From Participants to Agents: Grounded Simulation as a Mixed-Method Research Design

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Abstract:

This paper first introduces a mixed-method research design called *grounded simulation* and then refers to a study on diffusion of innovations for illustrating how this research design can be used. Grounded simulation integrates grounded theory (Glaser and Strauss, 1967) and social simulation. A grounded simulation project starts with in-depth investigations of social phenomena adopting principles and practices of grounded theory. These investigations involve listening to everyday experiences of research participants paying particular attention to *contexts* they describe and the way they make sense of the *rules of the game* in these contexts. Selected findings of the fieldwork are then simulated with agent-based models that generate a high number of virtual objects representing social and economic agents and their interactions. Grounded simulation experiments are suitable for studying the macro-level outcomes of routines, rules and contexts that emerge from the findings of the grounded theory fieldwork.

I. Introduction

Analyses of similarities and differences between social simulation (or computational social science) and more conventional research approaches have been parts and parcels of the scholarly attempts to make sense of this relatively new research route. It has been argued that simulations are the third type of symbol systems- differing from natural language and mathematics (Ostrom, 1988) - and the third way of scientific reasoning - differing from induction and deduction (Axelrod, 2005).

A simulation model typically consists of three main elements: a computer program (or code) that consists of mathematical functions and algorithms, pseudo-random number generators and a set of initial parameter values. The program element of simulation models is at the core of the abovementioned arguments about how simulations differ from different ways of representation and reasoning. The program introduces and describes the concepts that form the model and establishes the rules that govern, produce, or limit their behaviour. Hence, social simulation is a *constructive* research approach where the modeller often constructs a detailed hypothetical reality through his or her step-by-step decisions on the simulation program.

While it has already been repeatedly pointed out that comparable subjectivities apply to more conventional research and modelling tools, it is important to reflect on where such modelling decisions come from in order to be able to assess the strengths and weaknesses of simulation as a social research method. Some relevant questions are: *where do modellers start from when building a simulation model?* and *how do they make the decisions that develop the model?* Finding general and comprehensive answers to these questions may be difficult as modelling practices vary in different research fields, modellers have different styles and approaches and the requirements of research projects may vary. Clear-cut answers to such questions may also limit creative flexibilities this research route accommodates. Yet, certain tendencies in social

simulation practices can be identified for facilitating a dialogue about the strengths and weaknesses of simulation models and the types of knowledge claims they can produce, and guiding relatively new modellers in constructing their own approaches.

As for the starting points of simulation models, existing models, theories and insights related to the subject matter and research questions of the model have long been the usual suspects. In addition to well-established constructs in the field, social simulation researchers commonly refer to models and metaphors from game theory and physical and natural sciences. Since social simulation models are intrinsically dynamic, envisaging the evolutionary origin of the social phenomenon of interest and re-constructing the emergence of abstract, simplistic communities has also been a popular approach in the field. Modellers can also use relatively concrete and straightforward properties of material reality as the starting point of their model.

Regarding the ongoing decisions on developing the model, empirical data and findings have become a common source. Whether done explicitly by citing the existing literature, or intuitively through *commonsense* that modellers refer to while building their simulations, established findings of qualitative studies can influence social simulation models. In a similar way, quantitative data is used for calibrating the parameter values and representing relative importance of entities and relationships that are modelled.

Grounded simulation (GS hereafter) is a mixed-method research design that integrates grounded theory (Glaser and Strauss, 1967) and social simulation. GS aims to explore how research participants perceive and make sense of socio-economic contexts such as routines, norms and interdependencies, translate the research outputs of these explorations into algorithms and mathematical sentences and simulate them to observe the society-level implications of these interactions. From the standpoint of grounded theory fieldwork, GS enables extension of the research findings to other levels (e.g. macro or society level), or new hypothesised contexts and support further theorising under different scenarios. From the standpoint of social simulation, GS enables a closer connection to the way social contexts and various *rules of the game* are perceived and made sense of by individuals than the knowledge, *commonsense* and speculations of the researcher.

As mentioned above, informing social simulation models with qualitative evidence is nothing new. The point being made here is that a mixed-method research design that purposefully combines explorative qualitative fieldwork with simulation experiments has certain advantages over less structured practices. Agent-based simulations are compatible with the assumptions of complexity theory and evolutionary approaches and they are particularly useful in studying interactions and interdependencies between social and economic agents. Hence, understanding the nature and context of these interactions and interdependencies are key to informing agent-based models. Existing or independent qualitative studies of a phenomenon, on the other hand, may initiate from other research fields and objectives that do not focus on these aspects. In this respect, the major advantage of GS is shortening the distance between the qualitative and computational studies.

This paper is organised as follows; the next section presents brief reviews on the different components of grounded simulation. The third section then puts these elements together. The fourth section illustrates the use of the research design with a study on diffusion of innovations. The fifth section concludes.

II. Methodological Foundations

This section explains the methodological foundations of grounded simulation by presenting brief reviews of grounded theory and mixed-method research design. The section also introduces the suggested components of grounded simulation; in-depth interviews and agent-based simulations.

a. Grounded Theory

Glaser and Strauss (1967) define grounded theory as: "discovery of theory from data systematically obtained from social research" (p2). This differs from conventional theory development and verification processes that are intentionally kept separate in modernist social science. The starting point in grounded theory research is not existing theory, hypotheses or the researchers' understanding of commonsense, but data on everyday lives of individuals who have direct experiences of the phenomena of interest. In this sense, grounded theory starts with views and perspectives of those who are at the core of the research area and works *outwards* while analysing data, rather than starting with what researchers think the research area should be like and working *inwards* throughout the analysis (See Facer et al, 2001 for the borrowed terms of outwards and inwards).

