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Money, payment systems and innovation: simulation of a trust based model

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Introduction

The interest in diverse aspects from which we are fascinated led us to the realization of this work, first of all the perception of the centrality of trust and social relationships both to ensure the good functioning of economy and to accept an increasingly dematerialized money, secondly a personal curiosity towards initiatives developed on the web that have as their aim to innovate over the standard way of operate and thirdly the desire to gain a greater understanding of the methods and opportunities offered by agent-based modeling and computer-aided simulations.

More precisely the web project that inspired us is named Ripple and it is an open decentralized payment system in which people declare how much they trust their acquaintances indicating a maximum level of credit available to them and then let the system find, in the whole network of relationships, trusted pathways of available credit from a buyer to a seller in order to execute the payment of purchases through consecutive undertakes to pay.

The core of our work is the development of two NetLogo models, the first named Card model which is a simplified representation of a payment system based on credit cards and the second named Trust Based Model (TBM) that is a similarly simplified payment system based on social relationships of people which is inspired by the idea of Ripple but it is a completely original version. In the development of the two models we adopt a common approach which consists in imposing some assumptions, that sometimes may not be as likely, and we consider as common benchmark a situation in which transactions occurred only by cash.

We would like to clarify that with this work we do not want to prove any proposition, but rather our goals are to deepen the understanding of real world payment systems and, through the potential offered by agent-based simulations, to make an informed judgment about the strengths and

weaknesses of an alternative payment system based on social relationships of people such as that offered by our Trust Based Model.

In chapter one there is a review of some interesting results from neuroscience and sociology literature. Through the analysis of the results obtained in other studies, we initially observe how the central concept in Economics of Homo economicus is sometimes an oversimplified assumption as the analysis of the behaviors of people suggest that also emotions, sentiments and moral constraints matter. In the second part of this first chapter after recognizing that uncertainty is a prerogative in the life of every man we focus on the concepts of trust and confidence as they are the essential ingredients in the functioning of the economy, then we make a brief overview on the topic of Social Capital referring to ideas developed by sociologists such as Putnam, Bourdieu and Coleman; the most important element of this chapter is the recognition that the economic system is a network composed by people who intertwined relationships between them.

In chapter two we adopt a more historiographical approach by initially reviewing some different theories, with respect to mainstream, related to the origin of money and secondly by offering a view that sees the confidence in the state as a central element in the process of birth of generally accepted money. Then, we retrace the various stages leading to actual banking system highlighting the progressive shift from trust to confidence occurring in the various steps. Finally, we provide a brief description of a newly created virtual currency named Bitcoin.

In chapter three we analyze the infrastructure of different payment systems which allow the execution of cashless payments with the use electronic money. Initially without going into details we take care of interbank payment systems, then we focus on the structure of payment systems offered by card association through the means of credit cards and debit cards; in this section, referring to literature of two-sided market, we devote particular attention to the role of interchange fee and no-surcharge rule in "getting both sides on board" (Rochet and Tirole, 2003). In the last part of this chapter we briefly describe the original version of Ripple project from which we have drawn inspiration for our Trust Based Model.

In chapter four we initially describe the problem of complexity in Economics and how proponents of Agent-based modeling think to address it

with computer-aided simulations, then we devote a rather long section to describe firstly the basic of graph theory and secondly the three approaches commonly adopted to the modeling of real networks, finally we conclude with the presentation of the programs that we used for the construction of our simulations: NetLogo, Python and NetworkX.

Chapter five represents the core of our work. This chapter is divided into three parts: the first is dedicated to the explanation of Card model, the second to the explanation of Trust Based Model and in the third section there are some considerations related primarily to substantive differences between the two models. We decided to adopt a common approach in dealing with both models, we firstly describe the general structure and the NetLogo interface with which a potential user is called to interact, then we continue with the precise analysis of the parts of code, in our opinion, the most interesting and finally we run some simulations which we hope will be of interest to the reader. In the section related to Trust Based Model there is also a part in which we describe our tricky solution to the problem of having the NetLogo program interacting in real-time with the Python script developed ad-hoc to find trusted pathways from buyers to sellers.

Finally, Appendix A lists the NetLogo source code of both models while in Appendix B there is the Python source code related only to Trust Based Model: first the script that find pathways and let "I owe you" (IOU) to flow from buyers to sellers, and secondly the modded maxflow.py file present in NetworkX package.

Chapter 1

Neuroscience and sociology

1.1 Economics and insights from neuroscience

The incursions of economics in issues strictly related to psychology and sociology or vice versa are common, moreover other fields come up and also for the layman is not surprising to hear about experimental economics or behavioral economics. Sometimes, one of the result of these interconnections is that theories once rejected by the mainstream view are rehabilitated and receive new life; in fact the social sciences differently from the hard sciences (as mathematics) are characterized by a never ending research of new ideas and improvements of existing ones, that rarely reach the status of truism.

The reason of this peculiarity is to be identified in the mutable subject of study of social sciences, the *man* and the various forms in which he organizes as family, groups and society are always different due to evolutionary process. The mutable nature of man and the environment in which he lives does not mean that there are not similarities among different periods but only that things do not repeat exactly equally to themselves.

Besides it is commonly accepted that among the huge amount of studies, researches and publications the number of really breakthrough idea is limited, so it is not unusual that (also at distance of years) old but yet known ideas make their reappearance on surface, sometimes under different clothes, other times in a form immediately recognizable. We think that the short introduction above were necessary for the characterization of the following discussion, as a sort of *where we are*. In the subsequent paragraphs we will talk about the concept of *Homo economicus*, contrasting the mainstream

idea with insights on one hand from cognitive neuroscience and on the other hand from tenets of the legacy of Austrian school of economics, maintaining on the background the current world crisis that started in 2007 with the bust of the *housing bubble* in the US.

The current crisis is the last example of a long list of crisis characterized by the rise and then bust of a bubble, the Austrian authors like Hayek, Mises and Böhm-Bawerk identify as common causal mechanism a misallocation of resources that lead to invest too much in projects that finally would show up as unreliable; see French (2006) for an Austrian interpretation of tulip-mania in seventeenth century.

Without forgetting that the Austrian business cycle theory has as starting point of each cycle an unsustainable expansion of money supply, here we want direct attention to the subsequent phase of the process where individuals, both considered as consumers or producers, regularly take wrong decisions; how is it possible? This systematic erratic behavior is strongly rejected by the mainstream authors adherent to *Rational choice theory* which has as central figure that of *Homo economicus*; more specifically the *Homo economicus* is the concept of human beings as rational actors who have the ability to compare different opportunities from which choose rationally and consciously the best solution for their self-interest. The *Homo economicus* acts as a maximizer of an ideal personal utility function, trying to maximize its benefits and minimize its costs given its own preferences; the standard assumptions of Rational choice theory about individual's preferences are those of completeness, transitivity and independence of irrelevant alternatives.

Moreover, often some other assumptions are included (in order to allow the formulation of models manageable with mathematical tools): firstly the individual is considered to have full information about the different states of nature and about the effects of his choices, secondly each *Homo economicus* has the ability to weight every choice against every other ones giving them values consistent with a ordinal rank.

Despite the evident unrealistic assumptions of Rational choice theory, still today many models in the mainstream are based on this general framework; some improvements are been made with the hope of reach a more plausible representation without however abandoning the idea that the *reason* is central in the decision-making process, a remarkable work was that started by Simon in 1957 in which the individual was no more considered

as a maximizer but rather a satisficer, one seeking a satisfactory solution rather than the optimal one since endowed by limited cognitive capabilities and a finite amount of time to take a decision.

Differently the position held by authors adherent principally to Austrian legacy is consistent with an image of human beings acting sometimes apparently irrationally in a general context ruled by intrinsic uncertainty with the clarification that here uncertainty means not only ignorance of what future will actually happen but also ignorance on the various infinite possibility.

The importance of human nature (with all its peculiarities) in economic decision was noticed also by an author far from Austrian school, even Keynes (1936, 161) invokes a not so clearly defined *animal spirits* as a characteristic of human behavior:

> Even apart from the instability due to speculation, there is the instability due to the characteristic of human nature that a large proportion of our positive activities depend on spontaneous optimism rather than mathematical expectations, whether moral or hedonistic or economic [...] a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities

So, the idea that emotions, sentiments and moral constraints matter is not a new entry, notwithstanding a more structural rationalization of this elusive elements was possible only in recent years characterized by technological advances as we will shortly describe referring at times to the work of summarizing about neuroscientific discoveries of human behavior made by Lo (2011).

Through the study of individuals with brain tumors, lesions or other head injuries and with the use initially of microscopic techniques and then of the modern *Functional magnetic resonance imaging* known as fMRI the scientists manage to understand better the internal reactions of brain to external stimuli. As Lo (2011) says, "[...]reactions are hard-wired into human physiology, and while were often able to overcome our biology through education, experience, or genetic good luck during normal market conditions, under more emotionally charged circumstances, the vast majority of the human population will behave in largely predictable ways"; the very fact that the actual structure of human brain is the result of thousand of years

of evolutionary mechanism (which, incidentally is a period of various order of magnitude longer than the last two centuries characterizing the scientific and technological progress) suggests that some mechanism inside the brain operates without awareness on the part of the individual.

This quite common intuition was finally confirmed by the studies of Klüver and Bucy (1937) and Kapp et al. (1979) especially with regards to internalization of *fear*. The fear of unknown is still one of the most powerful motivating forces of our conscious and subconscious minds; neuroscientists have found that the *fight or flight* mechanism of response, once fundamental in daily survival activities of Homo Sapiens, is still present and speeds the reactions to external stimuli in a so fast way that we cannon even realize if not a posteriori.

Briefly, the physical explanation of the fast reaction to frightening situations is found in the direct neural connection between the amygdala and the brainstem, where the former is a small but distinct structure located deep within the brain that was recognized as the final destination of emotional stimuli while the latter is the central switchboard for all the muscles in our body. Despite the often usefulness, this direct connection may be counterproductive; put as simple as possible with an example, imagine to be an air plane pilot facing a stall, the natural reaction to a such potential life-threatening situation is to point the air plane upwards, towards the sky and away from the ground but the instinct in this case is misleading and complicates even more the situation. The only solution are hours and hours of training that finally allows to override the natural circuit of fear transmission.

Moving our attention to economic decision-making we can identify the same process at work, here is another factual evidence against a pure rational view of individual as suggested by Rational choice theory; again Lo (2011) describes clearly the point:

> The same logic applies to financial investments, risk management, economic policy and regulation, and crisis response. In each of these contexts, fear can play a productive role if properly balanced against other considerations [...] On a broader scale, if we allow our fear instincts to drive our reaction to financial crises, we may eventually regret the policy responses produced

> by our amygdala. This applies not only to investors, but also to regulators and policy makers, whose response to fear may have considerably larger consequences

and a paragraph afterwards

> we behave, think, reach conclusions, and make decisions with the effects of the emotional brain always running in the background. This has clear implications for economic behavior, as we have seen over the past several years

Obviously the life of people and their decisions have not only a negative side; from an historical point of view numerous advances have been made by neuroscientists: Olds and Milner (1954) show that in the brain there is a sort of *pleasure center* that can be activated by various rewards (where a reward can be real, like food, or something abstract, like an intellectual satisfaction), Carlsson et al. (1957) identify the *dopamine* as the basic chemical neurotransmitter of pleasure while Breiter et al. (2001) show the existence of a common pattern in how the human brain reacts to monetary gains and to taking of cocaine. In both cases there is a release of dopamine into the reward system and this allow to guess that there is a direct neural pathway for monetary reward as in the previous stated case of fear; the fact that the response to stimuli like monetary gains might be hard wired in our brain is not without consequences, Lo (2011) says:

> The implications for financial crisis is clear: an imbalance in an individuals dopamine system can easily lead to greater risk-taking, and if risk-taking activities are, on average, associated with financial gain, a potentially destructive positive-feedback loop can easily emerge.

Imagine now a similar sentiment diffuse among individuals in a society and we have here a neurophysical explanation of the initial phase of Hayekian business cycle where generalized euphoria helps the increase of the bubble; the *Homo economicus* of mainstream's tradition surely is not outside the picture but for no reason is the only origin of actions, there is the necessity to take into account also the apparently irrational behavior of persons that comes from an inescapable evolutionary process.

Another interesting theme is how people deal with uncertainty and risk; the following speech is instrumental to show the intrinsic limits of Rational choice theory when dealing with normative economics, in a numerous number of cases the effects of implemented policies or mandatory regulations are far from the forecasted ones if not opposites.

One of the first example is the so-called *Peltzman effect*, Peltzman (1975) published a controversial study in which he found that the automotive safety devices such as seat belts (required as mandatory) did little to reduce the numbers of deaths, the explanation was ascribed to an adaptive behavior by motorists who started to drive faster and more recklessly; a similar result was confirmed by the work of Sobel and Nesbit (2007), they focused on professional automotive races in US and the conclusion was that: "Our results clearly support the existence of offsetting behavior in NASCAR drivers do drive more recklessly in response to the increased safety of their automobiles."

The key element is that the initial stroke of the adapting behavior is a feeling of augmented security but what will happen if after some time the new measures turn out to be less reliable than initially claimed? A potential answer is that in the middle period the drivers of the example may end up taking more risk then rationally willing to take because they feel to be safer then before but in reality they are not.

The same line of reasoning may be applied in the analysis of the role, in the current financial crisis, of *credit ratings*. These instruments, initially strongly supported by governments, had a central role in the starting phase of the crisis when the AAA rating of various products turn out to be completely misplaced; in fact previously the investors (rationally and irrationally) were led to consider those products as safe assets while in reality they were not. In our opinion the lesson that should be learned is that every actions has a dual nature composed by an essence and an appearance and not necessarily the two must coincide, moreover the awareness of this duality is particularly important for all those people (here we are thinking about policy-makers) whose actions can have huge impact on life of others.

However, in dealing with human beings difficulties are present also when there is coincidence between essence and appearance as it is in particularly constructed controlled experiment; the simplification of which we are talking is that of limiting the number of possible outcomes of an action in order to

give them an accurate measure of risk which it is clearly impossible if the possible results are infinite. A remarkable result was reached by Kahneman and Tversky (1979)[1], they found that:

> Choices among risky prospects exhibit several pervasive effects that are inconsistent with the basic tenets of utility theory. In particular, people underweight outcomes that are merely probable in comparison with outcomes that are obtained with certainty. This tendency, called the certainty effect, contributes to risk aversion in choices involving sure gains and to risk seeking in choices involving sure losses.

Looking at the just quoted result, once again the underpinnings of Rational choice theory and related Utility theory are in trouble; for sake of completion we wish to notice that the initial intuition of asymmetric behavior by Kahneman and Tversky received also an a posteriori confirmation from a fMRI study developed by Kuhnen and Knutson (2005).

A peculiar example of risk seeking in a choice involving a sure loss (or a highly probable one) is the behavior adopted by bank regulators in the starting period of the current financial crisis, Huizinga and Laeven (2010) describing the stages of the crisis noted that:

> Bank regulators can in principle impose regulatory discipline on banks, and force them to adjust asset valuations and capital downward. However, at times of financial crisis when bank distress is widespread, regulatory forbearance is often applied to minimize disruptions to the real economy and the overall financial system caused by bank failures. As a consequence, discretion over financial reporting rules by bank managers combined with regulatory forbearance causes banks to understate underlying balance sheet stresses and to overstate regulatory capital

The behavior of monetary authorities, like central banks, is considered here as a form of *doubling down*[2] where regulators prefer to wait and see if the banks' assets increase in value rather than implement immediately

[1]Kahneman was Nobel price in Economics in 2002.

[2]Strategy adopted by trader that consists in double the weight in portfolio of an asset whose market price is lower than historical purchase price.

costly regulatory actions (in the end a request of raise the capital would possibly lead to a loss of confidence among the depositors and in the worst case trigger a bank run with potential systemic effects).

The chosen initial immobility of bank regulators is consistent with Kahneman and Tversky's intuition since in taking this decision the authorities underweight the not so remote possibility that persisted forbearance could lead to an even worse general situation, in fact it is not at all absurd imagine that bank regulators closer to typical figure of *Homo economicus* choose to intervene immediately in order to prevent even worse consequences in future.

Furthermore, taking for granted that forbearance was a chosen decision and not a casual circumstance, it is possible to identify in the behavior of bank regulators a further support element to another claim of Liberal-Austrian authors: the rejection of whatsoever intrusion by the policy-makers in the market mechanism; specifically, the showed initial patience contributed to fool even more the citizens about the real banks' situation leading them to take actions that would have regret in future.

1.2 Social-capital and Trust

Even six years after the outbreak of the crisis started in 2007, a brief look to the newspapers of the day allows to grasp a generalized sentiment of mistrust that continue to be widespread among people; when things go wrong it is a quite common reaction the denial of previous structures, being those tenets of collective life in society or institutions now mature. A peculiar case is that experienced in most countries around the world where, increasingly often, claims on repealing the pre-existing structures are made, a lot of people feel to having been betrayed on one hand by politicians and on the other hand by those *supposed* experts who were in charge to check and administer the "state of health" of our economy.

Unfortunately these quests for changes do not always lead to a genuine destruction/re-construction process in which culprits of wrong behaviors (in this case connected to financial crisis) are pushed off and made guilty but often it results in a short media fire that ends up with few (or worse no one) punished and then all goes on as usual. Moving to the technical side of the discussion, we can see that mainstream economics is not sinless, the models adopted to manage the risks proved *painfully* to be fundamentally

biased; even the Queen Elizabeth II in an appearance at London School of Economics in 2008 noticed the inconsistency of the current method: "If these things were so large, how come everyone missed them? Why did nobody notice it?" (Pierce, 2008).

Among others, one of the commonalities between the reaction of public opinion to conduct of politicians and to experts' mistakes is a growing distrust based on an infringements of expectations; looking at reactions it seems that the generality of people had expectations on behaviors of policy makers and skills of economists very far from those that then occurred. During the recent crisis the issue of trust emerges also in other circumstances: credit crunch due to mistrust of counterpart (be it a private or a financial institution), apprehension for the repayment of state's debt from some countries or implementation of stricter laws that would potentially favor someone at the expense of others.

Given its centrality we think that it is useful to analyze deeply the concept of trust and hereinafter we will speak about it with reference to literature. The importance of trust is not a new concept, Bruni and Sugden (2000) observe it already in the writings of classical authors as Hume and Smith, moreover Bruni and Sugden (2000) notice that

> It is a truism that a market economy cannot function without trust. We must be able to rely on other people to respect our property rights, and on our trading partners to keep their promises.

If we ask to somebody randomly chosen to imagine *trust* we guess that he would provide numerous examples from his own life with no difficulties since the experience of trust (or misplaced trust) is something that is familiar to everybody. What it might not be familiar is a deeper understanding: is there only one trust? is it possible to improve trust? is more trust better then less trust? what are the determinants of trust?

Before trying to answer all these questions is necessary to take a step back and consider the notion of uncertainty and social capital, the reasons for this temporarily change of focus are first of all that trust exists only in a context of absence of certainty and secondly that trust is seen alternatively as a fundamental component, as a by-product or as the masterpiece of social capital.

1.2.1 Risk and uncertainty

It is quite immediate that the notion of trust is naturally coupled with that of uncertainty, in fact in a hypothetical world where there is no unknowns the need to trust vanish; however in real world it is a truism that unknowns exists as everybody experiences in every single moment of his life, moreover as noted by Davidson (1991) "Time is a device which prevents everything from happening at once. In every real world choice, the prospective pay off associated with any action is necessarily separated by some period of calendar time from the moment of choice", then the very fact that limited knowledge of future state is paired with not contemporaneous realization of any actions leads individuals to have expectations (consciously or not) about the result of their actions.

It appears that often the terms uncertainty and risk are used loosely as synonyms, the actual framework about uncertainty has been shaped by studies of Knight and Keynes.

Knight (1921) says:

> Uncertainty must be taken in a sense radically distinct from the familiar notion of Risk, from which it has never been properly separated. [...] The essential fact is that "risk" means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomenon depending on which of the two is really present and operating. [...] It will appear that a measurable uncertainty, or "risk" proper, as we shall use the term, is so far different from an unmeasurable one that it is not in effect an uncertainty at all. We [...] accordingly restrict the term "uncertainty" to cases of the non-quantitative type

while Keynes (1936) says that

> By "uncertain" knowledge [...] I do not mean merely to distinguish what is known for certain from what is only probable. The game of roulette is not subject, in this sense, to uncertainty [...] The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper

> and the rate of interest twenty years hence, or the obsolescence of a new invention [...] About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not know!

For what concern our study the focus should be on relationship where there is true uncertainty since the other ones where risk is central should be downgraded to merely weighting of consequences and acting accordingly to economic preferences; as noted by Davidson (1991) the awareness that "economic conditions of true uncertainty are likely to be prevalent" should be a stimulus to promote policy directed to limit the uncertainty but without fall into the trap of believing to have complete knowledge to rules all relationships.

1.2.2 Social Capital

The first thing to notice when dealing with social capital is that a final definition does not exist, different authors have different views; however it is agree upon that the greater majority of definitions have as common element a focus on social relations that have productive benefits.

Among the others three authors influenced greatly the study of social capital: Pierre Bourdieu with attention on availability of resources and maintenance of power, James Coleman focusing on individuals pursuing their own interest and Robert Putnam with regard to civic participation and public associations. As noted by Field (2003) "Despite these differences, all three consider that social capital consists of personal connections and interpersonal interaction, together with the shared sets of values that are associated with these contacts"; each author proposes a different definition:

(Bourdieu and Wacquant, 1992) say,

> Social capital is the sum of resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition.

(Coleman, 1994) says,

> Social capital is defined by its function. It is not a single entity, but a variety of different entities having two characteristics in

> common: they all consist of some aspect of a social structure, and they facilitate certain actions of individuals who are within the structure.

(Putnam et al., 1993) say,

> Social capital here refers to features of social organization, such as trust, norms and networks, that can improve the efficiency of society by facilitating coordinated actions.

The above are rather vague, avoiding to define clearly the boundaries of social capital; notwithstanding the suggestion from Putnam (2000) is the most quoted and the same author not only does not reject the initial idea but in successive periods implements it with new insights:

> the core idea of social capital theory is that social networks have value [...] social contacts affect the productivity of individuals and groups

and

> to connections among individuals social networks and the norms of reciprocity and trustworthiness that arise from them.

The last formulation as noted by Field (2003) "presented trust (together with reciprocity) as an essential element of the norms that arise from social networks"; one more time trust is recognized as a central concept. The focus of social capital in not important only per se but various studies associate social capital with growth and improved economic performance: Knack and Keefer (1997) affirm that "*social capital* matters for measurable economic performance", Zak and Knack (2001) show a positive correlation between economic growth and social trust; Elinder et al. (2007) highlight a less comforting result but notwithstanding state that "even though trust may not be robustly related to growth, it could still be important to some degree and at least as important as many other - classic - variables."

Another core element of social capital is the presence of links among individuals, the very fact that relationships among people are not of the same kind every-time and everywhere led Putnam to introduce a distinction

between two forms of social capital: bonding (or exclusive) and bridging (or inclusive). Field (2003) observed quoting Putnam (2000) that "Bonding social capital tends to reinforce exclusive identities and maintain homogeneity; bridging social capital tends to bring together people across diverse social divisions. Each form is helpful in meeting different needs. Bonding social capital is good for underbidding specic reciprocity and mobilizing solidarity, while serving as a kind of sociological super-glue in maintaining strong in-group loyalty and reinforcing specific identities. Bridging connections are better for linkage to external assets and for information diffusion, and provide a sociological WD40[3] that can generate broader identities and reciprocity"; moreover, Claridge (2004) provides multiple interpretations, "Bonding is horizontal, among equals within a community whereas bridging is vertical between communities [...] bridging social capital is closely related to thin trust, as opposed to the bonding (splitting) social capital of thick trust."

From the previous description it seems that social capital leads undoubtedly to positive consequences but this is far from the case, Aldridge et al. (2002) identify some potential downsides of social capital: from a social point of view too much bonding capital and too little bridging capital might act as a barrier to social inclusion and social mobility or worst enhance conflicts rather than cooperation between communities with the effect of divide rather than bring together, from an economic perspective social capital might promote a "behaviour that worsens rather than improves economic performance".

Despite these weaknesses the usual position is to give more weight to beneficial effects, Putnam (2000) says that more social capital we will produce the better for us while Fukuyama (2001) believes that between situation with too much social capital and ones with too little, the latter are worse.

The loosely definitions of social capital are of little help when it comes time to attach numbers to the concept in order to conduct analysis and make suggestions, different characterizations bring with them also different ideas about quantification as observed by Fukuyama (2001) "One of the greatest weaknesses of the social capital concept is the absence of consensus on how to measure it"; despite the difficulties two broad approaches have been taken

[3] A lubrificant oil and water-displacing spray.

by mainstream authors, some create an index of associational activities and trust levels considering them good proxies of social capital (Putnam, 2000) while others base their work on survey (Knack and Keefer, 1997).

It is interesting to note that the great majority of studies on social capital based on survey method use the answers to questions on trust developed by World Values Survey[4] in 1981; a central question is "Generally speaking, would you say that most people can be trusted, or that you need to be very careful in dealing with people?" with possible answer - Most people can be trusted - Need to be very careful - Dont know. Here the underlying implicit assumption is that trust, or better reported trust is a good proxy for social capital.

However, as noticed by Field (2003) "any indicators inevitably are proxies, which do not measure social capital directly. Proxies are basically easy variables; they must have some clear connection to social capital, and they must be easy to measure (or even are already being measured). At best, the fit will be very loose indeed, and at worst it may be so baggy as to mislead rather than inform"; so a fixed point does not exist and for now all we can do is to lower the claims and be satisfied with the little we have without try to extract information where there are none.

1.2.3 Trust or Confidence

In talking about trust it is not clear if trust is a result of networks and exchange among people or if trust is a mandatory ingredients in the recipe of social capital, in our opinion there is for sure reflexivity between the two dimensions and there is not a cause-effects relation since more trust gives the opportunity to enhance links and network that in turn improve trust. Notwithstanding we consider trust as the central concept given its innate presence in all individuals in potential form, every person in fact, given the limited nature of man, is not a single atom but needs others in order to live; Fukuyama (1995) recognizes the importance of trust saying that "social capital is a capability that arises from the prevalence of trust in a society or in certain parts of it" and "communities depend on mutual trust and will not arise spontaneously without it."

[4]Global research project that explores peoples values and beliefs.

Field (2003) says that "the importance of trust can be seen across a variety of situations where we engage with others: sleeping with someone, using a credit card, getting married, taking a plane, picking a meal for ones children, wondering whether to report a crime, deciding how to vote, and choosing between different ways of saving the environment (or not)"; however we deem important to underline that the relationships that an individual might establish with another agent, be it another person or a firm or a government, are not always pervaded by the same notion of trust. For sure in every relation conducted over a period of time there are expectations that might be realized or betrayed; about this Luhmann (2000, 3) observes that:

> You cannot live without forming expectations with respect to contingent events and you have to neglect, more or less, the possibility of disappointment. You neglect this because it is a very rare possibility, but also because you do not know what else to do. The alternative is to live in a state of permanent uncertainty and to withdraw expectations without having anything with which to replace them

Without neglect the commonalities of expectations Luhmann (2000) proposes a distinction among *confidence* and *trust*, considering the former as the normal case while the latter as an improvement that require a "previous engagement"; Nooteboom (1996) makes the distinction even more clear: "if there is no choice, and one simply has to surrender to the powers that be, the belief that no harm will occur is a matter of confidence, not trust." The existence of trust requires the participative action of individual that has the option of choose if enter or not in the relationship while "confidence relates to bigger or wider systems or entities that we can hardly influence and that are more or less inevitable, such as God, the Law, police government and so on" as proposed by Beugelsdijk (2006).

We think that the formalization just proposed is not a merely exercise of categorization but it allows to have a more critical approach to studies and policies implemented to improve socially and economically our society: sometimes reforms aimed to increase trust miserably fail because policymakers do not recognize the lack of fertile soil for reforms to take root; in fact, trust and confidence are not two side of a medal not communicating

but rather subject to overlap in virtuous or vicious circles.

About this interrelation Luhmann (2000) observes that "a system - economic, legal, or political - requires trust as an input condition. Without trust it cannot stimulate supportive activities in situations of uncertainty or risk. At the same time, the structural and operational properties of such a system may erode confidence and thereby undermine one of the essential conditions of trust"; moreover Berggren and Jordahl (2006), in their study about how generalized trust is formed, reach the result that legal structure and security of property rights matter: "by providing a legal system and by exercising it in an impartial, just, and general manner, economic actors know that voluntary contracts are enforceable and can be relied upon. This enables them to trust other actors more directly; but there is also an indirect effect in that the economic process of exchange, with its incentives and mechanisms for dispositions of trust to emerge, is stimulated." The opposite influences of trust and confidence are clear and an increasingly complexity of the world can only lead to even stronger relations among the two prospects of expectations.

With respect to the actual economic situation we claim that there is need of enhance the level of confidence in the system in order to leave individuals free to develop trusting relationships in the manner in which each considers appropriate; institutions like governments and policy-makers should not worry about the final states of the relationships established by people, the focus should not be the appropriate shape of networks to reach but rather to create the suitable conditions and then stand back. After the initial phase of "place the foundations" efforts should be directed to "shift expectations from confidence to trust"; the desirable result (but for which we are not certain a priori) would be a greater awareness among people that would feel to be more responsible for the society in which they live.

Chapter 2

Money

2.1 Money: history and relations with trust

We start by noticing that the presence of a component of trust in every exchange or more general in every relation among individuals is undeniable, the very fact that knowledge about future is limited implies that expectations must be carried out by everyone and decisions based upon these expectations must be taken. In particular the thematic of trust is recurrent when dealing with money and in general with monetary system, the importance of trust stems from the fact that its presence is a *sine qua non* for an effective development of human relations. In the following, referring to the literature we will focus on the birth process of money and on its own peculiar characteristics trying to identify the link with the trust concept.

Given the different ways in which we can handle the theme of "money", it is important to be aware that what we consider money nowadays not necessarily was considered money in the past, commonalities among different periods in history are for sure present but details more or less important have been subjected to deep modifications; for this reason in the analysis is important to be flexible and take in account the specificity of the period to which we refer from time to time.

Given the evolving nature of the concept of money during history, a firm definition of money is yet to come; however we find the following by Wikipedia (2012a) fairly complete:

> Money is any object or record that is generally accepted as payment for goods and services and repayment of debts in a given

socio-economic context or country

We choose to refer to this formulation because it entangles various dimensions that we agree upon: first of all it allows money to be anything and not only an object with a physical nature but also a record that as we will see later takes commonly the form of an accounting entry, secondly it bounds the diffusion of money both geographically and socially, thirdly it contains (even if not explicitly stated) a notion of flowing of time in which relations among people happened and finally it considers the general acceptance as the main reason that leads to distinguish proper money from all other things.

