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A POLICY DECISIONS APPROACH FOR DEEP UNCERTAINTY
AN EXAMPLE FROM REGIONAL POLICY

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A policy decisions approach for deep uncertainty
An example from regional policy.

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1. Introduction

In this work, we consider an example of policy decision approach for deep uncertainty. Following the literature, we consider as source of deep uncertainty the heterogeneity of economic agents. The example is built on the differential effects of policy for regional areas whose economic agents each are heterogeneous in their preferences. We analyse how it is possible to choose the correct policy tool for obtaining a required regional differential effect.

During the last decade, in the policy agenda of national governments and international organizations has emerged the design of policies that seek to reduce spatial disparities in economic well-being - Regional policy[1].

As noted by Puga, "Despite large regional policy expenditures, regional inequalities in Europe have not narrowed substantially over the last two decades, and by some measures have even widened. Income differences across States have fallen, but inequalities between regions within each State have risen."[2]

A possible explanation could be that, a part from specific regional policy interventions, the general implemented policy could have specific differential effects on different areas.

The idea that both fiscal and monetary policies could have regional differential effects is well diffused in the literature. Vice versa, these kind of effects are not always correctly considered. "In reality, the nation is made up of diverse regions that are linked but that respond differently to changing economic circumstances. For example, the large declines in crude oil prices in the mid-1980s affected energy-producing regions very differently from energy-consuming regions."[3] Each area has "different resource potentials and confronts different obstacles to growth" Of course, the regional differential effects of a policy are difficult to be studied. If we accept the idea that the single effect in each region is subject to a complex behaviour and therefore to a certain degree of uncertainty. This uncertainty will grow when differential effects are of interest.

The analysis of this type of policy effects is usually based on macroeconomic models which link changes in policy instruments to some outcome measure about spatial disparities in aggregate output or consumption. Some models are pointing out more on the dynamics of technology-related-variables, others on the medium term variables as work, production, and consumption. Critical assumptions within the former kind of models are based on the dynamics of technology-related-variables[4],

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[1] See en.wikipedia.org/wiki/Regional_policy. The argument for regional policy is that it is both an instrument of financial solidarity and a powerful force for economic integration.
[2] Puga (2002).
[3] Carlino and DeFina (1996).
[4] These are defined exogenously, or endogenized by formalizing the effects of changes in input prices or R&D investments. For the critics of this kind of models See Robalino D. A. (2000) that note that the fact that "decentralized heterogeneous economic agents interact and share information about the dynamics of the economy and the characteristics of new technologies, has been always ignored. Yet, it

while they are mainly related to the utility maximization of *representative* economic agents in the latter group.

The use of representative economic agents implies the impossibility of considering social and information interaction[5].

"Ignoring social interactions and learning is understandable in order to keep macroeconomic models manageable. If modeling these process does not contribute significantly to a better representation of the economy, there is not justification to bear the cost of building and simulating more complicated models. .... [however] social interactions are the source of externalities that when ignored may generate policy recommendations which are seriously biased." [Robalino (2000)]

A good understanding of differential effects of an economic policy must be based on the mechanism at the basis of its operability.

Generally, economic systems are considered complex. Many theoretical analyses highlight that the mechanisms at the basis of the operability of the complex systems differ whit traditional one. In fact, for the modelization of complex systems we must take into account the characteristics of such systems and highlight a two-way tie between macro and micro – the problem of microfoundation. It is well known that it is not possible to set up analytical models for complex systems. In fact, these systems can be defined as systems for which no model less complex than the system itself can exactly and in detail forecast their behaviour. No crispy analytical models and solutions are possible

To deal with the microfoundation question correctly it has been emphasized the possibility of using heterogeneous agents simulation[6]. The side-effect is that, following the traditional approach to decision theory there is a strong difficulty in the application of results obtained from the agents simulation of complex systems to the analyses of economic policies effects and then to obtain policy hints. In fact, as each simulation will cause a different result the traditional approach to decision theory, based on global or local optimization, cannot be applied any more. As consequence, it is unusual that such kinds of analysis are conducive to economic policy suggestions. In fact, complex systems need both a different method of modelling and an alternative approach to the theory of decisions.

Salzano (2005) have demonstrated how policy suggestions could be obtained in the case of economic complex system, starting from heterogeneous agent simulations[7]. Here, we will try to show how it is possible to obtain economic policy suggestions for complex systems for the case in which we are interested in differential regional effects.

After a summary regarding the main results already obtained and of the basic model we will addresses the difficulties that appear when we are interested in differential regional effects and the way in which it is possible to obtain regional economic policy suggestions starting from heterogeneous agent simulations..

After having considered the state of the art, we will explicitly start from a New-Keynesian model based on the hypothesis of microeconomic rationing (fixed price

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is this process which is behind the diffusion of new technologies and ultimately the dynamics of macro variables ...".

[5] For a summary on this point see Salzano (2005).

[6] Is has been pointed out by Salzano (2005) that not all kind of heterogeneity has the same effect. We will consider here heterogeneity in preferences.

[7] In these Agent Based Models (ABM) the real world mechanisms are reproduced for obtaining a qualitative comprehension about the agents' behaviour. One avoid quantitative forecasts. Of course, the traditional tools for the analysis of effects of economic policy, based on optimality concept, cannot be used.

and salary in the short period), and Heterogeneous Agent[8]. Then, we introduce the explicit consideration of heterogeneity and not perfect information

We will consider our economy divided in two areas with some variables characterizing their agents.

We will use a "bottom-up" "top-down" mix approach. For the simulation we used one of the simpler and powerful "shells": *NetLogo*[9].

First, the macro-properties that emerge from the interactions between heterogeneous individuals localized in the two areas are analyzed without considering the public sector (bottom-up approach). Moreover, the modifications caused by such emergent properties on the individuals' preferences through the communication process will be considered (evolutionary "top-down" approach). Then, we will consider the effect of the increase of public expenditure, and the differential effects in the two areas.

The comparison with traditional results and the motivations of the differences will close the job.

2 The state of art - Relationship with the existing works

The economic analysis is developed by building models of social phenomena. As model we mean a *simplified* representation of reality. According with Varian, the efficacy of a model derives from the elimination of irrelevant details which allows the economist to concentrate on the essential elements of economic reality that he tries to understand. Of course, in this "reduction" the problem is how to choose which elements are essential. We consider that at least the sign of results must not change. "A complete reduction would be hopeless and interminable. ... Reduction is necessary to some extent, but it can never be complete." [10]

Until the 70's, a large part of Keynesian economics was only interested in macroeconomic aggregates like inflation, unemployment, and Gross Domestic Product, never considering what the relationship could be between them and the choices made by the different agents in the economy.