As a method or research strategy, grounded theory provides general principles and systematic but flexible guidelines. Delaying literature review until later stages of analysis, theoretical (or purposeful) sampling, recursive stages of data collection and analysis, and constant comparison of data units are among the distinguishing characteristics of grounded theory (Glaser, 1992). Analysis in grounded theory starts with individual units of data. Abstract categories that have a central role in explaining what data signify emerge progressively from continuous comparisons of these units. Later stages of data collection and analysis aim to describe properties of categories and identify their relationships with each other (Charmaz, 2006).

It is important to clarify that not starting from existing theories and with literature review and starting immediately with data collection does not mean that grounded theory research do not refer to the existing literature. On the contrary, while analysing data the researchers may need to refer to a broad range of studies in familiar as well as unfamiliar domains and investigate the insights previous studies provide about what the data in hand signify and vice versa. The aim of delaying the literature review to the later stages of research is not imposing pre-defined categories into the fieldwork data.

As research output, grounded theory consists of clear conceptual categories, descriptions of the properties of the categories and hypotheses or generalised relations among conceptual categories which can be tested by future research. Usefulness and fit-to-purpose of theory are important criteria in grounded theory methodology (Glaser and Straus, 1967). Yet, grounded theory that has all these characteristics may still not be regarded as complete or the end of the study. Given that data collection and analysis is a recursive process, "published word is not the final one but only a pause in the never-ending process of generating theory" (Glaser and Straus, 1967, p40).

By suggesting such flexible yet laborious guidelines, grounded theory challenges the practises of modernist social science where theory development occurs through logical deductions from a set of a priori assumptions. Glaser and Strauss have two considerations about logico-deductive theory development. Firstly, the authors argue that separation of theory and empirical research reflects the belief that a general theory can be applied directly to an empirical area, a belief that often results in practice with

forcing of data to predefined categories and neglecting other and new categories that could have emerged through the fieldwork. Instead, the authors suggest that researcher should also allow substantive concepts to emerge and then evaluate which, if any existing general theories may help generation of substantive theories. Grounded theory does not challenge the validity of logico-deductive theory generation. Instead, it rejects the modernist assertion that logico-deductive theory generation is irrefutably the only, or the best way of developing social science theories.

Secondly, the authors stress that there must be a better balance of efforts between verification and generation of theory. Once again, what is challenged here is not the importance of verification as a basic task in social sciences, but the over-emphasis on it in a way to deter theory generation. The authors argue that logico-deductive method of theory building and the over-emphasis on quantitative verifications support a scientific environment in which few grand theories, which may in fact lack foundation in systematically analysed data, are reformulated, modified, perfected and- due to lost emphasis on theory generation- seldom replaced. Glaser and Strauss argue that the conventional practice thus creates "theoretical capitalists" and "the mass of proletariat testers". In contrast, the authors argue that "it does not take a 'genius' to generate a useful grounded theory" (p.11), encouraging middle-range theories about specific social phenomena of interest (Glaser and Strauss, 1967; Charmaz, 2006, see also Merton, 1949).

b. Mixed-method Research

The term mixed-method commonly refers to employing both qualitative and quantitative methods (Johnson et al, 2007) in a research project and mixing in this context refers to "*the multifaceted procedures of combining, integrating, linking and employing multi-methods*" (Creswell et al, 2003; p. 212). While most authors regard mixed-methods as a research design strategy (Creswell and Plano Clark, 2011), there are also others, who see it as a distinct methodology, or the '*third methodological movement*' (Tashakkori and Teddlie (2003, p.ix).

The general aim of mixing methods is obtaining a better understanding of the phenomenon of interest than what qualitative or quantitative methods can provide on their own. Using both qualitative and quantitative methods can compensate for the weaknesses of each type of method, allowing both the perspectives of participants to be heard and comprehensive snapshots of the phenomena to be obtained. In their review of mixed-method studies, Green and colleagues (1989) identified that such improved understandings can be useful for various purposes including: triangulation (comparing results from different methods studying the same phenomenon), complementarity (enhancing findings of one method with others), development (using the results of one method to develop and implement another), initiation (discovering contradictions that reframe research questions), or expansion (of the breadth and range of inquiry through new inquiries). In addition, mixed-method research often facilitates collaboration and exchanges between different research domains, providing a broader range of theories and frameworks for the study (Creswell and Plano Clark, 2011).

Mixing can occur within one study or throughout several studies in a research project or programme (Creswell, 2003). The mixed-method design in which different types of data are collected in separate phases of research is called sequential (Creswell, 2003) or component (Caracelli and Greene, 1997) design and this is distinguished from concurrent (Creswell, 2003) or integrated (Caracelli and Greene, 1997) design in which different types of data are collected simultaneously.

c. In-depth Interview

In-depth interview is a frequently used qualitative research method that aims for obtaining what is commonly referred to as *thick descriptions* of social reality. In-depth interviews allow participants to provide a more complete description of their perspectives (Patton, 1990) and the researcher to explore unexpected findings. The underlying assumption of in-depth interviews is that individuals have important knowledge about the world, which can be accessed through an active questioning and listening process (Hesse-Biber and Leavy, 2006). In this method, the researcher allows the participants enough time to develop their own perspectives in issues that they see as important and relevant (Green and Thorogood, 2004).

