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Brain Drain: an Agent-Based Simulation

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If our ignorance is infinite,
the only possible course of action
is to muddle through as best we can.
Schwartz (2008)

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Preface

By speaking with any Italian young graduate it is impossible not to feel his/her discomfort in thinking to the working perspectives within the native country. Italian labor market is experiencing a catastrophic situation with unemployment levels reaching towering peaks and people's optimism sinking steeply. Migration flows, also, appear to be progressively more composed by intellectuals and researchers and the common feeling is that the coming future will be characterized by a hollow of economic, intellectual and social progress as we are losing some of our top minds. On the personal side, finally, it is sad to realize that the decision of moving abroad might be canalized more by the absence of any other good chance rather than curiosity or the desire for personal enriching experiences abroad, which strongly reduces the possibility of people returning home in the future.

My personal feeling is that the just mentioned issue is real. Italy is a strong source of high-skilled human capital to foreign countries, but which rank does it get in the world chart for brain drain source countries? Is it a relative high source or an absolute one?

The sensation is that Italy is not sole and probably not even the worst-case scenario of high-skilled migration flows. More generally, disadvantaged countries often are dried out of their top human capital. Also, these exploitation is often justified by emphasizing the positive effects of migration, such as influence on the human capital investment decision, remittances, network connections and social hubs, etc. What if, instead, extortionate exploitation of human capital of already disadvantaged countries sentences them to an inescapable backwardness and dependence to the most advanced ones?

These considerations baffled me and pushed me to investigate the issue closely. What are the effects of high-skilled migration? How do people decide whether to migrate or not? If it does, when does this phenomenon start to be problematic for the overall economy of a country and for the single deciding agent? How does migration influence the relative development of a country to another?

Of course it is hard to believe that a single research project can answer all these questions profoundly, still it might be a starting point for future implementations and more detailed analysis.

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Chapter 2

Introduction

The purpose of my thesis is constructing a reasoning tool of support for those interested in understanding the phenomenon of brain drain. The dissertation, indeed, is focused on the investigation of high-skilled migration. It tries to analyze its components and studies the effects of its outcomes.

Many analysis have been performed with reference to this phenomenon since the 1960s. This research study, then, is framed into a context of numerous surveys and academic articles, such as the works of Grubel and Scott (1966), Bhagwati and Hamada (1974) and Docquier and Rapoport (2012), etc. Through the use of agent-based simulation, this studying project proposes a different way of approaching the investigated issue. Brain drain presumes the achievement of high educational degrees, so the investment in human capital decision will play a core role. The influence of social network is taken into account, differently from much of the previous literature, as our concern is that it matters in the individuals' decisions. Economic output, unemployment, migration flows and labor market matching are the other main variables investigated. Most of the processes work in circular waves influencing and being influenced at the same time. Anderson *et al.* (1972) states that *the behavior of complex aggregates of elementary parts is not to be understood as the extrapolation of the properties of a few particles. At each level of complexity new properties appear.* The idea of this research work is capturing the emergent behaviors at each level of complexity and elaborate a deeper perception of the factors governing brain drain.

The thesis is structured in five main chapters.

Chapter 3 proposes a description of the methodology of agent-based simulations in general, providing a characterization of their potential in the study of socio-economic phenomena. It evidences the role of agent-based simulations in dealing with non-linear dynamics. Successively it justifies the use of this tool and responds to the main critics addressed to this methodology. This chapter also introduces the issue of social network theory referring especially to the contributions made by Carvalho (2014), Moreno (1934), Granovetter (1983) etc. and explains its main implications. Also it tackles with more practical issues, such as providing examples of agent-based models so as to prove their effectiveness in dealing with complex situations. Finally this chapter provides some

guidelines for correctly designing an effective agent-based simulation.

Chapter 4 focuses on summing up the existing theories with reference to the high-skilled migration matter. The chapter first deals with the issue of basic research as a catalyst of the economic growth. It then faces the issue of human capital investment, with reference both to the mainstream utilitarian view, such as Becker (1964) and Mincer (1958), and to some divergent vision, like that of Buchanan (1964) or Sen (1999). Thereafter the chapter analyzes the concept of mobility capital, with special reference to the work of Orru (2014). Consecutively it focuses more strictly on the brain drain analysis. The main contributions are structured in three main waves of analysis and the chapter reports the most important achievements and beliefs of each of the mentioned waves of investigation. Finally, the chapter takes into consideration geography models, with special reference to the work of Krugman (1991), as a different tool for looking at the effects of high-skilled migration flows. Last but not least, mainly through the work of Biondo *et al.* (2013) on returning migration flows, the review introduces some already existing examples of agent-based models applied to the question of brain drain.

Chapter 5 aims at taking a stock of the real world evidences of brain drain. The first part of the chapter is mainly concerned with the investment in human capital issue. It considers the actual situation of the educational achievements in the OECD and some other countries. Lately, the dynamics leading to these outcomes are tried to be understood. In particular the chapter analyzes the financing of tertiary levels education, which plays a core role in the individuals' decision. It also takes into account the benefits of tertiary education, as the advantages it provides compared to those who did not take part to it. Extra-earnings, the facilitation in finding a working place are some of the benefits analyzed in the chapter. To conclude the overview of the actual brain drain issue, the chapter presents some aggregate data on the migration flows in the last years, evidencing the main origin and destination countries, showing the trends of migrations and the different compositions of migration flows over time.

Chapter 6 provides a description of the simulation model built within this research work. The description presents the evolution of the simulation program. It starts from showing a mistaken code and the corrections that have been applied to it in order to produce a satisfying simulation. It describes the building steps, which permitted the passage from extremely simple simulations to the complete code. Finally it analyzes deeply and in detail the conclusive version of the simulation model. The code designed mostly deals with four characterizations: the social network construction and analysis, the human capital investment decision, the job search and spawning of migration flows and finally the functioning of the economics.

Lastly, chapter 7 wraps up the resulting outcomes of the experiments performed on the simulation model. Five categories of experiments are mainly performed. The first four are intended to achieve the resulting outcomes of the single variables on different processes. We first test the influence of different variables on the investment in human capital decisions. Later we perform experiments on the social network structure, the migration flows and the economic output. Finally, after having achieved a deep understanding of the functioning of the model and the variables on specific processes, we select

particular configurations in order to generate more specifically brain drain phenomena. Each of the clusters of experiments delivers interesting insights in terms of understanding the dynamics governing and the outcomes emerging from high-skilled migration flows.

Chapter 3

Introduction to Agent-Based Models

Agent-based models are spreading around many fields of scientific research, but they are still quite recent and not completely accepted by the scientific community as a whole. It is therefore necessary to spend some time in describing their functioning, justifications and objectives. This chapter is structured as follows. First it provides an explanation of the concept of complexity and non-linear dynamics and it focuses on the reasons behind the use of agent-based simulation with special focus on the issue of social networks. Successively the paragraph moves to analyzing some application of agent-based models and finally it describes a potential outline for building an effective agent-based simulation.

3.1 Non-linear dynamics and the role of Agent-Based Models

> Compactly, in agent-based computational models a population of data structures representing individual agents is instantiated and permitted to interact. One then looks for systematic regularities, often at the macro-level, to emerge, that is, arise from the local interactions of the agents. *Axtell (2006)*

The physical world is mainly characterized by linear or approximately linear systems, whose properties can be studied through an aggregation of the parts and predicted through well-defined equations. Societies, and in particular human societies, seem quite different. They are characterized by *path dependence*, that is the current situation being strictly dependent on the decisions that have been taken in any period before (Gilbert, 2004). Societies, then, can not be studied by partitioning them and studying any parcel separately, they are *complex systems*. Human societies, indeed, are full of non-linear relations and the society as a whole *emerges* from these non-linear interactions among individuals. In physical sciences as well it is possible to find emergent features. The difference, though, lies in the fact that human households can recognize the emergence of a particular aspect and respond to it. Moreover social systems are dynamic and constantly evolving and, differently from the physical systems, which are mainly composed

by similar units, human beings largely differ in their capabilities, desires and behaviors. Agent based models (ABM) are a powerful instrument to perform analysis of complex phenomena. Since the 1990s and even earlier, social simulation mechanisms have been implemented in order to artificially re-create societies and examine the emergent dynamics within them. ABM might be used for normative studies as well, that is to investigate the outcome of a particular action on the environment. They are computational approaches that study individuals' behavior from the complex adaptive system perspective (Janssen, 2005). The power of this strategy consists in the possibility of testing the attributes of the single agents and the hypothesis about the behavioral relationships and investigate how the micro-level decisions affect the macro-behaviors.

As social sciences, and more in general complex phenomena, can not be studied as a simple aggregations of the behavior of particles, they imply the need for adequate instruments. In Anderson *et al.* (1972), the authors state that although the reductionist hypothesis has been widely accepted by most of the scientific community as an instrument to study the reality, it encompasses a huge shortcoming: it does not imply a constructivist one. They state indeed that the constructivist hypothesis is seriously harmed by the contrasting effects of complexity and scale. Rosenblueth and Wiener (1945) underline the important role of *material models* as a powerful tool through which researchers may study the issue under questioning, by creating an artificial reproduction with similar features and similar properties and perform experiments on it. This definition can be addressed as a forefather of the contemporary ABM. It is an ancestor in the sense that, following Terna (2013) it needs to be completed with *randomness, heterogeneity, and continuous learning in repeated trial and error processes.* Moreover, the ABM approach overcomes the neoclassical idea of rational agents, which is given by mathematical feasibility of results more than veracity of the assumption, as behavioral rules are often extracted from empirical data. In this vision the process has to be reversed from what has been mostly used in the study of neoclassical economics. Holt *et al.* (2011) suggest that it is necessary to start from the data and then build up the model, as the idea that economics can be explained through a set of solvable equations does not provide a truthful analysis of the economic phenomenon.

To sum up, then, it is worth to mention Klabunde (2014). ABM models study societies as a complex system of heterogeneous, interacting and dynamic agents with bounded rationality. Unlike most of the mainstream macroeconomic theory, they usually encompass the issues of asymmetric information and agency problems. They may entail spacial and time-concerned aspects and different levels of aggregations of the households. ABM allow for network analysis, which fulfills an extraordinary important role in contemporary economics. Finally, ABM are sensational for performing experiments and test different kinds of actions. These features make them entirely compliant with the task of controlling the outcomes of specific interventions. On the other hand, ABM need to be carefully designed. Indeed, overly complicated models risk to be unreadable and, therefore, inefficient in their descriptive or normative goals. Moreover coding entails risks of bugs or errors that may harm the truthfulness of the outcomes. To conclude, a quote from Jean-Claude Trichet, then President of the European Central Bank, from its

speech of November 2010[1]:

> The atomistic, optimizing agents underlying existing models do not capture behavior during a crisis period. We need to deal better with heterogeneity across agents and the interaction among those heterogeneous agents. We need to entertain alternative motivations for economic choices. Behavioral economics draws on psychology to explain decisions made in crisis circumstances. Agent-based modeling dispenses with the optimization assumption and allows for more complex interactions between agents. Such approaches are worthy of our attention.

3.2 Justification for Agent-Based Modeling

The ratio behind ABM has been widely questioned by comparing it to other sources of computational approaches. Janssen (2005) states that there are different kinds of problems, in many cases equation-based models are more than enough to investigate the issue, while if the topic concerns coordination or strategic interaction, ABM might be a more complete and fitting instrument. Game theory has been widely used with this concern, but it assumes high cognitive capacity for agents. Moreover it is rigid, or fully random, in determining the rules of the game and finally it is mostly confined with a limited number of players. ABM overcomes these threshold by allowing for bounded rationality, evolving game-rules and complex social structures. Gilbert (2004) asserts that computer simulations can be used to investigate social phenomena. Mostly, theories are expressed through verbal argumentation and mathematical formalization.The former allows for complete flexibility, but it does not entail the possibility of performing experiments and tests. The latter, instead, overcomes this shortcoming, but at cost of increased rigidity. Computer programming is a third way to illustrate a theory, which combines the flexibility of verbal argumentation and the computational ability of the computer itself. According to Terna (2013) the computer program is indeed a form of mathematics and it allows the generation of time series to be studied with econometric tools. According to Axelrod and Tesfatsion (2009)

> simulation, like deduction, starts with a set of explicit assumptions. But unlike deduction, simulation does not prove theorems with generality. Instead, simulation generates data suitable for analysis by induction. Nevertheless, unlike typical induction, the simulated data come from a rigorously specified set of assumptions regarding an actual or proposed system of interest rather than direct measurements of the real world.

ABM has many positive sides. For instance it allows to perform experiments and inquire the outcome of changes in the involved variables. Moreover it permits the analysis

[1]Speech available at http://www.ecb.europa.eu/press/key/date/2010/html/sp101118.en.html; accessed August 5th, 2014.

of how do micro-phenomena enlarge to socially spread behaviors. Finally it grants to carefully go through the assumptions made, in order to code a realistic simulation and make it open for other researchers to test. Terna (2013) indicates three main uses for computer simulation. The first is the study of completely solvable agents, such as, for instance, the Monte Carlo simulation. The third is the analysis of completely intractable agents, where ABM is a substitute for very hard, if not impossible, mathematical study, and the second being a middle way between the extremes. ABM allows also for multilayer studies, where agents are contemporary themselves and parts of bigger entities.

On the negative side agent-based models are difficult to understand without carefully studying the code. They require an accurate control to avoid coding errors and bugs. Differently from traditional models, anyway, anomalies in ABM are not necessarily the symptom of a mistake, they can be the soul of an interesting discovery. Finally, ABM might be very difficult to be correctly specified, as they account for behavioral rules, which are not yet completely explored. In addition, the vast number of variables taken into account, where for many it is very hard to find available data, can harm the explanatory power or the veracity of the model designed. It is difficult, indeed, to find fitting data available for ABM purposes. Many qualitative data are collected with the aim of gaining a panoramic perspective on the emergence of institutions and societies among the population. Clearly these data are very unrefined. Quantitative data are more precise, but it is very rare that they take into account the presence of networks and interactions among agents, therefore they lack the analysis of these important aspects constituting complex systems. Moreover it is frequent for data to be collected at a moment in time, without focusing on the evolution of the process investigated. The use of panel-data is starting to overcome this issue, although they are still not very widespread and they are limited in scope. An alternative way of proceeding while working with ABM is deductive reasoning. It is possible to first code the program, simulating the process under investigation and then test it with real data to check its validity. This procedure may surpass the shortage of available data and provide powerful insights in the investigated phenomena. In this case, the programmer needs to be very careful. The first issue is that most models and theories on which programs are based are stochastic. This means that they depend on some random factor. The intuition then is finding a common trend, independent of the stochastic event. The outcomes of many performances and tests on the model will not be identical because of the stochastic element, the idea, then, is to find the common tendencies and regularities which will constitute the result of the simulation. The second weak point is that although the program generated might lead to the outcome that is effectively reflected by real data, this does not imply that the generated model is the way in which the result is obtained in reality. The fitting condition of the real data to the outcome achieved by the simulation is a necessary but not sufficient condition for the model to be valid.

