995); Berger, Udell (1995)): "since repeated lending from a bank provides credible certification of payment ability, borrowers may establish a relationship in order to gain a reputation for making timely loan payments" (Ongena, Smith 2000).

The amount of private information accumulated over time enables flexible contractual forms and facilitates long term contracting; in turn, contractual flexibility results into loan rate smoothing: it can be the case that either the firm accepts higher initial loan rates versus the promise of a lower permanent future interest rates, or the bank accepts to offer lower initial rates to attract new clients with the hope of making them grow over time.

In this line, it has been demonstrated (Petersen and Rajan (1995); Berger and Udell (1995); Bharat et al. (2004)) that the longer the relationship a firm has with a bank, the easier for it to get funds and the lower the interest rate charged.

As for the moral hazard problems, Rajan (1992) argues that private information accumulation helps to establish commitment since informed banks are able to exert some influence on firm's behaviour in that the threat of breaking off funding leads managers to accept positive net present value projects.

All these micro benefits taken together drive the economy toward an equilibrium characterized by lower aggregate financial costs and reduced credit rationing (Sharpe, 1990).

Though, Relationship Banking can also be a costly activity for borrowers since two different problems can rise.

Sharpe (1990) argues that banks' informational advantage make them behaving like a monopolist, holding up its customer from finding cheaper finance elsewhere: high quality firms that give up their current relationship and try to raise credit from outside uninformed banks, are bunched with low quality firms and are offered worse interest rates. In this way, informed banks are able to charge high quality firms with above cost interest rates as long as these rates are lower than the worse outside ones, extracting monopoly rents.

Actually, the empirical evidence seems to find no support for such claim: recalling Petersen and Rajan (1995), Berger and Udell (1995), Bharat et al. (2004) works, they find that longer financing relationship lower the cost of borrowing, contradicting the hold-up hypothesis of higher loan rates. On the contrary, in case of very concentrated markets, Elsas (2005) notices that Relationship Banking grows along with concentration, supporting the view that monopoly power fosters Relationship Banking.

The hold-up problem can be mitigated by publicly signalling firm's quality (Sharpe 1990), or considering reputation building, that is, repeated borrowing from RB bank increases firm's repayment reputation, allowing for easier access to other sources of finance (Diamond 1991).

Another different cost that Relationship Banking poses is the soft budget constraint, that is, the incapability of banks to "credibly deny additional credit when problem arise" (Boot, 2000): it can be the case that firms during financial distress times prefer to ask finance to their relationship bank rather than an outside bank, because they know that the inside bank will be more willing to finance them in order not to lose previous loans. The problem is that borrowers who realize to have this ex post renegotiation opportunity, would probably have corrupted incentives ex ante, not exerting too much effort to prevent bad outcomes (Boot 2000).

In the theoretical framework, I will design the Relationship Banking contract taking into consideration all these features, and in particular the fact that long term clients have a privileged access to credit with a lower interest rate.

4. The Model

The theoretical model deals with two different treatments: the first one, the Pure Asymmetric Information Treatment, is characterized by the impossibility for banks to ex-post discriminate entrepreneurs, while in the second one, the Relationship Banking Treatment, a contractual arrangement based on long term relationships is designed.

Before presenting the treatments, I proceed with the description of the basic framework within which they have been developed.

4.1 Basic framework: the Symmetric Information case

4.1.1. Investment opportunities

The economy is populated by a large number of entrepreneurs (indexed by *i*). Each entrepreneur has an initial wealth endowment A_{it} which he can decide either to leave with a bank earning the-risk free interest rate $\bar{r}_t$ or to invest in a productive project.

The gross return I_{it} to a productive investment of value h_{it} is formalized as a random variable characterized as

(1) $$I_{it} = \begin{cases} (1+\rho_i)\cdot h_{it} & \textit{with probability} \quad \sigma \\ h_{it} & \textit{with probability} \quad 1-\sigma \end{cases}$$

All the entrepreneurs face the same exogenous probability of success (σ) about their investment projects. These, in turn, deliver their outlet at the end of the same discrete time unit of investment, and subsequent projects by the same investor are equivalent to independent random draws.

Upon "discovering" a project randomly, the initial problem for the entrepreneur is to decide whether to invest in the project or to leave his wealth with the bank. To compare the alternatives, the entrepreneur considers the end-value of wealth[7]. Hence, from (1), for any amount of investment h_{it}, the entrepreneur expects to end up with

(2) $$\begin{aligned} E(I_{it}) &= h_{it}(1+\rho_i)\sigma + h_{it}(1\text{-}\sigma) \\ &= h_{it}(1+\rho_i\sigma) \end{aligned}$$

If he decides for the bank rent, his final wealth will be

(3) $$R_{it} = h_{it}(1+\overline{r}_t)$$

Thus, the entrepreneur will opt for the investment only if

(4) $$E(I_{it}) \geq R_{it}$$

which obtains for

(5) $$\sigma\rho_i \geq \overline{r}_t$$

Therefore, the entrepreneur will invest in the productive project if his expected rate of return is at least equal to the risk free interest rate he would receive leaving the amount invested with the bank.

Without loss of generality, I assume that this condition holds for every project; moreover, it is convenient to parameterize the rate of return of a project in terms of the break-even rate, so that we have

(6) $$\rho_i = k_i \cdot \frac{\overline{r}_t}{\sigma}$$

with $k_i \geq 1$, *and* $k_i = 1$ for the break-even rate of return. We may think of k_i as an entrepreneurs' personal characteristic that influences the rate of return, such as his managerial ability.

[7] Since both alternatives may stretch over time, it could be possible to adopt the net present value criterion. However, in consideration of the assumption that subsequent productive projects are like independent random draws, it is more convenient to treat them on single draw basis.

Once projects are realized , at the end of each period the computational model takes stock of the following accounting variables. First, each entrepreneurs' value added is calculated as

(7) $$y_{it} = \begin{cases} \rho_i \cdot h_{it} & \textit{with probability } \sigma \\ 0 & \textit{with probability } (1-\sigma) \end{cases}$$

Then, the economy's GDP is calculated in terms of value added

(8) $$Y_t = \sum_i y_{it}$$

4.1.2. Bank-firm interactions

Given the linearity of the productive technology, it turns out that for all $k_i \geq 1$, each entrepreneur is willing to invest his whole initial wealth. The entrepreneur can overcome his wealth constraint by borrowing from a bank an amount L_{it} such that:

(9) $$h_{it} = A_{it} + L_{it}$$

To avoid free-lunch results in the bank-firm relationship, it is also convenient to assume that whereas A_{it} is employable in a recoverable resource (e.g. land in a plantation project), L_{it} is only employable in non recoverable inputs (e.g. fertilizers). In other words, in case the project fails, the entrepreneur is left just with A_{it}. Consequently, when $h_{it} > A_{it}$,

(10) $$I_{it} = \begin{cases} (1+\rho_i) \cdot h_{it} & \textit{with probability } \sigma \\ A_{it} & \textit{with probability } 1-\sigma \end{cases}$$

As for the credit market, it is populated by a large number of banks which interact competitively and operate so as to maximize their net worth given the risk free interest rate $\bar{r}_t$. Banks do not face any limitation in their financing activity, apart from their profitability constraint.

In the first place I design a setup with symmetric information, i.e. in any bank-firm relationship both parties are freely and perfectly informed about the characteristics of the project (k_i, σ), their respective actions, and the project's outcome.

<u>The bank</u>

Upon granting a loan L_{it} to the project (k_i, σ), the expected end-value for the bank is

(11) $$E(V_{it}) = (1+r_{it}) \cdot L_{it} \cdot \sigma + B_{it} \cdot (1-\sigma) - (1+\bar{r}_t) \cdot L_{it}$$

Where r_{it} is the interest rate on the loan, and B_{it} is the amount the bank is able to recover in case of default. The last term on the right represents the bank's cost to gather the loan.

The profitability condition $E(V_{it}) \geq 0$, requires

(12) $$1+r_{it} \geq \frac{1+\overline{r}_t}{\sigma} - \frac{1-\sigma}{\sigma} \cdot \frac{B_{it}}{L_{it}}$$

Hence, as is intuitive, r_{it} should be higher, the lower the probability of success σ and the ratio B_{it}/L_{it}. Therefore, the bank's credit policy towards each entrepreneur will be identified by the triple (r_{it}, B_{it}, L_{it}).

In order to determine these variables, it should first be considered that in case the project failed, it would not be possible to recover anything but the entrepreneur's wealth A_{it}. As a consequence, $B_{it} \leq A_{it}$. Since the bank cannot recover more than the value of the loan, it should also be that $B_{it} \leq L_{it}$. Now, let us define $B_{it} = \beta_i \cdot A_{it}$ and $L_{it} = \lambda_i \cdot A_{it}$, where β_i and λ_i can easily be interpreted as, respectively, the collateral ratio and the leverage ratio for the relevant firm. Then, the profitability condition results

(13) $$1+r_{it} \geq \frac{1+\overline{r}_t}{\sigma} - \frac{1-\sigma}{\sigma} \cdot \frac{\beta_i}{\lambda_i}$$

from which we obtain the interest rate the bank would be willing to charge the entrepreneur

(14) $$r_{it} \geq \frac{\overline{r}_t}{\sigma} + \frac{1-\sigma}{\sigma} \cdot \left(1 - \frac{\beta_i}{\lambda_i}\right)$$

The entrepreneur

The expected net worth of the entrepreneur after the levered investment is

(15) $$E(W_{it}) = \left[(1+\rho_i)(L_{it}+A_{it}) - L_{it}(1+r_{it})\right]\sigma + (A_{it} - B_{it})(1-\sigma)$$

Since all entrepreneurs with $k_i \geq 1$ choose to invest rather than lock their wealth in a bank, their next step is to choose between borrowing or self-financing. The latter yields $E(\overline{I}_{it}) = A_{it}(1+\rho_i)\sigma + A_{it}(1-\sigma)$. Hence, borrowing is chosen only if $E(W_{it}) \geq E(\overline{I}_{it})$, i.e.

(16) $$\mu_{it} \cdot \sigma \cdot \lambda_i - \beta_i (1-\sigma) \geq 0$$

where $\mu_{it} = \rho_i - r_{it}$ is the operating margin. As a result, for the entrepreneur to participate in the loan contract, the interest rate has to be

(17) $$r_{it} \leq \rho_i - \frac{1-\sigma}{\sigma} \cdot \frac{\beta_i}{\lambda_i}$$

namely, lower than the difference between the net rate of return and the residual expected value of personal wealth in case of default (value at risk)[8].

Firm-bank relationship

If we now compare the bank's and the entrepreneur's participation constraints, we see that both are verified for

$$(18) \qquad \frac{\bar{r}_t}{\sigma} + \frac{1-\sigma}{\sigma} \cdot \left(1 - \frac{\beta_i}{\lambda_i}\right) \leq r_{it} \leq \rho_i - \frac{1-\sigma}{\sigma} \cdot \frac{\beta_i}{\lambda_i}$$

Since $\rho_i = k_i \cdot \bar{r}_t / \sigma$, a non-empty interval for r_{it} exists for

$$(19) \qquad k_i \geq 1 + \frac{1-\sigma}{\bar{r}_t}.$$

This threshold value of k_i determines the subset of entrepreneurs that can afford to choose debt instead of self financing. Notice that this is a *sub*set because this threshold value of k_i is higher than the threshold which discriminates between investment and bank rent ($k_i \geq 1$). The difference $\frac{1-\sigma}{\bar{r}_t}$ can be interpreted as the hurdle rate imposed by bank credit.

It is also worth noting how bank lending affects total investment in the economy: given that all entrepreneurs with $k_i \geq 1$ do invest anyway, and this set is given exogenously, bank lending does not change the number of investors but the scale of individual investments of those who can borrow.

In this setup, I represent credit market competitiveness as an environment where each bank is forced to adopt a minimax strategy, and for this reason it will be willing to offer the lowest possible interest rate. The relevant expression indicates that this policy requires the ratio β_i / λ_i to be as high as possible, that is, equal to 1. In other words, to compete on interest rates, banks wish to minimize downside credit risk by maximizing collateral relative to leverage. Therefore, each bank will end up with the same (zero profit) offer ($r_t^c = \frac{\bar{r}_t}{\sigma}$, $L_{it} = B_{it} = A_{it}$) to each entrepreneur. That is to say, each entrepreneur can receive a loan equal to his own invested and collateralized wealth *vis-à-vis* the competitive interest rate r_t^c.

Finally, the computational model is closed by wealth accounting at the end of each period, to be transferred to the next. Clearly, there are four categories of entrepreneurs. A proportion σ of successful entrepreneurs, and a proportion $1-\sigma$ of unsuccessful entrepreneurs. Each, in

[8] In other words, the net rate of return should cover the bank interest rate plus the value at risk of personal wealth

turn, consists of a subgroup which was self-financed ($k_i < 1 + \frac{1-\sigma}{\bar{r}_t}$) and another which was bank-financed ($k_i \geq 1 + \frac{1-\sigma}{\bar{r}_t}$). The previous formulae yield the end-period wealth of each category.

Note than one category, the bank-financed unsuccessful, go bankrupt, that is, they end up with zero personal wealth. These are driven out of the system and replaced next period with replicants with the same characteristics, except for the initial endowment that will be reset alike for all new entrants.

The remaining categories have positive end-period wealth. These use a share $(1 - \alpha)$ of wealth in the consumption of a one-period perishable good, and save the rest as next period initial wealth. Note that one of these categories, the self-financed unsuccessful, is left with the same initial wealth; hence consumption entails less wealth to be transferred to the next period[9].

4.2 Pure Asymmetric Information treatment

The first treatment is characterized by the presence of an information asymmetry (AI) in the form of hidden action (opportunistic behaviour) on the part of the entrepreneur.

<u>*The entrepreneur*</u>

We now assume that the entrepreneur, once received the loan, can employ it so as to satisfy some personal non-productive needs (e.g. raising a villa on his ground instead of a plantation) which give him a certain benefit:

(20) $$u_{it} = \omega_i c_{it}$$

Where c_{it} is the total amount of resources he employs for the non productive purposes; ω_i is an entrepreneur's personal characteristic not observable by the bank; u_{it} represents the whole benefit the entrepreneur receives from the non productive action c_{it}[10]. This action is neither observable ex ante nor verifiable ex post, and it dissipates all employed resources.

What is of interest here is to study the conditions under which the entrepreneur will use the borrowed resources for his own sake, i.e. $c_{it} = A_{it} + L_{it}$. First, the problem is relevant only in case the entrepreneur decides to apply for a loan, committing himself to employ it in production. Hence the entrepreneur should own a productive project to be submitted to a bank which can still

[9] For simplicity I do not report here the expression of all different end-period wealth values that are embedded in the computational model.

[10] For simplicity and comparability with the investment choice u_t can be regarded as a total index of the personal benefit with non explicit consideration of its time duration and distribution.

observe its characteristics (k_i, σ) ex ante. These characteristics should also make borrowing preferable to self-financing, $E(W_{it}) \geq E(\bar{I}_{it})$.

Second, if the entrepreneur chooses c_{it} he also plans to enjoy the whole benefit u_{it} and to default with the bank with no resources being left over. Since by assumption any productive project dominates bank rent, $E(\bar{I}_{it}) \geq R_{it}$, the incentive for choosing c_{it} arises if

(21) $$u_{it} \geq E(W_{it}) \geq E(\bar{I}_{it})$$

We know that the second relation is verified for $\mu_{it}\sigma\lambda_i - \beta_i(1-\sigma) \geq 0$. Since, in terms of personal wealth, $u_{it} = \omega_i(1+\lambda_i)A_{it}$, we have that the whole incentive condition holds for

$$\omega_i(1+\lambda_i) \geq \mu_{it}\sigma\lambda_i - \beta_i(1-\sigma)$$

that is,

(22) $$\omega_i \geq \frac{\mu_{it}\sigma\lambda_i - \beta_i(1-\sigma)}{1+\lambda_i} \equiv \omega_{it}^*$$

All the entrepreneurs with $\omega_i \geq \omega_{it}^*$ will behave opportunistically and default on their obligations with the bank. Moreover, it is clear that the threshold value ω^*_{it} depends inversely on the interest rate r_{it}. In fact, a higher interest rate makes the productive project less attractive (the operating margin μ_{it} is lower) and opportunistic behaviour is triggered at lower levels of the personal attitude ω_i .The personal value at risk in the bank contract, $\beta_i(1 - \sigma)$, works in the same way.

The dependence of opportunistic behaviour on the interest rate (and on the loan contract conditions more generally) is a typical feature of models of bank-firm relationships with AI. However, for baseline implementation, it is convenient to introduce the following simplifying assumption. Let ω_i^{**} the threshold value that obtains at zero interest rate, i.e.

(23) $$\frac{\rho_i\sigma\lambda_i - \beta_i(1-\sigma)}{1+\lambda_i} \equiv \omega_i^{**}$$

Then I specify the distribution of the personal characteristics among the entrepreneurs as a binomial one with

(24) $$\omega_i = \begin{cases} 0 & 1-\phi \\ \omega_i \geq \omega_i^{**} & \phi \end{cases}$$

Clearly, since ω_i^{**} is greater than any threshold value ω_i^* with positive interest rate, there is a fixed proportion φ of entrepreneurs who behave opportunistically for any positive interest rate charged by the bank. These prefer to enjoy their resources and leave the market. They are replaced by new ones randomly chosen in the space of personal characteristics.

The bank

As already mentioned, in this context the bank is able to observe neither the behaviour of the entrepreneur nor his own personal characteristic. Nonetheless, I let the bank know the proportion of honest and opportunistic entrepreneurs. Then, it sets the interest rate that maximizes its expected worth for any loan.

In calculating this expected value the bank has to take into account that in case the entrepreneur behaves opportunistically, it will not be able to recover any amount and it will incur a loss equal to the cost of gathering the loan. Hence, the expected value of any loan i under AI turns out to be

(25) $$E(\tilde{V}_{it}) = \left[(1+\tilde{r}_{it})L_{it}\sigma + B_{it}(1-\sigma) - L_{it}(1+\bar{r}_t)\right](1-\phi) - L_{it}(1+\bar{r}_t)\phi$$

The profitability condition $E(\tilde{V}_{it}) \geq 0$ requires

(26) $$1+\tilde{r}_{it} \geq \frac{1+\bar{r}_t}{\sigma(1-\phi)} - \frac{1-\sigma}{\sigma} \cdot \frac{\beta_i}{\lambda_i}$$

This is the same result as in the case of symmetric information up to the AI risk ϕ. By the same reasoning, we can still say that the bank will set $\beta = \lambda = 1$, and that competition drives the rate to the equality threshold.

As a result the bank will charge each entrepreneur the AI interest rate

(27) $$\tilde{r}_t = \frac{\bar{r}_t + \phi}{\sigma(1-\phi)}$$

Clearly, this interest rate implies a positive AI risk premium, increasing in ϕ, over the purely competitive rate r_t^C.

These, too, are typical results in the AI literature, that is,

- the AI rate is higher than the purely competitive rate
- the AI risk premium is equally charged onto all clients.

In turn, these results entail that

- the pool of applicants is reduced, in fact the productivity threshold for entrepreneurs to apply for a bank loan shifts from $k_i \geq 1+\frac{1-\sigma}{\bar{r}_t}$ to $k_i \geq \frac{1}{(1-\phi)}\left(1+\frac{\phi}{\bar{r}_t}\right)+\frac{1-\sigma}{\bar{r}_t}$ [11], [12]

[11] Since projects' characteristics are randomly distributed across entrepreneurs, we exclude that this may change the opportunistic proportion ϕ.

- honest entrepreneurs suffer a loss in the value of their project as a consequence of the presence of opportunistic subjects
- the AI rate, being higher than the competitive rate, reinforces the incentive to behave opportunistically (the threshold value ω_{it}^{*} falls, though, under our assumptions, this does not change ϕ).

4.3 Relationship Banking treatment

The previous considerations lead us to introduce a relationship banking (RB) agreement between the entrepreneur and the bank.

Suppose it is the first period a bank meets an entrepreneur: it will charge him the AI interest rate because it knows nothing about him. However, once the project has been realized, the bank is able to discriminate its incumbent clients:

- non defaulters are surely honest
- defaulters are partly unsuccessful honest and partly opportunists
- unsuccessful honest entrepreneurs are observable against opportunists since their projects leave their initial wealth as recoverable asset whereas the latter do not.

Therefore, opportunists and unsuccessful honest entrepreneurs are redlined forever and exit the system as they no longer possess employable wealth. The successful honest are willing to renegotiate their interest rate so as to get rid of the AI risk premium. Is this renegotiation in the bank's interest?

Comparing $E(V_{it})$ with $E(\tilde{V}_{it})$ we see that, under the pressure of competition, financing a project with r_t^C or $\tilde{r}_t$ yields the same (zero) end-value for the bank. Hence, even though the bank knows that a client is honest, it has no specific incentive to charge the purely competitive rate. On the contrary, knowing that if the client seeks to move to a new bank he will have to pay the "first-entry" AI rate, the bank has the opportunity to retain the client through offering the *slightest cut* below the AI rate. Of course, the closer the rate to the AI rate, the larger the rent the bank extracts from the honest entrepreneur. This situation reflects the problem of "the capture of the client" that the RB literature indicates as a possible costly counterpart of the benefits of the relationship. Note, however, that this situation manifests itself in its most severe form to the extent that there is no information flow about clients across banks. As a consequence, banks are un-

[12] Recalling our previous explanation of how bank lending affects aggregate investment, the consequence of AI is therefore not to be seen in the number of projects realized (all projects with $k_i \geq 1$ are still realized) but in the smaller subset of levered (i.e. large-scale) investments.

der competitive pressure only for new entrants, but act as information monopolists with incumbent clients.

Here I shall assume that there is room for some bargaining about the level of the interest rate in the interval $[r_t^c, \tilde{r}_t]$. As in Rajan (1992), I assign both agents an exogenous bargaining power, b_i for the bank and $(1-b_i)$ for the firm. The bargaining power counts for agent's reputation; then, the RB interest rate will be determined as

(28) $$r_{it}^R = b_i \cdot \tilde{r}_t + (1-b_i) \cdot r_t^c$$

To put it differently, r_{it}^R is the result of bargaining over the risk premium/rent to be left to the bank:

$$r_{it}^R = r_t^c + b_i(\tilde{r}_t - r_t^c)$$

If we assume that both parties have the same bargaining power, and that this distribution of power is the same *vis-à-vis* all clients, the RB interest rate becomes

(29) $$r_{it}^R = \frac{1}{2(1-\phi)}\left[\frac{\overline{r}_t}{\sigma}(2-\phi)+\phi\right]$$

I expect that simulations of these different setups shed some light on some aggregate properties of the economy regarding:

- the dynamics of aggregate output (i.e. aggregate investment financed in each period)
- the dynamics of aggregate wealth (i.e. reinvested profits)
- the rates of default

5. Simulation Results

The previous framework have been designed to tackle the problem of how heterogeneity of entrepreneurs influences the well established results in the literature that points at the superiority of RB regime against PAI.

In particular, here I'm interested in understanding whether introducing heterogeneity these results are still robust or loose validity; moreover, I want to test how the economy behaves over time when the bank is faced with heterogeneous entrepreneurs and with a different arrangement through which solving asymmetric information.

I start by imposing that entrepreneurs' characteristics k_i are drawn from a normal distribution with $\mu = 51{,}25$[13] and $\sigma = 1$: the entrepreneurs will differ in their rates of return that eventually will condition their ability of repaying the loan.

Not only, entrepreneurs will result differentiated in two different pools by their personal characteristic: as already discussed, those who have $\widehat{k}_i > \frac{1}{(1-\phi)}\left(1+\frac{\phi}{\overline{r}_t}\right)+\frac{1-\sigma}{\overline{r}_t} \approx 51.25$ will ask for bank financing, while the others will self finance investing previous period final wealth.

Recalling that $\rho_i = k_i \cdot \frac{\overline{r}_t}{\sigma}$, the last assumption translates in specifying that only entrepreneurs with $\rho_i \geq \widehat{k}_i \cdot \frac{\overline{r}_t}{\sigma}$ will ask for a bank loan, while those with $\frac{\overline{r}_t}{\sigma} \leq \rho_i \leq \widehat{k}_i \cdot \frac{\overline{r}_t}{\sigma}$ will remain wealth constrained.

At the end of each period, Banking Financing entrepreneurs have to repay the loan, and in case of bad luck they can incur in failure, and exit the market, just because of the debts' burden. Notwithstanding, if they are Relationship Banking firms, they have more probability of not failing thanks to better credit conditions that makes less heavier the debt repayment.

Moreover, I suppose that only Banking Financing entrepreneurs can either be opportunistic or not since there is no mean of having opportunistic Self Financing entrepreneurs.

At the end of each period, opportunistic entrepreneurs who defaulted the loan, exit the market and the new entrants are perfect copies of the exiting ones, but for their level of opportunism. Indeed, I assume that in each period the opportunism characteristic is redistributed among the new entries, still keeping the aggregate proportion constant.

As for Self Financing entrepreneurs, they do not carry the risk of exiting the market because in case of misfortune they are not going to have profits but they are not even incurring any loss due to loan obligations.

In the very first periods of the simulation exercise, I endow all type of entrepreneurs with the same initial level of wealth and with the same level of interest rate, so that heterogeneity in the wealth levels and the interest rates charged will arise only because of entrepreneurs heterogeneity.

Since I am not interested in empirically validate the model, I do not calibrate the model and the structural parameters do not pretend to be empirically plausible. Then, the focus of the

[13] The value corresponds to the break even $\widehat{k}_i$ assuming $\overline{r} = 0.01$, $\sigma = 0.75$ and $\phi = 0.2$

analysis is on the qualitative dynamics of the system, while results will be analyzed from a quantitative point of view only to assess treatments' superiority in terms of aggregate output and wealth levels.

The tables you will find in the following are constructed upon Montecarlo simulations of each treatment.

Therefore, baseline simulations have been realized referring to the following constant parameters setup:

Variable	Description	Value
T	Number of periods	400
N	Number of firms	100
σ	Probability of success	0.75
$\bar{r}$	Risk free interest rate	0.01
ϕ	Proportion of opportunistic entrepreneurs	0.2
d	Bargaining power coefficient	0.5
z	Consumption coefficient	0.75

Table 1: Parameters set up

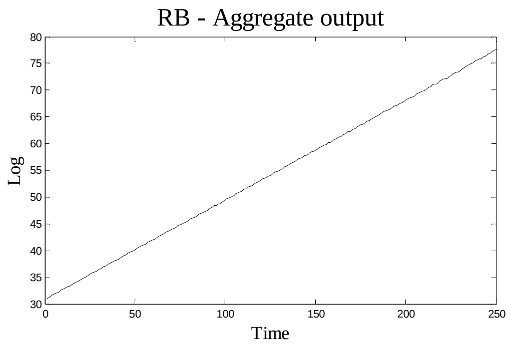
As for aggregate output and wealth, I will both analyze their quantitative differences across the two treatment and the differences in the short run qualitative dynamics, thus I filtered the series through the Hodrick-Prescott method, so as to forget about the long run trend.

Regarding the default rate, I compute a Failure Index defined as the sum of all honest entrepreneurs achieving negative profits over the total number of debt financing firms. Notice that just considering entrepreneurs who ask for a loan for the computation of the index, we can have an idea of how better financing conditions help the unlucky entrepreneurs since we presume that a lower interest rate will enable them to achieve positive profits.

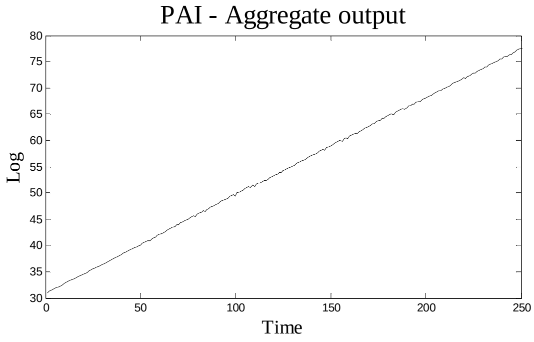
Section 5.1 presents the results of the simulations aimed at comparing the static and dynamic performance of the two previously presented treatments; instead, in section 5.2 I'm offering the evidence of how the system performs for different level of the δ parameter.

5.1. Pure Asymmetric treatment versus Relationship Banking treatment

Simulation results show that both treatments produce an output series displaying long term growth:



(a)



(b)

Figure 1: Aggregate output (logarithmic values) for Relationship Banking (a) and Pure Asymmetric Information (b)

At the macro level, after the implementation of the Wilcoxon test at 95% significance level, it is possible to demonstrate that GDP series under Relationship Banking and under the Pure Asymmetric Information regime do not significantly differ. The same results holds for what concerns aggregate final wealth.

	Output	Wealth
RB treatment	53.86	54.77
PAI treatment	53.76	54.67

Table 2: Average aggregate output and wealth levels (logarithmic values)

The result is at odds with the theoretical presumption asserting that a Relationship Banking regime performs better at the aggregate level as a consequence of better credit conditions. Nonetheless, the RB regime is characterized by a negative correlation between the level of wealth and the interest rate, suggesting that a decrease in the interest rate does foster firms' cumulative capacity.

In order to shed light on the reason why this beneficial effect doe not spread to the whole economy, it is worth considering separately the performances of the two types of entrepreneurs who populate the economy[14]. Remember that the presence of asymmetric information and the consequently higher interest rate, reduces the pool of applicants for bank credit[15], so that we have part of the entrepreneurs producing self financing. This pool of entrepreneurs can incur in bad luck too, but since they do not have any kind of debt obligation, they are not compelled to exit the market. The effect is that they continue growing and producing but for periods of misfortune.

Following Table 3, under Relationship Banking BF firms perform better with respect to the Pure Asymmetric framework, while SF firms' output and wealth remain constant among the two treatments.

	BF firms		**SF firms**	
	Output	*Wealth*	*Output*	*Wealth*
RB treatment	13.5	13.8	53.9	54.8
PAI treatment	11.6	11.8	53.8	54.7

Table 3: Average aggregate output and wealth levels for BF and SF firms (logs) under both treatments

This confirms that better credit conditions enable firms to accumulate more and consolidate. In particular, better credit conditions enable BF firms to consolidate and enhance their probability of becoming big ones. Indeed, the average dimension of each BF firm under RB results to be higher than under PAI:

	BF firms
	Average wealth
RB treatment	10
PAI treatment	7.9

Table 4: Average BF firms' wealth (logs) under RB and PAI

Comparing Table 4 and Table 3, it stands out that there is no sharp difference between average BF firm dimension and average aggregate BF wealth under RB, that is, it is very likely that the BF firms' size distribution results to be right skew. Indeed, average skewness for BF firms' distribution is 6.1, while the kurtosis is 40. The RB regime translates into having few big firms and a multitude of small ones. The particular credit arrangement is such that big firms are helped growing faster[16], while small firms are helped not exiting the market.

[14] To avoid redundancy, from now on Banking Financing entrepreneurs will be labeled as BF, and Self Financing entrepreneurs will be labeled SF.
[15] Remember also we assume that all the entrepreneurs decide for the productive investment, that is, all entrepreneurs have $k_i \geq 1$
[16] Under the RB arrangement, BF firms wealth's average growth rate is 36,3% while under PAI it is 28,1%

The same pattern is recognizable in the PAI treatment, but while the skewness of BF firms' size distribution is almost unvaried (sk^{BF}_{PAI}= 5.95), the kurtosis is smaller (K^{BF}_{PAI}= 38), that is, there are less big firms than in the previous case.

Notwithstanding better credit conditions, the cumulative potential that BF firms acquire under RB does not translate into a long run output growth; indeed, SF output grows constantly over time, while BF output is stuck into a well defined corridor. That is, the debt prevents firms' output from displaying long run growth because it aggravates firms' insolvency in bad luck times.

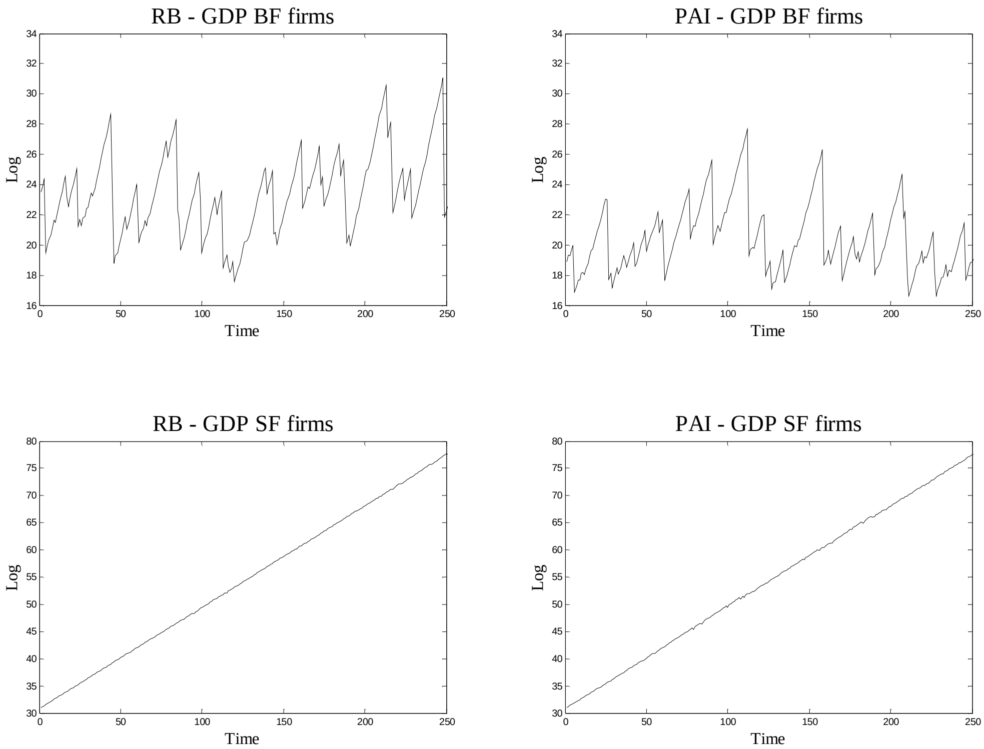


Figure 2: average output for BF and SF entrepreneurs under the two treatments

Indeed, in case a BF firm incurs in bad luck, if it does not have the resources to meet its obligations, it leaves its wealth with the bank, declares default and exits the market. Eventually, this translates into an output loss, that it cannot be recuperated by new entrants since they are endowed with lower wealth levels than those exiting. This happens for any credit regime, thus it can be argued that any banking financing regime limits firms aggregate productive capacity instead of promoting it.

Before going into the analysis of the macro dynamics, another result deserves attention.

I would expect firms' default rate in the RB regime to be lower than in the PAI one. Instead, the two Failure Rates are almost the same since $FR_{RB} = 14{,}32\%$ and $FR_{PAI} = 14{,}3\%$. This result combined with the better performance experienced by BF entrepreneurs in RB suggests that, given our framework, lowering the financing cost has a positive effect in what concerns firm's cumulative capacity, but does not have the same positive effect in reducing firm's default risk.

