Guilherme da Fonseca-Statter

The Economy as a Complex System

Contribution for a Marxian Inspired ABM or AbCE Analysis

ISCTE – Lisbon University Institute

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ABM or AbCE Analysis

«In my opinion, and from a philosophical point of view, it is only possible,to create a new complex systems theory, using the principles and methods of Hegel's dialectic philosophy»

Jan Sarnovsky - Technical University of Kosice

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«Science is what we understand well enough to explain to a computer, Art is all the rest»
Donald E. Knuth (foreword to «A=B» by Petkovsek, Wilf and Zeilberger)

1. Introduction

According to the literature, three different «symbol systems» have been available to social scientists: the familiar verbal argumentation of a descriptive nature, supposedly understandable to, or within the reach of, any logically minded educated person, mathematics and its formalisms, supposedly more rigorous but only available to trained readers, and the use of simulations through modelling using computer techniques, supposedly more vivid and realistic but also only available to trained professionals. In the words of Gilbert and Terna (2000)[1] *«computer simulation (or computational modelling) involves representing a model as a computer program. The key question is: What tools can we use in building our models, if we follow the «third way»?*

Judging from some measure of reluctance on the part of the vast majority of mainstream economists to go and learn computer programming techniques (Tesfatsion, 2003) it seems that simulations will have to be written in some kind of «Esperanto». One factor that moves against any movement (on the part of those mainstream economists) to go back to class rooms and learn a programming language, is also the current babelian pandemonium of competing «tools and techniques», each one claiming to be more effective and «simple to use». This Babel of computer dialects (even if they all claim to be varieties of one single «master language» – Java) goes against *«the emergence of a renewed enthusiastic effort in economic theory»*. The proponents of Swarm, for example, claim that it is a library of functions that offers tools that one would classify somewhere in the middle, between basic programming languages (Fortran, C, Java...) and the already available but closed packages for dynamic simulation. As with other offerings, in a medieval market place, it claims that *«it helps us to develop our own software, using a well-defined protocol and powerful tools to deal with agents' behaviour, interaction and time sequences»*. The proponents of Swarm conclude that *«it can be considered an excellent candidate to play the role of this necessary Esperanto»* (Terna, 2002)[2].

This paper is intended to be a very short version of an eventual future «doctoral thesis» on the general theme of complexity sciences and to be dedicated to the specific theme of a certain empirical law of behaviour of the capitalist system. As a consequence of the fundamental problem indicated in the opening paragraphs no attempt has been made to actually develop or present formal modelling specifications. The idea, at this stage, is to present the overall description of a future model that should be developed within the next two years. In any case it is my firm belief that a trained programmer could build a realistic model using just the specifications that are provided here. It has been done before (with much less sophisticated tools and techniques), there is no reason why it could not be done now.

Because of its intended scope, both this paper and the eventual future «doctoral thesis», will have to address a set of complementary issues such as the specificities of the neoclassical paradigm in economics and its relationship with the approach from the complexity sciences perspective. These issues will be also discussed in the context of the criticisms that have already been levelled at the neoclassical paradigm by the practitioners of the new emergent discipline of Econophysics, as well

[1] Cited in Terna 2002
[2] http://jemed.u-bordeaux4.fr/1013/1013.pdf

as by other scientists that came to the study of the economy from fields, apparently as disparate – from a social sciences point of view - as quantum physics and the theory of information.
Even though this is supposed to be a text for a specific type of an academic evaluation (as part of a doctoral programme in complexity sciences), the author has strived to keep it as readable as possible to a lay, but educated, person. For the benefit of new comers to the field of complexity, at least as it is applied to the overall field of social sciences (and it is worth underlining the fact that «economics» is a social science that should be better designated, in the good old classical tradition, as «political economy»), the text will have just enough definitions and clarifications, usually inserted as footnotes.
This paper will be divided in eight parts, of which this introduction is merely the first. In it I will try to introduce, very briefly, the intents of the other parts, as well as a short summary of the whole paper. After this introduction, I start with a short summary of some epistemological questions that arise when discussing the issue of complexity in the study of the Economy and how that has been perceived by the «economics» discipline. Considering that the problem of «units of measure» are crucial to a better understanding of some of the issues addressed here, I then move on to a brief discussion of the measurement problem, in sciences in general and in the social sciences in particular, and how that has been at the source of some polemics regarding the Marxian analytical approach to the explanation of the capitalist system and its inner logic. Most particularly in view of new complexity theories and the putative approach from the novel discipline of Econophysics. After that I will enter into a brief discussion of the issue of economic agents and how that has been approached from various points of view, as well as the various entities (namely the environment) involved in the overall economic process. This discussion of the various types of economic agents and how they are supposed to interact amongst themselves and with their environment, will be followed by a short discussion of the links established between the agents. This will include a brief epistemological discussion regarding such issues as «methodological individualism» *versus* «methodological holism», «homogeneous agents» *versus* «heterogeneous agents» and «static» *versus* «dynamic» analysis. In that discussion I basically suggest that some of the polemics often seem to be of a Byzantine type and do not really matter, to the search of an operational explanation, when one comes to the actual study of the real world economy.
I then move on to a more detailed definition of the various agents motivations and postulated or normally expected behaviour. This definition will be done – hopefully – in such a way as to permit a reasonably knowledgeable computer programmer to develop a model of the system without further ado. To conclude this part of the paper I will then present a concise description of the various algorithms to be programmed (in any computer language...) that are to be executed in line with the postulated behaviour of the pre-defined economic agents and their environment.
The basic tenet here is that a demonstration of the ineluctable and logical character of a specific and tendential law of the capitalist system – that of a falling tendency of the rate of profit – can be achieved in a «simply analytical» manner or, as will be case here, by resorting to the methodologies of «Agent-based Computational Economics». Indeed, it might be argued that this «AbCE» will be mere «window-dressing», to better illustrate a systemic behavioural law, through an algorithm that, in fact, will be inserted in one of the computational routines that make up the model being proposed here. Recalling here the different approaches, in the words of Pietro Terna of the Turin University,

> *«There are three different «symbol systems» available to social scientists: the familiar verbal argumentation and mathematics, but also a third way, computer simulation. Computer simulation, or computational modelling, involves representing a model as a computer program. The key question is: What tools can we use in building our models, if we follow the «third way»? Simulation will have to be written in some Esperanto: it is obvious that the current Babel is against the emergence of a renewed enthusiastic effort in economic theory. Swarm is a library of functions offering tools in the middle between basic programming (Fortran, C, C++, Java, ….) and closed packages for dynamic simulation; it helps us to develop our own software, using a well-defined protocol and powerful tools to*

deal with agents' behaviour, interaction and time sequences».

On the issue of how to characterize the motives and behaviour of economic agents, most Marxian approaches are cast at the macro-level and are concerned with large-scale historical processes. But Analytical Marxism recognizes that structural processes are played out at the micro-level:

> *«Whatever else one might want of a social theory, if we want to understand the mechanisms through which a given social cause generates its effects, we must try to understand why individuals act the way they do»* (Wright, 1994, p. 190).

As a micro-level concept, Wright sees class as a set of locations that are filled by individuals:

> *«To be in a class location is to be subjected to a set of mechanisms that impinge directly on the lives of individuals as they make choices and act in the world.… To develop a concept of class structure at the micro level of analysis is to elaborate the concepts in terms of such mechanisms»* (Wright, 1989, p. 275). [3]

There is one additional point, that under different circumstances might justify further elaboration. In the field of complexity and the science of economics, there is one particular issue that is not usually found in the literature and that might (some day) require some more attention and treatment than seems to be the case these days. As an hyper-complex system, the economy is full of «feedback mechanisms», often referred to as «automatic stabilizers». The issue I am referring to is the possible consideration of the «rate of profit» as a «feedback mechanism» that signals back to the system that it is no longer worthwhile to continue in search of profitable investment. This may sound like a very common triviality. What is perhaps not so trivial is the fact that, just like all «feedback mechanisms», this one has a temporality of its own, which is dependent on the rhythm of growth and accumulation prevailing in the system.

To conclude this introduction, one brief comment on some current misunderstandings on the issue of «complexity in the economy», seems to be in order. In any case the issue itself will be further discussed in the next section. One of the most common featuures of complexity seems to be the phenomenon of emergence and novelty, or the fact that some results from a (social or economic) process appear to be unexpected. Also, as a result of a shift in the emphasis on particles to an emphasis on links[4], it has become fashinable to speak of the «network economy». For this brief note I use a text from Barabási (2003):

> *«Hierachical thinking does not fit a network economy. In the traditional organizations, rapid shifts can be made within the organization, with any resulting losses being offset by gains in other parts of the hierarchy. In a network economy each node must be profitable».*

In these few and brief paragraphs it is possible to identify a number of misconceptions about the nature of the economy and of its complexity. Apart from the «constructionism» that seems to underlie the concept of a «network economy» (as being supposedly different from a «hierarchical» economy...), the real issue behind the scenes (so to speak) is the old classical problem of a definition of what is «productive», as opposed to «unproductive», work.

In a «hierarchical» framework, the leaders of each node (or business firm...) are deemed to strive to minimise «unproductive» work and to maximise «productive» work, where that «unproductive» work is usually considered to be that of administrative type of work and «productive» work is the one that most contributes to the process of new «value adding». One additional factor in this direction is that there is an inverse relationship between the repetitive nature of any set of work tasks, and the potential for new value adding opportunities. In other words, the more repetitive tasks tend to add less value that creative tasks do.

On the assumption (validated by a number of studies in labour sociology) that «repetitive manual labour» costs more to manage (seems to be more prone to conflicts) than does to manage «creative engineering» work, nodes (or business firms) that expand and develop new products try to outsource all the related activities of repetitive production, including those of an administrative

[3] http://atgstg01.ppppineforge.com/upm-data/13297_Chapter_8_Web_Byte_Erik_Olin_Wright.pdfffffff

[4] With such a shift on emphasis being usually considered as a paradigmatic shift...

nature.
In what relates to Barabási's contention above, the problem here arises in that these *new nodes,* that emerge from this outsourcing movement, once they have become independent and self-sustaining «business firms», must also become *profitable.* In other words, the work that was supposed to be «unproductive» (of value added or profit...) when incorporated in «hierarchically organized» nodes, now – through some magic potion - has to become «productive» as well.
So, in his conceptual construction of a «network economy» Barabási seems to be mixing up two different types of phenomena: on the one hand, the relationship between the «particles» and the «links» (which is the main theme of his work), and then, on the other hand, the relationship between the component *parts* and the *whole*. But more of this in the next section.

Since we will be talking extensively about «profit» and «profit rate» we must draw attention, from the outset to what exactly are we talking about when we talk about «profit».
In the first place there are many definitions of profit, out there in the world of business... There is the accountants' profit (the one that is subject to corporate taxes...), there is the “normal” profit and then there is the so-called “economic” profit. All of these are expressed in money terns and relate to an epiphenomenon of any market economy activity. For example, one of the most unnoticed (or least reflected upon...) types of profit, is the so-called “economic profit”, the one that is supposed to be zero under conditions of truly perfect competititon (if ever such a condition were to arise...).
When we speak of profit, as in the «falling tendency of the rate of profit», we are speaking of a «systemic profit», or «an economic surpplus» at system's level.
This “systemic profit” is the one that comes about at the deepest level of analysis and out of which the system has to withdraw portions of “surplus” to pay for the title of ownership (rent) to self proclaimed and leggaly recognised «owners of land», as well as portions of the same surplus to provide (through taxes, duties and levies) for the construction and maintenance of «public structures, services and facilities» of all types that are absolutely necessary for any economy activity. In this respect one could envisage the possibility that the current «sovereign debt crisis» is mostly due to the fact that corporate taxes have been substantially reduced all over the world, and that this reduction of taxes to be paid py corporations is due to their recognition (and efforts to counter) the deep effcts of the falling tendency of the rate of sysytemic profit; trying to maintain the *amount* of profits intact, by paying less taxes, in the face of the reduction of its *profit rate.*

2. The Epistemology Behind The Scene

> *«If a "religion" is defined to be a system of ideas that contains unprovable statements, then Gödel taught us that mathematics is not only a religion, it is the only religion that can prove itself to be one.»*
> John Barrow - «Pi in the Sky: Counting, Thinking, and Being»

In this section a discussion of the following points is attempted: the concept of complexity, the ideas of methodological individualism and methodological holism (as well as the relationship between the component parts and the whole), the problem of «rationality» and the supposedly opposed concept of «bounded rationality», the issue of homogeneity or heterogeneity of economic agents and the issue of «static» *versus* «dynamic» analysis and the related issue of «temporality» (or the time dimension) and the unidirectionality of the «Time» vector. One other point to be covered will be the issue of «scope of application» of the model being proposed here.
Since, in the literature, all these issues often appear mingled and usually without a systematic preliminary treatment, it seems that most authors rarely realise how crucial these points are for a discussion of any scientific research effort. Because all these issues are interrelated I shall be coming back to some of the issues while dealing with some of the others. As it just so happens with complexity matters, these are also intertwined issues...

> *«The science of complexity is based on a new way of thinking that stands in sharp contrast to the philosophy underlying Newtonian science, which is based on reductionism, determinism, and objective knowledge. This paper reviews the historical development of this new world view, focusing on its philosophical foundations... Determinism was challenged by quantum mechanics and chaos theory. Systems theory replaced reductionism by a scientifically based holism. Cybernetics and postmodern social science showed that knowledge is intrinsically subjective. These developments are being integrated under the header of "complexity science". Its central paradigm is the multi-agent system. Agents are intrinsically subjective and uncertain about their environment and future, but out of their local interactions, a global organization emerges. Although different philosophers, and in particular the postmodernists, have voiced similar ideas, the paradigm of complexity still needs to be fully assimilated by philosophy. This will throw a new light on old philosophical issues such as relativism, ethics and the role of the subject.»*
> Francis Heylighen, Paul Cilliers, Carlos Gershenson[5]

Some times, while reading some texts by philosophers and/or scientists on the issues of «complexity» and the developments of Agents Based Models, one gets the feeling that some of these authors do not seem to realize they are merely discussing *«schematic mirrors of presupposed or postulated human visible actions»* and the possibility that these *«schematic mirrors»* in their turn will then help human beings better understand their own motives and actions. Some kind of introspection by the intermediate use of «computer system», one might add... An example of that kind of reasoning, containing its own critique, is that found in Heylighen, Cilliers and Gershenson.
Complexity has been with humans in general, and scientists in particular, for a very long time. If we start from such a platitude there is not much, apparently, to be said about the subject matter of this short essay. And yet a definition of complexity is something that continues to evade philosophers and other authors who devote some measure of time to the exercise of defining this or that concept. For our part we will simply go back to the linguistic roots of the word itself. The Latin word «complexus» which was supposed to mean «that which is intertwined» or then «twisted together». There have been many different definitions and, often, one finds systems referred to as «complex» without further ado. In those cases, the author simply assumes that the reader knows what it is that (s)he is talking about. Bruce Edmonds, a philosopher at the Manchester Metropolitan University offers a survey of definitions of complexity and ends up proposing one *«which can be summarised as 'that property of a language expression which makes it difficult to formulate its overall behaviour*

[5] http://arxiv.org/ftp/cs/papers/0604/0604072.pdf

even when given almost complete information about its atomic components and their inter-relations». (Edmonds, 1999). Professors Cristoforo Bertuglia and Franco Vaio offer a perspective of complexity as being a property of systems and of their models which is intermediate between stability and chaos[6].

On the other hand, the idea itself of complexity does not enable a clear cut type of definition of the dichotomic type that would enable any scholar to declare that one particular system is complex while another one is not. That is how the notion of degree of complexity has naturally emerged in the field of complex systems studies, along with attempts at establishing some measurement criteria that would enable students in the field to assess the degree or level of complexity of their objects of study. Be that as it may, we will accept here a somewhat conventional definition that states that *»complexity involves a variable number of interlinked elements, arranged in structure(s) which can exist on many scales»*. These structures go through processes of change that are not describable by a single rule nor are reducible to only one level of explanation, these levels often including features whose emergence cannot be predicted from their current specifications. In other words, as opposed to the traditional reductionnist perspective of scientific research, we will encounter complexity whenever it is not possible to attribute one single cause to a particular effect. Furthermore, we face complexity whenever those effects themselves retroact upon the «initial» causes and change the nature and specifications of certain parameters of the system being studied. The recent and emergent «Complex Systems Theory» also includes the study of the interactions of the many parts of the system and the fact that these systems are non linear, where *non-linearity means that the output of a process is not directly proportional to the set of inputs.*

From a traditional perspective, the behaviour of a system, as a whole, is expected to be explainable by the aggregation of the behaviour of its parts. In doing this, scientists incur in what is termed, by philosopers of science, «reductionism». The totality of the system to be studied is reduced to its component parts and then, following the old adge of «divide and conquer», scientists believed to be better positioned to analyse and study the behaviour of the system by studying the detailed behaviour of its individual parts.

Because of these characteristics it has been said that «conventional» (linear) mathematics is not well positioned to treat complexity problems and, a a result, there is a need to resort to the use of the tools of intensive computation and computer modelling. In this case researchers usually resort to what is called «methodological individualism». In view of the criticisms encountered in the literature, levelled at «conventional» or «mainstream economics», we would expect that the new «computational intensive» methodogies, that are used in Agents Based Modelling[7], would follow a different methodological path. In fact the distinction to be made is of a different nature. It is not the issue of «reductionism» that is at stake[8] as this «reductionism» may have various meanings. In one case we may mean the «reduction of the whole to its component parts», in another case we may mean the «reduction of the whole to a skeleton of its characteristics».

When reviewing the most common criticisms coming from practitioners of «complexity sciences», one usually finds two main strands of criticisms: the one regarding an alleged «unbounded rationality» on the part of economic agents, and the other one regarding the supposedly non heterogeneity of «economic agents». The assumption of these criticisms is that, on the one hand, the neoclassical paradigm in economics postulates the existence of an ideal economic agent (the fictious *«homo economicus»*) endowed with «perfect» rationality and access to «all the necessary information»; and, on the other hand, the idea that we are all supposed to be, or to act like, that fictious *«homo economicus».*

Strictly speaking one could argue that this is a typical case of «barking up the wrong tree». It is, in a certain sense, similar to a critcism that would be levelled against Euclidean geometry for postulating the existence of «straight lines» based (that criticism) on the fact that the whole

6 Bertuglia, Cristoforo Sergio and Vaio, Franco - *«Nonlinearity, Chaos, and Complexity: The Dynamics of Natural and Social Systems»*

7 Or in or Agents-based Computational Economics, also known as «AbCE».

8 Paradoxically enough the modelling of a fraction of reality always is, by definition, a reduction of that same reality, even that fraction in itself constitutes an aggregate of parts or a «subsystem».

Universe is «curved» and therefore there are no «straight lines» out there in the «real world», and so the whole exercise of Euclidean geometry would therefore end up being wrong.
On the other hand, to confuse the postulated rationality of conventional neoclassical economics, with unbounded rationality is somewhat similar to a confusion between the idea of infinity, as a characteristic feature of certain variables, and the idea of infinity as a «quantity». It should be noted in passing that this kind of confusion permits some humourous mathematicians to «demonstrate» that 1 = 2 … And some less humourous conventional economists to discard the law of the falling tendency of the rate of profit, because its representative formula seems to result in «infinity divided by infinity» and the that that peculiar equation does «originate an indetermination»[9].
In the particular context of the economy (as a complex system) the main and crucial criticism to be formulated against the neoclassical paradigm is not so much one of «methodological individualism» but rather one of «statics» versus «dynamics». It has been amply noticed in the literature that the neoclassical paradigm in Economics has emulated the XIX century classical paradigm in Physics, in particular Newtonian mechanics. The «fathers» of neoclassicism in Economics[10] established a «general equilibrium» (of a static nature) as the analytical model of an invented economic «reality» that does not quite simply exist. In a manner not too dissimilar from the invention of Euclidian geometry. On the other hand, the aesthetic beauty of such a mathematical model has originated many praises and eulogies and, in a sense, «enslaved» the minds of generations of economists.
That analytical model is based on a very useful fiction or theoretical construct: that of the *«homo economicus»,* an economic agent who is (naturally) deemed to act rationally when furthering his or her interests and making use of his or her «God given» capabilities. But, as a result of that reductionism, the resulting analysis may bypass some important features of the dynamic economic process. In the words of Axelrod and Tesfatsion (2005),

> *«When interactions of the agents is contingent on past experience, and especially when the agents continually adapt to that experience, mathematical analysis is typically very limited in its ability to derive the dynamic consequences. In this case, Agents-based modeling might be the only practical method of analysis».*

And, furthermore, the

> *«intricate two-way feedback between microstructure and macrostructure has been recognised within economics for a very long time. Nevertheless, for much of this time economists have lacked the means to model this feedback quantitatively in its full dynamic complexity»*[11].

On the other hand, in what concerns the issue of classification of complex systems, in his book *«Cybernetics and Management»*, author Stafford Beer (1967) elaborates a taxonomy of complex systems, classifying these from «simple complex» to «hipercomplex» and puts both the human brain and a national economny in this last category. These systems are further qualified as being «probabilistic». In other words, and as indicated some 150 years ago by political economist John Stuart Mill (probably among other philosophers), all the «laws» governing the behaviour of a collective entity such as a national (or global) economy will have a strictly tendential character.

> *«If all the resources of science are not sufficient to enable us to calculate à priori, with complete precision, the mutual action of three bodies gravitating towards one another; it may be judged with what prospect of success we should endeavour to calculate the result of the conflicting tendencies which are acting in a thousand different directions and promoting a thousand different changes at a given instant in a given society: although we might and ought to be able, from the laws of human nature, to distinguish correctly enough*

[9] In conventional, static terms, the formula that represents the «law of the falling tendency of the rate of profit», when developped in a static «environment» (or in a «evenly rotating economy») does seem to indicate an indeterminacy: the rate of profit could go up or could go down as both terms of the equation seem to tend to infinity.
[10] Carl Menger, William Jevons and in particular Léon Walras.
[11] The beginning of this – a contribution to - is precisely what the model proposed here intends to show.

