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Endogenous Animal Spirits and Investment An Agent-based Model

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Endogenous Animal Spirits and Investment
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Introduction

In Chapter 12 of *The General Theory,* Keynes states that the formation of entrepreneurial long-term expectations on investments under genuine uncertainty is not supported solely by cold calculation. Rather, in his opinion, decision making concerning future courses of actions is affected by animal spirits - spontaneous optimism or urge to action - and by 'not rational' motives - 'habit, instinct, preference, desire, will, etc.' and 'passions'- that supplement and even substitute the probabilistic computation of benefits. This view has not encountered much favour among economists, after Keynes. On the one hand, irrational and psychological motives have been sensed as falling beyond the object of economic science. On the other hand, their inclusion into economic analysis would have amounted to consider long-term expectation as exogenous, and therefore, as exerting a completely arbitrary influence on economic behaviour.

Interest in the "animal spirits hypothesis" has consequently been quite low - except for the works of some post-Keynesian authors (for example Davidson 1991) - until the mid eighties when a renewed and persisting attention to the concept has emerged. Applications range from business cycle, to innovative behaviour, money, inventories dynamics, monetary and financial markets.

A first stream, inaugurated by the works of Weil (1989) and Howitt-McAfee (1992) investigates the influence of animal spirits on (either business or investment) fluctuations.

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Their analysis relies on multiple equilibria whose selection depends on animal spirits that, in the presence of increasing returns, act as to produce a self-fulfilling prophecy. If actors are pessimistic, (optimistic) about the future outcome of their actions their real return will be low (high). Switches from high to low spirits are exogenous and stochastic. A series of papers empirically grounds these findings by using econometric analysis (Chauvet-Guo 2003, Gaffeo-Gallegati 2000, Heye 1995). Factors affecting entrepreneurial attitudes fall out the scope of the analysis: the factors affecting animal spirits are not taken into account.

Another, more variegated, line of thought affords the issue of the (ir)rationality. For instance, Brock and Hommes (2000) reconcile the rational expectations hypothesis with the presence of animal spirits by "expressing beliefs in terms of deviations from a structural rational expectation equilibrium". In their model of financial market, asset price fluctuations are driven by a boundedly rational evolutionary selection of trading strategies that they define as rational animal spirits. Another interpretation of animal spirits in terms of bounded rationality comes from Dosi, Fagiolo and Roventini (2004 and 2006). In explaining business cycle they model the behaviour of investors as essentially depending on different rules of formation of adaptive expectations. In this case, the concept of animal spirits is reduced to a more or less myopic attitude of actors thus not grasping fully the impact and the nature of the concept as intended by Keynes.

An interesting attempt to deal with animal spirits is the metric devised by Middleton (1986, 1996). The basic idea is that perception is relative to the actor's previous experience. It follows that the same stimulus can be interpreted as more or less important according to the subject perceiving it. The sensitivity to individual reference point can trigger business fluctuations that are exaggerated with respect to the actual economic state. While grounding in a sound psychological framework Keynes' statement that 'slumps and depression are exaggerated in degree', Middleton's work is more in the vein of measuring animal spirits (see Middleton 1996) than a proper attempt at theorising and formalising the causes of their dynamics.

The literature considers animal spirits as a residual magnitude, a sort of black box that necessarily involves irrationality or randomness.[2] On the contrary, in Keynes' formulation

[2] Koppl (1991) states that "it may be useful to take animal spirits seriously", but thinks that we cannot hope for much from a positive theory of animal spirits.