In Waldherr and Wijermans (2013) the authors deal with the common negative answers and the criticisms to ABM. A first issue is that due to the resistance towards ABM simulations often researchers do not find the desired audience and feedbacks. Actually, to better explain this point, it is not the lack of feedbacks which stresses social

simulations modelers, but the authors state that feedbacks may be divided into two categories. *Constructive criticisms* are those which are addressed to emphasize critical or non-clear aspects of the model, that are then directed to improve the model itself. *Rejective criticisms* instead are hostile responses to the social simulation approach itself, with no regards to the specific model under investigation. When mentioning the lack of feedbacks towards social simulations, the authors are referring to the shortage of feedbacks of the first type. The purpose of this paper is identifying the common criticisms to social simulations and showing how do they turn into rejections and moreover helping social simulation modelers dealing with these critics. The authors inductively extracted ten main categories of common criticisms towards social simulation models. The classification comes from both a review of the literature of many social modelers such as Axelrod (2006), Axtell (2000), Epstein (2008), Macy and Willer (2002) and Miller and Page (2002) and through a simple survey they have submitted to 30 social simulation modelers of many different fields. Most criticisms deal with the complexity of the model. Ironically the same exact model can be perceived to be both too complex or too simplistic. Also, many criticisms may arise from the focus chosen by the researcher. Disapproval may come from the choice of the back-standing theory; often social simulation models are said not to be theory based, although theory is clearly present in the equations used in the programming code. This criticism, then, can be lead back to using the wrong theory, although it is not clear which one is the correct theoretical approach as it is common to many phenomena to be explained by many competing theories. Simulation models are also often described as non-realistic as not all of them and not every part of each of them can be confronted with real data. Although this criticism is reserved here to ABM only, it is to question whether it is not in fact an intrinsic characteristic of models in general. Even traditional mathematical models for studying, for instance, economic phenomena do not often have a realistic counterpart, but still they are used as instruments for analyzing and predicting the reality. Further criticisms arise from the choice of values and parameters, which are sometimes said to be chosen arbitrarily by the modeler. Modelers actually try to base their assumptions on real data, but there is always some part on which they do not have enough information for their modeling decision. This is actually a weak point, but as it is for many other modeling methods. More, in the field of simulation the issue can be often overcome by performing tests on the unknown variables and see the effects of different levels. Another critique that is often addressed to social simulation models is that of producing the desired results, as the modeler is designing the code, so the model can be designed to achieve whatever outcome the researcher wants. The outcomes, finally, are trivial and non-surprising. This last consideration does entail some truth, as the results are kind of lying in the programming code. On the other hand, what may be surprising are the dynamics that lead to the non-surprising result, as they may appear to be counterintuitive with respect to the common perception. Furthermore disapproval comes from the intricacy of the model, as the large number of variables involved often makes it hard to read the results or replicate the simulation. One of the strongest critics mentioned in the research paper is that social simulation is not a valid scientific approach for investigating any discipline.

In particular they are not enough mathematics-based for the study of economics, nor enough-empirically based for the study of sociology or biology. They are even deemed to be useless as they do not, according to the critics, entail any improvement when compared to mainstream methods. We have already shown the improvements that ABM entails in the analysis of socio-economic and complex phenomena in general. So, actually, this criticism comes from a sort of territoriality in the field of the study of the reviewer, who has a precast idea of how to do science in a particular field and is not willing to accept anything that slightly moves from the pre-built belief.

To sum up, rejective criticisms arise for two main reasons, lack of understanding or academic territorialism. In the first case the phenomenon may arise from different causes. It could be a different background, non particularly familiar with agent based modeling, or the mismatching between the purpose of the model and the expectations of the reviewer to originate misunderstandings and incomprehensions. Also it is large the resistance in comparing the human behavior to that of a simpler being, such as the agents protagonists of social simulations. When lack of understanding by the reviewers is the main reason of rejective criticisms, it is in the interest of the social simulations modelers trying to overcome this issue. The strategy is putting in the reviewer's shoes, understanding what is not clear to the listener and trying to explain it better. More, by doing this it is important to use the instruments, the lexicon and the visuals with which the audience is familiar with. Finally being more transparent and clear when describing the methods and the purposes of a specific simulation it is possible to move from rejective to constructive feedbacks. In the second case the issue is related to the protection of the reviewer of her/his own methods and the debate strongly depends on the willingness of the other party to be responsive or completely hostile. The focus of the discussion, in this case should not rely on arguing which one is the best method, but which one is the method that in any specific situation answers better to the problem under investigation. As we have mentioned in the first paragraph, many so-called weak aspects of the social simulations are common to more traditional and mainstream investigation methods as well. Relying on questionable assumptions happens very often, see the large amount of statistical models in which relationships between variables are assumed to be linear. The only difference between the two is that the mainstream methods have had time to eradicate themselves and become commonly accepted.

3.3 Social network theory

Social networks and agents' interconnections play a crucial role in any socio-economic process. Also, they are one of the main sources of emergence of non-linear dynamics and complex behaviors within the socio-economic environment of a community. In Carvalho (2014), for instance, the author investigates the role of interconnections within economic agents and the propagation of micro shocks to the macro environment. What he asserts is that being the current economic system in any field so inter-related with many other productive agents, competitors, customers, financial services and so on, it is reasonable, and it effectively happens, that micro local or sectorial shocks extend to wider and

varied sectors, provoking macro phenomena. In this consideration is entailed a profound reflection on the role of networks of any kind, social, personal, economic, etc., on the evolution of socio-economic processes. Many other research papers analyze the role of social networks in socio-economic phenomena. The idea of Moreno (1934) is that individuals may be influenced by social interactions although they do not realize it. By the use of sociometry, Moreno made it possible to make an abstract social structure more tangible. Borgatti *et al.* (2009) underlines that the issue of social interactions is a core element of individuals' actions. *Strong social ties* as a driver for socio-economic cooperative behavior have been shown by Karlan *et al.* (2009) and Dhillon *et al.* (2013). In Munshi (2014) the author sketches out how should traditional economic growth models be augmented with the study of network communities and their influence on the economic performance. On another front, the MIT has been applying matrix algebra and graph theory in order to discover the underlying order of social interactions. It has been shown that although in more disperse structures of society the minimum answering time to a problem is the shortest, structures with higher degree of centralization perform better. Indeed in disperse structures individuals should solve highly complex problems, while human societies prefer to communicate with a central individual, who then decides what the best answer is.

Many studies have then been launched, for instance it has been attempted to explain the role of cities and that of groups on human interactions. The main achievements of this field of studying have been the re-visitation of society not as a stable and fixed entity, but as a dynamic system made of inter-relations between individuals. Moreover the algebraic analysis of kinships allowed for the idea of a mathematical order behind the human chaos (Borgatti *et al.*, 2009). Finally, social network theory permitted many social outcomes to be depending on the interactions among agents. Other ideas have arisen, such that of building simplified models to represent human relations, starting from the fact that similar individuals face similar problems and provide similar responses. Besides, the so called SWT (Strength of Weak Ties) theory (Granovetter, 1983), which states that mere acquaintances can provide more novel information than strict relations, as the tight connections of an agent are very likely to know each other and therefore provide the same kind of information. Nowadays network analysis is a very popular field of study and its importance has been revealed by the widespread use that has been made of this discipline among many activities, such as management consulting and crime fighting.

Network interactions have already been widely studied in the field of physical processes, still the differences between the scientific approach and that of social sciences are evident. In particular, in physical science any dyadic phenomenon is considered as a network. On the contrary, in the social science, the analysts try to attach a different value to any sort of relation. Four main kinds of links may be found, as it can be seen from table 3.1.

Furthermore, in network analysis the structure is very important. Similar agents or similar networks can perform very differently if, respectively, their position in the network or the structure of the network is different. In this approach, the outcome is not only determined as a function of other explanatory variables, but also of the ties

Similarities	**Location** (e.g. Same spatial and temporal space), **Membership** (e.g. Same Clubs, Same Events, etc.), **Attribute** (Same gender, same attitude, etc.)
Social Relations	**Kinship**(e.g. Mother of, Sibling of, etc.), **Other Role** (e.g Friend of, Boss of, Student of, Competitor of, etc.), **Affective** (e.g Likes, Hates, Loves, etc.), **Cognitive** (Knows, knows about, sees as happy, etc.)
Interactions	e.g Sex with, Talk to, Advice to, Helped, Harmed etc.
Flows	e.g Information, Beliefs, Personnel, Resources, etc.

Table 3.1: A typology of ties studied in social network analysis.

that an agent has. In this perspective, very important is also the issue of centrality of a node, which may be interpreted as the capacity of a node to influence or distort the pace or the information between other nodes. A common task between the physical and the social analysis of network has been explaining how do interactions arise and how does the node centrality distribution evolve. The various reasons that have been identified, may be clustered into two main categories, opportunity based and benefit based reasons. Much effort has been put in explaining the consequences of networks. Where a node stays in the network affects its possibilities and constraints. Differently from physical sciences, in social sciences many node distributions are possible, with consequential diversified outcomes.

A core point of the social network analysis is that of transferring information from one to another, interconnected people, indeed, tend to influence each other. On the other hand a convergent behavior, does not necessarily imply that there is a transmission of information between nodes, but agents may become similar through an adaptation process because they face similar circumstances. Different sets of structures of the network may imply different possibilities to face specific circumstances. In particular, given an ego-network, where all the nodes are connected to the ego, a structural hole is defined as the lack of connections between a pair of nodes. In case of absence of structural holes, the nodes can bind together, organize and cooperate and become a strong force, this is the idea, for instance, of labor unions. On the other hand, if a node is not bound to any other, it can play with other nodes, dividing them and making them fight between each other. Characteristic of network analysis is also the exclusion mechanism, that is when a node can decide to exclude another from the transfer relation. This issue has strong influences on the power structure of the network. Indeed, it has to be noticed that in a network, the power of a node is strictly dependent on the power of all the other nodes.

Fontana and Terna (2014) suggest that the co-usage of ABM approach and the network analysis (NA) permits to better study, understand, and therefore act on a complex reality. In support of this, they present their *recipeWorld*, an ABM in which networks emerge due to meaningful economic relations. The definition of a complex

system, indeed, is one in which phenomena emerge from the interaction between the agents. ABM is well suited for simulating these mechanisms. In particular ABM could be used to overcome the issues encountered in traditional network analysis (NA), for instance, following De Caux *et al.* (2014) that of staticity of traditional NA. Also, they help in overcoming the issue of nodes, evidenced in Gilbert and Hamill (2009) and Roth (2007), as it seems that nowadays the traditional social structures lack of realistic foundations. In the traditional mathematical analysis of networks, moreover, the scope of interactions is very limited, therefore the emergence of a network is only explored through "combinatorics", but this becomes a huge computational problem, emphasized by the fact that the probability of each combinatoric is equal. These issue suggest that the traditional analysis of networks may lead to distort outcomes. On the other hand, the introduction of ABM in the study of emergent networks, may entail some positive aspects. First, Fontana and Terna (2014) state that *ABMs are inherently dynamic.* Second, they permit more wider sets of behaviors and variables, which allow a more realistic configuration of the nodes. Last but not least, the issue of combinatorics is practically eliminated. Indeed, although the number of possible configurations stays high, defining more complex relationships between agents and the emergence of social networks permit a greater control on which of the theoretical combinations will actually happen.

3.4 Examples of ABM

An ABM consists of a number of objects, the agents, moving within a virtual environment. Generally agents are programmed through an object-oriented programming language and are modeled trough a set of condition-action rules through which they perceive and react to the environmental conditions, interact with the other agents and pursue their goals. The basic idea is that economic agents combine flexibility, reactivity and the capability of interacting with each other. With the first we refer to the fact that humans are goal-directed, aiming at satisfying some objective or maximizing utility. By reactivity we mean the capability of responding to changes in the environment. The main issue is balancing these three characteristics. Traditional economics assumes agents to be selfish and rational but this does not apply in many cases. Agents often take into account motivations other than only maximizing their utility. Furthermore problems are frequently very difficult to analyze and agents might not have a clear perception of the whole dilemma and all the possible options. In ABM generally agents have a bounded rationality, they do not fully understand the issue under investigation and they do not have a clear overview of all the possible scenarios that any available choice would lead. Agents are not omniscient and it is not even ensured that among their perceptions there is the correct one. Perceptions are heterogeneous and depend on many variables, such as the level of information. Individuals, therefore, generate expectations, based on their perceptions of the reality and adapt them accordingly to the evolution of the external environment they are contributing to generate.

ABM can differ in some important features. For instance, an ABM can be more ab-

stract or descriptive. In the latter case the simulation is a believable, though simplified, version of the reality. The former instead might be a very limited model, meaningless in terms of representing reality, but useful in the conceptualization of some core aspect. Models, moreover, can be endowed with different degrees of realism. Some can be used to analyze "what would happen if..", while others can be trustful representations of reality in which performing experiments about different interventions, which could not be implemented in the real world. ABM can be positive or normative, where the latter means analyzing the outcome reached by using a particular action rather than another, and therefore provide advices on how to behave in the investigated situation. ABM models can therefore be used as effective predictive instruments in analyzing political intervention, by allowing for realistic assumptions such as bounded rationality and complex interaction in social systems. Most of the ABM, anyway, have a positive nature, that is a descriptive and analytical function, rather than a normative one. More, some ABM are spacially defined. This happens mostly when dealing with ecological economics, in this case the space is clearly defined and characterized. In other models, instead, the physical environment is omittable and the focus is switched to the network, interactions and links analysis rather than on geographical variables. Finally, agents might be simple or complex. Agents are defined simple if they act respecting easy condition-action rules, while systems have been developed, like the SOAR (Laird *et al.*, 1987) and ACT-R (Anderson and Lebiere, 1998), where agents are driven by complex cognitive systems. Experiments have shown that simple agents are enough if under investigation is the behavior of the population as a whole, while complex cognitive systems are needed when the actions of individuals or small groups need to be investigated.

3.5 Developing an ABM

Generating a good ABM is not easy and it requires some basic steps. First the question to be investigated needs to be clear from the beginning. Indeed, if the query is not definite the model may become too encompassing and complicated and therefore useless to study the reality. The ideal process is starting from a very simple program and, after perfectly understanding the underlying dynamics, enlarge it with more complex features. In this way an acceptable grade of simplification might be reached. Designing a model is easier if the underlying theory is clear enough to the programmer. This allows the coder to have an idea of what are the connected variables or comparing phenomena and moreover what are the assumptions that should be made. Once the query, the literature and the assumptions have been clearly and deeply studied and specified, it is possible to start with the design of the simulation.

Once the programmer starts the simulation, it is necessary to state which will be the objects taken into consideration, their hierarchy, their classification and their attributes. Attributes work as the mathematical variables and they are useful both in differentiating the agents and in analyzing the evolution of the attributes themselves. The hierarchy is also very important, indeed sub-classes will inherit the attributes of the encompassing class. Secondly the environment needs to be set, by defining the geographical character-

istics, if it is a spatial model, and the system of interactions within it. The processes just mentioned above are iterative and they need to be refined until the model seems consistent. After a first approximation of the static design has been implemented, it is possible to start introducing the dynamics of the game, both between agents and environment, but also between agents themselves. Finally, the last step is generating the interface, where the user can perform experiments by changing attributes values, varying modes and check the outcomes through plots and graphs. Changes on the interface variables permit the performance of tests and experiments by simulating other possible states of nature.

Chapter 4

Theoretical Foundations to the Brain Drain Issue

The following chapeter is meant to retrace the steps covered in the brain phenomenon analysis. In particular, we will focus on the literary review of the socio-economic processes occurred within the last 60 years. First we will recall the role of basic research as a factor of innovation and growth in modern economies. Later, we will continue with a more theoretically review of economic concepts such as human capital and mobility capital. Finally, we will conclude the review with a recap of the main breakthroughs in the brain drain analysis such as the empirical, the geographical and the agent based models.