> *the tendencies themselves, so far as they depend on causes accessible to our observation; and to determine the direction which each of them, if acting alone, would impress upon society, as well as, in a general way at least, to pronounce that some of these tendencies are more powerful than others.»*
> John Stuart Mill – A System of Logic, Ratiocinative and Inductive – Being a Connected View of the Principles of Evidence and the Methods of Scientific Investigation (1843- 6.9.1)

For our purposes here - and as a working approach, not as a definitive "definition" - we will consider a system as being «complex» whenever it is difficult (impossible?...) to establish one single relationship of cause and effect between two specific events within the system. For the purposes of this paper, the basic idea behind complexity is one of organic change whereby the system is in a permanent state of evolution. In that context, and merely to illustrate, we consider that whereas a highly sophisticated jet engine is simply a complicated thing, a bowl of spaghetti is a complex entity. In the case of that jet engine it is technically posssible and feasible to completely disassemble it into all its component parts, and then assemble it again, whereas in the case of the bowl of spaghetti, once we remove a thread of spaghetti, even if it still remains a bowl of spaghetti, it is now different and it is literally impossible to put it back as it was before. Quite simply it will never be the same again. So, a complex system will be one where we do have many intertwined parts, in a permanent state of interaction, changing with the passing of time and where the effects may have no direct relationship with causes that outside observers may be able to observe. On the other hand, by «economy» we intend to mean the social system of organisation of activities of production and distribution of goods and services, deemed useful by society at large, and exchanged through a set of markets, where prices are set and resources are allocated.
On the other hand, one must also bear in mind that, in the case of social systems, one has to be reminded that there is an historical ongoing evolution to be considered at all times. Human society as a whole is not only changing, it is also growing in size.
The title of this short essay may seem to require some form of elucidation. The inspiration from the ideas developped by Karl Marx, basically means the conscious adoption of his method of analysis of the capitalist system. This may seem somewhat strange for those who may happen to be minimally familiar with what passes for «marxist» ideas. It may further continue to seem strange if one considers that Marx's method of approach, in his analysis of the capitalist system, is usually considered to be, not one based on what we call today «agents based modelling», but one that is usually (and correctly) considered to be the ultimate example of an holist approach.
The current crisis in the world economy has provoked quite a number of books, articles and essays, apart from simple, even if educated, opinions from the most disparate quadrants. To cite a particularly relevant example I quote the following paragraph from a very recent paper by a number of scientists involved with what is usually called «complexity sciences».

> *«The economic crisis has to be stabilized immediately. This has to be carried out pragmatically, without undue ideology, and without reliance on the failed ideas and assumptions which led to the crisis. Complexity science can help here. For example, it is wrong to speak of "restoring the markets to equilibrium", because the markets have never been in equilibrium. We are already way ahead if we speak of "restoring the markets to a stable, self-organized critical state".»*
> «Can Science Help Solve The Economic Crisis?»
> Mike Brown, Stuart Kauffman, Zoe-Vonna Palmrose and Lee Smolin[12]

On reading such statements one is reminded of Marx's assertion about the permanently evolving situation of a «dynamic equilibrium» which now has been duly christened as *«self organised critical state»*, perhaps on the hope that this will give more credence to exactly the same ideas and concepts about the inner mechanisms of a functioning unregulated market economy. Interestingly enough, objective analysis will explain (and demonstrate...) that unregulated markets have always been in a situation of *«self-organised critical state»* and, while evolving in that condition, go through cycles of phases of expansion, crisis and stagnation. One might say that this simply is in the

[12] http://www.edge.org/3rd_culture/brown08/brown08_index.html

«nature of things». Also paradoxically enough, that wished for *«restoring the markets to a stable, self-organized critical state»* is supposed to require some kind of centralised coordinating mechanism. Which means some kind of «conscious intervention», as opposed to the «unplanned emergence» of whatever situation does eventually emerge.

The opening paragraph of that joint paper by various scientists on the issue of the currently visible economic crisis seems, already and in itself, to be a clear indication that its authors (Brown, Kauffman, Palmrose and Smolin) do not begin to understand the actual nature and causes of the economic situation we find ourselves in. I draw particular attention to its opening paragraph which explicitly states (mixing up causes and effects) that the *«main cause of the financial crisis is instability in the financial sector including the firms, institutions and markets which comprise it*.»

Two of these authors come from the fields of Biology, Physics and Astronomy, and two others come from the fields of Finance and Corporate Accounting. One author in particular (Kaufmann) is a well known expert in the complexity studies community. They all seem to be missing the historical, long term or secular perspective of the evolution of the capitalist system. According to their perspective, which seems to be somewhat critical of mainstream economics, if it were not for the lack of regulation and self discipline in the financial markets, if it were not for the unrestrained greed of certain bankers and speculators, then we would not have the kind of financial and economic crisis we are in.

As I hope to show later in the text, they do not seem to realise that it is not the *«speculative behavior»* of traders that has *«hijacked»* the *«legitimate functions»* of providing *«capital, as equity and debt, to the goods and services economy to allow it to thrive and grow. A second is to provide a stable repository for our collective savings. And a third is to responsibly provide appropriate credit to individuals».*

Further more, they do not seem to realise that the behaviour of those traders has been determined by the logic of the system. That they are actually doing merely what they are supposed to be doing, and they are doing it simply in accordance with standard and legal practices. There have been – and apparently there will always be - some highly dishonest individuals, but the financial crisis came about not because of the greed of these «speculative» individuals. The financial crisis came about because what they were supposed to be doing (*«to provide capital, as equity and debt, to the goods and services economy to allow it to thrive and grow. A second is to provide a stable repository for our collective savings»*) was (and is) in the nature of system and, no matter what, that would always cause this crisis to come about.

To use here the jargon that is currently used in complexity sudies, the crisis is merely the *emergent* phenomenon of the regular functioning of the capitalist economy, always in accordance with its intrinsic logic. It was not expected (at least not by those unware of such an intrinsic logic) and it did result from the normal functioning of those «rules of behaviour» that were implied in the postulated and empirically verified «laws», in the field of real life economic phenomena.

However (and this is very important from an epistemological perspective), the criticism that is being formulated here does not – in any way – invalidate those authors' demands for a strong regulated environment. In the words of these authors,

> *«Two basic assumptions must guide any thinking as we undertake these tasks. First, economies, financial institutions and markets cannot function without a context of rules and laws, which regulate them. In a market, each participant tries to do the best they can for themselves. In a properly architected and regulated market this contributes to the public good. There is simply no place for an ideological discussion about regulation. Stable systems in nature such as individual organisms and ecosystems are regulated. So must ours be. The only relevant question is do the regulations work or not, where work means that stable markets allow an orderly flow of capital to and from the goods and services economy and the people who comprise it.»*
>
> «Can Sciencve Help Solve The Economic Crisis?»
> Mike Brown, Stuart Kauffman, Zoe-Vonna Palmrose and Lee Smolin[13]

[13] http://www.edge.org/3rd_culture/brown08/brown08_index.html

The issue that then naturally arises is that of how effective could any regulations be, without a prior understanding of the inner logic of the system, on the part of any putative regulators.
What I propose to explain in this paper, also making use of complexity sciences tools, is the inner logic that makes the system to be bound to have these crisis in spite of any regulations or the absence of them[14]. As long as the functioning logic of the system is what it is, such logic being personified in the motivations of the fictious *«homo economicus»* of the neoclassical paradigm, then the system is bound to «obey» this kind of global, emergent behaviour.
As I hope to show, considering the current situation of world wide economic stagnation[15] and taking into account the fact that all Marxian economists have been talking and discussing, over the last 30 years or so, the dimension of this current crisis (as it was bound to come...), the one crucial criticism to be leveled at the conventional neoclassical paradigm is the fact that it simply ignores (has discarded) the analytical contributions provided by Karl Marx major opus, *«Das Kapital»*, namely the classical (but modified...) «labour theory of value» and the old and empirically observed «law of the falling tendency of the rate of profit»[16].
By discarding these important analytical contributions, by uncritically following Bohm-Bawerk's infamous blunder[17], the proponents of the neoclassical paradigm have long strayed into what has been classified as «*a mathematically pure ideology*» (Freeman, 1996).
Methodological individualism (usually and correctly associated with «agents based modeling») is often referred to as a bottom up approach, whereas methodological holism is often referred to as a top down approach. In the case of methodological individualism, its proponents claim that they are searching for explanations of an emergent order, out of apparent «chaos» or «disorder», in the absence of an overall coordinating centre. With that claim they seem to suggest that methodological holism is associated with the existence of an overall coordinating centre. In the specific case of political economy this, in its turn, is then associated with the existence of «big government» or the permanent and annoying interference of an «oppressive» State apparatus, in what would otherwise be a natural, spontaneous, emergent and harmonious order.
We are here facing two kinds of problems that do require clarification: On the one hand there is the issue of a recurrent conceptual confusion between the realm of analysis and that of social engineering. With reference to the functioning of the capitalist system, in the present exercise (and the same should apply to all practicioners of «agents-based modeling»), we will strive to confine ourselves to the exercise of analysis *of what is*, leaving aside any considerations of what some of us might wish it to be. Even if one may be tempted to engage in experiences in social engineering, based on any conclusions that may be derived from «virtual experiments» with the model proposed herewith. In any case, and in that context, these «experiments» would naturally be of a strict virtual nature. That being said, we must also be aware that the educational effect of studying this model and the possible discussions about certain «what if» scenarios, may indeed induce some experiments in social engineering in the real life.
On the other hand, and judging from the literature, it seems that methodological individualism and methodological holism are very often presented, not only as alternative approaches, but as strictly opposed approaches, thus generating a situation where it seems that if one approach is right, the other approach must necessarily be wrong[18]. That should not necessarily be so. In fact, if a theory does conform to the facts of that fraction of reality being observed, it does not really matter which approach is being used. And yet, the idea that «Agents Based Models» (as well as «Agents-based

[14] I, for one, have indicated that same probable outcome some twenty five years ago in a communication to the 5th Congress of the Portuguese Association of Informatics.
[15] *«Report of the Directorate-General for Economic and Financial Affairs of the European Commission» in* http://static.publico.clix.pt/docs/economia/prevprimaveracomissao.pdf
[16] Long before Karl Marx, already Adam Smith had noted this historical tendency in the behaviour of the system. Karl Marx «merely» tried to *explain* how it came about.
[17] In 1896 Boehm-Bawerk published an essay criticising an explanation by Marx of David Ricardo's problem of how «prices of production» are transformed into «values». As a result of that (erroneous) criticism mainstream economics discarded («to the dustbin of History»...) the concepts of «value» and the idea of a «law of value».
[18] In the sense of providing for «wrong» answers or results...

Computational Economics») is a more valid approach than that pursued by conventional economics, is a common characteristic found in the literature. As a result, conventional economics is then challenged as being less appropriate, *because it is supposed to ignore the variety of heterogeneous agents, a characteristic which is thus supposed to be specific to «agents-based modelling».*

A doctoral thesis in any branch of sciences, both in the realm of the so called physical or «exact» sciences and in the realm of the so called «social» sciences, is usually supposed to reflect some consensus in relation with what constitutes the corpus of knowledge assumed as being valid or relevant by the academic community. In a certain sense that consensus will also be what has become known, or considered as being, the «politically correct» wisdom. Even when it goes against a certain established canon, it should do so from an alternative acceptable position.

The following text, extracted from a recent doctoral thesis may provide us with a good example:

> *«The neoclassical approach to economic sciences today is the mainstream orthodoxy. Anyhow there is a lot of ferment and there are many active communities of heterodox economists developing a different view on social systems and the economic system. The keywords of these paradigms are* complexity, evolution, bounded rationality, heterogeneous agents, social network and agent based simulation. *In order to better understand those keywords it can be useful to introduce a comparison of the neoclassical view of economics comparing it with the one of the most promising alternative: the* computational economics.»
> Marco Lamieri (2006)

In this short, but representative paragraph, there are three important issues that do require some measure of clarification. These issues are: «evolution», «bounded rationality» and «heterogeneous agents». This is important in the context of the recent historical development of different approaches to the study of the economy as a complex system. As we shall see some of these issues have been discussed before, and at length, by some authors other than those that are part of the mainstream. It is a matter of elementary intellectual honesty to acknowledge their (even if involuntary) contributions to current developments in the field of research on the economy and the complexity sciences.

Nobel prize winnings notwithstanding, a discussion about the distinction between «rationality» and «bounded rationality» is certainly a very interesting one but, considering the real issues at stake, it may be reminiscent of that mythical discussion among religious scholars, on the sex of the angels, while the Byzantine Empire was literally falling apart around them. In this context we shall consider that rationality is simply the characteristic of any entity being able to process information in a consistent and coherent manner. As a mere illustrative example, a prey (like an antelope) that tries to escape the attack of a predator (like a lioness) is being perfectly rational when fleeing the perceived threat. The agent will be consistent in the sense of always having the same kind of response to the same kind of impulse, and coherent in the sense that any decision taken, or action implemented, is supposed to contribute (in the eyes of the agent itself) to the achievement of specified goals.

For example, Ludwig von Mises emphatically stated that the logical structure of human minds is the same for all human beings. This same logical structure does not mean that human beings are preprogrammed robots with one single and common version of some kind of a «behavioural software». Our minds are different in accordance also with differences in nurturing and up bringing. Each one of us possesses different informational backgrounds and, in accordance with our different «national» cultures, we make different value judgements. But, and this is the fundamental point underlined by von Mises, *logic is the same for all.* The issue is not one of «degree of rationality» (bounded, limited or unbounded...), the issue is «human reason» (or mental logical structure) and the learned (or not) capabilities to make «good decisions».

All of this as if economic agents had no memory nor emotions, did not transport with them an intellectual baggage made up of all those practices, traditions and ideas that make up a national culture, together with a shared common feeling of belonging to a specific ethnic group. This is not intended as a criticism levelled at a new approach to the study of social and economic systems,

but rather as a reflection on the nature, and problems thereof, of this new approach.
Be that as it may, when searching for any bibliographic references in the literature covering «scientific research» in the area of economics, on the specific issue of complexity in the economy, both as an object of study and as a theme of theoretical discussion, one tends to stumble upon what seems to be a recent phenomenon, this being the emergence of a new term, referring to an apparently new emergent discipline that goes by the name of «econophysics». More specifically, the invention of the name of this «new» discipline seems to have been authored by Eugene Stanley – a physicist by training – and the apparent purpose of this new discipline seems to be to seek to transfer to the study of economic phenomena, the methods of statistical physics. If we remind ourselves that one of the «fathers» of Sociology (Auguste Comte) named his discipline as «*Physique Sociale»*, there is hardly any criticism that a sociologist may advance against the name of this new approach to the study of economic phenomena.
However, it seems that the researchers of this «new» discipline seem not to realize the scientific aberration that they are dealing with. On the one hand they criticize conventional economists, arguing that these later ones base their research and analytical models on unrealistic assumptions, such as that of a (supposedly perfect) rationality of economic agents. The proponents of «econophysics» then propose another and different type of rationality, which they call «bounded rationality»[19]. As if conventional economists were not fully aware of the differences in the capability of both the access to, and processing of, information on the part of the many and varied types of economic agents.
What is at stake is not a matter of the «size» or the «type» of «rationality» of economic agents. What is at stake is the difference in degrees of access to information by the various economic agents. But then, this has been, over the centuries, a triviality with most students of economic phenomena and a part of common people's wisdom dealing with matters of commerce and trade. In this regard it should be recalled that part of the folklore of all peoples who are dedicated to the trade of whatever goods and services, is a centuries-old wisdom that tells us that *«secrecy is the soul of business».* Being expressed with more or less mathematical (or other) formalism, this truism does not mean anything else than the recognition by the economic agents that some of them happen to be «smarter» than others and specially and more often, that these *«smarter ones»* make their decisions based on more information than the one possessed by others in the same market.
From the days of Adam Smith that the idea of economic development and «the wealth of nations» being the unintended result of the interactions of individual agents, has been common currency among students of economic phenomena. Current researchers in complexity sciences seem to imply that the «invisible hand» of Adam Smith (an obvious metaphor...) was actually and really meant to be some kind of a *«well defined centralized system of coordination».* Hence their emphasis on an alleged novelty in the research methods of «bottom-up» approaches, as opposed to what is then qualified as the «top-down» approach of the conventional paradigm in economics[20].
The thesis referred above, presents us with a good example of the current trend in what has is now fashionable to call «Econophysics» or, in other instances, «Agents-based Computational Economics».
It just so happens that a significant number of the practitioners of this new discipline come from the realm of quantum physics where they have naturally been trained in the development of mathematical algorithms to explain the behaviour of elementary, subatomic, particles. The conventional mainstream in economics, based as it is on the research and analytical approach of methodological individualism, seems to be an adequate «expansionary field» for the application of mathematical skills acquired elsewhere. In this case quantum physics. Underlying this «invasion»

[19] Not to mention the fact that conventional or mainstream economics is based on the postulates of neoclassical economics as founded by engineers and economists of late XIX century who, literally, made used of equations in Newtonian mechanics in order to «explain» the behaviour of economic agents, developing some kind of a «marketplace mechanics».

[20] And yet, as every student of conventional economics knows, *«the heart of economics is micro-economics»*. In other words, the so called «bottom-up approach»...

is also de idea of an emergent behaviour that would come from the interaction of multiple heterogeneous agents[21], also studied in a new emergent science of networks. In that perspective it is not so much the agents (or the particles...) themselves that really matter, but rather their interactions and the connexions that are established amongst them.
In this context, I will pragmatically grant that Friedrich Engels was perhaps a minor philosopher (as compared with Kant, Hegel or Shopenhauer to name but a few of the best known names...) but, considering that he spent a good deal of time explaining economics to his friend Karl Marx (as well as supporting him financially[22]), one still has to consider as extremely relevant Engels' simple contribution to the modern philosophy of science in the form of his *«Dialectics of Nature»* and the *«Anti-Duhring»*. This thought comes about as a result of the fact that one of the themes of «complexity studies» is the notorious study of *«emergent properties»* and *«weak emergence»* versus *«strong emergence»* (Chalmers, 2006) and also the issue of *«more is different»* (Anderson, 1972). This comment is particularly relevant when one considers the problem of Time and the dynamic evolution of (any) system, most particularly an organic system such as the human society. This has to be seen in the context of the approach of quantum physicists to the problems of social studies in general and economic studies in particular.
One other example of the lack of appropriate contextualisation of ideas and concepts, that are specific to a particular branch of science,[23] may be found in a short paper by Anderson when talking about «broken symmetry» and referring to the issue of «intensive» research *versus* «extensive» research, and I quote:

> *«The arrogance of particle physicist and his intensive research may be behind us (the discoverer of the positron said 'the rest is chemistry'), but we have yet to recover from that of some molecular biologists, who seem determined to reduce everything about the human organism to 'only' chemistry, from the common cold and all mental disease to the religious instinct. Surely there are more levels of organization between human ethology and DNS than there are between DNA and quantum electrodynamics, and each level can require a whole new conceptual structure. In closing, I offer two examples of what I hope to have said. Marx said that quantitative differences become qualitative ones[24], but a dialogue in Paris in the 1920's sums it up even more clearly: Fitzgerald: The rich are different from us. Hemingway: Yes, they have more money.»* - Anderson, 1972

When it is an established practice in academic circles to acknowledge the earlier contributions of other scientists and philosophers to the development and progress of ideas and concepts, it seems at least somewhat peculiar that most of contemporary researchers in the field of complexity studies talk freely and at length of the «emergence» of certain novel characteristics in the natural and social world, what physicists call «phase transition», when the quantity of this or that vector is minimally changed, without a single reference to a seemingly forgotten «second law of dialectics». And yet such a common source of modern wisdom as the ubiquitous wikipedia tells us that:

> *«as mentioned above, Engels determined three laws of dialectics from his reading of Hegel's Science of Logic. Engels elucidated these laws in his work Dialectics of Nature: (1) the law of the unity and conflict of opposites,* (2) the law of the passage of quantitative changes into qualitative changes, *and (3) the law of the negation of the negation. The first law was seen by both Hegel and Lenin as the central feature of a dialectical understanding of things and originates with the ancient Ionian philosopher Heraclitus. The second law Hegel took from Aristotle, and it is equated with what scientists call phase transition It may be traced to the ancient Ionian philosophers (particularly Anaximenes), from whom Aristotle, Hegel and Engels inherited the concept. For all these authors, one of the main*

[21] Note one first problem with this «invasion» coming from the realm of quantum physics: the heterogeneity of parts...
[22] No sabbatical leaves or royal scholarships then...
[23] As when new usages of old ideas are not put into their legitimate historical context
[24] It is remarkable how some very important ideas get attributed to Karl Marx in a «matter of fact» type of statement. This idea of «quantity» changing into «quality» (usually called the «second law of dialectics» and now referred to as «phase transition), was formulated by Friedrich Engels, but based on the Science of Logic of G. W. F. Hegel.

illustrations is the phase transitions of water. There has also been an effort to apply this mechanism to social phenomena, whereby population increases result in changes in social structure.»[25]

Another question that requires some clarification is the issue of the «level», «layer» or «tier» of analysis that is relevant. This model is only applicable to the analysis of the capitalist system if that system is considered in its global (or planetary) totality. What is also meant by this assertion is that the effects of any decisions taken and implemented within the system will have consequences within the system itself. In this context there is no room for externalities «beyond» the planetary limits of the system. It seems we are still very far from an inter-planetary market place and, as a result, any surplus in the balance of payments, or the trade balance, of any national subsystem will have to be compensated in the corresponding deficits of other national subsystems. In other words, if one considers the system on a planetary scale, there are no «hidden places» or «unoccupied territories» where to dump any material consequences of the postulated (and empirically verified) functioning of the system. Still in this context one might consider that the proposed classification of different and heterogeneous economic agents (such as business entrepreneurs, owners of business firms, bankers, workers in general, civil servants and government officials, for example...) is, at the end of the day, an unnecessary classification, in the sense that what really matters is the relationship between «owners of capital» (at the global scale) and «owners of labour force» (also at the global scale). It should be clear that, in this context, we would be back to the mainstream conventional analysis, where every one is an *«homo economicus»,* and as if there was no real conflicts of interest (no class struggles...) between the various (and heterogeneous) economic agents, such as – within the same social class – between bankers and industrialists, for example. Or between industrialists and farmers[26]. In that sense it should become clearly apparent why there is an analytical interest in modelling the capitalist system using or considering different classes of economic agents.

In the development of a model to simulate the functioning of a free market based, non finalised, economic system, we start by having to consider three fundamental types of entities: the economic agents, the flows (of matter, information and energy) and the landscape or environment.

In what concerns the existence of various types of economic agents, we will consider one common characteristic, that of the so called *«homo economicus»*. Please note that the fact that we attribute a finality (an optimising function, that of maximising utility...) to each individual economic agent does not mean that we imply a finality (or an objective function) to the system as a whole. What we have in that case, at the level of the system as a whole, is that commonly called «emergent behaviour».