there are hints of a positive theory (see Marchionatti 1999) that – we believe – allow opening the black box. In Keynes' thought, 'the spontaneous urge to action than inaction" can be decomposed in two parts. The first one has a general impact since affects the behaviour of all the kinds of economic agents. Interpretation of the present and future economic perspectives sometimes is conditioned by 'waves of irrational psychology and emotions' that depend on 'the nerves and hysteria and even the digestions and reactions to the weather[…]'. The typical effect of this component of the animal spirits is to trigger a sort of self-fulfilling prophecy that results in short run fluctuations and erratic behaviour of economic variables. By definition, this part of the animal spirits eludes a systematic treatment. The second one – the spontaneous optimism - relates to the features of the entrepreneurs as represented in the Marshallian and Schumpeterian tradition, in Keynes' words "individuals of sanguine temperament and constructive impulses who embarked on business as a way of life". Spontaneous optimism is the characteristic that differentiates the entrepreneurs from the other economic actors: their willingness to undertake risky activities not only as a mere balance of costs and benefits but as a 'natural' propensity to engage in enterprises whose outcome is uncertain. This 'natural' propensity to bear the risk of investment plays an important role in sustaining the level of investments in the long run and in counteracting the negative effects of limited information and uncertainty. It is this aspect of the animal spirits that can be given a positive theoretical examination.

We share the idea that the agent-based simulation models (ABSM) are an advantageous way to actually apply the insights of old economists like Marshall, Hayek and Keynes (see for example Vriend 2002). In this paper, we firstly illustrate the tenets of Keynes' theory and then we derive its implications through an agent-based model.

1. Simulating Keynes: animal spirits meet complexity theory

Keynes took up Marshall's message of economics as a 'science of complexity' (see Marchionatti 2003). According to Keynes

"Economics is a science of thinking in terms of models joined to the art of choosing models which are relevant to the contemporary world. It is compelled to be this, because, unlike the typical natural science, the material to which it is applied is, in too many respects, not homogeneous through time" (Keynes 1973: 297).

In fact, economics deals with changing and unstable factors like "motives, expectations, psychological uncertainties" in a context of limited knowledge and structural uncertainty: this make the object of analysis complex[3]. This non-homogeneity through time compels economics to undertake inductive analysis and to take the particular characteristics of the historical world into account. In examining this material, economics uses introspection and value judgements in order to discover the relevant factors needed to build a model – in fact, according to Keynes, a complete and exact generalisation is not possible, due to the nature of economic material -.

That of long term expectations in the *General Theory* is the most important case where the features of non-homogeneity of the material make the analysis complex. In Keynes's theoretical framework, agents are heterogeneous, have bounded rationality and revise their behaviour as they accumulate information: their interaction generates an adaptive complex system in the contemporary sense (Arthur 1994). Long-term expectations depend on the most probable forecast that the agents can make and on the confidence with which they make the forecast. As the knowledge of the future is often "fluctuating, vague and uncertain", it is not possible to use a probabilistic theory of expectation. In such a situation the different agents are "guided to a considerable degree by the facts we feel somewhat confident about", because "it would be foolish, in forming our expectations, to attach great weight to matters which are very uncertain" (Keynes 1973, p. 148). Therefore, to get around this informative and cognitive shortage agents have to fall back on conventional judgement (that implies a shared way of evaluation of interacting investors – Keynes refers to the mass psychology of the market) and animal spirits. As Keynes writes:

"Generally speaking, in making a decision we have before us a large number of alternatives, none of which is demonstrably more rational than the others, in the sense that we can arrange in order of method the sum aggregate of benefits obtainable from the complete consequences of each. To avoid being in the position of

[3] Complexity as intended by Keynes could be labelled as 'dynamic' and 'computational' referring to non-linearity of the system's behaviour and to the bounded rationality of agents, respectively (Foster 2005).

Buridan's ass, we fall back, therefore, and necessarily do so, on motives of another kind, which are not rational in the sense of being concerned with the evaluation of consequences , but are decided by habit, instinct, preference, desire, will, etc" (Keynes 1979, p. 294)

In order to analyze this situation the economist cannot use deductive reasoning - "there is not much to be said about the state of confidence a priori" (Keynes 1973, p. 149). Rather, his analysis "must mainly depend upon the actual observation of market and business psychology" (ibid.) that is inductive reasoning. In other terms the non-homogeneity of the material through time compels economist to undertake inductive analysis and to take the particular characteristics of the real world into account. Doing this, economist must use an