As proposed by Simmel (1978, 162) "money [...] is entirely a social institution and quite meaningless if restricted to one individual", in particular the reference here is not only to money intended as medium of exchange but rather to money considered as unit of account in which comparisons of value are made.

The role of trust in every man life is strictly necessary given the surrounding uncertainty about future, Arrow quoted in Knack and Keefer (1997) recognizes that "virtually every commercial transaction has within itself an element of trust, certainly any transaction conducted over a period of time. It can be plausibly argued that much of the economic backwardness in the world can be explained by the lack of mutual confidence."

At this point the natural questions that arise are: if confidence is essential for economic growth and money is functional to this target, can we increase general confidence through money? how come that today we have nothing to complain in dealing with near-worthless pieces of paper and debt recorded electronically?

We consider the recognition of money as a social institution the essential characteristic of an on-going process that is not independent and timeless but it is continuously subject to the prevailing environment in which it develops. Bagheot (1873), in the description of the money market of London, claims that "money will not manage itself" while Ingham (2000, 29) summarizes in the following way the disposability to receive what it is prevalent as money in a particular historical period:

> Willingness to hold money is influenced by rational appraisal of current estimations of its future value; but this can never

> be more than a guide to further action that itself will, in part, determine the future value of money. Money's capacity to store value depends on a willingness to hold money in the present. In other words, the effectiveness of money as a store of value is based, to an important degree, on a commitment to a course of action that is based on trust that others will continue to accept our money.

In our opinion, the previous statement, despite the correct line of reasoning, does not highlight the reasons for which a particular object or way of behavior makes the jump from being only a potential money to became the accepted medium of exchange or unit of account. We argue that there is a sort of loop in saying that it is rational to accept money once it is yet present, but no mention to the origin of money is made; the rationality of holding money is confirmed by the field of game theory and once again is remarked by Ingham (2000):

> however, these approaches must presuppose what they set out to explain; that is to say, at the very best they can only demonstrate that it is economically rational for the individual to hold money once it is in existence and widely accepted

At this point we consider valuable try to understand what is the path that the social institution *money* has come to become what it is now: mainly paper banknotes and magnetic tracks electronically stored. With this in mind we will look at the the two prevalent approaches within economics about the origins of money; Lapavitsas (2003) notices about the two theoretical approaches that "the first, typical of classical and neoclassical economics, stresses the function of means of exchange and postulates that markets and money are intrinsically related. The second, its roots predating classical political economy, denies that markets spontaneously give rise to money and focuses on the function of value measurement (money as unit of account)."

Following the mainstream accepted theory, money emerges spontaneously from the market exchange and the ruling force is the self-interest behavior of individuals considered as atomistic units. Menger (1892) identifies the barter as the initial and essential form of exchange among individuals, however as noted by Jevons (1885) "The first difficulty in barter is to find two persons whose disposable possessions mutually suit each others wants. There may

be many people wanting, and many possessing those things wanted; but to allow of an act of barter, there must be a double coincidence, which will rarely happen"; Menger (1892) assumes that some commodities are more "marketable" than others and that participants to the market are able to recognize this characteristic. The very fact that highly marketable commodities make it easier to obtain the desired things overcoming the "double coincidence of wants" through subsequent exchanges put the early holders of these commodities in a position of advantage with respect to the others; the succeeding step is a recognition of the advantage by others participants that hungry for wealth begin to emulate the first holders. The result is a growing number of exchanges that involve the most "marketable" commodity that through repetition create habits that finally end with the emersion of money characterized by a self-reinforcing process of acceptation.

The mainstream approach hence considers money just for its function of reducing the transaction costs that would be unsustainable in a barter economy on a large scale, money for every other aspects is neutral with respect to real economy.

Instead the second approach to development of money, generally known as Chartalism, is focused on the notion of credit and on the essential role of state in the definition of what it is money.

In the opinion of proponents of this theory, barter is an activity limited to savages that do not have a social framework in which interact with one another while in a slightly more developed society the exchanges are not characterized by "immediate exchange of equivalents, but are based on the practice of *advance value now - return it later*" (Lapavitsas, 2003). The mainstream's core solution to the double coincidence of wants problem is questioned, Innes (1913) says:

> Adam Smith's position depends on the truth of the proposition that if the baker or the brewer wants meat from the butcher, but has (the latter being sufficiently provided with bread and beer) nothing to offer in exchange, no exchange can be made between them. If this were true, the doctrine of a medium of exchange would, perhaps, be correct. But is it true? Assuming the baker and the brewer to be honest men, and honesty is no modern virtue, the butcher could take from them an acknowledgment

> that they had bought from him so much meat, and all we have to assume is that the community would recognize the obligation of the baker and the brewer to redeem these acknowledgments in bread or beer at the relative values current in the village market, whenever they might be presented to them, and we at once have a good and sufficient currency. A sale, according to this theory, is not the exchange of a commodity for some intermediate commodity called the "medium of exchange", but the exchange of a commodity for a credit.

In the just quoted text the only assumption is that there is a recognition of obligation by the community; obviously an obligation goes hand in hand with sanctions and penalties if it is not complied and in this respect the story is rich of examples of code of the laws, one of the most ancient example is the Hammurabi code in Babylonia around 2000 years B.C.

Another critique to mainstream view of origin of money, different but not contradictory to Chartalism or to credit theories of money is that advanced by Grierson (1977); he denies the spontaneous origin of money from market and identifies in the social institution for the settlement of disputes the fundamental reason, Grierson quoted in Ingham (2000, 25) says that "the conditions under which these laws were put together would appear to satisfy, much better than the market mechanism, the prerequisites for the establishment of a monetary system. The tariffs for the damages were established in public assemblies, and [...] Since what is laid down consists of evaluations of injuries, not evaluation of commodities, the conceptual difficulty of devising a common measure for appraising unrelated objects is avoided."

The point of contact with a recognition of social nature of money is clear in the reference of Grierson (1977) to sanction mechanism for damages and compensation for injury and insult, such mechanism in fact is inevitably based on convergence of multiple subjective valuations about the entity of a crime and the appropriate penalty.

Heterodox authors like Knapp, Innes, Wray fierily criticize also the path that mainstream economists trace for the development of gold and silver stuffs as the most diffuse medium of exchange; during history precious metals had an unquestionable role, their specific characteristics of durability

and limited availability were important to distinguish them from the many other commodities that in different times and places served as medium of exchange, among the others: cattle, iron, salt, shells, dried cod, tobacco, sugar, nails.

Innes (1913) observes a peculiar difference among nowadays and the past, looking at a specific sovereign state today we have absolute standardization and a limited number of coins and banknotes while in past the differences for what concern weight and material composition of money were significant, the author says that "there can be no doubt that all the coins were tokens and that the weight or composition was not regarded as a matter of importance. What was important was the name or distinguishing mark of the issuer, which is never absent."

The same author explains the quest for standardization by saying that "accuracy was important more to enable the public to distinguish between a true and a counterfeit coin than for any other reason"; in this regard, taking in account also the recognition by Innes of advantages deriving by issuing of money, we can reasonably add that the final beneficiaries of a more clear distinction among true and false money were and are those enjoying the right to issue.

We consider the following long quotation from Innes (1913) very important, because allows to question the general theory according to which money spontaneously emerges and logically became accepted:

> There are only two things which we know for certain about the Carolingian coins. The first is that the coinage brought a profit to the issuer. When a king granted a charter to one of his vassals to mint coins, it is expressly stated that he is granted that right with the profits and emoluments arising therefrom. The second thing is that there was considerable difficulty at different times in getting the public to accept the coins, and one of the kings devised a punishment to fit the crime of refusing one of his coins. The coin which had been refused was heated red-hot and pressed onto the forehead of the culprit, "the veins being uninjured so that the man shall not perish, but shall show his punishment to those who see him." There can be no profit from minting coins of their full value in metal, but rather a loss, and it is impossible

> to think that such disagreeable punishments would have been necessary to force the public to accept such coins, so that it is practically certain that they must have been below their face value and therefore were tokens, just as were those of earlier days.

We can recognize here a first sign of the strict relation that exists between money and authority: the latter in order to maintain or improve its position is brought to intervene and in this way it may modify the social structure of money and the relations among citizens.

The role of the state is the core element of the so called Chartalism approach to development of money: Ingham (2000) says that "the creation of money, as unit of account and means of payment, is assigned to specialized legitimately sanctioned agencies-states, banks and so on-and its supply is strictly regulated. Commodities, such as precious metal, became money because they were *counted* by those who *counted*"; following the work of Wray (2003) we "mean that the *state* (or any other authority able to impose an obligation, whether that authority is autocratic, democratic, or divine) imposes an obligation in the form of a generalized, social unit of account (a money) used for measuring the obligation."

The last word of state in issues that affect money is recognized by Keynes (1930): "it is a peculiar characteristic of money contracts that it is the State or Community not only which enforces delivery, but also which decides what it is that must be delivered as a lawful or customary discharge of a contract which has been concluded in terms of the money-of-account. The State, therefore, comes in first of all as the authority of law which enforces the payment of the thing which corresponds to the name or description in the contract. But it comes in doubly when, in addition, it claims the right to determine and declare what thing corresponds to the name, and to vary its declaration from time to time when, that is to say, it claims the right to re-edit the dictionary. This right is claimed by all modern States and has been so claimed for some four thousand years at least. It is when this stage in the evolution of money has been reached that Knapp's Chartalism the doctrine that money is peculiarly a creation of the State is fully realized."

So what really matters is the acceptability of the money by the state, that by the way is defined by the same state through "re-edit the dictionary",

and from this acceptability money acquires general acceptance. Moreover Wray (2003) observes that "nor is it necessary to impose this obligation on all members of society. Even if only a small percent of society can be compelled to feel it necessary to pay up, such obligations can monetize an economy and move resources to authorities"; a clear example is that of "tally stick"[1] in medieval England: Innes (1913) notices that "the regular method used by the government for paying a creditor was by *raising a tally* on the Customs or on some other revenue-getting department, that is to say by giving to the creditor as an acknowledgment of indebtedness a wooden tally."

In our quest of connection between trust and money we consider appropriate to report a sort of overture to the role of state also by one of the father of mainstream economics: Menger (1892) says "however, by state recognition and state regulation, this social institution of money has been perfected and adjusted to the manifold and varying needs of an evolving commerce"; then we argue that a dimension of trust or better of confidence is present in the relationship between citizens and state: what it really matters is that individuals recognize to the authority the power to put obligation over them, a sort of confidence in power of coercion.

In this regard, we consider ourselves in agreement with the reflection of Wray (2003):

> To be clear, I do not imagine an all-powerful state [...] but rather a gradually evolving institution that at times was more, and less, accepted as a legitimate authority and that was more, and less, operated on democratic principles. All that is necessary is to posit that some sort of authority exists that can levy obligations on a population: anything from fines or tithes to fees and taxes. Such an authority can range from a powerful Egyptian pharo to a beleaguered Greek city state trying to wrest power

[1] Following the description provided by Innes (1913): a stick of squared hazel-wood, notched in a certain manner to indicate the amount of the purchase or, debt. The name of the debtor and the date of the transaction were written on two opposite sides of the stick, which was then split down the middle in such a way that the notches were cut in half, and the name and date appeared on both pieces of the tally. The split was stopped by a cross-cut about an inch from the base of the stick, so that one of the pieces was shorter than the other. One piece, called the *stock* was issued to the seller or creditor, while the other, called the *stub* or *counter-stock* was kept by the buyer or debtor. Both halves were thus a complete record of the credit and debt and the debtor was protected by his stub from the fraudulent imitation of or tampering with his tally.

> away from an elite [. . .], to a weak English crown, and from a fascist 1930s era government to a new millennium democratically elected representative form of government in which a supreme court intervenes to award the presidency to a previous rulers electorally-challenged scion.

The immediate consequence of these insights on the study of money is a shift toward purely sociological and political considerations, we think in fact that it is important to understand what elements lead individuals to be confident in authority; a support to this claim is also found in the work of Aglietta (2001): "the State is the sovereign because it is entrusted with the legitimate power to transfer, tax and spend in the name of the tutelary protection exercised by government over the members of society. Since the State is the guardian of the unit of account, its political authority imports a hierarchical trust to money." Moreover an additional layer to the discussion is given first of all by the recognition that what is money in each historic period put its roots in the authority present at the same time and secondly by the awareness of the countless examples (in history) of authorities institutions fell into ruin and then replaced by other ones; in fact, we argue that various and continuous changes of who or which entity is entitled to the power suggest that the search for greater trust in money deriving from confidence in authority is a never ending process or as proposed by Ingham (2000, 33) "that all monetary systems [. . .] are necessarily precarious and unstable. Consequently, they require constant intervention to both regulate and legitimize monetary practice and policy, and to control economic agents' disruptive and destabilizing pursuit of self interest. It must be stressed that this is not a matter of intervention in extremis, but a permanent, ongoing social reproduction of money through the readjustment of power relations, the social construction of the norms by which we move in step, and an endless ideological quest for the optimally correct and, therefore, natural, universally applicable monetary policy."

Moreover as observed by Wray (2003) the "creation of modern democratic government and belief in social obligations has proven to be evolutionarily superior to any other system" in providing the ideal conditions for development of a generally accepted money, because a substantial number of people feel instinctively an obligation to "pay up"; in other words the

recent born of democratic societies and the generalized advocacy of them by most people seem to had been an adequate motivation to instill confidence in social system in primis and so indirectly in money.

2.2 Money and Banks

Looking at works about monetary policies or about state of health of economy it is highly likely to encounter different interpretations and definitions of what must be considered money and to what extent. The very fact that money is generally considered to serve several heterogeneous functions (medium of exchange, unit of account, standard of deferred payment and store of value) leads to different empirical measures of the money supply. There is no single definitive measure of money supply, however it is functional to our discussion to refer to the classification proposed by ECB (2012a):

> Based on conceptual considerations and empirical studies, and in line with international practice, the Eurosystem has defined a narrow aggregate (M1), an "intermediate" aggregate (M2) and a broad aggregate (M3). These aggregates differ with regard to the degree of moneyness of the assets included.
>
> - Narrow money (M1) includes currency, i.e. banknotes and coins, as well as balances which can immediately be converted into currency or used for cashless payments, i.e. demand deposits and overnight deposits.
> - "Intermediate" money (M2) comprises narrow money (M1) and, in addition, deposits with a maturity of up to two years and deposits redeemable at a period of notice of up to three months. Depending on their degree of moneyness, such deposits can be converted into components of narrow money, but in some cases there may be restrictions involved, such as the need for advance notification, delays, penalties or fees. The definition of M2 reflects the particular interest in analyzing and monitoring a monetary aggregate that, in addition to currency, consists of deposits which are liquid.

- Broad money (M3) comprises M2 and marketable instruments issued by the MFI sector. Certain money market instruments, in particular money market fund (MMF) shares/units and repurchase agreements are included in this aggregate. A high degree of liquidity and price certainty make these instruments close substitutes for deposits. As a result of their inclusion, M3 is less affected by substitution between various liquid asset categories than narrower definitions of money, and is therefore more stable.

The statistics about the level of various monetary aggregates constructed following the above classification highlight that the great majority of money circulating in modern economies does not consist of coins and banknotes but is supplied by banks under the form of deposits. Hereinafter we will focus firstly on the peculiarities of banks which make them subject to stringent regulations and secondly, referring to the stages view of banking development proposed by Chick (1993), we will identify the presence respectively of trust and confidence.

The characteristic activity of banks consists in the recognized permission to receive deposit and manage them on behalf of clients, this permission is also at the core of the other services that are provided by banks; all over the world the banking system has proved to be one of the principal source of credit and liquidity both for small and medium sized firms and for households.

Banking system, especially during period of crisis, is subject to increasing attention by regulators because bank deposits are the money of the modern economies, Benston and Kaufman (1996) and Dow (1996) provide accurate critical analysis of the appropriate level of regulation and the rationale behind it. Shortly the idea is that, since the banking system has central role in supplying the means of payment and act as a store center of value then the final goal is to prevent a stop of the system that would inevitably leads to a collapse of the whole economy. The unique feature of banks is that the deposits of customers are recognized as liabilities (even from an accounting point of view) and moreover the system has developed during the years considering the deposit as immediately available at demand; Dow (1996) recognizes this capital certainty of sight deposit as an essential feature for

deposit to act as money.

We have a situation in which liabilities of banks, in form of deposits, are certain in amount and with potential zero maturity as they are repayable on demand while the assets of banks are uncertain in value and with indeterminate maturity; this asymmetry of maturity is the core reason of fragility of banks. The potential liquidity problem is exacerbated by regulations (i.e. various Basel Accords) that allow the maintenance of only a fraction of liabilities to cope the request of withdrawal by depositors, this structure also named "fractional reserve system" is not problematic until the bank faces withdrawal of a small fraction of deposit liabilities but becomes unsustainable if trust and confidence in the bank is lost by a greater number of depositors. Benston and Kaufman (1996) synthesizes clearly the picture: "banks are believed to be inherently unstable because they are structurally fragile. The perceived fragility stems from their maintaining low ratios of cash reserves to assets (fractional reserves) and capital to assets (high leverage) relative to their high short-term debt. But such fragility does not imply instability if depositors and bankers are aware of it and act appropriately"; moreover a liquidity crisis can develop into a solvency issue if the value of the banks assets cannot be fully realized while trying to liquidate them as quickly as possible.

Bank are special because as observed by Dow (1996) their "liabilities are used as money, their redeposit ratios are sufficiently high to allow them to hold longer-term assets without fear of illiquidity"; here for redeposit we mean a withdrawal that is made by a depositor to make a payment through a claim that does not consist in banknotes and this claim is deposited back in the same bank by the receiver of the claim that incidentally is depositor of the same bank, from the point of view of the singular bank involved in the process there is no reduction of assets since the liability represented by the withdrawal has not been really exercised but there is just a decrease of one account and an increase of another one.

With this in mind and not considering that there are agreements between banks we can observe that it is functional for the health status of a singular bank in an economy which is increasingly focused on the use of electronic money to expand its depositor's base. Since this process has not reach a final point and inevitable weaknesses are present, the state has an important role: quoting Dow (1996) "The primary purpose of prudential regulation has been

to ensure that banks' assets retain sufficient liquidity to meet any reduction in redeposits, and to discourage such a reduction in the first place. Regulation is warranted because the moneyness of bank liabilities is a public good: moneyness (rather than any particular money asset) satisfies the conditions of non-rivalry-in-consumption and non-excludability-in-exchange. The state produces moneyness by inspiring confidence in money's capacity to retain value. This confidence underpins the performance of money's role as means of payment and store of value. But most of all it underpins money's role as unit of account and thus denominator of contracts, which are central to the functioning of modern economies."

The liquidity risk that a single bank can face is not a weakness limited to this agent but may degenerate in a contagion that affects the whole banking system: in fact if a bank is subject to liquidity problem or even worst to solvency problem due to an excessive withdrawal of deposit then the risk that depositors of other banks feel also their own counterpart as in trouble is significant and undeniable; one of the possible interpretation of the spreading out of this feeling of distrust is the lack of clear information among depositors that leads to extend the concerns about the actual situation also to banks relatively more healthy than the bank in trouble.

During time various actions have been taken under the auspices of a reduction of the intrinsic risk of failure of banking system, Calomiris (2007) notes that "policies include assistance mechanisms intended to protect banks from unwarranted withdrawals of deposits (central bank lending during crises, deposit insurance, and government-sponsored bank bailouts), and a host of prudential regulatory policies (intended to promote banking system stability, and especially to prevent banks from taking advantage of government protection by increasing their riskiness, the so called moral-hazard problem of protection)."

The very fact that banks during history were not always present and at the center of the economy implies that over time there has been an evolutionary process, hereinafter we will look at the development of banking system referring to Chick (1993) as proposed by Dow et al. (2008); from now on we want to emphasize that the various proposed stages of the development of the banking system are not perfectly divided in atomic units, but rather are subject to overlap and span very heterogeneous both in different historical

periods and locus.

We argue that the changes that occur during the whole process are characterized by a progressive reduction of role of trust in favor of confidence: initially the relations consist in a system of interpersonal relationships ruled primarily by informal rules and conventions while secondly formal and explicit rules (represented by laws and regulatory systems proposed by state) have a greater role. The result is a progressive shift toward confidence since individuals deal mainly with institutions created or to address perceived weaknesses or resulting from repeated experiences; with the last sentence we refer clearly to the role of central banks and that of financial regulation as recipients of confidence.

In stage one, cash appears to be constituted by physical tokens and is widely used as a means of payment while deposits represent the accumulated savings by particular categories of population; the "service" required and offered is that of safe-keeping, banks as intended today do not yet exist and the relationships are practically entirely composed by individuals depositing their gold (or affine) into local blacksmith's hands. In our quest for trust or confidence it is clear that at this stage the dominance of trust is complete, the interactions are ruled by past interpersonal relationships, reputation and informal rules; a particular blacksmith is chosen because of its ability to guarantee the continued safety of assets that are assigned to him.

Stage two of the model is probably that more complex to achieve, it is characterized by the wide adoption of claims on deposits at blacksmiths as means of exchange and payment. Smith (1863, 236) addresses exactly this point:

> When the people of any particular country have such confidence in the fortune, probity and prudence of a particular banker, as to believe that he is always ready to pay upon demand such of his promissory notes as are likely to be at any time presented to him, those notes come to have the same currency as gold and silver money, from the confidence that such money can at any time be had for them

The focus is clearly on the trustworthiness of a particular banker, with respect to the previous stage here we have an increased presence of trust that it becomes shared trust on someone else among different individuals;

boundaries of this trust increasing process are given by the limited publicity that a potential banker could have, Dow et al. (2008) say that "because confidence in banks still tends to rest on local knowledge, the use of titles to deposits as a means of payment is limited to the local geographical area."

Once an appropriate diffused trust in a particular banker is established then a new subtle opportunity of "profit" is available to him: by noticing that the requests for reimbursement of deposits are limited, or put in other words that re-deposits are frequent, the banker could begin to expand credit beyond the amount of deposits he really has through the lending of part of what he has in custody and the contemporaneous guarantee of immediate availability of their deposits to initial depositors. We have in the just described process the raw seed of the fractional-reserve-banking practices and "irregular deposits" as proposed by Huerta de Soto (2009), banks now become vulnerable to liquidity and solvency problem.

The next stage, number three, in our vision is not a stand-alone step but rather an indistinguishable motion from stage two since the dynamics present do not yet evolve toward confidence at the expense of trust; in fact it is characterized by an increasing complexity of the entire panorama of newly born banks, whose recognizing that remaining alone would experience heavy losses when asked to return an huge number of deposit, then they realize that it is in their interest to develop a system of inter-bank lending. The immediate consequence is a potential decrease of initial reserve of each single bank since reserves could be acquired by other players, accordingly there is a development of banking system as a whole.

Stage four is without doubt that more significant in entire Chick's framework, Dow et al. (2008) recognize that this stage "is a turning point in terms of the role of the central bank when it assumes full responsibility for promoting confidence in the banking system, primarily by providing the lender-of-last resort facility"; the idea is that of an institution with extra power deriving from high reliability that will provide liquidity when the intra-banks market is not able to deal with a potential situation of systemic collapse. In economics literature there are substantially two opposite positions toward existence of central banks: those in favor say that the role and functions of financial institutions are too much important for the good development of economy and therefore institutions like central banks are absolutely necessary to prevent the bankruptcy of banks deemed systemically important

or *too big to fail*, those contrary argue that the presence of central banks with function of lender-of-last-resort distorts the proper performance of the market introducing elements of moral hazard in single financial actors that have the temptation to take on more risk.

In our opinion the subsequent phases proposed by Chick can be merged together and be considered as natural consequences of the previous ones: firstly non-bank-financial-intermediaries start to use the liabilities of bank as their reserve base and secondly banks, instead of waiting for loan requests, aggressively seek new lending opportunities. The result is a never ending struggle among regulators and financial institutions, with the former committed to limit activity and risk of banks while the latter intent on finding new sources of income.

Returning to our very object of analysis, the identification of trust and/or confidence, we argue that the firm shift towards confidence reach its climax with stage four as, nevertheless the publicized independence, the perception of central bank within and outside the banking system is that of an institution operating in strict connection with government and policy-makers and not that of an isolated authority. In addition to the strict link between state and central bank, the complexity of the banking system as a whole hinders the knowledge that depositors can obtain about each component of the network and how they are connected, the consequential uncertainty is then addressed by existence of confidence.

Since the lack of knowledge is hardly superable, the confidence in state considered as an institution engaged in an accepted social contract has a feedback effect in confidence in central bank: if citizens perceive that state is acting appropriately then they feel that also regulators as central bank are prepared and appropriate, so the shaky foundations of banking system are not in trouble, otherwise if state institutions lose their authority. It is valuable to note that feedbacks flow also in the opposite direction, state has only to gain from central banks perceived in positive manners.

Applying flexibly the Chick's framework to banking systems of modern developed countries we can identify as a crucial point in centralization of powers by the central banks the so called *Nixon Shock*[2] that bequeaths a system completely based on FIAT money, in this respect Krugman (1996)

[2]On 15 August 1971 the USA President Richard Nixon declared the ending of convertibility between U.S. dollars and gold.

summarizes the new era saying that "The current world monetary system assigns no special role to gold; indeed, the Federal Reserve is not obliged to tie the dollar to anything. It can print as much or as little money as it deems appropriate."

We agree completely with Ferguson (2008, 29):

> The intangible character of most money today is perhaps the best evidence of its true nature [...] money is a matter of belief, even faith: belief in the person paying us; belief in the person issuing the money he uses or the institution that honors his cheques or transfers. Money is not metal. It is trust inscribed. And it does not seem to matter much where it is inscribed: on silver, on clay, on paper, on a liquid crystal display. Anything can serve as money [...] And now, it seems, in this electronic age nothing can serve as money too

All the above discussion to states that for the development and growth of economy what it is absolutely necessary is the presence of confidence in social structure of state in a confidence-building process that require stability of national currency; in order to have stability central banks should behave in such a way that mere pieces of paper, today valuable, maintain their value also in future.

2.3 Bitcoin

The technological developments of recent years and the ever growing of virtual communities led to a proliferation of various virtual currencies which often are nothing more than digital versions of tokens that can be used only in a predetermined place but in other cases have special features that distinguish them.

The establishing of a new virtual currency scheme when performed by a for profit entity has almost always as objectives those of provide a financial incentive for community users to continue to participate or create lock-in effects that would hopefully generate greater revenues, the best known examples in this regard are Credits by Facebook, Linden Dollar in the virtual world of Second Life and Amazon Coin to be launched in May by the homonymous online retailer.

On the contrary in the following we will briefly describe a virtual currency, named Bitcoin, which differs from those mentioned a moment ago; in the publication by ECB (2012b) Bitcoin is refereed to as "a virtual currency scheme based on a peer-to-peer network. It does not have a central authority in charge of money supply, nor a central clearing house, nor are financial institutions involved in the transactions, since users perform all these tasks themselves. Bitcoins can be spent on both virtual and real goods and services. Its exchange rate with respect to other currencies is determined by supply and demand and several exchange platforms exist."

The birth of Bitcoin is to be found in the work of Nakamoto (2008), even if its first implementation occurred in January 2009; since then it has received increasing attention by the media, sometimes due to the usage in dubious business practices[3] while in other cases due to the opinion of some of its value as long-term form of investment or to the apparent fate of becoming the global currency in the future.

We make it clear that we are critical with those who foresee a definitive decline of actual currencies in favor of Bitcoin and the first of all reason is the completely lack of regulation and recognition of the latter, which hinders its use by tax-payers to free from the burdens imposed by the state. Notwithstanding we want to point out that, in our opinion, what differentiate Bitcoin from traditional currencies and makes it interesting is how this recent virtual currency scheme tries to solve the problem of double-spending.

For Wikipedia (2013b) double-spending " is a failure mode of digital cash schemes, when it is possible to spend a single digital token twice. Since, unlike physical token money such as coins, electronic files can be duplicated, and hence the act of spending a digital coin does not remove its data from the ownership of the original holder, some other means is needed to prevent double-spending"; the usual answer provided in traditional virtual currency scheme is a trusted central third party that verify and certify the rightful possession of digital cash while in Bitcoin by making use of advanced techniques[4] from informatics the possession is verifiable by each participants in

[3]Among the others: paying for bets on website from countries where gambling is not allowed and sale of drugs on the online black market operated as a Tor hidden service named Silk Road.

[4]Nakamoto (2008) in the abstract of his work says: "we propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a

every time without trusting a third party.

Finally, we can conclude that proposals coming or from the virtual world as Bitcoin or from the real world as the $1 trillion platinum coin proposed in US (Economist, 2013) are a clear sign that the debate about basic structures of economics, as money, is all but dead.

record that cannot be changed without redoing the proof-of-work. The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers."

Chapter 3

Payment systems

3.1 Interbank payment systems

As seen in previous chapters a striking feature of modern economies is the rapid growth in the use of money in electronic form; then we argue, given the apparently missing of physical tangibility in cashless transaction, that a deeper understanding of the processes occurring after whatever trade that imply transfer of value in cashless form is desirable. Moreover we claim that in our time, the relatively high simplicity of pursuing interaction (buy/sell) with people through electronic means has lead a great majority of people both to consider this opportunity as due and expected, while it were unimaginable only some decades ago, and both to miss the necessary backbone necessary to achieve this marvelous result.

From this recognition hereinafter we will provide a very general description of the payment system landscape with particular stress on the business of the principal agents involved in the continuous carrying out of transfer of value, firstly we will briefly deal with the topic on global scale while secondly we will focus on the recent European Union's integration experience of Target2 and the forthcoming Target2-securities.

Among the others CPSS (2011) and CPSS (2012b) are a priceless source of information for what concern the payment, clearing and settlement systems present in a great majority of developed countries all around the world; from these sources we have had the opportunity to finally grasp the complexity of the global system of interlinks among a swarm of institutions whose role is functional to the provision of fast, secure and precise financial

services.

There are two core points of our analysis: the first is the definition of electronic money as proposed by CPSS (2012a) "electronic money is defined as monetary value represented by a claim on the issuers which is stored on an electronic device such as a chip card or a hard drive in personal computers or servers or other devices such as mobile phones and issued upon receipt of funds in an amount not less in value than the monetary value received and accepted as a means of payment by undertakings other than the issuer", while the second is the recognition that in modern economies only one entity in each region with a different sovereignty power has the privilege to create new money out of thin air.

We want start our journey by noticing that the combination of fiat money based on nothing tangible[1] and the opportunity provided by new technology from the 1950's has given an impulse to the birth of a greater number of financial intermediaries.