Even though the previous findings show the efficiency of RB in enhancing BF firms, the beneficial effect does not spread to the whole economy because BF firms are too small and their contribution is too little with respect to SF ones. Indeed, SF firms' output and wealth constitute the 99% of total output and wealth, so that there is no room left for BF entrepreneurs to influence aggregate economy.

The peculiarities shown in the previous paragraph characterized economic dynamics too.

Under both the treatments output displays cyclical fluctuations, which variability does not differ across them.

	Output Variance	Wealth Variance
RB treatment	0.11	0.006
PAI treatment	0.11	0.006

Table 5: Output and wealth variability

Nonetheless, if we analyze the behaviour of the series separating BF firms and SF ones, the homogeneity in results does no longer hold.

In particular, Table 6 shows the variances of BF and SF firms' aggregate output and wealth:

	BF firms		**SF firms**	
	Output	Wealth	Output	Wealth
RB treatment	2.04	2.19	0.11	0.006
PAI treatment	1.53	1.42	0.11	0.006

Table 6: Wealth and output's variances for BF and SF firms

Notice that output and wealth volatility for SF firms are identical under both the hypothesis; moreover they are identical to aggregate output and wealth's variances as Table 5 testifies. On the contrary, BF output is much volatile in the RB regime than in the PAI one, and the same holds for wealth dynamics.

To shed some light on this discrepancy and explain the aggregate dynamics, I regress the volatility of aggregate output on the volatility of BF and SF output[17]. The presumption is that SF output plays the major role in determining both aggregate output's magnitude and dynamics.

Results are presented for both the treatments.

RB treatment: OLS estimates; 241 observations
Dependent variable: vary
HAC Standard Errors, Band width 4 (Bartlett's kernel)

	Coefficient	*Std Error*	*t*	*p-value*	
const	1,2745e-09	3,55526e-08	0,0358	0,97143	
varbf	-3,52895e-08	9,84002e-09	-3,5863	0,00041	***
varsf	1,00002	1,12474e-05	88910,7849	<0,00001	***

Table 7: regression results

As for Relationship Banking, aggregate output volatility is significantly explained by SF and BF output variances. SF output variance positively contributes to aggregate volatility: in particular, a change in SF output dynamics is translated into a proportional change in aggregate output dynamics, being the *varsf* coefficient equal to 1. The BF output volatility has a negative coefficient, suggesting that an increase in it translates into a decrease in aggregate volatility. Nonetheless, though significant, the influence of BF dynamics into aggregate one is so small that we can say that aggregate dynamics is not determined by BF one.

The PAI framework almost replicates these findings:

PAI treatment: OLS estimates; 241 observations
Dependent variable: vary
HAC Standard Errors, Band width 4 (Bartlett's kernel)

	Coefficient	*Std error*	*t*	*p-value*	
const	8,94563e-06	1,14803e-05	0,7792	0,43663	
varbf	1,44097e-05	9,51884e-06	1,5138	0,13140	
varsf	0,998518	0,00096418	1035,6141	<0,00001	***

Table 8: Regression results...

Here, BF output variance results not significant to explain aggregate output dynamics.

[17] Output volatility has been obtained calculating a moving variance over a 10 periods window for each filtered output series.

BF output dynamics plays such a small role in determining aggregate dynamics because BF firms are too little and their contribution to the aggregate is too small with respect to SF firms.

Moreover, the higher BF volatility under RB is the consequence of BF firms being greater in RB than in PAI, that is, in RB the firms which fail have bigger dimension with respect to the firms which fail under PAI. When a firm fails, the impact over the economic dynamics is stronger the bigger the firm.

Indeed, if we isolate failing BF firms in the two frameworks, we find out that failing BF firms in RB are bigger with respect to the same firms in PAI. The average initial wealth level of the latter is 18.6[18] while the same magnitude for the former is on average 22.4.

What is worth remembering here is the little influence BF firms have over the economy, that is, the economy I figured out is one in which firms that can count on RB are in a better position with respect to those without favourable credit terms; nonetheless, the former are so small with respect to SF firms that the economic dynamics is not influenced.

Then, upon the results already offered, it is not possible to claim that RB performs better than PAI. Indeed, aggregate levels and aggregate volatility are almost the same in the two treatments.

Notwithstanding, I believe the judgment about the efficacy of Relationship Banking to be strongly biased by the presence and the dimension of SF firms.

The latter are very similar in number to the former, that is, in our economy only half of the firms needs bank credit, while the others are able to self finance investment projects.

Now, let's imagine this is no longer true, and that the aggregate magnitudes would mainly results from BF firms' production; then, is Relationship Banking still efficient?

To answer this question, let's pay attention exclusively on the series regarding BF entrepreneurs. If we were to consider a framework in which SF firms' cumulative capacity was limited[19], then BF series would represent the aggregates of our economy.

If this was the case, the assessment of Relationship Banking would change.

Indeed, BF output is higher under RB; moreover, on average, under RB, Banking Financing firms are bigger than under PAI. Nevertheless, the hypothetical aggregate output in RB would be nearly twice as volatile as in PAI.

Therefore, aggregate output would no longer be growing over time.

That is to say that if we imagine a situation in which the economy is determined by firms which need banking financing to support their project, the implementation of Relationship Bank-

[18] Wealth in logarithmic terms

[19] For example, imagine we impose SF firms consume all their final period value added, so that they were obliged to invest always the same amount in the productive project.

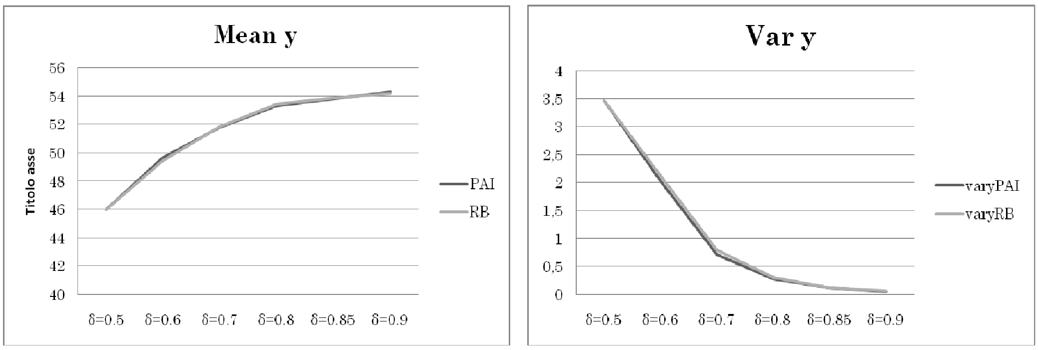
ing would only be beneficial for what concerns absolute values. As for dynamics, the framework would entail a higher degree of volatility and no long run growth. Then, under the hypothesis of Relationship Banking there is a trade off between output level and output dynamics.

5.2. Robustness check

In order to check for the validity of my results, in the following I present the results of MonteCarlo simulations run for each treatment letting the δ parameter changing.

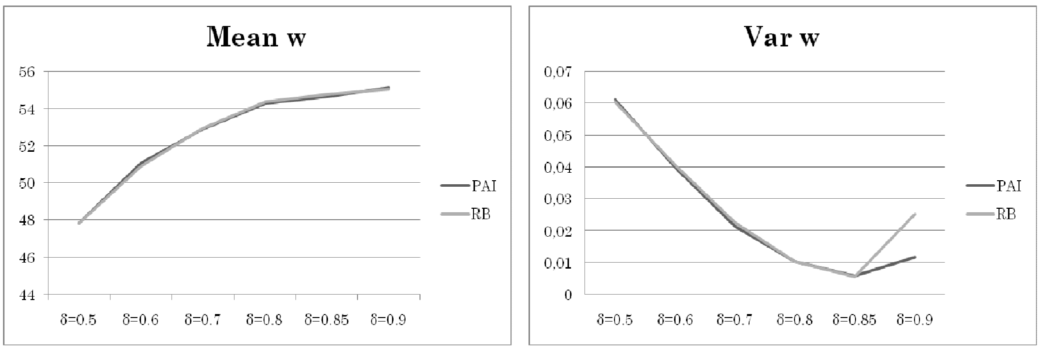
The rationale for letting δ change is to analyze whether the results are robust when the surrounding economic conditions change for firms. A low δ value would mean firms are passing through difficult times, while the opposite would imply firms are experiencing a favourable economic environment.

In the analysis, I will disregard extreme situations represented by δ values lower than 0.5. Indeed, since entrepreneurs knows the probability of default, it does not seem plausible to assume they are willing to undertake production knowing that the enterprise will most probably fail.



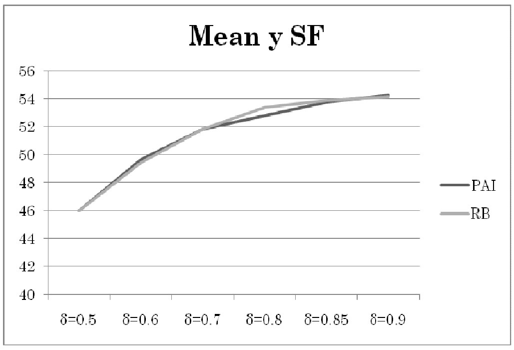
(a) (b)

Figure 3: average output (logs) and output variance for increasing δ parameter

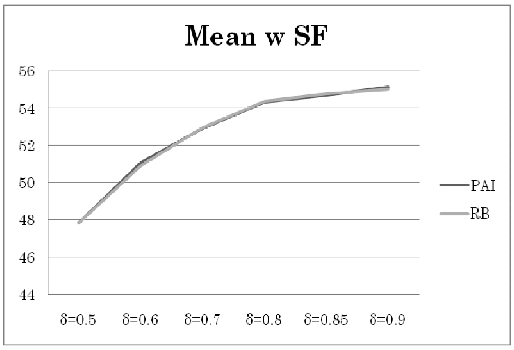


(a) (b)

Figure 4: average wealth (a) (logs) and wealth variance (b) for increasing δ parameter, under both PAI and RB



(a)



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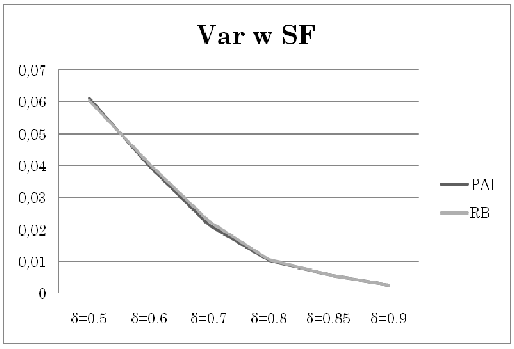
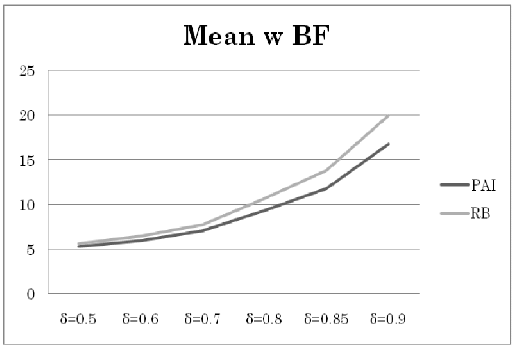
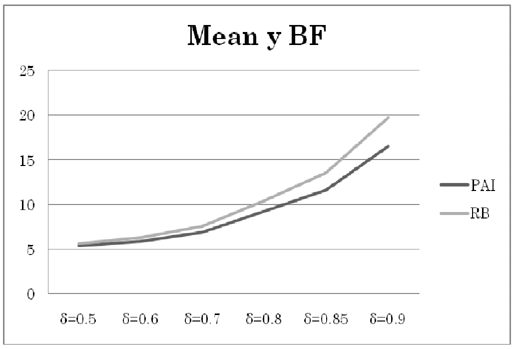


(c)

Figure 5: average output (a) and wealth (b), wealth variance (c) for SF entrepreneurs – increasing δ



(a)



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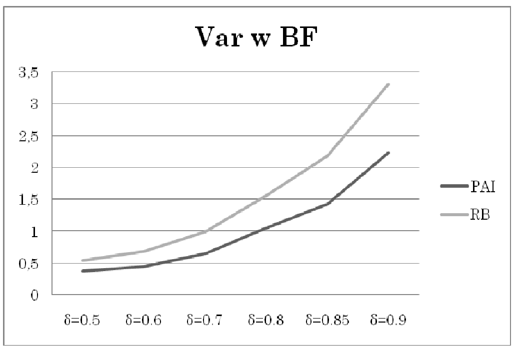

(c)

Figure 6: average output (a) and wealth (b), wealth variance (c) for BF entrepreneurs – increasing δ

MonteCarlo simulations confirm previous results.

Average aggregate output and average aggregate wealth are not significantly different across treatments[20]. The two magnitudes increase as long as the probability of success increases, but their growth pace decreases within the same parameter's window.

The same is true for what concerns SF entrepreneurs. The average output produced by SF firms is not significantly different under the hypothesis of RB or PAI, nor their aggregate wealth.

As for the variances of the previously cited series, notice that they follow the same decreasing pattern. Having the probability of success increasing directly translates into a decreasing probability of default for SF firms. Indeed, these firms do not bear the burden of the debt, and in case of misfortune they do not lose their initial wealth. As a result, their aggregate wealth does not experience high volatility, and in particular it decreases along with the probability of success increasing.

Since SF firms strongly influence the aggregate level, aggregate output and wealth are similarly stable and follow similar variability's patterns (Figure 5-6, panel b).

Indeed, at the aggregate level, and as for SF entrepreneurs, there are no reasons to assert that a Relationship Banking regime performs better with respect to a PAI one.

Notwithstanding, if we concentrate on Banking Financing firms, some interesting results stand out.

First of all, notice that the output produced by these firms and their aggregate wealth grows nearly exponentially under both treatments as long as the probability of success increases. Though decreasing along with δ, BF entrepreneurs have a higher return rate with respect to SF ones. Moreover, at each period they invest two times their initial wealth, so that if they are lucky they yield more than SFs do. The result is that when the probability of success increases, their aggregate wealth and output increase at a higher pace with respect to SF.

Moreover, for δ values lower than 0.6 there is no significant difference between RB and PAI with respect to both BF output and wealth. This contradicts previous results that point at the superiority of RB for BF firms. For δ values higher than 0.6, things revert and the RB regime enables BF firms to perform significantly better than under PAI.

Hence, it is possible to claim that Relationship Banking results not particularly helpful in bad times, when the probability of success is low, while it succeeds in enhancing firms' growth in relatively good times. In particular, the difference between BF performance in terms of aggregate wealth and output produced, deepens along with the increase in δ, that is, in good times RB

[20] For the entire paragraph, difference's significance has been assessed through the implementation of the Wilcoxon test at the 95% significance level.

produces an accelerating growth mechanism. On the contrary it does not help firms that already pass trough difficulties.

Furthermore, it is worth noting that the variability of BF wealth under RB is permanently and significantly higher than under PAI. Along with the growing efficacy in terms of aggregate levels, Relationship Banking implies higher degree of volatility for BF firms. As the probability of success increases, the trade off between level and stability worsens.

6. Conclusions

The model presented in this chapter was aimed at analyzing the macro dynamics of an economy characterized by asymmetric information, when we introduce the hypothesis of heterogeneous entrepreneurs and we endow banks with the possibility of ex post discriminating good entrepreneurs and offer them better credit conditions.

My starting point has been the credit view literature, which claims that the way in which firms finance their activity and the contractual arrangements chosen for it, has a great impact in explaining economic fluctuations.

I endorsed this view, and in particular I focused on Relationship Banking as a possible contractual arrangement through which solving problems connected with asymmetric information. Relationship Banking consists in offering privileged access to credit and better financing conditions to firms which undergo a long term relationship with their banks. The empirical literature demonstrates that these long term relations enhance reputation's effects through the possibility of constant monitoring, and that most of the time they translate into a concrete lowering of the interest rate charged.

The theoretical models that tackle the issue suggest the superiority of Relationship Banking with respect to a situation in which banks do not have the possibility of ex post discriminating entrepreneurs. Nonetheless, these models are founded on the hypothesis of the Representative Agent, so that their conclusions can be questioned. Moreover, none of them shows concerns about the impact of having relationships regulated by Relationship Banking on the macroeconomic dynamics, that is, whether the hypothesis influences the macro stability or not.

The theoretical framework developed here is based on the basic principles of the asymmetric information mark and seeks to explain whether admitting heterogeneity among entrepreneurs and RB contractual arrangements enhances our understanding of the macro dynamics in asymmetric information environments.

I assumed entrepreneurs to be heterogeneous in their managerial capacity, which in turn implies different rate of returns over investment, and in their opportunistic attitude. Entrepreneurs with a rate of return higher than a well specified threshold value refer to the bank for financing, while the others invest self financing. Among the banking financing entrepreneurs, at each period there is a fixed fraction of opportunistic that won't meet their obligations with the bank. Then, I set up two treatments: in the first one banks do not have the possibility of discriminating opportunistic and non opportunistic entrepreneurs, and apply the same interest rate to all. In the other, banks discriminate good entrepreneurs as the ones who have always been repaying their loans, and has the possibility of offering them a lower interest rate. Investment projects could incur in bad luck, which finally influences the capacity of good entrepreneurs to give back the credit.

The model has been simulated upon a constant set of parameters, and in particular I assumed the proportion of opportunistic entrepreneurs to be constant and known by the bank, as well as the risk free interest rate and the probability of success to be equal among the population.

Since I was interested both in the quantitative evaluation of RB superiority with respect to a pure asymmetric information framework and in the qualitative dynamics analysis, I computed aggregate output, aggregate wealth, average firms' wealth and a default rate index for both treatments. Therefore, output and wealth series have been filtered to concentrate on short run dynamics.

Assuming entrepreneurs' heterogeneity implies both that each of them has a different rate of return on the productive investment and that they can be grouped into two pools, separating Self Financing entrepreneurs from Banking Financing ones.

Contrary to the theoretical presumptions, Relationship Banking results not to be superior to the PAI treatment since average aggregate output does not significantly differs across treatments. The reason for this is to be found in the heterogeneity previously mentioned. Indeed, the presence of Self Financing entrepreneurs nullifies the positive contribution of RB: aggregate output is mostly determined by SF output, while BF production contributes only marginally. Separating the contribution of the two types of entrepreneurs, BF entrepreneurs perform definitely better under RB with respect to PAI, with both output and wealth levels higher in the first case. This confirms the presumption for which better credit conditions translate into a higher productive capacity and a higher accumulation capacity. Nonetheless, simulations results show also that this favourable impact does not spread to the probability of default, since the value of the Failure Index is similar among treatments. Indeed, RB arrangement performs well in enhancing firms' growth, but do not prevent them from failing.

Separating BF output and SF one, one result stands out. None of the two treatments display sustained BF entrepreneurs' output growth, this to say that any credit regime limits economic growth. Indeed, one would expect that under RB this could not happen. However, notice that RB impacts over credit conditions, and not over the probability of default, that is, favourable banking financing limits the probability of default, but does not positively impact on it. This in turn, combined with the fact that in my model each firm faces the same probability of success, implies that in each period a fixed proportion of firms will default, and this productive loss prevents aggregate BF output from growing.

As for economic dynamics, there is no sharp difference between RB treatment or PAI one. Both aggregate output and aggregate wealth display almost equal volatilities. Nonetheless, focusing attention on BF entrepreneurs, the variability of the series increases considerably under RB, while the same magnitude for SF entrepreneurs remains equal.

Indeed, this first set of results highlight two distinctive features of the model.

First, given entrepreneurs' heterogeneity, it is not possible to conclude that Relationship Banking is the best choice neither for what concerns the aggregate economy nor for what concerns macro stability.

Second, if we were to eliminate SF entrepreneurs' contribution and concentrate attention on BF behaviour, a trade off between absolute values and economic stability would emerge. Indeed, RB enhances BF firms cumulative and productive capacity, but at the same time it implies higher volatility. Moreover, whatever the banking arrangement is, BF output does not display long term growth, that is, RB is not able to enhance growth.

To go deeper into the understanding of Relationship Banking, I performed Montecarlo experiments letting the parameter δ change. The rationale for the choice resides in evaluating the robustness of the previous results and in assessing how the economy performs when the probability of success changes, that is, when firms pass through either good or bad times.

Montecarlo simulations almost confirm the impossibility to assert that RB is superior to PAI at the aggregate level and for what concerns macro dynamics.

On the contrary, results show that it is not possible to verify RB superiority for what concerns BF entrepreneurs for δ values lower than 0.6. Indeed, the credit regime does not support wealth constrained firms in bad times, or, at least, it does not do any better confronted with PAI. During good times, the credit regime acts as a growth accelerator for those firms. Moreover, as for macro stability, as long as the parameter δ increases BF firms' stability under RB worsen with respect to PAI.

Then, along with the improvement in the economic environment, the trade off between aggregate performance and stability for BF firms under RB, gains importance questioning the validity of the credit regime.

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Chapter 3

Keynes in the computer laboratory.An Agent-Based model with *MEC*, *MPC*, *LP*

1. Introduction

Offer of "authentic" interpretations of Keynes's ideas by means of more or less conventional tools and languages is extremely vast. Why add one more? Keynes's thought, after many ups and downs, successes and reversals, continues to exert influence on macroeconomics either as a cornerstone for followers or as a stumbling block for advocates of different views and theories (see e.g. Lucas (2004)). Recurrent booms and slumps of modern capitalism – the ongoing world financial turmoil is a dramatic example – keep the idea alive that there is more in the *General Theory* (*GT*, 1936) about the economic system we live in than it has been caught by subsequent "technical developments" (to paraphrase Blanchard (2000)), whether in the same Keynesian inspiration or pointing to alternative directions (Leijonhufvud (2008)). Thus, better understanding of Keynes's theory is not an issue of mere historical matter.

The first notorious problem encountered in this task is that translating Keynes's ideas into a coherent, formalized theoretical system has represented a formidable challenge ever since their appearance. The *General Theory* presents a literary model describing the functioning of a complex economic environment, quite difficult to reconcile with mathematical formalism. Keynes expressly refused to take this road. Indeed, it turned out to be nearly impossible to disentangle all the features and the intuitions that contribute to the complexity and richness of the *GT*. However, there is at least one point in Keynes's writings where the fundamental elements of his theory are summarized in a fairly simple and clear picture, namely in the 1937 paper "*The General Theory of Employment*" (*QJE*):

"The theory can be summed up by saying that, given the psychology of the public, the level of output and employment as a whole depends on the amount of investment. I put it in this way, not because this is the only factor on which aggregate output depends, but because it is usual in a complex system to regard as the causa causans that factor which is most prone to sudden and wide fluctuations. More comprehensively, aggregate output depends on the propensity to hoard, on the policy of the monetary authority as it affects the quantity of money, on the state of confidence concerning the prospective yield of capital-assets, on the propensity to spend and on the social factors which influence the level of the money-wage. But of these several factors it is those which determine the rate of investment which are most unreliable, since it is they which are influenced by our views of the future about which we know so little." *(QJE,* p.121*)*

In fact, the three pillars, the Marginal Efficiency of Capital (*MEC*), the Marginal Propensity to Consume (*MPC*) and the Liquidity Preference (*LP*) found their own place in the earliest systematization effort of Keynes's theory, the IS-LM model put forward by Hicks as early as 1937. On those building blocks, the construction of Keynesian macroeconomics was erected in the Fifties and Sixties thanks to the works of Modigliani, Klein, Hansen, Samuelson and many others who contributed to the so-called "Neoclassical Synthesis" (the popular term coined by Samuelson). However it was soon clear that, on the one hand, those first principles were not easily reducible to neoclassical first principles, while on the other hand, the more they were "neoclassicized", the more Keynesian economics was driven apart from Keynes's economics (to recall the terms used by Leijonhufvud's in his celebrated book of 1968 where he brought into full light the foundational flaws of the Neoclassical Synthesis).

The problem is still unsettled. Neo Classical economics tackled the question by strongly blaming the *GT* for lacking microfoundations, where this word has to be read as decision making based on optimization. Indeed, since the release of the *GT*, many economists have been claiming that the work was not suitable for explaining economic systems because it lacked any microfoundation and was not amenable to rigorous formal treatment. Apart from an ideologically biased component, it is fair to say that, until recently, Keynes's methodology has been quite hard to translate into a formal and quantitative language comparable to the one developed by the Neoclassical methodology. Even the most important strand of literature supporting Keynes's macroeconomics in recent times, namely the New Keynesians (see again Blanchard (2000)), seems to fail to capture the whole complexity of the economy envisioned in the *GT*. Although a tentative reconciliation of Keynesian macro with micro foundations has been carried out, the behavioural background that characterizes agents in the *GT* has been completely neglected. On the other hand, refusal of any formal and quantitative language has turned out to be a blind alley, more harmful than beneficial to the Keyensian cause.

The aim of this chapter is to take Keynes's own ideas on the business cycle to the computer laboratory and translate them into an Agent-Based Macro-Model. A first motivation is that ABM implementations are still in the development stage but they prove able to overcome the difficulties encountered at Keynes’s time and until very recently in translating his ideas into a computable, quantitative model. These developments allow us to challenge both conservative Neoclassicism and nihilist Anti-Neoclassicism on two grounds. First, progress in the research on micro behaviours that can pinpoint the foundations of Keynes’ macro framework, that is, the behavioural rules that guide agents in their decisions making. Second, advances in computational theories and applications that are rendering ABM methodology a rigorous and reliable platform to deal with the formidable constructive and interpretative problems posed by complex adaptive systems.

A second motivation for this ABM treatment of the economics of Keynes can be explained as "counterfactual history of thought". Suppose that this model does capture the so-far least tractable features of Keynes's economics: then its results can suggest how different Keynesian economics could have been if these results had been available from the beginning.

In my stylized interpretative model of Keynes's theory, *MEC*, *MPC* and *LP* play the principal role as determinants of the business cycle along the lines indicated by the previous *QJE* citation. Moreover, contrary to the Neoclassical Synthesis and subsequent developments, they are modelled with as much attention as possible, and as close as possible, to Keynes's methodological approach concerning decision making under uncertainty. This was in fact one of the points, if not the most important one, of departure of Keynesian economics (and subsequent macroeconomics) from Keynes's economics[21].

Here, too, Keynes's thought, before and after the *General Theory*, is far from being amenable to simple treatment. However, my methodological choices have been guided by two clear and univocal positions held by Keynes (again with particular clarity in the *QJE* article). First, his refusal of the perfect rationality hypothesis due to the lack of a rational basis of probabilistic computation of future states of the world – what he, like Knight, called "uncertainty" as opposed to probabilistic "risk" (in the following I will comply with this distinction of the two terms, though today it is no longer uncontroversial). Second, the indication of some "ingredients" which human beings resort to in order to cope with uncertainty, one of which is the weight assigned to others' opinions. As to the first point, I focus on the role of *Market Sentiments*, simply characterized as *optimism* and *pessimism*, in the way agents project their present state into a better or worse future state, as opposed to probabilistic computation of future events and expected payoffs. As to the second point, assuming – as Keynes does – that each individual knows how little he/she knows of the future, individual optimism/pessimism is filtered through a *social interaction*

[21] Indeed, in the *QJE* article Keynes indicates this point as the most important point of departure of his own theory from what he called the Classical (and we call the Neoclassical) theory.

process whereby it can be enhanced or corrected through random meetings with other optimistic or pessimistic individuals. The interaction process is the one proposed by Kirman (1993).

As a by product of these methodological choices, two other key features of the economics of Keynes that has gone astray along the way of macroeconomics are brought back to the front stage, *heterogeneity* (here under the dimension of attitudes towards the future) and *interaction* of agents. These two features are also the genes of what are now called "complex adaptive systems", a characterization of market economies drawn from contemporary natural sciences that to some authors seems much more appropriate than that of "simple optimized systems" of modern macroeconomics (see e.g. Colander et al. (2008)).

The first next two sections of the chapter provide an overview and textual evidence of Keynes's thought on the issues of interest: section 2 is about uncertainty and long-term expectations and their relationship with economic decision making; section 3 presents Keynes's treatment of *MEC*, *MPC* and *LP*. Section 4 discusses the literature contributions after Keynes. Section 5 introduces the ABM, while section 6 presents simulation results. The last section is reserved for final remarks and conclusions.

2. Uncertainty, Animal Spirits and Market Sentiment

In the *QJE* article, Keynes stated very clearly that his point of departure from the "classics" concerned the role of uncertainty in human decision making

"[…] At any given time facts and expectations were assumed to be given in a definite and calculable form; and risks, of which, though admitted, not much notice was taken, were supposed to be capable of an exact actuarial computation. The calculus of probability, though mention of it was kept on the background, was supposed to be capable of reducing uncertainty to the same calculable status as that of certainty itself […] I accuse the classical economic theory of being itself one of these pretty, polite techniques which try to deal with the present by abstracting from the fact that we know very little about the future" (*QJE*, pp. 112, 115).

In Keynes's view, the problem with classic perfect foresight or probabilistic risk is that agents lack *both* the knowledge *and* information basis they would need to compute exact mathematical expectations about future events. In his words, uncertainty

"does not mean merely to distinguish what is known for certain from what is only probable. […]The sense in which I am using the term is that […] there is no scientific basis on which to form any calculable probability whatever. We simply do not know" (*QJE*, p. 113).

If this is the case, there is no way to take decisions based on probabilities of future events since these probabilities are not computable. This problem is deemed particularly critical with regard to long-run expectations, which are in turn a key element in entrepreneurs' decisions about investment, the pivotal variable in the economics of Keynes.

How Keynes portrays uncertain decision-making about investment is generally associated with the popular idea of "Animal Spirits". Animal Spirits have come to denote almost everything is not fully rational, or even irrational, in entrepreneurial decision making. This roughly irrationalist use of the term is not appropriate, nor is it appropriate its exclusive association to entrepreneurs. As recently stressed also by Fontana and Marchionatti (2007), by evoking Animal Spirits Keynes seeks to denote, not a sort of irrational optimism of entrepreneurs, but the fact that human beings *in general* feel *urged to act* not perceiving, or positively overcoming, their lack of "scientific basis" for decision making as a limitation to action.

"Most probably our decisions to do something positive, the full consequences of which will be drawn out over many days to come, can only be taken as a result of animal spirits- of a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities" (*GT*, p.161)

"Individual initiative will only be adequate when reasonable calculation is supplemented and supported by Animal Spirits, so that the thought of ultimate loss which often overtakes pioneers, [...]is put aside as a healthy man puts aside the expectations of death. [...]If the Animal Spirits are dimmed and the spontaneous optimism falters, leaving us to depend on nothing but mathematical expectation, enterprise will fade and die" (*GT*, p. 162)

As these sentences testify, Keynes's Animal Spirits, upon closer inspection, are certainly a distinctive character of entrepreneurs, but they are not limited to this class of people. Moreover, attention is drawn to the important point that decision making under uncertainty is not to be meant as a purely irrational activity, but an activity where the lack of the "scientific basis" indicated by probability theory is supplemented by other practices and tools that human beings do associate with rationality (see in particular *QJE*, p. 114). In this sense, there seems to exist a clear analogy with the concept of "bounded rationality" that was later put forward by Simon (1955)[22]. There is, finally, no doubt, a non reducible, non rational residual:

"It is our innate urge to activity which makes the wheels go round, our rational selves choosing between the alternatives as best we are able, calculating where we can, but often falling back for our motive on whim or sentiment or chance" (*GT*, p. 163)[23].

The first conclusion of this preliminary discussion is that Animal Spirits *per se* are not a sufficient characterization of Keynes's approach to decision making under uncertainty. This point

[22] Simon, and the psychological literature that followed, pointed out two intrinsic causes of boundedness. One is *cognitive* and is due to limited computational and information-processing capacity of human mind (a typical example is inability to implement operationally the axiom of complete pair wise ordering of preferences in order to maximize utility). The other is *informational* and arises as the external environment does not provide all necessary information. Keynes seemed more concerned with latter than the former cause of bounded rationality.

[23] The interplay that takes place in brain activity between conscious rational reasoning and "interferences" coming from the unconscious and uncontrolled brain sectors is actively investigated in the so-called "neuroeconomics" (see e.g. Camerer (2007))

will be further developed in the discussion in section 3 of the literature spurred by the idea of Animal Spirits. The challenge posed by this approach concerns the practices and tools whereby humans do make their decisions complying with the ordinary standards of rationality as best as they can[24]. In Keynes's works we can discern the idea that this kind of decisions are the result of two motivations: one elaborated by the *single individual,* which may be more prone to "whim, sentiment, or chance", and the other coming from *social interaction.*

The first type of motivation is indicated in the previous quotations by the term *optimism*. In a Keynesian world, optimism can be defined as non-probabilistic *confidence* assigned to a favourable event or payoff. By contrast, *pessimism* is the same mechanism applied to an unfavourable event or payoff. It may be tempting to say that an optimist (pessimist) assigns probability one to the most (least) favourable outcome. Note, however, that since there is no matter for probabilistic assessment, it is not possible to say *a priori* that the confidence attached by the optimist to the favourable event, or that assigned by the pessimist to the unfavourable event, is "too high" (i.e. these are not simply "wrong" or "biased" probabilistic weights). Nor is it possible to infer that the attitude of the optimist (pessimist) towards the unfavourable (favourable) event is the complement to his/her degree of optimism (pessimism)[25]. In the ABM model presented in this chapter, optimism and pessimism will simply be treated as an on-off binary choice between believing in a favourable or unfavourable event or payoff.

The second type of motivation comes from exposure to others' opinions, since when relevant knowledge is missing people “fall back on the judgement of the rest of the world which is perhaps better informed” (*QJE*, p. 114).[26] The Kirman algorithm that I have adopted for my ABM allows for a simple and flexible treatment where agents are characterized by a prior attitude (optimist/pessimist) that can however been changed through random meetings with agents of opposite attitude. The frequency of changes of attitude increases with frequency of meetings with

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[24] After Simon, this was the research programme on "heuristics and biases" pursued by Kahneman, Slovic and Tversky (1982)

[25] The relationship, and distinction, between confidence, subjective probability and objective probability was deeply investigated by Keynes in his book, *A Treatise on Probability* (1921). In that book, he characterized confidence mainly as a motivation to action. The inconsistency that may arise by treating confidence like probability is exemplified by a well-known paradox. I am not an art expert. I am presented an abstract painting and I am asked to say whether the author is Picasso or not. Suppose I answer that I think it is Picasso, but I am not very confident. Can it be inferred that I am *very* confident that it is *not* Picasso? Certainly not, because this second statement would imply that I am able to express art judgements with high levels of confidence, which contradicts the premise that I am not an art expert.