While Webb and Webb (1932, p130) define interview as a 'conversation with a purpose', Kvale (1996) points out some of the differences between interviews and daily conversations. Accordingly, an interview goes beyond casual exchange of information and becomes a careful questioning and listening process. In addition, an interview is not symmetrical like a casual conversation; the researcher has some control over the conversation through the interview questions. Green and Thorogood (2004) compare a research interview with a job interview, a clinical history-taking and a police interrogation. The authors explain that unlike the job interview, a research interview does not aim to test the participants but rather to explore and compare their accounts for understanding the underlying structures. Unlike the health professional in clinical history-taking, the researcher does not aim to narrow down participant's responses to information that is useful for diagnosis according to previous knowledge but rather, tries to open up the responses without presumptions. Finally, unlike in a police interrogation, in a research interview existence of only one version of truth is not assumed. Instead, each participant's story is valid as his or her perspective of the phenomena.

There are two interrelated epistemological considerations about in-depth interviews. Scholars debate on the extent to which knowledge is created during the interview as opposed to reflecting a prior reality, and the extent to which active participation of the researcher is desired. Kvale (1996) uses two metaphors to illustrate two perspectives related to these considerations: interviewer as miner or traveller. The first perspective is positivistic and it regards knowledge as given. As follows, truth is like some buried metal and interviewing is an attempt to unearth it. The second perspective is constructionist and it regards knowledge as created. Interviewing therefore is a journey that collects narratives and impressions, and produces a story after returning home.

Miller and Glassner (2004) argue that while positivistic view has been criticised for not being realistic, the constructionist view that underlines knowledge is strictly context-specific does not offer much for those who would like to learn about social phenomena through interviews. In contrast, the authors suggest that narratives come out of worlds that exist outside the interview and researchers are capable of capturing elements of this world through their study. In this respect, "research cannot provide the mirror reflection of the social world that positivists strive for, but it may provide access to the meanings people attribute to their experiences and social worlds" (p.126).

In-depth interviews fit grounded theory approach quite well. From the perspective of grounded theory, in-depth interview questions should be general enough to cover different types of experiences and narrow enough to encourage the participant to elaborate on his or her specific experiences. In-depth interviews can provide large amount of data covering both descriptions and explanations of social phenomena, and therefore reduction of data with analytical and interpretive processes can be considered as an inseparable part of this research method (Hesse-Biber and Leavy, 2006). Within

the general guidelines of grounded theory, researchers should pay attention for not forcing data into perceived categories while analysing interview data (Charmaz, 2006).

d. Agent-based Modeling

When compared to qualitative and quantitative methods, computational methods based on computer simulations are relatively new. Computational methods facilitate systematic reasoning and analysis on complicated or complex settings by generating virtual elements that are thought to imitate real-life processes (Hartmann, 1996). Many of the assumptions needed for mathematical and statistical analyses can be relaxed in these simulations (Bankes, 2002).

Agent-based modelling is a computational method that generates many independent and interacting virtual agents (Macal and North, 2005) that are also the primary units of analysis (Garcia, 2005). Agents are "*self-contained programs which can control their own actions based on their perceptions of their operating environment*" (Huhns and Singh, 1998). That being said, typically in an agent-based model (ABM hereafter), there are both micro-level and macro-level rules (Casti, 1997) that specify the attributes and behaviour of agents. In this sense, while being autonomous and heterogeneous, agents are often instances of a more general category and share common properties. The rules that define agents' behaviour (or behaviour space) are often in the form of *if-then-else* statements embedded in the simulation program. Agents in an ABM can be built to represent independent (Bonabeau, 2001) and adaptive (Mellouli et al., 2003) individuals, or elements in a system. Through representations of individuals and their behaviour, ABM provides a more "*direct correspondence"* (Gilbert, 2008; p. xi) between what is empirically observed and modelled than, for example, in statistical modelling.

Like other types of modelling, agent-based modelling brings about simplifications (Gilbert and Troitzsch, 2005) of the perceived reality. Yet, it offers a different way of simplification by enabling the study of non-linear systems dynamically and as a whole, rather than in parts, to the extent that this reality can be reduced to mathematical and algorithmic abstraction. Instead of concentrating on a specific element, ignoring non-linearity or reducing the system to a set of causal variables and an error term, ABM studies how complex outcomes can be produced by simple schemata, depending on the ways agents interact (Garcia, 2005). This property is particularly useful to study emergent macro-level patterns of processes that involve the interaction of many heterogeneous and adaptive agents.

Hence, important conceptual elements of an ABM include: (i) different classes of agents and their attributes, (ii) their behaviour and interactions, (iii) the environment where these interactions take place and (iv) the history-dependent connections between simulated events. While building their ABM, modellers make explicit or implicit decisions on these elements. The ABM can then be used to run a large number of complex thought experiments (Di Paolo et al., 2000; Korb, 2007).

ABM can be built in different levels of detail. Gilbert (2009) defines a continuum, which has facsimile models - very detailed models of a very specific process- at one end and abstract models - simplistic models of general processes- at the other. The facsimile models aim for quantitative prediction and therefore their empirical validity can be tested. These models, on the other hand, do not provide much in terms of understanding complex phenomena. Abstract models have the opposite properties, they provide insight into complex processes but they provide qualitative prediction or generate macro-level patterns that seem plausible instead of quantitative prediction. Recognising merits and limitations of both ends, Gilbert emphasises the usefulness of middle-range

models referring to Merton (1949, like Glaser and Strauss, 1967 while explaining grounded theory).