4.1 Basic research as an Activator for Economic Growth

Education as catalyst for human capital formation and technology innovation is an important aspect of the economy of each nation. According to Nelson (1971) basic research is the source of the largest and more spectacular innovations which have been generated in the framework of scientific progress. For instance, it would not have been possible for Marconi to invent the radio without Maxwell's and Hertz's theoretical works. The main problem of basic research, lately, is that it might entail significant costs and its expected profitability is affected by high variance and time lags, which makes it a modestly appealing investment for private companies. Also, it suffers of external effects, the marginal benefit of a firm financing basic research is smaller than its social benefits. An intervention of government and other non-profit institutions, for example Universities, is then needed to bring the total amount of investment closer to the socially desirable amount. In Press (2013) the author as president member of the AAAS (American Association for the Advancement of Science) goes through the important role of basic research on innovation. The study starts from an analysis of the US GDP per capita exponential growth in the last 150 years. Figure 4.1 shows that in the last 130 years US GDP per capita has increased almost perfectly following a pure exponential. Press finds that one of the main reasons behind that might be the technology innovation, the so-called Solow

residual. For this reason investments in research and development are good for societies and these have to be implemented in order to grant the positive exponential growth of the economy. He continues then, focusing on the source of investments in this field and finds out that investments in basic research suffers the so-called *tragedy of commons* issue (Hardin, 1968). A public intervention in research funding is therefore needed, although, he says, with some further protections of the appropriability of the results.

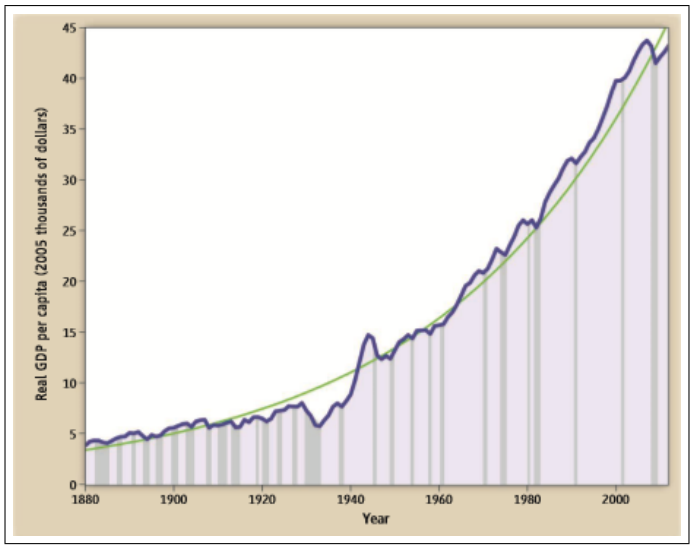

Figure 4.1: U.S. GDP per capita corrected for inflation in 2005 US dollars

Figure 4.2 shows on the horizontal axis the fraction of GDP that countries spent on R&D, while the vertical one shows the fraction of population being scientists or engineers. Three clusters are clearly visible. The first, the one of the industrial nations of the last 50 years (USA, Germany, Japan etc., but also the Scandinavian countries and, more recently, Singapore). This cluster may be identified as the technological leaders, with high R&D research public spending and a high percentage of highly educated individuals among population. The second cluster being identified by other developed countries, such as France, UK, Russia, etc. encompasses the technology follower nations. Finally, the third cluster, includes developing countries and Italy, which have a lower percentages of scientists over population and lower levels of investments on R&D research, this amount being, however, increasing in most of the countries.

According to Press *exponential growth comes from positive feedback, where the production of something enables you to produce even more.* Since centuries economists are studying the factors of production. Initially, the classic identified factors were land, labor and capital. Lately, human capital and intellectual property have been added as well in the analysis. It is capital in its broadest sense, including human and intellectual capital, that can spark an exponential economy. Solow (1956) has studied which part of the economic growth could be explained by the traditional production factors and he stated that the part that could not be explained by them, the so-called Solow-residual,

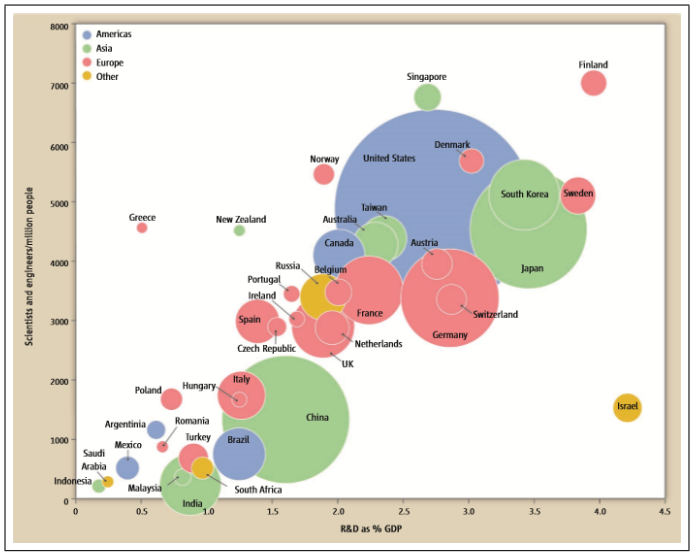

Figure 4.2: Research and development spending by country in 2011 by percent of GDP and percent of population who are scientists and engineers

could indeed be explained by technological progress. Technological progress can not be assimilated to capital, as it does not really belong to anyone, but still it can generate positive feedback and induce a positive circle for the economy.

One of the main issues with basic research is its financing. The returns from basic research are large, but they are generally enjoyed by the world as a whole and they are not necessarily enjoyed by the funders. It is true that discoveries can be turned into innovative goods, patents, and so on, but it is not given that this will happen in the laboratory or even in the country where basic discoveries have been made. Basic research is, thus, a public good. It would benefit all, but because it lacks of private incentives, there is the need for government intervention to avoid underinvestment. After 1957 US government has supported basic research following the positive economic trend. Initially two thirds of the financing for R&D were financed by the government, while only one third was financed by other non-federal sources such as private industries. In the last fifty years, this tendency has been reversed. The result is that nowadays investment is more focused on development, as private investment goes in this direction. Investment in R&D indeed allows easier and more appropriable profits rather than basic scientific research. This decrease in investments of the US government on basic research depends on the diminishing appropriability of the returns, now that ideas move faster and other countries can exploit the benefit of the discoveries.

The author suggests that this tragedy can be avoided following two paths. First, protecting the appropriability of returns. This works as kind of a protectionism of basic-science discoveries. Appropriability would be done by increasing the interconnections between research plants within the country, setting up idea incubators, research hubs and so on. In this way, through increased contacts among scientists and engineers all over the

nation, it would be possible to increase the pace of turning discoveries into innovations, and, therefore, economic growth. It is clear though, that as communication time is close to zero, even bundling together scientific communities does not prevent leaks of ideas or discoveries with the consequent appropriability issue they entail. More, basic research discoveries should be public. They represent cornerstones of the human kind scientific heritage. Strict appropriability could prevent them from exploiting their whole potential. The second path seems then much more interesting. It has arisen from some polls in which the public has expressed its appreciation for science results. According to Press, this implies the population to have somehow guessed the heavy-tailed configuration of scientific results. A heavy-tailed distribution is such that extremely big events are only a bit rarer than medium events. It is very different from a normal distribution, in which extreme events only have a very small probability of happening. In practice, this implies that events with huge positive consequences might effectively happen. Press suggests that scientific progress is heavy tailed, as it is possible to evince from the discovery of penicillin or nano-technologies. Since it is heavy-tailed, then, it is a good idea to invest on it as it will probably provide very high returns. Not only, Press suggests that the investment should be continuous and substantial to thrive its benefits. We also think that from the considerations made above and following from the results of Press, which state that the public does appreciate the role of science, it should be funded by the public sector.

4.1.1 Human Capital Theory

The previous section has underlined the importance of basic research as a catalyst for economic growth. Basic research is possible pursuant to the achievement of education and, thus, human capital. Human capital can be defined as *the stock of knowledge, skills and ability embedded in an individual* (Becker, 1964). In the latest years human capital has achieved a stronger importance in explaining countries' economic performance. Enhancing human capital, which can be done through education, training and mobility, entails both costs and benefits. The former can be direct, such as consumption costs, or indirect, such as foregone earnings. The latter are split into private and social returns to education. Social externalities to education are divided in three categories, *static, dynamic and non-pecuniary.* Static externalities refer to the positive influence of human capital on other production factors (Lucas Jr, 1988). The debate regarding static externalities is still open, many and contrasting research papers have been written on this regards, see Benhabib and Spiegel (1994); Temple (1999); Krueger and Lindahl (2000); Heckman (1997); Topel (1999); Rauch (1993); Acemoglu and Angrist (1999). Traditional econometric analysis does not seem to lead to unique and congruent outcomes with regards to the significance of human capital on the productive process, other sorts of externalities given. Dynamic externalities refer to effects on learning and technological change (Nelson and Phelps, 1966; Romer, 1990). The same Benhabib and Spiegel (1994) confirm that human capital stock does have a positive role influencing the economic growth. On the contrary Krueger and Lindahl (2000); Bils and Klenow (2000) think that the relationship is not necessarily causal. Galor and Tsiddon (1997) identify

a positive relation between the average human capital within the society, accounting for its distribution and composition, and the technological progress. At a later stage we will investigate other more recent research works where human capital positive externalities on economic growth are more than explained and justified. Finally, non-pecuniary externalities rely to the non-monetary effects of education on the society (Haveman and Wolfe, 1984; Lochner, 1999) and they are indisputable and positive although harder to be quantified.

According to most of Human Capital Theory, see Mincer (1958); Becker (1964); Schultz (1961), individuals take their investment in human capital decision as an optimization problem, counter-posing the expected gains to the expected costs of investing in education and maximizing utility. In the second instance, Endogenous Growth theory has provided many insights for which enhancing individual levels of human capital provides benefits to the society as a whole. This can be particularly seen in the works of Lucas Jr (1988) and Romer (1990). The former has studied the influence of concentrations of highly skilled workers in the society and has declared that they arouse positive human externalities, subsequently leading to enhanced productivity and growth. In this work can be identified the roots of the work of Moretti (2012). The latter has investigated the relations that exist between knowledge, human capital and economic growth.

Different approaches reject Human Capital Theory. For instance Buchanan (1964) states that human beings, differently from animals are characterized by a sense of becoming and that, quoting Appio Claudio Cecio, *homo faber fortunae suae*. Humans, then, are characterized by both natural and artifactual characteristics, where the first refer to the biologic and genetic elements of nature, but also to the culture and the customs which have characterized their behavior. Artifactual, on the other hand, refers to the possibility of choosing who each individual wants to be without any biological or cultural influence. Buchanan claims that modern economics neglects the artifactual nature of humans and thus penetrates misleading directions such as that of human capital theory. The critique he makes is that in human capital theory education is seen as a process of accumulation of future income streams, while in reality it is a process of becoming. In this perspective, analyzing the rate of return to education investments becomes questionable. More extensively, Buchanan critiques the teleological view of modern economics, which by attributing a final objective also to unintended actions, has reduced the study of economic phenomena to an objective function maximization under constraints. According to Buchanan, men and women move through time, constructing themselves as artifactual people. Each individual is not and can not be the same person in a utility maximization sense. The changes in character are subjective to the individual and can not be objectified by an outsider analyst into some utility function. More, individuals forge the institutions in order to realize a set of rules in which they are free to pursue personal realization. To recap Buchanan affirms a strong defense of individual liberty, which can not be advanced by modern economists who are locked into an utilitarian heritage. From his perspective, men and women desire liberty not to maximize their own utility, but to become the person they want to become. In

this sense liberty is the ultimate goal of humans decision making, and not utility.

Among the critics towards the utilitarian approach sticks out that of Sen (1999). The author states that when evaluating a situation, a crucial role is played by the information we know, that is called the informational base. Each evaluative approach is characterized by its own informational base, which entails both the information that is taken into account while making the decision, its degree of relevance and even which information is excluded. In the utilitarian approach, the violation of individual rights or the distribution of utility does not matter. The only relevant aspect is aggregate utility, which can be explained as the sum of individual utilities. Utilitarianism, initiated by Jeremy Bentham, has been the dominant ethical theory and the most influential theory of justice for over a century. The requirements of the utilitarian evaluation imply that different choices must be evaluated only by taking into account the results they provide (consequentialism) on the utility (welfarism) of the community as a whole (sum-ranking). Distribution among population or even the violation of individual rights do not play any role in the judgment of any action. In this utilitarian view, then, injustice consists in aggregate losses of utility compared to what could be achieved. It is clear from these reflections that the utilitarian approach entailed in the human capital theory does have some strong limitation. The modern utilitarian approach, indeed, sees utility as the numerical representation of choices. The advantage of this method is that it is not necessary to specify the concepts of happiness or utility, but on the other side it makes it impossible to do interpersonal comparisons from observing choices taken by different individuals. The common assumption of the same choice behavior, indeed, does not imply the same utility being achieved by different individuals, as the heterogeneity innate in the mankind, in the environments and in the societies plays a crucial role.

4.2 Mobility Capital

In places for the reasons mentioned above, countries are now fighting for gathering talented and specialized individuals in order to push economic growth. In particular, as just-graduated individuals are a particularly mobile category (Orru, 2014), foreign nations tend to provide grants, tax-reductions and even simplified immigration policies procedures to highly educated people in order to get their talent and exploit it for the economic development of the country. In this viewpoint many student mobility programs have been set. Through these projects, students spend a certain period of time abroad carrying on their academic careers. These programs can be divided between *credit mobility*, through which individuals spend just some time abroad, but can finish their own degree only by coming back to their home institution, or *degree mobility*, in which people complete a full academic program in a foreign country.

These exchanges allow individuals to gain what is called *mobility capital*, a sub-category of human capital made of languages, openness to other cultures, relational ability and so on. This is expected to be a key characteristic in the labor market and thus enhances the expected value of private returns to education. Not only, previous mobility experiences reduce the costs of future migrations in terms of psychic and information

costs, social networks in alternative locations and so on (Rodrigues, 2012). Student mobility programs, though, entail an intrinsic drawback especially for lagging regions. Prestigious Universities and blooming labor markets are often located in the core regions. Endowing individuals with *mobility capital* augments the chances of what is known as *brain drain*. With this term we refer to the event in which the top-skilled individuals of any field migrate to a different country in order to achieve a job position better fitting with their high level of education (Biondo *et al.*, 2013). This phenomenon is different from that of generic migration, in which people move from their homeland where they have no job possibility at all in order to escape poverty. Highly educated and specialized people will tend to look for a job position which is fitting their high preparation and which, consequently, pays a significantly high salary. Lagging regions then, incur the danger of loosing many talents, as their economies are not often able to offer enough highly skilled job positions. Orru (2014) PHD thesis work is focused on the influence of programs of student mobility on the economic performance of lagging regions, in particular he deals with the *Masters and Back* program financed by the Italian region Sardinia since 2005 for talented students willing to achieve a PHD or a Master diploma in prestigious foreign Universities. What he finds out can be unsophisticatedly summarized in the following quote.

> Specifically, increased student mobility could lead to unwanted geographical consequences, in particular brain drain – an issue that has been acknowledged both by the literature and by policy-makers.

The author does not assert that exchange programs of the just mentioned type are wrong *in toto*. They may have a *boomerang effect* if lately the sending country or region is not prepared to reintegrate the extremely high level returning human capital.

4.3 Brain Drain Literary Review

In Docquier and Rapoport (2012) the authors emphasize the large role of brain drain in the current migration flows and as one of the major evidences of globalization. They organize the literature of the past years regarding the brain drain phenomenon in order to better understand the progresses achieved within this field of economic analysis, underline potential extensions to the existing works and provide an overview of the current situation. They identify three main studying waves in the investigation of high-skill emigration.