[26] This social component of the individual attitude towards the future appears under different cloths in Keynes's works. For one aspect it may lead to *herd behaviour,* when consciously poorly informed people just imitate *actions* taken by supposedly more informed people (the typical example in chapter 19 of *GT* is buying or selling stocks as market leaders are buying or selling). Another manifestation of the same mechanism is the so-called *beauty contest* (still to be found in the financial chapter of *GT*) when (not so naive) people base their *judgement* about the occurrence of future events on other people's judgement about the same events rather than on independent information.

the other agents. This social dimension of individual decision making is a key aspect of the shift of content and characterization of rationality in a world of bounded rational *interacting* agents. As the ABM will show, in this world, contrary to the classical world of exogenously given probability distributions, the chance that an event occurs is not independent of the number of people who believe that it will occur. This phenomenon, also known as "*self-fulfilling prophecies*", on the one hand provides one explanation and justification why the single atomistic individual lacks the "scientific basis" to act according to the classical canons. On the other hand, it makes it *rational*, rather than irrational, to let one own's beliefs or behaviour be guided also by others' beliefs or behaviour as these are indeed part of the event-generating process.

As is in the very nature of the ABM methodology, and as was indeed Keynes's own aim, the crucial dimension of analysis is aggregate behaviour, which should be intended as the emergent characteristic of a population of interacting agents (e.g. Colander et al. (2008), Delli Gatti et al. (2008)). At the level of optimists/pessimists interaction, the resulting aggregate attitude is a representation of what is known as "*Market Sentiment*", the "disobedient psychology of the market" *as a whole* to which Keynes attached great importance in explaining sudden changes in the state of confidence of entrepreneurs, their willingness to invest, and hence economic fluctuations.

It is worth noting, however, that Keynes himself did not overestimate such influence and remarked:

> "We should not conclude from this that everything depends on waves of irrational psychology. On the contrary, the state of long term expectation is often steady, and, even when it is not, the other factors exert their compensating effects"(*GT*, p. 163).

He just claimed for remembering the role of agents' innate characteristics and psychology as important factors that help agents themselves to overcome the difficulties that the lack of information presented them with.

In this sense, Keynes in the *General Theory* was depicting the situation of "believably simple people coping with incredibly complex situations" as opposed to Neo Classical economics which seems to describe "the behaviour of incredibly smart people in unbelievably simple situations" (Leijonhufvud, 1996).

3. Protagonists on stage: *MEC, MPC* and *LP*

As said at the beginning, in the *QJE* article, Keynes identified three main fundamental factors in his theory of business cycles and unemployment, namely the *Marginal Efficiency of Capital (MEC)*, the *Marginal Propensity to Consume (MPC)* and the *Liquidity Preference (LP)*. In particular, the former plays the principal role in driving fluctuations, while the latter play a complementary part in determining the aggregate output level.

They all share a common characteristic, that is, they are "behavioural" magnitudes in that they are strongly influenced by how agents decide to cope with uncertainty.

3.1. The Marginal Efficiency of Capital

In the *GT*, lot of effort is devoted to describe how entrepreneurs make their investment decisions. Entrepreneurs decide whether to invest or not comparing the *MEC* of their projects with the interest rate: the *MEC* is

"[...] equal to the rate of discount which would make the present value of the series of annuities [π_t] given by the returns *expected* from the capital asset during its life just equal to its supply price", where the supply price is indeed "[...]the price which would just induce a manufacturer newly to produce an additional unit of such assets" (*GT*, p. 135)

That is to say, the *MEC* for a particular capital asset as of time t is that discount rate ρ_t for which

$$\sum_i \frac{\pi_{t+i}}{(1+\rho_t)^i} = P_{kt}, \quad i = 1, \ldots$$

Equivalently, we can use the Net Present Value (NPV) formulation, such that

$$\sum_i \frac{\pi_{t+i}}{(1+\rho_t)^i} - P_{kt} = 0$$

Keynes's interpretation is that, if the *MEC* is greater than the interest rate, it means that the expected return from investing in the capital asset is greater than the return from lending an equivalent amount of money at the current interest rate (Chick, 1983). Then, prospective profits make the project desirable and the investment is undertaken. On the other hand, if the current interest rate is higher than the *MEC*, it is more profitable to lend the money with respect to invest it, so that the project fails to be realized[27]. Keynes also accepted the principle that the larger the scale of investment, the lower the *MEC*[28] . As a result, the level of investment in the economy is determined up to the point where the *MEC* is equal to the interest rate.

[27] As is well known from the corporate finance literature, the foregoing is a broad general principle which may not be immediately operative. The first problem is that the NPV equation may have more than one solution for ρ (this occurs if the series of π_t is non-monotonic). The second problem is whether the capital asset is divisible or not. I shall address these issues in the section on the implementation of the model.

[28] This principle is controversial too. First, it should be specified whether it holds for a single investment or for aggregate investment. For a single investment, the NPV equation makes it clear that the princple holds true in terms of *value of the capital asset*: if P_k is larger, *cet. par.* ρ results smaller. Yet, in *real terms*, say the number of identical capital units of price P_k, the principle holds true only if there are internal diseconomies of scale such that π_t falls as the number of capital units increases. If one looks at aggregate real investment across individual investors, external diseconomies of scale must be at work.

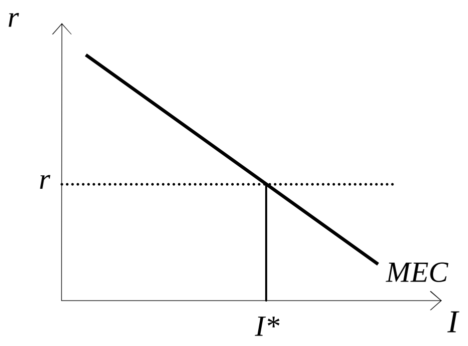


Figure 1

Movements of the *MEC* curve translate into changes in the investment demand. Nonetheless, Keynes asserted that changes in investment demand are not the result of absolute changes in the *MEC*, but to the *relative movement* of the *MEC* with respect to the interest rate. The *MEC* pulls investment only if it is raising while the interest rate decreases or does not change, but

"if the rate of interest were to rise *pari passu* with the marginal efficiency of capital, there would be *no* stimulating effect from the expectation of rising prices. For the stimulus to output depends on the marginal efficiency of a given stock of capital rising *relatively* to the rate of interest" (*GT*, p. 143)

Along this line of reasoning, in chapter 22 of the *General Theory*, Keynes pointed out that given the *MEC* being responsible for changes in investment , and investment playing an important part in determining the employment level, then aggregate economic fluctuations must be the outcome of changes in the marginal efficiency of capital:

"[But] I suggest that the essential character of the trade cycle and, especially, the regularity of the time-sequence and of duration which justifies us in calling it a *cycle*, is mainly due to the way in which the marginal efficiency of capital fluctuates. The trade cycle is best regarded, I think, as being occasioned by a cyclical change in the marginal efficiency of capital, though complicated and often aggravated by associated changes in the other significant short period variables of the economic system" (*GT*, p. 313).

Business cycles occur because of sudden changes in the *MEC*, and just afterwards they are aggravated by the remain factors, such as the fluctuations in the propensity to consume or in the state of liquidity preferences. If the *MEC* were not to change at all, we would end up in a situation of stable long run equilibrium.

Therefore Keynes suggested that what causes *MEC* movements is also responsible for aggregate economic movements. Hence to understand the business cycle is necessary to analyze what causes changes in entrepreneurs' *MEC*.

"[...] The marginal efficiency of capital depends, not only on the existing abundance or scarcity of capital-goods and the current cost of production of capital-goods, but also on current expectations as to the future yield of capital-goods." (*GT*, p. 315)

From this passage we can appreciate how the non probabilistic motives to action enter into the determination of economic dynamics through their influence over long term expectations and in turn over the *MEC*. The different expectations' formation mechanisms, determined by subjective entrepreneurs' feelings about the future and Market Sentiment, lead to distinct expected profits and finally to distinct *MEC* evaluations. But if entrepreneurs' *MEC*s change along with their spontaneous optimism or pessimism, then changes in the way in which entrepreneurs face the future causes movements in the aggregate investment demand. Again, in Keynes' words:

"It is important to understand the dependence of the marginal efficiency of capital of a given stock of capital on changes in expectations, because it is chiefly this dependence which renders the marginal efficiency of capital subject to the somewhat violent fluctuations which are the explanation of the trade cycle" (*GT*, p. 143-144)

As suggested by the previous paragraph, the occurrence of booms and slumps is the consequence of the unstable and volatile nature of long term expectations which

"being based on so flimsy a foundation, it is subject to sudden and violent changes. The practice of calmness and immobility, of certainty and security, suddenly breaks down. New fears and hopes will, without warning, take charge of human conduct. [...] At all times the vague panic fears and equally vague and unreasoned hopes are not really lulled, and lie but a little way below the surface" (*QJE*, p. 118).

More specifically, Keynes presented a new way for analyzing the occurrence of a crisis asserting that a crisis is that moment when the upwards forces that drive the boom come to rest and the economy finds itself in a situation of overinvestment. Over investment is

"[...]a state of affairs where every kind of capital goods is so abundant that there is no new investment which is expected, even in conditions of full employment, to earn in the course of its life more than its replacement cost. It is only the latter state of affairs which is one of over investment" (*GT*, p. 320-321).

Moreover, he added

"The situation, which I am indicating as typical, is not one in which capital is so abundant that the community as a whole has no reasonable use for any more, but where investment is being made in conditions which are unstable and cannot endure, because it is prompted by expectations which are destined to disappointment" (*GT*, p. 321).

That is, agents' decisions are driven by an "error of optimism", and when disillusion comes the same error is replaced by an "error of pessimism" with the result that the investment's yield, when overestimated before, is expected to be less than nothing: new investment collapses, unemployment rises and new investments *in fact* yield less than nothing. Moreover,

"The boom which is destined to end in a slump is caused, therefore, by the combination of a rate of interest, which in a correct state of expectation would be too high for full employment, with a misguided state of expectations which, so long as it lasts, prevent this rate of interest from being in fact deterrent. A boom is a situation in which over optimism triumphs over a rate of interest which, in a cooler light, would be seen to be excessive" (*GT*, p. 322).

In such a situation, when the economy is driven by "the disobedient psychology of the market", moving downwards the interest rate is useless, since the economy will be able to recover only when the "error of pessimism" would be exhausted and the *MEC* revives.

3.2. The Marginal Propensity to Consume

In chapter 8 of the *GT*, Keynes clearly stated that

"The amount that the community spends on consumption obviously depends (i) partly on the amount of its income, (ii) partly on the other objective attendant circumstances, and (iii) partly on the subjective needs and the psychological propensities and habits of the individuals composing it and the principles on which the income is divided between them" (*GT*, pag.91)

Indeed, the relationship between consumption and income follows a precise psychological law stating that people are willing to increase/decrease consumption when income increases/decreases, but not by the same amount, that is, the variations in the consumption level and in the income level have the same sign but $\Delta C < \Delta Y$: this means that the *Marginal Propensity to Consume*, defined as $MPC = \partial C / \partial Y$, is positive and less then unity.

Therefore, consumption results much more a function of real income rather than nominal (money) income, and of net income rather than gross income: for these reasons, among the objective factors that mediate the relationship between consumption and income there are changes in the wage-unit, changes in the difference between income and net income, changes in the fiscal policy.

Most importantly for my purpose here, is to analyze what Keynes presented as the subjective factors affecting the *MPC*. Indeed, he identified eight motives, namely, "Enjoyment, Shortsightedness, Generosity, Miscalculation, Ostentation and Extravagance." (*GT*, pag.108): all of them not only imply different *MPC*, but also different propensity to hoard, since that part of income which is not consumed becomes part of agents' hoardings.

Even if Keynes admitted that these subjective factors are relative stable over time, and that what really determines variations in consumption are variations in income, they still play an important role in the development of the theory, mostly because they represent a way to cope with the uncertainty that characterizes consumption decisions: whenever agents are not able to determine their *MPC* through exact calculations, they can rely on the previous motives to decide the amount to be consumed/hoarded.

3.3. The Liquidity Preference

One of the most important, and most controversial too, contributions of Keynes' *GT* regards the theory of the rate of interest. Keynes asserted that the mistake of the Classical Theory has been to derive the interest rate only in relation to agents' consumption and saving decision, while underestimating another set of decisions, namely, those regarding the form in which agents want to hold the excess money left after consumption.

He recognized that money can be retained as a store of wealth, preventing agents from investing it in other forms. Then,

> "[…]the rate of interest at any time, being the reward for parting with liquidity, is a measure of the unwillingness of those who possess money to part with their liquid control over it. […] It is the "price" which equilibrates the desire to hold wealth in the form of cash with available quantity of cash;" (*GT*, pag.167)

Therefore, *LP* – "a schedule of the amount of his resources valued in terms of money or of wage-units, which he will wish to retain in the form of money in different sets of circumstances (GT, ch.13 pag.166)"- in conjunction with the available quantity of money supplied by the monetary authority, determines the actual rate of interest.

However the important contribution in this respect is highlighting that *LP* is fundamentally a psychological magnitude. There are three substantial factors affecting the preference for holding liquid money, that is, the transactions motive, the precautionary motive and the speculative motive, but each of them shares a common feature, they all are motives related to agents' evaluations of the future.

If this is the case, than *LP* as well as the interest rate are subject to uncertainty, and fluctuate together with agents' sentiment and mood.

> "[Because], partly on reasonable and partly on instinctive grounds, our desire to hold Money as a store of wealth is a barometer of the degree of our distrust of our own calculations and conventions concerning the future. Even tho this feeling about Money is itself conventional or instinctive, it operates, so to speak, at a deeper level of our motivation. It takes charge at the moments when the higher, more precarious conventions are weakened. The possession of actual money lulls our disquietude; and the premium which we require to make us part with money is the measure of the degree of our disquietude" (*QJE*, p .116)

Then, "the rate of interest is a highly psychological phenomenon" (*GT*, pag.202), and as such it has to be modelled attaching a great deal of importance to the non rational motives affecting it.

4. Animal Spirits and Market Sentiment after Keynes

This section focuses on how the elements introduced so far have been treated in the literature after Keynes. Indeed, the papers presented below do not constitute the core of some school of economic thought, but rather marginal contributions. This because mainstream economics seems to have completely dismissed Keynesian intuitions about bounded rationality.

Indeed, economists after Keynes still lacked the mathematical instruments to deal with such a theory of bounded rationality as well as Keynes did, so that the perfectly rational agents and the perfectly coordinated markets gained ground.

Nonetheless, Keynes' message did not go completely unnoticed. Shackle highlighted that connecting the investment decision with the non rational forces governing economic men's minds was extremely important, since such connection tackles the basic question of the ultimate origin of the economic magnitudes we observe; moreover he remarked

> "Keynes' whole theory of unemployment is ultimately the simple statement that, rational expectations being unattainable, we substitute for it first one and then another kind of irrational expectation: and the shift from one arbitrary basis to another gives us from time to time a moment of truth, when our artificial confidence is for the time being dissolved, and we, as business men, are afraid to invest, [...]. Keynes in the *General Theory* attempted a rational theory of a field of conduct which by the nature of its terms could be only semi-rational" (Shackle, 1967, p.129).

In less evocative terms, Robinson (1963) based his own theory of accumulation upon similar premises, stating that to understand what moves the propensity to invest, economists must concentrate equally on historical, political and psychological factors affecting entrepreneurs; moreover, once these instances are taken into account into a theoretical model, then the same model result to be "inherently unstable and fluctuates even in otherwise tranquil conditions"; she advocates for economic fluctuations to be guided by non rational motives also when asserting that "The extent of fluctuations [...] depends upon the reaction of expectations to experience, and of investment plans to expectations".

Again, for the early authors who came after Keynes, the Keynesian approach to agents' limited rationality has resulted difficult to be translated into economic models, since there were no means through which modelling an expectations' formation mechanism related to the evaluation of future outcomes; therefore, at that time, it has been the technical limitation to prevent a full development of Keynes' intuitions.

Actually, the advent of the Rational Expectations paradigm enabled economists to analytically manage models in which current outcomes depend on their future realizations, but at the same time the new assumptions wiped Keynesian's bounded rationality argument off. The new models incorporated the hypothesis of perfectly rational agents and presented microfoundations in terms of aggregate magnitudes being based on individual solutions of optimization problems.

In such well behaved world, the hypothesis of Animal Spirits was revived by the so called sunspot literature that theoretically refers to general equilibrium and tries to incorporate the idea of economic fluctuations due to some instability not related to economic fundamentals. The principal aim of this strand was to demonstrate that Animal Spirits can have an influence even in Rational Expectations equilibria. The general result achieved is that models considering extrinsic uncertainty perform better in explain economic fluctuations than real business cycle standard ones.

The development of this literature was prompted by the initial contribution of Cass and Shell (1986). They separate the intrinsic uncertainty, that is, uncertainty related to economic fundamentals, from extrinsic uncertainty consisting in random phenomena that do not affect tastes, endowments or production technology, and which they label "sunspots". Consumers' utility function is defined over prospective consumption plans, which in turn depend on the realization of the sunspot random variable. Agents are perfectly rational, hold Rational Expectations and therefore they know exactly the probability of a sunspot event happening or not. There is no production in the economy. They conclude that by introducing sunspot activity in prospective consumption plans, they are able to end up with extrinsic uncertainty affecting equilibrium allocation. Consumption allocations and equilibrium prices change along with the presence or not of sunspot activity. They conclude that price uncertainty is not related to economic fundamentals and that indeed sunspots matter in equilibrium.

Azariadis and Guesnerie (1986) work in the same line and starting from the same set of assumptions regarding agents' rationality and the rationality of their expectations, they find that prices' uncertainty is not related to fundamentals' uncertainty. They motivate the finding showing that if people hold shared beliefs about their environment, price randomness arises through a self fulfilling mechanism, that is, a Rational Expectations equilibrium is achieved if expectations are self fulfilling.

Howitt and McAfee (1992) design a Rational Expectations model in which Animal Spirits are defined as an exogenous random variable that can alternatively take two values, 'high' or 'low'. Contrary to previous contributions, the authors explicitly refer to Animal spirits as random waves of optimism and pessimism, so that when the AS variable takes value 'high', it means that optimism is prevailing, while the opposite is true if the variable takes value 'low'. Prevailing optimism leads firms to expect a high future level of employment and hence a high level of aggregate demand. These positive expectations imply positive expectations about marketing cost too; therefore the cost reduction encourages firms to hire more, thus validating the initial expectations. An equivalent self fulfilling mechanism works in the opposite case when there is pessimism prevailing. They demonstrate that the model is able to display cyclical fluctuations in Keynes' style, that is, firms' decision and hence economic downturns are not driven by a price signal, but by a random signal uncorrelated to economic fundamentals. Moreover, in the second part of the paper they dismiss the hypothesis of Rational Expectations and introduce the possibility for agents' learning. They end up showing that even when an exogenous influence is present, like the Animal Spirits variable, people's beliefs converge to the Rational Expectations case.

Indeed, even advocating for a Keynesian inspiration, the sunspot literature rises two types of concerns. First, the term Animal Spirits is used in a rather broad sense and results different from the original Keynesian concept of innate motivation to action. The exogenous disturbance considered in this literature is better regarded as the influence of Market Sentiment on economic fluctuations, that is, as in Howitt and McAfee, how random waves of optimism and pessimism influences the economy. Moreover, except for Howitt and McAfee who introduce Animal Spirits in the determination of entrepreneurs' expectations, the previous works consider the impact of Animal Spirits either directly on agents' individual consumption function (Cass, Shell 1983; Azariadis, Guesnerie 1986) or on aggregate consumption function (Farmer, Guo, 1992). In Keynes, Animal Spirits and Market Sentiment do not directly influence the economy, but they mostly impact over entrepreneurs' and consumers' behaviour: in absence of relevant information, they contribute to determine entrepreneurs' long term expectations that in turn determine the expected *MEC*. This, therefore, is tied and depends upon prospective profits, so that it cannot be viewed in any form as a random variable. Contrary to Keynes, the effect of Animal Spirits is not correlated to the investment decision, but alternatively to the consumption and hiring behaviour.

Second, all the previous models endow agents with Rational Expectations[29] and assume them to know exactly the probabilities of the Animal Spirits (sunspot) event happening and to take decisions upon the evaluation of mathematical expected values. Then, these models deal with risk rather than uncertainty.

If this is the case, they depart from Keynes' view about uncertainty: Animal Spirits matter in the economy because there is non probabilistic uncertainty that prevents agents from using expected utility theory techniques, so it is difficult to reconcile sunspots with truly Keynesian Animal spirits in absence of uncertainty.

Therefore, it appears that the literature that sought to explain economic fluctuations in terms of non fully rational motives affecting the economy, failed in incorporating some of the most important Keynesian ideas.

In recent times, there have been attempts to revive the so called Animal Spirits interpretation in still different ways.

Harvey (2002) has tried to translate Keynes's chapter 22 into a system dynamics framework: he shows that giving the *MEC* a determinant role, it is possible to recreate fluctuations both

[29] Again, Howitt and McAfee (1992) differs in that the second part of their paper is devoted to the analysis of the system dismissing rational expectations hypothesis.

in expectations and in the economic activity in general. Overall, his works advocates the great importance of the way in which agents form expectations in determining economic dynamics. Yet it remains at a very rough level, without exerting effort in better explaining the factors affecting the *MEC* and in turn investment.

On the other hand, Fontana and Marchionatti (2007) develop a model which is very similar in scope to mine: they depart arguing that Keynesian economics can be better understood as a science of complexity in that Keynes attached a great deal of importance to "changing and unstable factors like "motives, expectations, psychological uncertainties" in a context of limited knowledge and structural uncertainty: this makes the object of analysis complex". They continue arguing that

> "This non-homogeneity through time compels economics to undertake inductive analysis and to take the particular characteristics of the historical world into account" (p. 4).

Given the economic complexity in which agents move,

> "[A]ccording to Keynes the right language for the construction of the model is not symbolic-mathematical language –Keynes referred to the traditional mathematical approach in economics based on linearity and systems of differential equations –, that seems not to be the best way to understand complex situations, but a quasi-formal way of exposition, i.e. ordinary language, as in Marshall, intended "to suggest the whole bundle of associated ideas". This methodological strategy of research has its core in the logical question: it is correct to apply a certain method to a certain specific problem?, or, is the approach adopted coherent with the properties of the system to be analyzed? In this sense we may say that the quasi-formal way of exposition was a correct approach to a complex problem in the absence of more formal approaches to cope with these complexities." (p. 5-6)

Therefore, they believe that the best way to assess this way of modeling is through Agent Based modeling, since ABMs result flexible enough as to enable economists to deal with literary models a la Keynes or Marshall.

Upon these premises they construct a quasi formal agent based model in which relations between variable are not formulated in strict mathematical terms. In particular they characterize the entrepreneur as an innovator and they assume the entrepreneurial behavior to be influenced by the political, social and economic atmosphere: they identify Animal Spirits as the Keynesian "urge to action", that is, the element that constitutes entrepreneurs' impulse to undertake innovation and investment.

Animal Spirits is described as a function depending on the political, the social, the economic atmosphere and on entrepreneurs' risk propensity: each of these components is in turn a function of trust, experience, innate ability. At each period entrepreneurs analyze their neighbors' behavior and based on this evidence they revise their perceived social, political and economic atmosphere and finally they update their Animal Spirits. If current Animal Spirits are higher than previous ones, investment and innovation are undertaken.

Simulation results show the consistence of the framework since investment results in cyclical dynamics just as empirical evidence demonstrates.

I feel very sympathetic with the approach and completely share the theoretical assumptions. However, it should be recognized that Keynes's non rational residual motives do not merely influence entrepreneurial activity, but all the economic decisions in general: for this reason, here I shall go further into the modeling effort and try to model consumers' behavior too.

Eventually, it is worth referring here to the works conducted by Bruun (1999, 2008): even not directly tackling the Animal Spirits approach, her work differs substantially with the previous literature that attempted to translate Keynes because she dismisses a priori the hypothesis of agents' rationality, letting behavioural rules having a role instead of optimizing processes.

In her most recent paper (2008), she designs a model in line with Keynesian macrofoundation and based upon the description of simple micro behavioural rules that each agent's type uses in taking decision. Agents' institutional environment is a monetary economy. Her final aim is to show that just endowing agents with simple behavioural rules instead of optimizing ones, it is possible to recreate a system which displays aggregate consistence.

The present work is very similar in scope with Bruun's since I move from the apparent failure of previous models in capturing the quintessential Keynesian feature and try to refresh it using ABM.

Nonetheless, my contribution differs in that I specifically want to build a model capable of assessing the impact of Market Sentiment and long term expectations on consumption, investment and the liquidity preference, while she offers a broader interpretation of Keynes's work not focusing on these feature.

It is also worth recalling that Market Sentiment has become a rather common tool for conjunctural analysis. Past studies as well as more recent ones (e.g. Taylor, McNabb (2007); Throop (1992)), indicate that changes in the consumer confidence indicators, such as the University of Michigan's Consumer Sentiment Index, cause changes in GDP both for Europe and US and that these indicators perform well in explaining GDP's variability. Moreover, they result good leading indicators for the business cycle since movements in the indexes lead turning points in the GDP, compared with other leading indicators. The consumer confidence indicators mostly represent people's mood towards the current state of the economy as well as the institutional environment, and for this reason they can be considered good proxy for Keynes's Market Sentiment variable: therefore, their being good leading indicators suggests that indeed the cycle is leaded by some factors not directly related to economic fundamentals but to agents' psychology.

Recent contributions from the behavioural and experimental literature (e.g. Leiser, Aroch (2008)) demonstrate that common people have just a naive understanding of economic variables and this is due to the lack of information and cognitive ability to process it[30], just as Keynes claimed. The result is that people treat and evaluate economic magnitudes in a rather "sentimental" way, attaching them good or negative values depending on whether the variable positively or negatively influences their standard of living, quite far away from any kind of economic plausibility or concern. The fact that agents could have different perceptions about economic variables depending on their mood then recall Keynes argument about Market Sentiment.

This to say that both the empirical evidence and the behavioural literature suggests that the influence of Market Sentiment on the economy is relevant, and it is connected to the fact that agents are constrained in their access to information and hence to the full understanding of economic dynamics, leading them to evaluate economic variable relying on heuristics and personal feeling. Then, along with the development of behavioural economics literature, Keynes' Market Sentiment argument has gained strength and it deserves a formal tentative treatment.

5. An ABM of a Keynesian economy

In this section I present an ABM model of a Keynesian economy, that is, an economy characterized by Keynes's three fundamental factors, *MEC*, *MPC* and *LP*, in the determination of investment, consumption and the interest rate. The analytical framework is thus essentially of the IS-LM type, while however not dismissing Keynes's most peculiar treatment of the three fundamental factors, that is, their being subject to agents' uncertainty and bounded rationality in the sense explained in section 2.

In particular, to capture the effect of uncertainty and bounded rationality on entrepreneurs' and consumers' decisions, the model focuses on the *Market Sentiment motive*, which, I recall, is here meant to be the interactive, "aggregate" result of agents characterized by a subjective non-probabilistic attitude (optimism vs. pessimism). It is the Market Sentiment of entrepreneurs and consumers that, by way of the *MEC*, *MPC* and *LP*, feeds the macroeconomic relationships determining investment, consumption and the interest rate. The economy is a closed one and it is populated by *N* entrepreneurs and *N* consumers, who are interacting and can change mood upon this interaction; they will alternatively be of two kinds, optimist or pessimist. To this reshaping of the IS-LM framework, it is also added an aggregate supply function that, drawing on Keynes's representation of the labour market, relates changes in economic activity with changes in the general price level (GPL).

The aggregate functions are to be interpreted as the emergent characteristics of a population of interacting agents in the meaning proposed by Colander et al. (2008) and Delli Gatti et al. (2008), though in my treatment the role of "bottom-up" interaction is restricted to the determina-

[30] See chapter 4 for a more detailed discussion

tion of the *MEC*, *MPC,* and *LP* drivers of, respectively, the investment, consumption and money demand functions that are instead directly treated as aggregate variables. This modeling choice has been done to ensure the closest resemblance to, and comparability with, traditional Keynesian models as well as other ABMs of Keynesian inspirations discussed in the previous section.

In what follows, I will first describe the modelling of the three building blocks of the IS-LM system, then the Kirman algorithm that generates optimist/pessimist interactions, and finally the aggregate supply function that closes the whole model.

5.2 The Marginal Efficiency of Capital

Let us start from the NPV equation for a single capital unit given in section 3.1:

$$\sum_i \frac{\pi_{t+i}}{(1+\rho_t)^i} - P_{kt} = 0$$

All capital units are technically identical and last for one period. Therefore, the NPV equation implies that

$$\frac{\pi_{t+1}}{P_{kt}} = \rho_t$$

which has the straightforward meaning that the *MEC* is the expected real return to capital. Capital units are homogeneous with consumption goods, so that a single GPL holds, $P_{kt} = P_t$.

Individual investment consists of a single capital unit. Entrepreneurs decide whether to invest or not comparing the *MEC* of a capital unit against the real interest rate. Any time the *MEC* results greater than the real interest rate it will be beneficial to invest, while if the *MEC* is lower than the real interest rate, the opposite will be true. Given the same real interest rate for all, aggregate investment will result higher or lower depending on whether entrepreneurs with higher or lower *MEC* prevail. Therefore, I first focus on the emergence of the "aggregate" *MEC*., $\bar{\rho}_t$

The latter is the result of Market Sentiment in the following way. All entrepreneurs observe the latest realization of the real return to capital in the economy, $\hat{\rho}_{t-1}$. Then an optimist believes it will rise by $\eta > 0$ in next period, whereas a pessimists believes the opposite. Let us call η the "momentun" of Market Sentiment. Given a fixed number of entrepreneurs *N*, for each period *t* let O_t and $(N - O_t)$ be the number of optimists and pessimists, respectively. Therefore, the aggregate *MEC* results from the linear combination of optimists and pessimists' expectations:

(1) $$\bar{\rho}_t = \frac{O_t}{N} \cdot (1+\eta) \cdot \hat{\rho}_{t-1} + \left(N - \frac{O_t}{N} \right) \cdot (1-\eta) \cdot \hat{\rho}_{t-1}$$

where

$$\hat{\rho}_{t-1} = \frac{\alpha \cdot Y_{t-1}}{K_{t-1}}$$

is a measure of the economy's rate of return to capital in the previous period: $\alpha \cdot Y_{t-1}$ represents a proxy for period aggregate profits as a share of GDP, while K_{t-1} represents the aggregate capital stock measured with the Perpetual Inventory Method[31].

Having a measure of the aggregate *MEC*, following both Keynes and Tobin (1969), the aggregate investment function can be described by

(2) $$I_t = \phi \cdot I_{t-1} + \lambda \cdot (q_t - 1) \quad ,$$

where $$q_t = \frac{\bar{\rho}_t}{\hat{r}_t}$$

Investment increases along with the aggregate *MEC* prevailing over the real interest rate. Yet the chance of this happening is greater when optimism prevails since it pulls *MEC* upwards; in the same way, it is also possible that the level of investment does not fall in periods of pessimism if the real interest rate is kept low enough. Therefore, this implies that investment inversely depends on the real interest rate, since an increase in the rate leads either to a decrease in the investment level, or to a lower increase in it.

The investment function also displays a certain level of inertia since current period investment partially depends on previous period's one: this to say that even if Market Sentiment influences entrepreneurs' mood, their investing strategy is somehow consistent with their past behaviour, so that it is not completely biased by psychological factors.

5.2. The Marginal Propensity to Consume

As for the consumption function, Keynes' psychological law states that consumption increases as long as income increases, and vice versa, but less than proportionally, and that this is the result of the willingness of households to save in good times in view of bad times. As a result, households smooth their standard of living over time. Therefore, upon this general characterization and following Keynes' argument about the subjective influences over consumers' spending behaviour, we should examine how optimism and pessimism lead to different consumption behaviour.

To this effect, we can take an insight from the interpretation of the Keynesian theory given by the initial elaborations of the Life Cycle and Permanent Income theories (Friedman (1957), Modigliani (1954)), in particular as regards the distinction between permanent or transi-

[31] In particular, we compute current period capital stock following: $K_t = \sum_{l=0}^{L-1} \left(1 - l/L\right) \cdot I_{t-l}$, where L is the life's length of the machinery.

tory changes in income. This may at first sight appear inappropriate, since these authors are generally associated with "neoclassical" reformulations of the consumption function. However, this interpretation is not entirely correct. In particular with regard to Modigliani, his original aim was to test and enhance empirically Keynes's intuition about consumption smoothing – a well-known empirical regularity. In fact, the key idea of Modigliani and Friedman, that households compare their present income with future prospects, as well as the idea of saving in good times to sustain consumption in bad times, were already in Keynes. Keynes's consumers *are* forward-looking.[32] The neoclassical twist of the theory occurred when it was assumed that households have perfect information or Rational Expectations about their future income streams, and on this basis they engage in lifetime expected utility maximization. In the present model, these two assumptions are (re)dropped, whereas Market Sentiments about future prospects are reinstated.

In particular, it is assumed that all consumers aim at a constant or normal level of consumption $\bar{C}$. This level of consumption is achieved as long as real income is constant and is expected to remain such. Then it is also assumed that optimistic agents are those who, in a situation of increasing income, believe it to be permanent, and hence raise their normal consumption by the same amount; in a situation of decreasing income, they believe it to be transitory, and hence they do not change their normal consumption by dissaving. Pessimistic agents behave symmetrically, judging income gains transitory, and hence saving them, while judging income losses permanent, and hence reducing normal consumption. Summarizing,

- If $Y_t - Y_{t-1} > 0$

  Optimists consume $C_t^O = \bar{C} + (Y_t - Y_{t-1})$

  Pessimists consume $C_t^P = \bar{C}$ and save $S^P{}_t = (Y_t - Y_{t-1})$
- If $Y_t - Y_{t-1} < 0$

  Optimists consume $C_t^O = \bar{C}$ and save $S^O{}_t = (Y_t - Y_{t-1}) < 0$

  Pessimists consume $C_t^P = \bar{C} - (Y_t - Y_{t-1})$

Hence, aggregate consumption results to be the linear combination of pessimists and optimists' consumption,

$$(3) \qquad C_t = \begin{cases} \bar{C} + \dfrac{O_t}{N} \cdot (Y_t - Y_{t-1}) & if \quad Y_t - Y_{t-1} > 0 \\ \bar{C} + \left(N - \dfrac{O_t}{N} \right) \cdot (Y_t - Y_{t-1}) & if \quad Y_t - Y_{t-1} < 0 \end{cases}$$

[32] In this respect, neither the traditional textbook Keynesian consumption function based on myopic consumers is particularly respectful of Keynes's thought.

Notice that income dynamics determines consumption increases or decreases, while Market Sentiment determines the quantitative impact of the latter over aggregate consumption. In particular, the *MPC* is not constant, but depends on the degree optimism among consumers. As long as $O_t < N$, the *MPC* is less than unity, but waves of optimism or pessimism raise or lower it. Moreover, the effect of optimism or pessimism is asymmetric during booms or slumps. If say optimism prevails during booms and pessimism during slumps, then Market Sentiment acts as cyclical amplifier; if instead consumers happen to change their mood in a countercyclical manner, then Market Sentiment helps smoothing the cycle.