The macro-level properties of an economic system are normally synthesized in the Walrasian, Keynesian, Neoclassical (and so on) equilibrium. They rest on equilibrium analytical models and, generally, imply a separation between the macro and micro levels (problem of aggregation) or, at best, on an unidirectional relationship between the former and the latter level through aggregated variables (often monetary variables) such as unemployment, inflation, interest rate, and level of prices or salaries.

Many studies have shown the insufficient realism of macro modellization because of the lack of microeconomic foundations. This is an usual question in science. In cact, as Jon Elster (1983) wrote: "Generally speaking, the scientific practice is to seek an explanation at a lower level than the explanandum."[11] The lack of both such a microfoundation and of a theoretical basis of general equilibrium has been one of the main reasons for a substantial abandoning of macroeconomic theories, above all the Keynesian ones[12]

The more recent attempt of mainstream economics to base macroeconomics on 'sound microeconomic foundations', or to reduce macroeconomics to

[8] For a critics of the Representative Agent and the concept of Heterogeneity, see: Kirman, A. (1992)
[9] For the shells see: http://ccl.northwestern.edu/netlogo/. For the proposed simulation see: http://www.ecople.org/ in "New Keynesian Simulation".
[10] Hodgson G. M. (1999)
[11] Jon Elster (1983, pp. 20-4) cited by Hodgson G. M. (1999)
[12] See: (Ruby 2003)

microeconomics, has been "motivated by a specific form of reductionism, based on the use of the individual as the given and fundamental use of analysis. ...[It] ... .has now run into the sand."[13] Both the hypothesis that all individuals have an *identical* utility function, rationality, and individual utility maximisation have devastating consequences for the microfoundations project. As Hodgson (1999) noted "We have no theoretical basis to assume that real-world market systems can ... [be based on] ... the interactions of atomistic individuals."

Arrow (1986, p. S390) declares: "... it is widely assumed that all individuals have an *identical* utility function. Apart from ignoring obvious differences in individual tastes, this denies the possibility of gains from trade arising from individual differences". … Starting from the assumption of individual utility maximisation, Sonnenschein (1972, 1973a, 1973b), Mantel (1974) and Debreu (1974) showed that …. "there is no basis for the assumption that excess demand functions in an exchange economy are downward sloping." The consequences for neoclassical general equilibrium theory are devastating [Alan Kirman (1989)]. In fact, "the assumption of rationality or utility maximisation .... gives no guidance to an analysis of macro-level phenomena." [Rizvi (1994a, p. 363)] "... the uniqueness and stability of general equilibria .... may be indeterminate and unstable unless very strong assumptions are made ... [society behaves as a single individual]". "The idea that we should start at the level of the isolated individual is one which we may well have to abandon" (Kirman 1989, p. 138).[14]

This was the end of microfoundations project in general equilibrium theory or attempts to base macroeconomics on neoclassical microfoundations.

As Rizvi (1994b)[15] pointed out, "it was this partially-hushed-up-crisis in general equilibrium theory in the 1970s that led to the adoption of game theory in the 1980s". "… theoretical work in game theory has raised questions about the very meaning of 'hard core' notions such as rationality. ... [The effect of this crisis has been] "... to turn economics into a branch of applied mathematics, where the aim is not to explain real processes and outcomes in the economic world, but to explore problems of mathematical technique for their own sake. .... Economics thus is becoming a mathematical game to be played in its own terms, with arbitrary rules chosen by the players themselves, unconstrained by questions of descriptive adequacy or references to reality. ... Anti-reductionists often emphasise emergent properties at higher levels of analysis that cannot be [completely] reduced ..." [16] to or explained wholly in terms of another level.

Many attempts to overcome this limit are present in the literature: fundamental market imperfections (Fokke and Folkerts-Landau 1982; Nishimura 1998), incomplete and asymmetric information, competition (Ng 1980), rationing[17] (Muellbauer, J. and R. Portes, (1978), Clower (1965), and Leijonhufud (1968)) and agents' coordination (Gallegati 1999a). Obviously, when information is incomplete and the markets do not clear instantaneously, the learning behaviour of the individual determines the system's dynamics. This has opened the path to several explanatory models of economy, more or less microfounded.

An interesting example of partial microfoundation is constituted by the New-Keynesian model (Salzano 1993, Gallegati 1999b). It is a micro-founded macro-

[13] Hodgson G. M. (1999)
[14] Hodgson G. M. (1999).
[15] Cited in Hodgson G. M. (1999).
[16] Hodgson G. M. (1999).
[17] See the large but dated survey by Salzano (1993).

model based on the hypothesis of the Representative Agent. In it, the consumer agent works with the purpose of acquiring assets and if he is rationed on one of the markets (assets or work) he changes his choices also on the other market.

The trouble was that, given the technical tools available at the time, an effective microfoundation of the macroeconomic model was difficult to obtain.

Of course, "The philosophical basis of ... [policy decisions] ... must make use of the concept of emergence."[18]

Some efforts have been made in the direction of our interest for obtaining : a) better models of aggregated or regional policy effect; b) policy suggestions.

2.1 Better models of aggregated or regional policy effect.

a) the role of social interactions for growth - the case of technology-related variables.

An example of the first case is Robalino D. A. (2000). Centring his analysis on the technology-related variables, he develops "an agent-based macro-econometric model for the developing world that endogenizes the process of technology diffusion by formalizing the role of social interactions. In this model, macro-behavior emerges from microeconomic decisions made by decentralized heterogeneous agents who are organized in networks. These networks influence agents information flows, their expectations about the dynamics of the economic environment, and ultimately their technology adoption decisions. The model is used to address the question of how to allocate aggregate income to the creation of human and produced capital, and how to distribute over time the consumption of natural resources and environmental services, in order to generate a sustainable growth path that maximize inter-temporal social welfare."[19]

An other example, based on Hetherogeneous Agents Simulation, is Salzano (2005)

b) A New-Keynesian microfoundated model based on Heterogeneous Agents.