According to some of its proponents the specific goals pursued by ABM researchers take four forms: empirical, normative, heuristic and methodological. The goal of empirical understanding will ask why have particular large-scale regularities evolved and persisted, even when there is little top-down control. A second goal is normative understanding, where the question is how can agent-based models be used as laboratories for the discovery of good designs of economic processes or entities. A third goal is heuristic where the issue is how to attain greater insight about the fundamental causal mechanisms in social systems. And a fourth goal is that of methodological advancement, where the issue is how best to provide ABM researchers with the methods and tools they need to undertake the rigorous study of social systems through controlled computational experiments (Axelrod and Tesfatsion, 2005).

Another important issue will be the one of *«modelling the behaviour of economic agents»* and how that research effort is perceived in the literature. I will use the words of economist Leigh Tesfatsion (2003) as a representative example of that endeavour. She starts the discussion of this issue with

[25] http://en.wikipedia.org/wiki/Dialectical_materialism

[26] Just to illustrate such a triviality, one is reminded of the fact that whereas bankers would like to maximise their rates of interest, industrialists, entrepreneurs and owners of business firms – quite naturally – would like to minimise the price they may have to pay for whatever financial capital they may require. The same goes for the struggle between industrialists and the providers of raw materials...

a chapter called *«Learning and the Embodied Mind».* In accordance with that author, researchers in the field of AbCE have been using a wide range of techniques to implement learning processes in those agents that play roles in their virtual environments. These techniques go from learning algorithms, neural networks, genetic algorithms and programming to a variety of *«other evolutionary algorithms that attempt to capture aspects of inductive learning».* Tesfatsion alerts us to the fact *«many of these learning representations were originally developed with global optimality objectives in mind, so caution must be used in applying them to economic processes».* In other words, if we are to follow through with Tesfatsion's reasoning, some «top-down» bias may have «contaminated» what was supposed to be a «bottom-up» approach.
Indeed, in the model being proposed here, that may be just what happens. In the sense that, in following the logical trail of Marxian concepts, the main algorithm in the model could be construed as constituting a finalised «top-down» approach, and this happens because among the «global» characteristics of the capitalist system we have that of «profit maximisation» for the system's capitalist class. On the other hand, it may be argued that it is also (at the same time...) a «bottom-up» approach where individual agents deliberate separately (without collusion...) and on an independent basis. The logic of the system provides for the emergence of the well known phenomenon where *«what's good for each individual is nor necessarily the best for the whole».*
In what concerns the issue of modeling the behaviour of social groups, such as a business firm, in the words of Tesfatsion,

> *«for computational models of team problems or fully automated economic processes, an investigator might find it reasonable to specify a global learning scheme in which the strategies of the computational agents jointly evolve in an attempt to satisfy one or more globally specified goals (e.g., productive efficiency).»*

Tesfatsion also draws attention to the fact that *«for computational models of economic processes with diverse human participants, the learning representations used for the computational agents will generally need to incorporate the salient characteristics of actual human decision-making behavior if predictive power is to be attained. In this case it will generally be necessary to introduce local learning schemes in which individual agents or groups of agents separately evolve their strategies on the basis of their own perceived local benefits.»*
Judging from the literature reviewed by Tesfatsion – and by this author following her references – it seems that a substantial intellectual effort has been put into the development of *«local learning techniques»* to enable virtual economic agents in virtual worlds to behave, as much as possible, like human agents are supposed to behave in the economies of the real world. However, and this is the main point of concern here, it seems that the overall logic that «pulls the strings» of the emergent behaviour seems to simply elude current research efforts, as these seem to be based on ideologically conditioned premises, such as that of the assumption of «socially responsible behaviour» on the part of business firms *qua* economic agents.
It also seems that much of that effort consists in highly sophisticated algorithms to mimic human decision making when, in fact, most of the time very simple rules are more than adequate to model human economic behaviour. Still in the words of Tesfatsion,

> *«A comparative analysis of thirty computational trading algorithms submitted to a double-auction tournament held at the Santa Fe Institute between 1990 and 1991. The submitted algorithms ranged from simple rules of thumb to sophisticated learning algorithms incorporating ideas from artificial intelligence and cognitive science. The winner of the tournament turned out to be one of the simplest algorithms submitted, a "sniping" (last-minute bidding) strategy roughly describable as follows: Wait while others do the negotiating, then jump in and steal the deal when the bid and ask prices get sufficiently close.»* - Leigh Tesfatsion - Agent-Based Computational Economics (2003)

As for the relationship between, on the one hand, conventional «analytical» approaches (using classical mathematics, and usually associated with «top down» analysis) and, on the other hand, the currently spreading techniques of computer programming to build models of real economies,

(usually associated with «bottom up» analysis), the same author is of the following opinion:

> «*As a professor of mathematics (as well as economics), I appreciate the beauty of classical mathematics. However, constructive mathematics is also beautiful and, in my opinion, the right kind of mathematics for economists and other social scientists. Constructive mathematics differs from classical mathematics in its strict interpretation of the phrase «there exists» to mean «one can construct.» Constructive proofs are algorithms that can, in principle, be recast as computer programs. To master a general programming language is to acquire a form of mathematical skill every bit as aesthetically pleasing, powerful, and practical as the differential calculus. Indeed, for economic purposes, computer programming is in some ways more powerful in that it facilitates the modelling of complex interactive processes involving kinks, jumps, and other forms of discreteness imposed or induced by empirical constraints. Consequently, programming frees us to adapt the tool to the problem rather than the problem to the tool. Every graduate economics program should incorporate general programming language requirements. It is time.»*
> Leigh Tesfatsion - Agent-Based Computational Economics (2005)

The issue of reduccionism and a clarification on what has been done

In this section we consider briefly the relation between «reality» and «model». By definition a model is a reduction of reality as it is perceived by any observer. Indeed, the observation exercise itself already is of a selective nature in the sense that human observers will always, by the nature of things, select and observe the out and inner world in a manner that can never be said to be «complete». What one must strive for and hope to achieve, is a model that reflects the basic, or most characteristic, features of the system being modelled.

When considering the development of an Agents Based Model the actual behaviour of human societies (in particular their economic perspective) one has to consider two basic issues:

- The definition (programming) of each agent's behaviour, which definition should reflect, as much as humanly possible, the observed behaviour of actual human agents.
- The definition (programming) of the «rules of the game» that is going to be played, which (once again) should reflect, as much as humanly possible, the observed behaviour of actual human societies.

In the case of the model being proposed here the ideal would the programming of different individual types of agents with possible different «utility functions» which would be superimposed on top of a common «utility function»», namely that of maximization of individual (self) benefit. In the case of the model that has already been developed a clarification is required. In the first place, the equation that was used is supposed to reflect the overall «rules of game» pertaining to the systemic behaviour of capitalism. In the second place, and strictly speaking, what has been done is the conversion into a Java-like programming language of a nonlinear differential equation. In this way it is much simples for an «experimenter» to play with the various parameters involved in the simulation. By means of that «experimentation» it should be possible for any «experimenter» to come to a set of parameter values that do correspond to empirically (historicall) observed facts and tendencies. This alone should the a sufficient method to confirm (or infirm) the «law of the falling tendency of the rate of profit» and to show that, paradoxically enough, both Karl Marx and Nobuo Okishio were right, even if they appeared to state the exactly opposite of each other.

3. The Units of Reference or the Measurement Problem

> *«I think that a particle must have a separate reality independent of the measurements. That is an electron has spin, location and so forth even when it is not being measured.I like to think that the moon is there even if I am not looking at it.»* - Albert Einstein

Conventional economists usually (and quite legitimately) take pride in their competence in the language of mathematics. Due to normal professional requirements, a number of economists, along with sociologists and accountants (to name just a few of academics and professionals that routinely deal with numbers) have been more adept to deal with statistics and other kinds of «number crunching» than with reasoning on the causes and effects of economic flows. However, and as noted by author Georgescu-Roengten (1972), conventional economists are more adept at dealing with the accounting of surface «flows» of goods and services, than with the accounting of underlying «stocks of resources». This bias, in itself, is already a good indicator of the current state of confusion regarding the causes of recurrent economic crises, as the conventional paradigm presupposes that the system should tend for a situation of static equilibrium, while continuing to grow in an indefinite manner, whereas the real economy continues to move and change within a context of continued exploitation of natural resources in a finite world.
Coming to the issue of measurement proper, it has been stated, by a number of experts of these matter of scientific research, that *measurement* is a crucial element of any scientific discourse in the sense that *«if you can not measure it, then it is not science».* This may have a certain ring of truth, but then we may also have to consider the qualitative side of things scientific. Not in the sense of some theory being aesthetically appealing (as they say about the beauty of the Walrasian general equilibrium in neoclassical economics), but in the sense of providing some form of explanation of why things are as they are, as in the Pareto's rule of 80/20 or the derived idea that the «rich get richer». Measurement is also an important issue when it comes to determine the occurrence of a «phase transition», and a particular system (or any other entity) changes its nature, from one condition to another, as a result of an extremely small change in the quantity of one of its possibly many parameters.
In the particular context of measurement both bottom-up approaches (as in ABM or AbCB) and top-down approaches (as in the so called analytical models) of the capitalist system, should be equally efficient at explaining *how* things happen – the concentration of wealth, for example – but seem to be lacking in providing plausible explanations of *why* these things are as they are. In this respect it is necessary to contemplate, at least in a very short and concise manner, the issue of measurement as it does provide for a clue to the reason why conventional (and «complexity») approaches, stop short of providing explanations of *why* things are as they are in the realm of economic phenomena.

That being said, one must start by defining which is the main magnitude to be measured and only then which are the criteria to be adopted for any measurements. In a market economy, such as that of capitalism, the central magnitude that needs to be measured seems to be the one of «marketable wealth» or «marketable value». In other words, whatever is susceptible of being offered for sale in a marketplace. The common view of the measurement of this particular magnitude («marketable wealth») is usually expressed by the criterion of «price» which, in its turn, is usually expressed in «units of money». We could, therefore, face here a problem similar to that of expressing the weight of a specific body in pounds or kilos, or the length of a distance in terms of meters or yards. In both cases, the end result would still be the same.
Some authors will draw attention to the fact that, from a contemporary perspective, all Physics is Quantum Physics and that non-quantum Physics is but a close approximation that goes on providing excellent operational results for «everyday» pragmatic usages. The reason for this non-quantum approximation comes from the Plank constant h[27], which is an extremelly small value. If

[27] The Plank constant is one of the fundamental constants of Physics and is used to describe the size of quanta. Its

that *h* were to be null or zero, then the laws of classical (Newtonian) physics would be exact and not just an excellent approximation. Be that as it may, no one disputes the scientific nature and the relevance of laws of Physics just because the results that arise from its laws are not «exact». However, in the case of Sociology or Economics, the matter seems to be totally different. A case in point is precisely the issue of measurement and the units in which economic entitities are supposed to be expressed, namely the value of goods and services, exchanged in the market.

In this context, the position adopted here is that the most universal criterion of measurement to be adopted, when comparing the relative magnitudes of this or that *«quantity of wealth»,* is then the socially perceived amount of human labour[28] (or effort) that is necessary for the (re)production of any *«quantity of wealth»* (a car, a skirt, a pair of shoes, a meal, a house...). This *«socially perceived amount of human labour»* is naturally to be expressed as the *«average quantity of time/energy that is required»* to re(produce) whatever fraction of *«marketable wealth»* that, at any moment in time, is available in any marketplace.

As a result of these observations, in this work (as in any other scientific work on the economy and society at large), the issue of measurement will seem to loom in the background and will rarely be addressed or discussed in any detail. Conventional, mainstream, economists will usually only talk of «prices», never of «values». From the point of view of the conventional (neoclassical) paradigm this issue is simply absent. Goods and services that are put on the market do not seem to have some kind of objective (or intrinsic) value that should be measured and/or evaluated by society at large, in the form of willing and solvent buyers. As a result of this posture, there are no objective values to be measured, only prices. In other words, «value» is not considered to be an analytical category worthy of mention or discussion.

In the days of the classical paradigm, the issue of «value» as an analytical category used to be the central issue in economic analysis. In a certain sense it still is the central issue, but only for a fringe number of economists: those of the Ricardian and of the Marxian traditions. Most other economists (the vast majority or the so called «mainstream») simply ignore the issue and make do without it. And yet, that issue, an institutionalised ignorance notwithstanding, continues to be crucial for a clear (and effective) understanding of the mechanisms that help explain economic phenomena out there, in the economies of real world, including the causes and nature of the current crisis.

I am referring here to the labour theory of value as expounded by the Classicals (namely Adam Smith, David Ricardo and John Stuart Mill[29]) but as slightly changed by Karl Marx[30]. This labour theory of value basically proposes that the (market) value of things (goods and services) is a dependent function of the total social labour time[31] that is need for the (re)production of those same things. By «total social labour time» is meant the current living labour of human beings, as well as the accumulated sum of past labour of preceding generations, a value that is embodied in machines, economic structures and technologies that represent «stored up labour» that is inherited from the work of those previous generations. By (re)production is meant not the the value of a specific thing that was produced some time ago, but the current value of its reproduction. In other words, the labour time content of any goods and services is continually being changed and, with the increase in total social productivity, something that was worth the equivalent of 100 Euros some ten years ago, may today be valued at only the equivalent of, say, 50 Euros.

As indicated, the issue of «value» and «price» was a fundamental issue in the days of classical Political Economy. Just like with natural phenomena, the capitalist system may have changed (and it has changed) in its formations and adaptations to environmental circumstances, but its essential

value is *approximately* h $\cong 6.626\times10^{-34}$ Joule × second.

28 This expression of *«socially perceived amount of human labour»*is intended to contemplate the possible and common argument about the (higher) relevance of the «utility criterion». As it should be obvious, it is the society as a whole that will determine the definitive assessment of the worth of any «marketable wealth», if it is useful or not...

29 To only name the best known exponents of the original classical school of economics

30 It is indeed a slight change but, nevertheless, a very fundamental one...

31 Since the classicals did not use the expression «time/energy», throughout this text, when the word «time» is used (in the context of «labour theory of value» and the measument of value) one should assume that word to stand for the binomial «time/energy».

features remain the same, namely the features of «private initiative» and the search for the maximisation of profits and accumulation. An interesting issue is that of how Adam Smith, (with his metaphor of the «invisible hand») usually considered as the «founding father» of economics is also discarded when it comes to the issue of a relationship between «values» and «prices». Smith used the expression «natural prices» instead of values to indicate the permanent and ongoing movement of variation of «prices» around «values», using the metaphor of «gravitation forces»:

> *«The natural price, therefore, is, as it were, the central price, to which the prices of all commodities are continually gravitating. Different accidents may sometimes keep them suspended a good deal above it, and sometimes force them down even somewhat below it. But whatever may be the obstacles which hinder them from settling in this centre of repose and continuance, they are constantly tending towards it.»*
> An Inquiry into the Nature and Causes of the Wealth of Nations -
> Adam Smith 1776 - Book 1, Chapter 7 - Of the Natural and Market Price of Commodities[32]

This raises the question of how to deal with the relationship between «values» and «prices», which is a relationship somehwat similar to that of a «measurand», the «instrument of measure» and its «expression in various computable units». The discussion of this intertwined relationship has turned into an infamous «transformation problem» in Ricardian economics. This «transformation problem» resulted from an explanation provided by Karl Marx in Book III of *«Das Kapital»* to an arithmetical and logical problem encountered by David Ricardo in his «Principles of Political Economy».

This problem is basically related to the proportionality between two fundamentally different types of capital (human labour or living capital and «machinery» or stored-up labour), in relation with the tendency, prevailing in the market place, for the equalisation of rates of profit. All of this in the context where the only and exclusive source of profit is assumed to be the «value added», which is originated, only and exclusively, in currently applied living capital or human labour. In other words, according to this approach, «machines» do not create *new* value, they just transfer a fraction of their own specific and stored-up value. David Ricardo was unable to provide for an explanation for the prevailing equalisation of profit rates, in a context of different proportions of «living capital» and «stored-up capital», which is naturally encountered in the real economies of the world.

Karl Marx did provide for an *explanation* of Ricardo's problem, which was misunderstood by some prominent critics, such as Boehm-Bawerk, whose authoritative critical judgement of that explanation has prevailed to this day in the world of academia. Interestingly enough, in the current jargon and problems of complexity studies it could be argued that the concept of *«attractors»* could be a useful tool of analysis to investigate how «values» transform themselves into «prices» on a dynamic basis.

In any case, if the capability of prediction of phenomena in any particular realm of reality, is a good enough criterion to assess the degree of «scientificity» of any branch of knowledge and if, furthermore, that capability is coupled with the possibility of rational explanation of the causes and mechanisms at work in the emergence of those same phenomena, then one is bound to arrive at the conclusion that the Marxian approach, to the explanations about the functioning of the capitalist system, is a «more scientific» approach than the marginalist approach (of the neoclassical school) that came to replace the classical approach, as amended by Karl Marx.

By «more scientific» one usually means a theory that is more in tune with reality and has a capability of reproducing and predicting events in accordance with the «discovered» logic of the system. In the case of the capitalist system, the source of wealth and value creation as well as the source of profits and the tendential behaviour of that particular magnitude.

But if this «Marxian theory of value» is to be a better explanation of economic phenomena, the question then arises why is it that the Marxian approach has been dismissed as irrelevant and non-scientific. Some observers of the world of academia will advance the idea that this dismissal has been based on strictly ideological grounds. According to some of these authors there is yet another, very simple and pragmatic idea: that of intellectual capital that is invested in the study of a

[32] Also available at http://geolib.com/smith.adam/won1-07.html

specific paradigm.
An example from the field of complexity studies may help illustrate this problem[33].

> *«Finally, there is the possibility that a new theory is indeed a better representation of reality (more consistent, less ad hoc, in better agreement with experimental data, etc.), but influential leaders have vested interests in the established paradigm, motivating them to construct firm, if irrational, defences of their traditional positions. An extreme example of such resistance was Galileo's trial and conviction by the Church of Rome as an heretic for the heliocentric views published in his Dialogue on the Two Principal Systems of the World [514]».*
> Alwyn C. Scott - «The Nonlinear Universe – Chaos, Emergence, Life»

However, from a purely «scientific standards» or research and inquest point of view, and as I expect to show in the development of this essay, this dismissal was due basically to a series of gross misunderstandings, coupled with some ideological bias (on the part of those that did initiate that dismissal), that should be absent from any scientific discussion or project. Of the more serious and gross misunderstandings that I have mentioned, I will refer here only to the issues of an empirically observed «law of the falling tendency of the rate of profit» and to the infamous problem of the «transformation of values into prices». I have provided elsewhere[34] a detailed analytical proof[35] of the empirically observed «law of the falling tendency of the rate of profit». One of the purposes of this project is precisely the demonstration of that same empirical law, using AbCE methodologies or what might be termed a «bottom-up» approach.
But, it should also be noted, that it was not only the apologists of the neoclassical paradigm that did dismiss the Marxian explanations as irrelevant or simply wrong. A number of «marxist» authors has also reached the conclusion that, with the continued technological development and increased productivity of capital goods, the «labour theory of value» has lost its importance as an explanatory analytical tool. One of the main reasons for that paradoxical position[36], is the fact that the «labour theory of value» makes systematic use of the «units of time»[37] criterion and this seems «too difficult to compute». It seems so much easier to simply compute and check «prices»... As if science, Ockam's razor notwithstanding, had to be easy and simple.
The authors that formulate these criticisms and discard the «labour theory of value» based on the operational difficulties of determining the *«exact»* value of things in terms of *«units of socially necessary labour time»,* seem to ignore that prices are a mere indication or a permanently changing, but very good approximation, of the *«average socially necessary labour time»* objectified in the goods and services that come into the market. If physicists were to adopt the same stringent approach, of discarding every measurement criteria that did not match the «exact» requirements that seem to prevail in the neoclassical paradigm, physicists would probably simply ignore or discard most measurements being conducted on a routine basis in pragmatic engineering applications. A case in point regarding this issue of measurement is the *«sigma 6»* movement in quality control[38].

To continue with this section on the «measurement problem», it should then be clear that the model being proposed here will work with *«average socially required units of time»* for the production (and physical distribution...) of whatever goods and services that are present in the market place. Since, in the model, all «goods and services» will be expressed as *«average units of*

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33 Another example from some «more conventional» economics discourse may be found in John Kenneth Galbraith
34 Fonseca-Statter, 1985, 2008 and 2009
35 Through what might be termed a «top-down approach»
36 «Paradoxical», from a Marxist point of view, of course...
37 Of «socially necessary labour» for the production of whatever goods and services, with this «socially necessary labour» being comprised of current living human labour and past labour stored up in the form of machinery and other equipment and infrastructures.
38 A movement that strives to achieve quality control through processes that operate with «six sigma quality» which are assumed to produce long-term defect levels below 3.4 «deffects» or «errors» per million and minimizing variability in manufacturing and other business processes.

time» , the results of economic activity (such as profits and taxes...) will also be expressed as *«average units of time»* . This is in line with common practice in the field of complexity studies where, for example, models of «prey and predator» in the context of natural available resources, measurement is expressed as «units of energy». In the case of the relationship between the values (or the prices...) of «things» and the corresponding «average units of time», we are merely going back to the explanation provided by the Classicals, such as Adam Smith:

> *«The real price of every thing, what every thing really costs to the man who wants to acquire it, is the toil and trouble of acquiring it. What every thing is really worth to the man who has acquired it, and who wants to dispose of it or exchange it for something else, is the toil and trouble which it can save to himself, and which it can impose upon other people. What is bought with money or with goods is purchased by labour, as much as what we acquire by the toil of our own body. That money or those goods indeed save us this toil. They contain the value of a certain quantity of labour which we exchange for what is supposed at the time to contain the value of an equal quantity. Labour was the first price, the original purchase-money that was paid for all things. It was not by gold or by silver, but by labour, that all the wealth of the world was originally purchased; and its value, to those who possess it, and who want to exchange it for some new productions, is precisely equal to the quantity of labour which it can enable them to purchase or command.*
> Adam Smith – An Inquiry into the Nature and Causes of the Wealth of Nations
> Book I, chapter 5 – Of the Real and Nominal Price of Commodities[39]

We should be aware of some specificities and differences in the interpretations of the classical labour theory of value between Adam Smith, David Ricardo and Karl Marx, but these specificities are irrelevant for the purposes of this paper, even though some critics will argue otherwise.
To summarize these considerations on the nature of the units of reference and the measurement problem, we will then have that the basic issue at stake is the quantity of marketable wealth, this marketable wealth being measured in terms of the *«average number of social working hours per unit of wealth»* that are currently (in the present) required for the reproduction of a similar product or service. Just like we might say that a person weighs «70 kilos» or «154 pounds» (which is exactly the same...), we should be able to say that this or that portion of a certain piece of «marketable wealth» is worth 100 Euros, 125 dollars or 10 hours of *«socially required working hours».*
For the purposes of our modelling, the basic parameters are then «initial wealth» and «increments of wealth», both expressed as equivalents to that *«average number of social working hours per unit of wealth».* In this context, the «rate of profit» is the ratio between the «increment of wealth» (taking place during period *n* (or after iteration *n...*), and the «amount of wealth» that was advanced to obtain that increment. In other words, our agents will be exchanging units of «time/energy», both in terms of currently available units – that come to pass as time goes on – and in terms of units of «time/energy» that were somehow not spent (consumed) and kept in store for future use.
To close this section one final remark, of a pragmatic nature, concerning the real economy of the real world of business firms, entrepreneurs, workers and consumers. In a world where thousands of production engineers work, day after day, in hundreds of industrial corporations around the globe, with the sole purpose of devising new and better methods and processes in order to minimise costs through the reduction of *«the required working hours» (*for the production and delivery of whatever products and services), it is – to say the least – perplexing that mainstream economists (who are often involved in the accounting side of this global effort to maximise productivity), should continue to ignore the labour theory of value, totally oblivious of its analytical significance. And it is even more perplexing when one considers that the agents in charge of actually running those business entities are not only fully aware of this but do publish books and other types of literature on the issue.
Browsing through the literature dedicated to «Value Engineering» one finds dozens of variations on a single theme: the search for better methods in the *«minimization of waste, energy and time»* in

[39] Also available at http://www.econlib.org/library/Smith/smWN.html

the performance of whatever tasks are required to produce and/ or improve whatever products and services. Even though there have been tremendous developments, changes and improvements in the area of «scientific management»[40], the basic fundamentals identified by Frederick Taylor remain operative in the world of business entities. His basic concern with time and motion studies remain entirely pertinent to this day. As a mere illustration of the crucial character of the binomial «time/energy» (in assessing «value») I now refer several instances of the routine praxis of «value engineering». According to the ubiquitous *Wikipedia*, value engineering as an empirical disciplineis is defined as being:

«the systematic method to improve the "value" of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is a primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements».