5.3. The Liquidity Preference

The model is further defined by the equilibrium equation for the money market. Let us start from a standard LM function where low case letters denote logarithms (except for the nominal interest rate r_t)

$$r_t = \frac{\mu}{\theta} y_t - \frac{1}{\theta} \cdot \left(m_t - p_t \right) \tag{4}$$

and μ is the income elasticity and θ is the interest-rate semi-elasticity of money demand, *m* is the exogenous money supply and p_t is the GPL.

Recalling Keynes's words from the 1937 paper, it seems appropriate to assume that Market Sentiment influences asset-holders' attitude towards liquidity too, and therefore the relationship between money supply and the interest rate. It is plausible that optimistic agents display a smaller propensity to use money as a storage of wealth because they are more confident and trustful about the future. On the contrary, pessimistic agents tend to have a higher liquidity preference because they feel unsecure and the possession of money lulls their fears. Confronted with the same levels of income, interest rate, and GPL, the pessimist will wish more money than the optimist.Therefore, in a money market dominated by pessimists the money demand receives a positive shock, which then impacts positively upon the interest rate, whereas the opposite occurs when the market is dominated by optimists.

To account for this interpretation of the money market, I introduce in the standard LM function a shock term that accounts for the relative impact of optimists or pessimists over the money demand.

The LM function then becomes:

$$r_t = \frac{\mu}{\theta} y_t - \frac{1}{\theta} \cdot \left(m_t - p_t \right) + \nu_t \tag{5}$$

The shock is given by:

$$(6) \qquad \nu_t = \left(\frac{O_{it}}{N}\right)\cdot \nu^O + \left(\frac{N-O_{it}}{N}\right)\cdot \nu^P$$

with $\nu^P > 0$ and $\nu^O < 0$.

Again, ν represents the relative impact of optimists' and pessimists' liquidity preference over the money demand

5.4. Aggregate supply

Although the *GT* lacks a complete and clear treatment of the supply side of the economy, I introduce an aggregate supply function trying to capture the main intuitions about the topic. In particular, I analyze what makes the entrepreneurs willing to increase employment and production.

The basic principle which characterizes supply theory in the *GT* is the distinction drawn in chapter 19 between contractual wages, which are in money terms, and actual real wages, which result from the GPL, the latter being out of control of single firms and workers. As a consequence, money wage bargaining takes place with a view to the GPL that will prevail *afterwards* . To adapt this idea to our ABM framework, let us assume that, at time *t*, the parties set the nominal wage rate W_t that will become operative in the labour contract for time $t+1$[33]. The nominal wage rate W_t is determined as $W_t = w^c_{t+1} \cdot P^e_{t+1}$, that is, entrepreneurs and workers agree over a contractual real wage rate w^c_{t+1} adjusted for the price level expected for period *t*+1. Then, in period *t*+1 the actual real wage rate that workers face is given by $w_{t+1} = \frac{W_t}{P_{t+1}} = \frac{w^C_{t+1}\cdot P^e_{t+1}}{P_{t+1}}$. This implies that despite the contractual arrangement of the previous period, entrepreneurs and workers may face a value for w_{t+1} which is different with respect to w^C_{t+1}. In particular, w_{t+1} will be higher (lower) than w^C_{t+1} if P_{t+1} is lower (higher) than expected. The price surprise works as long as the parties are not able to perfectly foresight the future price level, and as long as it is not possible to immediately adjust contracts to the current price level[34].

Therefore, the price surprise influences entrepreneurs' employment policy: whenever the price level is higher than expected, firms' labour costs diminish and they are willing to hire new

[33] For a similar treatment see Hargreaves.-Heap (1992) and Tamborini (2007).
[34] Contrary to entrenched, forced interpretation of chapter 19 of the *GT*, this phenomenon has little to do with money wages being fixed and with money illusion.

workers; when the price level is lower than expected the opposite happens. This translates into the following "Marshallian" aggregate supply function:

$$(7) \qquad \pi_t = \beta\pi_t^e + \varphi(Y_t - Y_{t-1})$$

This function can be dubbed "Marshallian" because it indicates, for an initial GPL $P_{t\text{-}1}$ and a given expectation P^e_t embedded into money wages (so that $\pi^e_t \equiv P^e_t/P_t - 1$), by how much the actual GPL P_t should rise (so that $\pi_t \equiv P_t/P_t - 1$) in order to induce firms to increase supply from $Y_{t\text{-}1}$ to Y_t. The parameter β captures the extent of forward indexation of money wages, while φ is a technological parameter. Clearly, with $\beta = 1$ and $\pi^e_t = \pi_t$ we fall in the neoclassical case of perfectly indexed money wages and perfect foresight, so that $Y_t = Y_{t\text{-}1}$, and aggregate supply is insensitive to GPL fluctuations.

As to price expectations, it seemed inconvenient to include them, too, into the realm of Market Sentiment. First, because this was not Keynes's choice, or at least, he did not give to price expectations the same importance he gave to the other factors considered so far. This was not casual. As explained in section 2, Keynes's concern about the effects of uncertainty on expectations was mainly related to their long-term dimension, whereas forecasts over price fluctuations have typically shorter-run horizon. As an alternative, I have chosen to stick with the Marshallian tradition of adaptive processes (e.g. Leijonhufvud, 1996), assuming adaptive inflation expectations, such that $\pi_t^e = \overline{\pi}_{t-3}$, i.e., expected inflation is equal to the average inflation of the last five periods.

Finally, the simple market-clearing condition for output is

$$(8) \qquad Y_t = I_t + C_t$$

5.5 Modelling Market Sentiment

As explained in section 2, Market Sentiment in this model is the result of repeated social interactions between individual optimists and pessimists. An effective model of this opinion formation mechanism has been put forward by Kirman (1993). This algorithm works as follow. At any point in time *t*, there are O_t optimistic agents out of a population of N agents. Agents meet randomly pair wise and exchange their opinions. If the two agents have the same opinion, nothing happens. If they have different opinions, there is a fixed probability $(1 - \delta)$ that one of the two changes opinion. There is also a (small) fixed probability ε that an agent changes his/her opinion independently. If we extend the interaction mechanism to the whole population, the social dynamics of optimists will be completely described by

(9) $$O_t = O_{t-1} + \begin{cases} 1 & with\ probability\ \ p^1_{t-1} = \left(N - \dfrac{O_{t-1}}{N}\right) \cdot \left[\varepsilon + (1-\delta) \cdot \dfrac{O_{t-1}}{N-1}\right] \\ -1 & with\ probability\ \ p^2_{t-1} = \dfrac{O_{t-1}}{N} \cdot \left[\varepsilon + (1-\delta) \cdot \dfrac{N - O_{t-1}}{N-1}\right] \\ 0 & with\ probability\ \ p^3_{t-1} = 1 - p^1_{t-1} - p^2_{t-1} \end{cases}$$

As can be noted, the probability of a pessimist becoming an optimist, $p^1{}_{t\text{-}1}$, or of an optimist becoming a pessimist, $p^1{}_{t\text{-}2}$, depends on the share of optimists and pessimists, respectively, so that the more numerous the social group the more social power it has. Nonetheless, the process' dynamics is completely determined by ε and by $(1-\delta)$, without any further assumptions.

Kirman's algorithm is peculiar in that it describes a process characterized by perpetual change, that is. O_t does not reach a steady state value, rather its evolution is characterized by sudden changes. Moreover, this sudden changes are solely driven by the endogenous interaction between agents rather than some exogenous shocks. For such characteristics, the process results particularly suited to represent Market Sentiment waves that finally could lead to fluctuations in agents' mood.

The algorithm described above assumes fixed probabilities ε and δ. As a consequence, Market Sentiment evolves as an exogenous process, totally independent of the parallel evolution of the economy. This may not be satisfactory, since it may be the case that either self conversion or conversion become more likely for those agents whose prior attitude turns out to be "falsified" by the actual state of the economy. That is to say, optimists are more likely to become pessimists during a slump, and pessimists to become optimists during a boom.

In terms of Kirman's algorithm, this translates into making the probability of conversion depending on the dynamic evolution of output. Thus, the probability of becoming an optimists increases as long as output is growing, while on the contrary the probability of becoming a pessimist increases when output suffers a reduction, that is,

(10) $$\delta^O_t = \begin{cases} \delta + \alpha & if\ \ Y_{t-1} > Y_{t-2} \\ \delta - \alpha & otherwise \end{cases}$$

$$\delta^P_t = \begin{cases} \delta + \alpha & if\ \ Y_{t-1} < Y_{t-2} \\ \delta - \alpha & otherwise \end{cases}$$

Since δ represents the probability of not changing mind, this specification entails the idea that an optimist will be less willing to change her mind if output is growing. In the same way, the probability for a pessimist not to change her mind increases when output is reducing.

The two probabilistic specifications translate into different economic dynamics. Then, both the situation will be taken into account when simulating the model: in particular, I will stay with the first version of Kirman's algorithm –let's name it Unconditional Market Sentiment- for the baseline simulations of the model, while the second version will be taken into account in a subsequent computational experiment labelled Endogenous Market Sentiment.

Operationally, we will assume that the prevailing sentiment among entrepreneurs corresponds to the prevailing sentiment among consumers, and that the two populations are of equal size. Since it is plausible to consider the general feelings about economic perspectives as a common belief among all society's components, with this assumption we avoid unrealistic situations in which consumers and entrepreneurs hold opposite views.

6. Simulation results

The implementation of our ABM is aimed at assessing what kind of dynamics the designed system produces once we introduce the influence of Market Sentiment on economic decision making. The generation process of Market Sentiment that has been chosen has an intrinsic dynamic structure of its own, and according to Keynes's view, this is also transmitted to the economy through the *MEC*, *MPC* and *LP*.

In the work presented in this chapter, simulations do not want to quantitatively account for economic fluctuations. Instead their scope is to qualitatively analyze the dynamics of the system, in the spirit of "counterfactual history of thought" expressed at the beginning: What are the macro-characteristics of this economy ? Does it behave as Keynes thought of it? Does it display critical states, such as prolonged depression? What is the role of money supply? Therefore, I have not calibrated the model, and parameters have not been set so as to have the ambition of replicating real magnitudes (this exercise is left for further research). Following the same line of reasoning, no parameter space exploration will be presented. Since my aim is to submit the Keynesian apparatus – including its parameter specification as it comes out from the history of economic thought – to a computational laboratory and check the resulting dynamics, there is no means for such an exploration. I'm not interested in assessing the different dynamics resulting from different parameter specification, but rather in assessing whether this possible translation of Keynesian theory produces exactly what Keynes had in mind in terms of economic fluctuations.

Next section presents the steady state solution of the model; therefore, in section 6.2 the Market Sentiment dynamics is put in motion and the basic characteristics of this dynamics will be presented, considering diverse Kirman's parameters set up. The following sections offer the results from different computational exercises: first, I will give account for the economic dynamics resulting from the assumption of Unconditional Market Sentiment. Then, the assumption is drop and I will offer simulations considering an Endogenous Market Sentiment mechanism. Finally, the last section is devoted to assess the problem of underproduction and underinvestment, and the efficacy of monetary policy in depression periods.

6.1. Baseline

Before presenting simulation results, let us see what the model's steady state solution looks like. In the steady state, Market Sentiment has no role in determining agents' expectations in that we assume the proportion of optimist to be constant over time and equal to $1/2$, and the momentum of the Market Sentiment being equal to zero, $\eta = 0$, so that $\bar{\rho}_t = \bar{\rho}_{t-1} = \bar{\rho} = \hat{r}$. Moreover, since $\bar{\rho} = \hat{r}$, $q = 1$. Prices display no variation, $\pi = 0$, and they are set at the level $P=1$ with the money stock $M=P=1$. If this is the case, our system boils down to:

$$I = 0$$
$$C = \bar{C}$$
$$Y = \bar{Y} = \bar{C}$$
$$r = \frac{\mu}{\theta}\bar{y}$$

The following table summarizes the parameter setup

Variable	Description	Value
T	Number of periods	400
N	Number of agents	1000
S	Number of intra-period interaction for the Kirman's algorithm	150
$\bar{C} = \bar{Y}$	Steady state values for consumption and output	100
ϕ	Persistence coefficient in the investment function	0.7
λ	Tobin's q weight	10
P	Price index	1
ν^O	Optimistic Liquidity preference momentum	-0.1
ν^P	Pessimistic liquidity preference momentum	0.1
θ	Interest rate elasticity	0.5
μ	Income elasticity of money	0.5

$1-\delta$	Probability of changing opinion when meeting someone in Kirman's algorithm	0.9
ε	Probability of changing opinion autonomously	0.000325
β	Inflation expectations' coefficient	0.9
φ	Output gap coefficient	0.2

Table 1 . Parameter set up

Along with the idea of implementing a counterfactual history of economic thought, I decided to set parameters as close as possible to those suggested by economic theory. For this reason, LM coefficients are borrowed from Tobin (1956). The rest of the parameter configuration reflects the idea of endowing the economy with at least an initial stability. Here I am seeking to demonstrate whether Keynes was right in advocating for market sentiment to generate business fluctuations: then, I have tried to reduce to the minimum the possible exogenous sources of instability, so as to reserve the prominent role in determining volatility to market sentiment.

6.2. Market Sentiment in motion

The system is put in motion after letting the proportion of optimists vary following the Kirman's algorithm. The algorithm displays perpetual change, and Market Sentiment waves of optimism and pessimism will be produced. At the same time, the Market Sentiment momentum in the *MEC* takes the non-zero value η = 0.1: hence, at each round optimists expect the *MEC* to increase by 10% over the realized return to capital, while pessimists hold the opposite expectation of 10% reduction.

In order to better understand the behaviour of the social dynamics, i.e. the source of Market Sentiment, I first briefly show here the results of simulating Kirman's algorithm with different levels of the coefficient ε and δ [35].

Let us consider the case in which the probability of self conversion is relatively high and the probability of being converted by another agent is relatively low: this traduces into having agents easily changing mind autonomously and hardly changing mind when meeting other different agents.

In this situation, the system spends its entire time fluctuating around the average value of 0.5 (Figure 3)[36]: none of the social groups prevails over the other.

[35] See also Westerhoff (2005) and Westerhoff, Hohnisch (2007)

[36] Setting $\varepsilon = 0.5$ and $1-\delta = 0.3$, the volatility of the proportion of optimists series is extremely low (*std* = 0.0012)

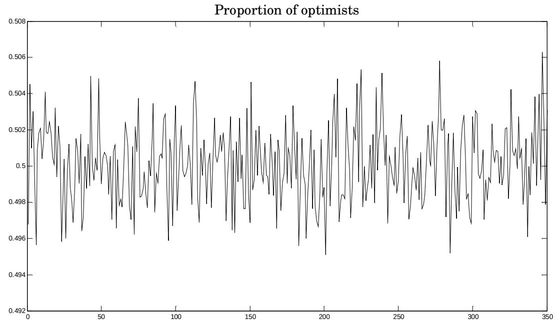


Figure 3: proportion of optimists when ε is high and $1-\delta$ is low

On the other hand, if we set the probability of self conversion relatively low and the probability of changing mind upon interaction relatively high, the system fluctuates within the extremes (Figure 4):

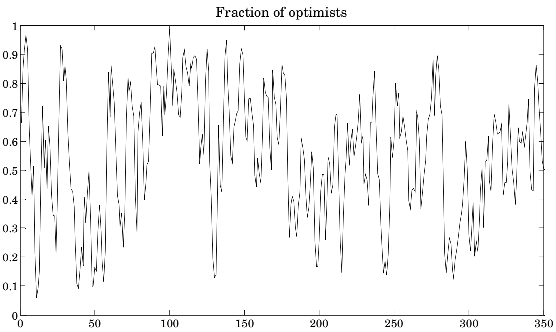
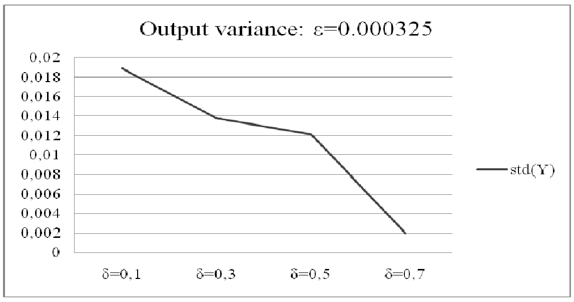


Figure 4: proportion of optimists' dynamics when ε is low and $1-\delta$ is high

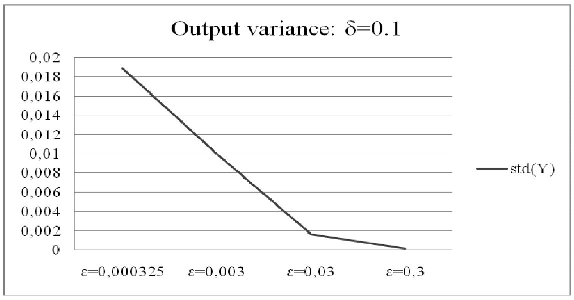
I have chosen to stay with the last parameter setup, since it describes the most interesting case: having the probability of self conversion relatively low and the probability of changing mind upon interaction relatively high means that agents rarely change their mind autonomously, instead they require to interact with others to be willing to change. Thus, agents' belief changes mostly because influenced by the prevailing Market Sentiment. Moreover, the resulting dynamics seems to well resemble the waves of optimism/pessimism Keynes asserted to influence the agents' behaviour under uncertainty.

Before presenting results in terms of variables dynamics, let me give a short insight about the influences of the algorithm dynamics over the economic one.

In order for this, I will present the trade off between Kirman system's volatility and output one obtained by simulating the model with different values for the previously presented Kirman's parameters.



(a)



(b)

Figure 5: output standard deviation under (a) decreasing probability of conversion upon interaction; (b) increasing probability of self conversion.

In figure 5 we can see how the output variability changes as long as δ increases, that is, as long as the probability of changing mind when interacting with other agents decreases. The direct consequence is that output standard deviation decreases. The same effect is obtained if we fix δ and let ε changing. This to say that output becomes less/more volatile when agents are let changing opinion more or less frequently.

6.3 Implementing the model with Unconditional Market Sentiment

In this section we consider the economic dynamics after the Market Sentiment is put in motion. Remember that in this first instance, we analyze the case in which people's sentiment is not driven by the output trend.

Accounting for economic dynamics, I will focus attention on variables' standard deviation and in particular on the relative volatility of consumption and investment with respect to GDP. Moreover, I will present cross correlation both between variables and output at different leads and lags, and between the same variables and Market Sentiment's leads and lags.

Therefore, series will be analyzed both in their long run and in the short run behaviour, for, I filter GDP, investment and consumption through the Hodrick-Prescott method[37].

[37] Following the literature, we set the smoothing parameter λ in the filter's equation equal to 100 for annual data.

Finally, I consider one simulation period as one year time; results are presented getting rid of the first 50 periods of the simulations in order to avoid spurious outcomes due to simulation's initial conditions.

The aim of the simulating exercise is to assess whether the Keynesian model presented in the previous section is able to produce consistent dynamic results.

Figure 5 shows the detrended GDP series:

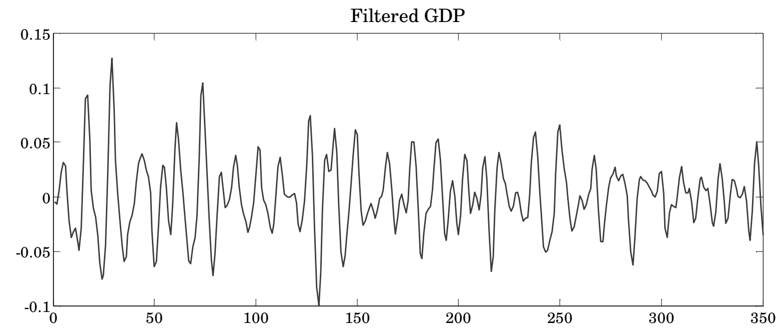


Figure 5: detrended output

Given the initial parameters set up, the model generates irregular fluctuations of different amplitudes and frequencies, resembling the business cycle ones.

In the long run, the GDP series does not display growth, and instead fluctuates into a quite definite corridor:

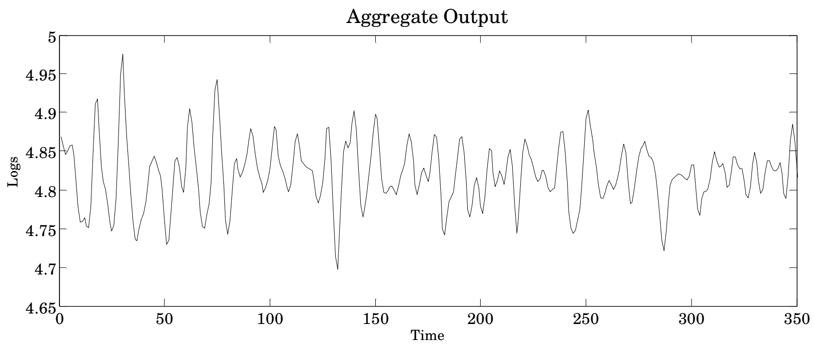


Figure 6: long run GDP

Notice that the GDP persistently stays above its steady state value ($\bar{y} = 4.6$ in logs): when we abandon the hypothesis of homogeneity among entrepreneurs' expectations, the system is not able to reach a stable equilibrium but it indeed rests quite above its potential, that is, introducing uncertainty and heterogeneity the economy gains efficiency.

Irregular fluctuations appear to be set off by the underlying social dynamics (Figure 7):

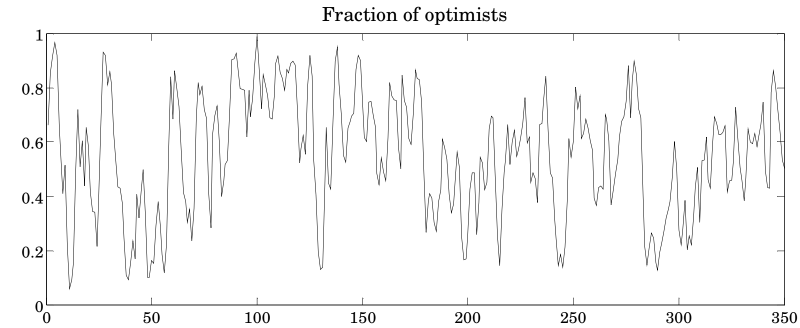


Figure 7: proportion of optimists' dynamics

Indeed, the simple correlation between the proportion of optimists in the economy in a given period and the related GDP is high ($corr(Y_t, O_t) = 0.6$).

Not only, analyzing the cross correlation structure between the proportion of optimists and output at various leads and lags (see also Table 3), the social dynamics appears to lead the business cycle, so that we can argue about Market Sentiment driven cycles.

At this stage, it is interesting to analyze the relations among the key series, that is, GDP, consumption and investment.

The empirical literature about business cycle[38] recognizes some regularities concerning the ratio between series' standard deviations, with consumption being nearly as volatile as output and investment being two/three times more volatile than GDP.

Our model seems to endorse this evidence:

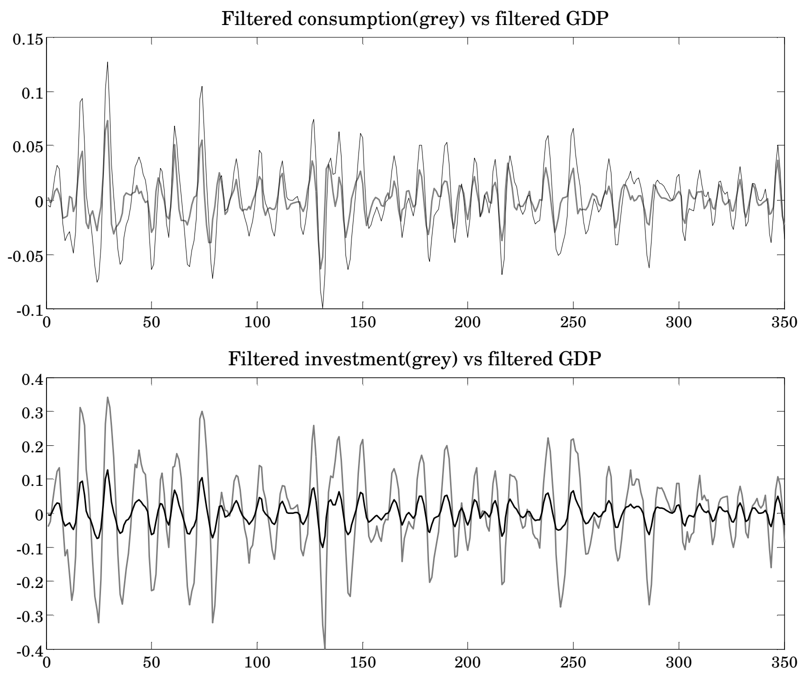


Figure 8: relationship between detrended consumption, detrended investment and detrended GDP

[38] See for example Agresti, Mojon (2001), Stadler (1994), Stock,Watson (1999).

Comparing detrended series' standard deviations, consumption is less volatile than GDP while investment's volatility is much bigger than GDP's one.

	Absolute	*Relative to GDP*
Output	0,018	1
Investment	0,091	5,03
Consumption	0,009	0,52

Table 2: detrended series standard deviations' ratio

In light of the motivation for choosing the parameter set up, the latter evidence results very interesting. Indeed, we have been able to obtain series' volatility even with stable structural parameters. This advocates for Keynes being right when claiming that the sources of economic fluctuations do really stay in the volatility of entrepreneurs' expectations. Moreover, consumption does its work in smoothing the cycle, while investment accounts for the majority of output variability.

The cross correlation structure between variables and output leads/lags presents some interesting results:

k	*-4*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*4*
Consumption	-0,6	-0,72	-0,32	0,39	0,85	0,72	0,28	-0,1	-0,26
Investment	-0,33	-0,02	0,4	0,8	0,93	0,58	-0,01	-0,46	-0,57
Nominal rate	-0,16	0,02	0,31	0,54	0,33	-0,29	-0,68	-0,49	-0,01
Real rate	-0,14	-0,01	0,26	0,48	0,3	-0,3	-0,68	-0,46	0,02
Inflation	-0,39	-0,44	-0,25	0,26	0,79	0,88	0,5	0	-0,29
Market Sentiment	-0,03	-0,01	0,02	0,08	0,15	0,2	0,14	0,01	-0,12

Table 3 : variable correlation with output at different *k* leads and lags.

Both consumption and investment are procyclical with respect to the cycle, but contrary to the empirical evidence and contrary to Keynes' supposition too, consumption leads the cycle while investment tends to lag it.

The nominal interest rate as well as the real one are procyclical reflecting a positive relationship between output increases and rates' increases. Moreover, both the rates lead output downturns by approximately one period time since they display the highest negative correlation with output at one period lag.

Along with the empirical literature, inflation is strongly procyclical.

Table 4 presents correlations between the previous series and the market sentiment dynamics:

k	*-4*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*4*
Consumption	-0,17	-0,06	0,07	0,12	0,12	0,08	0,03	0	-0,01
Investment	-0,06	0,06	0,17	0,22	0,15	0,07	0,02	-0,02	-0,03
Nominal rate	-0,01	0,07	0,11	0,03	-0,13	-0,12	-0,07	-0,03	0,01
Real rate	-0,01	0,06	0,1	0,02	-0,14	-0,13	-0,08	-0,03	0,01
Inflation	-0,11	-0,04	0,11	0,23	0,25	0,22	0,18	0,15	0,13

Table 4: cross correlations between variables and Market Sentiment at k leads/lags

As Keynes pointed out, consumption has just a small correlation with Market Sentiment dynamics, being the former mostly determined by output dynamics; indeed, the two variables that are principally affected by the market sentiment are investment and inflation. Investment lags Market Sentiment while inflation moves almost at the same pace of it.

Two final remarks.

First, both inflation and output series display a considerable degree of persistence, just as Keynes predicted.

k	*0*	*1*	*2*	*3*	*4*
Output	1	0,73	0,15	-0,32	-0,52
Inflation	1	0,7	0,17	-0,19	-0,3

Table 5: inflation and output autocorrelation

Second, the relationship between inflation and output is well resembled by the Phillips curve:

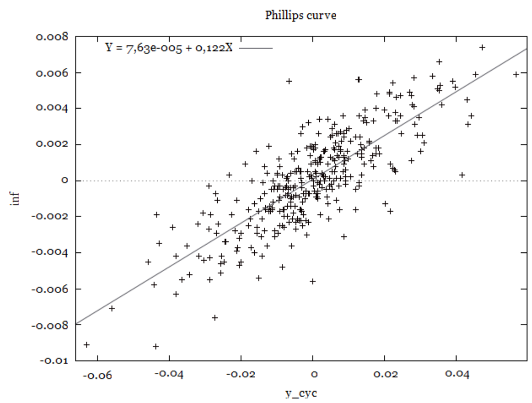


Figure 9: Phillips curve

6.4 Implementing the model with Endogenous Market Sentiment

In this section I will abandon the assumption about the exogeneity of the Market Sentiment and I will let it depending on the output trend. In this case, optimism/pessimism waves will be related to booms and recessions.

The output dynamics is strongly affected by this new assumption:

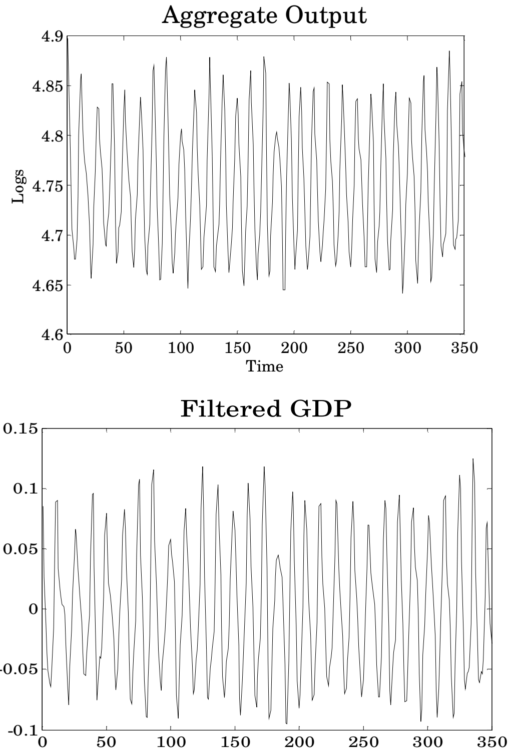


Figure 10: Endogenous Market Sentiment: aggregate and detrended GDP

There are no more irregular fluctuations but almost regular one, with GDP assuming an oscillating dynamics, both in the long and in the short run.

From the analysis of the cross correlation structure, some interesting results stand out.

k	*-4*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*4*
Consumption	-0,74	-0,53	-0,09	0,47	0,85	0,87	0,65	0,34	-0,02
Investment	-0,16	0,3	0,69	0,91	0,91	0,63	0,16	-0,34	-0,71
Nominal rate	0,3	0,42	0,5	0,57	0,41	-0,07	-0,5	-0,6	-0,48
Real rate	0,32	0,36	0,39	0,45	0,31	-0,14	-0,52	-0,56	-0,38
Inflation	-0,68	-0,39	0	0,48	0,89	0,96	0,71	0,31	-0,11
Market Sentiment	-0,25	-0,01	0,25	0,43	0,52	0,47	0,28	0	-0,27

Table 6: Endogenous Market Sentiment: correlation between variables and output at different k leads and lags

k	*-4*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*4*
Consumption	-0,44	-0,24	0,03	0,26	0,41	0,46	0,39	0,2	-0,03
Investment	-0,1	0,17	0,41	0,53	0,49	0,33	0,09	-0,16	-0,37
Nominal rate	0,13	0,29	0,38	0,28	0,05	-0,08	-0,17	-0,28	-0,31
Real rate	0,13	0,26	0,32	0,21	-0,02	-0,12	-0,18	-0,25	-0,26
Inflation	-0,42	-0,23	0,06	0,32	0,47	0,49	0,41	0,21	-0,04

Table 7: Endogenous Market Sentiment: correlation between variables and Market Sentiment at different *k* leads and lags

The qualitative relationship between variables does not change: consumption and investment are still procyclical; consumption leads the business cycle while investment lags it. Both the interest rates are procyclical, but negatively lead the cycle. Inflation remains strongly procyclical.

Nonetheless, the Market Sentiment variable does not lead the business cycle anymore, but it follows it, since the highest correlation is reached at 0 lags. This evidence is the direct consequence of having the Market Sentiment changing along with output: complementing the basic theoretical framework with an Endogenous Market Sentiment means allowing for a feed-back mechanism between the macro performance and the micro behaviour. Finally, this feed-back mechanism implies that the two series move almost at the same pace.

Moreover, notice from Table 7 that the quantitative correlation between all the variables and Market Sentiment is higher with respect to the case of Exogenous Market Sentiment: again, the responsible for this result is the presence of the feed-back mechanism previously cited.

Finally, it is worth noting that having endogenous Market Sentiment implies a higher persistence degree both for inflation and output with respect to the previous case, as Table 8 shows:

k	*0*	*1*	*2*	*3*	*4*
Output	1	0,83	0,41	-0,06	-0,48
Inflation	1	0,78	0,36	-0,05	-0,41

Table 8: inflation and output autocorrelation

Although this enriched framework performs well in reproducing most of Keynes's claims, in particular for what concerns variables' persistence, the overall economic dynamics is qualitatively unrealistic. Output harmoniously fluctuates around its mean value, with periods of output growth followed by periods of output downturn of equal length.

This effect is almost entirely due to the inner characteristics of Kirman's algorithm. The latter is designed so as to never persistently lay either in a state or in the opposite one: when the proportion of optimists/pessimists reaches values near to one, the algorithm automatically prompt the system towards the opposite direction driving the proportion towards zero.

Hence, on the one hand decreasing output leads the proportion of optimists towards zero; nonetheless, when the zero value is approached, the system automatically prompts the fraction of optimists. This in turn drives output growth and consequently enhances the number of optimists too. Then, without the automatic regulatory force of the algorithm, the system will either collapse or explode. In this sense, designing the Market Sentiment with the Kirman's algorithm implies assuming that there exist some quasi rational forces – something like a survival instinct- in the economy that prevents it from collapsing or exploding.

6.5 Reproducing under-production and under-investment

Both under the hypothesis of Exogenous Market Sentiment and under the hypothesis of Endogenous Market Sentiment, results have endorsed most of Keynes's intuitions.

Notwithstanding, both the treatments have failed in reproducing the phenomenon of under production and under investment, that is, none of the former display sustained periods of low production and investment.

My hypothesis is that responsible for sustained recessionary periods is a pessimistic mood that constraints people with no hope for the future and no incentives for the economy to revive.

Though, in the previous section I have shown that this is not possible with Kirman's algorithm. So, here, I want to demonstrate that, given the basic theoretical framework, the only way to obtain under-investment is to condition the Market Sentiment algorithm in such a way that for a given interval time pessimism prevails over optimism.

Hence I impose the proportion of optimists to fluctuate into the interval [0; 0.2] from period t=150 till the end of the interval time, that is, I am assuming that over the last 200 periods pessimism prevails.