Some first steps versus the solution of microfoundation, that we will follow in this work, have been proposed. At least a partial overcoming of the main limits of this sort of models as been tried with a New-Keynesian model based on Heterogeneous Agents. Salzano (2005) has extended New-Keynesian model to specific considerations of interacting heterogeneous agents. In this model- model of rationing with fixed prices[20] - it is possible to compare the results obtained with both Representative and Heterogeneous Agents. The shell of simulation is of a hybrid kind. In fact, it has aspects of both equation and agent simulation. Obviously, if there is only one individual and one firm the microeconomic and macroeconomic models coincide.

- The case of Representative Agents.

The representative agents have perfect knowledge about the offer and demand of other agents. On this basis, they set their optimal behaviour on every market. All the Individuals (who buy goods for consumption and who work) have the same preferences. Analogue hypothesis helds for the Firms (that produce and sell). "Government" is an agent who modifies economic policy (public expenditure - taxes) The public expenditure for "goods and services" is subject to preferential satisfaction.

Different equilibriums - of Keynesian, Neoclassical, Repressed Inflation and Under-Consumption type - can be caught up according to the kind of rationing met by agents on the market. Of course, in this case the model could also be solved

[18] Hodgson G. M. (1999)

[19] Robalino D. A. (2000)

[20] Following Bohm (1983), we could explicetly introduce price and wage modification based on demand and offer. This could be combined with incremental expectations or with "cost push terms".

analytically causing results that are compatible - even if in some way different because they are more general - with those obtainable on the basis of the traditional approach.

The agents possess a very simple and economically based personal equation: they manifest demand for goods if they think they are able to find work and vice versa; while the firms have an analogous function of supply and demand. The exchange is held in the intersection point of these functions.

According with the type of rationing we could reach various types of equilibriums In Fig. 1 the main types of equilibrium or regimes are depicted. The case in which no agent is rationed - the Walrasian case (fig. 1-a.) The Classic unemployment (fig. 1-b), is manifest when the consumer agent is rationed on both markets, while the firm does not assume more workers in order to satisfy the greater demand since the wages are too high. If the consumer agent is rationed on the work market and the firm is rationed on that of goods - a Keynesian equilibrium (fig. 1-c). [21] The regimes are the same for all agents of the same type. Here, the usual effects of public expenditure are obtained in each topical case. The shifting from one "Regime" to the other is possible.

Obviously, it is assumed the number of firms to be smaller or equal to that of the individuals. Moreover, as aggregated must be considered "analytically manipulable" both vertically and horizontally, each agent will manifest an equal part of demand or offer respect to the aggregated values

- The case of Heterogeneous Agents.

In literature various kinds of heterogeneity have been considered, but not all of them increase the model's realism (Mirowski and Somefun 1998). Often, they have been limited to make a partition of the reality in two or more subsets[22]. The RA model allows interrelations, only among agents of different kind (for example, consumers and producers) (Gallegati and Kirman, 1999; Salzano 2005). Here we will consider the heterogeneity of individual's preferences that does not show such a limit.

The New-Keynesian model can be completed by the presence of heterogeneity of the agents' preferences without losing its original characteristics. However, macroeconomic properties can emerge - a "bottom-up" approach. Of course, these preferences could be modified by acquired knowledge about the behaviour of other agents. During consumption time, they come into contact with other individuals with whom they exchange information on the goods and the work of each firm. On this basis, they can change their preferences. The individual could obtain information by meeting others (particularly friends) and can modify his choice of firm from which to buy or where to work; Individuals receive informations only by a restricted group of friends; the past level of macroeconomic activity could modify individual preferences in personalized ways according to personal history.

The consequences of this direct interaction among agents are very important. There are different sceneries for each agent. Moreover, we will introduce the possibility the individuals can exchange information about the situation experienced by each agent and that this can modify their preferences. This micro mechanism introduces feedback effects from the macro to the micro level ("top-down"). These feedbacks are the effects of rules that must be valid only in aggregate. When the hypothesis of heterogeneity in the agents' preferences is introduced we need one behavioural equation for each agent. This means that we must resort to simulations. For heterogeneous agents the punctual effect depends on the situation of rationing met

[21] For other cases and a wider esposition see: Salzano 2005.

[22] See Gallegati, Kirman (1999).

by each single agent and the total equilibrium of the exchanges is obtained as a sum of the single effects. This is different from the equilibrium that we would forecast on the basis of the aggregated demand and offer. Therefore, the result based on the aggregated demand and offer is different from the sum of the single results[23].

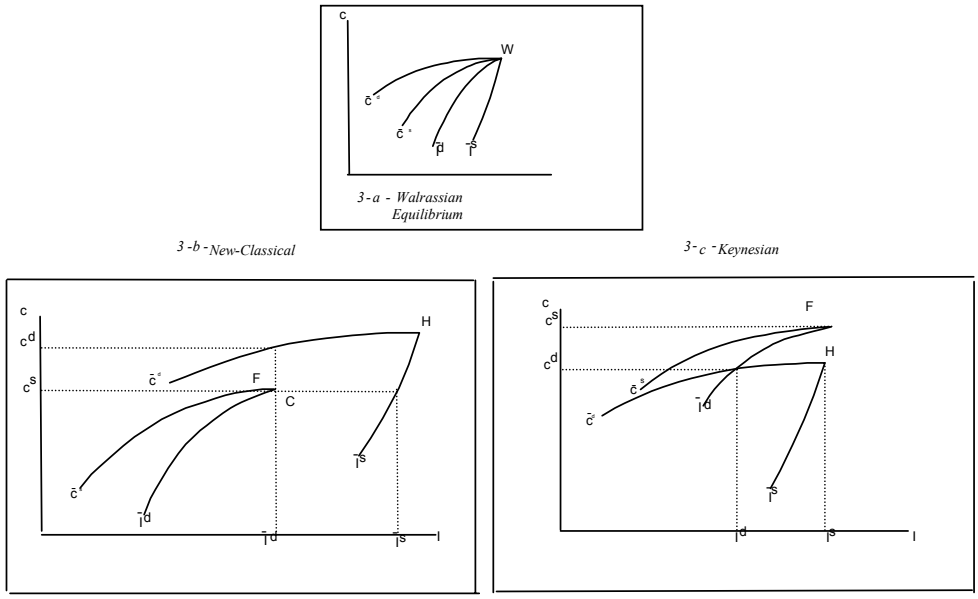

Fig. 1

The aggregation of the various equilibriums ("bottom-up") can provoke a total equilibrium which is different from the hypothetical one we can reach if the markets are aggregated before the exchange (complex dynamics). A corollary of this is that for each couple of agents - individual and firm - that exchange on the market, economic policy can have different effects.