In the words of Frederick Taylor:

> *«Scientific management requires first, a careful investigation of each of the many modifications of the same implement, developed under rule of thumb; and second, after time and motion study has been made of the speed attainable with each of these implements, that the good points of several of them shall be unified in a single standard implementation, which will enable the workman to work faster and with greater easy than he could before. This one implement, then is the adopted as standard in place of the many different kinds before in use and it remains standard for all workmen to use until superseded by an implement which has been shown, through motion and time study, to be still better.»*

And, according to John Willis of IT Revolution Press[41]:

> *«Henry Ford adopted many of Taylor's ideas, picking up where Taylor left off, so much so that many consider his assembly line an extension of Taylor's initial study. By 1927, Ford achieved* reductions in manufacturing cycle times from 750 to 93 minutes *while simultaneously reducing the cost of automobiles from $850 to $300.»*

To conlude on the issue of measurement (and its relationship) to value:

> *«Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it.»*
> H. James Harrington – Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity and Competitiveness,

[40] Including studies and practices involving synergies, human motivation and national culture...
[41] http://itrevolution.com/neo-taylorism-or-devops-anti-patterns/

4. The Economic Agents

> *«Thinking and acting are the specific human features of man. They are peculiar to all human beings. They are, beyond membership in the zoological species homo sapiens, the characteristic mark of man as man. It is not the scope of praxeology to investigate the relation of thinking and acting. For praxeology it is enough to establish the fact that there is only one logic that is intelligible to the human mind, and that there is only one mode of action which is human and comprehensible to the human mind. Whether there are or can be somewhere other beings - superhuman or subhuman - who think and act in a different way, is beyond the reach of the human mind. We must restrict our endeavours to the study of human action.*
> *This human action which is inextricably linked with human thought is conditioned by logical necessity. It is impossible for the human mind to conceive logical relations at variance with the logical structure of our mind. It is impossible for the human mind to conceive a mode of action whose categories would differ from the categories which determine our own actions.»*
> Ludwig von Mises - Human Action: A Treatise on Economics

Von Mises, originator of the concept of «catallactics»[42] and the related one of «praxeology»[43] considered that, for all practical purposes, human reason and economic calculation have limitations that are unavoidable, but still considered that there are no better alternatives (to economic calculation as a means of using scarce resources to improve our well being), than to consider that human action is rational. According to von Mises and his theory of praxeology, *«man acts because he is never fully satisfied, and will never stop because he can never be fully satisfied»*. This might seem like a simple point, but modern economics is built upon ideas of contentment-equilibrium analysis and the idea of indifference conditions. It is true that some economists construct models of dynamic equilibrium, but the idea of a dynamic equilibrium is oxymoronic to von Mises. An actual equilibrium may involve a recurring cycle, but not true dynamics. True dynamics involve non-repeating evolutionary change»[44]. In this regard it is interesting to note that von Mises, who opposed and discarded the Marxian labour theory of value, ended up being in complete agreement with Marx's contention that, in the capitalist system, there is no such thing as a «stationary dynamic equilibrium». All that there is in the capitalist system, is a permanent condition of disequilibrium, very much akin to that of a moving bicycle.
On the other hand, one of the most common criticisms levelled at the conventional or neoclassical paradigm in economics, on the part of scientists coming from other fields of knowledge, is the fact that – according to these critics – the neoclassical paradigm in economics assumes the existence of just one single type of economic agent, that of a fictitious *«homo economicus».* Some comments are in order in this respect.
In the first place this kind of criticism may be considered as being wrong in the sense that conventional or mainstream economics actually recognises *two* fundamental types of economic agents. That of the entrepreneur, capable of what followers of von Mises consider as «true human action», and that of the «others». In the model proposed here we start from a set of common characteristics, that usually are assumed to correspond to the observed behaviour of human beings in search of satisfaction of their basic (and not so basic) needs. The basic premise is that all humans try to maximise their «utility function» or, in other words, to maximise their personal well being. Once that basic premise has been established, other motivating factors are then added, in different ways and proportions to different types of «economic agents».
On the other hand, it should be obvious that this *«homo economicus»* is a theoretical construct designed to enable analysis of the system to better work out their hypothesis. It is also an implied

[42] Catallactics has been defined as the praxeological theory of the way in which free market systems reach exchange ratios and prices
[43] Praxeology has been defined as «the science of human action». Its most common use is connected with the work of Ludwig von Mises and the Austrian School of economics.
[44] In http://en.wikipedia.org/wiki/Human_Action

assumption that, when it comes to trade in the market, and in the final analysis, we all – conscious human beings – strive to get the maximum reward for the minimum effort. This is irrespective of the fact that some of us, under certain circumstances may find the «spending of effort» in itself, a pleasurable thing and, therefore, derive «maximum reward» also from the expenditure of effort.
As will be noticed, it is all a matter of definition and individual perception of «maximum reward» and «minimum effort». Be that as it may, the real issue is not whether this notion of a «homo economicus» means one single (homogeneous) type of economic agent, but rather a theoretical (abstract) substratum on top of which other differentiating features may be superimposed.
In any case, it should also be noted that there is another perspective to be considered when discussing the issue of *homogeneous* versus *heterogeneous* economic agents. In the specific case of the Austrian School of economics, Ludwig von Mises considered that economics, being «the study of human choice under conditions of scarcity», should be regarded as a particular branch of praxeology, this being the study of all human action. As opposed to the ideas of classical economists, von Mises rejected the use of empirical observation as a basis for the study of economics, and instead, favoured the use of logical analysis. According to him, empirical methods that are used in the so called natural sciences simply cannot be applied to the social sciences as the principle of induction does not apply. Meanwhile, following on the footsteps of von Mises, F. A. Hayek developed the concept of «catallactics» as the praxeological theory of exchange ratios and price formation in a free market system. Put together these concepts assume the existence of two fundamentally different economic agents in an «evenly rotating economy» or ERE. On the one hand, we have the *entrepreneur;* the one that creates new scenarios and through his actions and innovations keeps the economy moving in a «rotating equilibrium». On the other hand we have *all the others* (workers and consumers) who respond to impulses coming in from the economic environment, namely the demand for «labour power» and the supply of goods and services. According to this taxonomy (of two different economic agents) we would then derive the idea that the action of the economic agent «entrepreneur» is the one that is «truly distinct human action»
The terminology introduced by Ludwig von Mises was already, in itself, a criticism of the concept of the idea of a static equilibrium, used by economists and imported from equilibrium models used in classical physics. According to von Mises, the mathematical model of physical science had been unwisely adopted by economists who had failed to recognize the essential difference between the subject matter of human and non-human science. In the words of Patrick Gunning,

> *«this lack of wisdom was evident from the fact that when even the best mathematical economists set out to describe real economic activity, they had to resort to making assumptions or hypotheses about entrepreneurial activities. In introducing the term ERE, Mises was not proposing that economists adopt a new method of describing economic activity. He was merely proposing that economists use a more accurate phrase to describe the method they had always used but that some economists apparently failed to appreciate»*[45]*.*

Meanwhile, it could be argued that the adoption of such a terminology would make the artificial nature of conventional economics, too obvious. Perhaps as a result of this, the phrase *«evenly rotating economy»* was adopted by only one other economist of note, Mises' student Murray Rothbard. Mainstream economists have continued, instead, to use the terms «static equilibrium» or «general equilibrium». Meanwhile, von Mises, an honest proponent of a certain way of looking at economic phenomena, openly rejected positivism within economics and defended an *a priori* epistemology. His approach was based on a radical methodological individualism, not only from an analytical perspective but also from a »social engineering» perspective, arguing that an unregulated market system will, in the final analysis, be the best solution for all parties concerned. The catch phrase of *«less government, better government»* is based on such an assumption.
According to von Mises, the historical and statistical approaches were prone to subjectivism and instead he proposed to look upon what he believed to be the logical structure of *«human action».* Paradoxically enough von Mises (and conventional economists as well) tried to build a coherent

[45] http://mises.org/journals/rae/pdf/rae3_1_8.pdf

and *objective* economic theory based on some fundamental assumptions about the nature of human subjectivism... Be that as it may, in the model proposed here all economic agents start off by having in common those characteristics usually attributed to the common *«homo economicus».* On top of those common characteristics, we should define other differentiating characteristics. To use the terminology of «object oriented programming», that would be the «inheritance» feature.
According to the perspective of von Mises and his followers, in a «complex» situation we cannot build a theory that would enable us to predict how humans will act or what actions they will pursue, based on what we have observed being done in «simple» situations. Furthermore, there may be limits to what and how much we can learn from these «simple situations». Only the human actor knows the ends toward which he acts. *«Observers may try to «understand» why an actor behaved in a particular way, but this reason must be inferred from a complex set of data which can only be gathered once. Reproducible experiments are not possible because both the actor and the observer have been altered by the experiment».* In other words, if we were to follow von Mises precepts, there probably would be no modelling of human economic agents... In any case, in the virtual universe of modelling and computational economics, and in the words of Leigh Tesfatsion,

> *«Agents are encapsulated software entities that are capable (in various degrees) of adaptation to environmental conditions, are able to communicate with other agents and have the capability of goal-directed learning. Furthermore, they are autonomous in the sense that these software entities are capable of self-activation and self-determinism, based on their own internal processes. Apart from these characteristics, agents can be situated in virtual but realistically rendered problem environments. Their behaviour and interaction patterns may develop and evolve over time, that is to say, over a number of program iterations».*

When considering the existence of various types of economic agents we still assume a common underlying behaviour which is that one that is characterised as being *«economic behaviour»*. As discussed by classical political economists, long before the emergence of the utilitarian-marginalist school of thought, this theoretical construct corresponds to a certain *tendential* type of individual behaviour: that of maximising one's own personal satisfaction through the maximisation of one's own «utility function». In other words, how does one maximise one's own personal welfare.
So, *tendentially,* this general virtual «character» pursues, first and foremost, his (or hers) personal satisfaction. That being said, this means that other considerations will be of a relative importance and may on occasion influence (and override) the decision making process that would be expected if only «economic» factors were taken into consideration. This same virtual «character», when taking decisions, also has – *tendentially* – access to relevant and necessary information. This should not be conceptually confused with «access to *all* the relevant information» regarding any set of events or circumstances that may influence the outcome of any decisions. This individual «character» is defined as a «born calculator», in the sense that corresponds to the central character in the Transactional Analysis approach in Psychology of Freudian inspiration.
However, while building the computational model, in a second analytical moment of differentiation, all the economic agents then assume different roles, both because of different systemic functions, as well as differences in access to system resources and system control.
One of the most common criticisms, coming in from a number of practitioners of «complexity sciences», is the alleged fact that conventional economic analysis starts from the premise of an homogeneity of economic agents (under the guise of the famous *«homo economicus»*). A brief overview of the literature on economic planning reveals that, in fact, conventional economic modelling usually considers five different types of economic agents, namely «business firms», «families», «public administrations», «banks and other financial institutions» and «the rest of the world», with all these «agents» pursuing somewhat different goals. In any case it still seems, and that is the basis for a certain level of criticism, that those five types of agents[46] (each one of them) end up having a similar type of behaviour, hence the alleged «homogeneity. Be that as it may, in

[46] Some authors consider «four plus one» types of agents, as the «rest of the world» is an aggregation of the other four types of agents, residing outside the scope of the fraction of the world economy that is being modelled.

the model being proposed here, a number of different types of personalities is introduced, to add some realism to the modelling exercise. In any case, the final purpose of the model is a demonstration (or not...) of a particular and very critical feature of the system's logic. Strictly speaking, the type and number of different agents seems to be irrelevant for that demonstration, as the real relevant factors to be considered are that of «Labour» (of whatever kind that produces «value added»), and that of «Capital», whose ownership «merely» produces the payment – giving wealth newly created - to a fractional number of economic agents. In any case, in a short and preliminary classification of «economic agents», we may list the following types of «super classes»:

- Business firms (as represented by owners and/or executive directors)
- Families or equivalent social groups
- Government and/or Public Administration
- Banks and related financial institutions
- Insurance Companies

Within each one of these «super-classes» (or hierarchically underneath them), the ideia would be to consider some of the following various types – among many others - of «individual» agents:

- Owners and Entrepreneurs
- Directors and Executives
- Managers and Supervisors
- Wage Workers and Employees in general («Blue collar» ?... «white collar» ?...)
- Bankers or «money managers»
- Commercial Farmers
- Industrialists (manufacturers)
- Politicians (party leaders, members of parliament...)
- Civil Servants
- Professionals (lawyers, medical doctors, engineers, consultants...)
- Other self-empoyed workers

Strictly speaking these will all be archetypes (or prototypes...) that are intended to represent the social perception of what are their motives and exemplary actions.
When defining the above listed «economic agents» (or classes) we could conceive of the idea of differentiating them further in accordance with the various types of activity sectors. This seems to be particularly relevant in the case of «owners» and «entrepreneurs», but in fact would also apply to a number of other actors or agents. To illustrate this point suffice it to say that while pursuing the same fundamental objective (that of «maximising one's own utility function»), the same type of agents *coming from different sectors of activity* (for example, mining and fabrication, or agriculture and commerce...) will have conflicts emerging from that same common objective.
It should be stressed here that the above listings are of a very provisional nature, as some of the differences (conflicts of interest...) between some of the above categories (or «classes») may be irrelevant for the analysis or may be left to a third analytical moment.
It should also be clear that the above listing leaves out of our theatrical stage (...) some other types of actors such as «churches», non-governmental and non-profit seeking organisations, as well as the remnants of pre capitalist classes such as peasants and artisans. This we do for two kinds of reasons. On the one hand, the capitalist system has become overwhelmingly predominant in the world of globalised economy, and these types of agents are either remnants of historically bygone systems of social organisation and, on the other hand they are, strictly speaking, outside of (and irrelevant to) the logic of functioning of the capitalist system.
Also, if one wants to try to get to the «nitty gritty» of things, a situation could be conceived where a proportion of the same type of agents are defined and programmed with somewhat «random» features. For example, and only to illustrate the point, some of the workers could be programmed as being «trade union oriented» whereas another (variable?...) proportion of the same workers could be defined as having a «could not care less about the others» attitude.

5. The Systemic Flows

> *«The foundation of ecological reasoning is the irreversible flow of solar energy in unlimited quantity and the recycling of materials. The foundation of economics: an irreversible flow of fossil fuel from a limited source, and the irreversible flow of materials from a reservoir of non-renewable resources.»*
> Joel de Rosnay - Le Macroscope; Vers Une Vision Globale

Outline of a non regulated market economy

One of the critical issues in computational economics seems to be the determination of what are the performance capabilities of decentralised economies. How do regularities come about in the market place without the intervention of an actually existing «invisible hand». The conventional response has been to *assume* the existence of a virtual auctioneer, which *assumption* does not solve the problem, but merely replaces the Smithian idea of an «invisible hand» with the Walrasian idea of an «invisible auctioneer». Be that as it may, the «solution» found by the approach of computational economics, made possible with the advent of computers and the programming capabilities provided by the «object oriented» techniques associated with certain programming languages, is that of the «agents-based» modelling. This is done by constructing a virtual world of economic activities, that proposes to capture the basic characteristics of real economies, with economic agents, circular flows of goods, services and payments, specified amounts and types of information, as well as the postulated (but empirically confirmed) behavioural characteristics of economic agents.

With the reference to the «invisible hand» and the issue of its possible reification on the part of those who search for alternative explanations to the way the economy achieves some sort of coordination in the absence of a «coordinating centre», one has to remember and consider that, before the more recent contributions from the theory of networks, some economists and other observers had advanced ideas and hypothesis about the existence of such a «coordinating centre». Suffice it to refer to the work of Alfred DuPont Chandler, «*The Visible Hand: The Managerial Revolution in American Business*» (1977) and to the extensive work of such authors as Paul Baran and John Kenneth Galbraith on the structure of American capitalism. Among the more recent work, related to economic flows and links among business enterprises, I refer the work of Albert-Laszlo Barabási (*«Linked»*) which refers a study by Davis, Yoo and Baker from the University of Michigan Business School. This study found that there were 10.100 directorships held by 7.682 directors running the top 1.000 corporations listed by Fortune.

> *«While 79 percent of them serve only one board, 14 percent serve on two and about 7 percent serve on three or more. The measurements indicated that these few overlapping directors create a small-world network with five degrees of separation. Indeed, the distance between any two directors belonging to the major cluster, which contains 6.724 directors, was 4,6 handshakes on average»* (Barabási, 2003).

If we add on to this «small-world» structure, the herding behaviour proper of large groups that end up thinking alike, we find a very active and reasonably well structured «visible hand», running the affairs of the world economy.

In any case the purpose here is not to demonstrate or explain a phenomenon that has been extensively studied. My purpose here is to demonstrate that, out of the normal functioning of a (capitalist) market economy, where the function of «coordinating centre» is performed by a a cluster of a «small-world» type, being made up of like-minded business executives, there emerges a certain behaviour of one critical variable: *that of the rate of profit.* And also to demonstrate that, out of that emergence, there arises the potential for systemic crisis of overproduction and unemployment.

I have to stress, over and over again, the abstract character of this outline and, as a result, the fact that this rudimentary model should be applicable to the interpretation of the capitalist system as a whole, *and independently of its manifestations in any specifically distinct national environment.* It is

the capitalist system in itself that is being portrayed here, in its «decanted» purity, after having removed (or having left out of the picture) all the local peculiarities that originated from historical and geographical circumstances[47]. Not any particular national «imperialist» instance of that system. In this respect it will make no sense to seek explanations or express criticisms regarding the fact that *this model does not consider an export/import sector of the economy*. At the scale of the planet (the global economy) there are no exports, nor any imports. This clarification is not merely important but actually needs to be emphasised, if one considers the prevailing bias of studying economic systems in their local «national» environment. In the words of Leigh Tesfatsion:

> *«A general question that has not yet been addressed is what constitutes the most suitable scale of analysis for ACE modelling? Most of the illustrative ACE studies outlined in the previous section study economic processes that could be occurring within the borders of a single country. Indeed, many of these studies focus on single markets or small collections of markets, the traditional purview of the old of industrial organization. On the other hand, some ACE researchers have undertaken ACE studies of specially open economies or international economic systems. How useful will ACE modelling be for addressing issues at this more macro level of analysis in comparison with other methodologies that are currently being developed for the same purpose, such as statistical mechanics approaches.»*

The comment that seems relevant here is that the methodological approaches used in statistical mechanics are truly universal and related to the realm of physics, independently of where in the Universe its phenomena happen to be studied. So, in our effort to understand the complexity of the capitalist economy, what we should keep permanently in mind is that, on the one hand, one type of exercise is the study and understanding of the inner workings of the system (of a universal nature much in the manner of Euclidian geometry), and another different type of exercise is the study of its peculiar and particular instances, which are dependent on History and on Geography.
In fact, while we had various semi-autonomous national subsystems, within the global planetary system, it might have been reasonable to present statistics, as well as analysis that included the imports and exports, as well as the cross-border flows of goods, services and monies. Then it was amply justified to have discussions about the way governments interfered (or not) with the normal functioning of the capitalist market economies. Now, with the absence of an effective world system of economic governance[48], we may safely presume that *a model of an unregulated market economy, where profit maximisation rules the day, will quite probably reflect the intrinsic logic of the real world of global capitalism.*
Once we have sketched a classification of «economic agents», we will then have to consider the *flows* within the system. Flows that establish the connection between the «parts» or interacting «agents». These flows, as previously suggested, will be constituted by exchanges of «matter», «energy» and «information» (or «economically meaningful symbols»). It should be noted that, from a systemic point of view, that is what money is: a set of symbols representing a quantity and a quality of work performed and the wealth that results there from.
Taking a look at the following diagram we see several «agents» interacting in accordance with certain rules. These are to be discussed later in the text. Apart from the «agents» proper, there is also to be considered the environment. In this case, the locations where transactions take place and where the consequences of transactions are stored up. In other words, the places where «changes» happen upon the environment.
But before considering the flows themselves, it makes sense to elaborate a very brief sketch of the «role» played by the agents in that permanently ongoing flow of goods, services and symbols.
Both for reasons of logical and historical precedence we shall begin with the families «superclass».