"organised and orderly method of thinking out particular problems, and after we have reached a provisional conclusion by isolating the complicating factor one by one, when we have to go back on ourselves and allow, as well as we can, for the probable interactions of the factors among themselves this is the nature of economic thinking (Keynes 1973b, p. 297)"

In examining the material, the economist uses introspection and value judgements in order to discover the *relevant* factors needed to build the *relevant* model. According to Keynes the right language for the construction of the model is not symbolic-mathematical language – Keynes referred to the traditional mathematical approach in economics based on linearity and systems of differential equations –, that seems not to be the best way to understand complex situations, but a quasi-formal way of exposition, i.e. ordinary language, as in Marshall[4], intended "to suggest the whole bundle of associated ideas". This methodological strategy of research has its core in the logical question: it is correct to apply a certain method to a certain specific problem ?, or, is the approach adopted coherent with the properties of the system to be analysed ? In this sense we may say that the quasi-formal way of exposition was a correct

[4] Marshall emphasizes that, in dealing with economic complexity, the economist must use, along with deductive reasoning, trained common sense, that gives flexibility to reason and contextualizes models. This crucial position that Marshall gives to common sense implies that economics must conform itself to the everyday language: this makes it possible to maintain the shades of meaning that in common use every word has: "The economist … must make the terms in common use serve his purpose in the expression of precise thought, by the way of qualifying adjectives or other indications in the context. If he arbitrarily assigns a rigid exact use to a word which has several more or less vague uses in the market place, he confuses business men and he is in some danger of committing himself to untenable positions" (Marshall 1961: 81-2). In general, Marshall held that the appropriate style for economics to deal with economic complexity should be made of different languages (see Marchionatti 2003 and 2004).

approach to a complex problem in the absence of more formal approaches to cope with these complexities.
The relevant model is according to Keynes the result of a continuous correction of judgements:

"The specialist in the manufacture of models will not be successful unless he is constantly correcting his judgement by intimate and messy acquaintance with the facts to which his model has to be applied" (Keynes 1973b: p. 300).

We think that Keynes' idea of a quasi-formal style as a way of exposition of the model representing a complex situation may be reformulated in terms of an agent-based simulation model. In this paper we adopt such an approach since it permits to investigate, by means of computer simulations, Keynes' model of long-term expectation formation as emerging from the interaction of the agents "operating in artificial environment under rules that place only bounded demands on each agent's information and computational capacity" (Epstein-Axtell 1996, p. 4). ABMS theory is based on non-linear relationship among many variables for which there is no unique solution: this means that certain phenomena are unpredictable in principle, not that they are unexplainable in principle (Epstein 1999). The flexibility of the used programming languages makes it possible to represent heterogeneous agents and environments and to simulate their interaction according to different (qualitative and quantitative) rules.

2. The Theory and the model

The aim of the present work is to propose a positive theory of animal spirits. In Keynes's analysis animal spirits are mainly connected with entrepreneurial behaviour. Entrepreneurial activity is carried out by "individuals of sanguine temperament and constructive impulses" who consider business "a way of life" and play a mixed game of skill and chance (Keynes 1973, p. 150). This characterization of entrepreneurship by Keynes bears strong similarities with these of Marshall and Schumpeter (see Marchionatti 1999): these references permit to

define the entrepreneur essentially as an innovator. The existence and persistence of the animal spirits – that is the non-rational factors that induce entrepreneurial activity towards investments – influences the industrial performance. What determines these animal spirits? Is it possible to define "an animal spirits rule"? Like the state of confidence, such an analysis depends upon the actual observation of markets.