III. Grounded Simulation

This section puts together the elements that are introduced in the previous section - grounded theory, mixed-method research design, in-depth interviews and agent-based modelling - to form a research design for studying complex and dynamic social phenomena. This research design is called grounded simulation (GS) and it involves mixing in-depth interviews following grounded theory approach with ABMs. The basic premise of GS is investigating perspectives and day-to-day experiences of individuals who are involved in the phenomenon of interest aiming to reflect the contexts and rules that emerge from the narratives of research participants while constructing ABMs.

The findings of the grounded theory fieldwork can inspire and inform ABMs in at least two dimensions. They provide insights and information about the social context of the phenomena interest and the behavioural patterns related to these contexts. Information on social contexts is likely to be subtler, covering the classes, attributes and relationships of the agents as well as the important elements and/or properties of their environment. As complex social phenomena often involves abundance of dynamic relationships, reducing the perceived reality to the elements that seem more relevant to the grounded theory fieldwork participants is an important step for modelling. Information on the behavioural patterns shapes the actions of the agents and correspondingly the events in the simulation experiments. This information can cover the grounded theory participants' routines and habits as well as the way they perceive the *rules of the game*, that is the conditions and causalities that restrict their behaviour.

GS expands the use of mixed-methods to include computational methods. Although mixing experiments with observation has long been used in natural sciences (Maxwell and Lewis, 2003), the experiments in GS are thought experiments and the type of quantitative data collected through ABM's are simulated data. In this respect, GS is somewhat different than more conventional mixed-methods designs.

GS benefits from Glaser and Straus's (1967) views on grounded theory at two levels. Firstly, the qualitative fieldwork in the first phase of the research project is carried out according to the guidelines of grounded theory research for sampling, data collection and analysis. Secondly, the overall approach of grounded simulation is inductive, aiming to develop theory through social research and thought experiments, starting from individual units of data, moving *outwards* gradually but systematically towards theory building.

Although specific research designs and action plans may differ from project to project, the purpose of mixing in GS is closest to what Greene and colleagues (1989) call *complementarity* and *development* purposes, as the in-depth interviews and ABMs are used for studying overlapping but different aspects of the phenomena and the findings of the in-depth interviews are used to develop ABMs. Moreover, GS is generally compatible with *sequential* (or component) design where, the findings of qualitative and quantitative studies can be reported independently (Creswell, 2003), although the simulation study would probably cite the grounded theory study while explaining the modelling decisions and assumptions.

A sequential design GS project that involves mixing for complementarity and development purposes starts with in-depth investigations of social phenomena adopting principles and practices of grounded theory. These investigations involve listening to

everyday experiences of research participants paying particular attention to *contexts* they describe and the way they make sense of the *rules of the game* in these contexts. Selected findings of the fieldwork are then simulated with agent-based models that generate a high number of virtual objects representing social and economic agents and their interactions. Agent-based simulation experiments are used for studying the macro-level outcomes of contexts, routines and rules that emerge from the findings of the grounded theory fieldwork. In terms of the research outputs, sequential design allows the outputs of the grounded theory fieldwork and the ABM to be reviewed separately by most relevant research communities. It can also enhance the research's contributions to the existing literature by increasing the number of research outputs that are aimed for and broadening the audience.

GS is different from in that it purposefully combines explorative qualitative fieldwork and simulation experiments around common research interests and complementary research questions. In remaining of this section, I will elaborate on what GS has to offer as a research design as well as its limitations and possible drawbacks. At the positive side, GS is likely to provide an *even more direct correspondence* between what is observed and what is modelled than ABM's already offer independently. The grounded simulation model, as an integrated output of the research project is still a simplification of the phenomena of interest. Yet this simplification is done by taking what individuals who are at the centre of the phenomena perceived as relevant as the starting point rather than what the modellers expects or assumes to be relevant.

Another aspect of the *even more direct correspondence* is that ABMs are suitable for addressing some particular aspects of social complexity. They work particularly well when understanding evolutionary outcomes of social processes, spatial and geographical patterns, the role of social networks, interdependencies, expectations, and/or heterogeneity is important for understanding the subject area of the research. While these concepts and constructs are strongly embedded in the operation logic of complexity science, they may not necessarily be at the focus of the existing and/or independent qualitative studies, which may have initiated from other research domains with different assumptions and objectives. As GS is designed based on common research objectives and complementary research questions, it provides the researchers with the opportunity of covering these issues in the grounded theory fieldwork. Hence, the main point of GS is shortening the distance between the qualitative and computational studies, or between the research participants and agents.

As mentioned above, GS offers some advantages, especially for the study of social complexity. There are, however, some drawbacks related to GS too. Firstly, the research design should allow for adequate time for the grounded fieldwork and, more significantly, the laborious, inductive analysis of the fieldwork data. Secondly, and equally practically, most researchers are not trained both in qualitative research in grounded theory tradition and in simulation modelling. GS may require adoption of new research skills and/or interdisciplinary or inter-method collaborations between researchers.