The very fact that only central banks has the honor to potentially create an unlimited amount of money and that the accounting of money created has as only physical entity a sequence of magnetized cluster on a computer's hard disk implies that, however complex the whole financial system, it is always possible to identify a subject that has the power to say the final word on contrasted claims above the correct amount of money one is entitled to and this is represented by the central bank on duty; Padoa-Schioppa indirectly highlights the point in the foreword of CPSS (2003): "Contemporary monetary systems are based on the mutually reinforcing roles of central bank money and commercial bank monies. What makes a currency unique in character and distinct from other currencies is that its different forms (central bank money and commercial bank monies) are used interchangeably by the public in making payments, not least because they are convertible at par. Central bank money plays a key role in payment arrangements, as it has proved safe and efficient to have a central reference of value with which all other forms of the currency maintain this par convertibility. This role is long-established and, for the most part, uncontroversial"; in the just quoted text there is a distinction between central bank money and commercial bank money and

[1] Here we consider tangible in the sense of money based for example on gold reserves, as seen previously we are comfortable with money based on social contract and power of coercion of government.

the underlying idea is that "central bank money is generally completely safe in its jurisdiction [...] central banks are more credit worthy institutions than commercial banks in their own currency. They have explicit or implicit state support. In a fiat money system, where not constrained by a convertibility rule to another asset/currency, the central bank can always cover its obligations by issuing its own currency" (CPSS, 2003, 13).

Central bank money takes prevalently two forms: banknotes and deposits held at the central bank, the first form is available almost to everybody in the economy while the availability of the second one is restricted to particular typology of subjects (mainly banks); it comes from factual evidence that transaction characterized by low-value are generally conducted with the use of banknotes [2] but the great majority of high-value exchanges are conducted mainly through crediting and debiting of deposits (denominated mainly in commercial bank money) held at banks that in turn credit and debit their accounts held by central bank.

The simplest model of arrangement feasible to make a payment is represented by the transfer of banknotes from a payer to a payee since banknotes are bearer instruments, to guarantee its simplicity the central banks' focus is towards improving anti counterfeiting measures in order to enable individuals to be certain that the piece of paper proposed by the counterpart was actually issued by the central bank. This system has numerous weaknesses, it is highly inefficient if the scale of economy grows and broadly speaking it does not allow exchanges not vis-à-vis.

However different arrangements are necessary when two counterparts agree to conclude an exchange using electronic money, the constant is the presence of at least a third party trusted by both: a specific situation is when A and B are both customers of the same bank C and A owes B a certain amount of money, in this case C contemporaneously debit the deposit of A and credit the deposit of B and then communicates to customers that the transaction has been executed. The just described process is called "in-house settlement" and it is obviously a particular case since not necessarily the counterparts are customers of the same bank, nevertheless it represents with small differences what happens also at different levels above when A and B are banks and C is another bank or more often a central bank.

[2] However in recent years it can be noticed a switch to deposit based form also for small-value transactions.

When a payer customer of bank X owes a certain amount to a payee customer of bank Y there are basically two opportunities for the payments: Kokkola and Bank (2010, 37) identify or a bilateral arrangements between X and Y or an arrangements involving a service-providing third party, the evidence is in favor of the second case both for reasons of greater efficiency and improved flexibility. Moreover, the result of trying to identify the different arrangements among financial actors is a complex network with multiple tiers of intermediation that at a global level put the central bank money in a pivotal position. The presence of these strict interrelations embodies a potential for disastrous events since it is impossible to consider every possible evolution, May et al. (2008) says that

> Catastrophic changes in the overall state of a system can ultimately derive from how it is organized, from feedback mechanisms within it, and from linkages that are latent and often unrecognized. The change may be initiated by some obvious external event, such as a war, but is more usually triggered by a seemingly minor happenstance or even an unsubstantial rumor. Once set in motion, however, such changes can become explosive and afterwards will typically exhibit some form of hysteresis, such that recovery is much slower than the collapse. In extreme cases, the changes may be irreversible

One may say that the fear for an unpredicted break of a such fragile system is the basis on which ever increasing controls and rules are put on the street.

Historically we can highlight similarities and dissimilarities between services of clearing and settlement for what concern the transactions involving securities and those dedicated properly to payments: the former have seen broadly presence of private entities while the latter have been developed mainly under the aegis of central bank, the former have seen the affirmation of strongest competitors[3] after a more or less competitive process while the latter derive from no competition at all; the similarities instead are found both in the same eagerness for reliability, security and standardization and in the use of liquidity saving techniques.

[3]ICSD like Clearstream and Euroclear among the others.

The life of every post-trade is in fact composed by different steps: initially an agreement is reached between the counterparts, then it follows a period before the real settlement of the obligation in which one of the two counterpart (usually the vendor) bear the risk that the payer would not be able to fulfill its obligation, finally there is the definitive close of the transaction; the presence of counterpart risk has lead to a move toward centralized entities that interpose themselves trying to reduce the risk by bringing together an adequate number of financial institutions responsible for a massive number of transactions, moreover given the rising number of transactions to deal with and the initially limited amount of resources from the technological point of view it has been developed techniques for reducing the liquidity necessary for the settlement by netting existing positions.

It is clear that in a such complex environment there are a lot of flows of information, in fact exchange of data among participants is what really matters; in a bilateral agreement a common basis must be achieved among two parties but when more parties are present a shared basis must be accepted by all and a form of standardization is required. Internationally one of the main providers of communication network is represented by SWIFT[4]: the business of this society is to provide secure messaging services and interface software for payment systems and its wide adoption has lead to become the industry standard for syntax in financial messages (Wikipedia, 2013h).

In the end we believe that the challenge in global payment system is based almost only on purely technical advances both in the legal field and in the technological one: role of law sets the general framework in which improved technology and algorithms are implemented, it is in fact important that rights and obligations of each party involved in the process are established with legal certainty. Instead, in the description of communication networks, Kokkola and Bank (2010) recognize at first that "the most critical issue for payment systems communication networks is the security of the information transferred within them" and secondly that "in order to achieve a high level of security, a payment system must ensure the following for all data exchanged via its communication network:

Authenticity of the data Authentication allows a payment system to en-

[4]Society for Worldwide Interbank Financial Telecommunication, founded in 1973 by 239 banks from 15 countries, by the end of 2010 almost 10000 financial institutions from 209 countries were connected through its network.

sure that the senders and recipients of messages are really who they claim to be

Integrity of the data Integrity in communication networks means that the recipients of messages can be sure that the information transmitted has not been manipulated in an unlawful manner

Confidentiality of the data Confidentiality is achieved by allowing only network participants to view the information exchanged via the network

Non-repudiation of the data Non-repudiation is a mechanism providing evidence of both the identity of the sender of a message and the integrity of that message, such that the sender is unable to deny the submission of the message or the integrity of its content

We value to notice that the security in interconnected networks described above has been reached by the development of new practices in strong cryptography field.

Looking at payment systems all around the world we deem as significant the experience resulting from challenges of ever increasing integration posed by European treaties: the result has been finally reached firstly with the promotion of a Single Euro Payment Area (SEPA) that lead to "cost efficiency gains when processing is consolidated across borders rather than piggy-backed onto existing national operations" (Bolt and Humphrey, 2007) and secondly with the mandatory use of the ECB's controlled interbank payment system named TARGET2.

TARGET2 replaced the first generation TARGET (Trans-European Automated Real-time Gross Settlement Express Transfer System) in 2007 and it is a clear result of improvements in technology: now in the pan-European area there is a Single Shared platform for large-value payments while with the previous version there was an initial clearing and settlement level within national boundaries in a RTGS system owned by a national central bank and only after a clearing and settlement at European level. The European experience does not end with TARGET2, since the necessity of minimize risks and provide reliable instruments for a smooth functioning of the economy has lead to the TARGET2-Securities project which aim to "offer centralized delivery-versus-payment (DvP) settlement in central bank funds across all

European securities markets" (Wikipedia, 2012d); this is another example of how the initiative of the free market has been more innovative than state's one but in the end the state often adopts these innovations.

3.2 Card payment systems

It is undeniable that on the economic scene of today there is an increasing utilization of cashless form of money, we can ascribed multiple reasons to this preference over traditional cash: among the others there is a perception by an ever increasing number of people of increased convenience and enhanced protection, while by the governments there are targets like that of greater efficiency and higher control on citizens; in the following we will focus on payment cards given their ubiquity in pocket of almost every person living in a developed country.

We start our analysis by noticing that there are several types of payment cards and different ways to categorize them: a first peculiarity is to understand if a card is a stored-value one or not, the former embodies the funds and or data physically on the card itself while in the latter the funds and or data are maintained on computers affiliated with the card issuer. Hereinafter we will focus on payment cards of the second type and refer roughly to Wikipedia (2012c) descriptions by noticing that these cards are almost always electronically linked to an account belonging to the card-holder:

Credit Card It is a card entitling its holder to buy goods and services based on the holder's promise to pay for these goods and services. The issuer of the card grants a line of credit to the consumer (or the user) from which the user can borrow money for payment to a merchant or as a cash advance to the user. Credit cards allow the consumers to "revolve" their balance, at the cost of having interest charged.

Charge Card It is similar to a credit card, except that the contract with the card issuer requires that the card-holder must each month pay charges made to it in full (there is no "minimum payment" other than the full balance). A partial payment (or no payment) results in a severe late fee and the possible restriction of future transactions and risk of potential cancellation of the card.

Debit Card It provides an alternative payment method to cash when making purchases. Functionally, it can be called an electronic cheque, as the funds are withdrawn directly from either the bank account, or from the remaining balance on the card. In some cases, the cards are designed exclusively for use on the Web, and so there is no physical card. A subtype is represented by prepaid-debit-card.

Observing a payment card (of any kind is) there are recurrent information stamped or embossed on it: we can recognize among the others the logo of the issuing bank, the card-holder's name, the expiration date and the card brand logo; for what concern our analysis we will focus on the circuit (or more than one) to which the particular card belongs and we sometimes refer to it as card scheme.

Kokkola and Bank (2010) define a card scheme as "a technical and commercial arrangement set up to serve one or more card brands which provides the organizational, legal and operational framework necessary for the functioning of the services marketed by the brand"; in fact the presence of a scheme to which all parties involved conform is a necessity in order to consider card transactions a reliable payment instrument. Among other things, the rules laid down by the card scheme deal mainly with the standards to be applied in exchanging information among different parties involved in the process and make clear where liabilities lies both in the event of fraud or in the occurrence of technical problems within the infrastructure.

In the field of payment card systems there are essentially two different business models: a three-party scheme (also called close network) and a four-party one (also called open payment network); in a transaction the presence of a buyer and a seller is obviously common to both models, they differentiate since in the former the institution that runs the scheme is responsible for the issuing of cards and the acquisition of transactions while in the latter the issuing and acquiring actors are separate entities.

Despite some peculiar national realities, in the international market of payment cards there is the presence of few players: American Express is the leading example of three-party network while MasterCard and Visa have the greater market shares and follow a four-party model. Various differences, especially in the regulations to which the players are subjected, are detectable following the descriptions of the three company provided by CPSS (2012b):

American Express Company is bank holding company that operates its own network, processes transactions, and provides business-to-business services to merchants.

American Express derives its revenue primarily from card usage and secondarily from finance charges and fees.

As a bank holding company, American Express is subject to supervision and examination by the Federal Reserve [...] As a credit and charge card issuer, American Expresss lending and pricing practices are regulated by various agencies in the countries in which it operates. As an issuer of stored-value instruments, American Express is subject to money transmission laws. As the operator of a card network, American Express is often subject to anti-money laundering rules and data security laws.

[...] Within its general purpose card network, American Express generally acts as both a card issuer and merchant acquirer. Occasionally third-party banks might act as an issuer and/or acquirer on American Expresss behalf. Participants with access to the American Express network must abide by the networks rules and meet certain financial standards. In 2010, American Express had 91 million credit cards in force worldwide.

MasterCard Worldwide is a public traded company which has as clients primarily financial institutions that issue its cards and/or act as merchant acquirers for merchants that accept MasterCard cards. [...] As well MasterCard owns and manages an international telecommunications network and several processing centers. License-holding institutions market and issue cards to their customers in accordance with MasterCards rules and standards. MasterCard license holders independently set and charge fees and interest, decide on credit and spending limits, and choose which benefits should be offered to cardholders.

MasterCards revenue comes primarily from fees paid by its clients based on payments volume and services provided.

As the operator of a card network, MasterCard is often subject to anti-money laundering rules and data security laws.

In 2010, MasterCard had 975 million cards in force worldwide.

Visa is a public traded company which has as clients primarily financial institutions that issue its cards and/or act as merchant acquirers for merchants that accept Visa cards. [...] As well Visa owns and manages an international telecommunications network and several processing centers. License-holding institutions market and issue cards to their customers in accordance with Visas rules and standards. Visa license holders independently set and charge fees and interest, decide on credit and spending limits, and choose which benefits should be offered to cardholders.

Visas revenue comes primarily from fees paid by its clients based on payments volume and services provided.

As the operator of a card network, Visa is often subject to anti-money laundering rules and data security laws.

Approximately 2.2 billion Visa-branded cards were in circulation worldwide in 2010.

We argue that the more regulations that a a three-party model must submit and the greater and dispersed efforts that must be directly undertaken in order to run the business are decisive elements for a progressive shift towards four-party scheme: in fact since Visa or Mastercard are exposed to the credit risk of the issuer banks operating on behalf of the cardholders they manage the risk by assessing the financial quality of the issuer banks and ignore the soundness quality of individual cardholders while instead American Express since directly exposed to consumer credit risk it must evaluate continuously the credit quality of each one of its clients; CPSS (2012b) gives a support to this claim saying that "in countries where American Express believes there is higher financial risk, American Express uses third-party banks as issuers. American Express reports that its credit losses are generally lower when using this model than when it acts as a credit issuer."

The multi purpose nature of payment cards (mainly those issued in a four-party scheme) is the result of the impressive standardization reached and allow us to recognize that the core business of Visa and Mastercard is the elaboration of information and the final provision of reliable indications to their clients. Often payment cards can be used both in a POS allowing the

payment of an obligation deriving from a sell and in an ATM allowing the withdrawal of banknotes; in fact, in addition to the proper payment networks the two big players own the two biggest worldwide interbank network known as Visa Plus and Cirrus.

Focusing on four-party network we consider the companies that own and run the infrastructure as *orchestra's conductors* that provide the right timing to all performers involved in the passage without playing first-person: companies on a 7x24 base keep records of transactions and store the amounts issuer banks must be charged and acquirer ones accredited but do not carry out the settlement, they merely provide the data to allow settlement to be executed. Indeed the real settlement (sometimes on net basis) is conducted in a pre-identified settlement bank using the services of domestic clearing and settlement systems; the smooth functioning of the whole mechanism on a global scale is guarantee by the adoption of internationally recognized standards for transmission of financial data (like SWIFT) and the participation, direct or more often indirect, of all clients of the companies to national settlement platforms (like BI-REL by Bank of Italy), to supra-national networks (like TARGET2 by Eurosystem) and to global multi-currency cash settlement system (like CLS by CLS Bank). Moreover, since the card associations guarantee settlement of all payments sent through their network it is frequent that they require the participants to post collateral, typically in the form of letters of credit, bank guarantees, or secured cash accounts.

In the analysis of payment card systems we can adopt two points of view: everything else being equal, being a card-holder we benefit if more and more merchants are willing to accept our card while otherwise being a merchant we benefit if more and more customers possess a card that we are willing to accept; in other words it is present a strong network effect and the intrinsic value of cards is dependent on the number of users (both on buy and sell side of transactions).

Moreover, the type of network effect can be named two-side network effect after the recognition that the necessity for a payment card system to attract both merchants and cardholders is the determinant which makes it a typical example of two-sided market where an increase in usage by one set of users (cardholders) increases the value of participation of a complementary and distinct set of users (merchants), and vice versa.

Hereinafter we will be consistent with literature jargon of two-sided market and we will refer to card associations (like Visa and Mastercard) as platforms, recognizing that these organizations have the task of *getting both sides on board* (Rochet and Tirole, 2003). In the payment card market has been developed some peculiar arrangements that we will briefly describe in the following trying to grasp both the motivations behind each one of these arrangements and the different adoption by three or four-party scheme, secondly we will try to understand (with the provision of examples from literature) what are the possible results deriving from public regulations tampering with them.

Before going into a deep analysis we consider useful to review what are the flows of money that finance the whole payment card system; on one side the costs to which cardholders are subject depend obviously from the services provided, Baxter (1983) in fact observes that "the card-issuing bank can be viewed as engaged in two different businesses. It sell a transaction service involving valuable float to those non-revolvers who choose to pay their statement in full at the end of each billing cycle. It also sells a combination transaction service and consumer finance service to those who use their bank cards as an extended credit mechanism", therefore cardholders might pay an annual fee for being owner of a card, are subject to extra cost if they utilize the card in non-standard ways (for a credit card an example is the use of the card in ATM to get a cash advance) and if they use the revolving mechanism they must pay interest-based fee; on the other side merchants generally have two different source of costs: they are charged a fixed costs for the leasing of the hardware necessary to accept payments and they pay a discount fee on the value of each transaction paid by card.

From an empirical observation of two-sided markets Bolt (2012) recognizes "that platforms tend to heavily skew the price structure to one side of the market to get both sides on board, using one side as a profit center and the other side as a loss leader or at best financially neutral"; more specifically Baxter (1983) referring to payment cards states that "income from card holders is too small for the average card-issuing bank to cover its costs, whereas income from merchants is, on average, more than sufficient for merchant banks to cover their costs", and so he identifies the merchants as profit center while cardholders represent the loss leader side.

The necessity to have both sides on board and the contextual contin-

uously position at economic loss of the provider of services to cardholders determine an approach that it is at the same time different but similar in closed systems and open ones. Rysman and Wright (2012) notice that three-party systems (such as American Express) since are at the same time issuer of cards to consumers and acquirer of merchants are free to set the structure of prices that generate the maximum profit and incidentally this is composed by low card-holder fees and high merchant fees, while in contrast the platform in open system has not (and it is not suppose to have) the power to set fees to final users of cards since its direct customers are banks that compete both on the issuing of cards and on the acquiring of merchants, so the solution adopted in four-party schemes in order to give incentives to operate also to issuer banks was that of setting an interchange fee.

Rochet and Tirole (2002) identify the following rules as peculiar for the achieving and maintaining of a payment card system:

Interchange fee The acquirer pays a collectively determined interchange fee (the analog of an access charge in telecommunications) to the issuer.

Honor-all-cards rule All affiliated merchants must accept the card of any issuing member.

No-surcharge rule Affiliated merchants are not allowed to impose surcharges on customers who pay with a card.

Hereinafter we will mainly focus on interchange fee since, as we will see, this is the central arrangement for the good functioning of system, without however forget the relationships with the honor-all-cards rule and the no-surcharge rule.

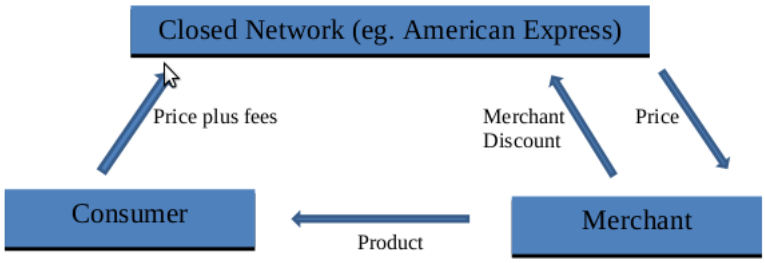

Figure 3.1: Closed Network scheme (source: Rysman and Wright (2012))

In order to understand the reasons behind the interchange fee is useful to

consider a three-party scheme, as highlighted in Figure 3.1 in this network there is no explicit transfer fee from the division dedicated to acquiring towards that involved in issuing because exists a coordination of actions given the uniqueness of firm. However, as noted by Rysman and Wright (2012), "there is an implicit interchange fee", in fact if one suppose that a closed card system is divided into two independent departments, each one would set its own prices to maximize its own separate profit and would not consider the effects on the other division; the issuing department would set the cardholders fee at level too high because it would not take into account that a greater number of cardholders could mean greater usage of cards and so greater revenues for the acquiring department so the global result would be lower revenues for the firm.

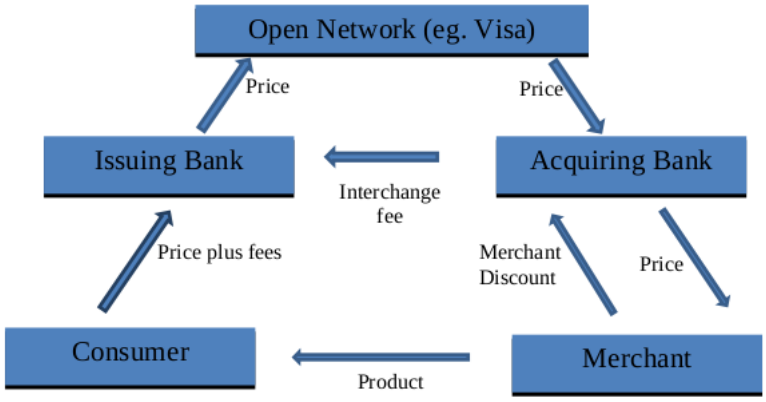

Figure 3.2: Open Network scheme (source: Rysman and Wright (2012))

The "coordination-solution" adopted in closed system is not applicable in open network since issuers and acquirers are independent, then the way to internalize the network effect is the setting of a default interchange fee whose structure is that or of a percentage of transaction value or a fixed fee per transaction and that operationally consists in a reduction of the amount paid by the issuer of the card to the acquirer of the merchant.

It is important to remark that the interchange fee does not absolutely represent a source of revenue for the owner of the open system that rather collects a substantial smaller switch fee for the provision of the infrastructure; Hunt (2003) through the recognition that platforms on one hand benefits from an increased usage of cards but on the other hand are unable to exercise direct control over the prices paid by cardholders and merchants,

notes that networks "influence those prices by setting the interchange fee." To point out the weak equilibrium underlying the interchange fee the same author suggest the following reasoning: "suppose the network raises an interchange fee paid to card issuers so that each card transaction is more profitable for those banks, card issuers will seek out more cardholders either by offering them more benefits or by reducing card-holder fees, merchants will observe more cardholders using the card [...] the trade-off is that raising the interchange fee raises costs for acquiring banks, and at least some of that cost is passed on to merchants [...] the higher cost of card transactions may cause some merchants to stop accepting the card."

For what concern the no-surcharge rule and the honor-all-card one we believe that we should make a distinction based on the historical period and on the general level of distribution/acceptance of payment cards: the two rules were undoubtedly accepted in the late 1960s and 1970s, when the process of building card acceptance began (with a focus on credit card), as they contributed to reduce the uncertainty that consumers would face if these rules were not present; however we notice that the approaches to the same rules started to change, when the new means of payment consolidate their diffusion, and are now very heterogeneous in different countries.

The honor-all-cards rule present in all agreement between an acquirer and a merchant had as initial purpose that of allow a smooth functioning of the system since a card-holder should only be concerned to know if the merchant accept or not a particular card-brand, without this rule as noted by Baxter (1983) the acquiring bank acting on behalf of merchant should conclude multiple bilateral agreements with all distinct issuing banks and would imply inefficiencies for the system as a whole and uncertainty for the cardholders which have to deepen if the particular merchant agrees to accept card issued by their issuing bank; concerns about the rule started to be raise when in 1980s the main card associations, in the quest to develop the market of debit cards on top of the existing credit card networks, tied the merchants adherent to the system to accept both credit and debit card of a same brand.

Regarding the no-surcharge rule, the criticisms have been moved very early since the rule is progressively being seen as a constraint to merchant's freedom of action, Rochet and Tirole (2011) hit the mark by describing

the compulsion as "must-take cards"; the result is that merchants are in a situation in which they cannot differentiate the price offered to consumers in order to directly pass to "willing-to-pay-by-card consumer" the costs that the acceptance of cards implies. Where the rule is present businesses had to recover the costs indirectly, that is, by passing on the costs of credit card transactions to all consumers of their goods and services, regardless of the payment method the individual consumer was using and so by setting a likely higher price that would have been set with no existence of payment cards.

However the situation around the world is in some way heterogeneous: in some countries under some versions of no-surcharge rule, merchants are allowed to offer discounts for the use of cash, but may not offer discounts or surcharges that steer consumers among different cards while in other countries policy-makers legislate that no-surcharge rule is not valid and so they require modifications of existing arrangements with merchants.

An interesting question is what happens if payment networks permit merchants to add a fee to transactions when consumers use a more expensive payment method, a likely answer is that merchants would pass the whole cost to consumers and so the latter would take in account also the increased cost of some means of payment in deciding the more efficient way to pay. However in the literature (Rysman and Wright, 2012) there are evidence that in countries in which surcharging is allowed, such as Australia, Czech Republic, Denmark, Ireland, Hungary, Netherlands, New Zealand and the U.K. the surcharging is not so widespread as one might think; Frankel (1998) argues that "merchants believe any benefit of charging different prices is not worth risking a negative reaction from customers" and that "consumers react more strongly to fees charged at the point of sale than to fees that appear later on their bank statement."

Another interesting observation by Rysman and Wright (2012) is that, "of those merchants that do surcharge, the average surcharge is around twice that of the merchant fee they face, and this average surcharge has increased even while merchant fees have decreased [...] surcharging seems to be used by some merchants as a form of add-on pricing, adding additional fees that appear only at the register, where it may be more difficult for consumers to opt out or make another payment selection (e.g., if they dont have sufficient cash on hand), and where doing so makes price comparisons

between merchants more difficult"; we have to notice that, notwithstanding the results just reported, the trend is towards a progressive prohibition of no-discrimination rule also in those countries in which is still allowed.

Once again Rysman and Wright (2012) highlight the central point of the argumentation against no-surcharge rule: "the antitrust argument against such a restriction is that it plays an exclusionary role, in that it is difficult for a new card system that is predicated on low merchant fees to enter the market and effectively compete. Even if the merchant finds the new card system to be attractive, it has no way of steering consumers to use it, beyond refusing to accept alternative cards. Furthermore, the inability to surcharge (or discount) perhaps gives greater power to the card system to raise merchant fees. More generally, a wholesaler that conditions the merchants price of its product on the price of a competing product could raise antitrust concern."

We deem valuable to note that even a country like United States see a recent movement in regarding the no-surcharge rule, in fact as reported by VISA (2013) "in November 2012, the United States District Court for the Eastern District of New York preliminarily approved a proposed settlement agreement in the *In re Payment Card Interchange Fee and Merchant Discount Antitrust Litigation* that resulted in a new law permitting surcharging from 27 January 2013; the change is not however decisive since it is limited to Visa and Mastercard and not to American Express, and moreover the extra fees continue to be illegal in some specific states.

A recurrent question through literature is whether interchange fees or card fees in general are set at the "wrong level" (McAndrews and Wang, 2008), assuming the right level as that which provide the most efficient outcome for a social welfare function; in fact what it is really questioned is if the fundamental mechanisms of payment card network remain essential when the networks are well established, Katz (2001) in his work questions whether network effects are relevant for mature payment networks that has yet gain a monopoly position.

The importance of the topic, that is not of theoretical only interest, is emphasized by some litigations that see merchants against card associations, where the former blame the latter to pursue anti-competitive behaviors that should be subject to punishment under antitrust laws; Rysman and Wright

(2012) divides the concerns about collusion into two types: "the first concern is that positive interchange fees are an anti-competitive device used by competing issuers (under the guise of a card platform) to enable them to collectively increase merchant fees. This concern centers around a charge of collusion, based on the claim that card platforms represent a collection of banks that otherwise compete with each other [...] the second concern is that the contracts that acquirers sign with merchants involve rules imposed by card networks that have been claimed to exploit their market power to extract merchant surplus and limit competition between card systems."

The same author reports that the standard defense of card associations leverages on general statement underlining the impossibility to provide payment cards without these fees and limitations, but the response is at the same time rather vague about the numerical impact of these same choices.

A number of theories and model have been proposed in order to assess the deviation (if any) between privately determined interchange fee and socially optimum one, the last in time is the so called "tourist test" (Rochet and Tirole, 2011) that can be synthesize as: "does the interchange fee lead to a merchant fee that would induce the merchant to turn down the card for a tourist who is known to have the cash and is already at the store, assuming that the merchant has this discretion and will not see the tourist again?." The idea of the creators of the test is that the highest interchange fee that does not lead the merchant to turn down the cards in such circumstances represents the socially optimum interchange fee, in our opinion the idea is not wrong but we agree with Borestam and Schmiedel (2011) in denying its use as a practical instrument to provide indications to policy-makers.

Making a comparison between more recent literature and older one on payment card system we notice a progressive increasing of cautious positions on claimed distortions in the card industry; among the others Rysman and Wright (2012) reminds that "there is no clear or obvious distortion in the private determination of interchange fees" in models yet developed because they "depend on specific sets of simplifying assumptions" that seriously distort the results since often do not take into account the dynamic nature of the system, while McAndrews and Wang (2008) goes even further saying that "the welfare analysis in the existing theories are quite formidable" when "one combines the unspecified merchant/consumer benefits from the use of a payment device with the strategic effects of imperfect competition and

differences in bargaining power."

Notwithstanding the fact that on one hand when "network effects and dynamic issues" are taken into account "policymakers (would) face a difficult problem in deciding what remedies, if any, will benefit consumers in the long run" (Hunt, 2003) and on the other hand the fact that the biases that emerge from literature based on simplified assumptions are "subtle in nature compared to what one would normally consider sufficient grounds for regulatory intervention" (Rysman and Wright, 2012); a series of interventions have been made by public authorities such as the Reserve Bank of Australia, the European Commission and the United States Government Accountability Office.

In the end we believe that taking an *a posteriori* point of view might be a useful exercise: a first naive approach in evaluating the distortion of privately set fees in card payment system would be that of looking at the level of agreed upon settlement after litigations promoted by associations of merchants against card associations (Sidel and A., 2012) and referring to those huge values an informed guess would be that the level of interchange fee was effectively higher that the competitive one; while a second interesting analysis is to look at the results of implementation of public regulations in payment card industry.

A unique case is that represented by reforms implemented by Reserve Bank of Australia, Gans and King (2003) notice that Australia was the first country to remove surcharge restrictions and directly regulate the interchange fee by imposing cap limit. However the expected benefits to consumers do not seem to have made, the reduction of merchants discount do not have lead to reduction of prices offered to consumers and the visible results were a progressive switch from credit card toward debit cards and a substantial decrease of rewards programs offered to cardholders.

Observing the market power exercised by merchants in take advantage of reduce costs by not passing them to consumers we argue that the problem can be better addressed on a political level, the point is in our opinion who has the loudest voice in extracting wealth, card associations or merchants?

We feel in agreement with Rysman and Wright (2012) in claiming that, if regulators were really interested in providing an efficient system, a feasible way to proceed might be "that government enter into the market with

its own product" and set directly the interchange fee; at least two further evidences of the potentiality of this option can be detected , the first is the effort undertaken by China and India respectively with ChinaUnionPay and RuPay, and the second is the project of an integrated SEPA for cards in Europe (Borestam and Schmiedel, 2011).