In the Keynes-Marshall tradition entrepreneurial behaviour is influenced by the political, social and economic 'atmosphere'. Atmosphere is the result of a delicate balance: the amount of political, social and economic change affects atmosphere, hence animal spirits, level of confidence and investment. More specifically, the factors affecting animal spirits are:

(i) political atmosphere: perceived as more o less favourable to business. Entrepreneurs as a group share an ideology (free individuality). In chapter 12 of the GT Keynes remarks on the political and social atmosphere "congenial to the average business man" as a factor positively influencing animal spirits:

> "economic prosperity is excessively dependent on a political atmosphere[…] if the fear of a labour government or a New Deal depresses enterprise this need not be the results either of reasonable calculation or of a plot with political intent; it is the mere consequence of accepting the delicate balance of spontaneous optimism" (Keynes 1973, p.162).

(ii) social atmosphere: that makes relations *between* entrepreneurs more or less cooperative. Entrepreneurs share a set of values, norms and beliefs (Casson 1995) that define a particular business culture (indeed a collective subjectivity). It promotes trust that in turn enables cooperation among undertakers "which is just as important as competition in achieving efficiency" (Casson 1995, p. 79).

(iii) economic atmosphere: it is determined by externalities spilling from learning processes in the activity of the firms, network externalities, technological interdependence that fosters innovation (the typical case is the Marshallian industrial districts). The external economies such as hereditary skills, grows of subsidiary trades, constant intercommunication of ideas, interaction between

suppliers and users engender advantageous learning processes that fosters the growth of industries and in so doing permits the persistence of spontaneous optimism;

(iv) age of firms and industries: Keynes maintains *à la Marshall* that in their old age firms and industries fail in innovative activity.

Summarizing, the relationship between the variables influencing animal spirits is the following: trust, promoted by business culture, positively affects cooperation between entrepreneurs; this, in turn, allows the exploitation of external economies and therefore determines industrial performance.

Our theory can be summed up in the following functional relations:

(1) $$AS = f(p_\alpha, s_\alpha, e_\alpha, r)$$

where p_α is the political atmosphere, s_α is the social atmosphere, e_α is the economic atmosphere and r is the risk propensity:

(2) $$p_\alpha = \overline{\beta}$$

which is kept constant trough a given series of runs.

(3) $$s_\alpha = f(trust)$$

The entrepreneur develops his degree of trust based on experience by observing the relationship between himself and his fellow undertakers. To emulate experience we endow each agent with an initial degree of trust and, then, we let it evolve according to observation. Namely, if the observed degree of trust is higher then his own degree than the degree increases (more cooperation) and vice versa (more competition).

(4) $$e_\alpha = f(externalities, s_\alpha, \gamma_t)$$

where *externalities* is the rate of exploitation of external economies and γ_t is the inborn ability to run. In turn, the possibility to extract knowledge from interaction is affected by the risk propensity (*r*) and the dimension of the network linking the entrepreneurs:

$$(5)\ externalities = f(dnet, r)$$

where *externalities i*s supposed to follow an "S" path: beyond a given threshold the degree dramatically increases:

$$(6)\ externalities_t = \frac{1}{1 + dnet_t^{-t}} + r$$

$$(7)\ r = f(a_t, \gamma_t)$$

where a_t is the age of the entrepreneur $a_t = a_{t-1} + 1$ which negatively affects the propensity to undertake risky projects whereas the level of skills is supposed to have a positive effect on risk propensity in that skilled entrepreneurs will be more willing to invest.

After having set the factors determining AS and their dynamic, let us turn to the behaviour of the agents.

Entrepreneurs apply deterministic rules to decide whether to invest. They look at the behaviour of their "neighbours" – being neighbourhood defined as the contiguity on *i* location in a vector of *n* agents- to determine their social and economic atmosphere, and then to modify their animal spirits accordingly. If, with respect to the previous periods, animal spirits are increasing then the agent will take the risk of investing while would withdraw in the opposite case.

The dimension of the neighbourhood (*i*) is a proxy for the goodness of information: the closer *i* is to *n* the more accurate is the formation of the animal spirits.