4.3.1 First Wave

The first wave dates back to the late sixties and it is embodied in researchers as Grubel and Scott (1966), Berry and Soligo (1969), Johnson (1967), Scott (1970) and many others. The pillar of these studies was the positive effect of highly skilled human capital migration on international trade. The brain drain phenomenon was seen as positive both for the host countries, which would have taken benefits from incoming highly

skilled professionals and academics. In the same way, a positive effect was conferred also to the source countries, that would have benefit from remittances and assets left home from the migrants. The assumptions made are market clearing, wages equal to marginal products and no externalities. In this framework, there is no room for welfare effect for those left behind, as long as domestic wage does not rise as a result of shifts in labor supply. Obviously, allowing for some distortion would clearly endanger the conclusions reached.

4.3.2 Second Wave

Bhagwati and Hamada (1974) and McCulloch and Yellen (1977) are representative of the second wave, which took distances from this approach. By considering various institutional settings, such as domestic labor markets rigidities, informational imperfections and other types of externalities, they reached the conclusion that brain drain is fundamentally bad for origin countries. They believe high-skilled migration to significantly contribute to enlarge international inequality.

Haque and Kim (1995) is another important example of the second wave of analysis of the brain drain phenomenon. The authors focus on the importance of human capital in economic growth. It has been shown by Lucas Jr (1988), Stokey (1991), Barro and Lee (2001) that human capital is a good explanatory variable of the growth performance of nations. While on physical capital there has been plenty of research, up to the date of publications of the discussed paper, not so much attention has been posed on the human capital factor. The behavior of the two elements, though, might be very similar. In the same way as capital is moved to where it generates higher returns, so labor moves towards locations with higher wage differentials. Growth has been endogenized allowing for constant or increasing returns to scale. In this new frame, brain drain assumes a key role as a source of difference between growth rates of countries.

Within the second wave have been explored possible policy implications regarding the brain drain phenomenon. In Bhagwati (1976), Bhagwati and Partington (1976), Bhagwati and Wilson (1989), Bhagwati and Hamada (1974), the authors analyze the hypothesis of a tax on high-skilled emigrants. This idea has more recently been recouped by Desai *et al.* (2009).

4.3.3 Third Wave

Finally the last wave of studies analyzed the phenomenon through empirical analysis, dynamic models[1] and endogenous growth models. The researchers within this wave assert that negative aspects of brain drain exist, such as fiscal and technological externalities for the source countries, but by expanding the investigation through empirical analysis they have identified also positive factors and found that these are prevailing. An example of these positive aspects is the capacity of countries to attract brains back. This, though, is only possible for countries with the capabilities of strongly investing in

[1] Which had already been used in the second wave as well, see for instance the paper Rodriguez (1975)

research and development and human infrastructures intensively (Charum and Meyer, 1999). The issue will be debated more extensively in the following lines. In Beine *et al.* (2001) the authors identify the role of high-skilled migration in positively mutating individuals' human capital investment decision. The intuition is that especially in countries where the labor chances for extremely high skilled professionals are very limited and so are the earning perspectives, the possibility of migrating to more developed countries might positively influence the individuals' human capital investment decision.

The very same work of Docquier and Rapoport (2012) comes back into the third wave passage. Previously Commander *et al.* (2004) performed researches on the brain drain phenomenon. The so called DIM 2000 (Docquier *et al.*, 2009) starts from the econometric study pursued by Carrington and Detragiache (1998). Grogger and Hanson (2011) used it to explain the international labor movements, as generated from two factors. The first is *positive selection*, which means that the migrants' skills are higher than that of the average population. The second is *positive sorting*, that implies that emigrants move to countries with a bigger return on skills. Belot and Hatton (2012) focused on the importance of wage differentials but also they identified that linguistic and cultural factors and geographical proximity are stronger than return to skills, poverty in source countries and immigration policies in receiving countries. Beine *et al.* (2011) found a core role for network diasporas. Indeed larger diasporas increase migration flows, because of network externalities and reduction in migration costs. On the other hand, it is true that there is no control for educational levels, therefore it is not clear whether this phenomenon can be amenable for brain drain.

A critique addressed by the author of this thesis is that none of the just mentioned papers takes into account where the education was taken. Indeed the issue of transferability of human capital is central in a complete analysis of brain drain, see Galarneau and Morissette (2008). Actually, people educated in the host country tend to have better wages than emigrants, while emigrant workers will not without fail find a job in which their education is completely rewarded. This aspect implies an increase in emigration while studying, rather than after getting the degree. Therefore a change in perspective should be made. See for instance the second wave of analysis largely focused on the financial issue of repaying the public investment on education of a migrant worker. But also it does require a shift in the collection of data, as in mostly of the dataset considered foreign students are not accounted for and thus contribute to underestimate the size of the phenomenon.

4.4 Economic Geography Models

Economic geography models, see Krugman (1990) and Fujita *et al.* (2001), bring together labor mobility and the tendency for uneven development of different areas and may be used in the framework of brain drain analysis. In particular, these models focus on how do transaction costs and economies of scale interact in determining the level of industrial concentration. The idea behind this process is that initial industrial expansion attracts labor force for working in the recent sector and this wave of incoming

people generates an increase in the demand for output. The exchanges, then, are favored by the reduced transaction costs generated by local proximity. The constraint of these models is the presence of an agricultural sector, which can not be moved and therefore generates demand for industrial goods that can not be concentrated (Krugman, 1990). By associating the industrial sector to an hypothetical high-skilled sector and the low-skilled sector to agriculture, these models can be perceived as brain drain models. The main outcome of these models can be summarized as following. First, the pressure for high-skilled migration may change with reference to the world-economy parameters, in particular transaction costs and costs of international trade. Second, uneven development is a natural and inevitable phase of global development. Finally, brain drain is detrimental for origin countries even in absence of any labor market failure. The critiques to these models rely much on the absence of factors such as returning emigrants, incentives to education, diaspora and network effects, which according to the third wave of investigation allowed for the possibility of a beneficial brain drain even for those left behind. On the contrary, an important strength of economic geography models is the general equilibrium nature, which endows them with strong internal consistency.

Moretti (2012) can be re-conducted to this set of analytic models. Friedman (2005) utters that lately the world is flattening and becoming smaller, as communication and technological innovations are demolishing the physical boundaries and barriers among different countries. According to the journalist, this will lead to a brutal competition for high skilled jobs, in which the traditionally most industrialized countries will suffer an unprecedented pressure from more recently developing countries such as India and China. In contrast, Moretti (2012) states that geography matters and analyzes how do differences in the economic development of cities influence geographical disparities of the social advancement. What the author reveals is that the concentration of innovators in a city, not only does enhance the number of employed in high-tech high-wage jobs, but it also does augment the number of unconnected working places and their respective salaries. He states that job growth in high-tech field causes job growth in unrelated local services and, furthermore, it operates through a multiplier effect so that a new job-position in an innovative service generates five jobs in local services[2]. Into the bargain, the dynamic is self-reinforcing. Cities with large brain hubs will tend to attract other graduates. This tendency is apparent when analyzing USA cities. Cities with larger percentages of individuals holding a college degree present higher levels of produced output and patents. Also, they show a higher average for the salary of those non-holding a college degree, finally, they display different tendencies for social phenomena, such as the rate of divorce or the life expectancy.

In Moretti (2013a) he makes some policy suggestions in order to fight the development gap pinpointed above. In the USA, indeed, around 40% of the households change addresses every five years, often moving from state to state. More, the mobility is positively correlated to education, the more instruction people get the more mobile they are. Among the college graduates, indeed, those moving out from their origin state are around the 50%, while they only are the 27% within high-school graduates and 17%

[2]In Moretti's work there is no methodology to support this assertion

among the dropouts. Moretti has ascertained that cities grow at different rates depending on the kind and the amount of industries which are located there. As the less the individuals are formed, the less they tend to move, the inter-cities gap can not do anything but growing. More, less educated people will not be able to exploit all the possible benefits of a developing city, unless it is the one they are born in. As a solution, then, Moretti proposes to add to the existing dole in areas in which unemployment is above the average a subsidy which pushes unemployed to move to a different city. In this way unemployed people would have the means to relocate and hopefully they will choose the areas in which they have more and better working possibilities, that are those with larger levels of development. According to the author, this mechanism will not harm the local communities. Indeed, the incentives to relocate will not only benefit those who take advantage of them. On the contrary, by reducing the labor force on ground, they will help people who are not willing to move away to find a job locally. It is undeniable, though, that this is an obstacle course. Rationally, if the benefit is pleasing enough, most of those who are looking for job will make capital of the benefits, leaving the burden of a local community without labor positions to those who are not able, or not willing, to move. In this way, the inequality among cities will not reduce, as the author states, but increase, with cities that not only have not been able to keep pace with the development of other areas, but that have also been deprived of most of their labor force and thus of any possibility of future progress.

In Moretti (2013b) the author also proposes a reinterpretation of the immigration policies. In his view immigration should not be fought but controlled and selected. This vision reminds much of a quote from the Italian journalist and writer Carlo Formenti, who in a conference made on October 19th 2014 has stated that:

In a capitalistic world, the border is not an unsurmountable barrier. It is a semipermeable membrane, that selects who enters and puts the others on hold. Also it lets those who enter go underground, so they are more exploitable.

Now, Moretti's article is clearly nor so sharp nor so critical as Formenti's statement. The intuition he makes, indeed, is that by allowing high-skilled foreign immigrants into the country, they will not "steal" the job of low-skilled Americans. On the contrary, the presence of an high-skilled worker can induce firms to invest more and thus raise the working prospects and earnings for low-skilled workers as well. Moreover, this happens with a multiplier effect, as, Moretti states, foreign high-skilled patent more and establish more enterprises than domestic ones. The arguments supporting this last affirmation are though very modest. Nor it is granted that incoming immigrants will find a job that fits with their education as much of the literature of many different countries has shown, see Galarneau and Morissette (2008), Chiswick and Miller (2009) and Fernández and Ortega (2008).

Moretti (2012): The New Geography of Jobs

An anonymous on line blogger, using the nickname "The Economic Development Curmudgeon" provides an interesting review of Moretti's book "The New Geography of Jobs". The core point relies on the intuition that since the 1980s the development of

local communities has been strongly dependent on the industries yonder located. There is a *great divergence* between the communities within which have been set innovation-based companies and those in which most of the economy relies on more traditional manufacturing industries. In the former case, the quantity of human capital needed to conduct the innovation-based company is larger, and thus it induces a greater productivity, which finally leads to higher salaries. As this phenomenon is self reinforcing, the more a community has attracted knowledge-based enterprises, the more it will attract them in the future (Moretti, 2013c). What is expected, then, is an agglomeration of knowledge-based communities and a strengthening of the gap towards those locations which have not been able to attract large amounts of human capital. Indeed, while according to the author the manufacturing sector is declining, that of highly technological companies, such as software, internet, pharmaceutical and scientific R&D, is blooming and is catalyzing economic growth. This aspect is clear when watching the trends of people employed in each of the two considered macro-sectors, with the former seeing a negative penchant and the latter a positive one. This aspect evokes Schumpeterian *creative destructivism* (Schumpeter, 1942) as the core point of capitalism itself, in which the haven of new economic ventures and investments in it deteriorates the rents of existing companies. According to Schumpeter this mechanism is the source of capitalistic economic growth, although he is skeptical whether it can hold on endlessly as hereinafter it could undermine the capitalistic institutional framework itself.

The higher wages associated with higher levels of human capital are not limited to those employed in the newness enterprise, but they spread among the entire community. For this reason the presence of innovation-based firms is beneficial for the community as a whole. Also, the divergence is not only economic, but according to Moretti, it enlarges to many other social aspects as life expectancy, divorce rates, crime and politics and electoral behavior. The same idea is shared, although from a different perspective, by Murray (2013), who states that the agglomeration of different clusters of people in detached areas of the cities, in this case extremely luxurious districts separated from all other neighborhoods, allows for a disgregation of the previously shared American values and for a consequent decay of the society.

Figure 4.3 shows a portrait of the distribution of human capital among USA, where human capital in this context is associated to individuals holding a college degree. In figure 4.4, instead, is represented the economic output originated from different areas of the country. It is apparent the conformity of the areas with higher conglomeration of human capital to those with larger output.

Currently USA is divided into three main categories of communities, brain-hubs, declining manufacturing areas and locations which could go either way. The three categories of locations are growing at different rates, this ensures an increasing level of inequality among wealth distribution over USA communities. This aspect is clearly in contrast to what is asserted by Friedman (2005), which states that internet and communicative innovations have made the world smaller, as now outsourcing especially highly demanding jobs is easier than before. Thus as it is easier for people of any community in the world to participate and therefore enjoy the benefits of being a member of an highly

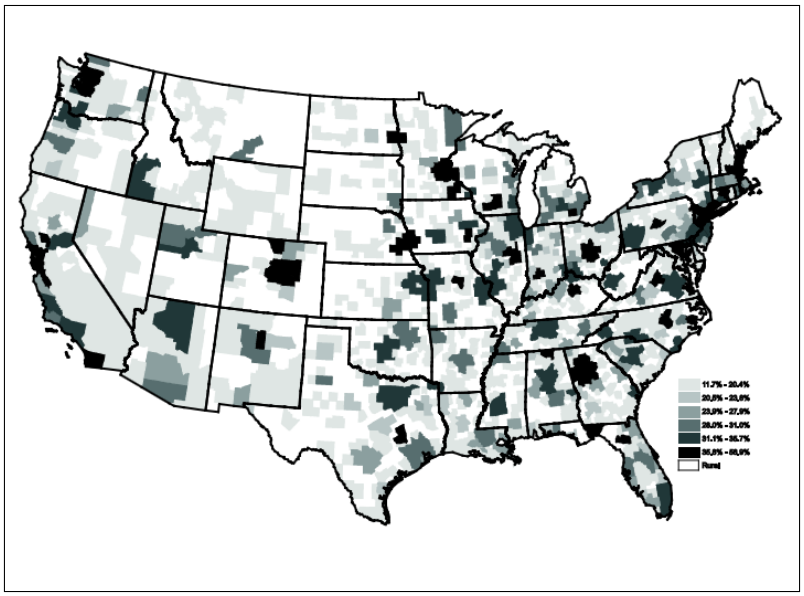

Figure 4.3: Share of Workers with College Degree

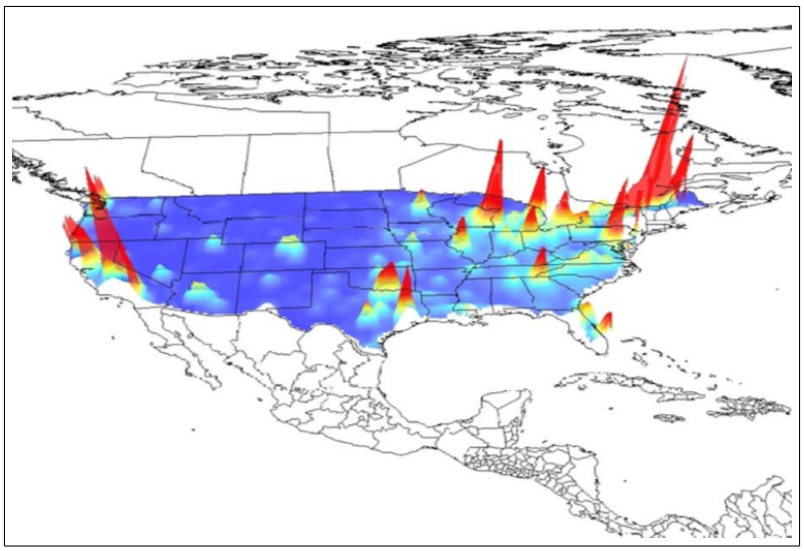

Figure 4.4: Economic Output per Square Kilometer

innovative company, the disparities among areas are reduced and many once washed out communities are now able to take part to the most activator of economic development. Some of the mentioned aspects, may actually occur and are occurring, as the progress of countries as China and India, but what is essentially different between the two points of view is that this growth is not even around the nation. There will be a catching up of these countries, but this will not arrive alike from some scattered area of the Gobi desert in the same way as from the University hub of Beijing.