The active involvement of governments in fact might reasonably encourage usage of payment cards in the quest towards a cashless society and be a way to fix fees proportional to at-cost price for the whole infrastructure of the system.

3.3 Ripple

We observe that the panorama of payment system sees a new entry, although still in an embryonic state, that we will briefly describe in this section.

The object of interest is a project named Ripple that is described by Wikipedia (2013f) as "an open-source software project for developing and implementing a protocol for an open decentralized payment network. In its developed form (it is not substantially implemented), the Ripple network would be a peer-to-peer distributed social network service with a monetary honor system based on trust that already exists between people in real-world social networks; this form is financial capital backed completely by social capital."

We want to notice that the idea of utilize personal obligations to conclude trades is all but new: when the economy of reference is represented by a small village where everyone is known to everyone else the structure is quite manageable but as the number of participants in the economy grows the issue becomes much more complex. Fugger (2004) is the first to think about exploiting existing social relationship of people and enhanced capabilities offered by technological advances in order to make payments through personal obligations possible also in more complex economies:

> I can use a simple "I owe you" (IOU) for payment, with three restrictions:
>
> 1. My IOU will only be accepted by my friends who trust me. I cannot pay strangers

2. Each of my friends will only accept an IOU from me up to a certain amount, depending on how much each one trusts me (measured by how much credit each will offer me)
3. If my friends accept my IOU, they cannot use it as currency outside the circle of my trusted friends.

and a little further:

> To facilitate decentralized payment via non-bank and non governmental intermediaries, we need to maintain a social network in which connections between parties are defined by granting credit. A computer will do the work of finding IOU payment paths through the network

Ghosh et al. (2007) in their work consider a trust network as "a decentralized payment infrastructure in which payments are routed as IOUs between trusted entities. The trust network has directed links between pairs of agents, with capacities that are related to the credit an agent is willing to extend another, payments may be routed between any two agents that are connected by a path in the network"; the idea is that a series of trust limits connected together consecutively form a trusted pathway through which a payment can move.

In Figures 3.3, 3.4 and 3.5 we have a graphical representation of how the process works: by combining the trust networks of the first two individuals is possible to create a pathway for IOUs even between the two people who do not directly trust each other.

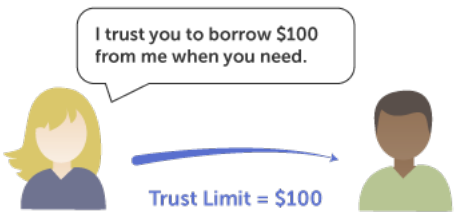

Figure 3.3: First trust-relationship (source: Ripple (2013))

As observed by Ripple (2013) "the system works because everyone along the path has vouched for the person just directly before him in the pathway",

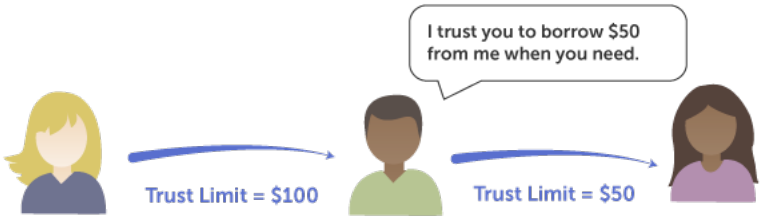

Figure 3.4: Second trust-relationship (source: Ripple (2013))

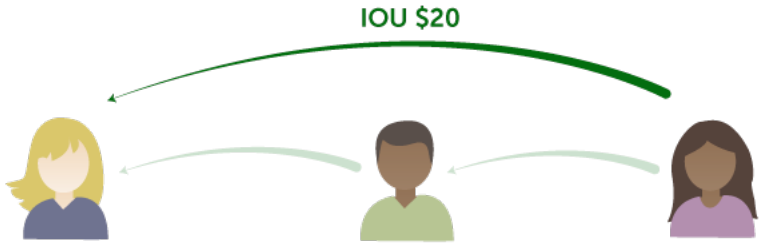

Figure 3.5: Composite trust-relationship (source: Ripple (2013))

in the example represented in Figure 3.5 the individual in the middle accepts an IOU from the left one and then issues an IOU of his own for the same amount to the right person who accepts his. The balance of the middle man then zeroes out and the IOU has moved along.

Chapter 4

General framework and tools

4.1 Complexity and ABM simulation

A recurrent term in scientific works is complexity and it is generally used to characterize something with many parts interconnected in intricate way whose relations lead to unforeseeable result. The thirst for knowledge, in the continuous attempt to limit the uncertainty, leads researchers to look for explanations by providing models of the specific complex system they want to understand.

4.1.1 Complexity

According to Terna et al. (2006, 20):

> [...] la complessità è la caratteristica propria di un sistema in cui l'azione degli agenti costituenti che operano ed interagiscono individualmente in modo talvolta anche molto semplice, secondo regole di coordinamento e di comunicazione generalmente co-evolute con il sistema produca effetti aggregati molto lontani dall'effetto apparente dei comportamenti individuali.

Vicsek (2002) recognizes that complexity is an inherently interdisciplinary concept and says that "in complex systems, we accept that processes that occur simultaneously on different scales or levels are important, and the intricate behaviour of the whole system depends on its units in a non trivial way", other authors go beyond saying that "the whole is greater than the sum of the parts."

The economy, considered as the proper object of study of Economics, has been, over and over again, identified as an example of a complex system that somehow need a different approach in order to make sense of it; we can identify as a kind of watershed between the standard conception of economy (represented by neoclassical mainstream approach) and the new complexity perspective the meeting occurred in September 1987 at the Santa Fe Institute in which a number of economists, physicists, biologists and computer scientists debate about "the economy as an evolving, complex system."

Arthur et al. (1997), remembering the results of the Santa Fe meeting in the introduction of their work, identify six features of economy that considered together represent obstacles for the traditional mathematics used in economics:

Dispersed Interaction What happens in the economy is determined by the interaction of many dispersed, possibly heterogeneous, agents acting in parallel. The action of any given agent depends upon the anticipated actions of a limited number of other agents and on the aggregate state these agents co-create.

No Global Controller No global entity controls interactions. Instead, controls are provided by mechanisms of competition and coordination between agents. Economic actions are mediated by legal institutions, assigned roles, and shifting associations. Nor is there a universal competitor a single agent that can exploit all opportunities in the economy.

Cross-cutting Hierarchical Organization The economy has many levels of organization and interaction. Units at any given level behaviors, actions, strategies, products typically serve as "building blocks" for constructing units at the next higher level. The overall organization is more than hierarchical, with many sorts of tangling interactions (associations, channels of communication) across levels.

Continual Adaptation Behaviors, actions, strategies, and products are revised continually as the individual agents accu-

mulate experience the system constantly adapts.

Perpetual Novelty Niches are continually created by new markets, new technologies, new behaviors, new institutions. The very act of filling a niche may provide new niches. The result is ongoing, perpetual novelty.

Out-of-Equilibrium Dynamics Because new niches, new potentials, new possibilities, are continually created, the economy operates far from any optimum or global equilibrium. Improvements are always possible and indeed occur regularly.

A characterization of the different approaches available to researchers, including the complexity perspective, is found in Gilbert and Terna (2000); after having recognize that "almost all social science research proceeds by building simplified representations of social phenomena" they observe that there are three available approaches to representation of a complex system: verbal argumentation, mathematical formalization and the "third way" of computer simulation proposed by Ostrom (1988).

The verbal presentation has the clear advantage of being at the reach of many but it has evident shortcomings since it is "hard for the researcher and the reader to determine precisely the implications of the ideas being put forward."

In field, as Economics, the formalism of statistical and mathematical equations allows a consistent activity of model-building and checking of results deriving from the imposition or not of various assumptions; however the previous sentence is not always true, Gilbert and Terna (2000) recognize that "the advantages of mathematical formalization [...] evaporate" when the equations which one would like to use to represent real social phenomena prove to be too complicated and so analytically intractable. Gilbert and Terna (2000) continues saying that "a common solution is to make simplifying assumptions until the equations do become solvable" but "unfortunately, these assumptions are often implausible and the resulting theories can be seriously misleading."

The third approach consists in representing a model as a computer program and utilize extensive computational resources to study the behavior of a complex system by computer simulation; now the researcher avoids the

derivation of a mathematical analytical solution, but rather experiments with the model through adjustment of parameters of the system in the computer and tries to understand what are the reasons that determine differences in the outcome of the various experiments. Terna et al. (2006) observe that:

> grazie alla capacità descrittiva flessibile di un codice informatico scritto ad agenti realizziamo dunque esperimenti mentali assistiti dal computer, in quanto troppo complessi per essere risolti senza l'ausilio del calcolo automatico. Ciò consente di verificare la conseguenza delle caratteristiche e delle capacità attribuite agli agenti nel contesto in cui operano. Una delle scoperte frequenti e possibili è infatti proprio il legame tra agenti semplici e risultati complessi.

4.1.2 ABM simulation

When implemented in social sciences the computer simulations are also referred to as Agent Based Model (ABM) or Multi Agent System (MAS), the central element is the presence of agents that behave following their own characteristic and peculiarities. We deem significant the description of ABM proposed by Economist (2010):

> Agent-based modeling does not assume that the economy can achieve a settled equilibrium. No order or design is imposed on the economy from the top down. Unlike many models, ABMs are not populated with representative agents: identical traders, firms or households whose individual behaviour mirrors the economy as a whole. Rather, an ABM uses a bottom-up approach which assigns particular behavioral rules to each agent. For example, some may believe that prices reflect fundamentals whereas others may rely on empirical observations of past price trends.

The description just quoted condenses different elements typical of ABM: first of all individual agents are typically characterized as having bounded rationality and presumed to be acting in what they perceive as their own interests being it an improved economic benefit or a better status, secondly the agents generally behave relying on heuristics or on simple decision-making

rules and thirdly the simulation of actions and interactions of agents is created in order to assess the effects on the system as a whole (Wikipedia, 2013a).

The task of the researcher is then to assign proper and clear rules to agents and then strive to look for emergence of unexpected phenomena which need greater dedication and study.

The ABM approach is not without detractors, whose often have as main topic allegedly inconsistent predictions from computer simulations. Epstein (2008) gives an answer to those concerns providing sixteen reasons other than prediction to build models:

1. Explain (very distinct from predict)
2. Guide data collection
3. Illuminate core dynamics
4. Suggest dynamical analogies
5. Discover new questions
6. Promote a scientific habit of mind
7. Bound (bracket) outcomes to plausible ranges
8. Illuminate core uncertainties
9. Offer crisis options in near-real time
10. Demonstrate tradeoffs / suggest efficiencies
11. Challenge the robustness of prevailing theory through perturbations
12. Expose prevailing wisdom as incompatible with available data
13. Train practitioners
14. Discipline the policy dialogue
15. Educate the general public
16. Reveal the apparently simple (complex) to be complex (simple)

In addition to the above list of reasons for modeling, we consider interesting another conceptualization by Epstein (2008), he distinguishes the

models in two typology: the implicit models and the explicit ones where the former are models in "which the assumptions are hidden, their internal consistency is untested, their logical consequences are unknown, and their relation to data is unknown" while the latter are models in which the "assumptions are laid out in detail"; Epstein (2008) is absolutely sincere in remarking that an explicit simulation is not a way to predict future without margin of errors but rather it allows to say that "on these assumptions, this sort of things happens" and "when you alter the assumptions that is what happens."

Explicit models and more specifically computer simulations are well suited for social science analysis, as noticed by Axelrod and Tesfatsion (2012) "ABM begins with assumptions about agents and their interactions and then uses computer simulation to generate *histories* that can reveal the dynamic consequences of these assumptions"; moreover the same authors suggest contact points and differences between ABM approach and both deduction paradigm and induction one:

> Scientists use deduction to derive theorems from assumptions, and induction to find patterns in empirical data. Simulation, like deduction, starts with a rigorously specified set of assumptions regarding an actual or proposed system of interest; but, unlike deduction, simulation does not prove theorems with generality. Rather, simulation generates data suitable for analysis by induction. In contrast to typical induction, however, the simulated data comes from controlled experiments rather than from direct measurements of the real world

We deem useful to remind that in applying the ABM approach we must be wary on the methodology of work adopted, in fact the risk of an error in the code is anything but implausible and the desirability of unexpected emergence has the potential to affect the simulation even worse; Gilbert and Terna (2000) about this point say that "debugging a program is always a difficult task and we can never be sure of producing completely error free code, the difficulty is worse in the context of agent based models, where the results of simulations can be unexpected and we cannot be sure whether they arise from features of the agents and their interaction, or from some hidden bug, it is therefore especially important to carefully check the code and to

apply the simulation model to relatively well understood and predictable situations before exploring new territories."

The suggested way to proceed is then to focus initially on perfectly understood models, even if they appear at a first sight unrealistic, and then by adding complexity address the consequences and reasons of these modifications in the results.

4.2 Network science and graph theory

We will start this section with a quoting from Barabási and Frangos (2002, 7), they say that "today we increasingly recognize that nothing happens in isolation. Most events and phenomena are interconnected, caused by, and interacting with a huge number of other pieces of a complex universal puzzle. We have come to see that we live in a small world, where everything is linked to everything else. We are witnessing a revolution in the making as scientists from all different disciplines discover that complexity has a strict architecture. We have come to grasp the importance of networks"

The above quotation contains, in our opinion, at least two interesting arguments: it highlights a progressive increasing attention, also, by the common man to consider things not as disconnected items but as parts of a greater whole and it stresses the idea that huge and intricate networks go hand in hand with the concept of complexity. Some examples of networks are provided by Barabási and Bonabeau (2003):

> The brain is a network of nerve cells connected by axons, and cells themselves are networks of molecules connected by biochemical reactions. Societies, too, are networks of people linked by friendships, familial relationships and professional ties. On a larger scale, food webs and ecosystems can be represented as networks of species. And networks pervade technology: the Internet, power grids and transportation systems are but a few examples. Even the language we are using to convey these thoughts to you is a network, made up of words connected by syntactic relationships

The presence of such a massive number of network structures in different contexts has been the fundamental reason for the development of the

so-called Network science as an interdisciplinary academic field , Committee on Network Science for Future Army Applications (2005) gives a working definition saying that "Network science is the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena"; a further evidence of the heterogeneous origin of network theory can be seen by noticing that "the field draws on theories and methods including graph theory from mathematics, statistical mechanics from physics, data mining and information visualization from computer science, inferential modeling from statistics and social structure from sociology" (Wikipedia, 2012b).

4.2.1 Euler's intuition

If we had to find a single point in history that represents the time when the foundations of actual network theory were laid, we certainly would choose the paper of Euler (1741) in which the author describes the solution[1] to an amusing problem that we will describe in the following.

The problem is known as *Seven Bridges of Könisberg* and the method developed to reach the solution is commonly considered the origin of graph theory. The city of Könisberg in Prussia[2] was set on both sides of the Pregel River, and included two large islands which were connected to each other and the mainland by seven bridges as highlighted in Figure 4.1.

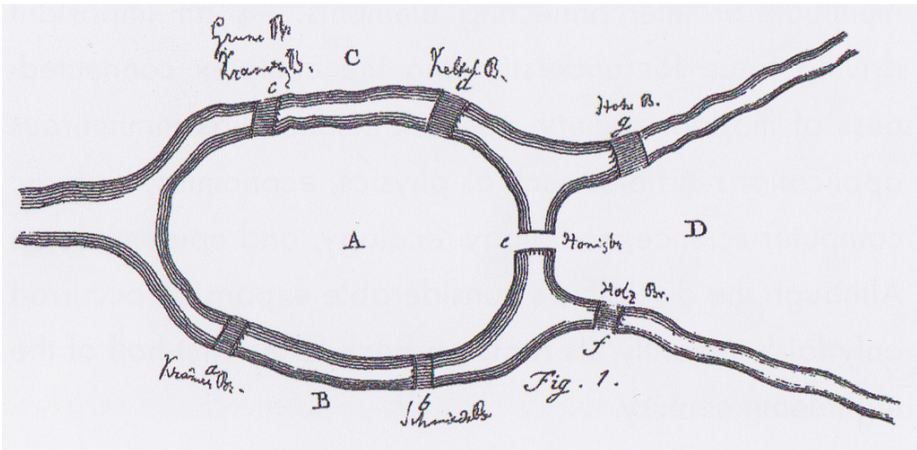

Figure 4.1: Map of Könisberg in Euler's time, source: (Wikipedia, 2013g)

[1]Euler actually found the solution in 1735.
[2]Now Kaliningrad, Russia.

Wealthy people of the time puzzled themselves with the question "Can one walk across the seven bridges and never cross the same one twice?." The context and the rules were clear: the islands could not be reached by any route other than the bridges, and every bridge must have been crossed completely every time (one could not walk halfway onto the bridge and then turn around and later cross the other half from the other side) and finally the walk need not start and end at the same spot.

Euler proved that the problem has no solution and as noted by Barabási and Frangos (2002, 11) the "proof[3] is simple and elegant, easily understood even by those not trained in mathematics. Nevertheless, it is not the proof that made history but rather the intermediate step that he took to solve the problem"; Euler's great insight lays in recognizing that the choice of route inside each land mass is irrelevant inasmuch the only important feature of a route is the sequence of bridges crossed. As proposed by Wikipedia (2013g):

> this allowed him to reformulate the problem in abstract terms (laying the foundations of graph theory), eliminating all features except the list of land masses and the bridges connecting them. In modern terms, one replaces each land mass with an abstract vertex or node, and each bridge with an abstract connection, an edge, which only serves to record which pair of vertices (land masses) is connected by that bridge. The resulting mathematical structure is called a graph

Since only the connection information is relevant, the shape of pictorial representations of a graph may be distorted in any way, without changing the graph itself; only the existence (or absence) of an edge between each pair of nodes is significant (Wikipedia, 2013g). For example, it does not matter whether the edges drawn are straight or curved, or whether one node is to the left or right of another and so 4.2 is just one of the infinite possible representations of the Seven Bridges of Könisberg. Once again the key concept is proposed by Barabási and Frangos (2002, 12): "the most important aspect of Euler's proof is that the existence of the path does not

[3]Nodes with an odd number of links must be either the starting or the end point of the journey; a continuous path that goes through all bridges can have only one starting and one end point; thus, such a path cannot exist on a graph that has more than two nodes with an odd number of links; as the Könisberg graph had four such nodes, one could not find the desired path.

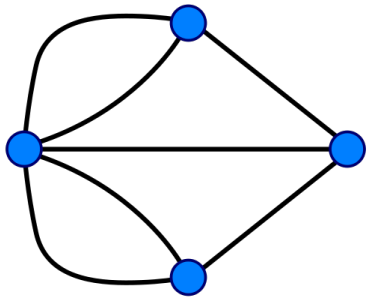

Figure 4.2: Königsberg's graph representation, source: (Wikipedia, 2013g)

depend on our ingenuity to find it. Rather, *it is a property of the graph*."

4.2.2 Some definitions

From the previous section we have understood that a graph is the mathematical abstraction of a network that in turn is a set of points connected by lines, Figure 4.3 is an example of such a network with ten nodes and nine links.

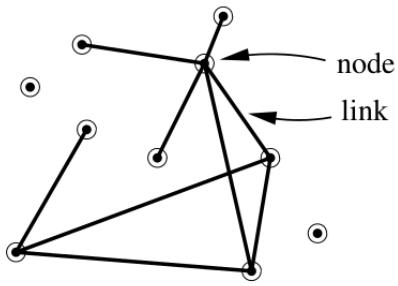

Figure 4.3: A small network example, source: (Gastner, 2011)

The interdisciplinary nature of network theory brings also different denominations for same concepts depending on the field under examination, in Figure 4.4 we want provide a mini "Rosetta Stone" for network related terminology. Each element in a network is represented by a site (physics), node (computer science), actor (sociology) or vertex (mathematics) and the connection between two elements corresponds to a bond (physics), link (computer science), tie (sociology) or edge (mathematics).

There exist different classifications of networks:

- According to the direction of the links: directed or undirected

	engineering and computer science	mathematics	physics	social sciences
"point"	node	vertex	site	actor
"line"	link	edge	bond	tie
"network"	network	graph	network	network

Figure 4.4: Network's elements, source: (Gastner, 2011)

- According to the kind of interaction: weighted or unweighted. A graph is a weighted graph if a number (weight) is assigned to each edge. Such weights might represent, for example, costs, lengths or capacities depending on the problem under scrutiny.
- According to the evolution of their topology: static or evolving. Networks do not appear suddenly. The network that we are studying is static (its structure is stationary) or it is still evolving
- According to the dynamics of the nodes: with/without dynamics. Nodes are dynamical entities that react to network-level stimuli and vice versa

Directed and undirected networks

This is the most important distinction, in fact all other peculiar characteristics of networks are build upon this primitive.

The type of relationship between nodes determines the category of the network: if relationships are symmetric then the network is undirected otherwise it is directed.

From a mathematical point of view an undirected simple network G = (N, L) is an ordered pair of a set of nodes N and a set of links L and the links are subsets of N with exactly two distinct elements, it is simply called graph (Figure 4.5).

If the undirected network has multiple links (multiedges) between two nodes and/or nodes connected to themselves (self-loops) then we call it multigraph (Figure 4.6).

A directed network (also called a directed graph or digraph) is a network where the links only go in one direction (Figure 4.7). The difference with the undirected network definition is that the elements in the link set L are now

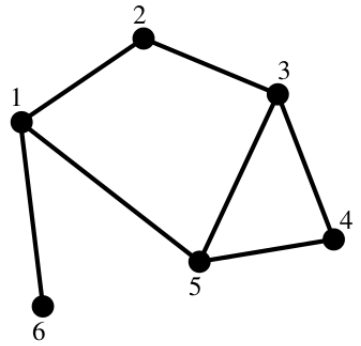

Figure 4.5: An undirected, simple network, source: (Gastner, 2011)

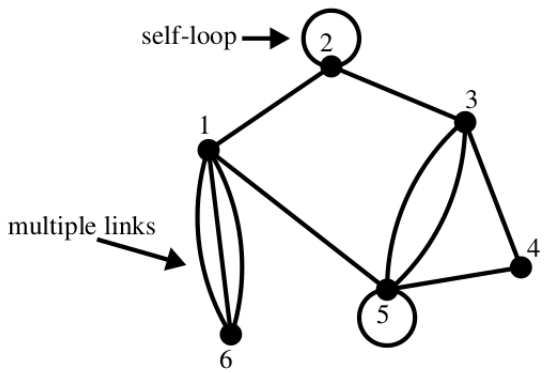

Figure 4.6: An undirected, complex network, source: (Gastner, 2011)

ordered (instead of unordered) pairs of nodes. The links can be represented by lines with arrows on them.

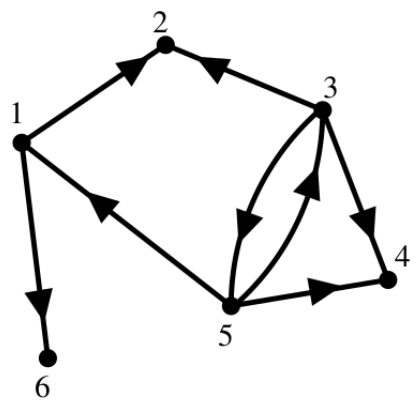

Figure 4.7: A directed network, source: (Gastner, 2011)

A directed network with multiple links between two nodes is called multidigraph.

4.2.3 Objects of interest

The real difference among networks in the past and those of today is not of a substantial type but it is more a matter of size and dimension, Barabási (2012) notices that, thanks to technological advances, we started to know not only the networks and the connections but also the timing of the interactions that happen through those connections; the immediate result is that the data size grows exponentially (see Figure 4.8 for an example of the evolution of network data size over time).

We borrow another quotation by Barabási (2012), inasmuch it is particularly illuminating in providing boundaries to what really matters: "What is happening right now is that now a new tool is becoming available, but as a result of the technological advances, there's so much data being created about us that science becomes a byproduct of all this data. The question really becomes not as much how you collect the data, but how do you make sense of it? And this comes under many different names. You can call it network science, you can call it human dynamics, you can call it computational social science, you can call it big data. Whatever you call it, down the line, what we're talking about is that there's a huge amount of information

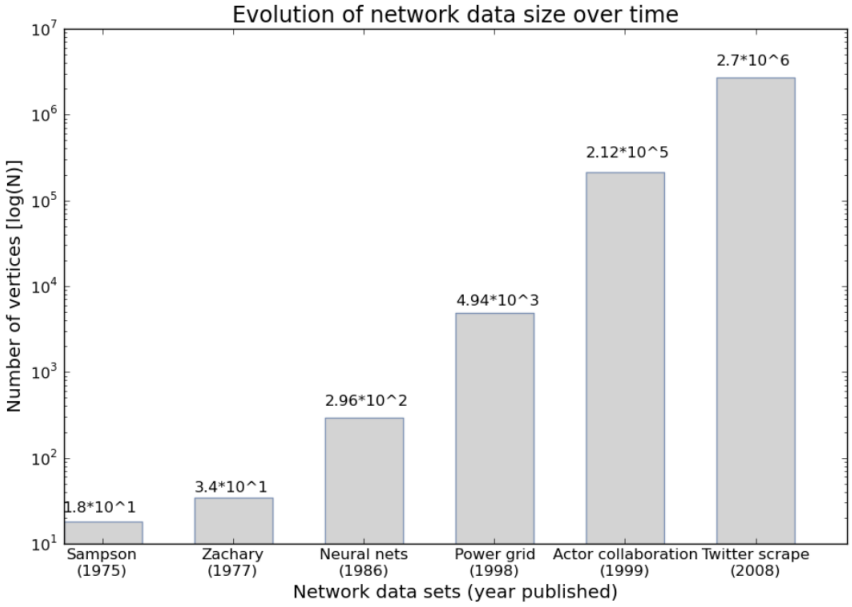

Figure 4.8: Evolution of network data size over time, source: (Hagberg and D., 2010)

collected about us and we need to make sense of it."

In order to make sense of the ever increasing data, scholars have developed some indicators related to universal properties of networks: universal in the sense that these attributes can be computed independently from the nature of phenomena that is represented by the specific network, being it a telecommunication network, a biological one or a social network. Among the others the most used indicators are (Wikipedia, 2012b):

Average Degree It is the average of degrees of each nodes in the graph, where the degree of a node x is the number of edges connected to it

Average Path Length It is calculated by finding the shortest path between all pairs of nodes, adding them up, and then dividing by the total number of pairs

Diameter of a Network It is the longest of all the calculated shortest paths for each nodes in a network

Clustering Coefficient It is the ratio of existing links connecting a node's neighbors to each other to the maximum possible number of such links

Connectedness It represents how the network is connected, if it is a complete graph, a giant component, a weakly connected component or a strongly connected component

Node centrality It is a measure of importance of a node in a network that can be analyzed in term or of closeness or betweenness

In addition to above features, we can recognize that often the directed networks carry additional information on their constituent elements, more specifically there are numbers attached to each edge that represent the capacity of each edge to receive and transmit a flow; obviously an hypothetical flow through an edge cannot exceed the capacity of the edge itself. A whole number of real problems have been attached by making use of flow network characteristics, we remind model of traffic in road system, fluid in pipes or current in electrical circuits.

A great number of algorithms has been developed with the aim of finding the shortest path and/or the maximum flow capacity between a source and a sink, they differ from one another with regard to the certainty of termination and the run time complexity.

In our Trust Based Model we first modify and then use the Ford-Fulkerson algorithm implemented in NetworkX software.

4.2.4 Three approaches to modeling of networks

Looking at history of network studies and to the strictly related field of graph theory we can identify three different paradigms that imply different level of attention to various networks' topology:

1. Regular graphs
2. Random graphs
3. Complex graphs

Regular graphs

After the death of Euler and until the mid-twentieth century the goal of scholars involved in graph theory was that of improve understanding of networks with recurrent intrinsic scheme. The contributions of authors such as Hamilton, Kirchhoff or Cayley focused, almost always, on regular graphs

and lattices where the former are graphs in which all nodes have the same degree (Figure 4.9) and the former are regular networks in which all nodes are coupled to their nearest neighbors.

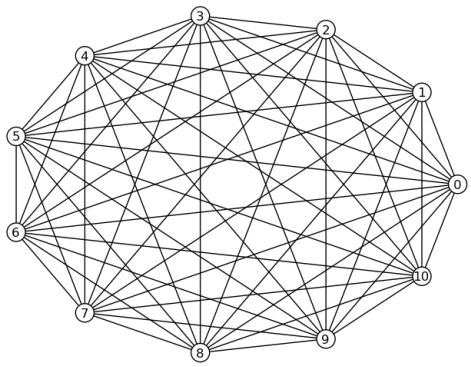

Figure 4.9: Regular graph with eleven nodes

Random graphs

In the literature of network science the work of Erdös and Rényi (1959) is generally considered a turning point, Barabási and Frangos (2002) says that the two Hungarian mathematicians were the first to tackle two important questions:

- How do real networks form?
- What are the laws governing their appearance and structure?

They essentially suggested that the right approach were that of building random graphs and then compare the created model with the real network; moreover they proposed two variants of random graph model (Wikipedia, 2013c):

G(n,M) model a graph is chosen uniformly at random from the collection of all graphs which have n nodes and M edges

G(n,p) model a graph is constructed by connecting nodes randomly; each edge is included in the graph with probability p independent from every other edge (Figure 4.10)

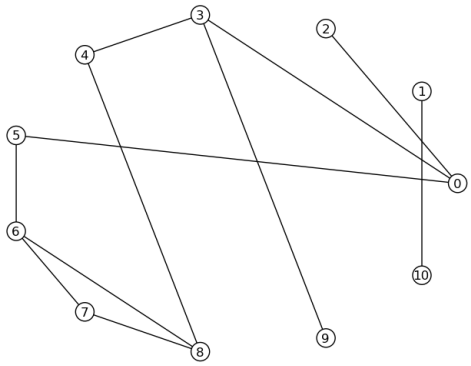

Figure 4.10: Random graph with n=11 and p=0.25

Random networks are also called exponential, because the probability that a node is connected to k other nodes decreases exponentially for large k. One of the most important results from the study of random networks was the discovery that giant component in the network can emerge when the probability of connection between two nodes exceeds a critical value.

Complex graphs

They are the last object of study in network science and they can be defined as networks with non-trivial topological features, with patterns of connection between their elements that are neither purely regular nor purely random.

Barabási (2012) gives a sort of manifesto of complex networks versus random one:

> It is almost common sense now that we live in the age of networks. What most people haven't really internalized is that these networks are not random. They have internal rules. Once you start seeing them, then you start looking at the very different way of how these networks function. The number of highly connected or less-connected nodes is never random in the network. The way they break down, the way they evolve is never random in these networks. The way that hubs link to their neighborhood, the way the community is formed, the way the communities look,

their number, their size, they all follow very precise laws and very quantifiable patterns.