This rule is grounded in Keynes' definition of investments evaluation in organised investment market (1937, QJE) Keynes states that it depends on "the judgement of the rest of the world", that is to say that they are the results of the endeavour "to conform to the behaviour of the majority or the average". In making his final judgement, the entrepreneur will look around to

see how his fellows are interpreting the current state of affairs. While, according to Keynes (1973b 151, RM1999) "the average expectation of those who deal on the Stock Exchange " are revealed by the price of share, in our model we assume that an entrepreneur can "talk" or else directly "observe" the atmosphere as perceived by the other entrepreneurs.

In such a scenario, it follows that – ceteris paribus – the same project could be rejected when animal spirits are low and accepted when animal spirits are high. In this perspective, the "cold calculation" part of the decision making process can be ignored. In fact, we assume that all entrepreneurs are rational in that they will always prefer the higher hiatus between return and cost and – therefore- difference in the level of investments will only depend on animal spirits.

This formalisation differs from the previous ones in two respects:

- causes affecting animal spirits are isolated and modelled. On the contrary, literature mainly considers them as dichotomic (high or low) discrete variables that change randomly.
- changes in animal spirits are endogenous: they are determined by the interaction of entrepreneurs in the industry in a given moment in time. As time passes entrepreneurs might evolve diverse investment strategies according to the state of the industries and to the behaviour of other entrepreneurs.

The use of adaptive agents gives us the possibility to endogenise animal in a twofold meaning:

- in a given moment in time the atmospheres will emerge as a macrostructure from micro interaction of entrepreneurs that are heterogeneous in features and experience and is not posited by the researcher nor randomly chosen,

- dynamically the micro and macro level co-evolve. The current atmosphere affects the behaviour of the entrepreneurs and their relative success. Assuming that more successful

entrepreneurs will be imitated the following generation of firms will copy their features which, in turn, determine the future atmosphere.

Thus, by starting with a generation of entrepreneurs which are heterogeneous in terms of risk propensity, willingness to cooperate, and age we can generate a dynamic of animal spirits which is completely endogenous.

3. Exploratory Simulations and Results

The first runs of the simulation aim at testing the plausibility of the theoretical propositions and the robustness of the model. To this purpose, the model is run in its simplest version: the population is made of 200 entrepreneurs initialised with random values of age, risk propensity, animal spirits and trust. Population is kept constant but as the age of the entrepreneur reaches a threshold value, all the variables are reset so that it can be said that a "new" firm is generated.

Each dot of the following figures represents the level of the variable under examination as determined by 250 steps of simulation. The observation span is 15000 steps. Our focus is on the wideness and direction of variations; therefore, there is no attempt at measuring the observed value. Initial parameters are chosen in order to range in a convenient way.

In what follows, we illustrate the dynamics of the key variables: trust, economic atmosphere, animal spirits, and investment. Figures show the behaviour of these variables in four different scenarios: high and low sensitivity - that is the magnitude of the adjustment that follows the observation of the neighbours and wide or narrow neighbourhood - that is precise or vague knowledge of the surroundings.

Trust (Figure 1) exhibits a limited variation in a range of 1.2 (in the case of wide neighbourhood) and 0.2 in the opposite case. The range is narrower in the case o low sensibility (Figure 1.1), thus we can say that our model is successful in rendering the idea that

business culture as social fact is a set of values quite stable in the short-medium period. As expected, the economic atmosphere presents a higher variability (figure 2 and 2.1). Animal spirits are the result of these different elements plus the risk propensity connected with the firm age in a context in which the political atmosphere is kept constant. They show quite wide regular oscillations (figure 3 and 3.1), which are amplified in the case of wide neighbourhood and high sensitivity. In fact, the presence of heterogeneity, adding information to the decision set of the agent, implies a higher variability. It must be said that at this stage of our research we assume a simple additive relationship between the three determinants of animal spirits (obviously, their relative weight is probably different both in a diachronic and synchronic sense). Investment (Figure 4 and 4.1), as simple function of the variation of animal spirits, shows a periodic oscillation particularly in the case of high sensitivity.