Furthermore, and more strategically, as one of the main guidelines of grounded theory is not forcing data into predefined categories, it is not possible to guarantee that the findings of the fieldwork will produce emergence of counterintuitive macro-level patterns that enhances the face value of research outputs in complexity theory communities. Then again, against the background of the richness and high level of dynamism complex social processes involve, it is very likely that researchers can obtain useful and coherent understandings of these under-explored settings and construct novel and original simulation models of them by listening to individuals who are at the core of these systems. Then once again, at the practical side, in some cases, it may be

more difficult to disseminate and publish such original models compared to ones that are positioned closely to existing well-known models.

IV. Illustration: A Grounded Simulation Model of Early Adoption Advantages During Diffusion of Innovations

This section illustrates the use of GS referring to the author's doctoral research project (Dilaver Kalkan, 2009) on consumer interdependencies during diffusion of innovations. It may be useful to note at the beginning that the GS design was not first developed and then applied to this doctoral research project, but it emerged out of the research requirements of this particular research as well as the author's methodological inquiries. The important gaps identified in the diffusion of innovations literature at the time, revealed the need for improving theoretical explanations of diffusion and the disappearance of qualitative studies in the diffusion literature highlighted the need for once again listening to viewpoints and experiences of individuals rather than speculating on behaviour and interactions of individuals, or, like it is common in the field, assuming all innovations are good for everyone, and so non-adoption can only be understood if we can find what is wrong with non-adopters.

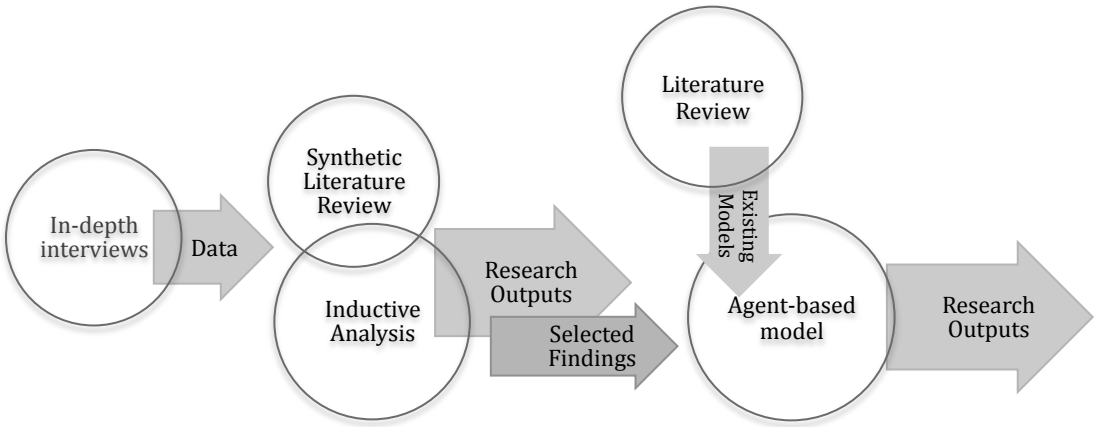

Figure 1: Research design of the diffusion study

Figure 1 shows the research design that emerged during the research project. The project produced two grounded theory papers and two simulation studies. Since adequately summarising all four studies would take more space than available the section concentrates on two that investigated early-adoption advantages and modelled the perceived *rules of the game* about these advantages. It suffices here to note that the remaining two studies focused on the context of diffusion, how individuals make sense of the value of innovations and different forms of selectivity diffusion involves with respect to characteristics and relationships of individuals. In the subsections that follow, first the background and motivations of the research are reviewed and then the mixing of in-depth interviews and ABMs are explained.

a. Background and Motivations:

Diffusion of innovations is an interdisciplinary research field expanding across the research interests of various disciplines. In terms of explaining how diffusion occurs, theoretical approaches vary in different research streams. Following studies on diffusion of agricultural innovations in rural sociology (Ryan and Gross, 1943; Rogers, 1995), some researchers think of diffusion as a communication and imitation process (see, for example Bass, 1969). Others, who are familiar with the diffusion studies in economics, regard diffusion as the cumulative result of rational decisions of individuals where costs and benefits of technology adoption improve in time (see probit approach in Stoneman, 2002). In more recent studies, diffusion is seen as a complex process in which costs and/or benefits of adoption improve with the number of existing adopters and hence the adoption decisions of individuals are interdependent.

In terms of empirical orientations, diffusion studies have almost disappeared in sociology in the recent decades (see, for example, Ruttan, 1996 for rural sociology) and in other disciplines, research efforts have been mainly quantitative, focusing on temporal aspects of diffusion. These inclinations produced analyses that work inwards from a priori definitions of adoption and diffusion, rather than working outwards (Facer et al, 2001), taking individuals' perspectives and experiences as the starting point.