> Cities are not just a collection of individuals but complex, interrelated environments that foster the generation of new ideas and new ways of doing business. Moretti (2012)

Economic growth is dependent on the environment in which it develops.

To be more specific, in Moretti's book the American industry has followed a clear path. Until the beginning of 1980s, USA manufacturing sector has been leading the national economy. Later, the effect of globalization has been that of outsourcing work in particular to countries where the labor costs are less expensive. This happened mostly for low-value-added manufacturing jobs rather than highly specific ones, but note that the former are more numerous. So what happened is that what is known as the *productivity paradox*. As many people where losing their job because of outsourcing, and thus fumbling working privileges, on the same time they were gaining as consumers, because of the copious and less expensive products incoming from the behindhand areas. So what the author is saying is that development can kill some jobs. In this case it has destroyed most of manufacturing working positions in the USA, but, on the other hand, it has created many other positions for high-skilled, high wage professionals and technicals. The low-skilled jobs, instead, have been concentrated around the sector of local services and personal care.

Furthermore Moretti makes a distinction between traded and non-traded sector. The difference relies on the fact that first one encompasses all the activities whose fruits can be enjoyed even away from the area within which they are produced, while the second category includes those activities, such as barbers or plumbing services, whose outcomes can not be savoured elsewhere. What he does underline is that although the second category is the most massive, it is the first category the catalyst of prosperity an the only activity which can improve people's living standards. The mechanism he diagnoses is, indeed, that as the innovative highly demanding, highly specific jobs are so well-paid, they imply a high request for side services, such as gastronomic, aesthetic, mechanical and so on. More the innovative company tend to locate close to each other, so one innovative company set somewhere may foresee the arrival of others and thus, the foundation of many other jobs and the increasing of local living standards. This all happens with a multiplier of 5, that is for one new innovation job created, 5 more side jobs arise[3].

Innovative industries, still, are quite different from more traditional ones. Their larger production costs is the fixed cost for R&D. On the contrary, easy access to the global

[3]No methodology is provided to support this assertion.

middle class and the possibility of charging higher prices, see the issue of economic rents, ensures them large profits. In this sense it has some optimum points when compared to the traditional industrial sector. On the other hand, in the creative-destructionist view in which many aspects of this book are located, he states that is the innovation sector in general that will keep on growing and push economic development. It is not the single community. Cities that nowadays are the nest of innovation may be and likely will be sooner or later overcome by other communities, with other new and more innovative ideas. The innovation of tomorrow will destroy the innovation of yesterday.

Currently the just mentioned mechanism has constructed a *Great Divergence* among American cities and areas. This inequality is not only economical. It is social and educational. Moretti starts from Bishop (2009) and he proceeds by adding human capital externalities. The intuition beyond what he states is that living in a brain hub surrounded by educated, well-paid, politically-engaged, healthy aware, with longer-lasting marriages etc. individuals entails human capital externalities and it enhances the human capital of the individuals in there and aligns the people to the highest living standards.Of course the contrary holds as well in the opposite direction. This sentence is criticized by the anonymous on line blogger, using the nickname "The Economic Development Curmudgeon" as it would lead to a world divided into two not only economically but socially and intellectually different classes, *A world of traded sector patricians and non-traded sector plebeians* although they do not believe that this is what the author was trying to affirm.

Moretti spends some words in order to specify why do innovative firms set close to each other when they could locate anywhere else. Of course something has already been mentioned by referring to the presence of human capital externalities. He identifies three core agglomeration points. First the presence of a copious and skilled labor force in a specific field. Second, the presence of high quality side services, such as, for instance, venture capital and finally knowledge spillovers, in which appears much of Krugman (1991). More, the author finds a new phenomenon: localized economies of scale. Clusters of innovative industries become more efficient as the cluster itself grows in size. On the contrary, this does not necessarily happen if a single company does grow. Unfortunately this assertion is not clearly proved. Anyway, what is underlying this whole reflection is the central idea that communities which have attracted some innovative company are deemed to attract more in the future in kind of a virtuous circle. This cycle seems to be self sustaining in the long term. An issue is that as any economic sector, innovation is subjected to creative destructivism. What is an cutting-edge innovation today, capable of providing large profits, can become the typewriter of tomorrow; clusters of innovative firms can break if they are not able to adapt themselves. In the same way those communities that have been struggling in the most recent period, should find in this mechanism a suggestion to re-launch economic performance: attracting a mass of innovative workers big enough to catalyze the virtuous circle.

The analysis ends with the core question of whether cities that have been left behind by innovation localization among the territory can effectively catch-up by attracting newness enterprises. The author reaches a very different conclusion from, for instance

that of Porter (1998). Porter analyzes why in an era where fastening and enlarging transportation and communication technologies still location plays as source of competitive advantage and it is still possible to remark the presence of specialized clusters. In his view the presence of clusters relies on the existence of some local factors that can not be taken from abroad, and these are *knowledge, relationships and motivation.*

Moretti, instead, brings back the location choices to factors that are not purely economic, but mostly based on personal characteristics of particularly brilliant entrepreneurs and fortuitous circumstances. The economy of a successful city is based on the equilibrium of both the demand and supply labor market. To the question *What comes first?* labor supply, so human capital, or labor demand, so companies, he states that *people follow jobs.* Cities become attractive for people when they start offering good working perspectives and not vice-versa. The catalyzer than has to be attracting companies, that in a later stage will attract human capital. What is the role of Universities in such an inner work is controversial. According to the author is true that these high-formation institutions generate and are the source of the highly specialized human capital which will foster the economic growth. On the other hand, even if patents and research made within the Universities is not to be neglected, it can not be the guarantee of economic success. Of course proximity between Universities and innovative clusters is likely to be a generator of positive human capital externalities and can propagate in time and size the success of the area. Finally, the author provides some political strategies for inducing innovative cluster in less favored areas. What he suggest is the *Big Push* that is a strong intervention of subsidies for the first innovators who are willing to locate in a specific area and later stop when the equilibrium becomes self sustaining. This strategy has some weak points. In particular it generates flows of incoming workers, that are not easily absorbed by the new born innovative sector and may go to enlarge the already large lines of unemployment. More the issue is attracting that kind of human capital that the newness sector is needing. Also, subsidies should be given to those industries which will be able in the future to construct a cluster, that are, in other words agglomeration prone. This aspect is of course very difficult, if not impossible to compute, and thus the government grants may be dispatched to companies who do not fulfill their role of catalyzers. In the evidence, finally, many examples of innovative clusters have not felt the need for government intervention to develop.

4.5 Agent Based Simulation and the returning issue within the Brain Drain phenomenon

In Meyer and Brown (1999) the authors critic the traditional brain drain analysis, starting from human capital theory and evaluating only the monetary and fiscal aspects of the brain drain phenomenon. They state that this issue is a collective one which depends on human interaction and evolution, in other words it is complex. For this reason, to conclude the literary review it is necessary to name the approach of social simulations. Also, traditional models for socioeconomic studies assume the rationality of agents. It has been proved though, by behavioral economics, psychology and so on, that agents are

not rational. In Axtell (2006) the authors aim at overcoming this shortcoming. They find out that even without complete rationality, it is possible to reach efficiency, the only difference will be the pace at which it will be reached.

This is to confirm that the assumption of rational agents is highly implausible. Traditional economic models though keep modeling on this precondition. ABM are useful, because they facilitate overcoming this necessity. More, as in the mentioned paper they can be used to test adaptive dynamics and predict public responses to changes in the environment.

Once having underlined the complexity of socio-economic phenomena such as the brain drain and once having highlighted the potentiality of ABM as a research method, one is naturally led to wonder why not exploiting ABM to study the brain drain phenomenon. This working research as well is framed into this perspective. Many authors indeed have performed research within this important field of study. Quintessential is the model of Biondo *et al.* (2013). This article aims at finding out how high-skilled individuals involved in the brain-drain phenomenon decide whether to come back or not to their native countries after some time spent abroad looking for a better career. In this paper, given that some of the "brains" have left, the authors analyze whether they will ever come back. Indeed, even if it is plausible that brain drain without return empoverishes the native country, it is possible that, if cultivated people go away, gain experience and then come back, this could be a good opportunity for the native country as well. The authors make use of an individual feature, social capital, rather than the consumption level. This index takes into account many relevant factors that influence migrating/coming back decisions, such as relationships, family, job conditions and so on. The issue faced by the agents is not a maximization under constraint. The constraint indeed, is not binding. This can be derived from the consideration made above that high-skilled migrants do have the possibility of having a job in the native land, although not remunerated or challenging enough.

Biondo *et al.* (2013): Return Migration After Brain Drain

It is necessary to spend some words analyzing the model proposed by the authors, in order to better understand the decisional mechanism applied by the agents. Among a period of time between $[0, \tau]$, where 0 is the moment in which the agent emigrates and τ is that in which he stops working[4]; there might exist a moment ς such that the agent decides to move back. This decision depends on the social capital in the home country c^H compared to that in the destination one c^F[5], defined as the $\sum_{i=1}^{N(t)^k} w_i^k R_i^k$; where k=H, F; w_i is the weight of each link and R_i is the relevance of each link. The authors assume that at the moment 0 the migrating agent already has one contact abroad and then they define the utility function as $u(t) = u[c(t)^k]$. They also make an assumption regarding the risk aversion attitude of the agents, that is supposed time invariant. With reference to this assumption, some critiques might arise as it is reasonable to think that

[4]No retirement issue is considered

[5]H and F are respectively home and foreign country

once an emigrant gets confidence with the new environment, the perception of risk and insecurity diminishes.

Formally, as in this moment the decision of leaving is taken for granted, then at $t = 0$ the equality:

$$u[c(0)^H] < u[c(0)^F] + E(0) \tag{4.1}$$

must hold, where E(t), in equation 4.1 is the expectation about the experience abroad[6]. The expectation decreases proportionally to the risk aversion factor a, but on the other hand social capital in the foreign country tends to increase. The social capital in the home country, instead, tends to decrease. The interaction between these opposite effects will be one of the pillars of the decision making process. It has to be taken into account that political measures might be settled by the government to re-attract emigrated highly skilled workers, therefore the authors allow the home social capital to be brought back at its maximum level when these policies are implemented. In this framework the moment ς of the coming back, if it takes place, will be characterized by the inequality:

$$[c(\varsigma)^H] \gg u[c(\varsigma)^F + E(0) - r(a)_E \varsigma] \tag{4.2}$$

and therefore the equation:

$$\varsigma = \frac{u[c(\varsigma)^F] - u[c(\varsigma)^h] + E(0)}{r(a)_E} \tag{4.3}$$

will provide the contingent moment ς in which the emigrated highly skilled worker will come back.

The simulation model is implemented by first defining three groups for the social capital of each agent: family, friends and job colleagues[7]. For any member of these group a value $w_i > 0$ is assigned, and this value will be different for any group, for instance higher for family than for friends, but equal among the members of each group. The second step is assigning the relevance for any of the contact, randomly chosen in a interval [0,1]. Once these values are assigned it is possible to compute $c(0)^F$ and $u[c(0)^F]$. By assumption the agent already has one colleague in the destination country with a value of R less than the the most relevant colleague in the home country. The emigrant starts his career from the bottom of the pyramid and, depending on the people he/she gets to know in the company, he/she will improve or not his working situation. In this regards a critiques may arise, as it seems that improvements in the working situation are only due to the network relations. No relevance seems to be attributed to skills, knowledge or technical formation. While living in the destination country the agent will enlarge the net of friends and acquaintances and therefore $c(t)^F$ will increase. On the other hand the risk aversion, randomly extracted from the interval [0,1], will reduce the expectation abroad. Finally given that by the formulation of the model

[6] Positive value

[7] Job colleagues are organized in pyramid form

$E(0) = u[c(0)^H] + R_1^F$, the social capital and therefore the utility level of living abroad can be computed.

The authors have performed experiments by assigning different values of risk aversion and initial social capital at home, subsequently, they have derived that three result areas can be identified: return, non-return and a mixed area. A separation line with equation $a/E(0)$ is separating them and passing from the mixed area. It is indeed the ratio between the risk-aversion and the initial expectation towards the experience abroad. For high values of this ratio, the agent will surely end up in the returning area, while when the values of the ratio are considerably small, it is highly probable for him/her belonging to the non-returning area. With this regards, some interesting considerations have been made in terms of the time horizon. Indeed, the more the time horizon is enlarged, the higher the probability of agents coming back. Although this paper explicitly does not take into account any retirement issue, it would be interesting to compute how does the potential gain evolve with the increasing age of the coming back agents. Indeed, for instance, if a worker comes back after a thirty years working abroad, the contributions to the home economy will be reasonably smaller than those of another coming back after ten years, as he will spend less time working at home. On the other hand it is possible that the contribution of someone who has been living abroad more time, might be larger because of the wider human capital. Finally, a really interesting feature of the simulation model presented is its non-deterministic nature. Indeed, it has been shown through experiments performed by the authors, that even agents with the same endowment in terms of home social capital, risk aversion, expectations and a specified time horizon, may end up with diverse decisions by repeating the test. Note that this does not happen for extreme values of the separation line, but only for intermediate ones.

In Monteleone and Biondo (2010) the authors perform a similar analysis though confined to the Italian case and not agent based. The focus on returning migration is indeed very important within a profound analysis of the brain drain phenomenon. After the second wave of literature regarding this issue, indeed, brain drain has assumed a more imprecise role. The third wave of analysis in particular has identified many positive aspects of brain drain (Mountford, 1997). Although the author of this thesis does not completely agree with the possibility of brain drain being a positive phenomenon for source countries, it is duty of an objective analysis to report all the perspective available. In this viewpoint returning high-skilled migration fulfills the role of one of the major positive aspects of brain drain[8]. The reasons behind the decisions whether to return or not are various. Zweig (1997) has analyzed the Chinese brain drain after the opening for academics to go abroad, achieve skills and competences and come back. Many of the academics who have left have never gone back. The author tries to identify the factors involved in this decision. Economic factors, such as the possibility to exercise a fitting

[8]For a matter of clarity, even in the perspective of the author of this paper, in presence of brain drain returning high-skilled migration is positive for the source country. What is in doubt here is the positivity of the high-skilled migration itself. Nor remittances, nor returning high-skilled workers can compensate the long term loss of human capital within a country.

job, that permits to make use of the personal skills and consequently perceive a higher salary is one of the main cause. Political stability in the source country has been found to be crucial as well. Family ties, such as weddings or offspring in the destination country are inversely related to the propensity to return. Finally, other aspects such as logistical support and opportunities for mobility play a core role in this decision. Returning is more likely to happen for richer source countries such as Eastern Europeans, Asian and Latin American countries, while the returning propensity is lower for poorer source countries as the African ones (Mayr and Peri, 2008). Among the European countries, Italy is one with a particularly low propensity to return especially related to emigrants in the academic and research sector, see Becker *et al.* (2004).