- The phase modifications and the "top-down" approach

In many economic models based on agents the macroeconomic aspects mainly play a role of emergent property. Vice versa, in real economic systems some of the emergent property (originating from the bottom-up approach) must be considered as a phase change, the consequence of which modifies the behaviour of agents (top-down approach). In simulation literature the consequences of phase modifications often are simulated by a simple Ising model[24]. The contemporary consideration of these aspects implies the use of a model that is a mix of the "bottom-up" and "top-down approaches[25]

At the economic level, the effect of the phase change can be seen by the fact that the economic agent modifies his behaviour as a consequence of the economic scenery in which he is or he thinks to be. This implies a macrofoundation of the microeconomic behaviour.[26] In the model, if a certain number individuals "is

[23] Of Course, in the case of RA, the effect of economic policy is identical for each agent while this must be considered only a specific case for heterogeneous agents.

[24] Perhaps, the most known among these simplified models is the bi-dymensional Ising. It can be used for simulating the behaviour of simple magnets. For an elementary exposition see: http://www. phy. syr. edu/courses/ijmp_c/Ising.html. It seems, there are some differences between the "macroeconomic" local scenary and the Ising Model. In fact the first could assume different "levels" that the latter cannot assume.

[25] This is not new. See the references cited in Salzano (2005).

[26] The importance of which has been emphasized both by Schelling (1978) and by Lane (1998 & 2002).

satisfied" or "not satisfied" by their exchanges and passes this information to others, the preferences of the latter would be modified and, therefore, new emergencies would emerge. In this way, the level of the micro - macro interrelations is not hierarchical, but it is circular.

Obviously, the model considers only the points most widely considered in literature; understanding their influence on the economic mechanisms provides a good starting point in order to elaborate more realistic models of regional effects of public policy.

2.2. The effect of HA and Policy suggestions.

Some Authors[27] have highlighted that for Heterogeneous Agents simulations, even for aggregate analysis, results will differ deeply for each simulation. We are in presence of "deep uncertainty"[28]. A single tool could give rise to different effects even in an aggregated landscape. The optimality criteria is not useful any more. We must abandon the approach to economic policy suggestions based on the traditional concept of optimization. As suggested by Banks, a decisional approach could be based on policy robustness[29]. This implies to take into account the deep uncertainty of complex systems and to proceed with the systematic comparison of the alternative options of economic policy. Therefore, we must apply an adequate system of analysis if we want to obtain suggestions that are correct. This system must be able to trace and track all the possible results of a range of simulations. The use of analytical tools, even if it is still possible in some case, does not seem to be adequate any more and we must abandon it. A way is trough a visual analysis tracing all the results in a single diagram.[30].

In order to obtain policy suggestions, based on a principle of "robustness" it seems possible to use the approaches of "Exploratory Modelling"[31] and "Adaptive Strategies". Here, we will highlight only the first approach. It implies two tools: The "Policy Landscape" and the "Analysis of Satisfactory Solutions".

2.3 The Exploratory Analysis

The "exploratory modelling" is an approach to decision-making under conditions of deep uncertainty[32]. The point of the exploratory analysis is that of being aware of the range of possible results that we could really obtain with the use of our policy tools. Only after this first part of the "exploratory analysis" we could pass to the second part and to the policy hint question.

It makes use of two techniques: ***Policy Landscape*** and ***the Analysis of satisfactory solutions***. These techniques permit ***the easy contemporary manipulation of results of sets of models***, use inductive reasoning on wide sets of computational experiments,

[27] See: Salzano (2005), Banks(....)

[28] See the definition of Banks (op. cit.)

[29] See Banks (2002) and references reported there.

[30] Information visualization is a compelling technique for the exploration and analysis of the large, complex data sets generated by these tools. Visualization takes advantage of the immense power, bandwidth, and pattern recognition capabilities of the human visual system. It enables analysts to see large amounts of data in a single display, and to discover patterns, trends, and outliers within the data. http://graphics.stanford.edu/projects/rivet/ For the relevance and usability of Visual Analysis in the case of complex systems, see: Shneiderman (2004). He said "I believe that the essence of information visualization ... is to accelerate human thinking with tools that amplify human intelligence. … The payoffs to users of information visualization tools will be in the significant insights that enable them to solve vital problems at the frontiers of their fields. ... The process of information visualization is to take data available to many people and to enable users to gain insights that lead to significant discoveries."

[31] See Bankes, S. (1993)

[32] This approach could also be called "Computer-Assisted Reasoning" (CAR). See Bankes and Gillogly (1994).

and provide a method for dealing with the ontology of deep uncertainty. They can make use of information obtained from the complex systems for obtaining economic policies hints.

The ***Policy Landscape*** finds its motivation in the fact that for deep uncertainty alternative presumptions can lead to different results for the wide variability of the possible results. In this case, a systematic examination of a whole set of the simulations of the reasonable models of reality could better capture, and contribute to represent, the necessary information. It allows that the calculations of the effects of economic policies is subordinated to a robustness test. Vice versa, the ***Analysis of satisfactory solutions*** is necessary because no recommendation of economic policy, obtained as a result of an optimization, regards to a single model can take account of all the knowledge that can be available for a complex adaptive system. In scenery that could easily vary like the complex system, an alternative to the suggestion of a single set of economic policies is to give the decision makers some sets of options that operate satisfactorily or reach one minimal threshold of effectiveness. Given the multidimensionality of the problem there is a strong judgment difficulty that implies the preference for a graphical tool that can show many possible alternatives all at once.

Differential Regional Policies Effects

In the case of regional analysis, for RA, we obtain equal result for each simulation. The consideration of agents heterogeneity contrasts such a result. In fact, supposing we have only two regions, each couple of the two groups of agents of each region will find a different equilibrium and the aggregated equilibrium will be even different for each region for the different interrelations that will manifest caused by its diverse socio-economic structure. The aggregated equilibria we reach (income or work and so on for region 1+ Region 2) on the base of a traditional macroeconomic model will be different from that we obtain on the base of a micro-founded model with Heterogeneous agents. The same is true for each regional equilibrium. This equilibrium is not necessary coincident with the aggregated ones[33]. "The sum is more [or different] than the parts".