Albert and Barabási (2002), supported by soundly evidence from results of studies on Web and on social networks, identify three central concepts characterizing complex networks:

Small worlds The small-world concept describes the fact that despite their often large size, in most networks there is a relatively short path between any two nodes where the distance between two nodes is defined as the number of edges along the shortest path connecting them. A recurrent example is the work of Milgram (1967), popularly known as *six degrees of separation*, in which the author claims that there is an acquaintances' path of length six between any couple of strangers in United States

Clustering The clustering coefficient is a measure of degree to which nodes in a graph tend to group together; focusing on social networks, there is frequent evidence that nodes in social networks are grouped in small clusters, representing circles of friends and acquaintances, in which each node is connected to all other nodes, with only sparse links to the outside world (Watts and Strogatz, 1998). In other words, often, in real networks the clustering coefficient is typically much larger than it is in a comparable random network with the same number of nodes and edges.

Degree distribution This is probably the most interesting understanding of complex network; in most real networks the probability that a node selected uniformly at random has a certain number of links (degree) follows, often, a mathematical function called a power law while in a random graph in which the edges are placed randomly, the majority of nodes have approximately the same degree, close to the average degree of the network. A network, whose distribution of edges follows a power law, is named "scale-free" and it is constituted by many nodes with few connections and few nodes called *hubs* with a large number of links. In Figure 4.11 we have the comparison between distribution of links in a random network that follow a Poisson distribution and the distribution of links in a scale-free network that follow a power law.

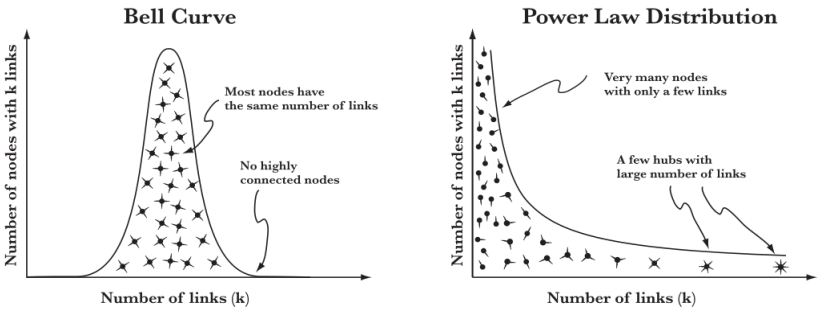

Figure 4.11: Distribution of links in random and scale-free networks, source: (Barabási and Bonabeau, 2003)

Thereafter the reason for the construction of models following the power-law distribution comes from their ability to describe the topology of real complex networks, the most famous generating processes for the growth of simulated networks consistent with power law are the Yule distribution proposed in new form by Simon (1955) and the preferential attachment process by Barabási and Albert (1999).

The substantial difference between a random graph generated by Erdös-Rényi model and a complex one generated following the Barabási-Albert preferential attachment model is that in the former all nodes are present rightly while in the latter there is an implicit notion of growth that in conjunction with the preferential attachment mechanism "help to explain the existence of hubs: as new nodes appear, they tend to connect to the more connected sites, and these popular locations thus acquire more links over time than their less connected neighbors. And this - rich get richer - process will generally favor the early nodes, which are more likely to eventually become hubs" (Barabási and Bonabeau, 2003).

In Figure 4.12 we have a complex network generated using "Barabási-Albert preferential attachment model" present in NetworkX software with parameter n=11 and m=3; we can notice that node 3 has a greater number of links with respect to other nodes, node 3 seems an hub in this graph.

We want to close this brief overview of networks with the introduction of a peculiar type of correlation present in directed networks, the *reciprocity concept*: Garlaschelli and Loffredo (2004) say that with link reciprocity we measure "the tendency of vertex pairs to form mutual connections between

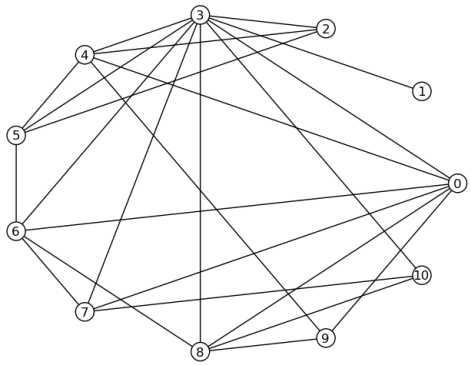

Figure 4.12: Complex graph with n=11 and m=3

each other. In other words, we are interested in determining whether double links (with opposite directions) occur between vertex pairs more or less often than expected by chance."

The analysis of this parameter might be interesting since on one hand "tells us how much information is lost when a directed network is regarded as undirected (as often done, for instance when measuring the clustering coefficient)" and on the other hand "it can reveal possible mechanisms of social, biological or different nature that systematically act as organizing principles shaping the observed network topology."

4.2.5 Dynamic network analysis

A recent development in network field, in our opinion with great potential, is represented by the emergence of a new paradigm of analysis called Dynamic network analysis (DNA), it is a field that brings together traditional Social network analysis (SNA) with Agent based simulation (ABM).

The main difference of DNA with respect to SNA is that DNA takes into account also the time variable, in fact the progress of DNA is based on the recurrent question of "How do networks change?."

Carley (2003) notices that "in contrast to traditional SNA, DNA considers the role of the agent in terms of processes and not just position. That is, the agents can do things: communicate, store information, learn. Further, the networks are dynamic and changing even as the agents change [...]

DNA explores the sensitivity of the measures and the impacts to error"; the implementation of ABM techniques allows scholars to explore how modeled networks evolve as a result of modification of parameters imposed in the simulation model.

Taken for given that thinking about networks from a dynamic perspective is absolutely essential to understand the modern world, we claim that, in addition to the above, there are at least two further elements in favor of a greater use of DNA: first of all the possibility of starting the simulation model with data extracted from real world networks and not from ad-hoc models constructed in order to generate data close to real one, secondly the possibility of implement learning reinforcement mechanism for agents such as those proposed in neural networks literature.

As a final remark we want to stress that scholars, first of all must be aware that SNA and/or DNA do not certainly give them the capacity to predict surely the future and secondly that the users of these techniques have to focus intensely both on the development of conjectures on the network modeled and on the never-ending search of significant information in the data; it is fact commonly recognized that if some patterns become more apparent as network size increases, on the other way a global network analysis of, for example, all interpersonal relationships in the world is likely to contain so much information as to be uninformative.

4.3 Tools

In this section we will briefly describe the software tools that we use in our simulations: NetLogo, Python and NetworkX.

4.3.1 NetLogo

NetLogo has a double nature, it is an agent-based programming language and it offers a programmable modeling environment for simulating natural and social phenomena. It was authored by Uri Wilensky, director of Northwestern Universitys Center for Connected Learning and Computer-Based Modeling (Wikipedia, 2013d), in 1999 and has been in continuous development (Wilensky, 1999). From the technical point of view we notice that it is a free and open source software, released under a GPL license and that

it is written in Scala and Java and runs on the Java Virtual Machine; the combination of these characteristics gives the software a high grade of flexibility since on one hand it has cross-platform capabilities, in fact it can be run on different operating systems provided the presence of the Java Virtual Machine and on the other hand the open nature of its license guarantees end users freedoms to use, study, share and modify the software.

The just reported flexibility combined with an ever increasing usage has also lead to the development of a large number of simulations, some of which have been inserted in the models library that is distributed with the program itself; among the others, there are models that address content areas in the natural and social sciences including biology and medicine, physics and chemistry, mathematics and computer science, and economics and social psychology.

The very peculiarity of an agent-based programming language and its related programmable modeling environment is that it was created from the beginning with its final use in mind, and so it offers build in features like ad-hoc functions and randomness in execution; the result is that "modelers can give instructions to hundreds or thousands of agents all operating independently [...] this makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from their interaction" (Wilensky, 1999), the advantage is that final users can focus mostly on the specificity of their models.

NetLogo offers a virtual world (a two dimensional one dividend up into a grid) in which different agents are setup and allowed to interact following the rules that end user of the program would provide them, there are four types of agents:

Turtles are agents that move around in the world

Patches are the ground over which the turtles move

Links are agents that connect two turtles

Observer is a being that oversees everything that is going on in the world

The Graphical User Interface of NetLogo consists of three parts:

Interface it is the environment in which the simulation is performed, here we can modify the values of parameters, check the running of the simulation and verify the results plotted on charts

Information it is a sort of mini documentation of the created simulation, here the creator of the model explains the core characteristic of the simulation, gives some hints on how to use it and suggests interesting experiments

Procedures it is the section in which it is actually written the code that governs the model

It is valuable to note that it is possible to use NetLogo in connection to other software that are more apt to perform different tasks, in our simulation of a Trust Based Model we create a link between the proper NetLogo model and a Python program in order to make particular computations.

The version of NetLogo that we use is 5.0.3

4.3.2 Python

Python is a general-purpose, interpreted high-level programming language whose design philosophy emphasizes code readability. It incorporates modules, exceptions, dynamic typing, very high level dynamic data types and classes. Python is one of the oldest most significant open-source programs, in fact its first release, by its creator Guido van Rossum at Centrum Wiskunde & Informatica, is dated 20 February 1991 (Wikipedia, 2013e).

The fact that Python interpreters are available for different operating systems gives Python cross-platforms capabilities and it allows the execution of the same code without modifications on different platforms. Python comes with a large and comprehensive standard library which gives the user the opportunity to use it in different fields; the goodness of its setting is confirmed by a strong adoption of it by large organizations as Google, Yahoo!, CERN and NASA.

The version of Python that we use is 2.7.3

4.3.3 NetworkX

As described by Hagberg et al. (2008) "NetworkX is a Python language package for exploration and analysis of networks and network algorithms. The core package provides data structures for representing many types of networks, or graphs, including simple graphs, directed graphs, and graphs with parallel edges and self-loops."

The original version was designed and written by Aric Hagberg, Dan Schult, and Pieter Swart in 2002 and 2003 while the first public release was in April 2005; NetworkX is an open source project and the so the end user can redistribute it and/or modify it under the terms of the BSD License, for this reason a lot of improvements come from the international community of users.

Among the various characteristics of NetworkX, we want highlight that it is highly efficient since for the construction of data structures makes extensive use of Python's data-type named dictionary and moreover it is very powerful since in it are implemented numerous algorithms for calculating network properties and structure measures such as shortest paths, betweenness centrality, clustering, degree distribution and many more.

Another plus is that NetworkX can read and write various graph formats and so it allows the end user to build links with other software.

The version of NetworkX that we use is 1.7-py2.7

Chapter 5

Simulation models

In this chapter we will present the two models that we have developed: the first one is a simplification of a payment system, more specifically one based on credit card, while the second one named Trust Based Model (TBM) consists in an implementation of a payment system based on social network of trust preexisting among people.

The models are structured with the aim of giving great freedom to the user, who is invited to experiment in a dynamic manner with different parameters; the common benchmark for both systems is a situation in which buyers and sellers involved in economic transactions have cash as only available method of payment.

In the following we will firstly focus individually on both models explaining the assumptions and peculiarities of our implementations and running some simulations trying to understand the reasons of the results we get, then finally we will make some considerations on the card-based model and the TBM underlying the structural differences between the two.

5.1 Card model

5.1.1 The interface

The starting point of the model is the recognition that in a typical payment card system there are basically three types of actors: there are the cardholders, the merchants who accept the payments by cards and the card-association that is responsible for the provision of the necessary infrastructure; in our model we try to take in consideration all those actors.

Taking inspiration from the literature on two-sided market we have structured the interface of our model with those parameters that, in our opinion, are mostly significant for a simulation of the functioning of a payment system card-based. In Figure 5.1 we have the interface of the NetLogo model that can be divided into three parts: on the top-center the representation of the world, on the right side the graphs on which we see the global results of interactions among agents and on the left and bottom-center a whole bunch of sliders which are further grouped according to the typology of actor to which belong.

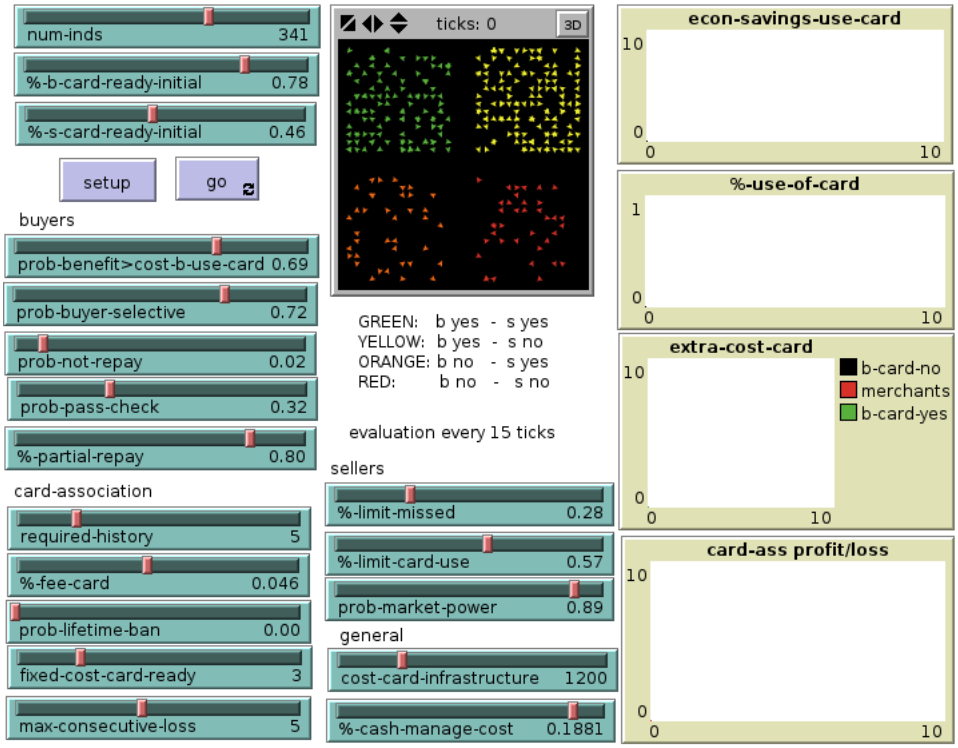

Figure 5.1: NetLogo interface

In this version of the model we assume that the infrastructure necessary for the functioning of the payment system is present from the beginning, moreover each agent is at the same time a buyer and a seller and can be on one side a cardholder or not and on the other side he can be ready or not to accept payments by cards; there are indeed four possible characterization on an agent and each one is represented by a different color in the world

view of NetLogo interface:

green Agent is a cardholder and is ready to accept card as mean of payment

yellow Agent is a cardholder but is not ready to accept card as mean of payment

orange Agent is not a cardholder but is ready to accept card as mean of payment

red Agent is not a cardholder and is neither ready to accept card as mean of payment

Here we have the first assumption, as the two sides of each agent are not correlated but rather are ruled by distinct variables and parameters.

In the *buyers* part of Figure 5.1 we have the variables related to agents when considered as buyers:

- prob−benefit>cost−b−use−card A greater value represents a greater probability that a cardholder perceives the benefit deriving from the payment through card greater than the higher cost deriving from the use of card instead of cash

- prob−buyer−selective A greater value means that cardholders who deem card payment preferable to cash ones, have a greater probability to escape a transaction when they find out that the seller is not ready to accept card payments

- prob−not−repay It represents the probability that a cardholder which has utilized his available credit line do not repay the amount used to card association

- prob−pass−check It represents the probability that an agent, who do not have a card, passes the required check process established by the card-association in order to get a card

In the *sellers* part of Figure 5.1 we have the variables related to agents when considered as sellers:

- %−limit−missed It represents the percentage limit of missed sales per period over which a seller ready to accept cards decides to start accepting payment by card

- %−limit−card−use It represents the percentage limit of cash sales over total amount of sale over which the seller decides to stop accepting payment by card

- prob−market−power It represents the probability that a seller is able to pass completely to buyers (through a proportionally higher price of the product) the fee determined by accepting card payments

In the *card-association* part of Figure 5.1 we have the variables related to the card association:

- required−history It represents the required number of consecutive passed result for applicants for card

- %−fee−card It represents the percentage on transaction's amount that the card-association collects

- prob−lifetime−ban It represents the probability that the card-association bans for lifetime a cardholder who does not repay the utilized credit of period

- max−consecutive−loss It represents the maximum consecutive period of loss that the card-association is available to accept before stopping to provide the infrastructure necessary to run the payment card system

In the *general* part of Figure 5.1 we have two variables related to general environment:

- cost−card−infrastructure It represents the fixed cost per period to keep running the infrastructure to enable card payments

- %−cash−manage−cost It represents the percentage cost of managing cash

In the right part of Figure 5.1 we have four graphs (plots in NetLogo jargon) that allow us to appreciate on an aggregate level what are the effects deriving from modifications of different parameters:

- econ−savings−use−card In this plot we can see the economic savings deriving from the reduction of required liquidity to conclude trade when payments by card are utilized

- %−use−of−card In this plot we can see the percentage of payments executed through card
- extra−cost−card In this plot we can see the distribution of extra cost implied by accepting card payments, the costs are born by three category of agents: by sellers that accept card and have no market power, by buyers with no card who buy via cash from a seller with market power ready to accept card payments, or by buyers-cardholder that decide to buy via cash from a seller that has market power and accept card
- card−ass profit/loss In this plot we can see the economic result of card association business; here, differently from the other graphs, the values refer to each period

In the model we assume that the length of a period is fixed to 15 ticks, and in each period some data are collected: sellers on one hand record the amounts of sales concluded through payment by cash or by card and on the other hand record the missed sales information, otherwise the card association at the end of each period receive the repayments of utilized credit by cardholders and make evaluation both on reliability of cardholders and on profitability of running the infrastructure. Some assumptions are imposed: buyers who do not yet possess a card are continuously active in the quest for a card, sellers ready to accept card payments cannot stop to accept cards in a moment antecedent to the end of the same period, the principal cause for a seller to bear the extra-cost deriving from accepting card payments is the recognition of missing of sales, the latter evaluation can be conduced because buyers who want to pay by card are assumed to explicit their refusal to proceeding with the purchase if sellers do not accept card, the agreed amount of purchase can always be paid in cash or by card with no limit.

Moreover we deem important to underline that in real world the parameters that in our model have been considered as separated and not correlated may be link or even have an high level of correlation; we believe that in a possible future implementation it is for sure interesting to take in account for these relations but hereinafter we will continue with the simplifications reported above hoping to avoid distorting too much the results that come from variations of variables considered singularly.

5.1.2 Description of code

After having described the interface we will now focus in detail on the most important parts of the NetLogo code which represents the backbone of the model.

The code begins with the definition of the variables that are going to be use: in 5.1 we list the variables that belong to every agent (turtle), in order to take in account the double nature of individual (buyer and seller) we put before the variable a "b" for buyer and a "s" for seller, in 5.2 we list the variables that belong to environment at an aggregate level.

Listing 5.1: turtles-own

```
turtles-own[
  b-card-ready?
  b-by-cash
  b-by-card
  b-by-card-period
  b-by-cash-period
  b-banned?
  s-card-ready?
  s-missed-sales-period
  s-by-card-period
  s-by-cash-period
  counterpart
  c-history-check
  demand
]
```

Listing 5.2: globals

```
globals[
  t-last-evaluation
  tot-s-card-ready-start-period
  infrastructure-available?
  tot-advance
  tot-repaid
  revenue-from-s
  result-card-association
  paid-by-b-card-ready-no
  paid-by-s-card-ready-yes
  paid-by-b-card-ready-yes
  loss-counter-card-association
  econ-savings-use-card
  %-use-of-card
]
```

The buttons setup and go in interface point to the code present in homonyms procedures: the former is executed only one time and results in the creation of a world in which an indicated number of individuals exists and makes them cardholders and sellers ready to accept card payments according to sliders named %−b−card−ready−initial and %−s−card−ready−initial, the go procedure instead is executed forever and represents the core of the program.

Listing 5.3: to setup

```
to setup
  clear-all
  set infrastructure-available? "yes"
  make-inds
  assign-card-ready-initial
  color-turtles
  reset-ticks
end
```

Following a temporal partition, buyers are asked each cycle to find a counterpart for the buy of some goods, then they have to choose what is their preferred method of payment (if cash or card) and finally they are asked to conclude the transaction. Secondly through procedure make−evaluation a whole number of evaluation are executed: buyers with no card possession evaluate if they are finally able to obtain a card, sellers decide to start accepting cards or if they consider accepting cards as an useless behavior decide to stop accepting cards and finally the card association check if cardholders are reliable and if profits are prevalent over losses. In go procedure, in order to reduce a possible font of disturbance that would make the analysis of the model intractable, we have decided to link the amount of demand to a number generated by a random-normal function and to maintain fixed the parameters of the density function for all ticks.

In conclude−trade procedure each individual pay to the counterpart the price agreed; in this procedure we make a distinction between individuals with only cash and individuals that have both cash and card: the former, after having set the counterpart randomly, conclude the exchange paying by cash while the latter, after an evaluation of the benefits deriving from the payment by card and the related costs, decide if pay by cash or card. The strong assumption here is that a buyer eager to pay by card but unable to conclude the purchase, as the chosen seller does not accept card, explicitly

Listing 5.4: to go

```
to go
  evaluate-profitability-infrastructure
  ask turtles [
    set b-by-cash 0
    set b-by-card 0
    set demand random-normal 100 20]
  set paid-by-b-card-ready-no 0
  set paid-by-s-card-ready-yes 0
  set paid-by-b-card-ready-yes 0
  color-turtles
  ask turtles [find-counterpart]
  conclude-trade
  update-b-by-card-period
  compute-statistics
  determine-who-pay-card-cost
  if (infrastructure-available? = "yes")[
    make-evaluation
    verify-check-and-obtain-card]
  tick
end
```

reports to the same seller his decision to skip the purchase and going elsewhere; this strong behavior is ruled by the slider prob−buyer−selective . In the remaining parts of the procedure we deal with the update of internal values of individuals and record the different choices in order to construct an historical set connected to each period.

The recognition that the determination of total cost of using payment cards instead of cash is all but simple leads us to construct the procedure named determine−who−pay−card−cost the way it appears. As seen in the chapter related to payment card systems the most discussed source of cost consists in the fee that card association imposes on the amount of purchase paid by card, however the determination of who pay the extra cost is not immediate but otherwise depends contemporaneously on peculiar characteristic of the merchants (seller) and of the buyers. In the model we impose also a source of fixed cost for the sellers fixed−cost−card−ready independent from the amount of purchases executed by card but as this cost has generally a negligible weight with respect to proportional fee we simplify the analysis by not considering it; so taking in account only the proportional fee it is interesting to determine who pays it and the degree of his payment.

Referring to economic literature we assume that the bearer of card cost

Listing 5.5: to conclude-trade

```
to conclude-trade
  ask (turtles with [b-card-ready? = "no"])[
    set b-by-cash demand
    ask counterpart [set s-by-cash-period (s-by-cash-period +
        demand)]]
  ask (turtles with [b-card-ready? = "yes"])[
    ifelse (prob-benefit>cost-b-use-card > random-float 1)
    [ifelse ([s-card-ready?] of counterpart = "yes")
      [set b-by-card demand
        ask counterpart [set s-by-card-period (s-by-card-period
            + demand)]]
      [ifelse (prob-buyer-selective > random-float 1)
        [ask counterpart [set s-missed-sales-period (s-missed-
            sales-period + demand)]
          if (count other turtles with [s-card-ready? = "yes"]
              != 0)[
            set counterpart (one-of other turtles with [s-card-
                ready? = "yes"])
            set b-by-card demand
            ask counterpart [set s-by-retaincard-period (s-by-
                card-period + demand)]]]
        [set b-by-cash demand
          ask counterpart [set s-by-cash-period (s-by-cash-
              period + demand)]]]]
    [set b-by-cash demand
      ask counterpart [set s-by-cash-period (s-by-cash-period +
          demand)]]]
end
```

depends in large part on the market power that sellers have: on one hand if a seller has high market power than he is able to pass the extra cost completely to all of his customers penalizing than those who pays by cash and so are subject to a price higher than what it would have been without card, on the other hand if a seller has low market power and accept payments by card then he is in first person the bearer of card cost since he is unable to pass the costs to his customers and so he sees a lower earning on those purchases concluded by card.

In our procedure in order to keep simple the analysis we assume that once the market power is verified the fee of card is pass completely to consumers or born completely by sellers depending on the presence or not of market power.

The verify−check−and−obtain−card and make−evaluation procedures, on one hand share the fact of being both executed only if the card-association be-

Listing 5.6: to determine-who-pay-card-cost

```
to determine-who-pay-card-cost
  ask turtles [
    let reference (random-float 1)
    if ((prob-market-power > reference) and ([s-card-ready?] of
        counterpart = "yes") and b-by-cash != 0 and b-card-ready?
         = "yes")[
      set paid-by-b-card-ready-yes (paid-by-b-card-ready-yes + b
          -by-cash * %-fee-card)]
    if ((prob-market-power > reference) and ([s-card-ready?] of
        counterpart = "yes") and b-by-cash != 0 and b-card-ready?
         = "no")[
      set paid-by-b-card-ready-no (paid-by-b-card-ready-no + b-
          by-cash * %-fee-card)]
    if ((prob-market-power < reference) and ([s-card-ready?] of
        counterpart = "yes") and b-by-card != 0)[
      set paid-by-s-card-ready-yes (paid-by-s-card-ready-yes + b
          -by-card * %-fee-card)]]
end
```

lieves that its business is lucrative and so provides the infrastructure but on the other hand in the two procedures we set different temporal boundaries to agents: in verify−check−and−obtain−card buyers with no card and not banned for lifetime by card-association seek to pass an hypothetical credit test at each cycle (tick) while in make−evaluation sellers and card-association evaluate their respective situations only at the end of each period, in other words the assumptions here are that sellers can not stop to accept cards and card-association can not check profitability of its business in any moment between two end dates.

Listing 5.7: to verify-check-and-obtain-card

```
to verify-check-and-obtain-card
  ask (turtles with [b-card-ready? = "no" and b-banned? = "no"])
      [
    ifelse (prob-pass-check > random-float 1)
    [set c-history-check (c-history-check + 1)]
    [set c-history-check 0]]
  ask (turtles with [b-card-ready? = "no" and b-banned? = "no"])
      [
    if (c-history-check = required-history)[
      set b-card-ready? "yes"
      set c-history-check 0]]
end
```

The most important procedure called in make−evaluation is evaluate−s−

Listing 5.8: to make-evaluation

```
to make-evaluation
  ifelse (t-last-evaluation = 15)
  [set t-last-evaluation 0
    revenue-from-repay-debt
    revenue-from-fixed-s
    compute-result
    evaluate-s-card-ready
    set tot-advance 0]
  [set t-last-evaluation (t-last-evaluation + 1)
    set tot-repaid 0]
end
```

card−ready, when it is executed the agents considered as sellers make an evaluation on the necessity or not to accept payments by cards: if a seller does not accept cards he compares the ratio of missed sales over the collections deriving from cash sales of the period and if the resulting value is greater than a given percentage limit he starts to accept cards, if otherwise a seller does yet accept payments by card he evaluates if continuing or not through a comparison of the ratio of sales concluded by cash payments over the total amount of sales in the period and if the resulting value is higher than a given percentage limit he stops to accept cards.

Even in this case the simplifying assumptions are quite strong: first of all sellers have as only benchmark in deciding to accept or not payments by card the amount of missed sales of the period but in real world there are no clear signs that these information are always and perfectly available to sellers as buyers when deciding where to buy are not required to signal to a potential seller that he skip the purchase because the latter is not ready to accept payment by card, secondly in the model the decision to stop accepting cards is based only on historical trend of sales and it is independent both from market power of seller (and so related ability to pass extra cost to consumers) and from the degree of fees imposed by the card association.

5.1.3 Some simulations

In this section we will run some simulations and we will try to interpret the results in light of the assumptions made and of the chosen starting point which turns out to be of central importance.

Moreover the results will be analyzed considering the effects on each

Listing 5.9: to evaluate-s-card-ready

```
to evaluate-s-card-ready
  ask turtles [
    ifelse (s-card-ready? = "no")
    [if (s-by-cash-period != 0)[
        if ((s-missed-sales-period / s-by-cash-period) > %-limit
            -missed)[set s-card-ready? "yes"]
        if (s-by-cash-period = 0 and s-missed-sales-period != 0)
            [set s-card-ready? "yes"]]]
    [if (s-by-cash-period + s-by-card-period != 0)[
        if ((s-by-cash-period / (s-by-cash-period + s-by-card-
            period)) > %-limit-card-use)[set s-card-ready? "no
            "]]]
    set s-by-cash-period 0
    set s-by-card-period 0
    set s-missed-sales-period 0
    set tot-s-card-ready-start-period (count turtles with [s-
        card-ready? = "yes"])]
end
```

different category of agents, the reason of this choice is that we argue that responding to a question like *the modification of this parameter has beneficial effects or not?* implies the place of the question *beneficial to who?*.

Simulation 1

In this simulation we will tweak with the slider named prob−buyer−selective which denotes the probability that the buyers who want to pay by card, as a result of an individual deliberate choice after an evaluation of benefit and cost of card vs cash, when find out that the chosen seller is not able to receive card payment then they signal their refusal to conclude the purchase and turn to a card ready seller.

The starting values of all parameters are those indicated in Figure 5.2 except the prob−buyer−selective slider that started at 0.25 and at tick 130 has been increased to 0.85.