The research project being summarised here aimed to improve existing theories on inter-consumer diffusion process and it focused on understanding the nature of interdependencies between adoption decisions of consumers. Interdependencies in this context means that the costs and/or benefits of adoption vary with the number and/or characteristics of previous adopters. The two major types of interdependencies are increasing and decreasing returns to adoption. In the former, the innovation becomes more attractive and, in the latter, it becomes less attractive as more agents adopt it. Following the seminal studies of Granovetter (1978), Farrell and Saloner (1985) and Arthur (1989), increasing returns to adoption (IR hereafter) is applied to both inter-firm and inter-consumer diffusion. The literature on decreasing returns to adoption (DR hereafter), however, remains limited and fragmented. This ambiguity about DR is problematic for at least two reasons. Firstly, neglecting early adoption advantages implies the assumption that there is no gain from innovativeness for consumers. Secondly and in relation to that, it is difficult to explain how the diffusion process begins when the only strategic action that consumers can take is waiting for adoptions of others.

b. Fieldwork:

The fieldwork of the GS study presented in this paper aimed to address the abovementioned gaps in the literature. how value of ICT is constructed by comparing a rapidly diffusing innovation with a relatively slow diffusing one. It aimed to study if and how individuals perceive adoption-related interdependencies with in-depth interviews. It aimed to explore if early adoption was a meaningful strategic action that research participants might consider to take and to unpack different components of early adoption advantages through the narratives of the research participants.

The study employed the grounded theory approach (Glaser and Strauss, 1967) and the data were collected with in-depth interviews. As *interdependency* is not an everyday concept, interview questions focused rather on the order of adoption and inquired whether adopting earlier or later than others in one's social environment had any meanings for the research participants.

Maximum-variation sampling strategy (Patton, 1990; Maykut and Morehouse, 1994) was adopted to select participants. This strategy involves selecting persons or settings that represent the greatest differences in relevant characteristics in order to obtain the broadest range of information. The recruitment of participants was done using the snowball technique and as the number of participants increased individuals who were different from the earlier participants in terms of gender, income, age and education were prioritised. Saturation with regards to the content of responses was reached after interviewing 48 participants. The resulting sample includes participants who vary between ages of 16 and 85, and 26 of the participants were female.

Data analysis was done inductively starting with open coding. All the narratives concerning what the two innovations mean for the participants were broken into units of meaning (Strauss and Corbin, 1990), which were then grouped under themes, constantly comparing different themes with each other and the case of computers with the case mobile phones. In line with the guidelines of grounded theory (Glaser and Strauss, 1967; Patton, 1990), the literature review, which is presented above, was not done before the fieldwork in order not to impose pre-defined structures during the collection of the data. Instead it was undertaken simultaneously whilst analysing the data, guided by the initial findings.

The findings of the fieldwork show that the research participants recognise different kinds of motivations for adopting innovations earlier than others and unpack different components of these early adoption advantages (EAA hereafter). Competitions of different sorts between the society members are at the core of these advantages. Furthermore, in most of the stories told by the participants, the value created by using the innovation is gained at the expense of some others. These stories also highlight the highly dynamic nature of EAAs. They show that the shared meanings attached to adoption and the strategic actions that individual can take co-evolve rapidly in response to the number and characteristics of existing adopters and the newly launched products. Overall, although an innovation may bring some additional value to the society, such as better outputs or more efficient production processes, arguably the bigger share of the EAA is a result of the redistribution of existing values within the society.

c. Simulation Experiments:

The simulation part of the study focused on early adoption advantages and the competitive nature of these interdependencies. Computer simulations were used as thought experiments aiming to reveal the macro-level outcomes of micro-level interactions. The model was intentionally kept simple so that the simulation results, which were not known prior to the simulation experiments, could easily be traced back and understood.

Agents in the model represent consumers and a pseudo-society consists of 1,000 agents. Social networks of the pseudo-societies are modeled based on an abstraction of social class structures. Agents are heterogeneous with respect to an attribute, which can be thought as the combined effect of human and financial capital. It is then assumed that networks are built based on this attribute; agents choose their friends randomly from a range of agents around themselves in the rank of accumulated characteristics. Institutions, which can be in conformity or conflict with the innovation, are modeled on top of this social network structure.

As briefly reported above, it was identified in the fieldwork that the most of the early adoption advantages are in the form of competitions between society members. This property of the phenomenon corresponds to constant-sum games in game theory literature. The simulation experiments covered both variable and constant-sum early

adoption advantages. In the constant-sum scenarios, the adoption decision of the agents was modelled in a way that agents benefit from the innovation if they adopt it earlier than others.

Hence, the adoption decisions of agents are modelled as cost-benefit comparisons with the effect of consumer interdependencies. Adoption decisions are influenced by the effect of institutions, the expected EAA and the cost of adoption. The innovation has a limited product life of two periods. Once agents adopt the innovation, they remain adopters for two periods. At the end of the product life they make a new adoption decision. A total of 6,000 simulation experiments were run under different scenarios and parameter values.