Chapter 5

Evidences of Brain Drain

Having a clear perception of the number of individuals involved in the brain drain phenomenon is useful for understanding the size and the significance of the issue under investigation. The following chapter is aimed at investigating the dynamics of the phenomenon in time, geography and sectorial distribution. As it has been explained, a necessary precondition for talking about brain drain as different from simple migratory flows, individuals involved need to have previously achieved highly specialized academic degrees. For this reason the following chapter is divided into two main sections. First section investigates the structure of the education systems of a large number of countries. The goal is to achieve a clear overview of the factors mainly influencing the human capital investment decision, such as tuition fees and student support, collecting evidences regarding graduation trends and probing the transition phase from education to the labor market. Second section, instead, is more focused on the evident migration flows, with an introductory part dedicated to migration flows in general and a concluding one summing up the dynamics of brain drain strictly.

5.1 Overview of the Education Systems

The data entailed in this research work mainly originate from the OECD indicators contained in OECD (2013). The record covers the educational framework from early schooling to tertiary education, together with various themes such as the evolving of education system settings, employment of human and financial resources in the learning institutions and how are wage premiums affected by the participation to the schooling system. The document, then, is a rich, clear and detailed overview of the educational system in a large number of countries. The publication, indeed, contains data regarding the 34 OECD countries, Brazil and the Russian Federation and the other G20 countries that do not participate to INES (Argentina, China, India, Indonesia, Saudi Arabia and South Africa). The data regarding Israeli are supplied by and under the responsibility of the concerned local authorities. Although the large coverage of the document, it is already clear that it does entail some limitation. As we will see at a later stage, a wide slice of the brain drain emigrants come from non-OECD countries, most of which are not

included in this study. The lack of data regarding educational systems in countries that play a protagonist role as source of high-skilled migration deeply bounds the outcomes achieved.

With regards to the amplitude of the analysis, though, it has to be mentioned the profoundity and vastness of the topics investigated. The coverage of the data encompasses the whole national educational system of the countries examined, although some lacking data limits the size of the analysis. All kinds of schooling are included, regardless of who sponsors them, the way they are delivered and to whom they are delivered (children, students, adults, foreigners, etc.). Vocational and technical training in the workplace is excluded, unless it consists of the combination of schooling and work-place apprenticeship. Courses for adults, which are primarily driven by leisure or personal enrichment are also excluded.

The categorization of the levels of education follows the International Standard Classification of Education (ISCED 1997), which is a statistic tool for developing analytical studies about education and which is made of six levels of education. Chart 5.1 reports this classification.

The data used are sensitive to changes in the duration of the graduation program, such as the Bologna system, which is gradually being implemented all around the European Union. Many countries distinguish between undergraduate and graduate programs, the data used in this document refer to first-degree graduates.

When the OECD average is used, it refers to an unweighted mean among the countries for which the data are available or can be estimated. Alternatively, the OECD total is computed as the weighted mean among the countries for which the data are available or can be estimated. Many times an EU21 average is presented. It is calculated as the unweighted mean of the data values of the 21 countries that are members of both the European Union and the OECD for which data are available or can be estimated. These 21 countries are Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, the Slovak Republic, Spain, Sweden and the United Kingdom.

5.1.1 Investment in Human Capital Determinants

It has been shown that especially according to the mainstream economic theory, individuals appear to have incentives for investing in education as this allows better working prospects and higher expected wages. These incentives have to compensate the disadvantage of postponing the entrance in the labor market, the perception of a salary and the consequent consumes. The comparison takes into account both direct and indirect costs and benefits of participating to a ISCED 5 or ISCED 6 education program compared to that of an ISCED 3 or ISCED 4. The benefits consist of the earning premiums and the unemployment effect, which is the higher probability of finding a job for high-qualified workers. Between the direct costs tuition fees are the most notable. Indirect costs entail many aspects, such as delayed wages, higher tax pressure and reduction in social provision given the higher income level of tertiary educated households.

ISCED classification	Terms used in this publication
ISCED 0	Pre-primary education. Minimum entry age of 3.
ISCED 1	Primary education. Entry age: between 5 and 7. Duration: 6 years.
ISCED 2	Lower secondary education. Entry follows primary education; duration is 3 years.
ISCED 3	Upper secondary education.Students are expected to have completed 9 years of education or lower secondary schooling before entry and are generally 15 or 16 years old.
ISCED 4	Post-secondary non-tertiary education.Duration usually the equivalent of between 6 months and 2 years of full-time study. Students tend to be older than those enrolled in upper secondary education.
ISCED 5	Tertiary education
ISCED 5A	Tertiary-type A education. Largely theory-based programs designed to provide sufficient qualifications for entry to advanced research programs and professions with high skill requirements. Duration at least 3 years full-time.
ISCED 5B	Tertiary-type B education Programs are typically shorter than those of tertiary-type A and focus on practical, technical or occupational skills for direct entry into the labor market. Minimum duration is two years full-time.
ISCED 6	Advanced research programs lead directly to the award of an advanced research qualification. The duration is 3 years, full-time,although the actual enrollment time is typically longer. Programs are devoted to advanced study and original research.

Table 5.1: International Standard Classification of Education

The opportunity costs are higher in countries where the salary after upper-secondary education is higher or where tertiary programs are longer. In almost every considered country the private benefit of attending a tertiary level course is larger than the one related to upper secondary or post-secondary non-tertiary education. Card (1999); Hartog *et al.* (1999) estimated that the rate of private rate of return to tertiary education lies around 6% to 10%. Indeed, the wage premium of a tertiary level attainment, is around the 60% of the income. Denmark, Sweden, Norway, Korea and New Zealand are exceptions. Gender inequalities persist, generally, indeed, the income premium is larger for men than women, except for Greece, Spain, Turkey and Portugal. International differences are very evident as well. The Czech Republic, Hungary, Poland and Slovenia are countries in which the differential is larger than the OECD average. This may depend on the low number of highly qualified individuals, which may have driven up their wages sharply.

Although not all the past economic literature completely agrees that education does have positive externalities (Venniker, 2000), the data show that not only does high level education entail a private premium, but it enhances social welfare. The larger expected tax revenues and the reduction in social contributions improve national economies. More, the numerous presence of highly skilled workers is more likely to allow for technological progress and, therefore, economic growth, see Moretti (2012) and Press (2013). This is clearly shown in figure 5.1[1], which represents both the private and social returns of a men investing in tertiary education. Across OECD countries, the average net public return for a man who completed tertiary education lies around the 100 000 USD and 60 000 USD for women, which are respectively three times and the double of the amount of public investment in their education. The public gain from tertiary educated people is increasing in the wage premiums. Indeed, the larger the income differentials, the more the salary of tertiary graduated individuals will fall in high income-tax brackets. Thus, highly qualified contributers will pay more and contribute more to the public benefit of tertiary education. This happens in particular in Austria, Germany, Hungary, Ireland, Italy, the Netherlands, Poland, Slovenia and the United States, countries where the wage differential is particularly large. In Scandinavian countries, where salaries are less varied, public benefit of education, in terms of increased fiscal contributions is less-likely to happen. The unemployment effect is less pronounced than the income effect when compared to the upper secondary non-tertiary education.

5.1.2 Direct Costs of Tertiary Education

From the considerations made above, it is clear that it is desirable for public institutions to extend the number of high-skilled graduates among the population both for fiscal reasons and for positive social externalities. The costs of education, both direct and indirect, are though holding back from achieving a University degree. Welfare payment schemes can encourage low-income students to further prosecute in their education. Asplund *et al.* (2008) state that *the influence of family background is working primarily*

[1] Available at: www.oecd.org/edu/eag.html

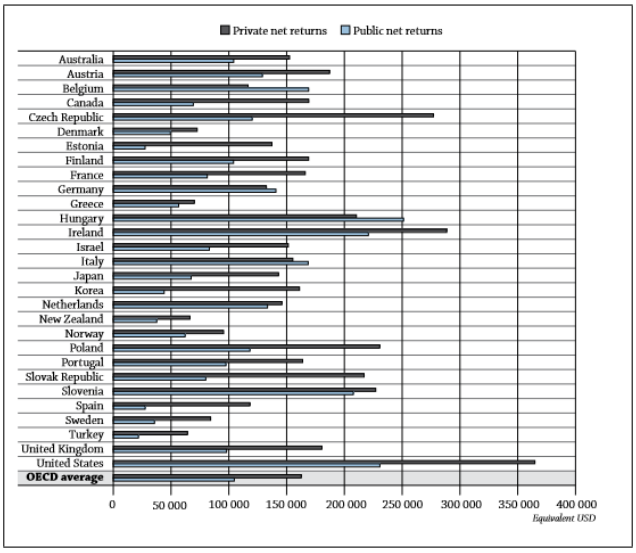

Figure 5.1: Net private and public returns associated with a man attaining tertiary education (2009) As compared with returns from upper secondary or post-secondary non-tertiary education Source: OECD

through early educational attainment and cognitive ability rather than having a direct impact on educational performance once enrolled and, hence, on subsequent labor market success. Although less favored in the enrolling decision, then, once in the University the schooling performance and the pace at which low-income students graduate is the same as the one of richer ones. On the other hand, disadvantaged families are constrained in the University choice and field of studies. It is harder, indeed, to find low-income students in prestigious institutions or fields. Even if it has been estimated that elasticity on tuition fees for attending University is low, low-income students are more price-responsive and therefore changes in the tuition fees or in the student supports have different implications for individuals coming from heterogeneous socio-economic conditions.

These considerations kill any discriminatory idea against universal studying right and works as one of many justifications for public intervention in enlarging access to education. On the contrary they evidence some still existing matter. Equity and redistributive issues must then be the core goals when outlining the financing sources for tertiary education.

The private cost of attaining education substantially varies among countries. Figure 5.2[2] shows the comparison between private and public investment for a woman who chooses to achieve a University title. The component of direct cost, which most notably are the tuition fees, is very large in countries as USA, UK and Netherlands, where it exceeds 100 000 USD. On the contrary it is very low in countries like Denmark, where the high-level schooling system is almost free of charge and a wide system of grants and subsidies is provided. The Danish grants system covers around the 40% of the

[2]Available at: www.oecd.org/edu/eag.html

total cost of tertiary education. The same line is applied also in other Scandinavian countries such as Sweden and Norway. Providing tertiary education at lower costs, indeed, may enhance the proportion of graduates and thus the number of those perceiving an higher salary in the future. On the contrary, it seems that those countries, where tertiary education is most expensive, see Australia, USA, Japan, Korea and UK, do not usually rely on grants but rather on student loans. Loans differ from grants as they must inherently be repaid after the graduation. Even if they are regulated in terms of repayment time and interest rate, they decrease the financial benefit of education. The purpose of these two financial support instrument is the same, as they both aim at allowing more disadvantaged households to participate to high levels of education.

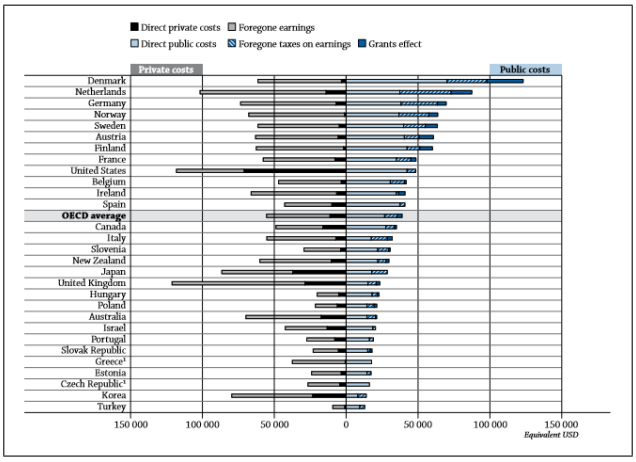

Figure 5.2: Public versus private costs for a woman attaining tertiary education (2009) As compared with returns from upper secondary or post-secondary non-tertiary education. Source: OECD

In figure 5.3[3] it is possible to notice the large differences that exist between the various OECD countries under investigation. The vertical axis shows the due tuition fees, while the horizontal axis shows the percentage of students enjoying some form of subsidy. The arrows show the direction in which the proportion of students receiving public aid is changed since 1995. It is clear that Scandinavian countries, notably Sweden, Norway, Denmark and Finland, are very student-friendly. Not only do they provide free-of charge tertiary education, but governments also largely invest in students' support of side-expenses, such as rents and other costs, with a wide system of economic support. In the upper right cluster of the graph are represented the countries, where the cost of tertiary education is particularly high, such as USA, UK, Australia, New Zealand and the Netherlands. The proportion of students receiving financial aid is very large, but as already said, mostly this support is made of student loans. The lower left cluster is mostly made of European countries where University fees are not so high and where the level of students public financial aid is very low.

[3] www.oecd.org/edu/eag.html

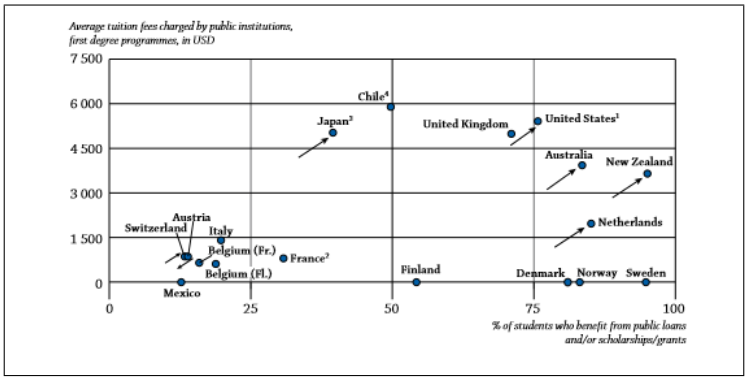

Figure 5.3: Relationship between average tuition fees charged by public institutions and proportion of students who benefit from public loans and/or scholarships/grants in tertiary-type A education (2011) For full-time national students, in USD converted using PPPs for GDP, academic year 2010-11. Source: OECD

Different financial aid instruments produce different outcomes and the correct mix of student loans and grants is under investigation. Tax reductions and tax credits are not considered in this analysis. Barr (1993) affirms that *loans from both an efficiency and an equity perspective, are the key to reform.* Supporters of loans generally assert that if the money devoted to grants would be spent in student loans instead, it would benefit much more potential students. Money for grants, indeed, are "lost", while those invested in loans will be paid back. Moreover loans shift some of the cost of provision to whom benefits from it the most, that is the individual student. Salmi (1999) asserts that student loans are an efficient tool for equity and generating opportunities especially for those with low-incomes. Moreover, as generally the conditions of assignation of a student loan are connected to the outcomes in the academy, they allow for an additional control of the quality of the institution generating a sort of meritocracy for the fundings. On the other hand, in the same paper, the author states that loans still entail some drawback. Indeed, they are all along financial instruments. They respond to the financial conditions for viability and this aspect seems to be rival to the primary purpose of generating equity. Furthermore, these instruments become more and more complex in times of economic vulnerability and high fluctuations, in which it becomes harder for *a priori* evaluating the future cost of the loan and eventually repay it. Opponents of student loans also argue that as loans have to be repaid, together with administration and servicing costs, they decrease the expected benefits of tertiary education achievements and, therefore, they are less effective than grants in encouraging University education.