The first things that we notice are that an increment of signaling of willingness to use card by some buyers determines an immediate increase in amount of purchases paid by card (see plot %−use−of−card) and a related increase of general economic saving deriving from less cash utilized keeping fixed the cost of managing cash (see plot econ−savings−use−card). The card-association in following periods shows increasing profit deriving directly from

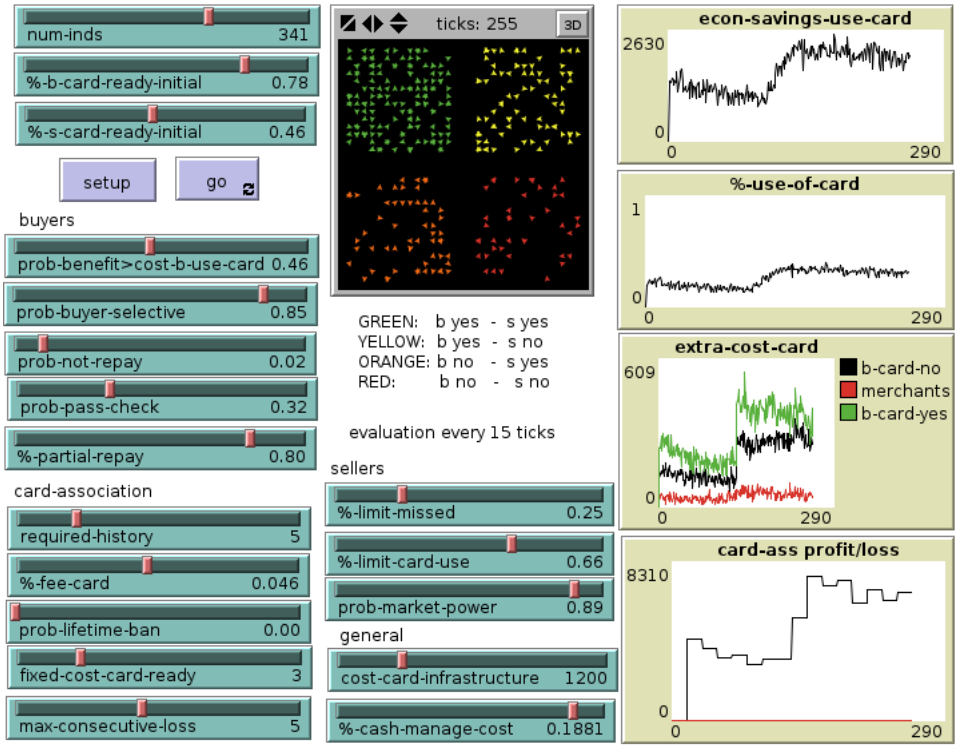

Figure 5.2: NetLogo interface - simulation 1

the rise of purchases finalized by card (see plot card−ass profit/loss).

However the most interesting information can be extrapolated looking at extra−cost−card plot taking in account the very high value (0.89) for the prob−market−power and the relatively low value (0.25) for the %−limit−missed. The degree of these two variables shall cause on one hand an increase in the number of sellers that decide to accept cards given the rising number of missed sales and on the other hand it determines that the extra cost, deriving from the fee imposed by the card association, is passed almost completely to consumers in the guise of a greater price for everybody.

Observing the graph we can see that the red line practically does not move from its fluctuating mean while the green and black lines jump upward denoting an increasing of cost incurred by buyers with no card and by cardholders who decide to buy via cash as they consider for their particular purchases that the benefit deriving from use of card do not compensate the extra cost, these extra costs derive from a greater number of sellers that

accept card and pass the costs to consumers.

The remaining part of profit for card-association is financed by those cardholders that consider the use of card instead of cash beneficial and then we claim that they can be seen as subjects who do not incur in unwanted extra-cost but rather feel good in paying for a service from card-association.

Simulation 2

In this simulation we will tweak with the slider named %−fee−card which denotes the proportional fee that card-association imposes on transacted, and that it is often object of debate in real world.

The starting values of all parameters are those indicated in Figure 5.3 except the %−fee−card slider that started at 0.078 and at tick 100 has been decreased to 0.030.

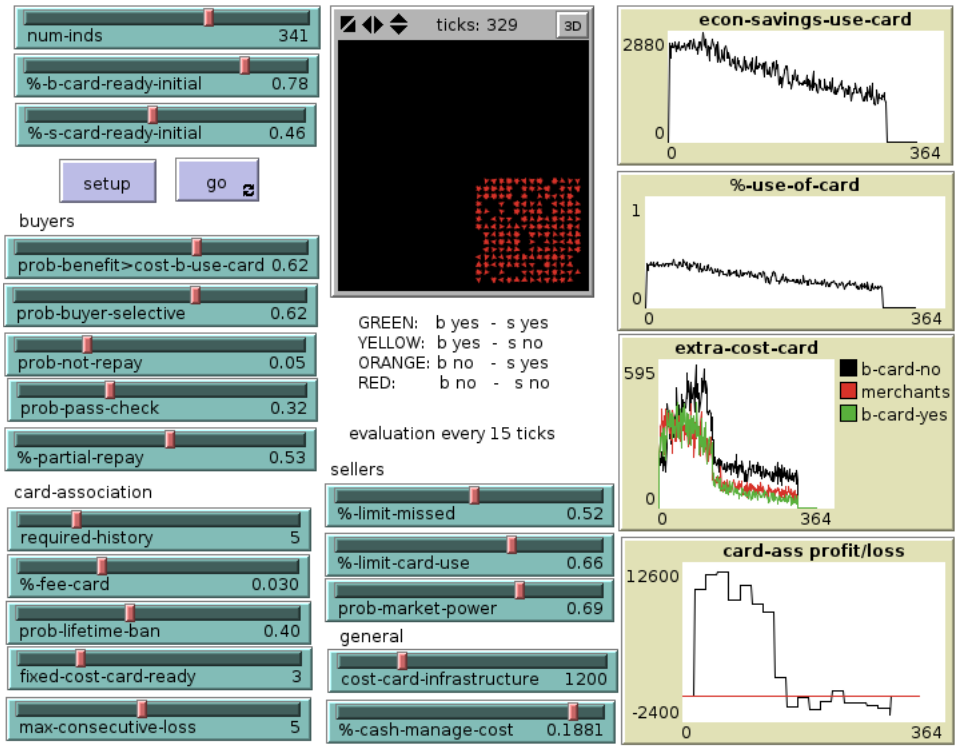

Figure 5.3: NetLogo interface - simulation 2

A short-lived glimpse to the interface highlights that the card-association has not been able to overcome a such great decrease of its principal source of

revenue and after having collected 5 consecutive periods of losses it decides to stop providing the infrastructure. Everything else being equal and assuming that sellers do not exploit the opportunity of maintain higher prices with lower costs, looking at plot extra−cost−card, we claim that in periods previous to failure of card-association both the consumers and sellers have seen a reduction of their cost.

The most troublesome results are that provided by the plots %−use−of−card and econ−savings−use−card, the two lines correctly go to zero when the card-association stops to maintain the infrastructure but before they do not respond to the change in %−fee−card; the main reason of this behavior is for sure to be found in how our model has been designed. In fact in order to simplify the simulated world we do not link the %−use−of−card variable with the strategies of buyers and sellers, but in real world we are almost certain that strong relations exist.

In our model an hypothetical policy-maker that seek on one hand to improve the social benefit deriving from the save of liquidity linked with an increase of card usage and on the other hand to reduce the extra-cost incurred by consumers and merchants should perform more than one action: the policy-maker should not only decrease the %−fee−card (hitting the revenues of card-association) but he should also increase the sliders named prob−benefit>cost−b−use−card and prob−buyer−selective, in doing so he would induce buyers to prefer card payments with respect to cash.

In addition to the above observations, we want to point out that if the general reliability of cardholders in repaying the utilized credit of the period was higher and so the slider prob−not−repay positioned on a lower value (i.e. 0.01) then we would observe that the card-association would be able to overcome successfully the same decrease in %−fee−card; the economic reason is that a great part of costs for card-association is composed by losses deriving from cardholders who fail to repay the anticipated credit.

Simulation 3

In this simulation we will tweak with the slider named prob−benefit>cost−b−use−card which denotes the probability that a cardholder perceives the benefits of pay by card greater than the costs connected with the use of the same card.

The starting values of all parameters are those indicated in Figure 5.4 except the prob−benefit>cost−b−use−card slider that started at 0.30 and at tick 110 has been increased to 0.86.

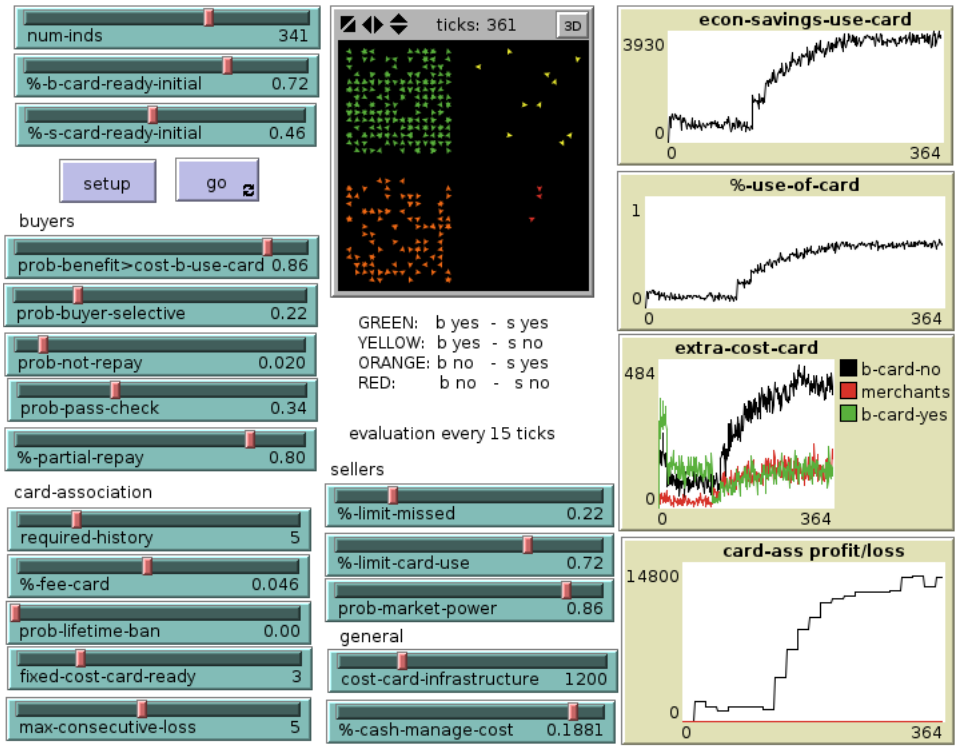

Figure 5.4: NetLogo interface - simulation 3

The first detail to notice is that we have an evident increment of the number of sellers that accept payments by card, the slider labeled %−s−card −ready−initial at the beginning of the simulation is set to 0.46 but at the end the percentage of sellers that accept card is close to unit (graphically we see that almost all agents are characterized by green or orange color).

For what concern the output on plots part of the NetLogo interface we see a marked increase in the use of card (see plot %−use−of−card) that goes hand in hand with increment of profit for card-association (see plot card−ass profit/loss) and increasing economic savings from a reduced need of cash to conclude purchases (see plot econ−savings−use−card).

It is interesting to observe that the economic reason of this increase of sellers who accept card can be identified in the underlying process of

signaling the refuse to conclude a purchase if payments by card are not accepted, moreover the process is quite effective even when the slider prob−buyer−selective is set on a relatively low value as 0.22.

The plot extra−cost−card gives us the opportunity to argue that the increasing number of sellers who accept card combined with the high incidence of sellers with market power results in a penalizing situation for those buyers who do not possess card and so are constraint to pay by cash (line black), otherwise the buyers-cardholders who conclude a purchase by cash see a limited increase of cost due to a lower probability of interact with a seller that do not accept card (line green) and finally also the merchants ready to accept card but with no market power see an increment in their due to a greater number of buyers willing to pay by card (line red).

5.2 Trust Based Model

In this second model we try to simulate the functioning of a payment system that is based on social relations of people, the underlying idea is try to exploit the allegedly availability of people to concede credit lines to acquaintances.

We firmly believe that the idea of credit lines is all but new, however the recent technological innovations and the ubiquitous presence of the Web that potentially brings people together direct us to ask whether such a system would work or not and under what conditions.

In the following we will at first describe the structure of our model focusing on some technical details related to the code and subsequently after running some simulations we will make some remarks on the results obtained.

5.2.1 The structure

Differently from the card model, the development of the Trust Based Model (TBM) is characterized by the use not only of NetLogo but also of Python plus its dedicated library for studying graphs and networks named NetworkX.

Taking a step back we notice that a social network (as all other network) is characterized both by nodes and edges, that are represented respectively by individuals and by relations among them. We use NetLogo to model the

network of granted line of credits among acquaintances by taking advantage of its core characteristics: the individuals are abstracted by agents named turtles while the relationships are represented by links.

The importance of both types of agents is evident, each individual is in fact a singular entity but the relationships that he establishes with other people are for sure each different from the other: in our specific case in fact an individual may be available to guarantee a certain amount of credit to one of his friend and for no reasons he is constrained to guarantee the same amount also to all his other friends.

A further element that we want to underline is that the relationships among individuals are bi-directional and not necessarily symmetric: if a person trust one of his acquaintances and is ready to guarantee him a positive credit line, this does not mean that the reverse is necessarily true; for this reason in our NetLogo simulation we utilize directed links.

In the turtles−own section of code there are the variables belonging to every agent (turtle), that are related on one hand to payment occurred by cash and on the other hand to those transactions executed through the TBM; when a person adheres to TBM the variable tbm−ready? is changed in yes, the amount paid by cash is stored in paid−by−cash, that payed by TBM is stored in paid−by−tbm while netted stores the amount of credit that it *cancels out* by the presence of two opposite obligations.

Listing 5.10: turtles-own

```
turtles-own
[counterpart
 demand
 executed
 tbm-ready?
 paid-by-cash
 paid-by-tbm
 demand-via-tbm
 demand-via-cash
 time-execution
 shared-cost-tbm
 time-cost-tbm
 total-tbm
 netted
]
```

On the contrary all the variables in the links−own section refer to characteristics proper of the functioning of the TBM.

The central idea is that when a person decides to adhere to TBM he signals how much credit he is available to concede to his acquaintances that adhere in turn to TBM. Looking at a specific case, when two person adhere to TBM the type−relationship variable of their links can assume three different values:

- stranger no credit line available between them
- friend positive credit line available between them
- banned in the past positive credit line available between them but now no credit line available between them

The amount of credit guaranteed is stored in granted−iou where the abbreviation IOU stands for "I owe you", in utilized −iou it is stored the amount of credit line that has been yet utilized, loss indicates the amount of credit that has not been repaid when required.

Listing 5.11: links-own

```
links−own
[granted−iou
 approved−iou
 approved−iou−original
 utilized−iou
 counter−direct−contact
 type−relationship
 time−from−last−evaluation
 both−ends−ready?
 old−utilized−iou
 time−from−last−contrary−movement
 loss
 agreed−max−iou ;in this model no, but in python yes
 available−iou ;in this model no, but in python yes
]
```

In globals are stored variables that allow us to grasp the aggregate situation of the world: %−executed−via−tbm represents the percentage of amount executed via TBM over the total demand amount that was asked to be executed via TBM while %−turtles−enjoy−tbm represents the percentage of individuals adhering to TBM that in each particular tick derive benefits from using the system.

Listing 5.12: globals

```
globals[
  savings-of-liquidity-from-use-tbm
  econ-savings-use-tbm
  mean-time-execution
  time-last-check-stranger
  %-executed-via-tbm
  %-friend
  %-stranger
  %-banned
  %-turtles-enjoy-tbm
]
```

5.2.2 NetLogo talks to Python

We want now describe a tricky part of our project, as we will see afterwards, in our model each agent in every tick make a purchase from a counterpart and pay it by cash or through the system based on trust; when the form of payment chosen is that of cash there is no problem since the features offered by NetLogo are appropriate to program the situation, however the tools offered by the same software are not appropriate to program the other choice.

In fact a payment through the TBM is considered executed when it is possible to find one or more trusted pathways from the buyer to the seller that allow the IOUs to travel, however NetLogo does not offer any kind of instrument to solve this sort of problem.

The solution we adopt is to devote the problematic computation work, of finding the pathways through the network, to an ad-hoc program written in Python and have it communicate with NetLogo.

The interaction among the two parts of our project happens in five steps:

1. NetLogo export the data - Python wait
2. Python import the data - NetLogo wait
3. Python performs computation on data - NetLogo wait
4. Python export the data - NetLogo wait
5. NetLogo import the data - Python wait

In order to prevent possible collision situation since both programs are running continuously and at the same time we have developed a checking

barrier on both side: NetLogo signals to Python the correct export of data through the creation of the file ok−data−by−netlogo while Python signals its own correct export of data creating the file ok−data−by−python.

Listing 5.13: export-nodes-edges

```
to export-nodes-edges
  carefully [file-delete "nodes-by-netlogo"][]
  file-open "nodes-by-netlogo"
  ask (turtles with [demand-via-tbm != 0])[
    file-write [who] of self ;source in python script
    file-write [who] of counterpart ;sink in python script
    file-write demand-via-tbm file-print " "] ;demand in python
        script
  file-flush
  file-close
  carefully [file-delete "edges-by-netlogo"][]
  file-open "edges-by-netlogo"
  ask (links with [both-ends-ready? = "yes"])[
    file-write [who] of end1
    file-write [who] of end2
    file-write granted-iou
    file-write approved-iou
    file-write utilized-iou file-print " "]
  file-flush
  file-close
  file-open "ok-data-by-netlogo"
  file-write "luca"
  file-flush
  file-close
end
```

However the use of plain Python is not enough to reach the objective of let IOUs travel and propagate from an individual to his chosen counterpart through all the covered intermediate trust relationships existing between the two.

Since we did not found a dedicated solution to perform the above task, we decided to develop our own. We found similarities to our problem in the mathematical field of optimization theory and more specifically in those algorithms developed to solve the so called "maximum flow problems", indeed we decided to take advantage of the implementation in the NetworkX library of one of such algorithms named Ford Fulkerson and we modified it properly to make it functional to our goal.

The two algorithms produce different results:

NetworkX - Ford Fulkerson it is called by:

Listing 5.14: import-nodes-edges

```
to import-nodes-edges
  while [not file-exists? "ok-data-by-python"][]
  carefully [file-delete "edges-by-netlogo"][]
  carefully [file-delete "nodes-by-netlogo"][]
  carefully [file-delete "ok-data-by-python"][]
  file-open "edges-by-python"
  while [not file-at-end?][
    ask link file-read file-read [
      set utilized-iou file-read]]
  file-close
  file-open "nodes-by-python"
  while [not file-at-end?][
    ask turtle file-read [
      set paid-by-tbm file-read
      set time-execution file-read]]
  file-close
end
```

nx.ford_fulkerson_with_demand(network,source,sink)

in this version there is no input except the network, the source node and the sink node; the output is the maximum flow possible from the source node to a sink node and the complete map of how this max flow passes through the network

Modded by us - Ford Fulkerson it is called by:

nx.ford_fulkerson_with_demand(network,source,sink,demand)

differently from the original version, this one allows the user to provide a desired amount that must be sent from the source to the sink; the output is the flow (less than or equal to the demand provided) transmitted from the source node to a sink node and the complete map of how this flow passes through the network

Indeed with the just described setup we are able to make NetLogo and Python communicating in a profitable way and the modded version of Ford Fulkerson algorithm allows us to execute payments through the network of trusted links by considering the buyer as the source, the counterpart as the sink and the demand as the agreed cost of the purchase to be finalized.

5.2.3 The interface

In Figure 5.5 we have the interface of the NetLogo model that can be divided into three parts: on the top-center the representation of the world, on the right and bottom-center some graphs on which we see the global results of interactions among agents and on the left a whole bunch of sliders which are grouped according to what elements of the model they control.

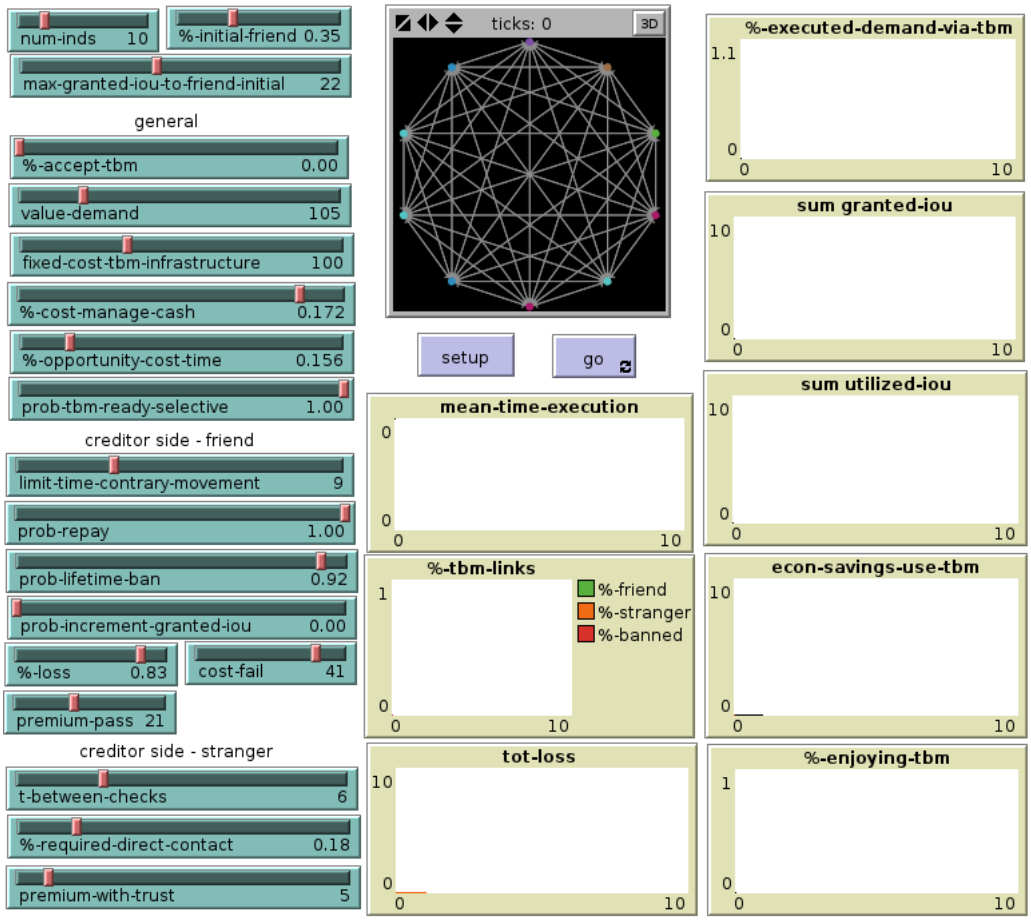

Figure 5.5: NetLogo interface

The first thing to notice is that the model is designed to have as benchmark a situation in which nobody adhere to the system based on social network, for this reason if we run a simulation with the %−accept−tbm slider set to 0 we would obtain a steady output on all graphs.

In the *general* part of Figure 5.5 we have the sliders that control some

variables related to the general environment:

- %−accept−tbm It represents the percentage of people that adhere to the TBM
- value−demand It represents the mean of costs of purchases of all individuals per every tick
- fixed−cost−tbm−infrastructure It represents the fixed cost per tick to keep running the infrastructure necessary to enable payments through the network of trust
- %−cost−manage−cash It represents the percentage cost of managing cash
- %−opportunity−cost−time It represents the percentage opportunity cost of time that a buyer who want to pay by TBM bears when he can not fully realize the payment through TBM
- prob−tbm−ready−selective It represents the probability that an individual adherent to TBM chooses as counterpart another person adherent to TBM

In the *creditor side - friend* part of Figure 5.5 we have the sliders that control the relationships with friends (those links which have positive granted −iou):

- limit−time−contrary−movement It represents the maximum allowed number of consecutive tick with no opposite movements in utilized−iou before asking for the return of utilized−iou
- prob−repay It represents the probability that individuals return the utilized−iou when asked by creditor
- prob−lifetime−ban It represents the probability that a person who fails to return utilized−iou to a determinate creditor be banned lifetime by the same creditor
- prob−increment−granted−iou It represents the probability that a person who returns correctly the utilized−iou be rewarded with an increase of granted−iou

- %−loss It represents the definitive percentage of loss of utilized −iou when the latter is not return correctly

In the *creditor side - stranger* part of Figure 5.5 we have the sliders that control the relationships with stranger (those links which have both ends adherent to TBM and zero granted−iou):

- t−between−checks It represents the number of consecutive tick in which individuals record information on transactions in order to make a decision about granted−iou to strangers

- %−required−direct−contact It represents the minimum percentage of contacts with strangers that it is required to assign granted−iou to strangers

- premium−with−trust It represents the value of granted−iou assigned to a new established friend relationship that comes from the passing of the %−required−direct−contact test

We conclude the description of the interface of our model with a brief comment of the different outputs that are reported on the eight plots:

- %−executed−demand−via−tbm In this plot we can appreciate the percentage of amount of purchases required to be payed through TBM that have been performed with success on tick base

- sum−granted−iou In this plot we can see the sum of granted−iou of all links on tick base

- sum−utilized−iou In this plot we can see the sum of utilized −iou of all links on tick base

- econ−savings−use−tbm In this plot we can appreciate the economic benefit/cost at general level deriving from the adoption of TBM on tick base

- %−enjoing−tbm In this plot we can see the percentage of individuals adherent to TBM that benefit from the usage of the payment system based on social network

- mean−time−execution In this plot we can see the average time of execution of payments through TBM

- tot−loss In this plot we can appreciate the sum of definitive losses on utilized −iou not returned when required

- %−tbm−links In this plot we can see the percentage respectively of friend relationships (green line) over total of links belonging to TBM, that of stranger (orange line) and that of banned (red line)

5.2.4 Description of code

After having described the interface we will now focus in detail on the most important parts of the NetLogo code which represents the backbone of the model.

Similarly to card model, the buttons setup and go in interface point to the code present in homonyms procedures: the former is executed only one time and results in the creation of a world in which an indicated number of individuals exists and, only if a positive value for %−accept−tbm is provided, a given percentage of them is made adherent to TBM.

Listing 5.15: to setup

```
to setup
  deal-with-files-related-to-interaction-with-python
  clear-all
  no-display
  make-individuals
  make-links
  compute-general-statistics
  reset-ticks
end
```

A quick look at the go procedure gives us the opportunity to separate it in different parts in accordance to the actions performed by the agents: at the start of each cycle buyers are asked to find a counterpart for the making of a purchase, then they have to choose in what way they want to pay (by cash or through TBM), hence they finalize their purchase and perform some evaluations.

We observe that a number of assumptions have been implicitly taken: the first one is that when an agent adherent to trust system selectively choose as counterpart another individual adherent to trust system we assume that the good/service required in purchasing can always be provided by everybody (in the model we assume that there are distinctions between who provide

Listing 5.16: to go

```
to go
  initialize-variables
  ask turtles [
    set demand (int random-normal (value-demand) (value-demand /
        10))
    find-counterpart
    decide-how-to-pay]
  interact-with-python-script
  ask turtles [pay]
  compute-general-statistics
  make-evaluation-about-friends-and-strangers
  compute-individual-statistics
  assign-tbm-ready
  evaluate-links
  tick
end
```

particular good/services and who decide to adhere to TBM), the second strong assumption is that when the buyer and the seller are both participants to TBM then there is a priority in trying to conclude the purchase through TBM, last but not least the structure of trust relationships among agents in the model is randomly created and so it is hardly even remotely similar to an analogue networks based on relationships among people in real world.

In initialize -variables procedure we make clear that the functioning of the payment network system based on trust relationship is permitted by the presence of a centralized infrastructure characterized by a fixed cost per each tick, cost which is shared equally between the members of the system at the start of every tick and regardless of whether the single individuals benefit or not from participating to the TBM.

After the above long list of simplifications and weaknesses connected to our project we want to explicit now one of the potential benefits, more specifically the only one quantified in our model, that a system of payment based on trust among people can bring with its diffuse adoption: we are talking of the potential netting of opposite debtor positions among individuals before the request to return the utilized -iou.

Given the cost of manage cash, both in the form of cost to obtain it and in the form of risk of theft, a reduction of liquidity required to perform purchases might be appreciated at individual level and might generate positive benefits at societal level.

In the description of go we deem important to focus on the make−evaluation −about−friends−and−strangers procedure that it is divided further in evaluate−friends and evaluate−strangers.

Listing 5.17: to evaluate-friends

```
to evaluate-friends
  ask links with [type-relationship = "friend"][
    ifelse ((utilized-iou < old-utilized-iou) or (old-utilized-
        iou = 0))
    [set time-from-last-contrary-movement 0]
    [set time-from-last-contrary-movement (time-from-last-
        contrary-movement + 1)]]
  ask links with [type-relationship = "friend"][
    if (time-from-last-contrary-movement >= limit-time-contrary-
        movement)[
      ifelse (prob-repay > random-float 1)
      [set utilized-iou 0
        if (prob-increment-granted-iou > random-float 1) [set
            granted-iou (granted-iou + premium-pass)]]
      [set loss (utilized-iou * %-loss)
        set utilized-iou (int (utilized-iou - loss))
        ifelse (prob-lifetime-ban > random-float 1)
        [set type-relationship "banned"
          set granted-iou 0]
        [set granted-iou (granted-iou - cost-fail)
          if granted-iou < 0
          [set granted-iou 0
            set type-relationship "stranger"]]]]]
end
```

We notice that in both evaluation procedures the agents that are called are the links instead of the turtles, this is not a mistake but it is just an artifice in order to maintain the code simple: the idea in fact is that each individual (turtle) on one side check the reliability of his friends when asked to repay the utilized−iou and on the other side decide which if any of the strangers might get a positive credit line.

These two procedures are central for the functioning of the model and moreover there are also here some strong assumptions.

The first one is that the period after which individuals are asked to check the reliability of their acquaintances with positive granted−iou is not fix but rather it is linked to a maximum number of consecutive tick (provided by the user of the program) that have elapsed since the last opposite movement in utilized−iou, the reason of this choice is that in a real world implementation the people might take every form of bilateral agreement on limit date to

Listing 5.18: to evaluate-strangers

```
to evaluate-strangers
  ifelse (time-last-check-stranger >= t-between-checks)
  [ask links with [type-relationship = "stranger"][
      if (([counter-direct-contact] of link ([who] of end2) ([
          who] of end1)) / time-last-check-stranger) > %-required
          -direct-contact [
        set granted-iou premium-with-trust]]
  ask links [set counter-direct-contact 0]
  set time-last-check-stranger 0]
  [set time-last-check-stranger (time-last-check-stranger + 1)]
end
```

require the return of utilized-iou without being all bound to an equal for all period.

A second cause of concern for a real application is the behavior of people in response both to a pass or to a fail of the request to return credit: in the model through the use of various sliders we set the probability that each individual has of passing the test, the response to a success with a potential form of reward and the probability of banning from obtaining credit line the agents who fails.

A further strong assumption is the way in which individuals decide to concede a credit line to a stranger, we assume that an individual is available to concede credit to a person if he repeatedly concludes purchases from him in a given set of time; the underlying idea is that generally we feel quite available to concede credit to another if the latter has something valuable to compensate us in case of a failure to refund in cash, and a person with which we repeatedly (in a given period) conclude purchases is assumed to have most likely something valuable to us.

5.2.5 Some simulations

Simulation 1

In this simulation we will tweak with the slider named %-accept-tbm which denotes the proportion of individuals that decide to adhere to the system of payment based on trust.

The starting values of all parameters are those indicated in Figure 5.6 except the %-accept-tbm slider that started at 0.30 and at tick 170 has been increased to 0.72.