Notice that assuming a fixed interval for the proportion of optimists reduces the volatility of the Market Sentiment, and consequently influences the dynamics of the other aggregate variables too.

After period t=150 detrended GDP, displays a standard deviation equal to $\sigma_Y = 0.005$ contrary to $\sigma_Y = 0.017$ for the previous time interval (Figure 11)

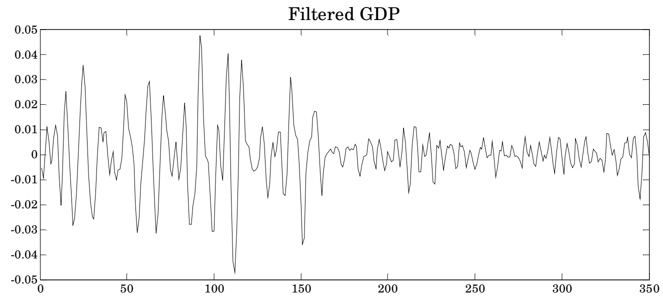


Figure 11: detrended GDP with alternating Market Sentiment (t= [0;150])
and with pessimism prevailing (t=[150;350])

A similar effect is present for all the other series, both in their short run dynamics and in the long run one.

More interesting, the prevailing pessimism entails a sustained period of underinvestment and under production:

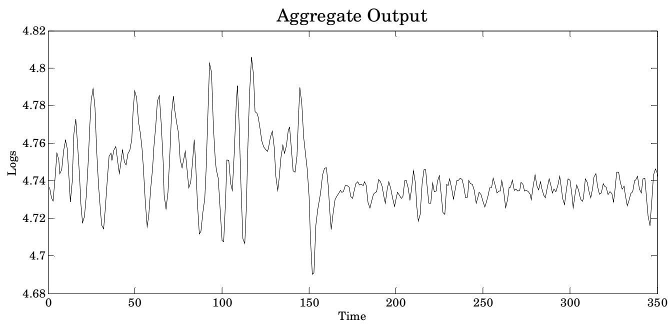


Figure 12: GDP with alternating Market Sentiment (t= [0;150])
and with pessimism prevailing (t=[150;350])

In the pessimistic period, average output drops from $y_t = 4.75$ to $y_t = 4.73$ [39].

When agents are predominantly pessimists, entrepreneurs believe their performance will deteriorate in the future and the aggregate marginal efficiency of capital decreases.

On the other hand, pessimism let agents increase their propensity to liquidity, pushing the nominal interest rate: when the money stock is kept constant, the combined effect of pessimism over the liquidity preference and of the declining output because of the decreasing marginal efficiency of capital, translates into a higher nominal interest rate. In turn, given lower inflation expectations due to diminishing output, a higher nominal interest rate triggers a higher real interest rate, which finally negatively impacts over the investment decision.

Hence, a vicious circle is set in motion that prevents the economy from the recovery.

Though it is not possible to recreate these results with the original Kirman's Market Sentiment dynamics, their importance should not go unnoticed. Indeed, we have found one source

[39] In log terms

for under production, and notably it is not strictly related to economic fundamentals but rather to agents' mood. Then, in this sense it is possible to understand why Keynes did not envision any escape from the crisis a part from making the Marginal Efficiency of Capital reviving through fostering entrepreneurs' expectations.

7. Conclusions

The scope of this chapter was to construct a agent-based macroeconomic model in the IS-LM style capable of complementing Keynes' macro framework and his behavioural microfoundation, and demonstrate that the theoretical framework enriched with bounded rationality is able to recreate economic fluctuations.

Indeed, since the release of the General Theory, many economists have been claiming that the work was not suitable for explaining economic system because it lacked any microfoundation.

However, recent contributions challenge this view advocating for a micro behaviour foundation of Keynes' macro framework: these works have tried to shed light on the micro component of Keynes' economies, i.e., the behavioural rules that guide agents in their decisions making. It is asserted that Keynes is different from the Neo Classical tradition in that he did not considered optimizing process at the very basis of human conduct but rather he imagined economic agents as being imprisoned in a very uncertain world, and, once compelled to take action, basing their decisions on heuristics, rules of thumb and personal feelings.

This kind of behavioural micro foundation open the way to an interpretation of the sources of economic fluctuations that is at odds with the most successful theories of Real Business Cycle: in *General Theory*'s chapter 22 Keynes stated that the origins of the business cycles were to be found in the disobedient market psychology, that leads entrepreneurs to change expectations about the future yield of capital assets following their personal attitude towards the future rather than exact economic calculations.

In this way, a boom corresponds to a period in which agents hold extremely positive expectations while the crisis happen when this illusions come to be disappointed.

To validate Keynes' intuitions about the non rational influences over economic fluctuations, in the spirit of a counterfactual history of economic thought, I made use of agent-based modelling techniques. The computational framework enabled me to overcome the difficulties encountered at Keynes' time in traducing his framework into a formal model since to design the agent-based model I did not need to rely on the traditional abstractions of the fully rational Representative Agent and I have been able to characterize the microeconomic level in terms of simple behavioural rules.

In particular I assumed that relying on the interactions with others, agents could alternatively become optimists or pessimists, and that their particular state of mind influences investment decisions, consumption decisions and liquidity preferences. So, the model is built on the behavioural hypothesis that when agents are optimists they have positive feelings about the future and this traduces into higher expectations about the marginal efficiency of capital and lower liquidity preference, while the opposite is true for pessimistic agents.

Simulations results have been presented referring to three different treatments of the basic framework.

First, I assume the Market Sentiment to develop without any correlation with GDP dynamics, that is, the probability of becoming pessimist/optimist is not influenced by GDP decreases/increases.

Simulations demonstrate that under this hypothesis the system is capable of displaying irregular economic fluctuations. Even if in the long run aggregate output moves into a well defined corridor, its short run dynamics resembles the business cycle one. Comparing consumption and investment volatility with that of output, we find that consumption is less volatile than output while investment is almost three times more volatile than GDP. Nonetheless, the cross correlation structure shows that investment does not lead the business cycle but lags it.

Overall, the system performs well in replicating most of Keynes's intuitions. In particular, it is worth noting that despite the initial parameter set up, which should have worked in stabilizing the economy, investment and output series are substantially volatile. Indeed, Market Sentiment dynamics is truly the engine for economic instability. Moreover, the correlation between Market Sentiment dynamics and output is highly significant, and their cross correlation demonstrates that the Market Sentiment leads the business cycle: the result confirms our hypothesis of having a business cycle driven by the social dynamics.

Second, I complement the original model letting the Market Sentiment depending on GDP evolution, in such a way that the probability of becoming an optimist/pessimist increases as long as GDP increases/decreases.

This further hypothesis has not affected the qualitative relationship between the variables. However, from a quantitative point of view, variables' covariance with lagged/leaded output is higher, and the same is true for variables' correlation with Market Sentiment leads/lags. The source for the increase in correlation resides in the hypothesis of having GDP dynamics feeding-back into the Market Sentiment one, strengthening the relationship between the two variables.

Remarkably, this scenario leads to have an higher persistence in variables' cross correlation, thus offering further evidence for Keynes' claims about persistence.

Nonetheless, the resulting output dynamics is highly unrealistic, since output harmoniously oscillates around its mean value. Indeed, I have shown that this is a consequence of the inner characteristics of Kirman's algorithm.

Although both the previous treatments are able to recreate the principal characteristics of Keynesian economics, they too both fail in reproducing the phenomenon of under production.

Since my hypothesis is that following Keynes, it is possible to have under production only assuming a prolonged pessimistic period, in the third results' section I seek evidence for this claim by fixing the proportion of optimist at a low level for a given interval of time.

Then, one of the most important Keynesian claims can only be replied if the mechanism that governs agents' interaction is stopped, that is, only if we assume that agents' interaction has no effect in making people changing mind. Indeed, this is not such an unrealistic situation. It is possible that for some exogenous reasons pessimism is so strong that no optimist is able to change any pessimist's mind; at a point in time then, an event happens that trigger agents' expectations and hence makes the economy reviving.

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Chapter 4

Inflation expectations and Market Sentiment: some computational experiments

1. Introduction

Drawing upon the theoretical framework presented in the previous chapter, our aim here is to test the performance of monetary policy rules in situations where the hypothesis of Rational Expectation is abandoned.

Indeed, I will show that once the RE hypothesis is dismissed, the performance of the monetary interventions strongly depends on how agents form their expectations and whether the monetary authority has access to agents' inflation expectations.

Section 2 briefly reviews and discusses the method of monetary policy under the Rational Expectations hypothesis, while section 3 assesses the most recent attempts to overcome it thanks to the so called Learning literature. In section 4 I propose a new framework for studying the effects of monetary policy based on the assumption of inflation expectations influenced by the Market Sentiment. Therefore, section 5 specifically outlines the characteristics of this framework while in the subsequent section simulations results are presented. Section 7 concludes.

2. A general overview of Neo Classical monetary policy theory

At the origin of the monetary policy debate concerns had been concentrated on whether the Authority should have had an active influence on the economy through discretionary policies or if better it should have had not care too much about economic dynamics, and let the system autonomously adjust to shocks.

The latter point of view was carried on by the Classical school, and it was overtaken just with the coming of the Keynesian revolution.

Indeed, in the *General Theory* Keynes devoted little effort in presenting a formal treatment of how monetary policy should be conducted, but nonetheless he definitely railed against the Classical view asserting that the Authority had to intervene in the economy in order to ensure that demand was neither excessive nor deficient.

Most importantly, while in previous works Keynes analyzed fluctuations in the price level and its stabilization, in the *General Theory* the price level is considered as historically determined and is kept exogenous to the system. It is mostly from this consideration that, regarding the *GT*, there always has been prevailing interest in fiscal policies.

The inflationary strife of the 70s undermined Keynesian theory, opening the way to different views about economic policy and monetary policy in particular.

Indeed, Neo Classical economics promoted a large consensus regarding the role of macroeconomic policy, namely, the monetary authority should be concerned with the level of output in the short run in such a way that non inflationary growth will be achieved in the long run.

Then, following Friedman (1968), the mainstream idea was that this objective could have been achieved through fixing the money supply. The authority should fix a well defined rate of growth for the money supply compatible with the rate of growth of the real economy, so that a zero inflation level would have been achieved. Upon this view, authorities should just determine the growth rate and then do nothing, since the system would have been able to autonomously adjust. Then, the monetarist view attracted much attention and became an influential policy because it permitted to overcome the problems related to the credibility issue and the inflationary bias.

Nonetheless, the approach presented various drawbacks, among which the recognition that, in well developed financial systems, it is not the money aggregate the properly control instrument for the Central Bank but instead the interest rate through which the amount of money is affected.

Moreover, starting with the end of the 80s, there has been the flourishing of the stream of literature (Bernanke, Blinder (1992); Bernanke, Gertler (1995); Clarida, Galì, Gertler (1998)) underlining the role of an active monetary policy in determining the business cycle, so that the way in which Central Banks conducted monetary policy became a relevant issue in understanding the dynamic of aggregate activity and the monetarist view lost its appeal.

Since then, the profession agreed in fixing the nominal interest rate as the policy instrument and in appointing how the interest rate should adjust to the actual state of the economy in order to control inflation and output dynamic, as the ultimate goal of monetary policy.

Moreover, there has been a growing consensus about the advantages of commitment in monetary policy rather than discretion (Allsopp, Vines (2000)): a Central Bank that makes clear what its objective is and how it is going to pursue it achieves better results than one in which the policy in always determined discretionally.

Even if the possibility of exerting some degree of judgement in conducting the policy period by period seems appealing, the clear and simple commitment to well specified monetary rules is more effective because it fosters monetary authority's transparency enhancing credibility, and it facilitates the private sector's process of forecasting.

Indeed, monetary policy theory sets on the broad distinction between instruments rules and targeting rules. The former determine the interest rate as a prescribed function of some variable of interest, while the latter are the result of a precise loss function minimization. Nonetheless, both the approaches account for commitment in monetary policy since they assume the monetary authority will commit to follow a predetermined policy rule instead of changing it period by period.

More specifically, targeting rules are derived from the solution of the Central Bank's optimization problem[40].

Given the structure of the economy, as typical DSGE models designed it, and the expectations augmented Phillips curves, the Central Bank wishes to minimize a loss function that normally takes the form of

$$L_t = \sum_t^{\infty}\left[(\pi_t - \hat{\pi})^2 + \theta(y_t - \hat{y})^2\right]$$

in which deviations of inflation and output from predetermined targets are specified.

The minimization boils down to the specification of an intertemporal path for the interest rate such that the target, in terms of inflation or output gap, will be reached in a determined amount of time.

Since the entire process is built on the capability of the monetary rule in influencing long term expectations, it results feasible only if agents are endowed with Rational expectations. The monetary authority assumes agents will form expectations in a rational way, coherently with the forecasted future course of the economy. Thus, the policy is optimal because it offers a nominal

[40] See Clarida, Galì, Gertler (1999); Svensson (1999); Woodford (2003)

anchor for inflation expectations that finally will behave exactly as the Central Bank wants them to behave.

The introduction of long term expectations into the economic model, being it through intertemporal optimization or the Phillips curve, partly changed the common ground over which the discretion vs commitment debate had been growing. Since then, it was no more a matter of intervention or not intervention of the authority, but a matter of the best way the authority could intervene in order to guide expectations, and therefore, upon these premises, commitment results the best policy.

On the other hand, instruments rules are simple reactive rules in which the instrument, the nominal interest rate, respond to changes in the price level or in the real income.

In this regard they did not rise as optimal rules, but rather have been developed in a more empirical context, namely the econometric evaluation of monetary policy rules using the methods of Rational Expectations macroeconomics.

Upon this setting, the most prominent contribution came from John Taylor who identified a "hypothetical but representative rule" (Taylor, 1993) following which the short term rate is to be raised in face of a rise in inflation and the output gap, or alternatively is to be lowered in case of a decrease in the two variables:

$$R_t = \pi_{t-1} + \varphi_\pi \cdot (\pi_{t-1} - \pi^*) + \varphi_y \cdot (y_t - y^*) + 0.02$$

An essential feature of the Taylor rule is that it obeys the Taylor principle, that is, the rule is efficient in lowering/increasing inflation as long as the interest rate over adjusts with respect to inflation, so that inflation coefficient φ_π is always greater than 1.

This kind of rule gained a lot of success since the end of the 90s because it performs well in approximating the US Fed monetary policy as well as other government's policies; moreover, they are rather simpler compared with complicated, optimal policy rules.

Importantly, Taylor rules do a better job in situations when there is uncertainty about the true structure of the economy since they result more robust than optimal rules (Orphanides, 2007).

Starting with the pioneer work of Taylor, a wide range of Taylor rules have been designed and tested to take into account the possibility of interest rate smoothing as well as to introduce expectational terms, in line with the increasing validity assigned to rules that incorporate inflation forecasts as a target[41].

[41] Among the variety of works that adopt Taylor rules, see for example Haldane,Batini(1998); Carare,Tchaidze (2005); Hetzel (2000)

Even if the instrument rule approach seems to have little in common with the theoretical oriented optimality approach, the two are built over a common fundamental hypothesis, that is, agents form expectations in a rational way. Agents are able to gather and process all the information they need to produce exact future forecasts.

The assumption makes possible for the optimal and optimized monetary policy to perform well in stabilizing the economy because it does really be able to condition agents in such a way to drive them towards the desired equilibrium. This is true also for instrument rules since they are derived econometrically from macroeconomic models that assume RE. Again, the hypothesis is the building stone of this kind of monetary theory and its effectiveness.

Therefore, as Howitt pointed out:

"The rational expectations paradigm [...] assumes that the economy is never out of a state of perfect coordination, that it always organizes activities into stable patterns in such quick order that the details of the stabilizing mechanism, and the uncertainty associated with those details, can safely be ignored. That is, in a rational-expectations equilibrium everyone's expectations about what will happen are consistent with the macroeconomic forces actually at work, and also consistent with everyone else's expectations, no matter what kind of policies are pursued." (Howitt, 1996, pag.)

3. Questioning Rational Expectations: the Learning Literature and developments

Almost contemporaneously to the success of the Rational Expectations hypothesis, a variety of experimental and psychological studies have flourished that contend the RE assumption demonstrating that the way in which people form expectations is just almost rational. Among the studies surveyed by Camerer (1995) the majority found little support for the Rational Expectations hypothesis, with forecast errors displaying non zero mean, autocorrelation and correlation with other variables[42]. Moreover, as pointed out by Duffy (2008), in recent years some macroeconomists have come to recognize that the Rational Expectations hypothesis presumes too much knowledge on the part of agents, mostly regarding the true underlying structure of the economy, whereas econometricians often are uncertain about it and rely on ad-hoc assumptions.

Therefore, the empirical evidence related to inflationary episodes suggests that inflation expectations can depart from RE and follow irrational fears, traducing into an independent mechanism untied from economic fundamentals (Orphanides, Williams 2003).

Along this view, in recent years the questioning of the RE hypothesis have entered the stage of the monetary policy debate, giving rise to different contributions that advocate for a deep examination of the inflation expectations' mechanism and for a monetary policy strongly based on the knowledge of these underlying mechanisms (Howitt, 1996).

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[42] Still, the Rational Expectation hypothesis results more reasonable in simple and univariate models compared to the multivariate models most often used.

Theoretical effort has been devoted to model expectations' formation in different ways, based on the assumption of agents' bounded rationality.

In particular, the literature concerning the effects of learning in altering monetary policy's outcomes[43] assumes agents to be not fully rational, but to be at least as smart as economists[44]. Agents form forecasts as economists do, that is, relying on some econometric model that they are able to refine period after period: they should finally end up learning the correct Rational Expectations so driving the economy towards a stable equilibrium.

The learning literature has been mostly concerned with studying whether the learning process posits constraints to monetary policy. Two different set of problems have been highlighted: on one hand, it has been demonstrated that some proposed interest rules do not perform well when agents' expectations are guided by learning, since agents' forecast errors lead to economic instability via the adjusting expectations mechanism. On the other hand, it has been shown that some monetary rules may lead to indeterminacy of equilibria, that is, they permit the existence of different equilibria, preventing the economy from setting in just one stable point, as should be desired. Then, effort was dedicated to finding the conditions under which a system where agents learn the RE solution would be able to achieve equilibrium's stability and determinacy.

Although the literature that addresses the interaction between monetary policy and learning is quite vast, I found particularly interesting the works conducted by Orphanides and Williams in the recent past (2007,2008) because their attempt has gone further to the traditional determinacy problem.

Indeed, they have assessed the stabilization properties of different Taylor rules pursuing Inflation Targeting in a context where people expectations are not rational but formed upon the resolution of a recursive algorithm. They argue that in order to understand the effectiveness of Inflation Targeting relative to other monetary rules it is necessary to take into account the environment of imperfect knowledge in which people form expectations. It is possible to include their contribution into the learning framework since their basic assumption regarding people's expectations is that people behave like economists when forecasting, that is, they refer to the principle of "cognitive consistency".

In their setting, both the Central Bank and the agents have imperfect knowledge about the economy: the Central Bank pursuits an Inflation Targeting policy while the public tries to infer the goal of the monetary authority, future inflation, through its past actions. Agents form expectations basing on a VAR model and are capable of learning.

[43] Although the literature is vast, important works are Evans, Honkapohja (1999,2001), Bullard, Mitra (2002).

[44] Following the principle of "cognitive consistency" (Evans, Honkapohja, 2008)

They test Taylor rules with different parameters specification and demonstrate that their performance get worse under imperfect knowledge with respect to the Rational Expectations case.

Moreover, departing from the hypothesis that people find it difficult to reason in terms of gap from desired levels, they test other two different kind of Taylor rules, one expressed and presented to the public in terms of gaps from variables' natural rate, whereas the other incorporated the key characteristics of Inflation Targeting, namely transparency and commitment, by expressing the rule in terms of levels rather than gaps from natural values.

Their results highlight the importance of imperfect knowledge to assess rules' performance, and in particular, given agents' bounded rationality, they argue that simple Inflation Targeting rules are superior because they give the opportunity to agents to better understand the conduct of the Central Bank, and in turn they enable the Central Bank to exert more control over expectations.

Their final message is that if the monetary authority wants to achieve economic stability, it has to implement simple rules that are able to credibly communicate the public the Central Bank's policy. Under imperfect knowledge, the best monetary performance is obtained only if the authority is able to guide people's expectations through transparent rules, so that agents are able to form expectations in an economic coherent way.

Moving away from the learning literature, there are not many contributions dismissing the hypothesis of Rational Expectations.

Though, in a recent paper, De Grauwe (2008) investigates the monetary policy's implications of abandoning the Rational Expectations hypothesis in a DSGE model, and letting forecasts be formed upon simple heuristics. The model consists of an aggregate demand equation, obtained from dynamic utility maximization, an aggregate supply equation, resulted from profit maximization, and a Taylor rule; an inflation targeting regime is assumed. Inflation and output expectations enter both the aggregate demand and supply equations.

Agents are assumed to be not fully rational, in that they form both inflation and output expectations in either two ways. As for output, the two forecasting rules divide into the optimistic (people expect output to grow) and the pessimistic one (people expect a lower level of output), while the inflation forecasting rules consist in the Extrapolators' rule (agents' expectations correspond to past inflation) and the Targeters' one (agents expectations correspond exactly to Central Bank's targeted inflation).

The proportion of agents choosing one rule instead of the other depends on their forecast performance: as long as more agents adopt one rule instead of the other, its performance increases and in turn more agents will adopt it.

The evaluation process gives rise to endogenous waves of optimism/pessimism which the author calls Animal Spirits referring to Keynes, and eventually, these fluctuations result responsible for the model to display cyclical economic fluctuations.

Moreover, contrasting this behavioural model's results with the ones obtained from solving the same model with RE, DeGrauwe finds out that the implications for monetary policy strongly vary across the two different models.

In particular, the degree of uncertainty generated by the optimism/pessimism waves about the transmission of monetary policy shocks traduces into the fact that the same policy shock can have different impacts depending on the degree of pessimism/optimism agents have about the future.

Notably, the main result is that monetary policy's effects, both in terms of output and inflation stability, are strongly influenced by the dismissal of the RE hypothesis.

4. Inflation expectations and Market Sentiment

Although innovative in their dismissing the Rational Expectation hypothesis, the Orphanides, Williams' paper and the DeGrauwe's one, as well as the learning literature in general, present some drawbacks. In particular, these models are all built over the common ground of optimization based micro foundation.

Relying on this conceptual framework implies conforming with the idea that aggregate functions result from rational optimizing processes. Then, it seems controversial assuming bounded rationality for agents' inflation forecasting process while admitting their complete rationality in utility or profit maximization.

This to say that there is room to go further into the understanding of the effects of monetary policy when agents are not fully rational by letting *all* economic decisions to be influenced by bounded rationality.

Thus, the very first motivation for this chapter is to take "seriously the radical uncertainty implied by our limited understanding of the economy, and analyze the effect of policy when the economy is far from a rational expectations equilibrium" (Howitt, 1996). In particular, my aim here is to understand how assuming all economic decisions to be influenced by non rational motives – the Market Sentiment hypothesis – impact onto the efficacy of the monetary policy.

In order to do this, I will depart from the theoretical framework developed in the previous chapter and I will complement it with some behavioural assumptions about the way in which agents form expectations.

My attempt here is not to interpret and apply Keynes's ideas about monetary policy, but anyhow the previous Keynesian model results more suitable for my purpose compared with any modified DSGE framework. Keynes's framework, instead, is completely built on the assumption that the informational constraint from which decision making through heuristics derives, pervades every fields of the economy. Starting from these intuitions implies assuming that not only the investment and the consumption choices will depend on Market Sentiment, but, consistently, also the forecasting mechanism will be influenced by it.

In this new framework, the Market Sentiment influences inflation expectations too, making them lower if optimism prevails. Moreover, I will assume the Market Sentiment to be endogenous and to vary following inflation dynamics.

This choice finds support in the behavioural economic literature that advocates for people to have just a lay understanding of economics, and so to be quite far away from the way of thinking of economists.

In this regard, my assumption is different from De Grauwe's one in that the proportion of agents choosing one forecasting rule rather than the other is determined through the social interaction and the ability of one agent to convince others to change their minds. Agents do not evaluate the performance of the rule as in the cited article, but, as in the previous chapter, they change mind only after interacting with others.

In De Grauwe the mechanism through which the economic environment feedbacks into the forecasting process passes through the evaluation of forecasting rules' performance. On the contrary, in my model, the economy feedbacks into agents' expectations because it influences the social dynamic. The capacity of one agent to convince others to change their mood is influenced by the effect of the perception of the dynamic pattern of inflation on agents psychology. Thus, for example, I will assume that if the economy displays short run inflation growth, then agents will be more prone to become pessimists.

In this way, the forecasting rules are not chosen for their relative performance but for how attractive the economic environment and social interaction make them.

Two different economic scenarios will be designed: on one hand I will consider a situation in which the Market Sentiment is regulated by the general inflation dynamics, and in which the Central Bank implements a fixed money supply rule (LM function); on the other, the Market Sentiment depends on the relative distance between actual inflation and its targeted level, and the Central Bank is clearly committed to a classical Taylor rule.

The rationale for having two separate scenarios comes from a recent paper by Tamborini (2007). The work is aimed at offering a new framework for the study of macroeconomics where the LM apparatus is not suppressed by instrument rules but rather amended to take into account some of its major disadvantages. The resulting model envisions the possibility of having two monetary policy regimes. In the first one monetary policy is conducted fixing the rate of growth of money supply, whereas in the other the authority sets the interest rate, through a rule that can be assimilated to the Taylor one.

Interesting, Tamborini demonstrates that under the hypothesis of Rational Expectations, the two regimes perform almost equally in stabilizing the economy, posing the concern of whether a regime of exogenous money implementing a Taylor rule does really result better than a regime implementing a fixed money supply rule.

My conjecture is that abandoning the RE hypothesis and letting the Market Sentiment to have a role in inflation expectations' determination the policy analysis is not trivial, and possibly diverges from the results of Tamborini's paper. The idea is that, from a behavioural point of view, the two monetary regimes entail different expectations formation's processes, implying different results for the monetary policy. This to say that the RE assumption works towards an homogenization of the economy that finally traduces into a smoothing of the monetary policy's effects.

Following from this reasoning, my further presumption is that if the inflation expectations' process matters for the impact of monetary policy, then this impact changes along with the relative weight the policy makers attach to inflation expectations. That is, stabilization will be different regarding different path for the parameters of the Phillips curve.

Summarizing, the very first motivation for this chapter comes from the recognition that even admitting a role for bounded rationality either in the form of learning or expectations' formation through heuristics, the theoretical framework upon which monetary policy have been studied poses some concerns. Indeed, it seems necessary not only to abandon the Rational Expectations hypothesis, but also to let bounded rationality pervading every economic fields.

This further assumption could possibly lead to a deeper understanding of the underlying dynamics of different monetary policy regimes, hence highlighting their inner differences. Then, it should result that two different monetary regimes, like the ones presented in Tamborini (2007), do really imply different monetary policy effects because the behavioural expectations' formation entailed is different.

In order to comply with my motivation, I will present a framework in which I will assume expectations to be influenced by the Market Sentiment as well as all the other economic decisions. The differences between the two monetary regimes that I will consider should finally be referred to this behavioural assumption. In particular, to remark the importance of inflation expectations in the economy, I will conduct some experiments letting the parameters of the Phillips curve varying.

5. Theoretical framework

The equations representing the economy are:

$$(1)\qquad C_t = \begin{cases} \bar{C} + \dfrac{O_t}{N}(Y_t - Y_{t-1}) & if\ \ Y_t - Y_{t-1} > 0 \\ \bar{C} + \dfrac{(N-O_t)}{N}(Y_t - Y_{t-1}) & if\ \ Y_t - Y_{t-1} < 0 \end{cases}$$

$$(2)\qquad I_t = d \cdot I_{t-1} + \lambda \cdot (q_{t-1} - 1) \qquad where\ \ q_t = \frac{\rho_t}{\bar{r}_t}$$

$$(3)\qquad Y_t = C_t + I_t + \varepsilon_{Y,t}$$

$$(4)\qquad r_t = \frac{\mu}{\theta} y_t + \frac{1}{\theta}\left(m - p_t\right) + v_t \qquad and \qquad \bar{r}_t = r_t - \pi^e_{t+1}$$

$$(5)\qquad \pi_t = \beta\pi^e_t + \phi\Delta Y_t + \varepsilon_{\pi,t}$$

$$(6)\qquad where \quad \rho_t = \frac{O_t}{N}\cdot(1+\eta)\cdot\hat{\rho}_{t-1} + \frac{(N-O_t)}{N}\cdot(1-\eta)\cdot\hat{\rho}_{t-1}$$
$$and \quad v_t = \frac{O_{it}}{N}\cdot v^O + \frac{N-O_{it}}{N}\cdot v^P \qquad with\ \ v^O < v^P$$

$\varepsilon_{Y,t}$, $\varepsilon_{\pi,t}$ are white noise disturbances terms. I choose to enrich the original framework including these random terms since I'm interested, among other things, in analyzing the stability of the system in the different scenarios in case of a shock happening. Moreover, the error terms renders the framework comparable to the more traditional ones adopted to study monetary policy alternatives.

O_t still represents the number of optimistic agents. Here I suppose that agents are not economically trained people, so that it is not possible thinking at them as behaving like economists.

The principal behavioural hypothesis that complements this framework regards the way in which aggregate inflation expectations are formed.

It is now assumed that inflation expectations are influenced by the Market Sentiment hypothesis, that is, the way in which people process economic information and form expectations is mediated through people's sentiment, and changes along with prevailing optimism or pessimism.

Indeed, as Leiser and Aroch (2008) pointed out, non economists have just a lay understanding of economic relationships. For this reason, given the difficulty they face in exploring economic concepts, they oversimplify the underlying structure and make judgements about economic variables' causal relations relying on heuristics, reasonable self-evaluation and shallow understanding.

The authors run a set of laboratory experiments on different groups of economically trained and not economically trained students, and they demonstrate that even if non economists were not able to fully understand the concepts they were presented, anyway they answered to well defined questions about causal relationships[45] between economic variables just committing on some superficial knowledge about the economy. Upon this imperfect knowledge, they can just rely on heuristics to form evaluations.

In this regard, lacking specific information, it seems plausible to assume that to form inflation expectations' as well as evaluating other economic variables, agents will rely on common sense and on the prevailing Market Sentiment.

Therefore, Leiser and Aroch identify the "good-begets-good" heuristic as the principal device people use to establish economic relationship. They show that common people tend to separate economic variables in two different pools, the positive and the negative ones, stating that if a good economic variable is to increase, then all the other good ones are to increase too, even if this is implausible from an economic point of view[46]. By the same reasoning, it is considered as a good thing if one of the variables that belongs to the negative pool decreases.

As for inflation, experimental subjects mostly put it into the negative variables pool, in agreement with the literature that highlight how much people dislike inflation.

In a survey conducted among US, German and Brazilian people – both economists and common people – Shiller (1996) asks participants if they were to worry for an increase in infla-

[45] Questions were of the type: "If variable A increases, how this will affect variable B?"
[46] Consider for example that people put in the negative pole variables rate of inflation together with interest rates, meaning that an increase in the interest rate will be related to an increase in inflation

tion and why they were to. The vast majority of people demonstrate to strongly fear inflation since they assert that inflation deteriorates their standard of living, harms national prestige, leads to political chaos and damages national morale.

Interestingly, when asked what would be the effects of inflation on income, people show to have no clear idea whether income would rise, stay the same or decrease, leading to the conclusion that people feels inflation as hurting real incomes rather than nominal ones.

The mentioned causes for inflation varied a lot, but they were principally related to the bad behaviour of some people (people that spend too much, big corporates seeking profits, governments setting bad policies) while just few people pay attention to strictly economic causes[47].

Indeed, Shiller's results point in the same direction as Leiser's ones: common people do not understand well the functioning of the economy; nonetheless they are interested in economic news reporting inflation developments because they do really live inflation as a very bad event.

Drawing upon this evidence, I will match an optimistic mood with decreasing inflation expectations, and a pessimistic mood with increasing expectations. What I'm arguing is that optimistic agents, who in general envision the future in a better way, will be more prone to expect that inflation will decrease, while pessimistic agents that are scared about the future, will be more willing to expect an increase in inflation. Remember that I'm assuming that people do not forecast upon economic evidence, but rather among other type of judgements or heuristics, including their mood.

Hence, aggregate expected inflation will decrease with regard to past inflation when optimism prevails, that is,

$$\pi_t^e = \frac{O_t}{N} \cdot (1-\eta) \cdot \bar{\pi}_{t-3} + \frac{(N-O_t)}{N} \cdot (1+\eta) \cdot \bar{\pi}_{t-3} \qquad (7)$$

where $\bar{\pi}_{t-4}$ is average inflation over the previous four years.

Notice that lot of importance is still attached to past inflation: this to say that people do not make forecasts on completely irrational basis, but they rely on their past experience.

In order to better support the previous assumption we considered the relationship between a possible proxy for the market sentiment variable and inflation expectations for the US[48], in order to check for the presence of some correlation advocating for the hypothesis that market sentiment influences inflation expectations. As a proxy for market sentiments we chose the Con-

[47] Indeed, the ones who succeed in responding in an economic plausible way were economists

[48] Source: St. Louis FED Data Base- FRED; UMSENT series for the Consumer Sentiment index (1978-2008), and MICH series for inflation expectation (1978-2008): both the series are produced by the University of Michigan Survey Center

sumer Sentiment Index that measures the public's perception about the future course of US economy: indeed, the University of Michigan calculates it to judge consumers' level of optimism/pessimism. Then, we computed the simple correlation between the CSI series and the inflation expectations one, and it resulted that there exist a significant negative correlation between the variables[49], suggesting that when the CSI increases, that is when optimism prevails, inflation expectations decrease, just as we are pretending in this chapter.

Given this general assumption about inflation, in the following I outline the two monetary regimes under study.

Let's call the first one the Old Regime .

The Old Regime is characterized by a monetary authority that pursues a fixed money supply policy implementing the LM function already discussed in the previous chapter. Therefore, the monetary authority does not communicate to the public its policy, or its money supply target, so that people is offered no nominal anchor for inflation expectations.

Given the experimental evidence about the sentimental way in which people confront with inflation, I assume that Market Sentiment changes along with inflation dynamics, and in particular, people tend to be more optimistic when they realize inflation is decreasing, while they start worrying and becoming pessimist when inflation is increasing. In some way, this corresponds to a lack of confidence in the authority, which, in people's view, is the responsible for national economic stability. If inflation increases, then people feel the event as if the authority was not doing enough for preventing this, and they lose trust. In the opposite case, if inflation is decreasing people is led thinking that the monetary authority is working well, and they are more confident about the future increasing their trust.