An analogue and more ample difference is obtained for the effect of economic policy (public expenditure - PE)

Of course, the question is worst when we deal with regional differential effects in the hypothesis of HA. In this case large problems exist. In fact, in the traditional approach diverse differential results could be obtained only using different tools or by modifying the level of the used tool. Vice versa, in the complex approach they are obtained even when the same tool is used at the same level. This is the effect of heterogeneous agent interrelation.

There is a dimensional question here, because for each point that is a possible solution of a first system (or region) we have to calculate its possible difference with respect to all the points of possible solution for the other system. This means that we obtain a different solution for each possible value of our second system[34]. In fact, the dimension for each solution's value of the second system, we obtain a new system. Therefore, there is an increase of dimensional space of the solution of the complete system.

[33] For a demonstration see Salzano 2000.

[34] Of course, this could mean an increase in the "dimension" of the solution. This is similar to the question faced in no-zero-sum games if we do not know what is the sum of the real results, but only the percentage of one of competitor with respect to the other.

We need to proceed to a policy choice based on an ample dimensional space then that usually considered for aggregated complex systems. Thus, even if the starting methodology remain the same, for the appraisal of the regional differential effect of economic policy we must validate and, if it is the case, modify the methodology already proposed for complex aggregated systems. Therefore, even in this case, we must apply an adequate system of analysis if we want to obtain more correct suggestions.

3) The simulation context

On the base of the model delineated before, we considered the differential effect of the same levels of public expenditure (PE) on two regions. For sake of simplicity: a) the whole economy is constituted by only two regions whose agents have different characteristics; b) economic agents operate in a New-Keynesian scenery with rationing; c) each agent can only have interrelations with other agents of its area[35]; d) we studied only the level of production of the two regions; e) only the individuals were considered different in the two regions; f) individuals were different only in the elasticity of aggregate demand to work possibility.

3.1)The analysis of simulations' results

We will concentrate on: a) The implication of Ha - emergence of macroeconomic characteristics - The volatility of results and the insurgence of endogenous fluctuations b) the implications of HA on regional differential effect of a simple economic policy -public expenditure; c) how deep an attention must be reserved for choosing the more robust policy when we make use of agent simulations, and the modification of methods necessary – if any – for the analysis of differential effects.

a) The implication of Ha - emergence of macroeconomic characteristics - The volatility of results and the insurgence of endogenous fluctuations

The main implication of HA hypothesis regards the emergence of macroeconomic characteristics that are not present in the case of RA. This is evident if we compare two graphs, both obtained with the same economic structure for the production in the two regions, with and without the HA hypothesis (Fig. 2). In the graph only one level of PE is reported. While without it, the two level of income are equal and remain so for every different simulation (we run each simulation at time 1; of course, the same is valid even with time simulations), in the case of HA, we obtained every time a different result. Therefore, the HA caused the emergence of a volatility in the results.

Of course, if considered with respect to time, this fact implies the emergence of ***endogenous fluctuations***.

b) the implications of HA on regional differential effect of a simple economic policy -public expenditure.

Many simulations have been carried out on the base of the proposed regional model. We obtained the level of production for each region and its differences for each level of public expenditure (Fig. 3 a, b, c). Here, for clarity, only the first 30 run are reported. Each line indicates a different level of PE. From the graph it is easy to see how for each level of PE many different differential effects could obtained. The values are the ones obtained in each simulation. Moreover, the levels of their

[35] Many kind of interrelation between the agents of the two regions could be considered. Different hypothesis could be of interest for more sophisticated models. For example, the hypothesis of non zero transport costs when agents can exchange and relate with all the other agents of the economy could be of interest for a heterogeneous agent version of Kanbur-Keen or similar model of fiscal competition [see Kanbur & Keen, (1993); Mintz & Tulkens, (1986)].

variations (Min & Max) are different and not monotonically increasing with the level of PE.

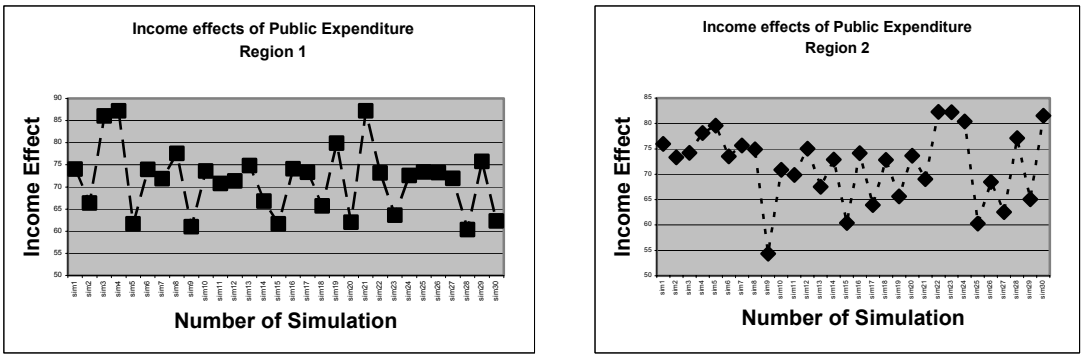

Fig. 2

Therefore, suppose a government would like to obtain a certain level XX (indicated by the relative colour in Fig. 3.c) of differential effect between the two regions. It could choose every value of PE. In fact, each of them could have the desired effect, but also ... every other effect. This is the trouble and it is why an "Exploratory Analysis" seems necessary.

c) how deep an attention must be reserved for choosing the more robust policy when we make use of agent simulations – tools for analysing the effect of policies

The use of the information obtained by the study of complex systems for the formation of economic decisions and for economic policy suggestions is not well diffused. Vice versa, the study of complex systems supplies powerful instruments which capture useful information on the behaviour of economic systems (agent simulations are an example of this). This seems due by the fact that the approach generally used to suggest economic policy is intended for policy creation that must operate well on some "single" forecast of the future course of economy[36].

This traditional methodology is in strong contrast with the complexity concept itself. In fact, every system whose behaviour can be captured from a precise model does not give origin to any "emergence" and therefore cannot be defined complex. Vice versa, the behaviour of complex adaptive systems cannot be captured from a precise model and thus exactly forecasted because ***deep uncertainty*** characterizes them.