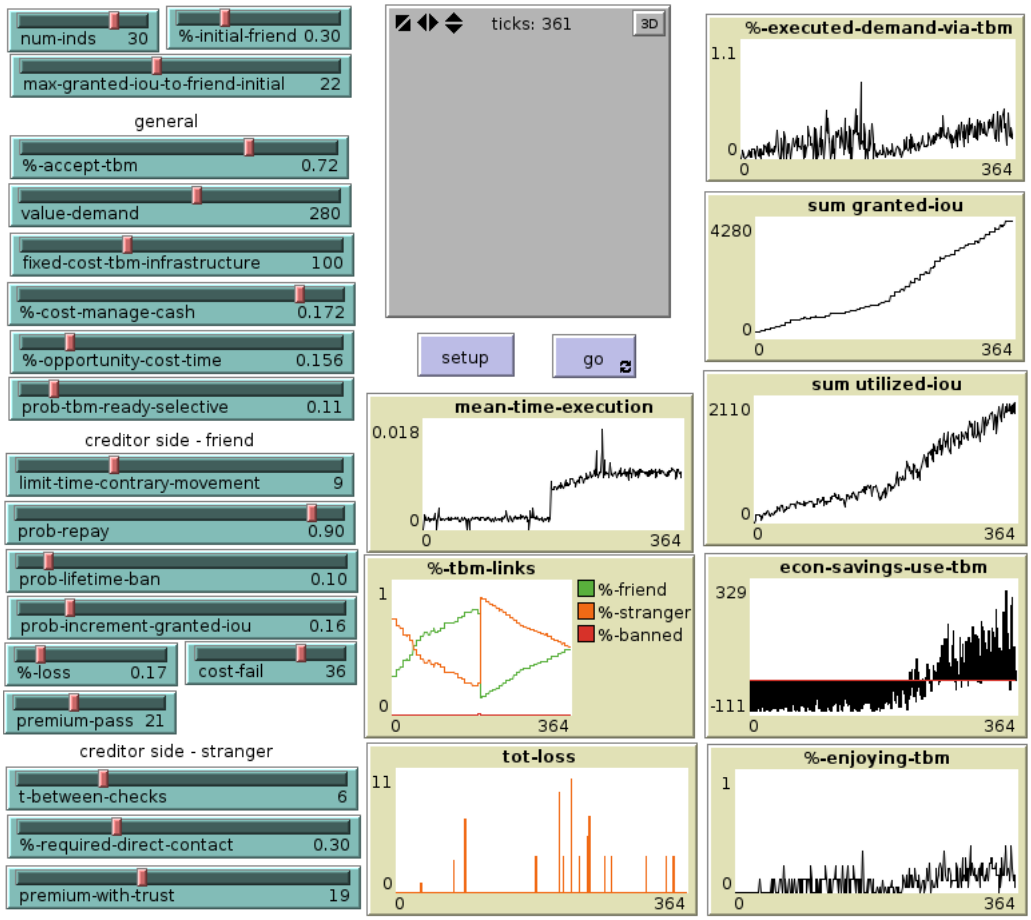

Figure 5.6: NetLogo interface - simulation 1

With this simulation we are interested in understand what are the effects of an increase in the base of users of a yet running TBM system, a first sight to the plots suggests that such increase in the number of users seems to have important beneficial effects that are summed in a reduction of liquidity required to finalize the purchases of the individuals in society. We can see on econ−savings−use−tbm plot that the system considered in its totality it is always inefficient for every tick before the increase of users, however the alteration of this parameters does not determine the immediate switch to a position of profit (represented by black bars above the zero-line in plot econ−savings−use−tbm but rather marks a progressive tendency to a more favorable situation for payments through TBM.

The concurrent forces deriving from the increase in %−accept−tbm that lead the system to be be profitable in long-term expectations are to be identified on one hand in the huge increase in the granted−iou all through the system as reported on sum granted−iou plot and on the other hand in the increase of requested amount of purchases to be settle in TBM: the increase in granted−iou determines the formation of an increasing number of exploitable paths among people and this leads to an increasing likelihood that greater amounts of demand−via−tbm being settle through TBM. Given our assumptions of fixed cost for the system, when the total of paid−by−tbm exceed the correlated critical line of cost the TBM became profitable from the societal economic point of view.

Moreover we remember that both the speed and the occurrence of the process just described are directly correlated with the parameters imposed on the system by the user of the model, the most important in this case are those values set in creditor side − stranger part of the interface. In plot %−tbm−links we see that when %−accept−tbm is increased there is a rise in the number of stranger-relationship, which are gradually transformed in friend-relationships with the guarantee of granted−iou when occurred the required limit number of direct contact indicated in %−required−direct−contact; the rise of sum−granted−iou might be much smaller or even non-existent if the slider %−required−direct−contact was set to a greater value given the the fixed period of reference.

Finally we would point out that the increase in %−accept−tbm determines an increase in the mean execution time of finding a feasible path from the buyer to the seller (see plot mean−time−execution), we deem meaningful to notice that this increase should be taken in account in a real implementation of a payment system based on trust since potential user may value negatively the extra-time required to conclude the transactions.

Simulation 2

In this simulation we will tweak with the slider named prob−repay which denotes the probability that individuals return entirely the utilized −iou when requested.

The starting values of all parameters are those indicated in Figure 5.7 except the prob−repay slider that started at 0.94 and at tick 100 has been

decreased to 0.24.

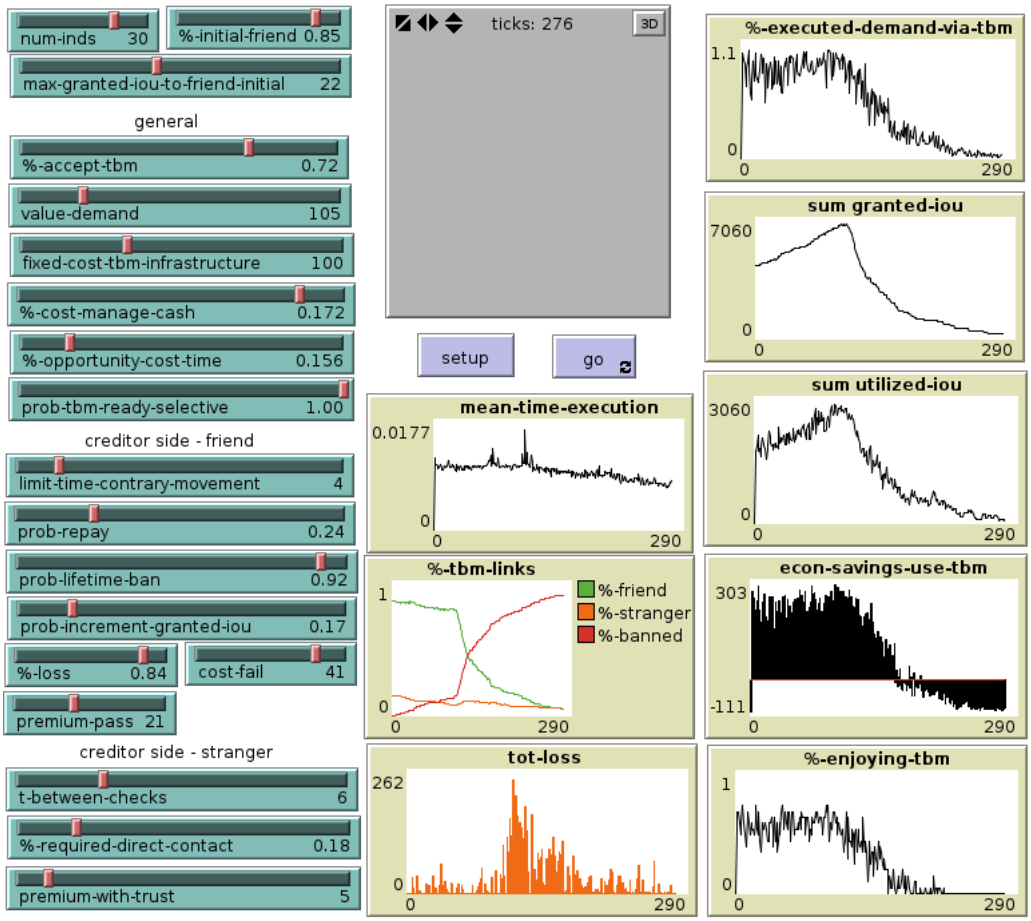

Figure 5.7: NetLogo interface - simulation 2

We start by noticing that a reduction in the probability of repayment of utilized credit line may be considered as equivalent to a reduction in reliability of individuals, as they increasingly betray the expectations placed previously on them through the guarantee of the same credit line.

As we can see on plots econ−savings−use−tbm and %−tbm−links the starting point of the simulation is a system of payments based on trust that it is well functioning and in which there is a prevalence of friend-relationships (with granted−iou greater than zero) over stranger ones, signals of the soundness of the system may be identified in the continuous fluctuation of the ratio defined as paid−by−tbm over demand−via−tbm in a region of value close to

unity (see plot executed−demand−via−tbm) and a relatively high percentage of people adherent to TBM who benefit from doing so.

The results of a such maintained fall in probability of repay is a progressive impairment of the TBM which ends with a system not more profitable for its users. Before describing the process that leads to this failure we want to stress the strong assumption that it is made in this case: we assume in fact a high probability (0.92 in prob−lifetime−ban slider) that individuals react in a decisive manner to a failure in repayment of utilized −iou, as they fully revoke the previously granted line of credit and marks as banned for lifetime those defaulting.

We are conscious that this assumption and the huge decrement induced in prob−repay are strong hypothesis that hardly occur in real world, notwithstanding we deem interesting to utilize them in order to better understand how our model works.

The modification made affects the system in two ways: on one side it determines a revoking in granted−iou of defaulting individuals (see plot sum−granted−iou) and on the other it determines a huge increment on total losses borne by users of TBM. Moreover the two effects are perversely connected in a vicious circle: when the induced shock occurred the amount of total losses rise in a decisive manner and then continues to be higher than before but with a decreasing trend (see tot−loss plot), the reason of this behavior is that before the shock occurred the sum of utilized −iou is very high since the system as a whole is performing well but when the modification happened the total amount transacted by the system decrease (since lower granted−iou are observable) and so also the losses. The combination of these two effects results in a progressive fall in the percentage of executed payments over those required to be settled through TBM (see plot %−executed−demand−via −tbm) which linked with the increasing losses causes a fall in the number of satisfied users of TBM (see plot %−enjoying−tbm).

The persistent final unprofitable situation of the system as a whole (see plot econ−savings−use−tbm) must be then considered as a complete failure from the societal point of view, as the cost of running the infrastructure is well above the economic benefits deriving from the lower liquidity required for payments occurring through the system.

5.3 Final considerations

In this section we will summarize the results that the development of our two models has allowed us to reach.

We start by observing that, under our simplifying assumptions, both the modeled payment system based on credit card and that based on social network show in some particular cases to be competitive when compared to only cash transactions, however a clear statement on which one is the most profitable is in our opinion quite difficult due to the many structural differences of the two.

We deem valuable to recognize that the opinion just given rests not so much on the numerical results of our experiments but rather largely on the problems encountered in the design and development in NetLogo of the two models; in other words the mental path towards the development of the models, by the imposition of sometimes plausible assumptions but other times not so much likely, allowed us to capture the peculiarities of each system.

When dealing with payment systems based on credit card as those observable in reality and that modeled in our work we can surely observe that an evaluation of the beneficial effects has to be carried out by distinguishing the various subjects involved in the system, the main reason is given by the two-sides nature that consists in cardholders who generally do not have explicit costs and sellers that on the other hand are in the position to pay a percentage more or less substantial of their sales paid by card to card-association that it is operating for profit. Then the extra-cost borne by some represents the benefit for others, more specifically the card-association through the provision of services as protection against fraud and reward programs to cardholders is able to extract value or from merchants or from by-cash buyers depending on the degree of market power of the seller able to accept card.

Completely different is the situation in TBM, first of all there is the lack of a for profit entity like a card-association and secondly the users of the system are placed on the same level, what does that imply? In our opinion it implies that there could be a missing of incentives for people to start to adopt TBM that results in a failure of the system based on trust as observed similarly in the world simulated in our first experiment in TBM section; in

fact for the system to be advantageous for its users a critical level of adoption has to be exceeded.

Assuming however a massive adoption, a further obstacle that preclude a definitive numerical comparison between Card system and TBM is represented by the uncertainty surrounding each payments required to be executed through the payment system based on trust, in fact, differently from credit card network, the possibility to conclude the transaction depends on the existence of pathways with enough credit available from the buyer to the seller.

Looking at the two system adopting a graph theory approach we can visualize the system based on card as a sort of stylized inverted tree with a static nature where at the bottom there are the leaves representing the individuals (buyers and sellers) and at the top there is the card association while the system based on trust can be represented as a cloud of points connected by ever-changing links; once you know the pretty stable characteristics of the links (determined by the card-association) going from one leaf to another is straightforward where finding the routes in the dynamic context of TBM turns out to be expensive both in terms of time taken and of uncertainty in the success of the search.

In our opinion, additional elements to the detriment of a widespread adoption of an hypothetical system based of social network are to be identified in the distrust of technological innovations by a large part of society and even more in a somewhat predictable reluctance of individuals to quantify, by indicating explicitly granted credit lines, the trust that they have towards their friends and acquaintances.

Moreover, starting from the shared observation by Barabási and Albert (1999) that many networks related to people assume forms far from those generated by a random process we argue that in a real application of a system based on social network the topology of the same network would surely be completely different from that randomly constructed with NetLogo in our TBM; the heterogeneity of relationships among people would in fact likely lead to a structure characterized by a limited number oh hubs that would assume a such central position in the functioning of the system itself to result in potential bottlenecks in the searching of pathways of available credit line from buyers to sellers.

The last element which benefits further the credit card system over the

TBM is represented by the management of misbehavior adopted by final users of the systems: as seen in the real world the scams and fraud occurring in the system based on card are already substantially incorporated while in the TBM the reaction of the system to criminal conduct, as that of individuals who first manage to get lot of confidence and then betray, is substantially unknown.

Conclusions

Both the study of the theoretical aspects related to trust, money and payment systems, carried out in first three chapters, and the deepening of topics related to complexity and network theory that culminated with the development of our two models, carried out in the last two chapters, play an equally important role in the formation of a personal opinion on the work that has been done and the possible future implementations.

First of all, the discussion about money from an historical point of view led us, on one hand, to be aware that money is not the object per se as what really matters is that money is a credit recorded with some signs while on the other hand the discussion led us to notice that money generally accepted is almost always closely related to a subject, be it a democratically elected government or a king, whose authority is recognized and the power of coercion is accepted.

Money considered as a social institution is strictly connected with issues such as uncertainty and trust, in chapter one we highlighted that the presence of trust is necessary for the proper functioning of an economy but still not enough, a further ingredient required is a widespread feeling of confidence that both feeds and is fed by trust.

The massive dematerialization of money in our time is a further confirmation, if any were needed, of this fact: in chapter two in evaluating the role of banks in creating money we concluded that the uncertainty deriving from complexity of banking system is addressed by existence of confidence in state which it is projected onto central banks and indirectly on singular banks. In chapter three we analyzed the life of a cashless payment focusing first on interbank payment systems and secondarily on card payment systems: we initially recognized that the core of global payment systems is the information that it is transferred among the various parties, then we remarked

the presence of a deep standardization and interconnection between proper card payment systems and national or supranational clearing and settlement systems and lastly we provided a brief description of a recent project named Ripple whose objective is to become an open decentralized payment network based on trust that already exists between people in real-world social networks.

The desire to investigate the potential of agent-based simulation has led us to develop two models with the objective of making a comparison between the two, the first is a simplified credit card system while the other is a similarly simplified payment system based on social relationships of people inspired by the Ripple project. The simulations made but even more the whole process of rationalization and design of both models leads us to conclude that a detailed comparison between the two is hardly practicable due to the very different operating mode of each one.

Notwithstanding the difficulties, we can say that a largely adopted payment system based on trust could at least in theory offer advantages on a concurrent card based system: the simulations made show that a massive participation could benefit users of the system on one hand by reducing the cash required for the conclusion of trades and on the other hand by avoiding them to bear the extra costs imposed by the card association.

We are aware that some of the numerous assumptions that have been made are very strong and sometimes detached from reality, in future implementations it would be desirable for the card model to take into account also the correlation between the different variables that determine the use and acceptance of cards while for the Trust Based Model to provide a distribution of population closer to one resulting from a power law instead that resulting from the random process implemented in NetLogo.

In the end we are left skeptical to the possibility of a successful development on large scale of a payment system based on trust as that simulated by us, among the others the reasons that led us to this opinion can be synthesized as follow: a substantial lack of incentives to adhere to the system because the benefits deriving from less use of cash are only potential and not known a priori, a widespread hesitancy by people towards technological innovation, a predictable unwillingness to quantify trust in granted credit line and an unpredictable system's resistance to misconduct by members. We deem interesting to note that, near the end of our thesis work, the Rip-

ple project itself has undergone drastic changes to its initial structure that can be traced to difficulties in finding trusted pathways between buyers and sellers. Another element that we have not taken into account in our model, but that would have a major impact in the development of such a system in the real world is the role of state in question related for example to taxation.

Because of the difficulties suggested above, we are more likely to predict future innovations in the field of payment systems that derive from realities still already recognized by the state, whether them related to the banking sector or to telecommunications with mobile payment systems. In this regard we recall the study of Zywicki (2013) which shows how "reloadable prepaid cards have been one of the fastest-growing sectors of the consumer payments marketplace in recent years"; in our opinion, it is highly probable that the two-sided market structure of card payment systems will continue to be central and with it, as reflected also in our simplified NetLogo model about card, the presence of multiple stakeholders like merchants, cardholders and card associations.

Recognizing the growing demand for tools useful to make cashless payments, and the increased competition among suppliers of these instruments, we expect a shift towards ones less expensive for customers and more profitable for card associations. In this respect, debit cards may benefit both consumers eager of cashless instruments and card associations looking to greater profit due to lower costs than those typical of credit cards as monitoring activities and failure in repaying the granted credit.

Appendix A

NetLogo code

A.1 Card model

```
turtles-own[
  b-card-ready?
  b-by-cash
  b-by-card
  b-by-card-period
  b-by-cash-period
  b-banned?
  s-card-ready?
  s-missed-sales-period
  s-by-card-period
  s-by-cash-period
  counterpart
  c-history-check
  demand
]

globals[
  t-last-evaluation
  tot-s-card-ready-start-period
  infrastructure-available?
  tot-advance
  tot-repaid
  revenue-from-s
  result-card-association
  paid-by-b-card-ready-no
  paid-by-s-card-ready-yes
  paid-by-b-card-ready-yes
```

```
  loss-counter-card-association
  econ-savings-use-card
  %-use-of-card
]


to setup
  clear-all
  set infrastructure-available? "yes"
  make-inds
  assign-card-ready-initial
  color-turtles
  reset-ticks
end


to make-inds
  crt num-inds [
    set demand random-normal 100 20
    set b-card-ready? "no"
    set s-card-ready? "no"
    set b-banned? "no"]
end


to assign-card-ready-initial
  ask n-of (num-inds * %-b-card-ready-initial) turtles [
    set b-card-ready? "yes"]
  ask n-of (num-inds * %-s-card-ready-initial) turtles [
    set s-card-ready? "yes"]
  set tot-s-card-ready-start-period (count turtles with [s-card-
      ready? = "yes"])
end


to color-turtles
  ask turtles [
    if (b-card-ready? = "yes" and s-card-ready? = "yes")[
      set color green
      setxy (-2 + random -14) (2 + random 14)]
    if (b-card-ready? = "yes" and s-card-ready? = "no")[
      set color yellow
      setxy (2 + random 14) (2 + random 14)]
    if (b-card-ready? = "no" and s-card-ready? = "yes")[
```

```
      set color orange
      setxy (-2 + random -14) (-2 + random -14)]
    if (b-card-ready? = "no" and s-card-ready? = "no")[
      set color red
      setxy (2 + random 14) (-2 + random -14)]]
end


to go
  evaluate-profitability-infrastructure
  ask turtles [
    set b-by-cash 0
    set b-by-card 0
    set demand random-normal 100 20]
  set paid-by-b-card-ready-no 0
  set paid-by-s-card-ready-yes 0
  set paid-by-b-card-ready-yes 0
  color-turtles
  ask turtles [find-counterpart]
  conclude-trade
  update-b-by-card-period
  compute-statistics
  determine-who-pay-card-cost
  if (infrastructure-available? = "yes")[
    make-evaluation
    verify-check-and-obtain-card]
  tick
end


to update-b-by-card-period
  ask turtles with [b-by-card != 0][
    set b-by-card-period (b-by-card-period + b-by-card)]
  set tot-advance (tot-advance + ((sum [b-by-card] of turtles) *
      (1 - %-fee-card)))
end


to conclude-trade
  ask (turtles with [b-card-ready? = "no"])[
    set b-by-cash demand
    ask counterpart [set s-by-cash-period (s-by-cash-period +
        demand)]]
  ask (turtles with [b-card-ready? = "yes"])[
```

```
    ifelse (prob-benefit>cost-b-use-card > random-float 1)
    [ifelse ([s-card-ready?] of counterpart = "yes")
      [set b-by-card demand
        ask counterpart [set s-by-card-period (s-by-card-period
            + demand)]]
      [ifelse (prob-buyer-selective > random-float 1)
        [ask counterpart [set s-missed-sales-period (s-missed-
            sales-period + demand)]
          if (count other turtles with [s-card-ready? = "yes"]
              != 0)[
            set counterpart (one-of other turtles with [s-card-
                ready? = "yes"])
            set b-by-card demand
            ask counterpart [set s-by-card-period (s-by-card-
                period + demand)]]]
        [set b-by-cash demand
          ask counterpart [set s-by-cash-period (s-by-cash-
              period + demand)]]]]
    [set b-by-cash demand
      ask counterpart [set s-by-cash-period (s-by-cash-period +
          demand)]]]
end


to find-counterpart
  set counterpart one-of other turtles
end


to make-evaluation
  ifelse (t-last-evaluation = 15)
  [set t-last-evaluation 0
    revenue-from-repay-debt
    revenue-from-fixed-s
    compute-result
    evaluate-s-card-ready
    set tot-advance 0]
  [set t-last-evaluation (t-last-evaluation + 1)
    set tot-repaid 0]
end


to revenue-from-repay-debt
  ask turtles with [b-by-card-period != 0][
```

```
    ifelse (prob-not-repay > random-float 1)
    [set tot-repaid (tot-repaid + (b-by-card-period * %-partial-repay))
      set b-by-card-period 0
      set b-card-ready? "no"
      if (prob-lifetime-ban > random-float 1)
      [set b-banned? "yes"]]
    [set tot-repaid (tot-repaid + b-by-card-period)
      set b-by-card-period 0]]
end


to evaluate-s-card-ready
  ask turtles [
    ifelse (s-card-ready? = "no")
    [if (s-by-cash-period != 0)[
        if ((s-missed-sales-period / s-by-cash-period) > %-limit-missed)[set s-card-ready? "yes"]
        if (s-by-cash-period = 0 and s-missed-sales-period != 0)[set s-card-ready? "yes"]]]
    [if (s-by-cash-period + s-by-card-period != 0)[
        if ((s-by-cash-period / (s-by-cash-period + s-by-card-period)) > %-limit-card-use)[set s-card-ready? "no"]]]
    set s-by-cash-period 0
    set s-by-card-period 0
    set s-missed-sales-period 0
    set tot-s-card-ready-start-period (count turtles with [s-card-ready? = "yes"])]
end


to compute-result
  set result-card-association (revenue-from-s + tot-repaid - tot-advance - cost-card-infrastructure)
  ifelse (result-card-association < 0)
  [set loss-counter-card-association (loss-counter-card-association + 1)]
  [set loss-counter-card-association 0]
end


to revenue-from-fixed-s
  set revenue-from-s (fixed-cost-card-ready * tot-s-card-ready-
```

```
      start-period)
end


to determine-who-pay-card-cost
  ask turtles [
    let reference (random-float 1)
    if ((prob-market-power > reference) and ([s-card-ready?] of
        counterpart = "yes") and b-by-cash != 0 and b-card-ready?
         = "yes")[
      set paid-by-b-card-ready-yes (paid-by-b-card-ready-yes + b
          -by-cash * %-fee-card)]
    if ((prob-market-power > reference) and ([s-card-ready?] of
        counterpart = "yes") and b-by-cash != 0 and b-card-ready?
         = "no")[
      set paid-by-b-card-ready-no (paid-by-b-card-ready-no + b-
          by-cash * %-fee-card)]
    if ((prob-market-power < reference) and ([s-card-ready?] of
        counterpart = "yes") and b-by-card != 0)[
      set paid-by-s-card-ready-yes (paid-by-s-card-ready-yes + b
          -by-card * %-fee-card)]]
end


to compute-statistics
  set econ-savings-use-card ((sum [b-by-card] of turtles) * %-
      cash-manage-cost)
  set %-use-of-card ((count turtles with [b-by-card != 0]) /
      count turtles)
end


to verify-check-and-obtain-card
  ask (turtles with [b-card-ready? = "no" and b-banned? = "no"])
      [
    ifelse (prob-pass-check > random-float 1)
    [set c-history-check (c-history-check + 1)]
    [set c-history-check 0]]
  ask (turtles with [b-card-ready? = "no" and b-banned? = "no"])
      [
    if (c-history-check = required-history)[
      set b-card-ready? "yes"
      set c-history-check 0]]
end
```

```
217
218
219 to evaluate-profitability-infrastructure
220   if (loss-counter-card-association >= max-consecutive-loss)[
221     set infrastructure-available? "no"
222     ask turtles[
223       set b-card-ready? "no"
224       set s-card-ready? "no"
225       set result-card-association 0]]
226 end
```