The results of the simulation confirm the internal consistency and the validity of Keynes-Marshall's theoretical framework in that the formalisation of their descriptive and sophisticated interpretation provides a sound and stable behaviour of the variables of interest which is consistent with the observed facts in investments' cyclical dynamics. It does corroborate our statement that a positive theory of animal is conceivable in a non-mainstream framework of analysis.

Figure 1.: High sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents

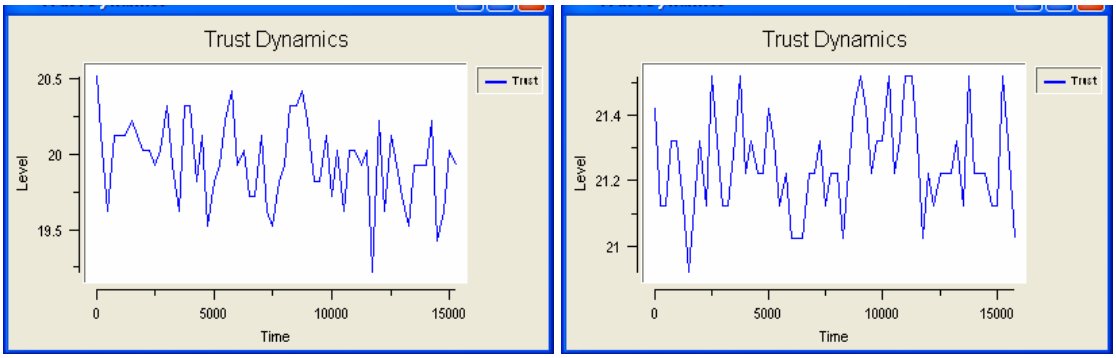


Figure 1.1 Low sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents

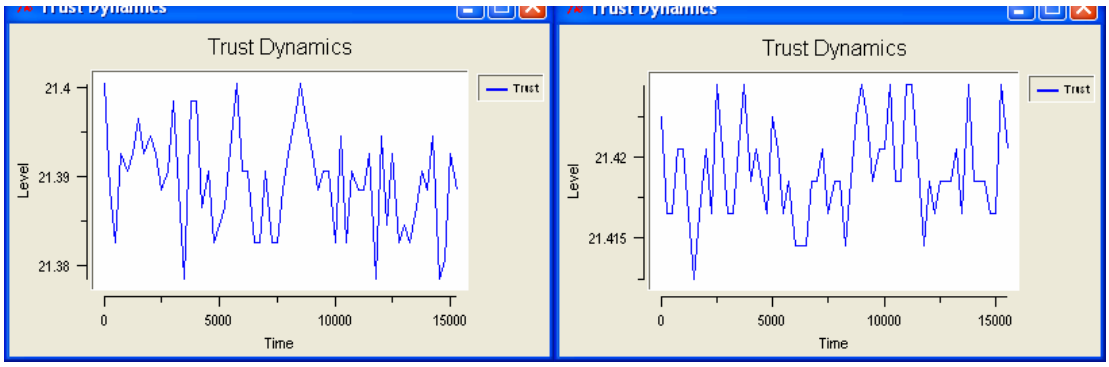


Figure 2. High sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents

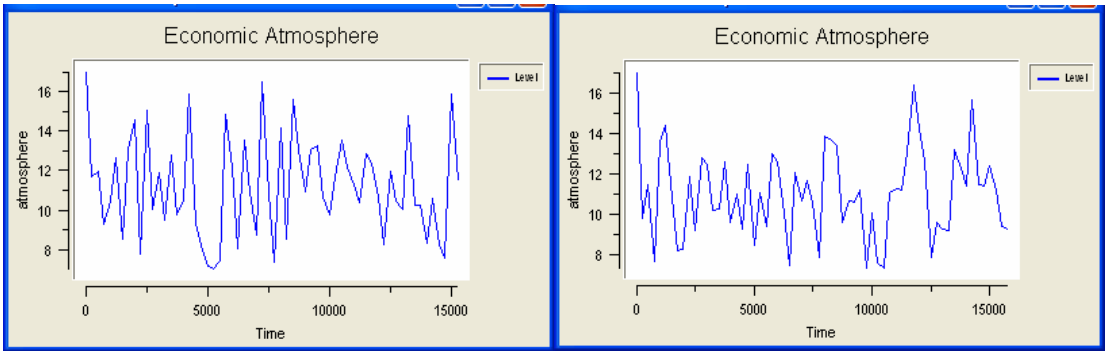


Figure 2.1: Low sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents

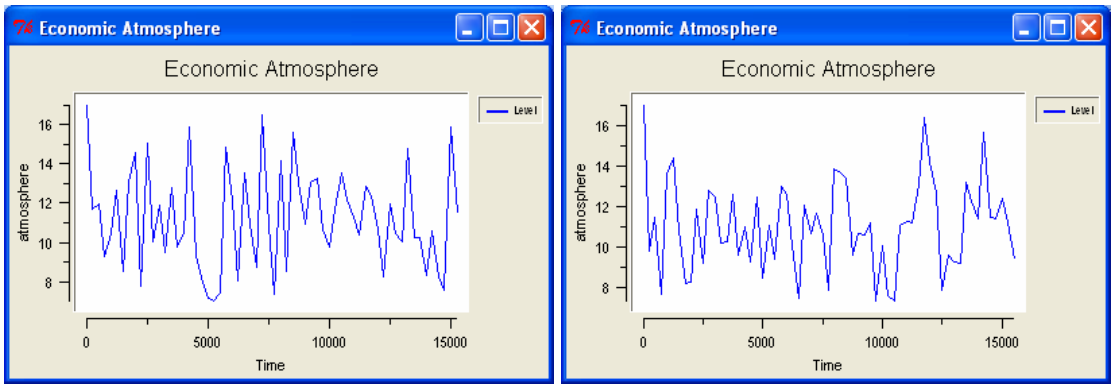


Figure 3. High sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents

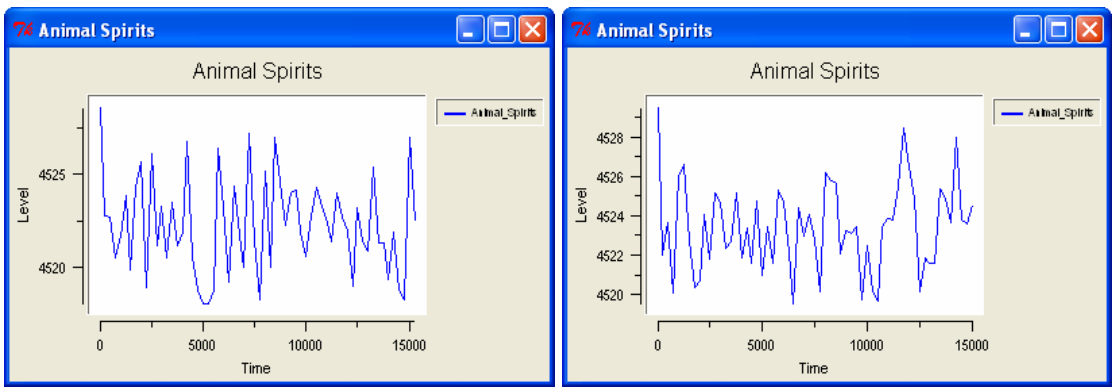


Figure 3.1 Low sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents