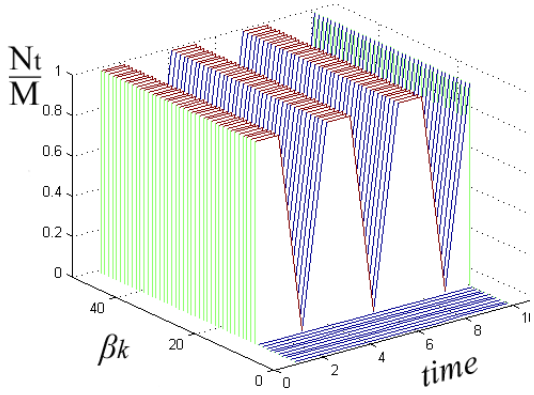

Figure 2a: Variable-sum EAA

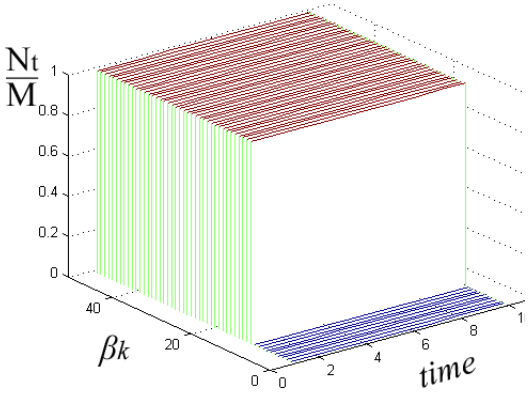

Figure 2b: Constant-sum EAA

Simulation findings revealed that when early adoption advantages are in the form of variable-sum games, diffusion outcomes at the macro level follow oscillating patterns like in Figure 2a. This oscillation occurs because the expectations about diffusion are built adaptively. In the first period all agents expect that the diffusion will be low and so their early adoption advantages will be high enough for them to adopt. In the next period, however, they see that the actual diffusion level is very high; all agents are adopters. This means they are not creating any use-value with the innovation at all. When the end of the product life comes, expecting the future diffusion levels will continue to be high, they cease adoption.

More interestingly, when the innovation entails constant-sum early adoption advantages, the society locks-in to the innovation as shown in Figure 2b. That is, at first, like in the variable-sum scenario, all agents adopt expecting that the diffusion levels to be low and their use-value will be high. When they realise that actual diffusion levels are high, on the other hand, they do not cease adoption as in the previous scenario. This is because if they cease adoption, they may be one of the few non-adopters who need to bear the loss corresponding to the early adoption advantages of adopters. Hence, they continue adopting the innovation, albeit not happily.

This demonstrates an interesting possible outcome of consumer interdependencies: involuntary technology adoptions. That is; for some society members, adoption is a worse state than their initial state before the launch of the innovation. Once the innovation is launched and some adoptions occur, however, non-adoption becomes an even worse state. The major implication of involuntary technology adoption is the possibility that a society 'locks-in' to inefficient, partially harmful or destructive technologies that entail this particular form of consumer interdependency.

V. Conclusions

This paper introduces a mixed-method research design that supports the *constructive* nature of computational social science research with the *inductive* and *hands-on* principles of grounded theory. The research design mixes in-depth interviews with agent-based modelling for this aim. This mixing of methods results with a research approach that starts from the way interview participants perceive and experience their environments and social contexts, their relationships and the conditions, motivations and causalities that shape their behaviour.

This approach is likely to deliver more realistic or relevant models compared to those in which the modeller takes his or her own worldview or commonsense as the starting point because it gives voice to individuals who are more directly involved in the processes, issues and problems the modeller aims to address. Compared to models built on extensive literature review, GS design both has advantages and disadvantages. It may fall short of referring to all theoretical arguments in the existing literature in all their depth, richness and conceptual aesthetics but in cases where path-dependent development of academic literature diverges from the fundamental properties of the continuously evolving and complex social realities, GS has the advantage of breaking the path and making a fresh yet well grounded start. With regards to models built based on exiting empirical data, GS offers a direct correspondence between interest areas of social simulation and complexity theory with the topics of discussion and inquiry in the fieldwork.

References:

Arthur, W. B. (1989) 'Competing Technologies, Increasing Returns, and Lock-in by Historical Events', *Economic Journal*, 99(394), 116-31.

Axelrod, R. (2005) 'Advancing the Art of Simulation in the Social Sciences', forthcoming in Rennard, Jean-Philippe (ed.) Handbook of Research on Nature Inspired Computing for Economy and Management, Hersey, PA: Idea Group.

Bankes, S.C. (2002) Agent-based modeling: A revolution? Proceedings of National Academy of Science (PNAS), 99 (3), 7199–7200.

Bass, F.M. (1967) 'The New Product Growth For Model Consumer Durables', Management Science, 15(5), 215-227.

Bonabeau, E. (2001) 'Agent-Based Modeling: Methods and Techniques for Simulating Human Systems', Proceedings of the National Academy of Sciences, 99(3), 7280-7287.

Caracelli, V. J. and Greene, J.C. (1997) 'Crafting mixed-method evaluation design', in Greene J. C. and Caracelli V. J. (eds.), Advances in mixed-method evaluation: The challenges and benefits of integrating diverse paradigms [New Directions for Program Evaluation No. 74], San Francisco: Jossey-Bass, pp. 19-32.

Casti, J. L. (1997) 'Would-be worlds: how simulation is changing the world of science', New York: Wiley.

Charmaz, K. (2006) Constructing grounded theory: a practical guide through qualitative analysis, London: Sage.

Creswell, J.W. (2003) 'Research Design: Qualitative, Quantitative, and Mixed Method Approaches, Thousand Oaks, London and New Delhi: Sage.

Creswell, J.W.; Plano Clark, V.L.; Gutmann M.L. and Hanson W.E, (2003) "Advanced Mixed Methods Research Designs", in Tashakkori, A. and Teddlie, C. Handbook of mixed methods in social & behavioral research, Thousand Oaks, London and New Delhi: Sage, 209-240.

Creswell, J.W., and Plano Clark, V. L. (2011). Designing and conducting mixed methods research (2nd ed.). Thousand Oaks, CA: Sage.

Dilaver Kalkan, O. (2009) Competition and Co-operation: Four Studies on Consumer Interdependencies during Diffusion of Innovations, Unpublished PhD Thesis, Lancaster University Management School.