A.2 Trust Based Model

```
1  turtles-own
2  [counterpart
3   demand
4   executed
5   tbm-ready?
6   paid-by-cash
7   paid-by-tbm
8   demand-via-tbm
9   demand-via-cash
10  time-execution
11  shared-cost-tbm
12  time-cost-tbm
13  total-tbm
14  netted
15 ]
16
17
18 links-own
19 [granted-iou
20  approved-iou
21  approved-iou-original
22  utilized-iou
23  counter-direct-contact
24  type-relationship
25  time-from-last-evaluation
26  both-ends-ready?
27  old-utilized-iou
28  time-from-last-contrary-movement
29  loss
30  agreed-max-iou ;in this model no, but in python yes
31  available-iou ;in this model no, but in python yes
```

```
]


globals[
  savings-of-liquidity-from-use-tbm
  econ-savings-use-tbm
  mean-time-execution
  time-last-check-stranger
  %-executed-via-tbm
  %-friend
  %-stranger
  %-banned
  %-turtles-enjoy-tbm
]


to setup
  deal-with-files-related-to-interaction-with-python
  clear-all
  no-display
  make-individuals
  make-links
  compute-general-statistics
  reset-ticks
end


to make-individuals
  set-default-shape turtles "circle"
  crt num-inds [set tbm-ready? "no"]
  assign-tbm-ready
  layout-circle turtles max-pxcor
end


to make-links
  ask turtles [create-links-to other turtles]
  evaluate-links
  ask n-of ((count links with [type-relationship != "no-tbm"]) *
      %-initial-friend) (links with [type-relationship != "no-
      tbm"])[
    set granted-iou (1 + random max-granted-iou-to-friend-
        initial)
    set type-relationship "friend"]
```

```
end


to assign-tbm-ready
  while [(count turtles with [tbm-ready? = "yes"]) < int (num-inds * %-accept-tbm)][
    ask one-of (turtles with [tbm-ready? = "no"])[
      set tbm-ready? "yes"]]
  while [(count turtles with [tbm-ready? = "yes"]) > int (num-inds * %-accept-tbm)][
    ask one-of (turtles with [tbm-ready? = "yes"])[
      set tbm-ready? "no"
      show "WARNING: it is not allowed a reduction of turtles adherent to TBM"]]
end


to evaluate-links
  ask links [ifelse (([tbm-ready?] of end1 = "yes") and ([tbm-ready?] of end2 = "yes"))
    [set both-ends-ready? "yes"]
    [set both-ends-ready? "no"]]
  ask (links with [(both-ends-ready? = "yes") and (type-relationship != "banned")])[
    ifelse granted-iou = 0
    [set type-relationship "stranger"]
    [set type-relationship "friend"]]
  ask (links with [both-ends-ready? = "no"])[
    set type-relationship "no-tbm"]
end


to go
  initialize-variables
  ask turtles [
    set demand (int random-normal (value-demand) (value-demand / 10))
    find-counterpart
    decide-how-to-pay]
  interact-with-python-script
  ask turtles [pay]
  compute-general-statistics
  make-evaluation-about-friends-and-strangers
  compute-individual-statistics
```

```
  assign-tbm-ready
  evaluate-links
  tick
end


to initialize-variables
  ask links [
    set loss 0]
  ask (links with [both-ends-ready? = "yes"])[
    set approved-iou granted-iou ;not used in this model
    set old-utilized-iou utilized-iou]
  ask turtles [
    set time-execution 0
    set demand 0
    set paid-by-cash 0
    set paid-by-tbm 0
    set time-cost-tbm 0
    set total-tbm 0
    set netted 0
    ifelse (tbm-ready? = "yes")
    [set shared-cost-tbm (fixed-cost-tbm-infrastructure / count turtles with [tbm-ready? = "yes"])]
    [set shared-cost-tbm 0]]
end


to find-counterpart
  ifelse (tbm-ready? = "yes")
  [ifelse (prob-tbm-ready-selective > random-float 1)
    [ifelse ((count other turtles with [tbm-ready? = "yes"]) != 0)
      [set counterpart (one-of other turtles with [tbm-ready? = "yes"])]
      [set counterpart (one-of other turtles with [tbm-ready? = "no"])]]
    [set counterpart (one-of other turtles)]]
  [set counterpart (one-of other turtles)]
  ask link ([who] of self)([who] of counterpart)[set counter-direct-contact (counter-direct-contact + 1)]
end


to decide-how-to-pay
```

```
  ifelse ((tbm-ready? = "yes") and (([tbm-ready?] of counterpart
      )= "yes"))
  [set demand-via-tbm demand
    set demand-via-cash 0]
  [set demand-via-cash demand
    set demand-via-tbm 0]
end


to interact-with-python-script
  let n-nodes-demand-via-tbm (count turtles with [demand-via-tbm
      != 0])
  let n-available-links (count links with [both-ends-ready? = "
      yes"])
  if ((n-nodes-demand-via-tbm > 0) and (n-available-links > 0))[
    export-nodes-edges
    import-nodes-edges]
end


;in import-nodes-edges there is the part of payment by tbm
to pay
  set paid-by-cash (demand-via-cash + (demand-via-tbm - paid-by-
      tbm))
end


to make-evaluation-about-friends-and-strangers
  evaluate-friends
  evaluate-strangers
end


to evaluate-friends
  ask links with [type-relationship = "friend"][
    ifelse ((utilized-iou < old-utilized-iou) or (old-utilized-
        iou = 0))
    [set time-from-last-contrary-movement 0]
    [set time-from-last-contrary-movement (time-from-last-
        contrary-movement + 1)]]
  ask links with [type-relationship = "friend"][
    if (time-from-last-contrary-movement >= limit-time-contrary-
        movement)[
      ifelse (prob-repay > random-float 1)
```

```
187        [set utilized-iou 0
188          if (prob-increment-granted-iou > random-float 1) [set
               granted-iou (granted-iou + premium-pass)]]
189        [set loss (utilized-iou * %-loss)
190          set utilized-iou (int (utilized-iou - loss))
191          ifelse (prob-lifetime-ban > random-float 1)
192          [set type-relationship "banned"
193            set granted-iou 0]
194          [set granted-iou (granted-iou - cost-fail)
195            if granted-iou < 0
196            [set granted-iou 0
197              set type-relationship "stranger"]]]]]
198 end
199
200
201 to evaluate-strangers
202   ifelse (time-last-check-stranger >= t-between-checks)
203   [ask links with [type-relationship = "stranger"][
204       if (([counter-direct-contact] of link ([who] of end2) ([
              who] of end1)) / time-last-check-stranger) > %-required
              -direct-contact [
205         set granted-iou premium-with-trust]]
206   ask links [set counter-direct-contact 0]
207   set time-last-check-stranger 0]
208   [set time-last-check-stranger (time-last-check-stranger + 1)]
209 end
210
211
212 to compute-general-statistics
213   ask turtles with[tbm-ready? = "yes"][
214     let old-situation (sum [old-utilized-iou] of my-out-links -
          sum [old-utilized-iou] of my-in-links)
215     let new-situation (sum [utilized-iou] of my-out-links - sum
          [utilized-iou] of my-in-links)
216     set netted (paid-by-tbm - (new-situation - old-situation))]
217
218   set savings-of-liquidity-from-use-tbm (sum [netted] of turtles
        )
219   ifelse (count links with [both-ends-ready? = "yes"] != 0)
220   [set econ-savings-use-tbm ((savings-of-liquidity-from-use-tbm
        * %-cost-manage-cash) - fixed-cost-tbm-infrastructure)]
221   [set econ-savings-use-tbm 0]
222
223   ifelse (count turtles with [demand-via-tbm != 0] != 0)
```

```
  [set mean-time-execution ((sum [time-execution] of turtles) /
      count turtles with [demand-via-tbm != 0])]
  [set mean-time-execution 0]

  ifelse ((sum [demand-via-tbm] of turtles) != 0)
  [set %-executed-via-tbm (sum [paid-by-tbm] of turtles / sum [
      demand-via-tbm] of turtles)]
  [set %-executed-via-tbm 0]

  ifelse (count links with [both-ends-ready? = "yes"] != 0)
  [set %-friend ((count links with [type-relationship = "friend
      "]) / (count links with [both-ends-ready? = "yes"]))
    set %-banned ((count links with [type-relationship = "banned
        "]) / (count links with [both-ends-ready? = "yes"]))
    set %-stranger ((count links with [type-relationship = "
        stranger"]) / (count links with [both-ends-ready? = "yes
        "]))]
  [set %-friend 0
    set %-banned 0
    set %-stranger 0]
end


to compute-individual-statistics
  ask turtles with [demand-via-tbm != 0][
    set time-cost-tbm (paid-by-cash * %-opportunity-cost-time)]
  ask turtles with [tbm-ready? = "yes"][
    set total-tbm ((%-cost-manage-cash * netted) - (sum [loss]
        of my-in-links) - shared-cost-tbm - time-cost-tbm)]
  ifelse (count turtles with [tbm-ready? = "yes"] > 0)
  [set %-turtles-enjoy-tbm ((count turtles with [tbm-ready? = "
      yes" and total-tbm > 0]) / (count turtles with [tbm-ready?
      = "yes"]))]
  [set %-turtles-enjoy-tbm 0]

end


to export-nodes-edges
  carefully [file-delete "nodes-by-netlogo"][]
  file-open "nodes-by-netlogo"
  ask (turtles with [demand-via-tbm != 0])[
    file-write [who] of self ;source in python script
    file-write [who] of counterpart ;sink in python script
```

```
    file-write demand-via-tbm file-print " "] ;demand in python
        script
  file-flush
  file-close
  carefully [file-delete "edges-by-netlogo"][]
  file-open "edges-by-netlogo"
  ask (links with [both-ends-ready? = "yes"])[
    file-write [who] of end1
    file-write [who] of end2
    file-write granted-iou
    file-write approved-iou
    file-write utilized-iou file-print " "]
  file-flush
  file-close
  file-open "ok-data-by-netlogo"
  file-write "luca"
  file-flush
  file-close
end


to import-nodes-edges
  while [not file-exists? "ok-data-by-python"][]
  carefully [file-delete "edges-by-netlogo"][]
  carefully [file-delete "nodes-by-netlogo"][]
  carefully [file-delete "ok-data-by-python"][]
  file-open "edges-by-python"
  while [not file-at-end?][
    ask link file-read file-read [
      set utilized-iou file-read]]
  file-close
  file-open "nodes-by-python"
  while [not file-at-end?][
    ask turtle file-read [
      set paid-by-tbm file-read
      set time-execution file-read]]
  file-close
end


to deal-with-files-related-to-interaction-with-python
  carefully [file-delete "edges-by-netlogo"][]
  carefully [file-delete "nodes-by-netlogo"][]
  carefully [file-delete "edges-by-python"][]
```

```
  carefully [file-delete "nodes-by-python"][]
  carefully [file-delete "ok-data-by-python"][]
end
```

Appendix B

Python code

B.1 Trust Based Model

```
import networkx as nx #WARNING: substitute with modded maxflow.
    py by luca
import time
import os
import sys


def main_loop():
    while True:
        while (not os.path.exists('ok-data-by-netlogo')) :
            #print 'waiting'
            pass

        os.remove('ok-data-by-netlogo')


        timing = {}

        timing['TOTAL :']=[0,0]
        timing['TOTAL :'][0]=time.time()

        #import data
        timing['import edges:']=[0,0]
        timing['import edges:'][0]=time.time()
        networkbynetlogo = open('edges-by-netlogo', 'rb')
        network = nx.read_edgelist(networkbynetlogo,
            create_using=nx.DiGraph(), nodetype=int, data=(('
```

```
        granted-iou',int),('approved-iou',int),('utilized-iou
        ',int),), edgetype=int)
    networkbynetlogo.close()
    timing['import edges:'][1]=time.time()

    timing['import nodes:']=[0,0]
    timing['import nodes:'][0]=time.time()
    nodesbynetlogo = open('nodes-by-netlogo', 'rb')
    nodes=[]
    for line in nodesbynetlogo:
        nodes.append([int(n) for n in line.strip().split('
            ')])
    nodesbynetlogo.close()
    timing['import nodes:'][1]=time.time()



    #initial check settlement + update last direct contact
        counter
    counter_initial = 0
    for n,nbrs in network.adjacency_iter():
            for nbr,attr in nbrs.items():
                if (network[n][nbr]['utilized-iou'] != 0 and
                    network[nbr][n]['utilized-iou']) != 0:
                    counter_initial +=1


    #for cycle necessary to buy via tbm
    for node in nodes:
        source = node[0]
        sink = node[1]
        demand = node[2]


        timing['LOCAL :']=[0,0]
        timing['LOCAL :'][0]=time.time()


        #compute effective capacity
        timing['effective capacity :']=[0,0]
        timing['effective capacity :'][0]=time.time()
        for n,nbrs in network.adjacency_iter():
            for nbr,attr in nbrs.items():
                network.add_edge(n,nbr, maxagreediou = min(
```

```
                    network[n][nbr]['granted-iou'], network[n][nbr]['approved-iou']))
                network.add_edge(n,nbr, availableiou = max(0, network[n][nbr]['maxagreediou'] - network[n][nbr]['utilized-iou'])) #to deal with previously acceepted credit but after remove concession with debt yet present
                network.add_edge(n,nbr, capacity = network[n][nbr]['availableiou'] + network[nbr][n]['utilized-iou'])
        timing['effective capacity :'][1]=time.time()


        #find first feasible path
        timing['feasible path :']=[0,0]
        timing['feasible path :'][0]=time.time()
        flow_value, flow_dict = nx.ford_fulkerson_with_demand(network,source,sink,demand) #WARNING: ad-hoc function created by luca
        timing['feasible path :'][1]=time.time()

        """
        #find max flow
        timing['max flow :']=[0,0]
        timing['max flow :'][0]=time.time()
        print 'max flow available: ',nx.max_flow(network,source,sink)
        timing['max flow :'][1]=time.time()

        #find minimum cost path
        timing['min cost path :']=[0,0]
        timing['min cost path :'][0]=time.time()
        network.node[source]['demand']=-demand
        network.node[sink]['demand']=demand
        flow_dict = nx.min_cost_flow(network)
        timing['min cost path :'][1]=time.time()
        """

        #verify - update - settlement (saturating all paths capacity available!)
        if flow_value != 0:

            node.append(flow_value)
```

```
96
97                  #update graph directly
98                  timing['update graph :']=[0,0]
99                  timing['update graph :'][0]=time.time()
100                 for sflow in flow_dict:
101                     for eflow in flow_dict[sflow]:
102                         network.edge[sflow][eflow]["capacity"]
                                -= flow_dict[sflow][eflow]
103                         network.edge[sflow][eflow]["availableiou
                                "] -= flow_dict[sflow][eflow]
104                         network.edge[sflow][eflow]["utilized-iou
                                "] += flow_dict[sflow][eflow]
105                 timing['update graph :'][1]=time.time()
106
107                 #settlement
108                 timing['settlement :']=[0,0]
109                 timing['settlement :'][0]=time.time()
110                 for n,nbrs in network.adjacency_iter():
111                     for nbr,attr in nbrs.items():
112                         #if (network[n][nbr]['availableiou'] !=
                                network[n][nbr]['capacity']) and (
                                network[n][nbr]['utilized-iou'] != 0)
                                :
113                         settlement = min(network[n][nbr]['
                                utilized-iou'],network[nbr][n]['
                                utilized-iou'])
114                         network[n][nbr]['utilized-iou'] -=
                                settlement
115                         network[nbr][n]['utilized-iou'] -=
                                settlement
116                         network[n][nbr]['availableiou'] +=
                                settlement
117                         network[nbr][n]['availableiou'] +=
                                settlement
118                 timing['settlement :'][1]=time.time()
119             else:
120                 node.append('0')
121
122
123             timing['LOCAL :'][1]=time.time()
124             #print 'LOCAL: ', timing['LOCAL :'][1] - timing['
                    LOCAL :'][0]
125
126             #the following is used to pass the singular
```

```
execution time to netlogo
        node.append(timing['LOCAL :'][1] - timing['LOCAL :'][0])


        #print statistics timing
        #   for action in timing:
        #       print action, timing[action][1] - timing[action][0]



    #export data
    timing['export data :']=[0,0]
    timing['export data :'][0]=time.time()
    nx.write_edgelist(network, 'edges-by-python', data=['utilized-iou'])

    nodes_by_python = open('nodes-by-python', 'w')
    for node in nodes:
        nodes_by_python.write(str(node[0]))
        nodes_by_python.write(' ')
        nodes_by_python.write(str(node[3]))
        nodes_by_python.write(' ')
        nodes_by_python.write(str(node[4]))
        nodes_by_python.write('\n')
    nodes_by_python.close()

    ok_data_by_python = open('ok-data-by-python', 'w')
    ok_data_by_python.close()
    print '\n' 'success' '\n'
    timing['export data :'][1]=time.time()


    timing['TOTAL :'][1]=time.time()

    #print statistics
    print 'nr nodes: ', network.order()
    print 'nr edges: ', network.size()
    print 'TOTAL: ', timing['TOTAL :'][1] - timing['TOTAL :'][0]
```

```
if __name__ == '__main__':
    try:
        main_loop()
    except KeyboardInterrupt:
        print >> sys.stderr, '\nExiting by user request.\n'
        sys.exit(0)
```

B.2 Modded maxflow.py

In this section we include the lines of code that must be added/modified to the original file provided in NetworkX library in order to be able to run the Trust Based Model.

Substitute the original lines with the following ones.

```
__all__ = ['ford_fulkerson',
           'ford_fulkerson_flow',
           'max_flow',
           'min_cut',
           'ford_fulkerson_with_demand',#luca
           'ford_fulkerson_flow_with_demand', #luca
           'max_flow_with_demand'] #luca
```

Add the following at the end of the original file.

```
def ford_fulkerson_with_demand(G, s, t, demand, capacity='capacity'):#luca
    if G.is_multigraph():
        raise nx.NetworkXError(
                'MultiGraph and MultiDiGraph not supported (yet).')

    if s not in G:
        raise nx.NetworkXError('node %s not in graph' % str(s))
    if t not in G:
        raise nx.NetworkXError('node %s not in graph' % str(t))

    auxiliary, inf_capacity_flows = _create_auxiliary_digraph(G, capacity=capacity)
    flow_value = 0   # Initial feasible flow.

    remaining_demand = demand #luca

```

```
    # As long as there is an (s, t)-path in the auxiliary digraph, find
    # the shortest (with respect to the number of arcs) such path and
    # augment the flow on this path.
    while True and remaining_demand > 0: #luca
        try:
            path_nodes = nx.bidirectional_shortest_path(auxiliary, s, t)
        except nx.NetworkXNoPath:
            break

        # Get the list of edges in the shortest path.
        path_edges = list(zip(path_nodes[:-1], path_nodes[1:]))

        # Find the minimum capacity of an edge in the path.
        try:
            path_capacity = min([auxiliary[u][v][capacity]
                                 for u, v in path_edges
                                 if capacity in auxiliary[u][v]])
        except ValueError:
            # path of infinite capacity implies no max flow
            raise nx.NetworkXUnbounded(
                    "Infinite capacity path, flow unbounded above.")

        if path_capacity > remaining_demand: #luca
            path_capacity = remaining_demand #luca

        remaining_demand -= path_capacity #luca

        flow_value += path_capacity

        # Augment the flow along the path.
        for u, v in path_edges:
            edge_attr = auxiliary[u][v]
            if capacity in edge_attr:
                edge_attr[capacity] -= path_capacity
                if edge_attr[capacity] == 0:
                    auxiliary.remove_edge(u, v)
            else:
                inf_capacity_flows[(u, v)] += path_capacity

            if auxiliary.has_edge(v, u):
```

```
                if capacity in auxiliary[v][u]:
                    auxiliary[v][u][capacity] += path_capacity
            else:
                auxiliary.add_edge(v, u, {capacity:
                    path_capacity})

    flow_dict = _create_flow_dict(G, auxiliary,
        inf_capacity_flows,
                                  capacity=capacity)
    return flow_value, flow_dict



def ford_fulkerson_flow_with_demand(G, s, t, demand, capacity='
    capacity'):#luca
    return ford_fulkerson_with_demand(G, s, t, demand, capacity=
        capacity)[1] #luca


def max_flow_with_demand(G, s, t, demand, capacity='capacity'):
    #luca
    return ford_fulkerson_with_demand(G, s, t, demand, capacity=
        capacity)[0] #luca
```

Bibliography

Aglietta, M. (2001). Money: a matter of credit and trust. Technical report, mimeo., séminaire Crises monétaires dhier à aujourdhui, Paris.

Albert, R. and Barabási, A. (2002). Statistical mechanics of complex networks. *Reviews of modern physics*, 74(1):47.

Aldridge, S., Halpern, D., and Fitzpatrick, S. (2002). *Social Capital: A discussion paper*. Performance and Innovation Unit.

Arthur, W., Durlauf, S., and Lane, D. (1997). *The economy as an evolving complex system II*. Addison-Wesley Reading, MA.

Axelrod, R. and Tesfatsion, L. (2012). On-line guide for newcomers to agent-based modeling in the social sciences. `http://www2.econ.iastate.edu/tesfatsi/abmread.htm#ABMSocSci`. [Online; accessed 25-January-2013].

Bagheot, W. (1873). Lombard street.

Barabási, A. (2012). Thinking in network terms. `http://edge.org/conversation/thinking-in-network-terms`. [Online; accessed 25-January-2013].

Barabási, A. and Albert, R. (1999). Emergence of scaling in random networks. *science*, 286(5439):509–512.

Barabási, A. and Frangos, J. (2002). *Linked: The New Science Of Networks Science Of Networks*. Basic Books.

Barabási, B. and Bonabeau, E. (2003). Scale-free. *Scientific American*.

Baxter, W. (1983). Bank interchange of transactional paper: Legal and economic perspectives. *Journal of Law and Economics*, 26(3):541–588.

Benston, G. and Kaufman, G. (1996). The appropriate role of bank regulation. *The Economic Journal*, 106(436):688–697.

Berggren, N. and Jordahl, H. (2006). Free to trust: Economic freedom and social capital. *Kyklos*, 59(2):141–169.

Beugelsdijk, S. (2006). A note on the theory and measurement of trust in explaining differences in economic growth. *Cambridge Journal of Economics*, 30(3):371–387.

Bolt, W. (2012). Retail payment systems: Competition, innovation, and implications.

Bolt, W. and Humphrey, D. (2007). Payment network scale economies, sepa, and cash replacement. Technical report, Federal Reserve Bank of Philadelphia.

Borestam, A. and Schmiedel, H. (2011). Interchange fees in card payments. *ECB Occasional Paper*, (131).

Bourdieu, P. and Wacquant, L. (1992). *An invitation to reflexive sociology.* University of Chicago Press.

Breiter, H., Aharon, I., Kahneman, D., Dale, A., and Shizgal, P. (2001). Functional imaging of neural responses to expectancy and experience of monetary gains and losses. *Neuron*, 30(2):619–639.

Bruni, L. and Sugden, R. (2000). Moral canals: trust and social capital in the work of hume, smith and genovesi. *Economics and Philosophy*, 16(1):21–45.

Calomiris, C. (2007). Bank failures in theory and history: the great depression and other" contagious" events. Technical report, National Bureau of Economic Research.

Carley, K. (2003). Dynamic network analysis. In *Dynamic social network modeling and analysis: Workshop summary and papers*, pages 133–145. Comittee on Human Factors, National Research Council.

Carlsson, A., Lindqvist, M., and Magnusson, T. (1957). 3, 4-dihydroxyphenylalanine and 5-hydroxytryptophan as reserpine antagonists.

Chick, V. (1993). The evolution of the banking system and the theory of monetary policy.

Claridge, T. (2004). Types of social capital. `http://www.socialcapitalresearch.com/literature/theory/types.html`. [Online; accessed 15-December-2012].

Coleman, J. (1994). *Foundations of social theory*. Belknap Press.

Committee on Network Science for Future Army Applications, N. R. C. (2005). *Network Science*. The National Academies Press.

CPSS (2003). *The role of central bank money in payment systems*. CPSS publications. Committee on Payment and Settlement Systems - Bank for International Settlements.

CPSS (2011). *Red Book vol. 1*. Payment, Clearing and Settlement Systems in the CPSS Countries. Committee on Payment and Settlement Systems - Bank for International Settlements.

CPSS (2012a). *Innovations in retail payments*. Report of the Working Group on Innovations in Retail Payments. Committee on Payment and Settlement Systems - Bank for International Settlements.

CPSS (2012b). *Red Book vol. 2*. Payment, Clearing and Settlement Systems in the CPSS Countries. Committee on Payment and Settlement Systems - Bank for International Settlements.

Davidson, P. (1991). Is probability theory relevant for uncertainty? a post keynesian perspective. *The Journal of Economic Perspectives*, pages 129–143.

Dow, S. (1996). Why the banking system should be regulated. *The Economic Journal*, 106(436):698–707.

Dow, S., Ghosh, D., and Ruziev, K. (2008). A stages approach to banking development in transition economies. *Journal of Post Keynesian Economics*, 31(1):3–33.

ECB (2012a). The ecb's definition of euro area monetary aggregates. `http://www.ecb.int/stats/money/aggregates/aggr/html/hist.en.html`. [Online; accessed 13-December-2012].

ECB (2012b). *Virtual currency schemes*. European Central Bank.

Economist, T. (2010). Agents of change. `http://www.economist.com/node/16636121`. [Online; accessed 23-January-2013].

Economist, T. (2013). Platinomics. `http://www.economist.com/blogs/freeexchange/2013/01/economics-platinum-coin-option`. [Online; accessed 23-January-2013].

Elinder, M., Berggren, N., and Jordahl, H. (2007). Trust and growth: a shaky relationship.

Epstein, J. (2008). Why model? *Journal of Artificial Societies and Social Simulation*, 11(4):12.

Erdös, P. and Rényi, A. (1959). On random graphs i. *Publ. Math. Debrecen*, 6:290–297.

Euler, L. (1741). Solutio problematis ad geometriam situs pertinentis. *Commentarii academiae scientiarum Petropolitanae*, 8:128–140.

Ferguson, N. (2008). *The ascent of money: A financial history of the world*. Penguin Press HC.

Field, J. (2003). *Social Capital*. Key Ideas. Taylor & Francis.

Frankel, A. (1998). Monopoly and competition in the supply and exchange of money. *Antitrust Law Journal*, pages 313–361.

French, D. (2006). The dutch monetary environment during tulipmania. *Quarterly Journal of Austrian Economics*, 9(1):3–14.

Fugger, R. (2004). Money as ious in social trust networks & a proposal for a decentralized currency network protocol. *Hypertext document. Available electronically at http://ripple. sourceforge. net*.

Fukuyama, F. (1995). Social capital and the global economy. *Foreign Aff.*, 74:89.

Fukuyama, F. (2001). Social capital, civil society and development. *Third world quarterly*, 22(1):7–20.

Gans, J. and King, S. (2003). A theoretical analysis of credit card reform in australia. *Economic Record*, 79(247):462–472.

Garlaschelli, D. and Loffredo, M. (2004). Patterns of link reciprocity in directed networks. *Physical Review Letters*, 93(26):268701.

Gastner, T. (2011). Networks: Theory and applications. `http://www2.imperial.ac.uk/~mgastner/teaching/networks_autumn11/lecture_notes.pdf`. [lecture notes].

Ghosh, A., Mahdian, M., Reeves, D., Pennock, D., and Fugger, R. (2007). Mechanism design on trust networks. *Internet and Network Economics*, pages 257–268.

Gilbert, N. and Terna, P. (2000). How to build and use agent-based models in social science. *Mind & Society*, 1(1):57–72.

Grierson, P. (1977). *The origins of money.* Athlone Press London.

Hagberg, A. and D., C. (2010). Hacking social networks using the python programming language (module ii - why do sna in networkx). `http://github.com/drewconway/NetworkX_Intro_Materials/blob/master/2-Why_Do_SNA_with_NX/module_II.pdf`. [Online; accessed 25-January-2013].

Hagberg, A. A., Schult, D. A., and Swart, P. J. (2008). Exploring network structure, dynamics, and function using networkx. In Varoquaux, G., Vaught, T., and Millman, J., editors, *Proceedings of the 7th Python in Science Conference*, pages 11 – 15, Pasadena, CA USA.

Huerta de Soto, J. (2009). *Money, bank credit, and economic cycles.* Ludwig von Mises Institute.

Huizinga, H. and Laeven, L. (2010). Bank valuation and regulatory forbearance during a financial crisis. *European Banking Center Discussion Paper*, (2009-17).

Hunt, R. (2003). An introduction to the economics of payment card networks. *Review of Network Economics*, 2(2).

Ingham, G. (2000). babylonian madness: on the historical and sociological origins of money. *What is money*, 1:16–41.

Innes, A. (1913). What is money. *Banking LJ*, 30:377.

Jevons, W. (1885). *Money and the mechanism of exchange*. Internat. sci. series.

Kahneman, D. and Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, pages 263–291.

Kapp, B., Frysinger, R., Gallagher, M., and Haselton, J. (1979). Amygdala central nucleus lesions: effect on heart rate conditioning in the rabbit. *Physiology & Behavior*, 23(6):1109–1117.

Katz, M. (2001). *Reform of Credit Card Schemes in Australia II*. Reserve Bank of Australia: Sydney.

Keynes, J. (1930). *A Treatise on Money: Volume 1: The Pure Theory of Money*. Macmillan & Company.

Keynes, J. (1936). The general theory of interest, employment and money.

Klüver, H. and Bucy, P. (1937). " psychic blindness" and other symptoms following bilateral temporal lobectomy in rhesus monkeys. *American Journal of Physiology*.

Knack, S. and Keefer, P. (1997). Does social capital have an economic payoff? a cross-country investigation. *The Quarterly journal of economics*, 112(4):1251–1288.

Knight, F. (1921). Risk, uncertainty and profit. *New York: Hart, Schaffner and Marx*.

Kokkola, T. and Bank, E. C. (2010). *The Payment System: Payments, Securities and Derivatives, and the Role of the Eurosystem*. European Central Bank.

Krugman, P. (1996). The gold bug variations. `http://www.slate.com/articles/business/the_dismal_science/1996/11/the_gold_bug_variations.single.html`. [Online; accessed 18-December-2012].

Kuhnen, C. and Knutson, B. (2005). The neural basis of financial risk taking. *Neuron*, 47(5):763–770.

Lapavitsas, C. (2003). Money as a'universal equivalent'and its origin in commodity exchange.

Lo, A. (2011). Fear, greed, and financial crises: A cognitive neurosciences perspective. *Available at SSRN 1943325*.

Luhmann, N. (2000). Familiarity, confidence, trust: Problems and alternatives. *Trust: Making and breaking cooperative relations*, 6:94–107.

May, R., Levin, S., and Sugihara, G. (2008). Complex systems: ecology for bankers. *Nature*, 451(7181):893–895.

McAndrews, J. and Wang, Z. (2008). The economics of two-sided payment card markets: pricing, adoption and usage. *Federal Reserve Bank of Kansas City Working Paper*, (08-12).

Menger, C. (1892). On the origins of money. *History of Economic Thought Articles*, 2:239–255.

Milgram, S. (1967). The small world problem. *Psychology today*, 2(1):60–67.

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. *Consulted*, 1:2012.

Nooteboom, B. (1996). Trust, opportunism and governance: A process and control model. *Organization studies*, 17(6):985–1010.

Olds, J. and Milner, P. (1954). Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. *Journal of Comparative and Physiological Psychology; Journal of Comparative and Physiological Psychology*, 47(6):419.

Ostrom, T. (1988). Computer simulation: The third symbol system. *Journal of Experimental Social Psychology*, 24(5):381–392.

Peltzman, S. (1975). The effects of automobile safety regulation. *The Journal of Political Economy*, pages 677–725.

Pierce, A. (2008). The queen asks why no one saw the credit crunch coming. `http://www.telegraph.co.uk/news/uknews/theroyalfamily/3386353/`

The-Queen-asks-why-no-one-saw-the-credit-crunch-coming.html. [Online; accessed 15-December-2012].

Putnam, R. (2000). Bowling alone: Civic disengagement in america. *New York*.

Putnam, R., Leonardi, R., and Nanetti, R. (1993). Making democracy work princeton.

Ripple (2013). Ripple advanced. https://ripple.com/working-with-ripple/. [Online; accessed 14-February-2013].

Rochet, J. and Tirole, J. (2002). Cooperation among competitors: Some economics of payment card associations. *Rand Journal of economics*, pages 549–570.

Rochet, J. and Tirole, J. (2003). Platform competition in two-sided markets. *Journal of the European Economic Association*, 1(4):990–1029.

Rochet, J. and Tirole, J. (2011). Must-take cards: Merchant discounts and avoided costs. *Journal of the European Economic Association*, 9(3):462–495.

Rysman, M. and Wright, J. (2012). The economics of payment cards.

Sidel, R. and A., J. (2012). Card giants to pay 6 billion. http://online.wsj.com/article/SB10001424052702303919504577525284273006706.html. [Online; accessed 15-January-2013].

Simmel, G. (1978). The philosophy of money, translated by tom bottomore and david frisby. *London, Henley and Boston*.

Simon, H. (1955). On a class of skew distribution functions. *Biometrika*, pages 425–440.

Smith, A. (1863). *An Inquiry into the Nature and Causes of the Wealth of Nations*. A. and C. Black.

Sobel, R. and Nesbit, T. (2007). Automobile safety regulation and the incentive to drive recklessly: Evidence from nascar. *Southern Economic Journal*, pages 71–84.

Terna, P., Boero, R., Morini, M., and Sonnessa, M. (2006). *Modelli per la complessità: la simulazione ad agenti in economia*. Il mulino.

Vicsek, T. (2002). The bigger picture. *Nature*, 418(11):131.

VISA (2013). Merchant surcharging. http://usa.visa.com/merchants/operations/surcharging.html?ep=v_sym_merchantsurcharging. [Online; accessed 15-January-2013].

Watts, D. and Strogatz, S. (1998). Collective dynamics of small-worldnetworks. *Nature*, 393(6684):440–442.

Wikipedia (2012a). Money — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Money&oldid=513965717. [Online; accessed 9-November-2012].

Wikipedia (2012b). Network science — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Network_science&oldid=530112547. [Online; accessed 28-January-2013].

Wikipedia (2012c). Payment card — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Payment_card&oldid=529562488. [Online; accessed 12-January-2013].

Wikipedia (2012d). T2s — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=T2S&oldid=503768413. [Online; accessed 1-January-2013].

Wikipedia (2013a). Agent-based model — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Agent-based_model&oldid=533525122. [Online; accessed 24-January-2013].

Wikipedia (2013b). Double-spending — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Double-spending&oldid=537750996. [Online; accessed 14-February-2013].

Wikipedia (2013c). Erdös-rényi model — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Erd%C5%91s%E2%80%93R%C3%A9nyi_model&oldid=534236745. [Online; accessed 29-January-2013].

Wikipedia (2013d). Netlogo — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=NetLogo&oldid=532075659. [Online; accessed 23-January-2013].

Wikipedia (2013e). Python (programming language) — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Python_(programming_language)&oldid=534367328. [Online; accessed 24-January-2013].

Wikipedia (2013f). Ripple monetary system — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Ripple_monetary_system&oldid=534194874. [Online; accessed 14-February-2013].

Wikipedia (2013g). Seven bridges of konigsberg — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Seven_Bridges_of_K%C3%B6nigsberg&oldid=534443406. [Online; accessed 25-January-2013].

Wikipedia (2013h). Society for worldwide interbank financial telecommunication — wikipedia, the free encyclopedia. http://en.wikipedia.org/w/index.php?title=Society_for_Worldwide_Interbank_Financial_Telecommunication&oldid=530808767. [Online; accessed 1-January-2013].

Wilensky, U. (1999). Netlogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

Wray, L. (2003). *Understanding modern money.* Edward Elgar.

Zak, P. and Knack, S. (2001). Trust and growth. *The economic journal*, 111(470):295–321.

Zywicki, T. (2013). The economics and regulation of network branded prepaid cards. *George Mason Law & Economics Research Paper*, (13-06).