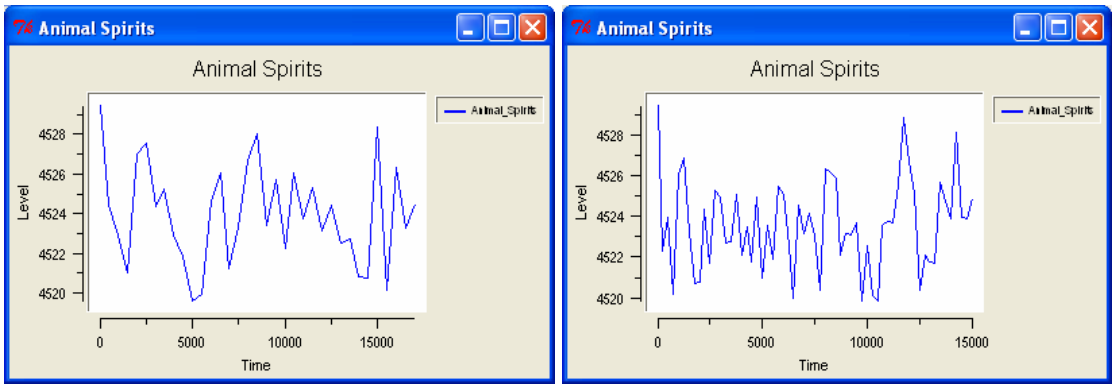


Figure 4. High sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents

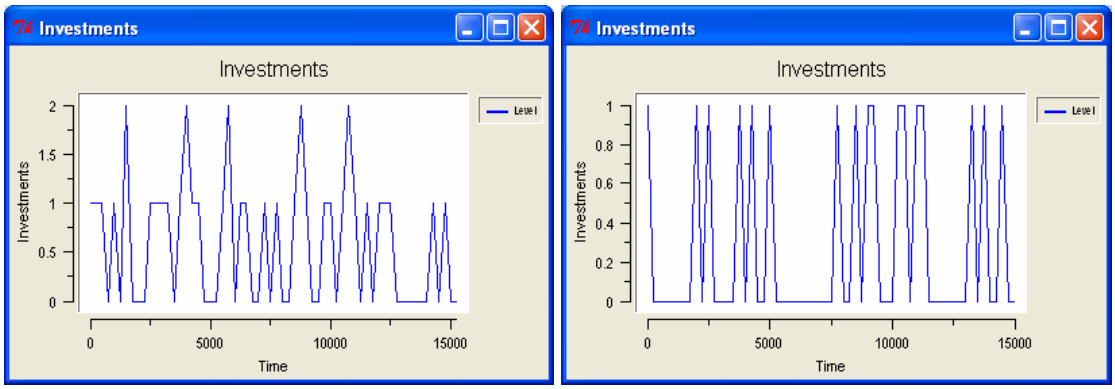
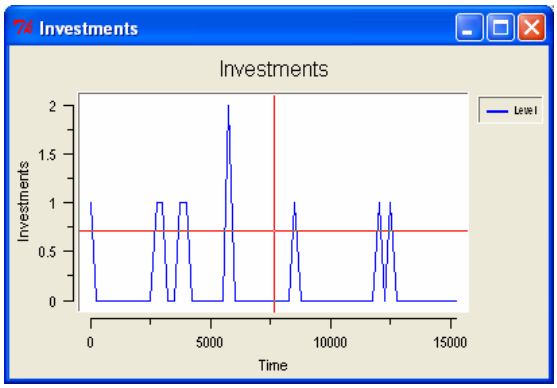


Figure 4.1 Low sensitivity

On the left: neighbourhood of 100 agents. On the right neighbourhood of 10 agents


Investments
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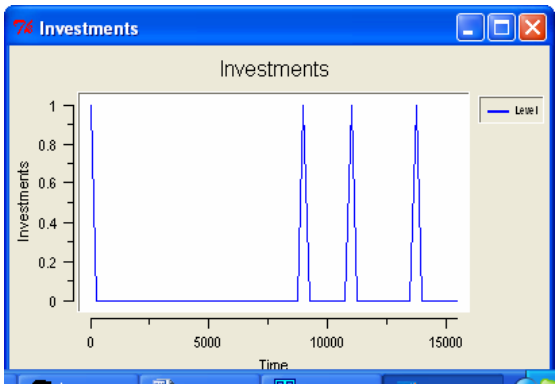
Investments
Investments
Investments
1
0.8
0.6
0.4
0.2
0
0
5000
10000
15000
Time
Level

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