OECD countries spend an average of about 22% of their public budgets for tertiary education on support to households and other private entities. Figure 5.4[4] shows the differences of investments among the OECD countries and also the several combinations of various financial tools. It is clear that there is no uniform strategy. More than one

[4]Available at: www.oecd.org/edu/eag.html

third of the countries for which the data are available only relies on grants and transfers to institutions. Some others, like Iceland and Japan, only rely on student loans. Others, finally, use mixes of the available tools. It is interesting to note that the countries in which student loans are offered are the places where support to students accounts for the largest slice of public expense in tertiary education. From figure 5.5[5], indeed, it is possible to deduce the public investment in education of the countries under investigation. The larger the public investment, the lower the direct private cost for the household. Note that direct costs account for around one fifth of the total cost of education. On average across the OECD countries, public investment in an individual's tertiary education is around 39 000 USD and it is highest in Austria, Denmark, Germany, the Netherlands, Norway and Sweden as it is clear from figure 5.5[6]. The cost of education in most of OECD countries largely levies on the public sector. On average among OECD countries the households pay around the 30% of the total cost of education. Only in some countries, like Australia, Japan, Korea, the United Kingdom and the United States, do privates pay more than half of the total burden. Countries that offer particularly large aids are Denmark, Finland, Sweden, Austria and the Netherlands. It does not appear to exist any relation between the size of the University costs and the amount of aids offered.

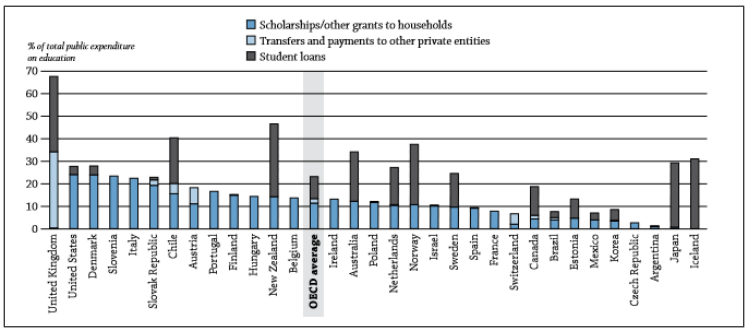

Figure 5.4: Public support for tertiary education (2010) Public support for education to households and other private entities as a percentage of total public expenditure on tertiary education, by type of subsidy Source: OECD. Argentina: UNESCO Institute for Statistics (World Education Indicators Programme)

The core issue for nations is balancing the financial support to the institutions provided by tuition fees and keeping equity of access and opportunities especially for those coming from low-income-affluent families. Tuition fees, indeed, are notably one of the main sources of financing for Universities, although in many countries they only represent a small percentage of the total cost of providing education. On the other hand, high tuition fees may harm the possibility for many households of taking part to tertiary education programs. Systems of public grants and economic aid provided by the public may entail a solution for this issue, being significant source of equity in the pro-

[5]Available at:www.oecd.org/edu/eag.html
[6]Available at:www.oecd.org/edu/eag.html

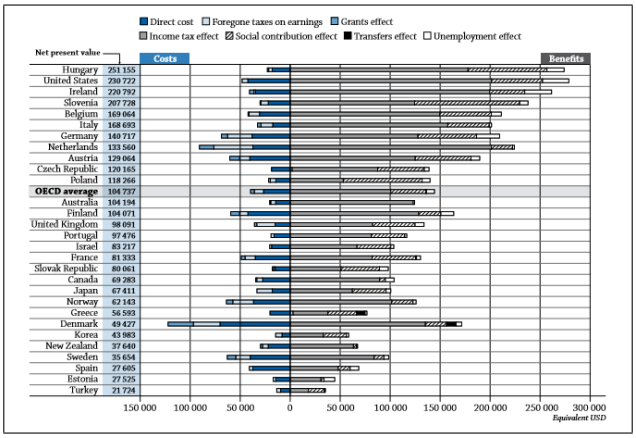

Figure 5.5: Private costs and benefits for a man and for a woman attaining upper secondary or post-secondary non tertiary education (2009) As compared with returns from below upper secondary education. Source: OECD

vision of public education. Figure 5.6[7] shows the annual amount of tuition fees required in the countries at the expenses of privates for participating to ISCED 5A education programs. More, it shows which percentage of the total cost of provision it represents. Lowering tuition fees may entail some drawback with reference to the quality of the institutions. Indeed, with special reference to the last period of economic crisis, it might become harder for countries to keep on providing low-cost education and vast systems of grants. Still low-cost education accompanied by welfare aid is a strong instrument for going towards equality. Among the investigated countries, Poland, Denmark, Finland, Iceland, Mexico, Norway, Slovenia and Sweden provide free of charge education. Other European countries generally charge only low tuition fees lower than 1500 USD. Tuition fees appear to be quite constant for most of the countries for first and second degrees, exemptions made for Australia, Chile, Ireland, New Zealand and the United Kingdom. Turkey is the only country where fees for second degree programs are lower than for the first.

In many countries tuition fees differ for national and international students. Generally grants systems are applied to all those studying in the national institution. On the contrary it is common for many OECD countries to charge higher tuition fees for foreign students. This trend may have strong impacts on the decision of where to study. In Austria, Canada, Denmark, Ireland, the Netherlands, New Zealand (except for foreign doctoral students), Poland, the Slovak Republic, Slovenia, Sweden, Switzerland, Turkey, the United Kingdom and the United States tuition fees for non-national (or non-EU) students are almost the double than those for local students. In Australia foreign students are not eligible for financial support.

Around half of the countries under investigation modify tuition fees according to the field of education. The ratios behind this differentiation might be various. The gap

[7] Available at: www.oecd.org/edu/eag.html

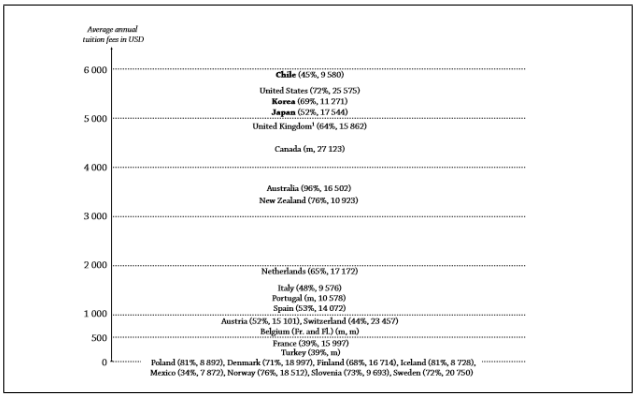

Figure 5.6: Average annual tuition fees charged by tertiary-type A public institutions for full-time national students (2011) Converted in USD using PPPs for GDP, academic year 2010-11 Source: OECD

may depend on the cost of providing a particular type of education, as it is for instance in Ireland, UK and New Zealand. Here fields as health-care and agriculture are more expensive than business, law or social science as they require the use of costly machineries and plants. Another reason might be the importance attributed by the country to the field of study. In Australia tuition fees differ with regards to the demand of the labor market and the shortage of specific skills.

As to conclude the description of the funding education system strategies within the countries under investigation, chart 5.2 presents four models that summarize the different schemes applied for sharing the cost of tertiary education among governments, students and their families and other private entities.

5.1.3 Evidence of Tertiary Education Dynamics

As a precondition for the brain drain is the achievement of at least a master degree. It is thus necessary to spend some words with regards to the actual diffusion of tertiary education. We have already talked about the cost of investing in human capital formation in the previous section. As we have seen *in itinere*, most of the mainstream economics sees the decision to achieve an academic education as a pure comparison of utilities, where the costs of education, both direct and indirect, and the expected salary play a core role. Education, indeed, is often used in economics as an indicator and a signal of the underlying inscrutable human capital. Commonly, higher level of educational attainments lead to higher income levels, as the skills and capabilities obtained in the educational process are often evaluated as a higher human capital and therefore a larger productivity. Still, obviously, many exemptions exist and many other factors are drivers of labor income.

Currently, the economies have moved from being mass-based production to knowledge-based, allowing for new discoveries, innovations and, possibly, progress. The demand for high skill individuals is still higher than its provision and therefore their wages are

Model 1	Countries with no or low tuition fees and generous student support systems. Nordic Countries such as Denmark, Finland, Iceland, Norway and Sweden. They have more progressive tax systems. ISCED 5A students pay no tuition fees and they enjoy a a generous public support and a large amount of public grants. Citizens pay higher tax rates. The entry rate for tertiary level students is 75%. The underlying idea to this approach is equality in opportunities and the fact that access to tertiary education is a right rather than a privilege. Note, in the last years, Denmark and Sweden introduced tuition fees for international students
Model 2	Countries with high tuition fees and well-developed student-support systems. Australia, Canada, the Netherlands, New Zealand, the United Kingdom and the United States. High costs for tertiary type A education but large public support. Private entities contribute the most to finance tertiary institutions. The entry rate for tertiary level students is 76%. Tuition fees are higher than 1500 USD per year, but 75% of the students receive public support. The public investment in tertiary education is higher than the OECD average. These nations spend more on core services per tertiary student and have a relatively high level of revenue from income tax as a percentage of GDP, compared to the OECD average. This system is seen as a good way to increase access to tertiary education, although in periods of crisis it imposes a significant burden especially on more disadvantaged households.
Model 3	Countries with high tuition fees but less-developed student support systems. Chile, Japan and Korea. Tuition fees are on average higher than 4500 USD. Student support system are not well-developed. Generally entry rates are below the OECD average of 60%, exemption made for Korea (69%). These are the countries that spend the less on student public support. It has to be mentioned that the latest reforms are moving these countries towards model 2.
Model 4	Countries with low tuition fees and less-developed student-support systems. All others European countries for which data are available and Mexico. Tuition fees are moderate, generally lower than 1300 USD per year. Around 40% of students benefits from public support. Tertiary institutions heavily depend on the state for funding. The entry rate for tertiary level students is around 56%. Students may enjoy support from other institutions other than the state, which is not covered in this analysis. Student loans are only very limitedly available. Public spending and tax revenues from income as a percentage of GDP changes significantly among this group compared to other groups. Data regarding this model seem to show that low tuition fees do not necessarily encourage University participation.

Table 5.2: Models of tertiary education financing

higher. A wide proportion of high-skilled individuals should be desirable by any public institution of any country. For this reason the trend is enlarging the access to tertiary education and the delivery means exploited. More, in order for a better integration between education and labor market, many countries have launched educational programs such as the vocational education and training (VET), which aligns the tertiary level achievements to market demand by allowing people to study for specific technical jobs.

Note that during the economic crisis, the so-called austerity measures and the contraction in public expenditure have seriously damaged the engine of public education in many states. Despite this last aspect, figure 5.7[8] shows that the rate of households attaining a University title is increasing. From 2000 on, indeed, the number of individuals between 25-34 who has accomplished a tertiary education program is often larger than those with an age rate between 25-64. The average tertiary attainment rate is increased by 10%. Upper secondary school (ISCED 3) has become the standard level for young people.

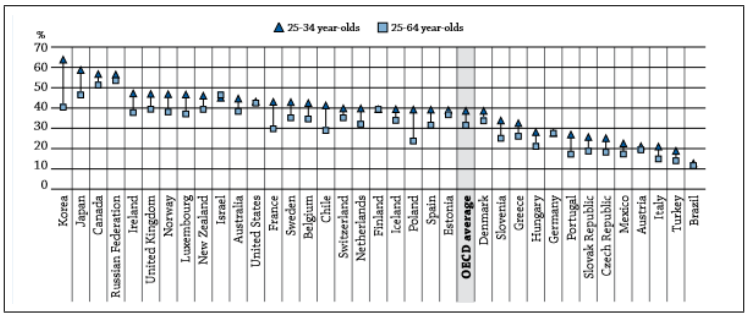

Figure 5.7: Population that has attained tertiary education (2011)-Percentage by age group. Source: OECD

Even if increasing, the proportion of households participating to tertiary education levels is still around an OECD average of 33% for women and 30% for men. As mentioned, this proportion depends both on the difficulties encountered while facing highly demanding courses, tuition fees and related loans, which may discourage the participation to highly specialized education, finally the opportunity cost of postponing the entrance in the labor market and delaying the wage. Figure 5.8[9] shows a representation of the OECD countries, with reference to the achievement of tertiary education and the difference attainment rates between younger and older age ranges. The vertical axis from the bottom to the top shows whether there is an intergenerational educational attainment gap. The horizontal axis, instead, compares the proportion of the households with tertiary attainment to the OECD average.

It is clear the deep heterogeneity within different countries. Only in Ireland, Spain and UK attainment rates for tertiary education are higher than those for the secondary one. In Austria, the Czech Republic, Germany, Poland, the Slovak Republic and Slove-

[8] Availbale at: www.oecd.org/edu/eag.html
[9] Available at: www.oecd.org/edu/eag.html

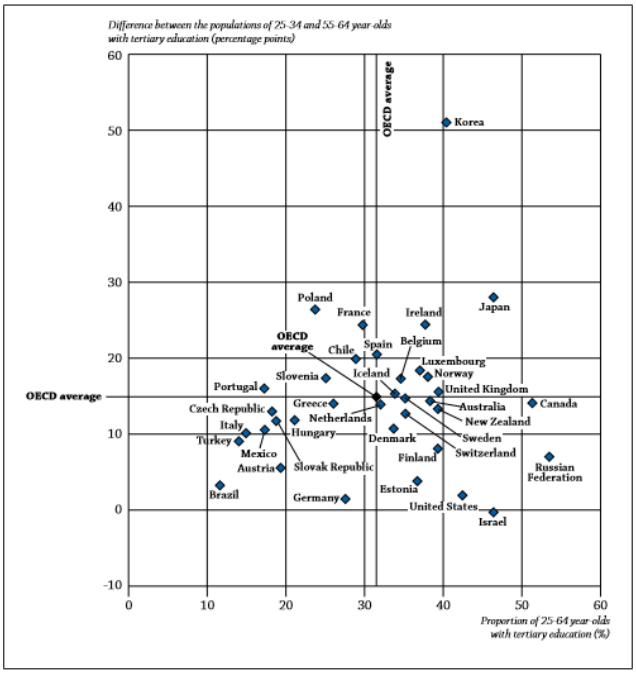

Figure 5.8: Proportion of population with tertiary education and difference in attainment between 25-34 and 55-64 year-olds (2011). Source: OECD

nia, more than half of the total population has gained an upper secondary or post-secondary non-tertiary VET qualification as the highest level of attainment. Italy, Portugal and Spain are the sole EU countries where the number of individuals with only below upper secondary education is larger than those with upper secondary or with tertiary degrees.

Gender inequalities still resist in educational attainments, employment rates and wage levels, although narrowing and sometimes reversing. Controlling for gender, indeed, the data show that the growth in ISCED 5A graduation rates has been sharper for women in several OECD countries rather than for men. Countries like Czech Republic, the Slovak Republic and Slovenia have seen increases of around 25 percentage points or more from 2005 to 2011. With some exemptions, at PHD level, the graduation rate of women is slightly lower (0.1%) than that of men. The attainment rate of tertiary education for women has significantly increased and it is currently larger than that of men. The situation changes if age ranges are taken into consideration. Indeed, if the analysis of younger people shows the just mentioned trend, the proportion of men in a age range of 55-64 years holding a highly specialized title is larger than that of women in the same interval. Figure 5.9[10] shows the portrait of the differential in attainment rates between age ranges for both men and women. The trend is clear. The increase of younger women studying is much larger than that of men when compared to older generations.

[10] Available at: www.oecd.org/edu/eag.html

Moreover, in almost every country, this indicator is positive. Some exemptions are depicted, such as Israel, USA and Germany. Note that talking about this last European country, it is necessary to underline that VET qualifications are excluded from this graph and the diminishing tendency might be biased by the strong presence of these courses in the country under investigation.