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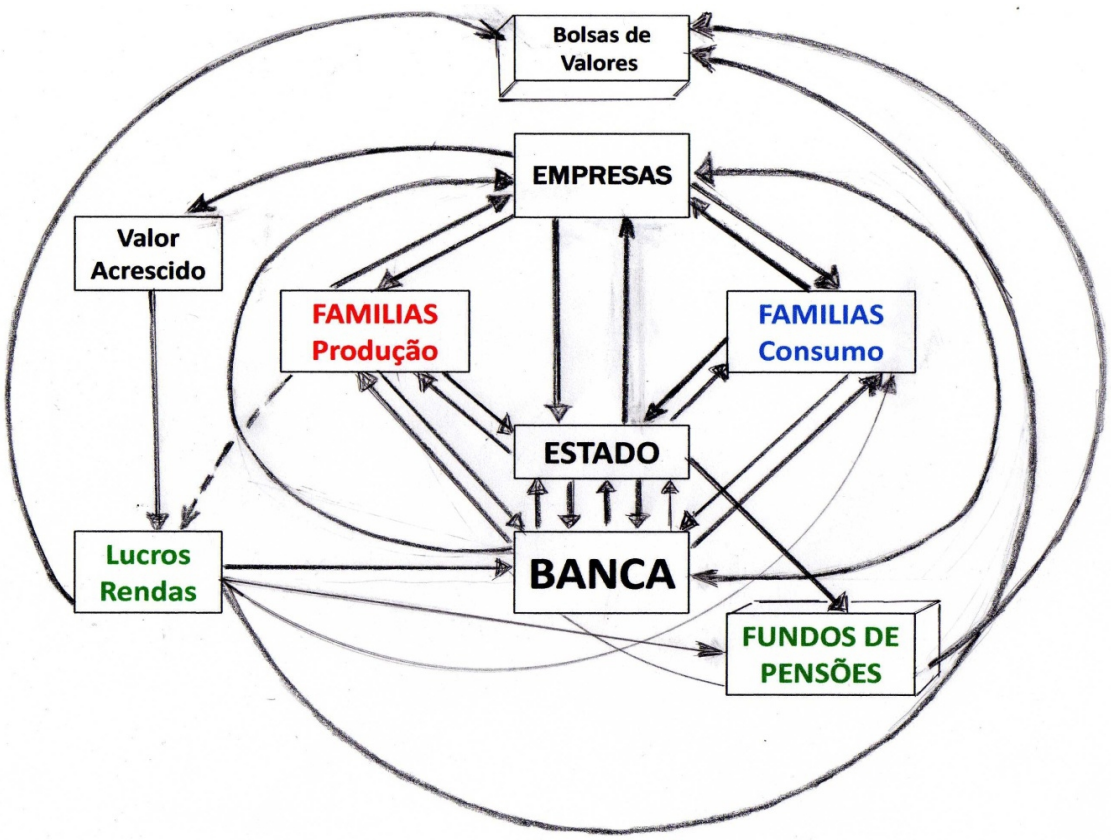
47 One is reminded here of the dilemma of wine growers: is it the *«terroir»* or the *«cépage»*?... Capitalism could be seen as particular kind of «tree» that originated in the Western Europe and was then gradually transplanted to other regions where it adapted to local conditions but retaining the very same «genetic code» of its original source...

48 The United Nations agency (UNCTAD) that might have been in charge of that kind of governance has been reduced to a centre of specialised studies and a forum of discussions of some irrelevant matters. As for the WTO-OMC, it has been reduced to function as a «court of conciliation» to resolve minor trade disputes.

There was a time, before the emergence and pre-eminence of capitalism when families were simultaneously the locus of production and the locus of consumption and social reproduction. With the advent of capitalism, and the historical emergence of the business enterprise, these two systemic functions were split. We now have to consider that the only real and most meaningful locus of production (for the emergent behaviour of the system as a whole...) is the «business firm».



The Systemic Flows between the Nodes or Entities

The productive role that «families» play in that systemic function is now subordinate and/or dependent on the decisions and role of «business firms». That being said, the flows between these two types of super-classes are as follows:

The families are shown here as fulfilling two distinct systemic functions: that of «production» and that of «consumption». Strictly speaking these two functions are but two sides of one single coin. The consumption function is also – at the same time - the fulfilling of the productive function of reproducing the labour power that is required by the system, both current (of the workers themselves) and for the future (the rearing of children to replace older and retiring workers). However, for analytical purposes we have to look separately at these two systemic functions.

The families, in their «productive functions», provide the business firms with «labour power», both in terms of physical energy and in terms of information (knowledge or skills). In exchange of that the families receive from the business firms, wages and salaries in the form of money payments (which corresponds to information «certificates» that testify the quantity and quality of the work that was provided by the families).

On the opposite side, the business firms provide the families with whatever goods and services the families are supposed to need for their continued functional existence and reproduction. In exchange the business firms receive from the families part of the symbols (money) that they have

received as payment for their sale of «labour power».
Next we have the relationships and corresponding flows between the aggregates of families (in both roles as «consumers» and as «suppliers of labour force») and the State, as well as the relationships and corresponding flows between the aggregates of business firms and the State.
In what concerns the relationships between the families and the State, the families (in their «productive functions») provide labour force to enable the regular functioning of departments in the public administration. In exchange those families receive from the State departments, wages and salaries in the form of money payments (which again corresponds to information «certificates» that testify the quantity and quality of the work that was provided by the families).
On the opposite side, the State departments provide the families with a number of services that are deemed essential for the regular functioning of the system as a whole, such as the provision of justice and law enforcement, public health services, regulation of natural monopolies.
The same type of flows occur between the aggregate of business firms (and naturally between each one individually...) and the State. The business firms provide goods and services to the State, in exchange for payments, and the State provides the business firms with services without which the business firms simply could not operate, namely law enforcement (and most specifically the enforcement of contracts), and the protection of business firms' properties, as well as the provision of trade and industry regulations (including natural monopolies) and the smooth functioning of general administrative services. In exchange for the provision of these services the business firms are expected to pay various kinds of levies and taxes.
The next kind of flows to be considered is that one between all these entities (families, business firms and the State – or general public administration) and those entities whose systemic function is the management of those «certificates of wealth produced» (money...): *the banks.*
Most families (for all practical purposes, we could consider all of them) receive their wages and /or salaries once a month, with that amount being deposited with a bank. According to conventional wisdom and as an empirically verified fact, all the banks are supposed to do is to utilise the money they receive in deposit, as a lever in the financing of investments and credit consumption. However, apart from lending out money, both for capital investments and for the easing out of consumption, that comes strictly from their deposits, banks have the functional capability of literally creating money. This functional capability may be programmed into the model but, for the purposes of our model, that capability will only «worsen» the situation (from a logical point of view) and «help postpone» the emergence of the phenomenon we are seeking to show and explain.
As a result of systemic flows, and given the initial endowments of each economic agent, and in particular those agents that will have been endowed with the ownership of capital (the business firms), each agent will have to decide what to do with the results from each iteration. Given the original differences in endowments, a similarity in the rate of growth (supposedly prevailing in the system as a whole) will cause absolute differences in the growth of each agent. As a result the relative seller-buyer strengths or capabilities will start to become «intervening factors», with the larger agents getting an incentive to acquire the smaller agents. This may cause «relative buyer/seller concentration».
The system should be able to show the growing size of stored up flows that end-up in the node here named «Pension Funds». Strictly speaking there should be another arrow (a «link») flowing from the node «Pension Funds» to «Families-Consumption». This was not an oversight and must be clarified. The reason is that those flows from «Pension Funds» to «Families-Consumption» are actually *delayed* flows from the node «Business Firms» to «Families-Production» which have not been met (in the past) by equiproportional flows from «Families-Consumption» to «Business Firms».
This *delayed* or postponed consumption causes an increase in the node «Pension Funds» of amounts of money whose purchasing value must be protected. From this need to protect, preserve (or even enhance) the purchasing value of those amounts deposited with the node «Pension Funds», arises the need for a continually increasing flow from «Pension Funds» to «Stock Exchanges».

Apart from that, there is also to consider the continually ongoing growth in productivity. From that arises a continued growth of «value added» per unit of «working time», both in absolute and in relative terms. As a result of that continued growth of overall systemic productivity, the amount of profits will tend to continue to grow and the same will tend to happen to the amount or size of the flow from that node («Profits and Rents») to the node «Stock Exchange».
In view of the ongoing economic crisis and the flurrying of activity in devising *alternative,* but politically correct, explanations for the crisis, one final comment on the conventional but, again, politically correct, perspectives on *alternative modelling*, seems justified.
For that purpose I shall use two examples of the currently available conventional, but alternative, wisdom. In the words of Jared Sagoff, of the Argonne National Laboratory, writing on the issue of agent-based economic modelling and the ongoing efforts to develop a better, presumably more efficient, way to avert this crisis from getting even worse,

> *«As the stock market continues its dive, economists and business columnists have spilled a lot of ink assigning responsibility for the ongoing financial calamity. While hindsight might be clear as day, researchers at the Argonne National Laboratory, are trying to create new economic models that will provide policy-makers with more realistic pictures of different types of markets so they can better avert future economic catastrophe*[49]*.*

Or, in the words of Charles Macal, another Argonne systems scientist,

> *«Traditional economic models rely heavily on «equilibrium theory,» which holds that markets are influenced by countervailing balanced forces. Because these models assume away the decision-making processes of individual consumers or investors, they do not represent the market's true internal dynamics» «The traditional models don't represent individuals in the economy, or else they're all represented the same way - as completely rational agents,» ««Because they ignore many other aspects of behaviour that influence how people make decisions in real life, these models can't always accurately predict the dynamics of the market.»*

In this context it is worthwhile to remember, as per the theory of networks and the phenomenon of «phase transition», that it is not so much the characteristics and the postulated (or observed) behaviour of individual agents, that is important for the modelling of the economic system, as such. What really matters, according to those perspectives, is the relationships themselves and how they keep changing. In other words, if for an efficient way of modelling the economy, what is really important is the set of relationships that are established amongst the various economic agents, then it does not really matter (very much) how much detail one considers and includes in the description of behavioural characteristics of each individual type of agents.

[49] http://www.drdobbs.com/high-performance-computing/212200935

6. The Definition of Agents Behaviour

> *«"When I use a word," Humpty Dumpty said, in a rather scornful tone, "it means just what I choose it to mean. Neither more or less". "The question is", said Alice, "whether you can make words mean so many different things". "The question is", said Humpty Dumpty, "who is to be master. That is all".»* - Lewis Carroll

Introduction

Considering the previous examples of alternative wisdom «coming to the rescue» of conventional mainstream economic theory in the development of better exploratory models, I fear that, unless they come to include analytical categories derived from Marxian analysis, namely the labour theory of value and the conflicting objectives of consumption and accummulation, not much will come of those contributions.

This section should correspond to a preliminary or preparatory detailed formulation of a model to simulate the behaviour of the capitalist system, as if left to its own intrinsic logic, without any outside interference from an yet non existing «world government». But before that is attempted, some comments are in order regarding the nature (and usefulness) of some modelling exercises.

In the first place one has to face up to the plethora of «tools», «platforms» and «workbenches» that have been developed by pragmatic, business oriented, software engineers who, quite naturally, try to sell their wares to any interested customers who might be interested in simulating business processes in general and industrial processes in particular. Ranging from «Customer Relationship Management» and «Processes Re-engineering» to the design of «Fault Tolerant System» and their testing before production. In relation with this market niche we then have the development of specific subdisciplines such as MDA or «Model Driven Architecture» and PIM or «Platform Independent Modelling». However, and this should be properly noted, from a strictly scientific research point of view, these are «mere» tools and the knowledge of their operation and usability should not be confused with the specific scientific endeavour in itself.

The Modelling of Human Behaviour

The modelling of human behaviour is a complex task that, through practice, has been reduced to the observation, copying and mimicking of currently observable behaviour. As a result of this process, researchers will then try to formalise the sequence of observations, decisions and actions in terms of values, language, symbols and information inputs in general. Behaviour modelling within human groups has been most obvious in the rearing of young children who spend many hours, playing «lets pretend» games among themselves and with relevant grown-ups with whom they usually interact.

Modelling is also something that adults continue to do when trying to learn how to adjust to unfamiliar situations and surroundings. The same general principles are then transposed into the creation of virtual social agents interacting among themselves in a virtual environment created by means of software engineering.

One first observation that then comes to mind is that, no matter what, our models will always reflect our own perception of how things are and how our agents are supposed to behave. In a book published in 2000, Professor Bernd Schmidt discusses the still current methodologies for the development of simulation models in the social sciences. To summarise the ideas in that book I will simply refer to the words of Frédéric Amblard in a recent review of Bernd Schmidt's work.

Bernd Schmidt' starts from the idea that, in spite of their existence and obvious usefulness, many works about modelling, within the social sciences, do not use existing specification languages like the Discrete Event System Specification formalism (DEVS) and Unified Modelling Language (UML) to describe their models. The conventional argument for using such common formalisms is to provide a better understanding of the structure of those models, in a manner similar to the way that is currently used in other fields, like robotics. The debatable reason that Bernd Schmidt gives for the current state of affairs in social sciences is that there is actually no correct reference model to express every model of human behaviour. Bernd Schmidt then proposes the PECS agent

architecture to fill the perceived gap in methodologies to correctly model human behaviour in social sciences. PECS actually stands for «Physical conditions», «Emotional state», «Cognitive capabilities» and «Social status». Schmidt defines PECS as is a multi-purpose reference model for the simulation of human behaviour in a social environment. Particular emphasis is placed on emergent behaviour which is typical of the formation of groups and societies in social systems.
Human behaviour is highly complex in its nature and structure as it is influenced by physical, emotional, cognitive and social factors. As a consequence, the human being is then perceived as a psychosomatic unit (with cognitive capabilities), who happens to be embedded in a social environment. In the words of Schmidt,

> *«the PECS reference model aims to replace the so-called BDI (Belief, Desire, Intention) architecture (Rao 1995). Architectures which conceive of human beings as rational decision-makers are only to a very limited degree sensible and useful. Restriction to the factors of belief, desire and intention is simply not appropriate for sophisticated models aiming to model real social systems.»*

The other point to be underlined is the substantive and significant difference between modelling machine-type events (such as industrial processes...), or even the logic and logistics of a system where human behaviour may (eventually) be equated to that of programmable robots, and the modelling of systems behaviour where the system outcome may be dependent upon variable individual characteristics, that are susceptible of being mimicked in a computer program.
In the words of Urban and Schmidt (2001)[50]

> *In contrast to the application of agent technology to technical domains the structure, the properties and the behaviour of agents must not be selected freely when they are used in the context of modelling. In fact it is a basic requirement for good models to display structural and behavioural similarity with the original system. For the design of agents this means, that they have to be constructed in a way, which makes them similar to their real counterparts with respect to their structure and behaviour. When an agent is used for modelling a human being for example, the agent has to be equipped with all properties and behavioural patterns of the real human which are of relevance in the given scenario.*
> Christoph Urban and Bernd Schmidt (2001)

The Purpose of Modelling in Social Sciences

Even a brief review of complexity sciences and modelling as applied to social sciences, reveals that quite often the exercise of modelling itself seems to take precedence over the research effort as a scientific exercise. I stated *«even a brief review»* based on the fact that a number of articles that have been consulted keep referring to similar types of modelling. As an illustrative example of this, I refer to a 17-pages paper submitted to *«Complexity International»* and published in Volume 3 (April 1996) by Robert B. Johnston. In it the author proposes to discuss the theme *«From Efficiency to Flexibility: Entropic Measures of Market Complexity and Production Flexibility».* The paper includes a reasonably detailed discussion of the process of «quantifying complexity and flexibility with Shannon's entropy, the entropy analysis of the model, its requisite variety, the cost of inflexibility and the derivation of *E(B)* – errors per batch - from Information Theory». But in the end, or rather right at the beginning, the author indicates that *«the purpose of the model is to examine how the constraint of production in batches greater than one, limits the flexibility or responsiveness of the producer».* Or, in other words, to examine how the production of any particular good (a car, a pen...) *in batches larger than 1 (one)* forces the producer to incur a loss of flexibility. One wonders if the author really expected any manufacturer to not be aware of the problems (costs and benefits) of alternative systems BTO (or «build to order», batches of one...) and BTP (or «build to plan», batches of various sizes), where BTO implies higher set-up costs (for a one of a kind item...) and BTP means spreading overheads amongst various items of an equal nature or with the same characteristics. It should also seem obvious (therefore not requiring a demonstration), that BTO

[50] Available at http://www.aaai.org/Papers/Symposia/Fall/2001/FS-01-02/FS01-02-027.pdf

means maximum flexibility, both in manufacturing and post-sale servicing...
Be that as it may, the purpose of the modelling exercise that is proposed here is not to test any new processes but rather, as suggested before, to try and demonstrate a certain emergent phenomenon in the realm of Political Economy. We shall assume as valid a number of behavioural characteristics on the part of our economic agents, with such characteristics usually being considered as normal, by consensus among observers and analysts of the economy.
That being said, what we will have here, will be a set of mathematical functions that should characterise the individual motives and behaviour of each different type of economic agents, most particularly that of business firms (as decided by their owners and/or directors). It could also be stated that even when we attempt to model the behaviour of the capitalist system based on postulated individual «agents» behaviour, we are in fact postulating system behaviour at the macro level, as when we postulate this or that maximising function.
We start off with the most basic premise of them all: that of an *«homo economicus».* We will not dwell here in the discussion concerning the validity and alleged errors of the neoclassical paradigm in economics[51]. The discussion about the perfect *versus* bounded rationality of economic agents, is very important and interesting but, at the end of the day, if we want to attempt a modelling of an economic system we must start off from some basic assumptions. In this case we start from the assumptions that economics agents have access to simply relevant information, as there is no way anyone can have access to all the information that is actually available (time is a limiting factor...), let alone having access to all the information that actually exists in the social universe and may have a bearing on any economic situation and the decisions that are to be taken.
So, our basic and initial assumption is that all individual economic agents strive to maximise their own individual well being. As what might be considered as a concession to anthropologists and other social scientists, including economists of an institutional inclination, we will consider that «maximising one's own well being» includes the maximising of the well being of one's own family.
One of most common criticisms levelled at conventional (mainstream) economics, is the idea that this paradigm only assumes one single type of agents (with the behavioural characteristics of the famous *«homo economicus»*). What we assume here is that, on top of those basic characteristics, we also have to consider other complementary and differentiating characteristics.

The Characterisation of Individual Types of Agents

Even though, in its most elementary or reduced form, we could envisage a model with only two types of agents (those who own «capital» and those who own «labour force»), as is usually done by orthodox Marxists, it might be interesting to consider a more varied characterisation of social agents, such as «civil servants» and, within the «owners» class, a further subdivision of various subgroups considering, for example, «industrialists», «farmers», «bankers» and «traders».
The important point to underline here, however, is that in the final analysis and for the overall behaviour of the system, what really matters is the «*functional role»* played by the two fundamental groups. This *«functional role»* is independent of the actual individual agents or groups of agents and their «class consciousness»... Be that as it may, a first rough approach to a realistically looking model should then consider, at least, the following types of agents and their environment.

Owners of Business Firms

We shall assume the existence of a number of agents whose sole «social and systemic function» is the ownership of capital. In a sense, society (or the system) pays them an income as a reward of

[51] The neoclassical paradigm is based on the so-called general Walrasian equilibrium. This is a *«precisely formulated set of conditions under which feasible allocations of goods and services can be price-supported in an economic system organized on the basis of decentralized markets with private ownership of productive resources.*
These conditions postulate the existence of a finite number of price-taking profit-maximizing firms who produce goods and services of known type and quality, a finite number of consumers with exogenously determined preferences who maximize their utility of consumption taking prices and dividend payments as given, and a Walrasian Auctioneer (or equivalent clearing-house construct) that determines prices to ensure each market clears. Assuming consumer non-satiation, the First Welfare Theorem guarantees that every Walrasian equilibrium allocation is Pareto efficient» (Tesfatsion, 2005)

past labours or initiatives or risk taking. It could further be argued by the proponents of main stream theories that these economic agents have the responsibility of ensuring the smooth functioning of the production function in the economy as a whole. This they do either directly (in which case they also fulfil the function of directors or executive management), or through contractual delegation (in which case they restrain themselves to merely receiving an income without current - on going – work of any kind being performed.) The point do retain is that from a systemic point of view, these economic agents do not have to work (to actually perform any kind of work), and act as «mere consumers» (usually of luxury goods). In that function they strive to maximise consumption.

Directors and Executives of Business Firms

We shall assume the existence of a number of agents whose «social and systemic function» is the supervision and control of production activities of all kinds. In a sense, these agents are «mere» processors of information, and in doing this they are expected to coordinate the production activities of other working agents. The owners of business firms pay them an income that is sufficiently high to reward their loyalty and an incentive to maximise results of the business firms and, as a result, also to maximise the income of the owners of business firms.

Because they are supposed to be in competition, these agents will strive to maximise their own share of the total *«economic cake»* (expressed as *«appropriation of number of hours equivalents»*) and will take periodic decisions (one per iteration) as to what to do with the surplus produced (as always expressed as *«number of hours equivalents»).* Which fraction will be consumed, which fraction will be accumulated as »savings« and which fraction will be «re-invested». The growth in «social productivity» will be a parameter left out of the decision making of these agents, and will be a parameter for the «experimenter» to play with.

As a result of these incentives these agents will tend to behave as surrogates of the owners and, eventually, as if they were the owners themselves. They will try to minimise costs and to maximise sales. We also assume here a tendency, on the part of these agents to start considering the legal owners as «parasitic» landlords and will try to replace them as legal owners of the business firms. From a systemic point of view, the result is a struggle regarding the division of any surpluses being produced. The behaviour implications of this kind of relationship has been extensively studied in the literature under the general term of «principal-agent problem» or the «agency dilemma». This research topic is supposed to discuss the problems that originate with conditions of incomplete and asymmetric information when a «principal» (the owner) hires an «agent», as the two parties will not usually have the same interests and/or the same access to relevant information.

Workers and Dependent Professionals

Under this category we will assume the existence of a number of agents whose basic characteristic will be the fact that their sole ownership is that of their own individual work capabilities.

These agents will try and sell their work capability in order to survive and reproduce themselves. This «survive» and «reproduce themselves» must be seen in an objective and sociologically relevant manner. It is not the «mere» biological survival and reproduction that is meant here. It is the fact that these agents will try to continue active as workers and professionals. Iteration after iteration each working hour that they try to sell becomes more productive. The increments in productivity will be a parameter to be manipulated by the experimenter of the virtual world being created. The issue of different qualifications and different types of work being «offered for sale» is not unimportant but, at the level of the system as whole, is irrelevant. What really matters is the average of the total aggregation of «labour force» or «work capability» being offered for sale (or hire...).

It is often argued that skilled workers, and highly qualified professionals in particular, on the assumption that they are paid «high salaries», can afford to save a significant portion of their income and, as a result, also attempt to become «owners of capital». From a systemic perspective this is irrelevant. For two kinds of reasons. In the first place, what characterises the economic agents «owners of business firms» is the fact that that ownership enables the control of other

agents' work and the control of the final destination of any surpluses being produced. The fact that some other economic agents become owners of small fractions of capital does not change the systemic nature of that ownership[52].