In order to formulate credible economic policy suggestions for complex adaptive systems, we must find strategies that operate reasonably well (that are robust) for a large range of reasonable sceneries rather than to indicate an "optimal policy"[37]. They must be robust for all the range of possible behaviours of a complex and adaptive system. Therefore, the models must be used not to forecast results but to supply knowledge about the direction of the effects of possible policies.

Suppose we would take account of the effect of a public expenditure. Per simplicity, and for the possibility of comparing our results, we could hypothesize that both the areas start with the same industrial structure. Then, only the differences in the individual preferences will have influence on the fiscal policy effect. Of course, we hypothesized the amount of public expenditure will be directed equally to each productive structure.

[36] For this part see Banks (op. cit.) e Bankes, S. and Lempert, R. J. (1996).
[37] Lempert R. J. (2002):

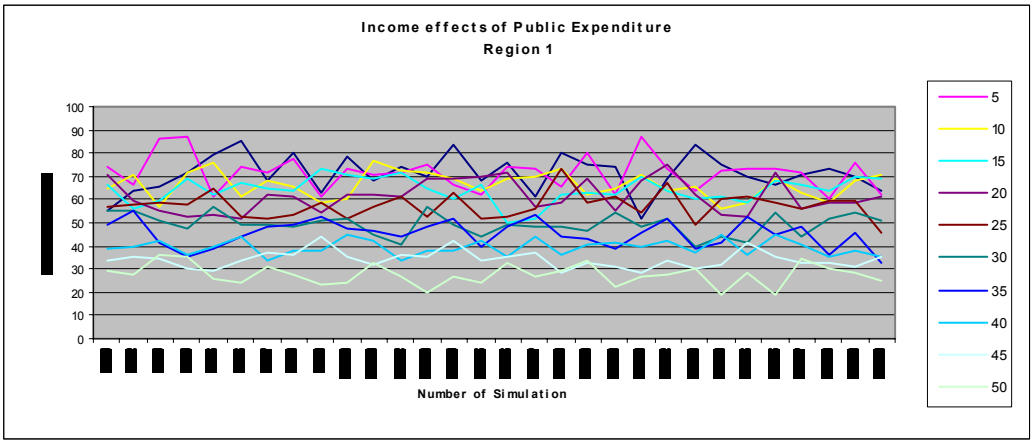

Fig. 3.a

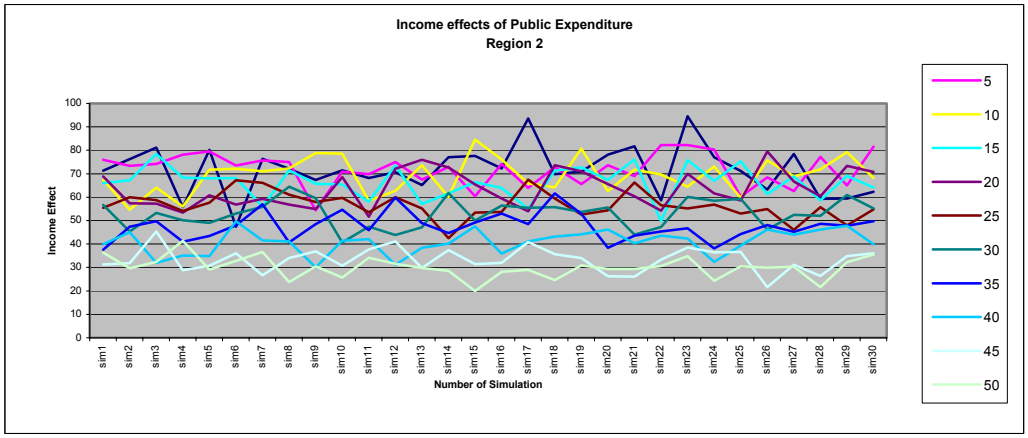

Fig. 3.b

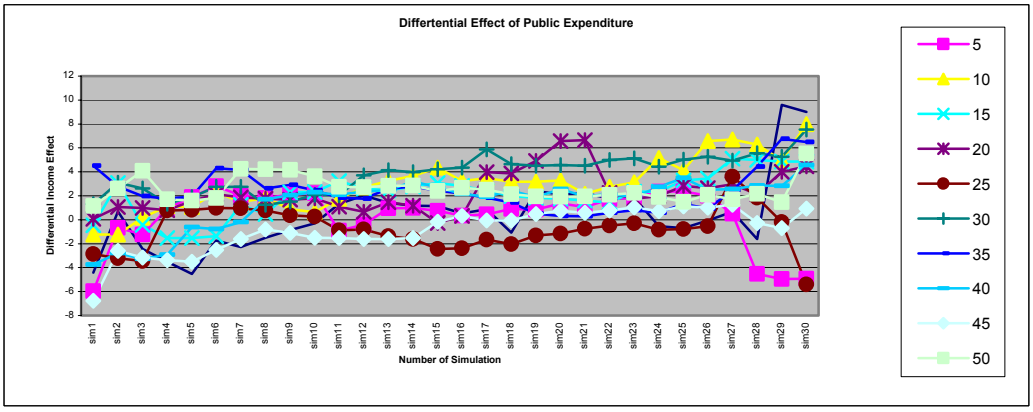

Fig. 3.c

3.2 The implementation of Policy Landscape approach for regional fiscal policy

The effects of public expenditure in the two regions can be summarized if Fig. 4.a – 4.b, and the differential result in Fig. 4.c (the difference between the results in the two regions). Of course, the graphs are built on the base of the previous explained methodology. On the Figures the simulations are ordered in increasing order of their effect. The vertical axes indicates the level of Public Expenditure; colours indicate the level of effects.[38] Moreover, the colour of each point of Fig. 4.c indicates the level of

[38] Of course, when modelling a concrete economy, in order to try to highlight the effects of economic policy we must start from the effective value of the transactions or from some other known aggregated

difference of effect in the two regions.

On the base of Fig. 4.c it seems evident that we should choose a level of public expenditure of S1, S3 or S7. In fact, these levels could allow us to reach the highest differential effect. Clearly the level S7 is more robust.