Hence, the probability of changing opinion in the Kirman's algorithm becomes:

$$\delta_t^O = \begin{cases} \delta + \alpha & if \quad \pi_{t-1} < \pi_{t-2} \\ \delta - \alpha & otherwise \end{cases}$$

$$\delta_t^P = \begin{cases} \delta + \alpha & if \quad \pi_{t-1} > \pi_{t-2} \\ \delta - \alpha & otherwise \end{cases} \qquad (8)$$

where α is the amount by which the probability of remaining optimist/pessimist changes with inflation. That is, when inflation is decreasing, δ_t^O, the probability or remaining optimist

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[49] $corr = -0.72, \quad p - value = 0.000$

when one is already an optimist, increases[50] by an amount equal to α; and the opposite happens for an increase in inflation.

Notice that although the scenario results plausible given the experimental evidence presented above, it entails a counterintuitive relationship between output and inflation that anyhow can be interpreted as the result of a supply shock.

Prevailing optimism entails two opposite forces at work in the economy. On one hand, optimism fosters output through its effect on investment and consumption, while on the other it reduces inflation expectations and possibly inflation too.

Moreover, notice that optimism reduces the interest rate, implying that in the stock market we have asset price inflation.

Now, consider the second monetary regime, the so called Modern Regime.

Here, the authority is clearly committed in following a classical Taylor rule which entails a 1% target for inflation. The authority pursues transparency to help the forecasting process, so people is aware both about the policy implemented and about the target and therefore can count on a nominal anchor for their expectations.

In this situation the Market Sentiment will be influenced by the Central Bank reaching the targeted level of inflation or not. The public will be more willing to be confident in the future if actual inflation sets behind the targeted level, while it will lose confidence about future economic conditions if actual inflation is above the target. Again, if the Central Bank is not able to reach its goal, people lose confidence in the authority and starts worrying.

Thus, the probability of becoming either pessimist or optimist will change according to:

$$\delta_t^O = \begin{cases} \delta + \alpha & if \quad \pi_{t-1} < 0.01 \\ \delta - \alpha & otherwise \end{cases}$$

$$\delta_t^P = \begin{cases} \delta + \alpha & if \quad \pi_{t-1} > 0.01 \\ \delta - \alpha & otherwise \end{cases} \tag{9}$$

where $\pi = 0.01$ is the targeted inflation level.

The same opposite forces are at work here. If optimism prevails, output receives a positive acceleration, while inflation receives a negative one. Moreover, we still have asset price inflation when optimistic agents are the majority.

[50] This in turn implies that the probability of changing mind and becoming a pessimist, $1-\delta$, decreases.

A final remark regards the inflation target. Although by construction inflation fluctuates around its steady state value[51], here I decide the targeted inflation level to be 0,01. Indeed, it seems to me more realistic and more safe for the part of the Central Bank, to assume a non zero inflation target.

6. Simulation Results

The designed framework has been implemented in order to assess one basic question, that is, if we assume bounded rationality pervades all economic decisions, how does monetary policy affect the economy?

Trying to answer, I will follow two different paths.

First, I will compare the results of bounded rationality for monetary policy both in the Old Regime and in the Modern one, showing that the Market Sentiment assumption has an important impact.

Second, I will separately analyze the two Regimes to address how the relative weight given to inflation expectations impact over the efficacy of monetary policy, that is, if expectations are truly important for economic stability or not.

As in the previous chapter, the study does not pretend to be quantitatively comparable with empirical evidence, so that it should be regarded as an experiment rather than a replication exercise, and for this reason parameters have not been calibrated.

Indeed, the parameter set up is the same as before:

Variable	Description	Value
T	Number of periods	400
N	Number of agents	1000
S	Number of intra-period interaction for the Kirman's algorithm	150
$\bar{C} = \bar{Y}$	Steady state values for consumption and output	100
ϕ	Persistence coefficient in the investment function	0.7
λ	Tobin's q weight	10
P	Price index	1
ν^{O}	Optimistic Liquidity preference shock	-0.1
ν^{P}	Pessimistic liquidity preference shock	0.1
θ	Interest rate elasticity	0.5

[51] See section 6.3 in Chapter 3

μ	Income elasticity of money	0.5
$1-\delta$	Probability of changing opinion when meeting someone in Kirman's algorithm	0.9
ε	Probability of changing opinion autonomously	0.000325
α	Probability of changing mind momentum (Kirman's algorithm)	0.005
β	Inflation expectations' coefficient	0.9
φ	Output gap coefficient	0.2

Table 1: parameters set up

In the next section I will compare the two regimes in terms of inflation and output volatility in order to estimate the effects of the monetary policy; moreover, to check for differences in terms of economic structure, I will study their impulse response function to interest rate shocks.

Afterwards, I will let the Phillips curve parameters changing in order to account for differences in policy's effectiveness when the weight attached to inflation expectations changes.

6.1. The Old Regime versus the Modern regime

Table 2 shows the simulations' results for inflation and output standard deviation in both the regimes. It is undoubtedly clear that the monetary policies produce different outcomes; in particular, we have that the Modern Regime performs better in stabilizing the economy with respect to the Old one.

	Old Regime	***Modern Regime***
Inflation std	0.0042	0.0009
Output std	0.023	0.006

Table 2: inflation and output standard deviation in the two regimes

Under the hypothesis of inflation expectations guided by the Central Bank's target which in turn operates through the Taylor rule, the inflation and output standard deviations are much lower with respect to the other case.

Even graphically, it is possible to appreciate the quantitative differences between the two regimes:

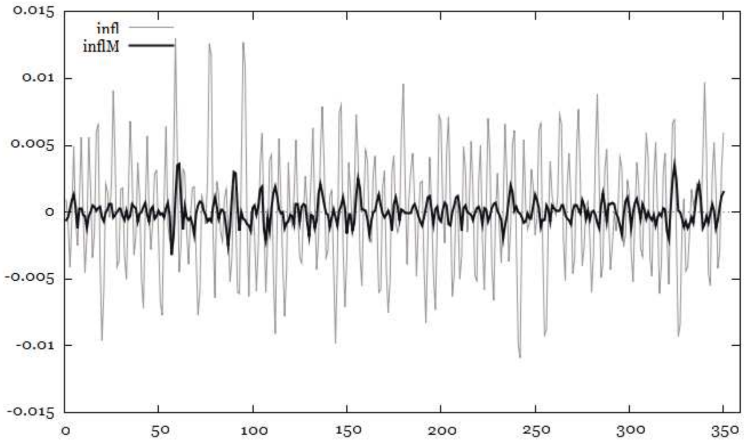
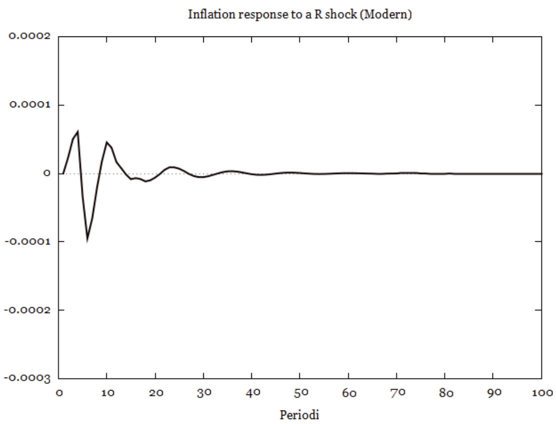


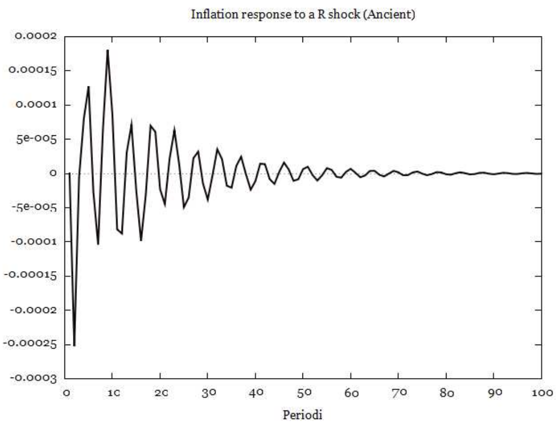
Figure 1: inflation dynamics in the Old Regime (grey line)
and in the Modern One (black line)

This very first set of results offers some evidence supporting my initial claim, namely, that abandoning the Rational Expectation hypothesis the two regimes lead to different stabilization paths.

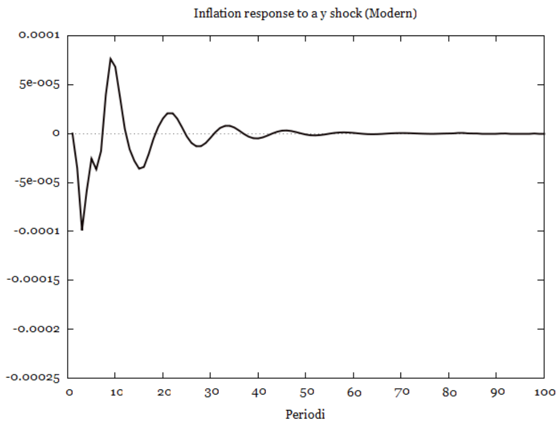
In order to endorse my view and to shed some light on the underlying stabilization mechanisms, let me present the impulse responses of inflation to interest rate, output and Market Sentiment shocks.



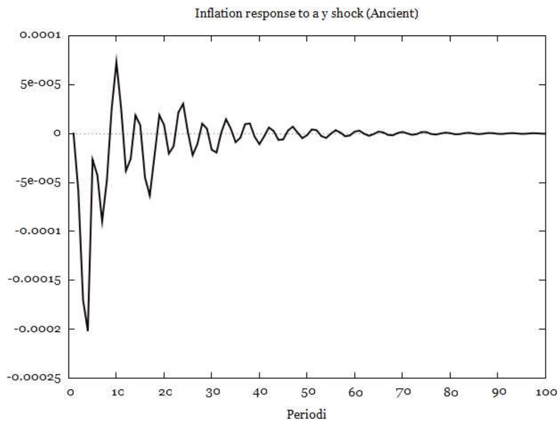
(3.a)



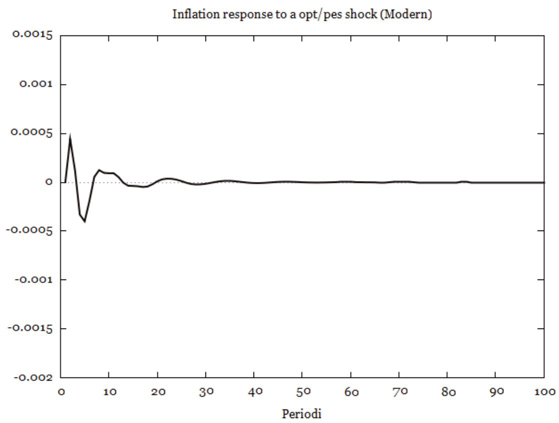
(3.b)



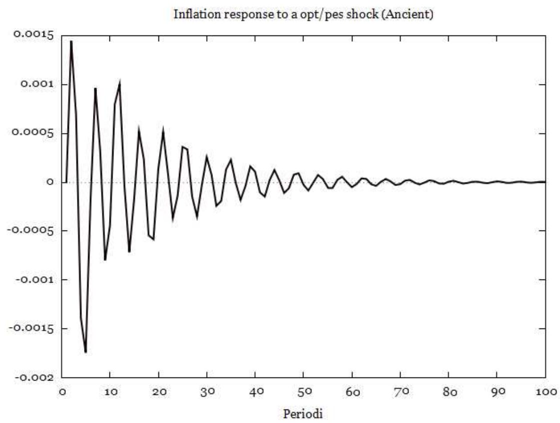
(3.c)



(3.d)



(3.e)



(3.f)

Figure 3: Comparing Modern and Ancient regimes: impulse responses of inflation to an interest rate shock (3.a and 3.b); to an output shock (3.c and 3.d); to a Market Sentiment shock (3.e and 3.f)

The impulse responses of inflation to different shocks confirm that the Old Regime is much more instable than the Modern one. Indeed, as you can see in figure 3.a and 3.b, the interest rate shock takes approximately 80 periods to exhaust its effects in the Old Regime, while it takes approximately 40 periods in the Modern one. The stabilization pattern in the Old Regime implies an oscillating behaviour that is not at all present in the Modern case.

Moreover, in the Old Regime inflation immediately responds negatively to the shock, while in the other case it responds positively; not only, from a quantitative point of view, interest rate shocks in the Old Regime impact much more heavily on inflation with respect to the Modern case.

The same reasoning can apply to output shock and Market Sentiment ones: the overall stabilization path is almost the same, but there are both qualitative and quantitative differences in the two patterns.

The most important feature is that the Old economy is much less able to internalize shock than the Modern one, so that it takes considerably more time for the former to stabilize with respect to the latter. That is, the effects of the shocks last much more.

Indeed, if we compare the two regimes in terms of monetary policy, this evidence allows us to claim that having inflation expectations well anchored stabilizes the economy and reduces the persistence of shocks (Mishkin (2007), pag.12).

Then, the framework offers support for Mishkin's analysis: "Because the public has become confident that the Fed will do the right thing, *expectations now behave in a manner that makes economy more stable* to begin with." (Mishkin (2007), pag.15; emphasis added).

Let me now shed some light on the role of the expectations mechanism in determining economic dynamics.

Consider the case of the Ancient Regime. In this context the Market Sentiment, and in turn inflation expectations, reacts to any movement in inflation. If we depart from a situation of prevailing optimism, we end up with output increasing because of the positive MEC and MPC's impulse , and with inflation expectations decreasing. As long as the increase in output is not so big as to overcome the negative effect of inflation expectations, then actual inflation will not grow. Instead, if the output prompt is heavy enough, the constraining expectations effect is not sufficient and finally actual inflation do rise.

If this is the case, in the next period there will be high probability of having pessimism prevailing, which in turn entails higher inflation expectations. Nonetheless, pessimism entails a negative effect on output too. So, the positive effect of expectations on inflation is counteracted by the decreasing output until inflation starts decreasing too and optimism returns.

The critical element here is the lag in the timing of the process. Since Market Sentiment responds to inflation with lags, and so does output to Market Sentiment, the process is characterized by some time discrepancies that makes it unstable. In other words, the lags make it possible to have moments in which inflation is not under control of the monetary authority.

This mostly happens because people do not have any nominal anchor to which anchoring expectations.

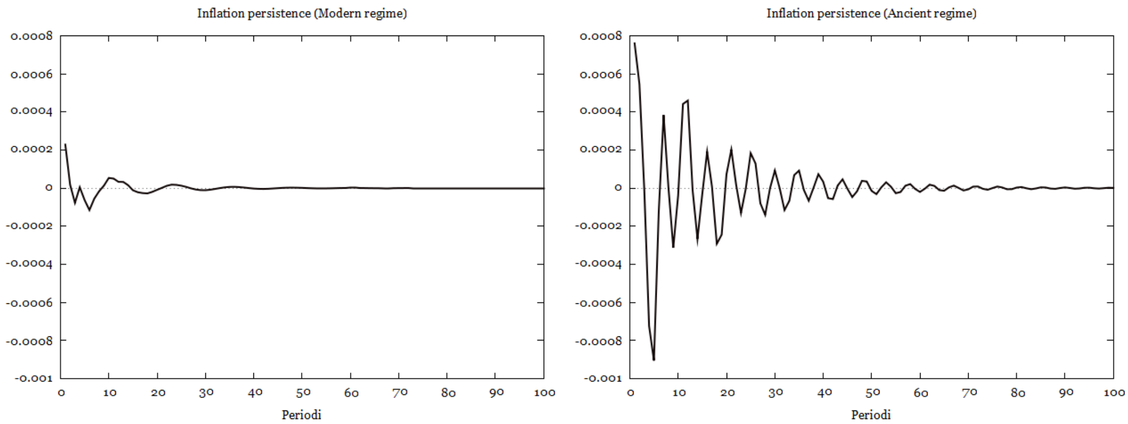
Consider now the Modern Regime. The Market Sentiment changes only if inflation overcomes its targeted level. Again, if we start from a situation of prevailing optimism output receives a positive impulse while inflation expectations receive a negative one. Actual inflation is kept under control by negative expectations, and so it will be until the output growth becomes too heavy to be constrained by expectations.

The difference with the previous situation is that unless the targeted level is overcome, the Market Sentiment will not change and the economy settles in a context of increasing output and decreasing inflation expectations because optimism prevails. That is, people is less willing to change mind because their reference point is a fixed one, and it does not vary through time as in the previous regime: they are not worried by inflation increasing as long as the latter is kept under the target. In this way inflation expectations result much more stable, and in turn contribute to the stability of the economy.

Moreover, with the presence of the fixed target we can get rid of the time lag problem because Market Sentiment adjusts faster to economic dynamics[52].

Notwithstanding the differences just highlighted, in both the Regimes the counterintuitive relationship that exists between inflation expectations and output dynamics results of great importance for the stabilization process. The Old Regime is definitely more unstable with respect to the Modern one, but the same mechanism that enables the Modern to be more stable, prevents extraordinary volatility from happening in the Old too.

The higher inertia of the expectations mechanism in the Old Regime makes it possible to explain why the system takes more time in internalizing shocks (Figure 3). Not only, the same reasoning can be applied to explain why inflation in the Old Regime displays much more persistence with respect to the Modern case (Figure 4).



(a) (b)

Figure 4: impulse response of inflation to an inflation shock in
(a) the Modern Regime and in (b) the Old one.

Then, my behavioural assumptions seem to give support for some well-known New Keynesian models' findings, namely, that commitment and optimal monetary policy are therefore better than discretion.

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[52] In the Modern Regime people compare previous period inflation with the target, while in the Old Regime people compare inflation at time t-1 with inflation at time t-2.

A framework in which the Central Bank is committed in controlling inflation and makes explicit its objectives stabilizes the economy much more than a framework in which the monetary authority controls the money supply and does not communicate any policy report.

Therefore, someone might say that introducing bounded rationality has not improved the already existence knowledge. Indeed, the interesting aspect here is that the greater instability the Old Regime displays with respect to the Modern one, is due to the different expectations formation process, and not to exogenous shocks.

Although the relationship between output and inflation entailed in the expectations process can be assimilated to a supply shock, it is completely generated endogenously, and derives from two particular assumptions about the behaviour of the agents, namely, that optimism makes them prone to invest and produce, and that optimism translates into lower inflation expectations. It is the interaction between the latter that determines the degree of systemic stability .

6.2 Flexible money supply rule

Previous results are obtained assuming the Central Bank pursues a fixed money supply rule.

Upon this assumption, the results can be questioned since what I am comparing is a regime in which the monetary authority is completely passive with one in which the monetary authority actively influences the economy. One can argue that the instability is the effect of such a passiveness.

For this reason, in the following I will dismiss this hypothesis and I will let the Central Bank in the Old Regime to actively react to inflation.

In particular, the further assumption is that the authority reacts to an increase in inflation by lowering the money supply by a certain amount, whereas it increases the money supply when inflation decreases.

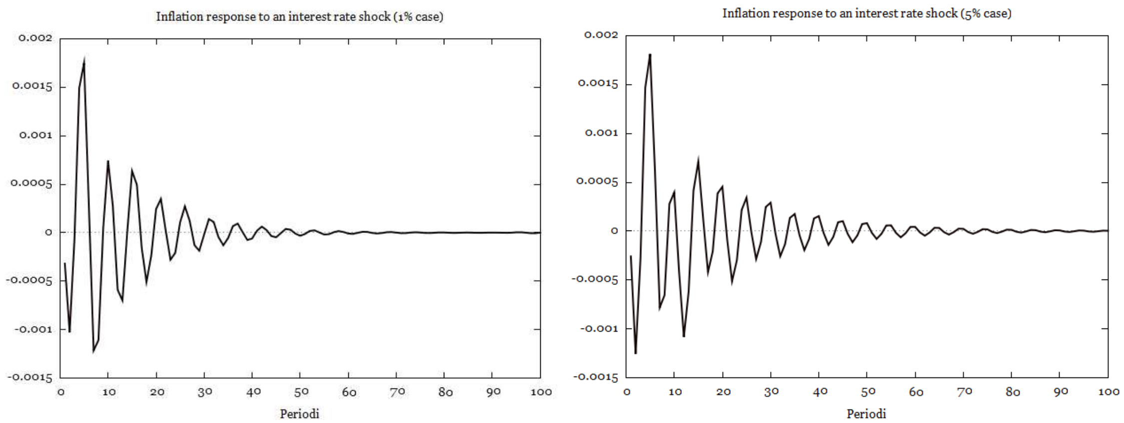
Table 3 presents the evidence about inflation standard deviation and output one in case of a 1% increases/decreases of the money supply, and in case of a 5% increase/decrease in the same magnitude.

Old Regime	***1% change***	***5% change***
Inflation std	0,004	0,007
Output std	0,023	0,06

Table 3: Old Regime: inflation and output standard deviations in case of a 1% change in the money supply and in case of a 5% change in it.

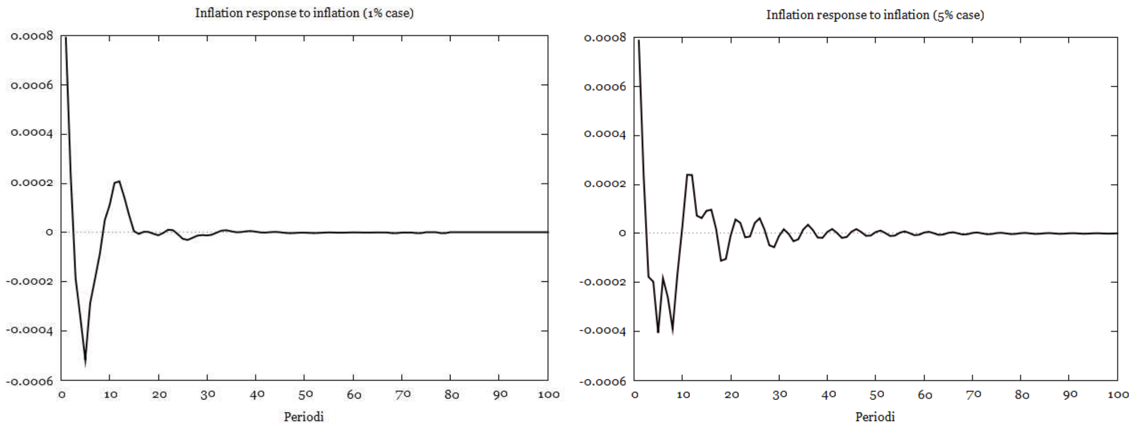
In case of a 1% change in the money supply there is no significant improvement in terms of diminishing output and inflation standard deviations with respect to the previous basic Old Regime case, that is, the monetary intervention does not contribute to decrease systemic volatility. Nonetheless, if the money supply is let changing by a 5%, the volatility considerably increases, that is, an even more strict monetary intervention is of no help for the stabilization of the economy.

Therefore, if we concentrate on the impulse responses in the two cases, some interesting results come out.



(a) (b)

Figure 5: Impulse responses of inflation to an interest rate shock in the case of a 1% change (a) and in case of a 5% change (b)



(a) (b)

Figure 6: Impulse responses of inflation to an inflation shock in the case of a 1% change (a) and in case of a 5% change (b)

In case of a 1% change, the active monetary policy implies a greater capacity for the system to absorb shocks. In case of an interest rate shock the adjustment path does not qualitatively differs much with respect to the case of passive policy, but the time interval the system spends stabilizing is lower. Most importantly, the persistence of inflation (Figure 6.a) is quantitatively lower and qualitatively follows a pattern very similar to the Modern Regime.

In case of a 5% change, the stabilization process lengths with respect to the 1% case. As for inflation persistence, the stabilization pattern resembles the one followed in the Modern Regime, but it is longer and more unstable with respect to the less severe policy case.

Indeed, these latter results endow us with substantial more information with respect to the previous cases.

First, an active monetary policy does not contribute to lower inflation volatility, but it helps the economy in absorbing more rapidly the shocks. Nonetheless, if the authority implements a severe policy, inflation reacts increasing its volatility and spending more time in absorbing the shocks.

Second, once we attach an active role to the Central Bank, the Modern Regime – the New Keynesian way of assessing monetary policy – is better with respect to the Old Regime – the Monetarist view of assessing monetary policy – only for what concerns inflation volatility. Moreover, a not too strict money supply policy succeeds in stabilizing the economy as well as a Taylor rule based policy.

6.3 Changing the importance attached to inflation expectations

To underline the importance of inflation expectations in determining the impact of the monetary policy, here I will address how the economy behaves if we let the parameter of the Phillips curve varying, that is, if the weight attached to inflation expectations changes.

In particular I will consider three levels:

	β	ϕ
a	0,9	0,2
b	0,7	0,4
c	0,5	0,6

Table 4: Phillips curve's parameters set up

Upon previous results, my presumption is that when less weight is attached to inflation expectations, the monetary authority finds it difficult to exert control over inflation, which in turns displays more instability.

The analysis is conducted separately for the Old Regime and for the Modern one.

Let's consider first the Old Regime.

	$std\pi$	$stdY$
a	0,004	0,02
b	0,009	0,02
c	0,014	0,02

Table 5: Inflation and output standard deviation in the Old Regime for different combinations of the Phillips curve's parameters

	μ_Y
a	115,4
b	115,5
c	116,5

Table 6: Average output in the Old Regime for different combinations of the Phillips curve's parameters

As you can see from Table 5, inflation and output standard deviations increases along with the decreasing weight attached to inflation expectations.

This is a direct consequence of the previously explained mechanism. Indeed, the latter has shown that inflation expectations exert a stabilization effect on actual inflation, contrasting the impact of output. Lessening the role of expectations in the determination of actual inflation implies damping this stabilization effect, and at last making inflation more volatile.

The role of expectations is emphasized if we concentrate attention on the output dynamics. Indeed, output standard deviation as well as average output levels (Table 6) do not change between the three treatments, implying that inflation volatility does not increase because of output growth but because of the smaller inflation expectations' negative impact.

As you can see from Table 7 and Table 8, the same pattern is recognizable for the Modern Regime.

Although both standard deviations remain lower with respect to the Old Regime, they increase along with the decrease of the inflation expectations parameter.

	$std\pi$	$stdY$
a	0,0009	0,006
b	0,0017	0,005
c	0,0025	0,005

Table 7: Inflation and output standard deviation in the Modern Regime for different combinations of the Phillips curve's parameters

	μ_Y
a	117,8
b	117,8
c	117,8

Table 8: Average output in the Modern Regime

for different combinations of the Phillips curve's parameters

Again, the result is due to the weakening of the negative impact of inflation expectations, since output variability stays constant.

7. Conclusions

In the present chapter I sought to explore the implications for the design of monetary policy when facing an economy populated by truly bounded rational agents.

Although the recent learning literature has worked towards a better understanding of the effects of monetary policy when agents are bounded rational, its principle of cognitive consistency still appears a strong assumption. Moreover, these models consider bounded rationality only for the inflation expectations process, while disregarding its effects on the whole economy.

To give account of these limitations and to demonstrate that the way in which people form expectations strongly affects monetary policy, I have relied on the model developed in the previous chapter, and I complemented it with some behavioural hypothesis regarding the expectations mechanism.

I envisioned two different monetary regimes – the Old Regime and the Modern one – which shares the assumption that inflation expectations are mediated through Market Sentiment, increasing when the predominant Market Sentiment is pessimism and decreasing in the opposite case.

The motivation for this assumption has mainly come from the recent evidence produced by the experimental and behavioural literature, which points out some important features.

Many experiments demonstrated that the Rational Expectations assumption is at odds with the way common people make forecasts; moreover, it has been showed that not only people do not possess Rational Expectations but also that the majority of them has just a naïve understanding of economic dynamics, and judges economic variables in a rather sentimental way.

Nonetheless, the two regimes differ in that within the Old Regime the Central Bank follows a money supply rule and optimism/pessimism changes along with inflation dynamics; whereas in the Modern Regime the monetary authority is committed to a Taylor rule, and optimism/pessimism depends on actual inflation being above or behind the targeted level.

Contrary to the result obtained by Tamborini (2007), I hypothesized that once the Rational Expectation is abandon and bounded rationality is let influencing all economic decisions, the two regimes entail different stabilization processes.

Indeed, simulations results offer support for my conjecture.

Under the Old Regime inflation is much more volatile than in the Modern one, and if hit by a shock the system spends considerable more time in adjusting.

Although simulations results endorse the traditional New Keynesian view that commitment is better than discretion, the significance of my findings rely in showing that the instability of the two systems is due to the peculiar inflation expectations mechanism, and not to some exogenously imposed shocks.

As a further computational exercise, I abandoned the assumption of the Central Bank in the Old Regime pursuing a fixed money supply rule, and I let it deciding the best policy to implement depending on inflation dynamics. That is, the authority now increases the money supply any time it realizes inflation is decreasing and decreases it in the other case.

Interestingly, if the authority changes the money supply by 1% as a reaction to inflation, inflation volatility remains the same as before but the capacity of the system to internalize the shocks increases. In particular, inflation stabilization resembles the one obtained under the Modern Regime. However, if we assume the Central Bank to implement more severe policies, say a variation of money supply by 5%, inflation volatility increases considerably and the time the system spends in stabilizing does not decrease.

Indeed, these results demonstrate that the Modern Regime is definitely better than the Old Regime only in case the authority implements passive policies. In the opposite case, the Modern Regime performs better than the Old one only for what concerns inflation volatility. Moreover, a too strict policy is of no help for stabilizing the economy.

Then, the significance of our framework is emphasized since the origin for this evidence is to be found in the psychological mechanism that govern economic decisions.

Finally, I devoted one last section in remarking the importance of inflation expectations by letting the parameters of the Phillips curve changing. The β parameter is let diminishing until it results lower than the output gap parameter. Indeed, the resulting inflation pattern shows that inflation volatility increases together with the decreasing of the beta parameter. Then, giving the prominent role to expectations translate into less volatile (and possibly lower) actual inflation.

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Conclusions

Conclusion

This dissertation investigated the potential of agent-based modelling in analyzing economies as complex dynamic systems.

In particular, three main issues have been explored. First, I studied the implications of heterogeneity in a credit economy in which bank-firm relationships are regulated through Relationship Banking. Second, I offered an interpretation of Keynes's most important intuitions from the *General Theory*, based on the role played by the non rational residual motives in determining economic dynamics. Finally, I analyzed the impact of different monetary policy regimes under the hypothesis of agents being bounded rational.

The dissertation has been articulated in four chapters.

Chapter 1 briefly presented the concept of agent based modelling. After discussing some important features characterizing traditional economics, I documented the major critics against the framework, and assessed how the complexity approach has tried to overcome them. In this context, agent-based modelling results the most suitable instrument to deal with traditional economics drawbacks. Finally I sketched the idea that Classical economics has much in common with the complexity approach, in particular considering the economics of Marshall.

Chapter 2 tackled the macroeconomic implications of firm-bank interactions. The motivation for the analysis came from the recognition that the literature assessing the role of asymmetric information in causing economic fluctuations (see for example Bernanke, Gertler, 1999; Kiyotaki, Moore) does not take seriously into account agents' heterogeneity, nor the variety of contractual arrangements the lender can offer to the borrower. For, I constructed a model of a credit economy in which entrepreneurs are heterogeneous in their productive capacity and in their opportunistic behaviour. In order to take over their productive projects they have to invest an amount of money which is proportional to their current wealth. It is possible to separate entrepreneurs between those who can self finance production, and others who have to ask for banking credit. Then, I considered two treatments. In the first one the bank is not able to discriminate good and bad entrepreneurs and thus it charges all the loans with the same interest rate. In the second one, the bank is able to ex post recognize good entrepreneurs in their being long term clients (they have always given back their loan), and therefore is willing to offer these entrepreneurs a lower interest rate (Relationship Banking).

Since the literature points at the superiority of Relationship Banking (Sharpe, 1990), I conducted simulations in order to assess whether the Relationship Banking treatment does really perform better than a Pure Asymmetric Information one. Results demonstrates that in both the cases the model produces output series displaying long term growth, and economic fluctuations of different frequencies and amplitudes in the short run. Nonetheless, at the aggregate level average output are almost the same in both treatments. A deeper analysis has shown that this effect is due to the presence of entrepreneurs' heterogeneity, with self financing entrepreneurs contributing more to output because not constrained by the debt burden. Getting rid of these firms, output produced by banking finance entrepreneurs under Relationship Banking is higher that under Pure Asymmetric Information; the same results holds for the wealth levels. The same relationship can be find looking at the dynamics of the system. Output and wealth series at the aggregate level have the same volatility, while concentrating on BF series these result more volatile under the hypothesis of RB. Therefore, the proportion of defaulting firms stays equal for both the treatments.

Then, the superiority of Relationship Banking is not trivial. Upon the hypothesis of agents' heterogeneity and limiting our attention to banking financing entrepreneurs, the RB contractual arrangement is superior to the PAI one for what regards the productive capacity. RB still performs better in enhancing cumulative capacity, but it is of no help in terms of decreasing the probability of default. Moreover, RB entails a higher level of volatility for Bf entrepreneurs. Indeed, there exists a trade off in the RB regime, so that quantitative superiority is achieved at more volatility costs. Finally, an interesting results that deserves further research shows that in both treatments banking financing entrepreneurs' output displays no growth but it is stuck in a well defined corridor, that is, banking financing poses some limits for macro growth.

In 3 an ABM interpretation of Keynes's ideas has been offered. What particularly I worked for is to revive the Keynesian argument about the residual non rational motives that pervade economic decisions. In line with recent literature (see e.g. Marchionnati, Fontana (2007), or Bruun (1999, 2008)), I claimed that the General Theory does not lack microfoundation – as Neoclassical economics asserted – since Keynes micro founded General Theory's aggregate functions through agents' behavioural rules. For this reason, agent-based modelling can perform well in giving a formal treatment of Keynes's literary model. The model is built around the three pillars of *GT*, namely the Marginal Efficiency of Capital, the Marginal Propensity to Consume and the Liquidity Preference. The three are characterized in a behavioural manner, since it has been assumed that they change along with the Market Sentiment, that is, along with optimism and pessimism waves. In particular, if optimism prevails in the society, entrepreneurs do invest because they expect higher future profits which in turn encompasses a higher MEC; consumers increase consumption; both consumers and entrepreneurs diminish their Liquidity Preference, thus inducing a negative shock over the interest rate. It has to be noted that designed that way, the model assesses two more issues that make Keynes an ABM ante litteram. Indeed, my framework accounts for heterogeneity of agents (people can be either optimistic or pessimistic) and interaction (interacting with other agents people can change their mood following an opinion formation mechanism presented in Kirman (1993)). The framework has been analyzed referring to two treatments. First I assumed the Market Sentiment to be completely independent of economic dynamics; second, I assumed the Market Sentiment to change along with output dynamics, so to have people more prone to become optimistic when output is growing.