Bankers, Insurers and «Investors»

These particular agents are supposed to be the «guardians» of that money that corresponds to the equivalent of work (always expressed as "*number of socially required and worked hours"),* that has been produced but not consumed. What is commonly known as «savings». These particular agents (or a fraction of them) also have the characteristic or capability of «creating money». In other words they have the capability of «cheating» the system by generating «fake» equivalents of work that was (not really) performed and not consumed. The result should be a devaluation of «stored savings» and a corresponding need to increase the number of hours that should have been performed... In any case, and for the purposes of this first draft of a model proposal, in what concerns the next item (the «landscape»), these agents will be seen as having the size of their holdings, grow after each iteration.

The Stage or Landscape

In this particular subsection the idea is to try and define the social environment where the agents make their decisions, perform their actions and from where they «suffer» the consequences, such as the accumulation of wealth (in terms of *«accumulated capital»* expressed as the «*total number of worked hours whose product was not consumed but will help improve overall productivity»*), or the number of unemployed agents of the particular class «workers and professionals», expressed as the result that comes from dividing the «need for work to be performed» by the number of «available workers and professionals», but keeping fixed the «number of working hours».

What we have here will then be a set of mathematical functions that should characterise (or display, show) the emergent behaviour that results from the actions of individual agents. The purpose of this model should also be seen in the context of the generally available and current wisdom, concerning the economy, both from a positive perspective (looking at things as they are supposed to actually be...) and from a normative perspective (looking at things as some of us would like to see – and improve – them...). Hence a reference to «welfare economics» as an exercise that – short of being apologetic of the current (neoclassical) paradigm – pretends to demonstrate that economic facts are as they are (or that they are in accordance with some natural order of things), and the best way of «making the best of it» is to pursue certain «corrective measures». In other words, things are better as they are than they would probably be, if we tried to improve upon them...

There are two fundamental theorems of welfare economics. The first states that any competitive equilibrium or Walrasian equilibrium leads to a Pareto efficient allocation of resources. The second states the converse, that any efficient allocation can be sustainable by a competitive equilibrium. Despite the apparent symmetry of the two theorems, in fact the first theorem is much more general than the second, requiring far weaker assumptions.

The first theorem is often taken to be an analytical confirmation of Adam Smith's «invisible hand» hypothesis, namely that competitive markets tend toward the efficient allocation of resources. The theorem supports a case for non-intervention in ideal conditions: let the markets do the work and the outcome will be Pareto efficient. However, Pareto efficiency is not necessarily the same thing as desirability; it merely indicates that no one can be made better off without someone being made worse off. There can be many possible Pareto efficient allocations of resources and not all of them may be equally desirable by society. Not to mention the fact that the real economy is not a «zero-sum» game, as so often acknowledged by proponents of the neoclassical school.

The ideal conditions of the theorems, however are an abstraction. For example, states that in the

[52] We draw attention here to a caveat: as indicated by Anderson «more is different». If certain workers or highly paid professionals increase their portion of ownership beyond a certain threshold, then they stop being «workers» to become «owners of business firms»... They, as individuals, change their nature, but the systemic functions of «owners of business firms» and «workers» remain unchanged. At least as we have a capitalist system... Which is the one we are studying.

presence of either imperfect information, or incomplete markets, are not Pareto efficient. Thus, in most real world economies, the degree of these variations from ideal conditions must factor into policy choices. The second theorem states that out of all possible Pareto efficient outcomes[53], one can achieve any particular one by enacting a lump-sum wealth redistribution and then letting the market take over. This appears to make the case that intervention has a legitimate place in policy. Redistribution can allow us to select, from all efficient outcomes, for one that has other desired features, such as distributional equity. The shortcoming is that for the theorem to hold, the transfers have to be lump-sum and the government needs to have perfect information on individual consumers' tastes as well as the production possibilities of firms. Additionally, an additional mathematical condition is that preferences and production technologies have to be convex.

The Algorithms

Some preliminary remarks on definitions

As with any system model the basic requirement is a definition of a system of units of measure. Conventional economists express most economic magnitudes or amounts in terms of prices, which in turn are expressed as quantities of money. This raises several issues which are not addressed here (not discussed in detail) but that must be, at least, referenced. The main issue of concern is the classical issue of the objective (measurable) «value of things», the standard that enables trade to take place and justifies the expression that one particular brand of a motor car is worth as much as certain number of a particular brand of a television set (for example). What do they have in common, so to speak, that enables producers and consumers to make their assessments and comparisons and enable the exchange of their respective services and products.

This exercise being «Marxian inspired» we adopt here the labour theory of value which assumes that, *in the final analysis*, the objective value of things (goods and services) in the capitalist market economy, is determined by the social average of labour time that is assumed to be necessary to be expended for its (re)production. Just to clarify – and we are referring here to the issue of «relative prices» - we will assume that a particular brand of a standard family car is worth as much as five thousand pen drives (or memory sticks, for example...) of any specific brand, if and only if the (re)production of that particular family car requires five thousand times the total amount of social time/energy it takes to produce one unit of the specified pen drive or memory stick.

For a detailed discussion of the (in)famous «transformation problem» (of values into prices) please see Fonseca-Statter (2009). As a result of this enunciated premise, all the magnitudes and computation results in this model will be expressed in «hours of work». In other words, parameters such as «Total», «Constant» or «Variable» Capital, as well as «Surplus Value» or «Necessary Value» are expressed as the equivalent in terms of «hours of total social work» (of the entire society or system being modelled), expressed as multiples of an «average social work» (considering the average social productivity prevailing in the system).

What we will «discover» then, when we run the simulations with the model described in this paper, will be a set of relationships (extracted from observed reality) and the consequences that emerge from the postulated logic of the model. It must be emphasized that this postulated logic (a set of

[53] Pareto efficiency, or Pareto optimality, is a concept in economics with applications in all areas of the discipline as well as engineering and other social sciences. The term is named after Vilfredo Pareto, an Italian economist who used the concept in his studies of economic efficiency and income distribution. Informally, Pareto efficient situations are those in which it is impossible to make one person better off without necessarily making someone else worse off. Given a set of alternative allocations of goods or outcomes for a set of individuals, a change from one allocation to another that can make at least one individual better off without making any other individual worse off is called a «Pareto improvement». An allocation is defined as «Pareto efficient» or «Pareto optimal» when no further Pareto improvements can be made. Such an allocation is often called a «strong Pareto optimum (SPO)» by way of setting it apart from mere «weak Pareto optima» as defined below. Formally, a (strong/weak) Pareto optimum is a a maximal element for the partial order relation of Pareto improvement/strict Pareto improvement: it is an allocation such that no other allocation is «better» in the sense of the order relation. Pareto efficiency does not necessarily result in a socially desirable distribution of resources, as it makes no statement about equality or the overall well-being of a society

programmable algorithms) pretends to be a summary of empirically observed «rules of behaviour». In other words, one of the basic requirements for any eventual criticisms would be a demonstration – beyond any reasonable doubt – that the model specifications and its postulated logic do not correspond to the empirically observed facts of reality.

The choice of «units of time» as a common criterion for the system as a whole is in line with most commonly accepted practices in the management and control of the real economy in the real world of production and distribution of goods and services. In that respect the reader is invited to check the works of Jacques Lachnitt (1994) or Lawrence D. Miles (1989) .

As a result of this option, the model will show the consequences of the interplay between the various uses of «units of time» in general and of «working hours» in particular. All of this considering that a particular «number of hours» will always correspond to a particular «amount of value», which could then be expressed as units of money of any particular quantity of «units of gold» (for example...).

In that context then, the rate of profit will basically correspond to a ratio between a certain *«number of hours B»* (that which corresponds to the amount of profit in a particular iteration of the model) and a certain *«number of hours A»* (that which corresponds to the amount of total capital that was advanced at the beginning of that particular iteration of the model). As indicated before, when we refer to «time units» we are actually considering the binomial «time/energy».

Most biological and social models that are encountered in the literature resort to the same type of abstraction when expressing units of measurement. For example, the «predator-prey» model and its interactions with the environment, will include «units of energy» (consumption of grass) that would enable a certain ratio of growth of «rabbits» or «sheep», in the presence of foxes or wolves that also do require a certain amount of energy to also reproduce themselves.

In this section we consider the various algorithms that will have to be programmed in order to model and simulate the behaviour of the system as a whole based on the interactions of the various economic agents and what is supposed (but empirically verified) to happen in the various sites of activity.

The behaviour of the rate of profit

This is supposed to result in an emergent behaviour. Conventional analysis of this behaviour, even when it comes from some Marxian authors, seems to result in an *«indeterminate result».* Some of these Marxian authors also quote Marx himself and the listing that he provided of what he then called the «counter tendencies», leading some of these analysts to the conclusion that this issue is too complex to be treated in a conventional mathematical manner (Meek, 1967).

There will be four parameters to be considered: (1) the rate of investment, (b) the organic composition of capital, (c) the rate of surplus value and (d) the rate of increase in aggregated social productivity (both in capital goods industries and wage (or consumer) goods industries.

The algorithm should consider two basic types of input data: (e) the initial situation and (f) the assumptions regarding the above four parameters. In other words, apart from being able to specify an «initial situation», the analyst should be able to specify various alternatives of expected (or assumed) behaviour of the type «what if» the decision makers in the system decide «this» or «that». The parameters of these decisions («what if»...) are the ones specified above.

As for the initial situation, the analyst should be able to specify the following parameters: (e.1) the amount of *«constant capital»* (the available resources inherited from previous generations, what society has...); (e.2) the amount of *«variable capital»* (the available resources to «feed» and enable the reproduction of society in general and the working population in particular); (e.3) the number of hours per day (average) dedicated by all members of the working population, to the production (*latu sensu*) of goods and services to be transacted in the markets; and (e.4) the number of wage workers employed by the system.

As an option to be considered on a later stage of development, one might consider the following additional assumptions that would turn the model into a «more complex» exercise.

- To set limits to the number of employable workers (due, for example, to demographic constraints).
- To set limits to the number of hours that each employable worker is allowed to work (per period).

An Algorithm or Program to Compute the Evolving Behaviour of the Rate of Profit

Purpose: To evaluate the behaviour of the overall Rate of Profit, prevailing in the economy, during a time series and in an unregulated free market environment, under certain changing circumstances, such as:
- Constant or Increasing Rate of Investment
- Increasing Organic Composition of Capital, this increasing rate also being susceptible of change
- Variations in the increasing Rate of Surplus (or «rate of exploitation»)
- Increases in Productivity, both in «capital goods» industries and in «wage or consumer goods» industries.

Premises:
- The system assumes an indefinite number of workers available to enter the labour force and a constant number of total working hours.
- The system also assumes a system of constant real wages, these being expressed as a number of hours or «socially required work» (an overall social weighted average) that enables the workers an average and “socially acceptable” level of consumption.
- The system assumes that a percentage of the number of “units of time/energy” (expressed as “number of hours”) at the end of each iteration produced in excess of “units of time/energy” that were input at the start of that same iteration, will revert back to the system's next iteration in the form of “net investment” (a.k.a. as “flow back rate”).

The program should consider and treat two different types of input data:
A - Input data defining the situation of departure at any one point in time:
- Constant capital prevailing in that society at a particular moment expressed in terms “units of time/energy” stored-up *ab initio* or from previous generations.
- Variable capital prevailing in that society at that same particular moment, also expressed in terms of “units of time/energy” that will now be spent or used.
- Average number of hours per working day
- Number of workers availabe (or present) *ab initio* in that society or system.

B - Input data with the various variable assumptions for the algorithm to compute results:
- Rate of accumulation or flow of capital from period N as investment into period N+1 expressed as a percentage. As a matter of detail, this is to be considered as “investment net of depreciation”.
- Productivity increment into capital goods industry sectors.
- Productivity increment into wages goods industry sectors.

Optionally (for future instances of development of this “model”):
Assumptions about the initial and changing conditions may become more complex by adding a number of constraints on the model such as:
- Maximum top limit on the number of workers available in the system
- Setting a limit to a demographic growth, either biological (within the system) or migratory from outside the system (impossible on a world wide basis).
- A rate of growth for hours worked per day per worker (even if this is historically unrealistic).
- A rate of «negative growth» for hours worked per day per worker (the diminishing number of average work hours per day…) which could reflect what has been observed historically).

Notes on the computation within the model:

1. Display (or «Print») the initial situation after computing the following data items:
   a. Total capital: «Total-Capital» = «Constant-Capital» + «Variable-Capital»
   b. Ratio of «Constant-Capital» to «Variable-Capital», e.g. 1 / 4
   c. Organic Composition of Capital, e.g. 0.25
   d. Surplus Product: Number of Excess or Surplus Hours worked by the average worker over and above the socially minimum required for the society to «stand still» (that is, no

accumulation), times the number of workers in the system or «Excess x Workers».
e. Surplus Rate or «s / v»
f. Profit Rate or «s / c + v».

2. Skip one line (for clear presentation) and start displaying detail lines resulting from computations in the model, following the data in the assumptions input data set.

A - In principle, one data set of input (with the various variable assumptions) should cause the printing of one page (or the displaying of one screen) with the results in a table.
B - following the display (or printing out) of one page of, say, 30 years, the system should (as a matter of routine) convert the displayed table into a graphic with curves showing the evolution of each and every one the columns in the table.
C- Note that one set of assumptions or premises should cause the printing out of one page (or one screen) with results for those assumptions.

3. Details of computations – line after line (one per automatic iteration)

A - Compute new «Total-Capital» by multiplying previous «Total-Capital» (or the sum of «Constant-Capital» and «Variable-Capital») by the rate of investment. This we may call «flow-back».
B - Compute new Ratios by applying to each one the related or respective productivity increments
C - Obtain an Index of new Capital Structure by adding the two ratios (wage industry sectors and capital industry sectors)
D - Divide the new «Total-Capital» by this previously obtained Index and multiply the result by each one of those ratios.
E - This should give the new «Constant-Capital» and the new «Variable-Capital».
F - Subtract the new ratio for Variable-Capital from total average number of hours worked per day per worker.
G - This should give new «surplus-work» in hours per day.
H - Compute new number of workers that can be hired with New Variable Capital at New Daily Rate or «Variable / Daily Rate (or Minimum Hours Required) = Number of Workers»
I - Compute new «Surplus-Amount» by multiplying «Number-of-Workers» by «Surplus-Work», after determining this «Surplus-Work» by subtracting necessary or «Required» work from Total (or normal) working hours, thus:
J - Total or normal working hours – Minimum hours required = Surplus Hours of work
K - Number of workers x Surplus Hours of Work = Surplus Amount
L - Compute new «Organic Composition of Capital» by dividing new «Constant-Capital» by «Variable-Capital»
M - Compute new «Rate-of-Exploitation» by dividing «Surplus-Amount» by «Total-Capital».
N - Compute new «Rate-of-Profit» by dividing «Surplus-Amount» by «Total-Capital».

4. Display detail line with results of computation for period N+1. Immediately afterwards, set N+1 back to N and go to the first instruction under paragraph 3.

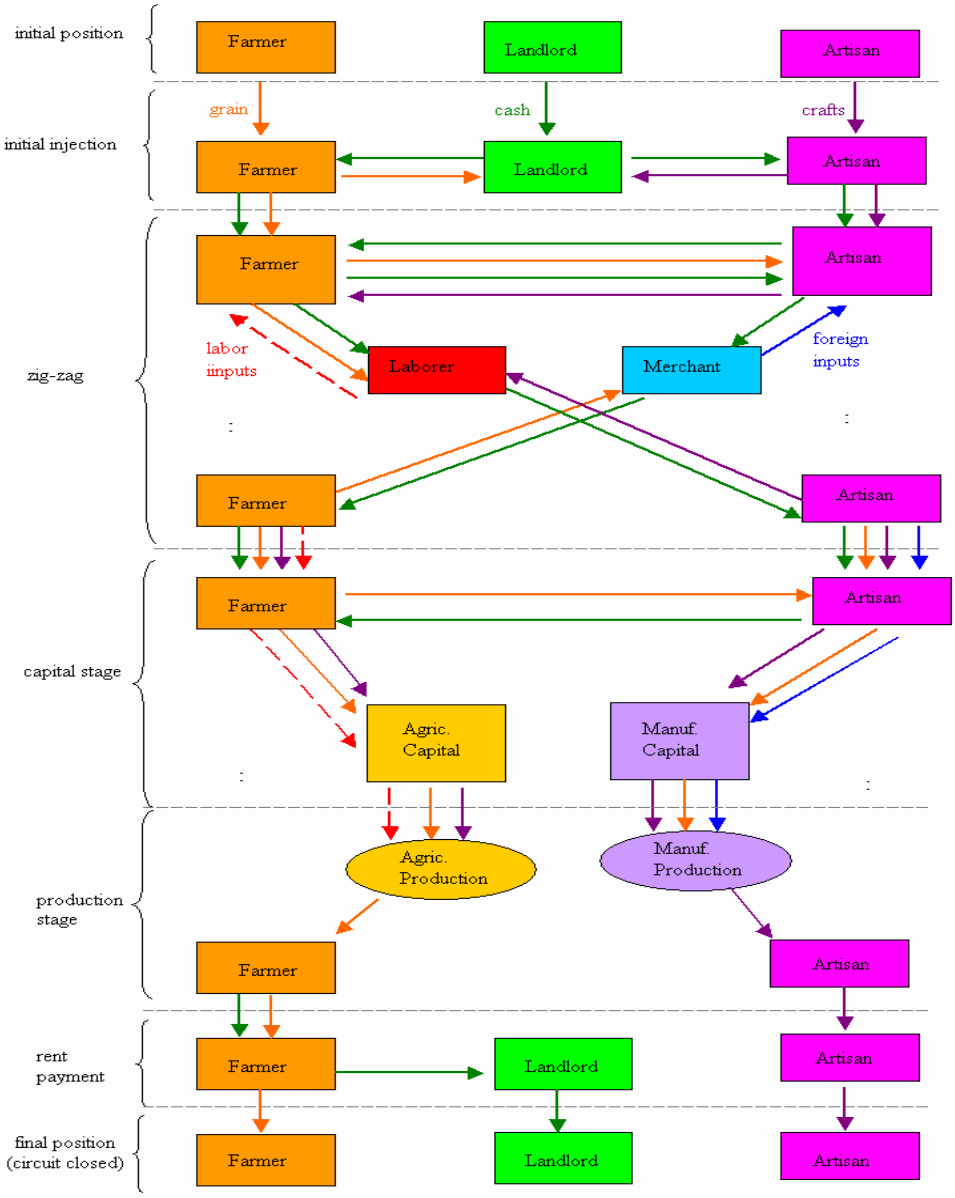
5. At the end of 30 lines or periods of time (30 years, for example. It could be any number decided in advance), printout a «comments» line indicating the contents and/or description of assumptions or premises.

6. Go to next set of different assumptions (to be input by the observer) and then proceed to a new page or scenario.

7. The Ideal Modelling Scenario

> *«By seeing only nodes and links, we were privileged to observe the architecture of complexity. By distancing ourselves from the particulars, we glimpsed the universal organizing principles behind these complex systems»* - Albertl-László Barabási: «Linked»

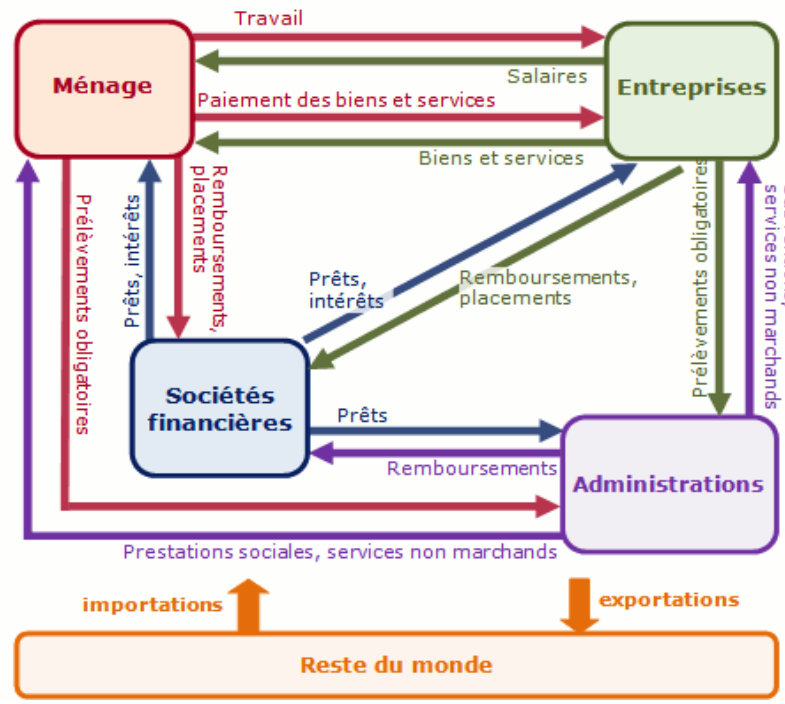
Most modelling of the economic system, starts from a visual picture of the economic circuits that are considered most relevant. In a certain sense they all go back to the original *Tableau Économique* by François Quesnay[54] and the Physiocrats of the late XVIII century. This representation of the economy is particularly adapted to computer simulation and visualisation, and as a result, such a modelling was only revived already in the second half of the XX century by Wassily Leontief, when computers became generally available, who was awarded a Nobel Prize for his work with Input-Output Tables.