Vice versa, it could happen that the highest effect is not robust; this case will manifest when near the level chosen for all the line of simulations (0-30 on the horizontal axe) we find very low values. This is what happen for the level S1. Here, it would be necessary to choice the level of PE giving rise to the highest effect compatibly with a sufficient level of robustness. Then, it will be more apt to chose a value whose effect is bounded with effect all similar for similar values of PE and for many simulation-runs, even if it will allow to reach a minor level of differential effect. Therefore, its result is more "robust". In this case it is not possible to associate any probability to each level of effect. In fact, if we increase the number of simulations, the probabilities will fluctuate. Perhaps, we could only tentatively associate to each level of PE a fuzzy measure of pertaining to a group of high, medium, or low effect.

More different cases could manifest: a) It is possible that at some level of PE the effect on the region 1 could be negative, Vice versa, there are other values of public expenditure for which, even if the differential effect is strong, it is not obtained at the cost of a decrease of the value of region 1. Therefore, it could be opportune to build some graphical representation in which we take into account the constraint R1>=0. Obviously, in this case other choices are possible - based on robustness criterion - that are different from the previous ones. b) it is possible some counter-factual result. In fact, if the scenery (Keynesian, Classic, and so on) of one of the region will change we could obtain a strong differential effect for a region when the public expenditure devoted to this region is less that the amount devoted to the other.

Of course, this is only a first step towards the formulation of better policy suggestions for dealing with regional difference. In order to be successful, the differential policy for complex adaptive systems will itself have to be adaptive, but this is reserved for a different work.

4) Conclusions

A large part of current policy debate is about differential regional effect of policy. As it is easy to understand, for evaluating the differential effect of a public policy, we have to subtract the effect on a country on that of the other. The fact is easy for the case of RA because we are in the presence of only one result for all simulations. Vice versa, for HA as we have multiple results, each being equally possible, it is very difficult to reach a firm conclusion. This situation is worst in the case of differential effect for the increase of dimensionality. Here, we suggested a procedure to obtain more certain policy hints in the case when such kind of effects are of interest.

On the base of the analysis conducted, it is evident: a) that the effect of regional policy tools (public expenditure in this example) is strongly modified if we use a model based on Heterogeneous Agent Simulation that take into account the interactions of individuals; b) that in the case of economic policies intended to obtain

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value. Thus, after having obtained a wide set of simulations we must only take into consideration the parameters that at time zero (the present time) could give rise to values of our aggregate variable similar to those effectively observed. In our case, applying the methodology of the "Reasonable Scenery of Economic Policy" it would be possible to choose a sub-set of our simulations and concentrate further study exclusively on these values. This successive study can consist both in a deepening of implications of the single variables and in an analysis based on the "Set of the Level of the Satisfactory Solutions".

differential regional effects, even the approach to decision theory based on robustness find some limits. Otherwise, it is possible to overcome them with a more subtle analysis about the effect of the policy in each single regions. Therefore the approach to HAS could be profitably used even for obtaining this kind of policy hints. In this landscape the "devolution" and federal problems could be better considered. Even the Oates model could be revisited on a more firm base.