Once simulated, the first treatment has been able to reproduce the majority of Keynesian intuitions. Output series is characterized by irregular fluctuations of different amplitudes and frequencies. Analyzing the cross-correlation structure, these fluctuations are set off by the Market Sentiment dynamics so that it is possible to argue about Market Sentiment driven business cycle. Comparing output with consumption and investment, the former is less volatile than output while the latter is almost four times more volatile than output; contrary to Keynes's idea, consumption leads the business cycle whereas investment lags it. Inflation and output present a considerable degree of persistence; moreover, the simulated data are able to generate a Phillips type relationship between inflation and output. Therefore, the second treatment demonstrated the capability of replicating the most important economic relationships too. Moreover, in this treatment inflation and output have shown a higher persistence degree with respect to the previous one. Although the two treatments have performed well in replicating Keynes's ideas, they fail in producing one of his most important claim, namely, the phenomena of under production and under investment. That is, output in both treatments does not exhibit prolonged recessionary periods. Indeed, I have been able to reproduce the phenomena under study fixing the proportion of optimists, in such a way that for a given interval time pessimism prevails in the economy. Then, I found support for Keynes's claim that recessions are the consequences of long lastly periods of decreasing Marginal Efficiency of Capital.

The last chapter adds to the literature that assesses the impact of monetary policy under the hypothesis of agents' bounded rationality. What have mainly motivated me in this analysis has been the recognition that the literature that pretends to tackle bounded rationality in monetary policy, limits itself to consider the inflation expectation process, while assuming perfectly rational agents for all the other economic decisions. I found it quite controversial, and for this reason I decided to test the impact of different monetary policy upon the theoretical framework developed in the previous chapter. Moreover, I dismissed the principle of cognitive consistency (Evans, Honkapoija 2008) that belongs to the learning literature, and I assumed agents form inflation expectations relying on some heuristics derived from personal feelings and common sense. In this way, inflation expectations change along with Market Sentiment, being them higher when pessimism prevails and lower if the opposite is true. The rationale for this choice comes from the experimental and behavioural literature, in particular Leiser, Aroch (2008) who demonstrate that people have just a naive understanding of economic variables, and treat them in a rather sentimental way. Therefore, I envisioned two different monetary regimes. The Old Regime is characterized by a fixed money supply rule, and by the fact that the Market Sentiment dynamics is influenced by the inflation dynamics, with the probability of becoming a pessimist increasing if inflation displays short run growth. The Modern Regime encompasses a Central Bank committed to follow an inflation target through the implementations of a Taylor rule, and in which the probability of becoming a pessimist/optimism increases if inflation overcomes/stays below the target.

Simulations results demonstrate that the way in which people form inflation expectations has an important role in explicating the differences among monetary regimes. Indeed, the Old Regime resulted more unstable for what concerns both inflation and output with respect to the Modern one. Moreover, in the former inflation displays much more persistence to interest rate shocks as well as to output and Market Sentiment ones. The results can be traced back to the presence of a counterintuitive relationship between output and inflation that works as a stabilization mechanism. Indeed, when optimism prevails people expect that future inflation will decrease and future output will increase, a relationship which can be assimilated to a supply shock but it is endogenously generated by the system. Notwithstanding, this discrepancy operates towards stabilizations since when output grows too much and succeeds in increasing actual inflation, the resulting pessimistic mood traduces into a constraint for output and finally a constraint for inflation.

Moreover, as a further assumption, I dismiss the hypothesis of a fixed monetary policy rule and I let the Central Bank changing the money supply along with inflation. Results for a 1% change in the money supply demonstrate that an active monetary policy does not lower inflation volatility but increases the capacity of stabilization of the system. Notwithstanding, this is true only if the policy is not too strict.

Finally, to support the importance of inflation expectations I conducted some computational experiments letting the parameters of the Phillips curve varying in such a way that the inflation expectations parameter gradually loses its strength. Results show that lowering the beta parameter implies higher and more volatile inflation.

Indeed, although the evidence reinforces the Neoclassical argument about the importance of commitment in monetary policy, the validity of the model is given by the fact that the systemic instability is due to agents' approach to economic variables. In this way, I have been able to shed light on the inner mechanisms that regulate the relationship between inflation expectations and actual inflation.

Overall, this thesis has demonstrated the importance of considering economies like complex, adaptive, dynamic systems for a deeper understanding of macroeconomic dynamics. Indeed, the introduction of heterogeneity, interaction and bounded rationality into the developed frameworks has led to the emergence of unexpected properties.

In the second chapter, agents' heterogeneity implies that the superiority of Relationship Banking is not something trivial, and that financing production through banking finance may be not the best choice for a firm since the debt burden seems to prevent production's growth. In the third chapter, the contemporaneous impact of heterogeneity, interaction and bounded rationality enabled a rigorous assessment of Keynes's General Theory. This counterfactual history of economic thought demonstrates that Keynes was definitely right in attaching importance to the non rational motives governing the economy, and that he can still have much to say about actual economies, in particular for what concerns the actual crisis. Considering the way in which I have obtained under production, if we were to follow his reasoning, we should conclude that lowering the interest rate is of little help, and that economies will really revive only if some event triggers agents' confidence again. Assuming agents' bounded rationality in the fourth chapter, has enabled me to demonstrate that at the very basis of economic stability there is a mechanism that draws so much into people's psychology. Not only, it has been possible to show that the outcomes of any monetary regime depend on the way people form expectations.

Further research

The three topic treated in the chapters offer the possibility of expanding the research along various paths.

For what concerns chapter 2, I assumed the proportion of opportunistic entrepreneurs to be constant and independent from the interest rate. Indeed, it seems plausible to remove this hypothesis, and look for the macro implications. Therefore, following the literature that assesses the credit channel of monetary policy transmission (see Bernanke, Gertler (1995)), our framework results suitable to explore the macro implications of monetary policy conducted under the alternative hypothesis of Pure Asymmetric Information and Relationship Banking when agents are heterogeneous.

The results obtained simulating the Keynesian model in chapter 3 have witnessed the dependence of variables' dynamics on the inner characteristics of the Kirman's algorithm. Indeed, further research can go in the direction of looking for different mechanisms able to describe the social dynamics. I think two possible roads can be explored. On one hand, given that conditioning the social dynamics on output dynamics produced the kind of results I have presented, I can look for some different opinion regulation's rule, that is, assuming that people change mind for example following some exogenous impulse or the dynamics prices instead of output. The other possibility is to look for a completely different way through which governing social dynamics: in particular, it would be interesting to evaluate the chance of using networks to model the opinion formation process.

Finally, the analysis discussed in chapter 4 can be improved first of all by studying the implications of changing the impact of Market Sentiment over inflation expectations. That is, it would be interesting to study how the intensity of changes in expectations (changing the magnitude of the momentum through which people update expectations) affects the monetary policy outcomes. Moreover, given the debate on Inflation Targeting as well as the debate on the different forms the Taylor rule can assume [53], the framework results useful in evaluating whether these different policies do really lead to more or less efficient outcomes, or whether their efficacy simply and homogeneously relies in being able to condition inflation expectations.

[53] Svensson (1999), Levin, Natalucci, Piger (2004), Haldane, Batini (1998), Kuttner (2004), Bernanke, Miskin (1997), just to give some examples.

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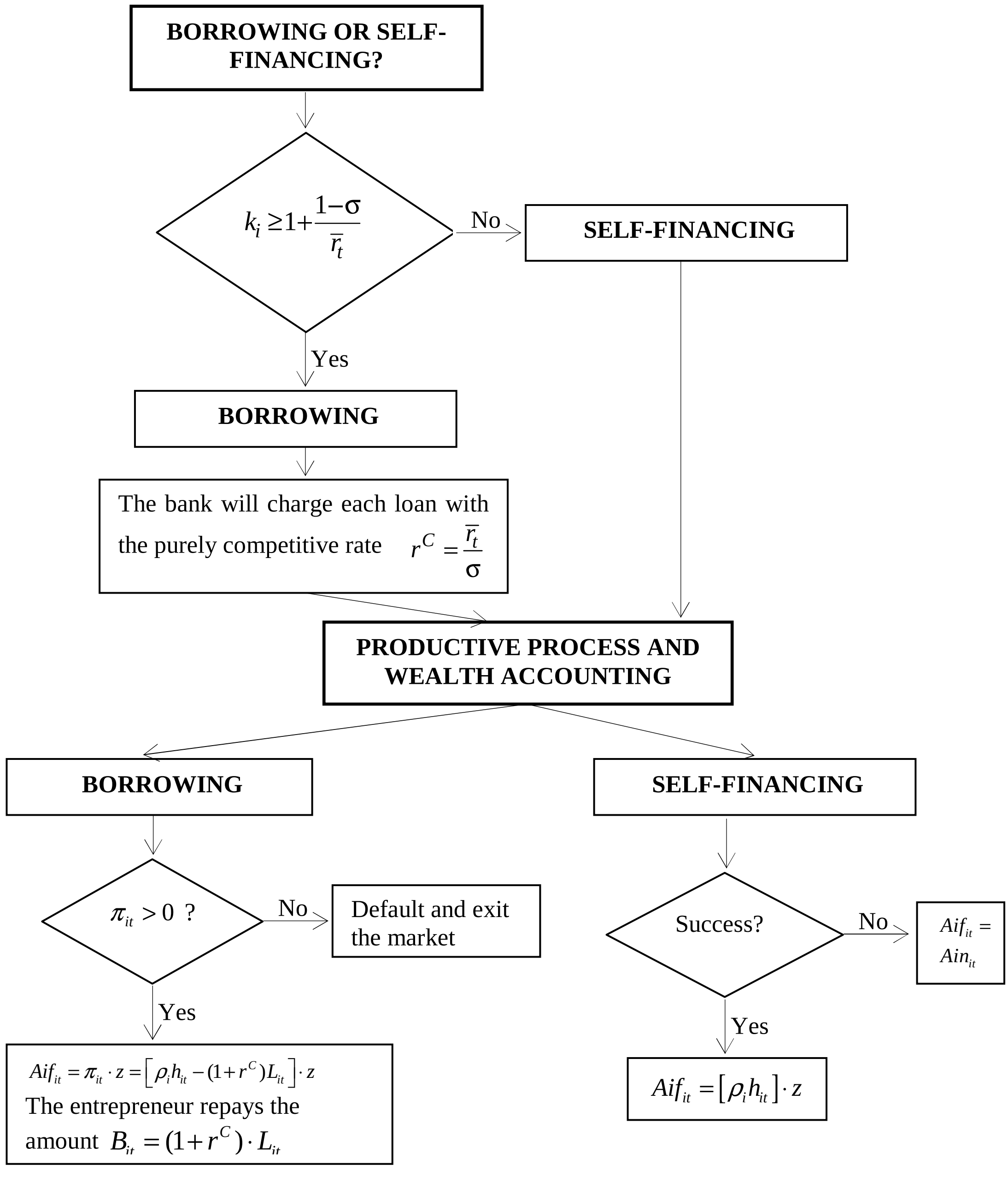
Appendix A

Chapter 2 – Flow Diagram

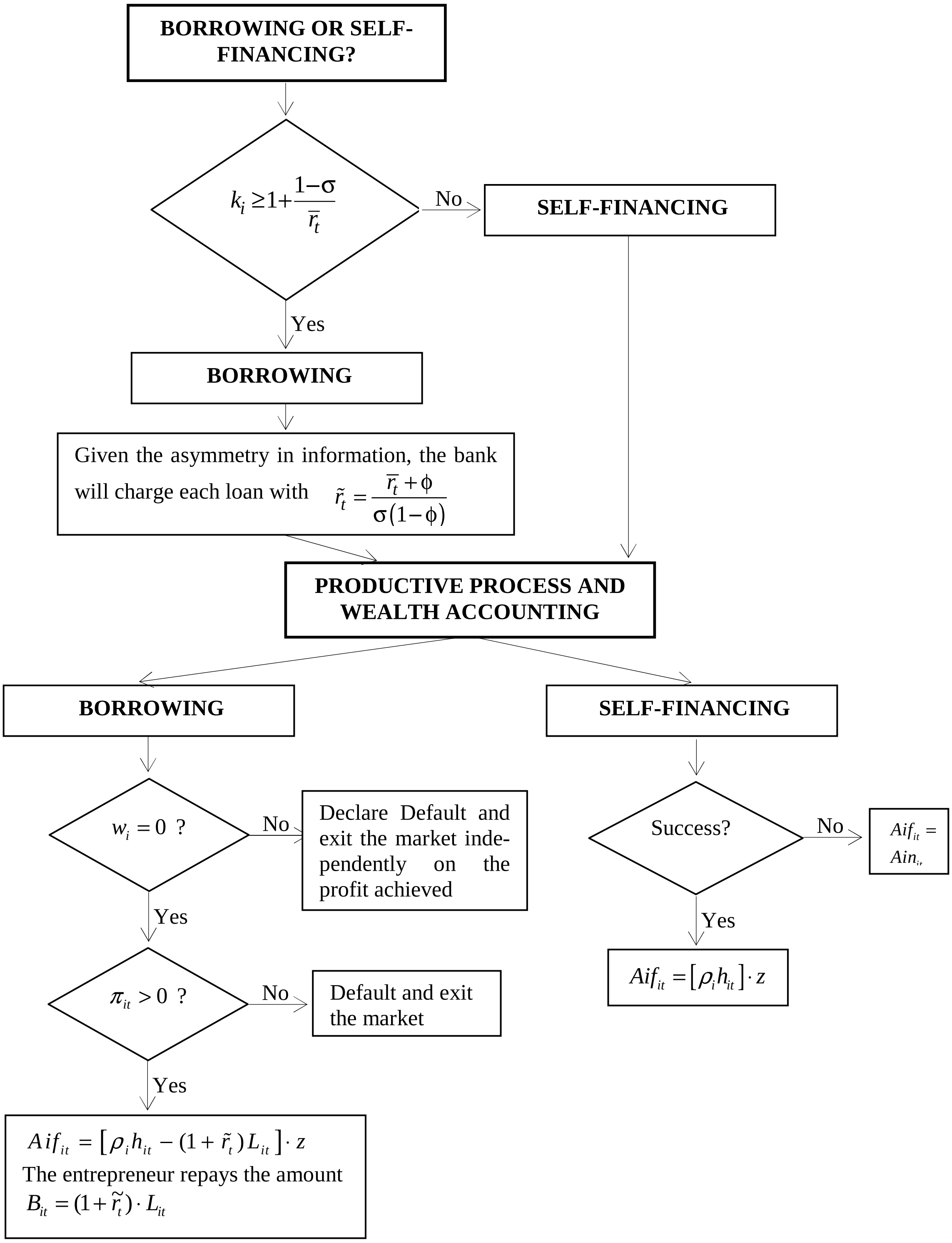
1) Symmetric information case



- Ain_{it} = entrepreneur *i*'s initial wealth at period *t*
- π_{it} = entrepreneur *i*'s profit in period *t*
- Aif_{it} = entrepreneur *i*'s final wealth at period *t*
- B_{it} = amount to be repaid by entrepreneur *i* in period *t*

2) Pure asymmetric information case

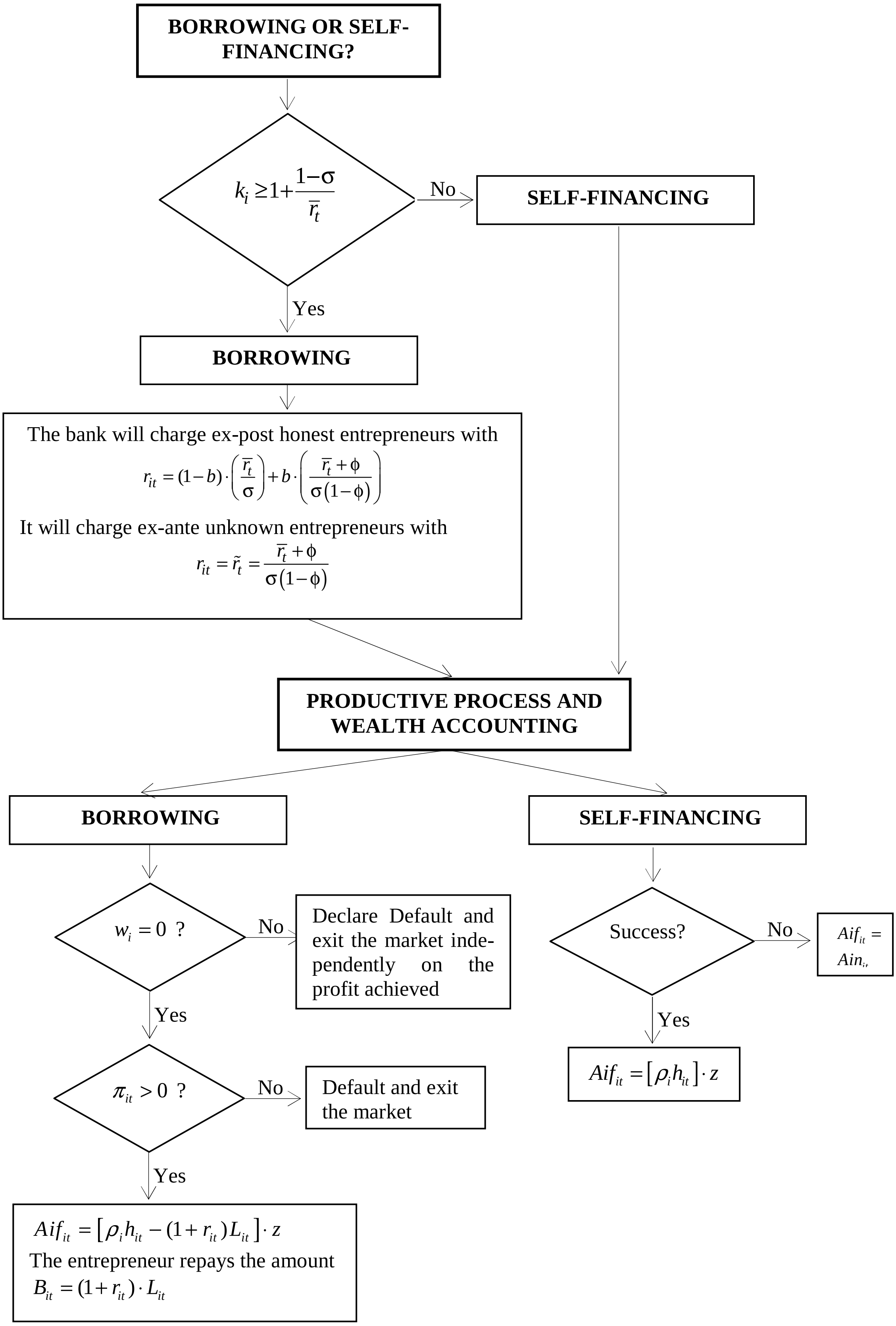
- There is a fixed proportion □ of opportunistic entrepreneurs;
- The bank is not able to ex-ante recognize them;



- $w_i = 0$ honest entrepreneur
- $w_i = 1$ opportunistic entrepreneur

3) Relationship banking case

- There is still a fixed proportion of opportunistic entrepreneurs;
- The bank is able to recognize ex-post honest entrepreneurs; once recognized, these entrepreneurs are offered a lower interest rate;



- *b* = bank's exogenous bargaining power

Appendix B

Codes

1. Chapter 2 – Firm-bank relationship and the macroeconomy

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%   Chapter 2 - PAI treatment   %%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all
f=100;   %n. firms
T=400;   %n. periods
M=200;   %n. Montecarlo simulations
sigma=0.85; %prob. success
rbar=0.01;  %risk-free int.
z=0.8;  %consumption

%%%%%  Matrices  %%%%%%%
ki=zeros(f,1);
V=zeros(T,M);
Aib=zeros(T,1);
Afb=zeros(T,1);
Ais=zeros(T,1);
Afs=zeros(T,1);
Af=zeros(T,M);
Ai=zeros(T,M);
vabf=zeros(T,M);
vasf=zeros(T,M);
av_bf=zeros(T,M);
av_sf=zeros(T,M);
f_rate=zeros(T,M);
kurt=zeros(T,M);
kurt2=zeros(T,M);
skbf=zeros(T,M);
sksf=zeros(T,M);
sk=zeros(T,M);
w_tot=zeros(f,T);
wealth=zeros(f,M);
kurto=zeros(T,M);
Stat=zeros(M,14);
y_cyc1=zeros(251,M);
w_cyc1=zeros(251,M);
wf=zeros(T,M);


for m=1:M

%%%%%%%%%%%%%%%%%%%%%%
%INITIALIZE THE SYSTEM
%%%%%%%%%%%%%%%%%%%%%%

A=51.25;
%assign ki
for i=1:f
    ki(i)=normrnd(51.25,1);
end
rho=zeros(f,1);
for i=1:f
    rho(i,1)=ki(i)*(rbar/sigma); %net rate of return (nrr)
end

rhob=rho(rho(:)>=(A*(rbar/sigma))); %nrr for BF firms
```

```
rhos=rho(rho(:)<(A*(rbar/sigma)));  %nrr for sf firms
a=numel(rhob);
s=numel(rhos);

   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   %First simulation period for BANK FINANCING ENTREPRENEURS
   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

   %arrays for bank financing entrepreneurs
   wi=zeros(a,T);
   ain=zeros(a,T);
   aif=zeros(a,T);
   l=zeros(a,T);
   y=zeros(a,T);
   pigreco=zeros(a,T);
   b=zeros(a,T);
   B=zeros(a,T);
   vb=zeros(a,T);
   fallimenti=zeros(a,T);

   phi=0.2;  %proportion of opportunistic entr.
   rai=((1+rbar)/((1-phi)*sigma))-(1/sigma); %int. unknown entrepreneurs


           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
           %Personal characteristics algorithm
           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

           for i=1:ceil(phi*a)
               wi(i,1)=1;
           end

            g=randperm(a);
            x=wi(g,1);
            wi(:,1)=x;

           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

    for i=1:a
        ain(i,1)=1;  %initial wealth level
        l(i,1)=ain(i,1); %loan amount
    end
    for i=1:a
        B(i,1)=l(i,1)*(1+rai);
    end

    for i=1:a
        c=rand;
        if c>0.15
           y(i,1)=(1+rhob(i))*(2*ain(i,1));  %production
           vb(i,1)=rhob(i)*2*ain(i,1); %value addedd
        else y(i,1)=ain(i,1);
            vb(i,1)=0;
        end
    end

    for i=1:a
        if wi(i,1)==0   %honest entrepreneurs
          pigreco(i,1)=y(i,1)-((1+rai)*l(i,1));
          if pigreco(i,1)>0 %who achieve positive profits
              b(i,1)=(1+rai)*l(i,1); %refund entirely the loan
              aif(i,1)=z*pigreco(i,1);% calculate their final wealth
           else b(i,1)=ain(i,1);  %otherwise, they refund the bank with the minimum poss-
ible amount, i.e., current period wealth
               aif(i,1)=0; %and exit the market
          end
        else b(i,1)=0;
            aif(i,1)=0;% opportunistic entrepreneurs don't meet their obligations at all
        end
    end

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %First simulation period for SELF FINANCING ENTREPRENEURS
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
    Ain=zeros(s,T);
    Aif=zeros(s,T);
    ys=zeros(s,T);
    vs=zeros(s,T);

    for i=1:s
        Ain(i,1)=1;
        c=rand;
        if c>(1-sigma)
           ys(i,1)=(1+rhos(i))*(Ain(i,1));  %production
           vs(i,1)=rhos(i)*Ain(i,1); %value added
           Aif(i,1)=z*ys(i,1); %final wealth
        else ys(i,1)=Ain(i,1);
            vs(i,1)=0;
            Aif(i,1)=z*Ain(i,1); %final wealth in case of misfortune
        end
    end

    Afb(1)=sum(aif(:,1));
    Afs(1)=sum(Aif(:,1));

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%              MAIN LOOP              %%%%%%%%%%%%%%%%%%%%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for t=2:T

           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
           %Personal characteristics algorithm
           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

              x=find(b(:,t-1)<B(:,t-1));
              q=numel(x);
              p=ceil(phi*numel(x));
              e=zeros(numel(x),2);
              e(:,1)=x;

              for j=1:p
                  e(j,2)=1;
              end
              for j=p+1:q
                  e(j,2)=0;
              end
              palli=randperm(q);
              g=e(palli,2);
              e(:,2)=g;

              for i=1:a
                 if b(:,t-1)==B(:,t-1)
                    wi(i,t)=0;
                 end
              end
              for i=e(:,1)
                  wi(i,t)=e(:,2);
              end
           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        %BANKING FINANCING ENTREPRENEURS
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        for i=1:a
            if b(i,t-1)==B(i,t-1)
               ain(i,t)=aif(i,t-1);  %initial wealth level
               l(i,t)=ain(i,t); %loan amount
           else ain(i,t)=1;%wealth level if new entrants
                l(i,t)=ain(i,t); %loan amount
            end
        end

        for i=1:a
            B(i,t)=l(i,t)*(1+rai);
        end
```

```
        for i=1:a
            c=rand;
            if c>(1-sigma)
               y(i,t)=(1+rhob(i))*(2*ain(i,t));
               vb(i,t)=rhob(i)*2*ain(i,t);
            else y(i,t)=ain(i,t);
               vb(i,t)=0;
            end
        end

        for i=1:a
            if wi(i,t)==0   %honest entrepreneurs
               pigreco(i,t)=y(i,t)-((1+rai)*l(i,t));
               if pigreco(i,t)>0 %who achieve positive profits
                 b(i,t)=(1+rai)*l(i,t); %refund entirely the loan
                 aif(i,t)=z*pigreco(i,t);
               else b(i,t)=ain(i,t);  %otherwise, they refund the bank with the minimum
possible amount, i.e., current period wealth
                 aif(i,t)=0;
               end
            else b(i,t)=0;
                aif(i,t)=0; % opportunistic entrepreneurs don't meet their obligations at
all
            end
        end

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        %SELF FINANCING ENTREPRENEURS
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        for i=1:s
            Ain(i,t)=Aif(i,t-1);
        end

        for i=1:s
            c=rand;
            if c>(1-sigma)
               ys(i,t)=(1+rhos(i))*(Ain(i,t));
               vs(i,t)=rhos(i)*Ain(i,t);
               Aif(i,t)=z*ys(i,t);
            else ys(i,t)=Ain(i,t);
                 vs(i,t)=0;
                 Aif(i,t)=z*ys(i,t);
            end
        end


       %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
       %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%isolate failing firms and compute their average initial wealth
        for i=1:a
            if pigreco(i,t)<=0
                fallimenti(i,t)=ain(i,t);
                wf(t,m)=sum(fallimenti(:,t))/a;
            end
        end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%calculating aggregate magnitudes
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

vabf(t,m)=sum(vb(:,t));  %bf value added
vasf(t,m)=sum(vs(:,t));  %sf value added
V(t,m)=vasf(t,m)+vabf(t,m);%total value added

Aib(t)=sum(ain(:,t));  %aggregate initial bf wealth
Afb(t,m)=sum(aif(:,t));  %aggregate final bf wealth
Ais(t)=sum(Ain(:,t));  %aggregate initial sf wealth
Afs(t,m)=sum(Aif(:,t));   %aggregate final sf wealth
av_bf(t,m)=mean(aif(:,t)); %average wealth bf firms
av_sf(t,m)=mean(Aif(:,t));  %average wealth sf firms

Af(t,m)=Afb(t,m)+Afs(t,m); %aggregate final wealth
```

```
f_rate(t,m)=numel(find(pigreco(:,t)<0))/a; %failure index

w_tot(1:a,t,m)=aif(1:a,t); %all firms' wealth as at the end of the period
w_tot(a+1:f,t,m)=Aif(1:s,t);

kurt(t,m)=kurtosis(aif(:,t)); %kurtosis bf wealth
kurt2(t,m)=kurtosis(Aif(:,t));  %kurtosis sf wealth
kurto(t,m)=kurtosis(w_tot(:,t)); %kurtosis total wealth
skbf(t,m)=skewness(aif(:,t));  %skewness bf wealth
sksf(t,m)=skewness(Aif(:,t));  %skewness sf wealth
sk(t,m)=skewness(w_tot(:,t)); %skewness total wealth

end
%%%%%%%%%%%%%%%%%%%%%
%%% End time loop%%%%
%%%%%%%%%%%%%%%%%%%%%

%filtering
[y_trend1]=hpfilter(log(V(150:T,m)),100);
[w_trend1]=hpfilter(log(Af(150:T,m)),100);
[w_bf_trend1]=hpfilter(log(Afb(150:T,m)),100);
[w_sf_trend1]=hpfilter(log(Afs(150:T,m)),100);
[va_bf_trend1]=hpfilter(log(vabf(150:T,m)),100);
[va_sf_trend1]=hpfilter(log(vasf(150:T,m)),100);
%detrending
y_cyc1(:,m)=log(V(150:T,m))-y_trend1;
w_cyc1(:,m)=log(Af(150:T,m))-w_trend1;
w_bf_cyc1=log(Afb(150:T,m))-w_bf_trend1;
w_sf_cyc1=log(Afs(150:T,m))-w_sf_trend1;
va_bf_cyc1=log(vabf(150:T,m))-va_bf_trend1;
va_sf_cyc1=log(vasf(150:T,m))-va_sf_trend1;

%statistics matrix
Stat(m,1)=var(y_cyc1(:,m)); %output variance
Stat(m,2)=var(w_cyc1(:,m)); %wealth variance
Stat(m,3)=var(w_bf_cyc1);   %bf wealth variance
Stat(m,4)=var(w_sf_cyc1);   %sf wealth variance
Stat(m,5)=mean(log(V(150:T,m))); %average aggregate output
Stat(m,6)=mean(log(Af(150:T,m))); %average aggregate wealth
Stat(m,7)=mean(log(av_bf(150:T,m)));%average wealth bf firms
Stat(m,8)=mean(log(av_sf(150:T,m)));%average wealth sf firms
Stat(m,11)=mean(log(Afb(150:T,m))); %average aggregate wealth bf firms
Stat(m,12)=mean(log(Afs(150:T,m))); %average aggregate wealth sf firms
Stat(m,13)=mean(log(vabf(150:T,m))); %average output bf firms
Stat(m,14)=mean(log(vasf(150:T,m))); %average output sf firms

for i=1:f
wealth(i,m)=mean(w_tot(i,:));  %final total wealth dn
end

end

%%%%%%%%%%%%%%%%
%%End M loop%%%
%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%Montecarlo simulations data processing

data=zeros(T,17);
logs=zeros(T,4);

for t=1:T
    data(t,1)=(sum(V(t,:)))/m; %aggregate value added
    data(t,2)=(sum(av_bf(t,:)))/m;  %average wealth bf firms
    data(t,3)=(sum(av_sf(t,:)))/m;   %average wealth sf firms
    data(t,4)=sum(Af(t,m))/m;  %aggregate wealth
    data(t,5)=((sum(f_rate(t,:)))/m);  %failure rate
    data(t,6)=(sum(vabf(t,:)))/m;  %value added - bf firms
    data(t,7)=(sum(vasf(t,:)))/m;  %value added - sf firms
    data(t,8)=sum(kurt(t,:))/m;   %bf wealth kurtosis
    data(t,9)=sum(kurt2(t,:))/m;  %sf wealth kurtosis
    data(t,10)=sum(kurto(t,:))/m;  %aggregate wealth kurtosis
```

```
    data(t,11)=sum(skbf(t,:))/m;   %sf wealth skewness
    data(t,12)=sum(sksf(t,:))/m;   %sf wealth skewness
    data(t,13)=sum(sk(t,:))/m;   %aggregate wealth skewness
    data(t,17)=sum(wf(t,:))/m;   %average wealth bf failing firms
    logs(t,1)=log(data(t,1));
    logs(t,2)=log(data(t,4));
    logs(t,3)=log(data(t,2));
    logs(t,4)=log(data(t,3));
end

wealth_dist=zeros(f,1);
for i=1:f
    wealth_dist(f)=mean(wealth(i,:)); %distribuzione media ricchezza fine M
end


filtered=zeros(251,4);

% Filtering (Hodrick-Prescott filter)
[y_trend]=hpfilter(log(data(150:T,1)),100);
[w_trend]=hpfilter(log(data(150:T,4)),100);
[w_bf_trend]=hpfilter(log(data(150:T,2)),100);
[w_sf_trend]=hpfilter(log(data(150:T,3)),100);
[va_bf_trend]=hpfilter(log(data(150:T,15)),100);
[va_sf_trend]=hpfilter(log(data(150:T,16)),100);
%Detrending
y_cyc=log(data(150:T,1))-y_trend;
w_cyc=log(data(150:T,4))-w_trend;
w_bf_cyc=log(data(150:T,2))-w_bf_trend;
w_sf_cyc=log(data(150:T,3))-w_sf_trend;
va_bf_cyc=log(data(150:T,15))-va_bf_trend;
va_sf_cyc=log(data(150:T,16))-va_sf_trend;

%statistics matrix
filtered(:,1)=y_cyc;
filtered(:,2)=w_cyc;
filtered(:,3)=w_bf_cyc;
filtered(:,4)=w_sf_cyc;

stat=zeros(1,14);
stat(1)=sum(Stat(:,1))/M;
stat(2)=sum(Stat(:,2))/M;
stat(3)=sum(Stat(:,3))/M;
stat(4)=sum(Stat(:,4))/M;
stat(5)=sum(Stat(:,5))/M;
stat(6)=sum(Stat(:,6))/M;
stat(7)=sum(Stat(:,7))/M;
stat(8)=sum(Stat(:,8))/M;
stat(9)=sum(Stat(:,9))/M;
stat(10)=sum(Stat(:,10))/M;
stat(11)=sum(Stat(:,11))/M;
stat(12)=sum(Stat(:,12))/M;
stat(13)=sum(Stat(:,13))/M;
stat(14)=sum(Stat(:,14))/M;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%   Chapter 2 - RB treatment   %%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all
f=100;   %n. firms
T=400;   %n. periods
M=200;   %n. Montecarlo simulations
sigma=0.85; %prob. success
rbar=0.01;  %risk-free int.
z=0.8;  %consumption

%Matrices
ki=zeros(f,1);
Aib=zeros(T,1);
Afb=zeros(T,M);
Ais=zeros(T,1);
Afs=zeros(T,M);
Af=zeros(T,M);
Ai=zeros(T,M);
V=zeros(T,M);
vabf=zeros(T,M);
vasf=zeros(T,M);
av_bf=zeros(T,M);
av_sf=zeros(T,M);
f_rate=zeros(T,M);
kurt=zeros(T,M);
kurt2=zeros(T,M);
skbf=zeros(T,M);
sksf=zeros(T,M);
sk=zeros(T,M);
w_tot=zeros(f,T);
wealth=zeros(f,M);
kurto=zeros(T,M);
Stat=zeros(M,14);
y_cyc1=zeros(251,M);
w_cyc1=zeros(251,M);
giulia=zeros(T,1);
wf=zeros(T,M);

for m=1:M

%%%%%%%%%%%%%%%%%%%%%%
%INITIALIZE THE SYSTEM
%%%%%%%%%%%%%%%%%%%%%%

A=51.25;
%assign ki
for i=1:f
    ki(i)=normrnd(51.25,1);
end

rho=zeros(f,1);
for i=1:f
    rho(i)=(ki(i)*(rbar/sigma)); %net rate of return(nrr)
end

rhob=rho(rho(:)>=(A*(rbar/sigma)));%nrr for BF firms
rhos=rho(rho(:)<(A*(rbar/sigma)));  %nrr for sf firms
a=numel(rhob);
s=numel(rhos);