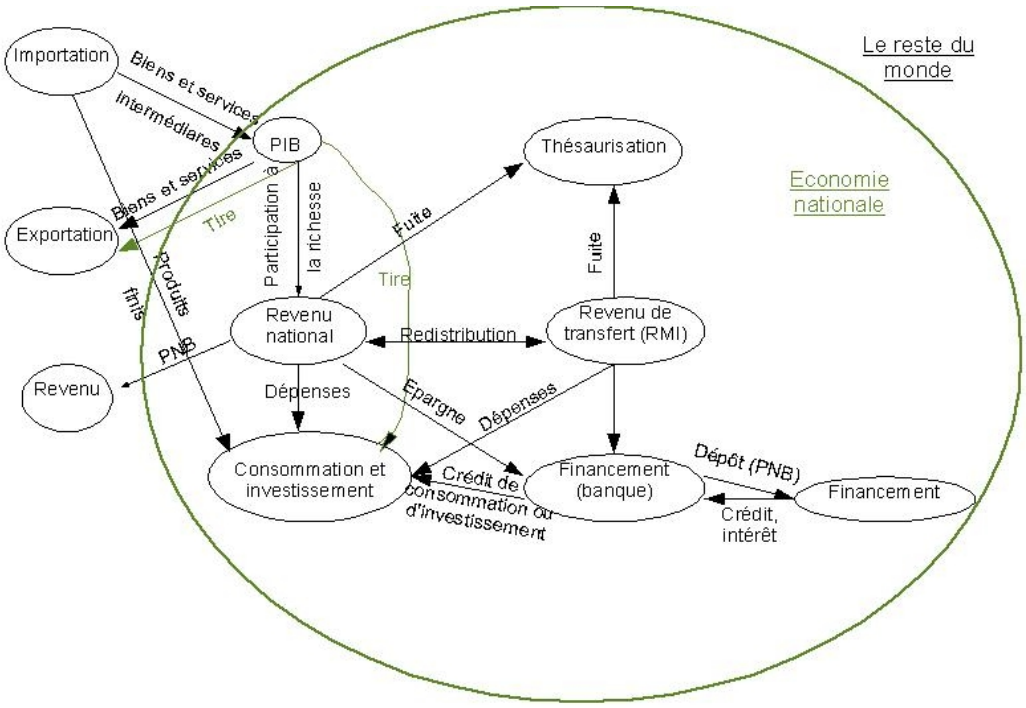
[54] http://homepage.newschool.edu/het/essays/youth/tableausum.htm

Before presenting what is envisaged here as an «ideal modelling scenario», and in order to better understand the differences and specificities of the model being proposed, and just for illustrative purposes, it is necessary to present some of the currently available graphic models, all of them presenting in slightly modified form the idea of a circular flow of goods, services and money.

Conventional Models of Economic Flows



http://www.maxicours.com/img/2/3/1/9/231967.gif



http://www.daskoo.org/upload/images/le-circuit-economique-selon-les-operations-realisees-par-les-agents-economiques.jpg

In this context, the graphic proposed in this paper – and the set of algorithms that should make it up – has three fundamental «innovations»: (1) Firstly, on the one hand, it stresses the «destination and future role» of the money that corresponds to wealth created, *but not consumed nor invested.* This is partially (but fundamentally) represented by the node «pension funds». (2) Secondly, on the other hand, it shows the role played by financial markets as a number of financial flows converge upon the node named here as «stock exchanges», where they play different roles, in accordance with the different stages in the evolution of the system. (3) Finally, it ignores (in the sense that it leaves aside) the existence of a node that would represent «the rest of the world». For the time being, at least, humanity does not yet have colonies in other planets with whom to exchange goods and services or, in systems theory terms, with whom to exchange «matter», «energy» and «information». That being the case, all the wealth that has been created but not consumed nor invested, *must flow back into the system,* re-entering that circular flow, one way or another.

The ideal modelling tool that should result from this exercise would be able to provide a simulation environment very similar to the models presented in the publicly available *Netlogo* application system, namely the ones presented under the rubric «Models Library - Wealth Distribution»[55]. This model simulates the distribution of wealth. It follows the idea that *«the rich get richer and the poor get poorer»,* which is a familiar saying that expresses the measure of inequity in the distribution of wealth. In that simulation, we see Pareto's law at work, in which there are a large number of «poor» or red people, fewer «middle class» or green people, and still fewer «rich» or blue people.

That particular modelling exercise is a simple example illustrating the availability of modelling tools and the possible redundancy of «re-inventing the wheel», so to speak, in matters related to «social and economic modelling». From the point of view of scientific advance, it seems to be much more interesting to build upon already existing knowledge, than to try and re-invent things anew.

At this stage, and considering the state of the art in economic modelling, what really matters is the further development of already existing tools, provided that those further developments do add something new and meaningful to the knowledge and understanding of social and economic reality.

The literature abounds with the existence of various graphics, all of them representing the circular flows of goods, services and money, among the various economic entities. They all represent «families», «public administration», «business firms», «financial institutions» and the «rest of the world». Following in the footsteps of the Austrian School and its «evenly rotating economy»[56], these graphics suggest – even if unwillingly – the idea of an harmonious and static system, permanently in equilibrium. It also fosters the idea of compartmentalized «national economies», as if capitalism was not an historical phenomenon of world-wide dimension.

Another example of model building, written in the Java programming language, of what is already available to experimenters who may want to «play with» and change or enhance specifications could be the work of Lars Olert («Economic Circular Flows»)[57].

Perhaps the most defining characteristic of the model being envisaged here is its descriptive character. In a recent book[58] on the subject of modelling and simulation, authors Edmonds and Moss propose a supposedly new approach the slogan «Keep it Descriptive, Stupid» (or *KIDS*), that encapsulates a trend in increasingly descriptive agent-based social simulation. This is supposed to be in contrast with the well known jargon of management praxis, «Keep It Simple and

[55] Copyright 1998 Uri Wilensky. All rights reserved. The full copyright notice is in the Information tab. See http://ccl.northwestern.edu/netlogo/models/WealthDistribution

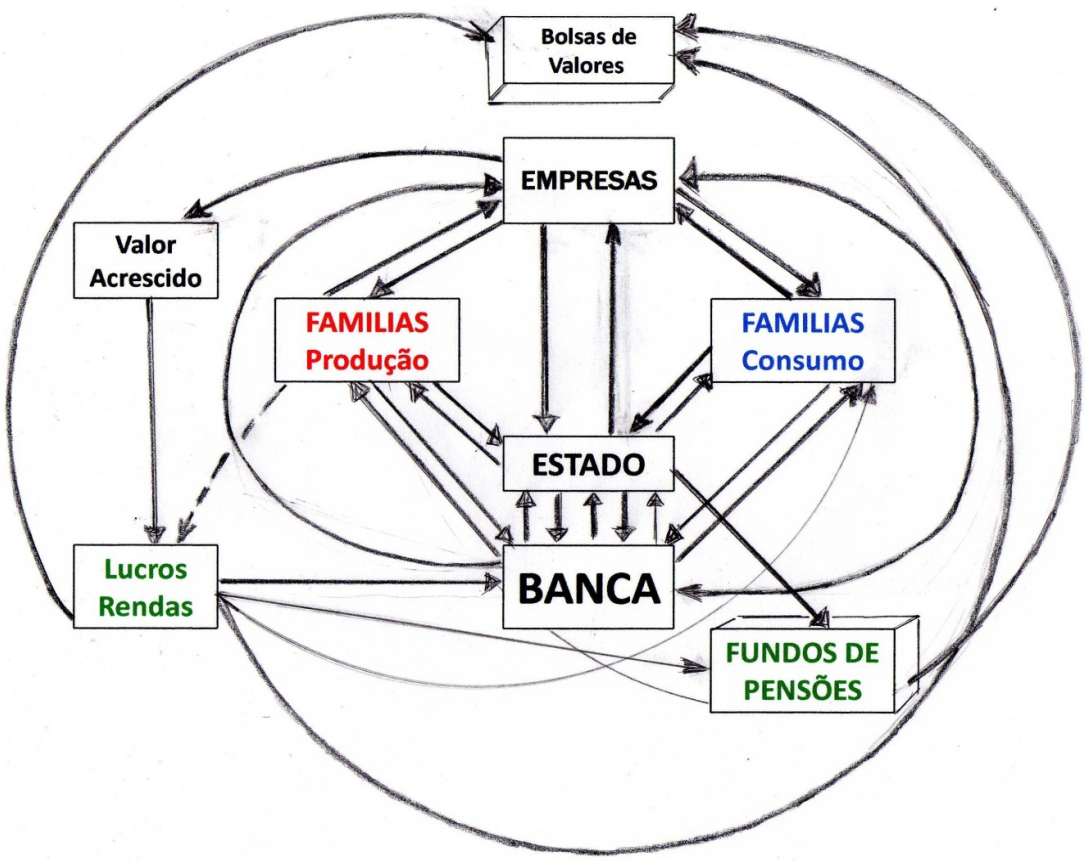
[56] According to the glossary of the Ludwig von Mises Institute, the «evenly rotating economy» is *«an imaginary economy in which all transactions and physical conditions are repeated without change in each similar cycle of time. Everything is imagined to continue exactly as before, including all human ideas and goals. Under such fictitious constant repetitive conditions, there can be no net change in any supply or demand and therefore there cannot be any changes in prices. The evenly rotating economy is a helpful device for studying the logical effects produced by the introduction of particular individual changes.»* Available at http://mises.org/easier/E.asp

[57] http://home.swipnet.se/~w-61407/english.htm

[58] Edmonds, B. and Moss, S. (2005) «From KISS to KIDS – an 'anti-simplistic' modelling approach», in P. Davidsson et al. (Eds.): Multi Agent Based Simulation 2004. Springer, *Lecture Notes in Artificial Intelligence*, **3415**:130–144.

Stupid» (or *KISS*). This newly suggested approach of *KIDS* requires that one *«starts with the simulation model that relates to the target phenomena in the most straight-forward way possible, taking into account the widest possible range of evidence, including anecdotal accounts and expert opinion».* This is supposed to contrast with the *KISS* approach, in which one is supposed to start from the simplest possible model and then only move to a more complex model if one is forced to do it. In the words of Edmonds and Moss (2005):

> *«Equation-based and statistical modelling have a relatively long history and are relatively well developed. Simulation modelling has a much shorter history and its methodology is less well developed. In many (but not all) fields academics are still feeling their way as to how and when to use simulation modelling. Further, just as there are many branches of mathematics, there are many kinds of simulation modelling. Within each domain it takes time to develop ways in which equations can be usefully applied, what sort of 'leverage' it can provide one, what the pitfalls are and how to go about it.*
> *It is thus an open question whether a simulation models usefully inform one about some phenomena or whether they only give the comforting impression of doing so; simulation model is not a panacea but just another tool. I hope that in this chapter I will be able to sketch some guidelines to aid the useful use of simulation modelling and avoid the deceptive uses.*[59]*»*



The proposed graphical representation, with emphasis on «Stock Exchanges» and «Pension Funds», both as «arenas» and «agents»

With this ideal model displaying a circular flow on a «window» in a computer screen, the flows represented by pointed arrows should be seen as moving particles (dots or micro arrows...) whose

[59] http://cfpm.org/cpmrep118.html

relative dimension and speed should be proportional to the size of such flows, with this size being representative of «number of hours» of socially productive work. Since «business firms» have long been recognised as «primary places of accumulation», the size of «accumulated wealth» should be seen to be on the increase. This could be represented by a growing number of dots representing «units of time» equivalents.

As a matter of fact – and in accordance with historically observed data – the overall screen image of the above circuit could itself be seen as growing, as the overall, global, economy has been growing, both in relative and in absolute terms, as well as in terms of population and wealth. What the model, or simulation that is thus enabled, should also be able to show, would be the eventual differences in growth and distribution of wealth, going into different groups of economic agents.

In a very literal sense, what we envisage is that «behind» each one of those squares, representing different groups of economic agents, there will be algorithms representing their leading and determining motivations, often in contradiction with each other (a zero sum game, if you will[60]...). Most of the algorithms that express «supply and demand» and «market clearing» conditions (among others like «technology dispersion») are already available. *The important innovation proposed here is merely the inclusion of an algorithm that expresses the behaviour of the rate of profit over a period of a number of years.* The ideal modelling and simulation system should then allow the experimenter to play with a number of variables, from the rate of investment (what percentage of surplus produced in iteration *n* is applied as growth of both parcels of capital in iteration *n+1*) to the resulting growth in productivity, going through the variations in tax rates that force redistribution of surplus produced and the blockage (or an increase in the costs of transaction...) of the flows from «pensions funds» to «stock exchanges». These experiments should be enabled through the availability of windows where the experimenter introduces whatever quantities he or she deems to make sense, and then «see what happens».

[60] A zero sum game only in the sense that the growth portion itself, of the economic cake, can only be divided in so many ways. If some economic agents get a certain percentage of it, the others cannot have more than what remains of it. Even if, in the end, all economic agents end up better of. Except that some will be 10% better off, whereas others may be only 5% better off....

8. Some minor contributions for an enventual actual modelling effort

> *«Great things are not done by impulse, but by a series of small things brought together»*
> Vincent Van Gogh

> *«The fractal forms of communication in this book are nested inside each other. A simple sentence can contain all of my thesis, and the elements of a chapter enrich a proposal already discussed in another context.»* - Joel de Rosnay - L'Homme Symbiotique

In this section are listed several behavioural features and characteristics of both the Agents and the Environment, for a future model, conceived as a more detailed development of the model whose results are being presented here. As seems to be usual in modelling efforts there are some basic parameters, these being «initial wealth» and «increments of wealth», both expressed as equivalents to the *«average number of social working hours per unit of wealth».* In this context, the «rate of profit» is the ratio between an increment in the marketable wealth and the amount of wealth that was advanced, at the beginning of any iteration, in order to obtain that increment.
It should also be noted that most of these «different» characteristics can be – and are routinely – reduced to some basic and fundamental «groups». The heterogeneity arises from the fact that these groups end up pursuing conflicting intermediate goals, in order to achieve their basic common goal: that of maximizing each one's own «utility function».
On the other hand, it should further be noted that most of these functions or characteristics have already been programmed in some form using object oriented programming languages. What has not been programmed – to the knowledge of this author – is a particular behavioural characteristic of the business firms representatives (owners, directors, executives...), whenever the feed back from the system alerts them for one of two emergent phenomena: the progressive exhaustion of opportunities for profitable investment and/or the levelling off of the rate of profit. The signals for these two phenomena, from a modelling point of view, will be the piling up of unsold stocks or the reduction in available purchasing power. This being noted, the variety of economic agents will only serve the purpose of possibly illustrating conflicts of local interests among the various types of agents belonging to the same super class.
The capitalist system is here being defined as a social system of production and distribution of goods and services, whereby a group of economic agents are the *predominant* legal owners of production goods (they can use these production goods at their private independent discretion), whereas another group of economic agents have as their exclusive source of income their own personal work capability. The system allows the existence of other types of economic agents, that may influence the behaviour of these *two fundamental groups* but, in the final analysis, it is the coexistence of these two groups, and their on going struggles and the logical contradictions that result from their postulated and empirically observed decisions and actions, that qualifies the system as being a capitalist system.
The transit of particular individuals between these two super-classes does not invalidate the existence and qualification of the system as such. It should further be noticed that, in any case, the conventional postulates of mainstream economics, are observed, in the sense that the emergence of any and eventual «strange» phenomena in the simulation, will have to be the result of processing that is based on conventional wisdom, which in turn is based on empirical observation of real economic agents acting in the real world economy. Also, and specifically, the characteristic of «Individual Optimality»[61] is common to all agents and drives their decisions and courses of action.
In any case we must be fully aware of the theoretical distinctions between «social classes» (and the role played there by «individual agents») and «economic classes». In the model that is suggested here for future development, and whose first tentative instance is being presented, we

[61] All demands of individual agents (consumers and producers...) *«are optimal demands conditional on consumer expected prices and consumer expected dividends, and all firm supplies are optimal supplies conditional on firm expected prices» (Tesfatsion, 2005).*

intend to try and attempt to merge these two perspectives, following in the foot steps of Wright (1989). In that context one has to provide for various alternatives for the programming of a weighted decision making framework, that might enable experimenters «play with different 'what if' scenarios».

The Agents Themselves

The language used in this description will be somekinf of an hybrid between «systems» language and the jargon of social scientists.

Business Firms		
	Owners	Given some initial endowment they strive to maximize their own revenue («number of units of working hours» equivalents) by contracting «directors» and «executives» to actually run the operations of their enterprises.
	Directors	Represent «Owners», supervise »Executives« and get paid a portion of »increments«. Do not participate in control of operations. After each iteration do not spend a portion of their »increments« and try to invest that portion through «money managers».
	Executives	Sell their labour power in exchange for maximum revenue based on achievement of results. Salaries and Bonuses are based on their own achievement of maximizing profits, that is, «maximum increment of wealth» per business firm. They decide upon investment (hire of workers and professionals) based on the result of two assessments: (1) levelling off of sales volume as indicated by a levelling off of purchasing power in the hands of «Families as Consumers». (2) the result of the following computation: «compare rate of profit at the end of this iteration with rate of profit at the end of previous iteration. If equal or higher then devote x% of profit to hire of new workers and professionals and to purchase from other business firms». This split being a parameter subject to experimenter discretion. The rate of profit for each and every iteration («do while»...) takes the following format: *«rate of profit equals the ratio between increment obtained and payments to workers, divided by the ratio between amount of production goods used up during the production period and the amount of payment to workers, plus one»*
	Farmers	Given some initial endowment (land and utensils) they employ workers and strive to maximize their own revenue («number of units of working hours» equivalents), by selling their produce to «Industrialists». They try to minimize expenses with machinery bought from «Industrialists» and their payment to «Workers». They are supposed to maximize the portion of their income that goes into the next iteration («investment»), as long as the rate of profit is at least equal to the one of the last iteration.
	Industrialists	Given some initial endowment (factories, buildings, machineries and utensils) they employ managers and workers and strive to maximize their own revenue («number of units of working hours» equivalents), by selling their produce to «Farmers», «Traders» and «Families». They try to minimize expenses with machinery bought from other «Industrialists» and their payment to «Workers». They are supposed to maximize the portion of their income that goes into the next iteration («investment»), as long as the rate of profit is at least equal to

		the one of the last iteration.
Families, both as producers and consumers		
	Workers	Sell their labour in exchange for an amount of value (as equivalents to «working hours») that is enough to maintain same level as before. In the particular case of «workers-as-employees», without any other source of income but the sale of their work capability, the critical issue is the fact that mainstream economics does not recognise the idea or concept that these economic agents produce more than they consume[62]. Their employment will depend on the «variable capital» available as a result of decision made by agensts belonging to the «business firms» class.
	fessionals	Sell their labour in exchange for an amount of value (as equivalents to «working hours») that is enough to maintain their same level as before. Their «survival» will depend on the existence of enough «surplus» to use their services.
	Peasants	Self-sufficient. Sell their own produced goods in exchange for the equivalent of goods and services they do not produce.
	Artisans	Sell their own produced goods and or services in exchange for the equivalent of goods and services they do not produce.
Public Officials		
All the agents in this class will try to get a bigger slice of the surplus generated in each iteration at the expense of both «business firms» and «workers» (the amount of surplus value generated that is supposed to go to «variable capital».		
	Executives	Try (sometimes succeed) to «take a bigger slice» of the surplus cake. Tend to favour business owners (expressed as a % of decisions). A parameter that may be left to the experimenter.
	Civil Servants	Take a percentage of profits and of «variable capital» and provide for increases in productivity (through provision of services) and provide for additions to (total aggregate) «constant capital» (through the provision of infrastructures to society). Try (sometimes succeed) to «take a bigger slice» of the surplus cake. Also a parameter that may be left to the experimenter.
	Professionals and Scientists	Try (sometimes succeed) to «take a bigger slice» of the surplus cake. Their services provide for increases in productivity (through provision of services) and provide for additions to (total aggregate) «constant capital» (through the provision of infrastructures to society)
Bankers, Insurers and Money Managers		
	Executives	Collect unspent surplus produced («savings»), and through that device are able to «create» money. This is supposed to be kept and «invested». Apart from the provision of services, they try to appropriate a slice of the surplus cake and re-route this «money» into the purchase of «capital». This they do through the mechanisms of stock exchanges. As they observe the evolution of the rate of profit, they decide upon investment (the purchase of shares) based on the result of two assessments: (1) levelling off of sales volume as indicated by a levelling off of purchasing power in the hands of «Families as Consumers».

[62] It t is interesting to note that the modern «inventor» of the tax concept of «value added» (now commonplace in most industrialised countries), was not an economist by training but an engineer...

		(2) the result of the following computation: «compare rate of profit at the end of this iteration with rate of profit at the end of previous iteration». If equal or higher then devote x% of profit to hire of new workers and professionals and to purchase from other business firms. This split being a parameter subject to experimenter discretion.
	Employees	Sell their labour in exchange for an amount of value (as equivalents to «working hours») that is enough to maintain same level as before. In the particular case of «workers-as-employees», without any other source of income but the sale of their work capability, the critical issue is the fact that mainstream economics does not recognise the idea or concept that these economic agents produce more than they consume.
	Brokers	Act as mediators between buyers and sellers (mostly of shares in business firms). Collect a fraction of the surplus being produced.
	Pension Funds Managers	Collect monies from «workers», «employees», «business firms» and «government officials». As they are entrusted with the upkeep of the values deposited with them they strive to maximise their appropriation of shares in business firms.

9. Annexes - Including references to own currently existing model

9.1 - From the Literature

In this final section are included some extracts from the literature that are believed to be interesting and relevant for future reference and expansion. Attention is specially drawn to the already current availability of «computerised» knowledge in the field of models to simulate the reality of economic phenomena. What seems to be missing from some of these models is «simply» the integration of an algorithm to compute the evolution, and the resulting effects, of the rate of profit.

First are included some references to, and short descriptions of, already developed and freely available tools. Next there is a more detailed reference to, and extracts thereof, a model developed by Prof. Leigh Testafatsion, regarding a simple market economy of «hash and beans».

The Tools of Experimentation» and «Research»

A very brief and sketchy listing of currently available «models» that have already been designed and that are available to anyone interested in «playing» with various parameters, on what might be termed »what if» scenarios. Some of these tools could be expanded upon and result in effective tools of analysis of the real word economies, *if only their theoretical assumptions were in accord with observed reality.* As already noted elsewhere, the basic problem of current economic analysis and simulation is that they are based on a profoundly wrong paradigm: that of neoclassical marginalist school that ignores (has pushed under the rug, so to speak) the original contributions of classical political economy, as improved upon by the writings of Karl Marx. Most particularly the issues of «price» and «value» (as briefly discussed in the section dedicated to the «measurement problem») and the tendential behaviour of the rate of profit.

Bank Reserves Algorithm

A program or algorithm that models the process of money creation in an economy through banking institutions, based on the fact that most of the money in the banks does not have to stand still «doing nothing». Based on some basic assumptions about the level of reserves and prudential rules of management, observers will interact with the system by changing certain parameters, such as rates of savings versus spending and borrowing...

Based on those basic assumptions, the «agents» in the model will interact with each other simulating business transactions by selling and buying «places» in the model space. This is presumed to be equivalent to most transactions where people buy and sell the equivalent of some inherited or acquired property.

The algorithm may also contemplate parameters such such as depreciation of money value and rate of monetary expansion. All of these parameters being based on individual. agents decisions. Based on certain initial allowances (coming in from inherited receipts, for example...) the algorithm then will compute «Money Total», «Savings Total», «Bank Loans», «Cash in Wallets Total», «Bank Reserves» and «Loans Total».