Di Paolo, E.A., Noble, J. and Bullock, S. (2000) 'Simulation models as opaque thought experiments', in: Seventh International Conference on Artificial Life, 497-506, Cambridge, MA: MIT Press.

Facer K, Sutherland R, Furlong R, and Furlong J (2001) What is the point of using computers?: The development of young people's computer expertise in the home. Farrell, J. and Saloner, G. (1985) 'Standardization, Compatibility, and Innovation', The RAND Journal of Economics, 16(1), 70-83.

Garcia, R. (2005) 'Uses of Agent-Based Modeling in Innovation/New Product Development Research', Journal of Product Innovation Management, 22(5), 380-98.

Gilbert, N. (2008) Agent-based Models, London: Sage.

Gilbert, N and Troitzsch, K.G (2005) Simulation for the Social Scientist, Buckingham and Philadelphia, Pa: Open University Press.

Gilbert, N (2009) 'Middle Range Models: Modelling Real World Social Processes' Conference Proceedings of European Conference on Complex Systems, University of Warwick, September 21-25, 2009.

Glaser B. G. and Strauss, A. L. (1967) The discovery of grounded theory: strategies for qualitative research, Chicago: Aldine.

Glaser, B.G. (1992) Emergence vs Forcing: Basics of Grounded Theory Analysis, Mill Valley, CA: Sociology Press.

Granovetter, M. (1978) "Threshold Models of Collective Behavior", American Journal of Sociology, 83(6), 1420-1443.

Green, J.C., Caracelli, V.J. and Graham, W.F. (1989) "Toward a Conceptual Framework for Mixed-Method Evaluation Designs", Educational Evaluation and Policy Analysis, 11(3), 255-74.

Green, J. and Thorogood, N. (2004) Qualitative Methods for Health Research, London: Sage.

Hartmann, S. (1996) "The World As a Process", in R Heselmann, U Müller and K Troitzsch (eds), Modelling and Simulation in the Social Sciences from the Philosophy of Science Point of View, Dordrecht: Kluwer, 77-100.

Hesse-Biber, S. N. and Leavy P. (2006) The Practice of Qualitative Research, Thousand Oaks, CA: Sage.

Huhns, M.N. and Munindar, P.S. (1998) Readings in Agents, San Mateo, CA: Morgan Kaufmann.

Johnson, R.B., Onwuegbuzie, A.J. and Turner, L.A. (2007) " Toward a Definition of Mixed Method Research", Journal of Mixed Method Research, 1(2), 112-33.

Korb, K. (2007) 'The Epistemology of Computer Simulation', 13th International Congress of Logic Methodology and Philosophy of Science, Beijing, 9-15 August, 2007 and The Epistemology of Computer Simulation: The Big Questions, both retrieved from <http://www.csse.monash.edu.au/~korb/> on 4 March 2009.

Kvale, S. (1996) Interviews: An Introduction to Qualitative Research Interviewing, Thousand Oaks, CA: Sage.

Macal, C.M. and Michael J. N. (2005) 'Tutorial on Agent-Based Modeling and Simulation', in. Kuhl, M. E ; Steiger, N. M.; Armstrong, F. B. and Joines, J. A. (eds.) Proceedings of the 2005 Winter Simulation Conference.

Mellouli, S.; Moulin, B. and Mineau, G.W. (2003) 'Laying the foundations for an agent modelling methodology for fault tolerant multi-agent systems', in Omicini, A., Pett, P. and Pitt, J. (eds.) Fourth International Workshop Engineering Societies in the Agents World, Revised Selected and Invited Papers, Springer, 275-293.

Merton, R. K., (1968, [1949]) Social theory and social structure, New York: Free Press.

Maxwell, J.A. and Lewis, D.M. (2003) 'Mixed Methods Design: An Alternative Approach', in Tashakkori, A. and Teddlie, C. Handbook of mixed methods in social & behavioral research, Thousand Oaks, London and New Delhi: Sage.

Maykut, P. and Richard M. (1994) Beginning Qualitative Research: A Philosophic and Practical Guide, London: The Falmer Press.

Miller, J. and Glasner, B. (2004) 'The 'Inside' and the 'Outside': Finding Realities in Interviews', in Silverman, D. (eds) Qualitative Research: Theory, Method and Practice, London: Sage.

Ostrom, T.M. (1988) 'Computer Simulation: The Third Symbol System', Journal of Experimental Social Psychology, 24(5), 381-392.

Patton, M. Q. (1990) Qualitative evaluation and research methods, Newbury Park, CA: Sage.

Rogers, E.M. (1995, [1962]) Diffusion of Innovations, New York: Free Press.

Ruttan, V.W. (1996) "What Happened to Technology Adoption-Diffusion Research", Sociologia Ruralis, 36(1), 51-73.

Ryan, B. and Gross, N.C. (1943) 'The Diffusion of Hybrid Seed Corn in Two Iowa Communities', Rural Sociology, 8(1), 15-24.

Stoneman, P. (2002) The Economics of Technological Diffusion, Oxford: Blackwell Publishers Ltd.

Strauss, A.L. and Corbin J. (1990) Basics of qualitative research: Grounded Theory Procedures and Techniques, Newbury Park: Sage.

Tashakkori, A. and C. Teddlie (2003). Handbook of Mixed Methods in Social and Behavioral Research. Sage: Thousand Oaks, C.A.

Webb, S. and Webb, B. (1932) Methods of Social Study, London and New York: Longmans, Green.