   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   %First simulation period for BANK FINANCING ENTREPRENEURS
   %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

   %arrays for bank financing entrepreneurs
   wi=zeros(a,T);
   ain=zeros(a,T);
   aif=zeros(a,T);
   l=zeros(a,T);
   y=zeros(a,T);
   pigreco=zeros(a,T);
   b=zeros(a,T);
```

```
B=zeros(a,T);
vb=zeros(a,T);
r=zeros(a,T);
fallimenti=zeros(a,T);

phi=0.2; %proportion of opportunistic entr.
d=0.5; %bargaining power parameter
rai=((1+rbar)/((1-phi)*sigma))-(1/sigma); %int.unknown entrepreneurs
rrb=d*(((1+rbar)/(sigma*(1-phi)))-(1/sigma))+(1-d)*(rbar/sigma); %RB int.rate

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        %Personal characteristics algorithm
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

        for i=1:ceil(phi*a)
            wi(i,1)=1;
        end
         g=randperm(a);
         x=wi(g,1);
         wi(:,1)=x;

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


 for i=1:a
     ain(i,1)=1;  %initial wealth level
     l(i,1)=ain(i,1); %loan amount
 end
 for i=1:a
     B(i,1)=l(i,1)*(1+rai);
 end

 for i=1:a
     c=rand;
     if c>(1-sigma)
        y(i,1)=(1+rhob(i))*(2*ain(i,1)); %production
        vb(i,1)=rhob(i)*2*ain(i,1); %value added
     else y(i,1)=ain(i,1);
         vb(i,1)=0;
     end
 end

 for i=1:a
     pigreco(i,1)=y(i,1)-((1+rai)*l(i,1));
     if wi(i,1)==0   %honest entrepreneurs
       if pigreco(i,1)>0 %who achieve positive profits
           b(i,1)=(1+rai)*l(i,1); %refund entirely the loan
           aif(i,1)=z*pigreco(i,1);
        else b(i,1)=ain(i,1);  %otherwise, they refund the bank with the minimum poss-
ible amount, i.e., current period wealth
            aif(i,1)=0;
       end
     else b(i,1)=0;
         aif(i,1)=0;% opportunistic entrepreneurs don't meet their obligations at all
     end
 end

 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 %First simulation period for SELF FINANCING ENTREPRENEURS
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 Ain=zeros(s,T);
 Aif=zeros(s,T);
 ys=zeros(s,T);
 vs=zeros(s,T);

 for i=1:s
     Ain(i,1)=1;
     c=rand;
     if c>(1-sigma)
        ys(i,1)=(1+rhos(i))*(Ain(i,1));   %first period production
        vs(i,1)=rhos(i)*Ain(i,1);
        Aif(i,1)=z*ys(i,1);
     else ys(i,1)=Ain(i,1);
         vs(i,1)=0;
```

```
            Aif(i,1)=z*ys(i,1);
        end
    end



    Afb(1)=sum(aif(:,1));
    Afs(1)=sum(Aif(:,1));

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%                  MAIN LOOP                %%%%%%%%%%%%%%%%%%%%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for t=2:T

           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
           %Personal characteristics algorithm
           %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

             x=find(b(:,t-1)<B(:,t-1));
             q=numel(x);
             p=ceil(phi*numel(x));
             e=zeros(numel(x),2);
             e(:,1)=x;

             for j=1:p
                 e(j,2)=1;
             end
             for j=p+1:q
                 e(j,2)=0;
             end
             palli=randperm(q);
             g=e(palli,2);
             e(:,2)=g;

             for i=1:a
                if b(:,t-1)==B(:,t-1)
                   wi(i,t)=0;
                end
             end
             for i=e(:,1)
                 wi(i,t)=e(:,2);
             end
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        %BANKING FINANCING ENTREPRENEURS
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        for i=1:a
            if b(i,t-1)==B(i,t-1) %if debt has been repaid
                ain(i,t)=aif(i,t-1);
                r(i,t)=rrb; %int=RB rate
            else r(i,t)=rai; %otherwise, int=PAI rate
                ain(i,t)=1; %wealth level if new entrants
            end
        end

        for i=1:a
           l(i,t)=ain(i,t); %loan amount
        end
        for i=1:a
            B(i,t)=l(i,t)*(1+r(i,t));
        end

        for i=1:a
            c=rand;
            if c>(1-sigma)
               y(i,t)=(1+rhob(i))*(2*ain(i,t));
               vb(i,t)=rhob(i)*2*ain(i,t);
            else y(i,t)=ain(i,t);
               vb(i,t)=0;
```

```
            end
        end

        for i=1:a
            if wi(i,t)==0   %honest entrepreneurs
                 pigreco(i,t)=y(i,t)-((1+r(i,t))*l(i,t));
               if pigreco(i,t)>0 %who achieve positive profits
                 b(i,t)=B(i,t); %refund entirely the loan
                 aif(i,t)=z1*pigreco(i,t);
               else b(i,t)=ain(i,t);  %otherwise, they refund the bank with the minimum
possible amount, i.e., current period wealth
                 aif(i,t)=0;
               end
            else b(i,t)=0;
                aif(i,t)=0;% opportunistic entrepreneurs don't meet their obligations at
all
            end
        end



        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        %Self financing entrepreneurs
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        for i=1:s
            Ain(i,t)=Aif(i,t-1);
        end

        for i=1:s
            c=rand;
            if c>(1-sigma)
               ys(i,t)=(1+rhos(i))*(Ain(i,t));
               vs(i,t)=rhos(i)*Ain(i,t);
               Aif(i,t)=z*ys(i,t);
            else ys(i,t)=Ain(i,t);
                 vs(i,t)=0;
                 Aif(i,t)=z*ys(i,t);
            end
        end

       %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
       %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%isolate failing firms and compute their average initial wealth
        for i=1:a
            if pigreco(i,t)<=0
                fallimenti(i,t)=ain(i,t);
                wf(t,m)=sum(fallimenti(:,t))/a;
            end
        end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%calculating aggregate magnitudes
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
vabf(t,m)=sum(vb(:,t));  %bf value added
vasf(t,m)=sum(vs(:,t));  %sf value added
V(t,m)=vasf(t,m)+vabf(t,m);%total value added

Aib(t)=sum(ain(:,t));  %aggregate initial bf wealth
Afb(t,m)=sum(aif(:,t));  %aggregate final bf wealth
Ais(t)=sum(Ain(:,t));  %aggregate initial sf wealth
Afs(t,m)=sum(Aif(:,t));   %aggregate final sf wealth
av_bf(t,m)=mean(aif(:,t)); %average wealth bf firms
av_sf(t,m)=mean(Aif(:,t));  %average wealth sf firms

Af(t,m)=Afb(t,m)+Afs(t,m); %aggregate final wealth

f_rate(t,m)=numel(find(pigreco(:,t)<0))/a; %failure index

w_tot(1:a,t,m)=aif(1:a,t); %all firms' wealth as at the end of the period
w_tot(a+1:f,t,m)=Aif(1:s,t);

kurt(t,m)=kurtosis(aif(:,t)); %kurtosis bf wealth
```

```
kurt2(t,m)=kurtosis(Aif(:,t));  %kurtosis sf wealth
kurto(t,m)=kurtosis(w_tot(:,t)); %kurtosis total wealth
skbf(t,m)=skewness(aif(:,t));  %skewness bf wealth
sksf(t,m)=skewness(Aif(:,t));  %skewness sf wealth
sk(t,m)=skewness(w_tot(:,t)); %skewness total wealth

end
%%%%%%%%%%%%%%%%%%%%%
%%% End time loop%%%%
%%%%%%%%%%%%%%%%%%%%%

%filtering
[y_trend1]=hpfilter(log(V(150:T,m)),100);
[w_trend1]=hpfilter(log(Af(150:T,m)),100);
[w_bf_trend1]=hpfilter(log(Afb(150:T,m)),100);
[w_sf_trend1]=hpfilter(log(Afs(150:T,m)),100);
[va_bf_trend1]=hpfilter(log(vabf(150:T,m)),100);
[va_sf_trend1]=hpfilter(log(vasf(150:T,m)),100);
%detrending
y_cyc1(:,m)=log(V(150:T,m))-y_trend1;
w_cyc1(:,m)=log(Af(150:T,m))-w_trend1;
w_bf_cyc1=log(Afb(150:T,m))-w_bf_trend1;
w_sf_cyc1=log(Afs(150:T,m))-w_sf_trend1;
va_bf_cyc1=log(vabf(150:T,m))-va_bf_trend1;
va_sf_cyc1=log(vasf(150:T,m))-va_sf_trend1;

%statistics matrix
Stat(m,1)=var(y_cyc1(:,m)); %output variance
Stat(m,2)=var(w_cyc1(:,m)); %wealth variance
Stat(m,3)=var(w_bf_cyc1);   %bf wealth variance
Stat(m,4)=var(w_sf_cyc1);   %sf wealth variance
Stat(m,5)=mean(log(V(150:T,m))); %average aggregate output
Stat(m,6)=mean(log(Af(150:T,m))); %average aggregate wealth
Stat(m,7)=mean(log(av_bf(150:T,m)));%average wealth bf firms
Stat(m,8)=mean(log(av_sf(150:T,m)));%average wealth sf firms
Stat(m,11)=mean(log(Afb(150:T,m))); %average aggregate wealth bf firms
Stat(m,12)=mean(log(Afs(150:T,m))); %average aggregate wealth sf firms
Stat(m,13)=mean(log(vabf(150:T,m))); %average output bf firms
Stat(m,14)=mean(log(vasf(150:T,m))); %average output sf firms


for i=1:f
wealth(i,m)=mean(w_tot(i,:));  %final total wealth dn
end

end

%%%%%%%%%%%%%%%%
%%End M loop%%%
%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%Montecarlo simulations data processing

data=zeros(T,17);
logs=zeros(T,4);

for t=1:T
    data(t,1)=(sum(V(t,:)))/m; %aggregate value added
    data(t,2)=(sum(av_bf(t,:)))/m;  %average wealth bf firms
    data(t,3)=(sum(av_sf(t,:)))/m;   %average wealth sf firms
    data(t,4)=sum(Af(t,m))/m;  %aggregate wealth
    data(t,5)=((sum(f_rate(t,:)))/m);  %failure rate
    data(t,6)=(sum(vabf(t,:)))/m;  %value added - bf firms
    data(t,7)=(sum(vasf(t,:)))/m;  %value added - sf firms
    data(t,8)=sum(kurt(t,:))/m;   %bf wealth kurtosis
    data(t,9)=sum(kurt2(t,:))/m;  %sf wealth kurtosis
    data(t,10)=sum(kurto(t,:))/m;  %aggregate wealth kurtosis
    data(t,11)=sum(skbf(t,:))/m;  %sf wealth skewness
    data(t,12)=sum(sksf(t,:))/m;  %sf wealth skewness
    data(t,13)=sum(sk(t,:))/m;   %aggregate wealth skewness
    data(t,17)=sum(wf(t,:))/m;   %average wealth bf failing firms
    logs(t,1)=log(data(t,1));
    logs(t,2)=log(data(t,4));
```

```
    logs(t,3)=log(data(t,2));
    logs(t,4)=log(data(t,3));
end

wealth_dist=zeros(f,1);
for i=1:f
    wealth_dist(f)=mean(wealth(i,:)); %distribuzione media ricchezza fine M
end


filtered=zeros(251,4);

% Filtering (Hodrick-Prescott filter)
[y_trend]=hpfilter(log(data(150:T,1)),100);
[w_trend]=hpfilter(log(data(150:T,4)),100);
[w_bf_trend]=hpfilter(log(data(150:T,2)),100);
[w_sf_trend]=hpfilter(log(data(150:T,3)),100);
[va_bf_trend]=hpfilter(log(data(150:T,15)),100);
[va_sf_trend]=hpfilter(log(data(150:T,16)),100);
%Detrending
y_cyc=log(data(150:T,1))-y_trend;
w_cyc=log(data(150:T,4))-w_trend;
w_bf_cyc=log(data(150:T,2))-w_bf_trend;
w_sf_cyc=log(data(150:T,3))-w_sf_trend;
va_bf_cyc=log(data(150:T,15))-va_bf_trend;
va_sf_cyc=log(data(150:T,16))-va_sf_trend;

%statistics matrix
filtered(:,1)=y_cyc;
filtered(:,2)=w_cyc;
filtered(:,3)=w_bf_cyc;
filtered(:,4)=w_sf_cyc;

stat=zeros(1,14);
stat(1)=sum(Stat(:,1))/M;
stat(2)=sum(Stat(:,2))/M;
stat(3)=sum(Stat(:,3))/M;
stat(4)=sum(Stat(:,4))/M;
stat(5)=sum(Stat(:,5))/M;
stat(6)=sum(Stat(:,6))/M;
stat(7)=sum(Stat(:,7))/M;
stat(8)=sum(Stat(:,8))/M;
stat(9)=sum(Stat(:,9))/M;
stat(10)=sum(Stat(:,10))/M;
stat(11)=sum(Stat(:,11))/M;
stat(12)=sum(Stat(:,12))/M;
stat(13)=sum(Stat(:,13))/M;
stat(14)=sum(Stat(:,14))/M;
```

2. Chapter 3 – Keynes in the computer laboratory

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Chapter 3 - Keynes in the comp.lab.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all

%%%%%%%%%%%%%%%%%%%%%%%
% Set up of the routine
%%%%%%%%%%%%%%%%%%%%%%%
T = 400; %n. periods
N = 1000; %n. agents
S = 150; %n. intraperiod interactions

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Initialize variables and parameters
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Parameters
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

shock_up=0.1; shock_down=-0.1;
mu=0.5;C=100; d=0.7;  gamma=15;lambda=8;
del = 0.1;
xsi = 0.000325;
alfa=0.8;
teta=0.5;
beta=0.9; Phi=0.2;
G=10; %machinery's life

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Variables
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

r=zeros(1,T); c=zeros(1,T);
y=zeros(1,T); i=zeros(1,T); R=zeros(T,1);
agents = zeros(1,N); newagents = zeros(1,N);
k = ones(S,1)*0.5;
ki = zeros(T,1);
q=zeros(1,T);
nu = zeros(S,1);
nui=zeros(1,T);
nup=zeros(1,T);
exp_inf=zeros(1,T);
P=ones(1,T);
infl=zeros(T,1);
A=zeros(1,T);
rho=zeros(1,T);
ybar=zeros(1,T);
av_infl=zeros(1,T);
K=zeros(1,T);
Rho=zeros(1,T);
m=zeros(1,T);
shock=zeros(1,T);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%First periods of the simulation
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
giu=15;
gn(1:giu)=0; gn(giu+1:T)=0.1;
ki(1:giu)=0.5;
i(1:giu)=100;
y(1:giu)=100;
c(1:giu)=100;
m(giu:T)=1;
R(1:giu)=log(100)*(mu/0.5);
q(1:giu)=1;
infl(1:giu)=0; ybar(1:giu)=y(1:giu);
Z=zeros(1,T);
omega=0.005;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
%%%%%%%%%%          Main loop       %%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for t=giu:T


      k(1) = k(S);
      nu(1) = k(1)*N;
      agents = rand(1,N)>0.5;

                %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                %Kirman algorithm
                %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                for j=2:S
                    agprob = rand(1,N);
                    rswitch = (agprob<xsi);
                    recruitf = (  agprob>xsi ) & (agprob<xsi+(1-del)*nu(j-1)/(N-1));
                    recruitc = (  agprob>xsi ) & (agprob<xsi+(1-del)*(N-nu(j-1))/(N-1));
                    newagents = agents;
                    newagents( (agents==0) & (rswitch==1) ) = 1;
                    newagents( (agents==1) & (rswitch==1) ) = 0;
                    newagents( (agents==0) & (recruitc==1) ) = 1;
                    newagents( (agents==1) & (recruitf==1) ) = 0;
                    agents = newagents;
                    k(j) = mean(agents==0);
                    nu(j) = sum( agents==0);
                end

                k = k(1:S);
                ki(t)=mean(k(1:S));
                nui(t)=ceil(mean(nu(1:S))); %n. of optimists

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %DETERMINATION MACRO VARIABLES
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

     %consumption
     if y(t-1)>y(t-2)
         c(t)=C+ki(t)*(y(t-1)-y(t-2));
     else c(t)=C+((1-ki(t))*(y(t-1)-y(t-2)));
     end

     %investment
     i(t)=(d*i(t-1))+lambda*(q(t-1)-1);

     %aggregate output
     y(t)=c(t)+i(t);

     %calculating MEC
     K(t)=i(t)+(9/10)*i(t-1)+(8/10)*i(t-2)+(7/10)*i(t-3)+(6/10)*i(t-4)+(5/10)*i(t-
5)+(4/10)*i(t-6)+(3/10)*i(t-7)+(2/10)*i(t-8)+(1/10)*i(t-9);
     Rho(t)=(alfa*y(t))/K(t);
     rho(t)=(ki(t)*((1+gn(t))*Rho(t)))+((1-ki(t))*((1-gn(t))*Rho(t)));

     %calculating inflation
     ybar(t)=log(y(t))-log(y(t-1));
     exp_inf(t)=mean(infl(t-3:t-1));
     P(t)=P(t-1)*(1+(beta*(exp_inf(t)))+(Phi*ybar(t)));
     infl(t)=(P(t)-P(t-1))/P(t-1);
     shock(t)=(1-ki(t))*shock_up+ki(t)*shock_down;

     %LM curve
     R(t)=((mu/teta)*log(y(t)))-(log(m(t))/teta)+(log(P(t))/teta)+shock(t);
     r(t)=R(t)-exp_inf(t); %real int rate
     q(t)=rho(t)/r(t);


end

%%SERIES' FILTERING
[y_trend]=hpfilter(log(y(51:T)),100);
[i_trend]=hpfilter(log(i(51:T)),100);
[c_trend]=hpfilter(log(c(51:T)),100);
```

```
[R_trend]=hpfilter(log(R(51:T)),100);
[r_trend]=hpfilter(log(r(51:T)),100);
[infl_trend]=hpfilter(log(infl(51:T)),100);
[ki_trend]=hpfilter(log(ki(51:T)),100);

%%DETRENDING SERIES
y_cyc=log(y(51:T)')-y_trend;
c_cyc=log(c(51:T)')-c_trend;
i_cyc=log(i(51:T)')-i_trend;
R_cyc=(log(R(51:T)))-R_trend;
r_cyc=(log(r(51:T))')-r_trend;
infl_cyc=(log(infl(51:T)))-infl_trend;
ki_cyc=(log(ki(51:T)))-ki_trend;

%%%variances
sigma_iy=std(i_cyc)/std(y_cyc);
sigma_cy=std(c_cyc)/std(y_cyc);
st_dev_c=std(c_cyc); %std consumption
st_dev_i=std(i_cyc); %std investment
st_dev_y=std(y_cyc); %std output
st_dev_R=std(R_cyc); %std nominal rate
st_dev_r=std(r_cyc); %std real rate
st_dev_infl=std(infl_cyc); %std inflation

%%%%%%CROSS-CORRELATION ANALYSIS

%cross corr between output and all the variables
lag=(-4:4);
lagx=-4:0.01:4;
% lags=(-4:4);
[a,lags]=xcorr(y_cyc,c_cyc,'coeff');
ca=a(346:354);
[b,lags]=xcorr(y_cyc,i_cyc,'coeff');
cb=b(346:354);
[v,lags]=xcorr(y_cyc,R_cyc,'coeff');
cc=v(346:354);
[d,lags]=xcorr(y_cyc,r_cyc,'coeff');
cd=d(346:354);
[e,lags]=xcorr(y_cyc,infl(51:T),'coeff');
ce=e(346:354);
[f,lags]=xcorr(y_cyc,ki_cyc,'coeff');
cf=f(346:354);

%%cross correlation all variables with market sentiment
[g,lags]=xcorr(ki(51:T),c_cyc,'coeff');
cg=g(346:354);
[h,lags]=xcorr(ki(51:T),i_cyc,'coeff');
ch=h(346:354);
[o,lags]=xcorr(ki(51:T),R_cyc,'coeff');
ci=o(346:354);
[l,lags]=xcorr(ki(51:T),r_cyc,'coeff');
cl=l(346:354);
[m,lags]=xcorr(ki(51:T),infl(51:T),'coeff');
cm=m(346:354);
[n,lags]=autocorr(infl(51:T));
cn=n(1:5);
```

3. Chapter 4 – Inflation expectations and Market Sentiment

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Chapter 4 - Inflation and Market Sentiment: Modern Regime
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all

%%%%%%%%%%%%%%%%%%%%%%%
% Set up of the routine
%%%%%%%%%%%%%%%%%%%%%%%

T = 400; %Number of periods
N = 1000; %Number of agents
S = 150; %Number of intra-period interactions

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Initialize variables and parameters
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Parameters
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

shock_up=0.1; shock_down=-0.1;
mu=0.5;  C=100; d=0.7; lambda=10;
del = 0.1;
xsi = 0.000325;
teta=0.5;
alfa=0.8;
beta=0.9; Phi=0.2;
G=10;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Variables
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

r=zeros(1,T); c=zeros(1,T);
y=zeros(1,T); i=zeros(1,T); R=zeros(T,1);
agents = zeros(1,N); newagents = zeros(1,N);
k = ones(S,1)*0.5;
ki = zeros(T,1);
q=zeros(1,T);
nu = zeros(S,1);
nui=zeros(1,T);
exp_inf=zeros(1,T);
P=ones(1,T);
infl=zeros(T,1);
A=zeros(1,T);
shock=zeros(T,1);
rho=zeros(1,T);
ybar=zeros(1,T);
av_infl=zeros(1,T);
K=zeros(1,T);
Rho=zeros(1,T);
m=zeros(1,T);
ys=zeros(T,1);
is=zeros(T,1);
rs=zeros(T,1);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%First periods of the simulation
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
giu=15;
gn(1:giu)=0; gn(giu+1:T)=0.1;
ki(1:giu)=0.5;
i(1:giu)=10;
y(1:giu)=C;
c(1:giu)=C;
m(1:T)=1;
R(1:giu)=log(100)*(mu/0.5);
q(1:giu)=1;
infl(1:giu)=0; ybar(1:giu)=y(1:giu);
Z=zeros(1,T);
omega=0.003;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%       Main loop    %%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for t=giu:T


      k(1) = k(S);
      nu(1) = k(1)*N;
      agents = rand(1,N)>0.5;


      %inflation expectations regulated by the target level
      if  mean(infl(t-3:t-1))<=0.01
          del_opt(1)=1-del+omega;
          del_pes(1)=1-del-omega;
      else del_opt(1)=1-del-omega;
           del_pes(1)=1-del+omega;
      end
                %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                %Kirman algorithm
                %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                for j=2:S
                    agprob = rand(1,N);
                    rswitch = (agprob<xsi);
                    recruitf = (  agprob>xsi ) & (agprob<xsi+(del_opt(1))*nu(j-1)/(N-1));
                    recruitc = (  agprob>xsi ) & (agprob<xsi+(del_pes(1))*(N-nu(j-1))/(N-
1));
                    newagents = agents;
                    newagents( (agents==0) & (rswitch==1) ) = 1;
                    newagents( (agents==1) & (rswitch==1) ) = 0;
                    newagents( (agents==0) & (recruitc==1) ) = 1;
                    newagents( (agents==1) & (recruitf==1) ) = 0;
                    agents = newagents;
                    k(j) = mean(agents==0);
                    nu(j) = sum( agents==0);
                end

                k = k(1:S);
                ki(t)=mean(k(1:S));
                nui(t)=ceil(mean(nu(1:S))); %numero di ottimisti



    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %DETERMINATION MACRO VARIABLES
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     ys(t)=normrnd(0,0.00005);
     is(t)=normrnd(0,0.00005);

     %consumption
     if y(t-1)>y(t-2)
         c(t)=C+ki(t)*(y(t-1)-y(t-2));
     else c(t)=C+((1-ki(t))*(y(t-1)-y(t-2)));
     end

     %investment
     i(t)=(d*i(t-1))+lambda*(q(t-1)-1);

     %aggregate output
     y(t)=c(t)+i(t)+ys(t);

     %calculating MEC
     K(t)=i(t)+(9/10)*i(t-1)+(8/10)*i(t-2)+(7/10)*i(t-3)+(6/10)*i(t-4)+(5/10)*i(t-
5)+(4/10)*i(t-6)+(3/10)*i(t-7)+(2/10)*i(t-8)+(1/10)*i(t-9);
     Rho(t)=(alfa*y(t))/K(t);
     rho(t)=(ki(t)*((1+gn(t))*Rho(t)))+((1-ki(t))*((1-gn(t))*Rho(t)));

     %determining inflation
     ybar(t)=log(y(t))-log(y(t-1));
     av_infl(t)=mean(infl(t-3:t));
     exp_inf(t)=(ki(t)*((1-gn(t))*av_infl(t)))+((1-ki(t))*((1+gn(t))*av_infl(t)));
     P(t)=P(t-1)*(1+(beta*(exp_inf(t)))+(Phi*ybar(t)))+is(t);
```

```
    infl(t)=(P(t)-P(t-1))/P(t-1);
    shock(t)=(ki(t)*shock_down)+((1-ki(t))*shock_up);

    %Taylor rule
    R(t)=infl(t)+0.5*(infl(t)-0.01)+0.5*(log(y(t))-log(100))+0.7+shock(t);

    r(t)=R(t)-exp_inf(t); %real interest rate
    q(t)=rho(t)/r(t);

end


%%SERIES' FILTERING
[y_trend]=hpfilter(log(y(51:T)),100);
[i_trend]=hpfilter(log(i(51:T)),100);
[c_trend]=hpfilter(log(c(51:T)),100);
[R_trend]=hpfilter(log(R(51:T)),100);
[r_trend]=hpfilter(log(r(51:T)),100);

%%DETRENDING SERIES
y_cyc=log(y(51:T)')-y_trend;
c_cyc=log(c(51:T)')-c_trend;
i_cyc=log(i(51:T)')-i_trend;
R_cyc=(log(R(51:T)))-R_trend;
r_cyc=(log(r(51:T))')-r_trend;

%%%VARIANCE
sigma_iy=std(i_cyc)/std(y_cyc);
sigma_cy=std(c_cyc)/std(y_cyc);
st_dev_y=std(y_cyc);
st_dev_inf=std(infl(51:T));

%STATISTICS
mean_y=mean(y(51:T));
mean_inf=mean(infl(51:T));
median_inf=median(infl(51:T));
max_inf=max(infl(51:T));
min_inf=min(infl(51:T));



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Chapter 4 - Inflation and Market Sentiment: Old Regime
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all

%%%%%%%%%%%%%%%%%%%%%%%
% Set up of the routine
%%%%%%%%%%%%%%%%%%%%%%%

T = 400; %Number of periods
N = 1000; %Number of agents
S = 150; %Number of intra-period interactions

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Initialize variables and parameters
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Parameters
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

shock_up=0.1; shock_down=-0.1;
mu=0.5;  C=100; d=0.7; lambda=10;
del = 0.1;
xsi = 0.000325;
teta=0.5;
alfa=0.8;
beta=0.9; Phi=0.2;
G=10; %vita del macchinario
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Variables
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
r=zeros(1,T); c=zeros(1,T);
y=zeros(1,T); i=zeros(1,T); R=zeros(T,1);
agents = zeros(1,N); newagents = zeros(1,N);
k = ones(S,1)*0.5;
ki = zeros(T,1);
q=zeros(1,T);
nu = zeros(S,1);
nui=zeros(1,T);
exp_inf=zeros(1,T);
P=ones(1,T);
infl=zeros(T,1);
A=zeros(1,T);
shock=zeros(T,1);
rho=zeros(1,T);
ybar=zeros(1,T);
av_infl=zeros(1,T);
K=zeros(1,T);
Rho=zeros(1,T);
m=zeros(1,T);
ys=zeros(T,1);
is=zeros(T,1);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%First periods of the simulation
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
giu=15;
gn(1:giu)=0; gn(giu+1:T)=0.1;
ki(1:giu)=0.5;
i(1:giu)=100;
y(1:giu)=C;
c(1:giu)=C;
m(:)=1;
R(1:giu)=log(100)*(mu/0.5);
q(1:giu)=1;
infl(1:giu)=0; ybar(1:giu)=y(1:giu);
omega=0.003;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%       Main loop    %%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for t=giu:T

      k(1) = k(S);
      nu(1) = k(1)*N;
      agents = rand(1,N)>0.5;


      %inflation exp. regulate dby past inflation dynamics
      if  infl(t-1)<infl(t-2)
          del_opt(1)=1-del+omega;
          del_pes(1)=1-del-omega;
      else del_opt(1)=1-del-omega;
           del_pes(1)=1-del+omega;
      end

                %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                %Kirman algorithm
                %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                for j=2:S
                    agprob = rand(1,N);
                    rswitch = (agprob<xsi);
                    recruitf = (  agprob>xsi ) & (agprob<xsi+(del_opt(1))*nu(j-1)/(N-1));
%+1 al numero di ottimisti
                    recruitc = (  agprob>xsi ) & (agprob<xsi+(del_pes(1))*(N-nu(j-1))/(N-
1)); %-1 al numero di ottimisti
                    newagents = agents;
                    newagents( (agents==0) & (rswitch==1) ) = 1;
                    newagents( (agents==1) & (rswitch==1) ) = 0;
                    newagents( (agents==0) & (recruitc==1) ) = 1;
                    newagents( (agents==1) & (recruitf==1) ) = 0;
                    agents = newagents;
                    k(j) = mean(agents==0);
```

```
                nu(j) = sum( agents==0);
            end

            k = k(1:S);
            ki(t)=mean(k(1:S));
            nui(t)=ceil(mean(nu(1:S))); %numero di ottimisti

    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %DETERMINATION MACRO VARIABLES
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     ys(t)=normrnd(0,0.00005);
     is(t)=normrnd(0,0.00005);

     %consumption
     if y(t-1)>y(t-2)
         c(t)=C+ki(t)*(y(t-1)-y(t-2));
     else c(t)=C+((1-ki(t))*(y(t-1)-y(t-2)));
     end

     %investment
     i(t)=(d*i(t-1))+lambda*(q(t-1)-1);

     %aggregate output
     y(t)=c(t)+i(t)+ys(t);

     %calculating MEC
     K(t)=i(t)+(9/10)*i(t-1)+(8/10)*i(t-2)+(7/10)*i(t-3)+(6/10)*i(t-4)+(5/10)*i(t-
5)+(4/10)*i(t-6)+(3/10)*i(t-7)+(2/10)*i(t-8)+(1/10)*i(t-9);
     Rho(t)=(alfa*y(t))/K(t);
     rho(t)=(ki(t)*((1+gn(t))*Rho(t)))+((1-ki(t))*((1-gn(t))*Rho(t)));

     %determining inflation
     ybar(t)=log(y(t))-log(y(t-1));
     av_infl(t)=mean(infl(t-3:t));
     exp_inf(t)=(ki(t)*((1-gn(t))*av_infl(t)))+((1-ki(t))*((1+gn(t))*av_infl(t)));
     P(t)=P(t-1)*(1+(beta*(exp_inf(t)))+(Phi*ybar(t)))+is(t);
     infl(t)=(P(t)-P(t-1))/P(t-1);
     shock(t)=(ki(t)*shock_down)+((1-ki(t))*shock_up);

     %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     %flexible money supply case
%     if infl(t)>infl(t-1)
%         m(t)=m(t-1)*1.05;
%     else m(t)=m(t-1)*0.95;
%     end
      %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

    R(t)=((mu/teta)*log(y(t)))-(log(m(t))/teta)+(log(P(t))/teta)+shock(t);   %traditional
LM

    r(t)=R(t)-exp_inf(t); %real interest rate
    q(t)=rho(t)/r(t);

end
time=1:1:350;

%%SERIES' FILTERING
[y_trend]=hpfilter(log(y(51:T)),100);
[i_trend]=hpfilter(log(i(51:T)),100);
[c_trend]=hpfilter(log(c(51:T)),100);
[R_trend]=hpfilter(log(R(51:T)),100);
[r_trend]=hpfilter(log(r(51:T)),100);

%%DETRENDING SERIES
y_cyc=log(y(51:T)')-y_trend;
c_cyc=log(c(51:T)')-c_trend;
i_cyc=log(i(51:T)')-i_trend;
R_cyc=(log(R(51:T)))-R_trend;
r_cyc=(log(r(51:T))')-r_trend;

%%%VARIANCE
sigma_iy=std(i_cyc)/std(y_cyc);
sigma_cy=std(c_cyc)/std(y_cyc);
st_dev_c=std(c_cyc); %std consumption
```

```
st_dev_i=std(i_cyc); %std investment
st_dev_y=std(y_cyc); %std output
st_dev_R=std(R_cyc); %std nominal rate
st_dev_r=std(r_cyc); %std real rate
st_dev_inf=std(infl(51:T));

%%%STATISTICS
mean_inf=mean(infl(51:T));
median_inf=median(infl(51:T));
mean_y=mean(y(51:T));
max_inf=max(infl(51:T));
min_inf=min(infl(51:T));
```

Tutti ogni tanto ci
Perderemo nella nebbia, ma
La passione per la verità
Ci riporta in strada,
come siamo diversi
specchiati negli occhi
della gente, poche
fontane ridanno
il nostro verde.
Siamo tutto ciò che amiamo,
il resto è sovrastruttura.

F. SdB

My gratitude goes here to all the persons who helped me in completing this thesis, in many different ways.

Edoardo Gaffeo and Roberto Tamborini, I really have to thank them for all I have learned in writing this dissertation, and for guiding me towards method and originality.

All the people from CIFREM, in particular Dominique and Fabio P. And the good and special friends I have met in the doctoral program, Francesca B. and Francesca M.
From the department of Economics, Andrea Fracasso, for the really useful discussions and for his helpfulness.

Daniela, Sonia, Federico, Matteo, Sara, Claudio from OPES, for not being just colleagues but friends.

Silvia, Elena and Fabrizio from Emergency Trento for their precious friendship.

My dearest friends ever, I am what I am because I know I can count on them, Cinzia, Francesca and Monica.

My “new” family, Rosario, Iole and Carmela.

My family, Maurizio, Patrizia and Mattia, for their unconditional love and support, for having made me a happy child and a strong woman. My uncle Guido, my aunt Lucia and Francesco.

Bruno and Celide, my grandparents, to whom this thesis is dedicated. I cannot find the words to express what they have meant to me, but I know that I have completed this thesis because of their dignity and their strength, and I miss them so much.

And finally, Luigi.
The latest years have not been simple, and life has put me to test so many times. I felt like a small boat in an enormous ocean, but my husband has been the light in the shadow and the harbour there to embrace me. I’m freely going around through life, but when I look at his eyes I feel at home.