Cash Flow Algorithm

This algorithm is intended as an extension to the previous one on Bank Reserves and considers Savings Total, «Wallets Total» (that is, «Current or Checking Accounts» plus bank notes...), «Loans Total» and «Money Total». It is supposed to model the creation of money through a private banking system. In the context of Agents Based Modelling, «private banking» merely means that decisions are taken by individual bank managers and bank customers, not by a central banking authority. Strictly speaking, and from a systemic point of view, all the banks in the «private banking system» could be State owned, as long as the rules of appointment of their executives were logically equivalent to the rules governing the «principal – agent» relationship of the principal-agent or the «agency dilemma theory», with the fundamental (*afterwards...*) difference of banking profits flowing back into the coffers of the State rather than into the coffers of some specific private individuals.

In any case, this algorithm stil provides for a central bank authority (the experimenter...) that will set limits to the reserve ratio as the key determiner of how much money is created in the system.

Wealth Distribution

This algorithm will consider a certain number of people in any given self contained population. The algorithm will take into account the reproduction rate, life expectancy and the percentage of «best land» (or degree of concentration of wealth resources) as a starting or given situation. It will also consider the

productivity prevailing in the system and its rate of growth.
As a result of its intended simulation, this algorithm will then show the Pareto «law of distribution» at work in the system. It does so, from a non-conventional (or heterodox) perspective but still showing or indicating that the Marxian «the rich get richer and the poor get poorer» principle, is a natural feature of the economic system. It explains the mechanism, does not explain why but, in any case, that is nor the purpose of a simulation model.
The algorithm shows the result of its simulations by means of the well known «Lorenz Curve».

The Hash and Beans Economy

In her extensive work on «Agents-based Computational Economics», Leigh Tesfatsion has mainly approached current (and conventional) wisdom on economic analysis from a «bottom-up» point of view, rather than de supposedly «top-down», analytical, approach of more conventional economics. As a result of that, the results obtained are in line with the results obtained from a traditional Smithian «invisible hand» type of approach.
She starts by considering a Walrasian equilibrium modelling of a simple one-period economy with two production sectors, where the economy is populated by a finite number of profit-seeking firms producing hash, a finite number of profit-seeking firms producing beans, and a finite number of consumers who derive utility from the consumption of hash and beans.
Each firm has a total cost function expressing its production costs as a function of its output level. Each consumer is endowed with an equal ownership share in each firm as well as an exogenous money income. Leigh Tesfatsion then goes on to a definition of a set of model conditions that are to be observed (postulated), such as
(a) Individual Optimality: *At* e*, all consumer demands are optimal demands conditional on consumer expected prices and consumer expected dividends, and all firm supplies are optimal supplies conditional on firm expected prices.*
(b) Correct Expectations: *At* e, *all expected prices coincide with actual prices, and all expected dividends coincide with actual dividends calculated as consumer shares of actual firm profits.*
(c) Market Clearing: *At e, aggregate supply is greater than or equal to aggregate demand in both the market for hash and the market for beans.*
(d) Walras' Law (Strong Form): *At e*, *the total value of excess supply is zero; i.e., the total value of all demands for hash and beans equals the total value of all supplies of hash and beans.*

After a number of details and considerations, to take into account a number of premises of current neoclassical approaches, the author then moves on to explain how the theoretical construct of that mainstream approach (the «Walrasian Auctioneer») is replaced by another theoretical construct, that of *«agent-driven procurement processes».*
This is then followed by the specifications of a number of rules regarding the postulated behaviour of agents and their encounters, namely:
- Terms of Trade: *Firms must determine how their price and production levels will be set.*
- Seller-Buyer Matching: *Firms and consumers must engage in a matching process that puts potential sellers in contact with potential buyers.*
- Rationing: *Firms and consumers must have procedures in place to handle excess demands or supplies arising from the matching process.*
- Trade: *Firms and consumers must carry out actual trades.*
- Settlement: *Firms and consumers must settle their payment obligations.*
- Shake-Out: *Firms that become insolvent and consumers who fail to satisfy their subsistence* consumption needs must exit the economy.

The author goes presenting an outline of what she calls the «ACE Trading World»

> *«Consider an economy that runs during periods T = 0, 1, . . . , TMax. At the beginning of the initial period T = 0 the economy is populated by a finite number of profit-seeking hash firms, a finite number of profit-seeking bean firms, and a finite number of consumers who derive utility from the consumption of hash and beans.*
> *Each firm in period* T = 0 *starts with a non-negative amount of money and a positive production capacity (size). Each firm has a total cost function that includes amortized fixed costs proportional to its current capacity. Each firm knows the number of hash firms, bean firms, and*

consumers currently in the economy, and each firm knows that hash and beans are perishable goods that last at most one period. However, no firm has prior knowledge regarding the income levels and utility functions of the consumers or the cost functions and capacities of other firms. Explicit collusion among firms is prohibited by antitrust laws.

Each consumer in period T = 0 *has a lifetime money endowment profile and a utility function measuring preferences and subsistence needs for hash and beans consumption in each period. Each consumer is also a shareholder who owns an equal fraction of each hash and bean firm. The income of each consumer at the beginning of period* T = 0 *is entirely determined by her money endowment. At the beginning of each subsequent period, each consumer's income is determined in part by her money endowment, in part by her savings from previous periods, and in part by her newly received dividend payments from firms.*

At the beginning of each period T 0, *each firm selects a* supply offer *consisting of a production level and a unit price. Each firm uses a learning method to make this selection, conditional on its profit history and its cost attributes. The basic question posed is as follows:*

«Given I have earned particular profits in past periods using particular selected supply offers, how should this affect my selection of a supply offer in the current period? Each firm immediately posts its selected supply offer in an attempt to attract consumers. This posting is carried out simultaneously by all firms, so that no firm has a strategic advantage through asymmetric information.»

At the beginning of each period T 0, each consumer costlessly acquires complete information about the firms' supply offers as soon as they are posted. Consumers then attempt to ensure their survival and happiness by engaging in a price discovery process *consisting of successive rounds. During each round, the following sequence of activities is carried out. First, any consumer unable to cover her currently unmet subsistence needs at the currently lowest posted prices immediately exits the price discovery process. Each remaining consumer determines her utility-maximizing demands for hash and beans conditional on her currently unspent income, her currently unmet subsistence needs, and the currently lowest posted hash and bean prices. She then submits her demands to the firms that have posted these lowest prices. Next, the firms receiving these demands attempt to satisfy them, applying if necessary a* rationing method. *Consumers rationed below subsistence need for one of the goods can adjust downward their demand for the remaining good to preserve income for future rounds. Finally, actual trades take place, which concludes the round. Any*

firms with unsold goods and any rationed consumers with unspent income then proceed into the next round, and the process repeats.

This period-T price-discovery process comes to a halt either when all firms are stocked out or when the unspent income levels of all consumers still participating in the process have been reduced to zero. Consumers who exit or finish this process with positive unmet subsistence needs die at the end of period T. Their unspent money holdings (if any) are then lost to the economy, but their stock shares are distributed equally among all remaining (alive) consumers at the beginning of period T + 1. This stock share redistribution method *ensures that each alive consumer continues to own an equal share of each firm. At the*

end of each period T 0, each firm calculates its period-T profits. A firm incurs positive (negative) profits if it sells (does not sell) enough output at a sufficiently high price to cover its total costs, including its fixed costs. Each firm then calculates its period-T net worth (total assets minus total liabilities). If a firm finds it does not have a positive net worth, it is declared effectively insolvent *and it must exit the economy. Otherwise, the firm applies a state-conditioned profit allocation method to determine how its period-T profits (positive or negative) should be allocated between money (dis)savings, capacity (dis)investment, and (non-negative) dividend payments to its shareholders.*

In summary, the ACE Trading World incorporates several key structural attributes, institutional arrangements, and behavioural methods whose specification could critically affect model outcomes. These include: initial numbers and capacities of hash and bean firms; initial number of consumers; initial firm money holdings; consumer money endowment profiles; initial firm cost functions; consumer utility functions; market price discovery and trading protocols; world protocols regarding stock ownership, firm collusion, and firm insolvency; firm learning methods; firm rationing methods; and firm profit allocation methods.

The degree to which the ACE Trading World is capable of self-coordination can be experimentally examined by studying the impact of changes in these specifications on micro

behaviours, interaction patterns, and global regularities. For example, as detailed in Cook and Tesfatsion (2006), the ACE Trading World is being implemented as a computational laboratory with a graphical user interface. This implementation will permit users to explore systematically the effects of alternative specifications, and to visualize these effects through various types of run-time displays.

After a number of descriptive details and consideration on the definition of equilibrium[63], where the Leigh Tesfatsion seems to ignore all the classical literature on the issue of a permanent non equilibrium prevailing (as in the nature of things) in the capitalist economy, the author offers us a set of Java programming language specifications, regarding the modelling of her *«Hash and Beans»* market economy. This seems to be an excellent example of publicly available (and «computer-based») knowledge, to be built upon by the provision of additional and possibly innovative partial algorithms, such as the one proposed by the author of this «paper».

9.2 – The Results of a Simulation

The Table that is presented next in the text is the result of a provisional simulation restricted to a very short number of variables, namely:

- «total aggregate capital»
- «total variable capital»
- «total constant capital»
- «ratio of improvement in social aggregate productivity»
- «ratio of constant capital to variable capital», a.k.a. «organic composition» a.k.a. «***K***»
- «ratio between "variable capital" and "surplus produced"», a.k.a. «rate of exploitation», a.k.a. «***e***»
- «employment» or «number of needed/employable workers»
- «rate of profit» a.k.a. «***r%***»

The details of the algorithm that produces these results were presented at the end of Section 6.

As indicated then, the program itself enables two types of input data:

- Input data defining the situation of departure at any one point in time:
    - Constant capital prevailing in that society at a particular moment
    - Variable capital prevailing in that society at that same particular moment
    - Average number of hours per working day
    - Number of workers in that society or system
- Input data with the various variable assumptions for the algorithm to compute results:
    - Rate of accumulation or flow of capital from period N as investment into period N+1 expressed as percentage. As a matter of detail, this is to be considered as investment net of depreciation
    - Productivity increment into capital goods industry sectors
    - Productivity increment into wages goods industry sectors

Even though this model has been developed[64] to study the sequential behaviour of a specific variable – that of the «systemic» rate of profit – the results upon other variables are shown, and most particularly that of «number of employable workers».

As can be seen, the rate of profit goes up at the beginning of the iterations, as predicted by the Okishio Theorem, *but then levels off and starts to decrease,* which goes against conventional and politically correct theory.

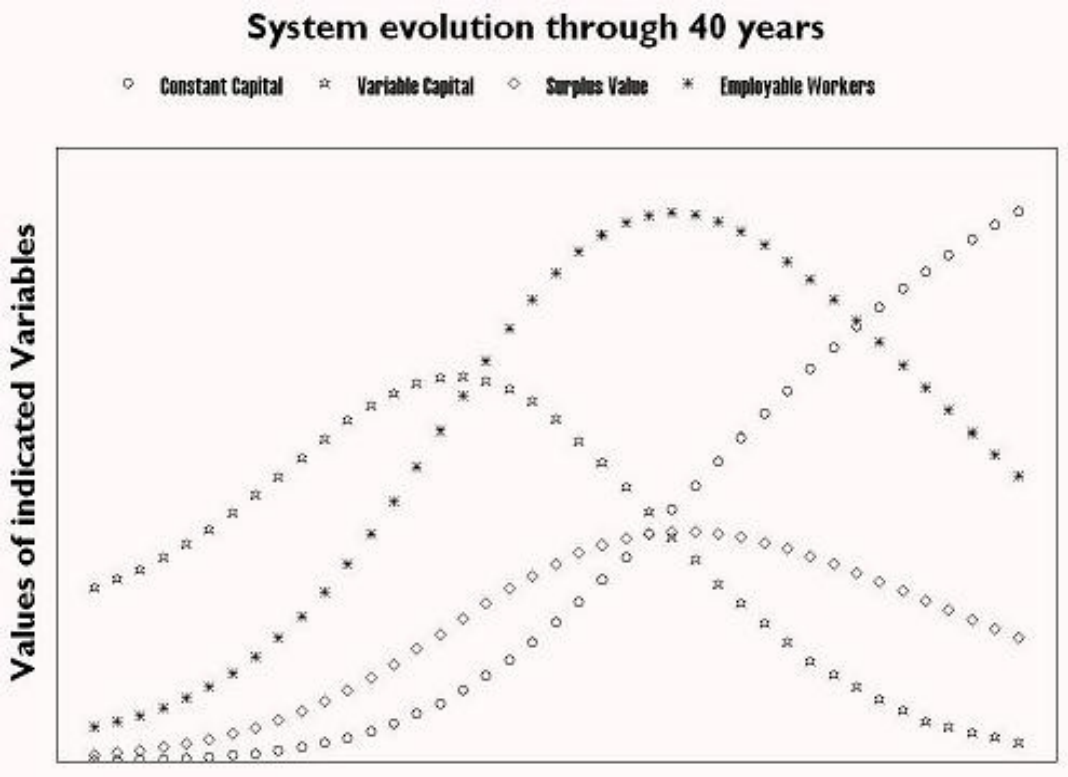
What may also be observed is that there is a delay in what concerns the evolution in the number of

[63] *«Definitions of equilibrium appearing in scientific discourse differ in particulars depending on the system under study. All such definitions, however, would appear to embody the following core idea: a system is in equilibrium if all influences acting on the system offset each other so that the system is in an unchanging condition. It is important to note the absence in this core definition of any conception of uniqueness, optimality, or stability (robustness) with regard to external system disturbances. Once the existence of an equilibrium has been established, one can further explore the particular nature of this equilibrium. Is it unique? Does it exhibit optimality properties in any sense? Is it locally stable with respect to displacements confined to some neighbourhood of the equilibrium? If so, what can be said about the size and shape of this «basin of attraction»?...*

[64] Using «RPG II - Report Program Generator» in an IBM System/3 computer, in sporadic manner during the period of 1979-1980. The results were then presented to the 5th Congress of the Portuguese Informatics Association.

employable workers. The level of employment starts to decrease only after a number of iterations and this seems to be due to the fact that increments if productivity will enable the availability of a sufficiently large amount of surplus that may be re-directed to «variable capital». But then, this amount also levels off and starts to decrease, originating in its turn a levelling off and decrease of employable workers. That is when the systemic crisis sets in.
This exercise was based on the contents of a chapter of the book by Ronald Meek, *«Economics, Ideology and Other Essays»* (1967).

	Ratios			Amounts			Number Workers	Ratios	
C	c	v	K	c	v	s		*e*	r %
12,000	1.00	5.00	0.20	2,000	10,000	10,000	2,000	1.00	83.33
13,000	1.10	4.94	0.24	2,536	10,465	12,585	2,305	1.29	96.81
14,259	1.21	4.12	0.29	3,237	11,021	15,729	2,675	1.43	110.31
15,832	1.33	3.74	0.36	4,154	11,680	19,550	3,123	1.67	123.48
17,787	1.44	3.40	0.43	5,344	12,444	24,156	3,660	1.94	135.81
20,203	1.60	3.09	0.52	6,893	13,312	29,768	4,309	2.24	147.34
23,180	1.76	2.80	0.63	8,946	14,232	36,598	5,080	2.57	157.89
26,840	1.90	2.54	0.76	11,588	15,250	44,790	6,004	2.94	166.98
31,319	2.12	2.30	0.92	15,022	16,298	54,562	7,080	3.35	174.21
36,775	2.33	2.09	1.11	19,386	17,309	65,811	8,325	3.78	178.96
43,356	2.56	1.93	1.39	24,886	18,470	78,740	9,721	4.26	181.61
51,230	2.81	1.72	1.63	31,778	19,451	93,639	11,909	4.81	**182.78**
60,594	3.09	1.54	1.98	40,266	20,328	109,982	13,031	5.41	181.51
71,592	3.39	1.41	2.40	50,562	21,030	128,120	14,916	6.09	178.96
84,404	3.72	1.28	2.91	62,797	21,608	147,202	16,881	6.81	174.40
99,124	4.09	1.16	3.53	77,223	21,902	166,908	18,881	7.62	168.38
115,815	4.49	1.05	4.28	93,863	**21,950**	187,100	20,905	8.52	161.55
134,525	4.93	0.95	5.19	112,789	21,734	207,046	22,870	9.53	153.91
155,230	5.42	0.86	6.30	133,972	21,257	225,923	24,718	10.63	145.54
177,822	5.96	0.78	7.64	157,243	20,579	243,251	26,383	11.82	136.79
202,147	6.55	0.70	9.36	182,627	19,517	259,303	27,882	13.29	128.27
228,077	7.20	0.63	11.43	209,729	18,351	272,939	29,129	14.87	119.67
255,371	7.92	0.57	13.89	238,226	17,145	283,645	30,079	16.54	111.07
283,736	8.71	0.51	17.08	268,042	15,695	292,045	30,774	18.61	102.93
312,941	9.58	0.46	20.83	298,599	14,338	297,352	31,169	20.74	95.02
342,676	10.53	0.41	25.68	329,831	12,842	**300,388**	**31,323**	23.39	87.66
372,715	11.58	0.37	31.30	361,180	11,540	300,360	31,190	26.03	80.59
402,751	12.73	0.33	38.58	392,580	10,177	298,213	30,839	29.30	74.04
432,572	14.00	0.30	46.07	423,500	9,075	293,425	30,250	32.00	67.83
461,915	15.40	0.27	57.04	453,961	7,959	286,821	29,478	36.04	62.09
490,597	16.94	0.24	70.59	483,739	6,853	278,707	28,556	40.67	56.81
518,468	18.63	0.21	88.72	512,698	5,799	269,421	27,520	46.62	51.96



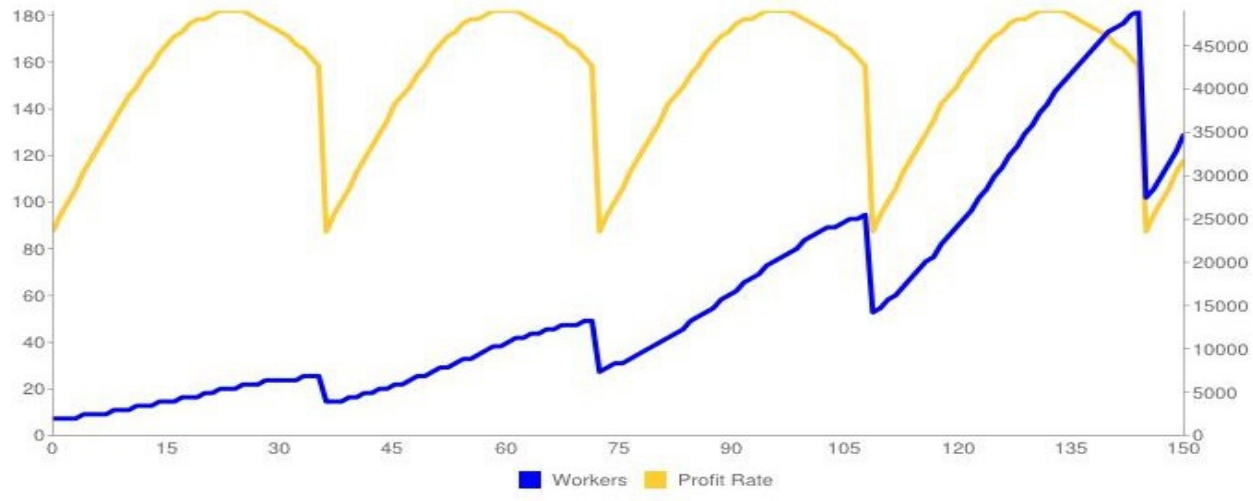
9.3 – The Original Model Updated

Meanwhile, the reader of this essay is invited to go to the web site referenced bellow and to try his/her own hand at some rudimentary «experimentation». This updated version of thie original algorithm was developped with the assistance of José António Silva, a doctoral student of «Complexity Sciences» at ISCTE – Lisbon University Institute[65].

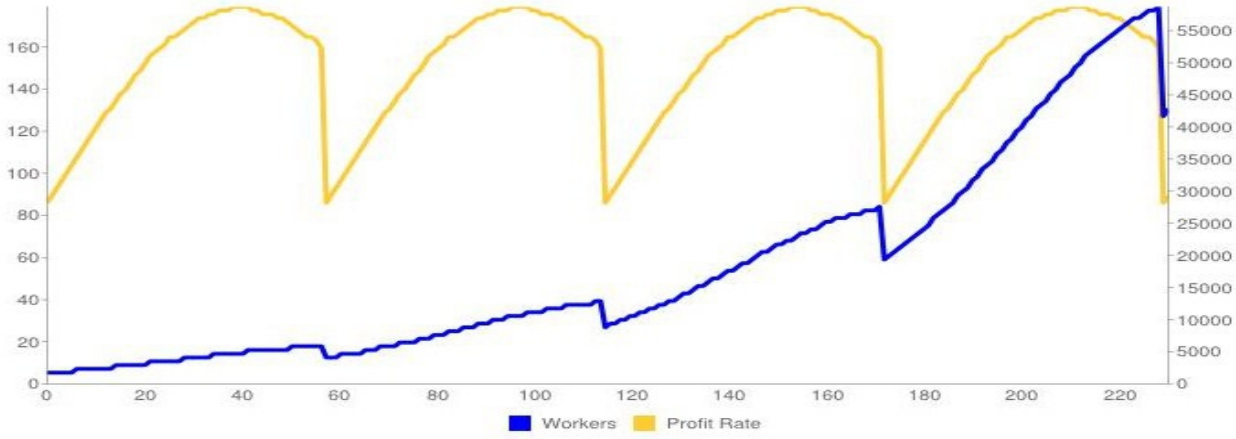
http://93aff163536444a69b2fc23bfb3184.appspot.com/

The following images were obtained with various «experiments» and they all seem to show the inherent tendency of the capitalism system for Non-Equilibrium, as well as the recurring ups and downs in the evolution of the profit rate together with the overal secular growth of emplyment interspersed with crisis of systemic unemployment.

[65] http://www.complexsystemsstudies.eu/



The result considering a flow-back rate of 2,2% with a 4,3% positive impact on productivity in the "constant capital sector" and 4,4% positive impact on the "variable capital" sector and a periodic destruction («potlatch» effect) of 45% and system evolution over a period of 150 years



The result considering a flow-back rate of 1,2% with a 2,6% positive impact on productivity, a periodic destruction («potlatch») of 25% and evolution over a period of 230 years

FINAL AND CONCLUDING REMARK

If only all those authors and modellers out there in academia were capable of (or willing to) including in their entrepreneurial «agents» definition, a Java command or «sentence» in the nature of a statement like: *«maximize the portion of your income that goes into the next iteration («investment»), as long as the rate of profit is at least equal to the one of the last iteration»...* Provided, of course that the model attempts, on a routine basis, to estimate the profit rate. And that this «profit rate» is accepted as a fundamental motivator of economic agents...

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