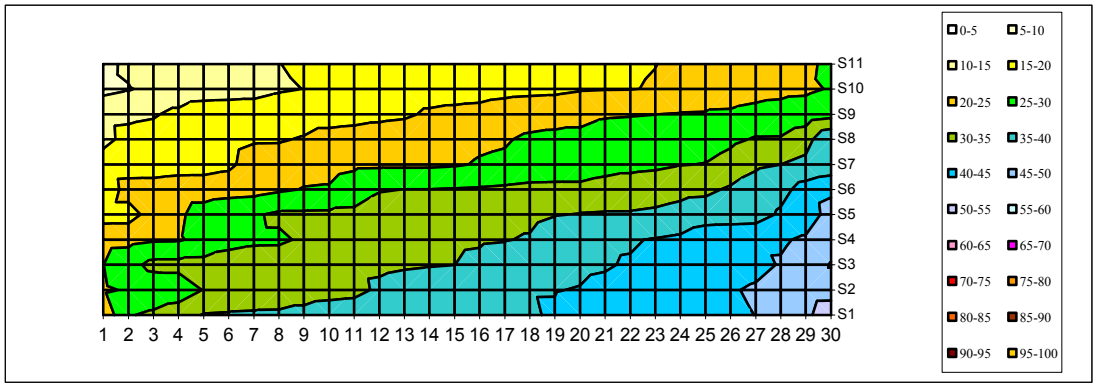

Fig. 4.a

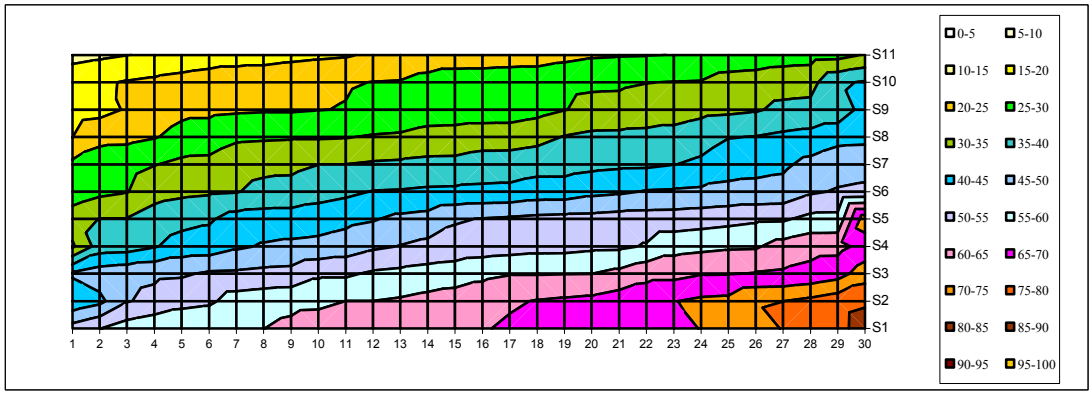

Fig. 4.b

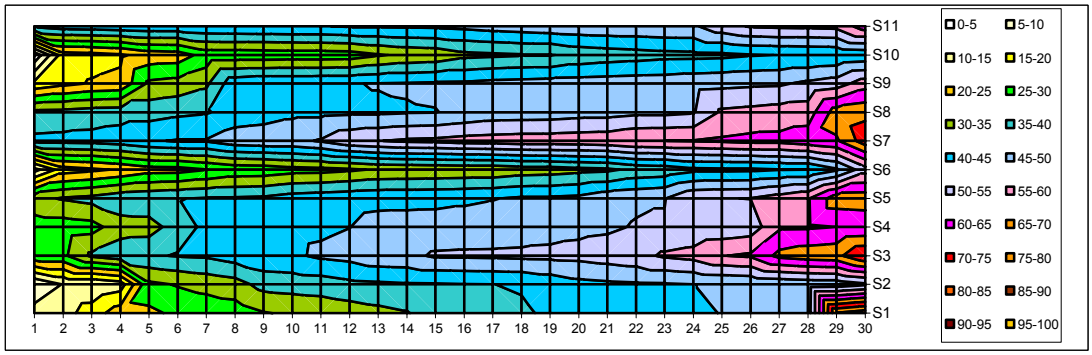

Fig. 4.c

Bibliography

Arrow, K. J. (1986) 'Rationality of Self and Others in an Economic System', *Journal of Business*, 59(4.2), October, pp. S385-S399. Reprinted in Hogarth and Reder (1987) and in Eatwell, John, Milgate, Murray and Newman, Peter (eds) (1987) *The New PalgraveDictionary of Economics*, 4 vols. (London: Macmillan), vol. 2.

Bankes S. (2002): *Tools and techniques for developing policies for complex and uncertain systems*; PNAS-May 14, 2002, vol. 99, suppl. 3, 7263-7266; www.pnas.org/cgi/doi/10.1073/pnas.092081399

Bankes, S. (1993): *Exploratory Modelling for Policy Analysis* **;** Oper. Res. 41, 435-449

Bankes, S. and Gillogly, J. (1994): Exploratory Modelling: Search Through Spaces of Computational Experiments, *Proceedings of the Third Annual Conference on Evolutionary Programming* , http://www. evolvinglogic. com/Learn/absandpapers/explsearch. html

Bankes, S. and Lempert, R. J. (1996): Adaptive Strategies for Abating Climate Change: An Example of Policy Analysis for Complex Adaptive Systems; in *Evolutionary Programming V: Proceedings of the Fifth Annual Conference on Evolutionary* Programming, eds. Fogel, L. J., Angeline, P. J. & Back, T. (MIT Press, Cambridge, MA), pp. 17-25

Bohm V. (1983): Quantity Rationing vs. IS-LM. A syntesis, Disc. Paper. N. 252-83, Un. at Mannheim

Carlino, G. A.; DeFina R. (1996): Does Monetary Policy Have Differential Regional Effects?; *Federal Reserve Bank of Philadelphia Business Review Articles*

Clower R. W., (1965) The Keynesian counter-revolution: a theoretical appraisal in F. Hahn e F. P. R. Brechling (ed.) *The Theory of Interest Rates*, London; MacMillan

Elster, J. (1983) *Explaining Technical Change* (Cambridge: Cambridge University Press).

Fokke D. and I. Folkerts-Landau (1982): *Intertemporal Planning, Exchange and Macroeconomics,* Cambridge University Press.

Gallegati M, (1999a): Agents Heterogeneity and Coordination Failure: An Experiment, (with D. DelliGatti and D. Mignacca), in M. Gallegati and A. P. Kirman (ed.), *Beyond the Representative Agent*, 165-82, Elgar, Cheltenham.

Gallegati M, (1999b): The New Keynesian Economics: A Survey, (with P. G. Ardeni, A. Boitani and D. Delli Gatti), in M. Messori (ed.), *Financial Constraints and Market Failures* , Elgard, Cheltenham.

Gallegati M. and A. P. Kirman (ed.) (1999): *Beyond the Representative Agent*, p. 165-82, Elgar, Cheltenham.

Hodgson G. M. (1999): *"Institutions and the Viability of Macroeconomics: Some Perspectives on the Transformation Process in Post-Communist Economies"*

http://graphics.stanford.edu/projects/rivet/

Kanbur R., Keen, M. (1993): Jeux Sans Frontieres: Tax Competition and Tax Coordination When Countries Differ in Size, *American Economic Review*, 880-85 ;

Kirman, A. (1992): *Whom or what does the representative individual represent?*, J. Economic Persp. 6, 117-36

Kirman, Alan P. (1989) 'The Intrinsic Limits of Modern Economic Theory: The Emperor Has No Clothes', *Economic Journal (Conference Papers),* 99, pp. 126-139.

Lane D. A. (1998): Is what is good for each good for all? in B. Arthur, S. Durlauf and D. Lane (Eds.) Economy as a Complex, Evolving Sistem II, Addison-Wesley, Reading (Mass).

Lane D. A. (2002): Complessità: Modelli e inferenza, In Complessità e biologia, P. M. Biava (Ed.) Bruno Mondadori Editori, p. 13-42.

Lempert R. J. (2002): *A new decision sciences for complex systems*; PNAS May 14, 2002, vol. 99 Suppl. 3 p. 7309-7313 Colloquium Paper Platforms and Methodologies for Enhancing the Social Sciences through Agent-Based Simulation

Mintz, J., Tulkens, H. (1986): Commodity Tax Competition between Member States of a Federation: Equilibrium and Efficiency, *Journal of Public Economics*, 149-56.

Muellbauer, J. and R. Portes, (1978): *Macroeconomic Models with Quantity Rationing*, The Economic Journal, 788-821.

Nishimura, K. (1998): *Expectation Heterogeneity and Price Sensitivity*, European Economic Review, 42 619-629.

Puga, D. (2002): European regional policies in light of recent location theories; *Journal of Economic Geography* 2(4): 372-406, *cepr Discussion Paper* 2767 – December 2001

Robalino D.A. (2000): *Macroeconomic Policy Implication of Interacting Agents - Social Capital, Technology Diffusion and Sustainable Growth in the Developing World* RAND

Ruby A. (2003): http://www. digitaleconomist. com/intro_4020. html

Salzano M (1993): *Le variabili fiscali nei modelli Neo-Keynesiani* , Liguori Editore, Napoli, 1993 and 2001.

Salzano M. (2005): *Una simulazione neo-keynesiana ad agenti eterogenei;* in Terna, Boero, Morini & Sonnessa, (Ed.) Simulazione, modelli ad agenti e scienze sociali. Mulino

Schelling, T. (1978) *Micromotives and Macrobehavior,* New York: Norton.

Shneiderman (2004): Foreword: Information Visualization: Beyond the Horizon (Chen, 2004). http://www.cs.umd.edu/users/ben/Chen-InfoViz-book-foreword.pdf