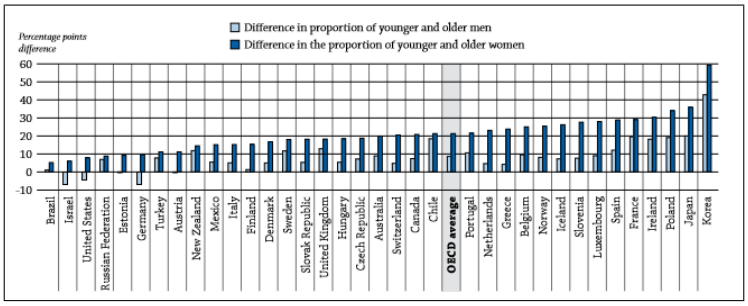

Figure 5.9: Difference in the proportion of younger and older adults with tertiary education (2011). Percentage points difference by age group (25-34 and 55-64 years old) and gender. Source: OECD.

Since 1997, the proportion of graduated in ISCED 5A has risen of 20% while that of ISCED 5B has remained stable. In every country for which comparable data are available, the proportion of households graduating from an ISCED 5A course has increased significantly. Currently, among the countries taken into consideration, the average is around 39% of young people graduating from a bachelor program and 17% from a master degree program. The introduction of the Bologna process has emphasized this positive trend. The shortening of the degree programs, indeed, has allowed a sharp increase in the graduation rate in countries like the Czech Republic, Finland and the Slovack Republic between 2004 and 2008. Significant differences may arise among countries. For instance in Belgium the average is much lower, around 25% for first degree programs. On the contrary, this differential is compensated by the strong presence of ISCED 5B programs. Tertiary type B education programs follow a different trend. The OECD average has remained constant during the years under questioning around the 11%. Nevertheless, the situation strongly differs among different countries. While in Spain the introduction of innovative advanced VET programs has enhanced the proportion of ISCED 5B graduates, the opposite has occurred in Finland with the complete suppression of the VET educational curricula.

PHD programs, ISCED 6, only represent a small part of tertiary education, currently the 1.6%, but this proportion has doubled in the last 17 years.

The issue of international students is relevant as well. This term refers to individuals who have moved abroad expressly for studying. They are considered first-degree graduates in the destination country, regardless of the education they have received in the origin one. They fulfill a core point, as the graduation rate of countries with a high percentage of international students is artificially inflated. When removing international students from the aggregate data, the proportion of graduates decreases dramatically.

This issue is particularly felt in tertiary education. The size of the issue, indeed, is increasing in the degree of specialization of the course. In the UK, for instance, the proportion of first-degree graduated decreases of around 10% and that of masters' degree graduated of around 12% when subtracting international students. The issue of international students is particularly felt also within PHD programs, the highest educational entitlement. In 2011 the PHD graduates have been the 1.6% of young people on average across OECD countries, with an increase of 0.6% since 2000. Countries with the highest increase in advanced research graduation rates are Denmark, Ireland, New Zealand, the Slovak Republic and the United Kingdom. China had a graduation rate of 2.2

The graduation age for the bachelor degree lays around an average of 27 years and 35 for PHD programs, but strong differences among countries exist. These may be linked to structural factors, such as the length of secondary and tertiary education programs, the compulsoriness of the military service or the lack of adequate funding systems, which may force students to simultaneously working, leading to a delayed graduation time. Moreover, the postponing of the graduation time, may be linked to the will of retarding the entrance in an insecure and non-favorable working environment. Sure is that the high graduating age and the increasing number of University students entail a significant social change. Policy makers should mind that the increasing and enlarging age of students involves the necessity of suitable financing instruments and services.

5.1.4 Educational attainment and the participation to labor market

The comparison of labor conditions among people with different educational attainments seems to shore up what has been mentioned before, that is households do have strong incentives in investing in education as this improves the working prospects. Figure 5.10[11] clearly shows that there is a significant difference in the employment rate when comparing graduates to individuals who only attained secondary school degrees. Schooling, indeed, is often used as a signal of individuals' abilities and skills. The employment rate shows the matching of human capital among the society to what is demanded on the labor market. The rapid technological progress of recent years has strongly damaged the contractual force of the low-qualified workers, indeed, those are more likely to find their jobs having been automated. Furthermore, the economic crisis has seriously contracted the employment rates of most of the OECD countries, hitting harder low-skilled workers than high-skilled ones. In the last fifteen years, indeed, the rate of unemployment has always been lower for those with higher educational attainments. Moreover, in the recent years this gap is widening. Forgetting inter-national differences, in average among all the OECD countries in 2011 the unemployment level was around 12.6% for adults with ISCED 2 education, 7.3% for adults with ISCED 3 degree and, finally, 4.8% for those with ISCED 5 or ISCED 6 titles.

The crisis has surely modified the relation between the educational system and the labor market. From 2008 to 2011 the unemployment rate grew in almost every OECD country apart from Germany, with peaks in countries such as Spain and Greece. In par-

[11] Available at: www.oecd.org/edu/eag.html

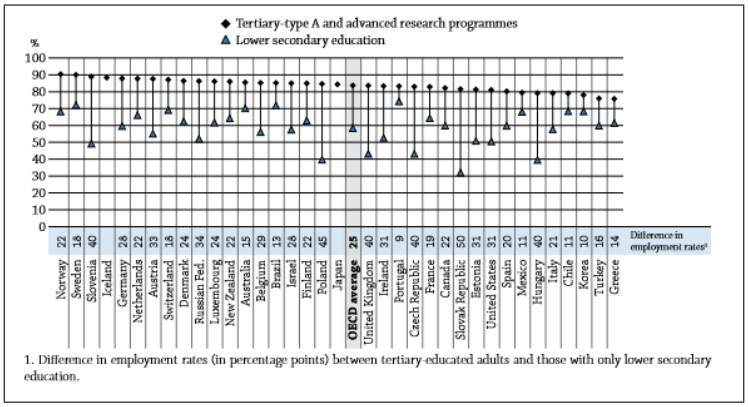

Figure 5.10: Employment rates among 25-64 year-olds, by educational attainment (2011). Source: OECD.

ticular, in these years the unemployment rate has expanded of about 3.8% for ISCED 2, 2.4% for ISCED 3 and 1.5% for ISCED 5 and ISCED 6 graduates. The unemployment rate of low-qualified workers increased faster for men than for women. Moreover unemployment rates have shown a bigger variation among younger than older cohorts, in particular on OECD average between 2008 and 2011 the mutation has been respectively 5% compared to 3%.

A generational gap exists as well with higher unemployment rates for younger generations, especially if low-skilled. Across OECD countries, the gap, indeed, passed from 9.3% for ISCED 2 to 3.1% for ISCED 3 and 2.8% for ISCED 5 and ISCED 6 entitled. More, the probability of working full-time is much higher for those with a tertiary level of education (75%) than for those with upper secondary education (71%) and those with below upper secondary education (64%). A gender issue affects the probability of working full time, which is higher for men (80%) than for women (60%) in almost any country under examination. Inter-generational differences exist within this aspect as well. In the case of men, the proportion of younger households working full time is generally higher than that of older ones. In the case of women, instead, this tendency is not so evident, often are older cohorts which are more probably working full time. This fact may depend on the childhood care services offered in the country.

It is clear, then, that gender inequalities persist. Across OECD countries and education levels, only 65% of women are employed compared with 80% of men. The gender gap in employment is negatively related to the educational attainment. Although the gender gap decreases while increasing education, even in tertiary education level, the proportion of employed women keeps on being much lower than that of men even though since 2011 the number of graduated women is larger than that of men.

Finally, VET programs have higher probability of employment (76%) than general ones (70%). Indeed these programs are often performed in cooperation between the educational institutions and employers, reducing the on-the-job training necessities for the new hired. These curricula are especially designed for creating experts and specialized

professional figures that can easily find a fitting position in the labor market. Countries like Germany, where the VET system is particularly significant could better respond to the increasing unemployment rate of young people. On the other hand, VET programs entail a meaningful drawback. The high degree of specialization implies them not to easily adapt to a changing environment. Moreover, the VET are more complicated than other titles to be included in data analysis, as the differences among countries with regards to these programs are significant. Some countries, for instance, include them in ISCED 5 programs, while in other cases they belong to ISCED 3 or ISCED 4 categories.

5.1.5 Extra earnings from educational attainments

In figure 5.11[12] it is clear that increasing the educational attainment the income level grows. By normalizing the income level of upper secondary graduated, the figure shows how do the levels of income for ISCED 5 and ISCED 6 differ from those of ISCED 2 graduates across different countries. With reference to EU countries, the largest differential is shown in Slovenia and Ireland, while the variation is much lower in countries as Sweden, Denmark and Belgium. On average, the relative earnings for tertiary-educated adults is over 1.5 times that for adults with upper secondary or post-secondary non-tertiary education. Earning differentials between individuals with below and upper secondary education strongly vary across countries, passing from 15% of difference in countries such as Germany, Belgium and Ireland, to more than 35% in the USA and Greece.

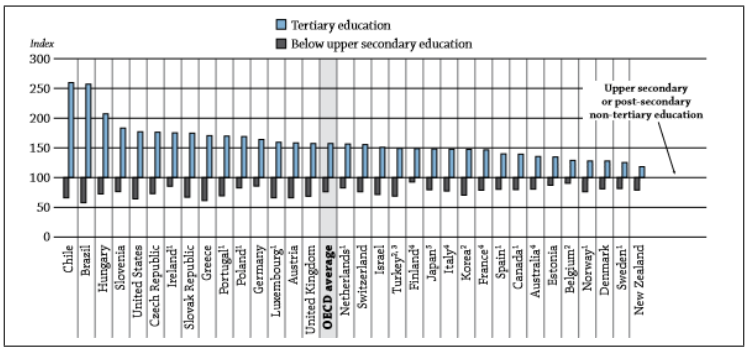

Figure 5.11: Relative earnings of 25-64 year-old workers, by educational attainment (2011). Upper secondary or post-secondary non-tertiary education = 100. Source: OECD.

More, labor earnings are increasing in age for high educational attainments and vice-versa. This implies that two individuals, one with ISCED 6 and one with ISCED 2 qualifications, not only will start with different incomes, but the gap is deemed to become even larger with the time. Note that the income level also depends on the chosen field of education (Carnevale *et al.*, 2012).

Finally, there is an income gap between different genders. In particular, among

[12] Available at: www.oecd.org/edu/eag.html

OECD countries, the larger gap is between individuals with tertiary educational attainments. In Austria, Belgium, Finland, new Zealand, Slovenia and Spain tertiary-educated women earn about 75% or more of what tertiary-educated men earn, a proportion that decreases to 65% when talking about Brazil, Chile and Estonia. As they grow older, women enjoy less the income increase, indeed, when they are in an age range between 55-64 years old they can expect to earn only the 72% for ISCED 5 or ISCED 6 graduated and the 74% for ISCED 3 graduated of what men earn. Finally, only upper-secondary level educated women can expect a relative increase in wage compared with that of equivalent men, while for tertiary or below secondary educated women no relative increase is expected.

5.1.6 The passage from education to the labor market

Perkin (1996) states that the current is a *professional society*, individuals are expected to gain *knowledge, skills and competences* potentially relevant for entering the labor market. Education acquires *training* characteristics, that is it tries to supply to the needs of society. Also, the educational setting places a sort of meritocratic role, granting improving working conditions to those who have invested more in education (Teichler *et al.*, 1980). In this perspective, there is a sort of exchange between the society and the educational system, in which the latter ensures high-skilled and competent professionals employed in the most demanding and important tasks, and the former grants to those who have invested for becoming such a core pillar within the society more favorable working conditions in terms of status, income, etc. Ideally, in the mainstream view, it would be so. In reality there is no perfect match between the notions achieved while taking part to the educative process, no grant that investment in human capital is rewarded as it should or that meritocracy is the sole determinant of the labor market settlement. In Teichler (2002) the author presents the outcomes of a survey conducted in 1999 called *Higher education and Graduate Employment in Europe*, which although timeworn, presents some evidences of the just mentioned malfunctioning of the transition from education to the labor market. Some trends identified within this paper are still extant, for instance the presence of involuntary part-time jobs, precarious working conditions, gender inequalities and non-uniform trends around Europe, with the southern countries being lagged.

Moving from the schooling system to the labor market is a phase dependent on many and various factors. The quality of education, the demographic and the economic conditions play an important role in the transition from schooling to the working environment. Governments have largely invested and acted in order to increase the proportion of students, which is indeed grown from 2000 to 2011 from 41% to 47%. Note that this trend is starting to reverse in many countries, especially those affected harder by the crisis. On the contrary, within the same period, the proportion of young people in employment is decreased. Mostly two periods have sentenced the largest drops: the internet bubble between 2000-2003 and the real estate bubble in 2008.

Other factors affecting unemployment are the demographic conditions and local traditions, for instance in some countries it is common for women to raise families full-time.

The findings of *Education at a glance 2013* suggest that on OECD average in 2011 within the 15-29 years old 47% is occupied in achieving educational attainments, the remaining 53% is divided between a 37% employed, 7% unemployed and 9% outside the labor force.

The NEET, nor in education nor training people, is remained stable around the 15%. A wide proportion of NEETs individuals reveals an economic breakdown and it can constitute a signal of the inefficiency of the pathways from schooling to working. In some countries in particular, NEETs are a matter of concern for the governments, as these people are more likely to be part of the submerged economy, that is nor taxed nor secured. More, individuals in the NEET category are less-likely to be re-integrated in the labor market. This increases the probability of long-term negative effects, such as the reduced probability of finding a job and improving earning prospects, loss of human capital and even mental diseases such as depression, which have been proven to be connected with situations of unemployment (OECD, 2008). During the recent economic crisis, the proportion of NEETs boosted, mostly because unemployment among young people and low-skilled workers increased sharply. Differently from unemployed, who will probably be re-integrated when the economy recovers, it will be harder for governments to re-integrate those who are out of the labor force completely.

Due to the adverse economic conditions, the proportion of employed has decreased dramatically, as it moved from 44% in 2000 to 41% in 2008. The effects of the economic crisis have been felt differently within different age-ranges. Indeed, the youngest cohort, between 15-19 years old has seen a decrease in employment of 2% compensated by an increase of individuals in education of the same amount. The older cohort, instead, has seen a decrease in employment of 2% compensated by a 1% increase in education and by a 3% increase in NEETs.

Countries that offer VET programs have suffered less of young unemployment. In particular these are Australia, Austria, Belgium, the Czech Republic, Germany, Italy, the Slovak Republic, Switzerland and the United Kingdom, although participation in these programs is less-affluent in Belgium and Italy.

The analysts have estimated the expected studying years for a typical 15 years-old, who is appraised to spend 7.1 more years in education. This amount is increased from 2007 (6.8 years) probably because the less favorable economic conditions induce young households to stay longer in education. More, the analyzed archetype was expected to hold a job for 5.6 years, be unemployed for 1 and to be out of the labor force for 1.4 years before turning 30. Note that for women, the probability of being out of the labor force, which is nor to be student, nor employed, nor seeking for a job, is much larger (1.9 years) than for men (0.9 years).

The issue of part-time jobs is important to be talked about, as a large slice, more than half in fifteen OECD countries, is involuntary. High percentages suggest that is hard for households to find a full-time job and employment is precarious. CEDEFOP (2012) states that in the EU countries *compared to 2008, the share of young people who work part-time although they would like to have a full-time job increased in all EU countries except for Germany, where it remained at a similar level.* This proportion

strongly varies among different countries, passing from 10% in the Czech Republic, Estonia, Korea, New Zealand and Switzerland, to almost 60% in Chile and Spain, 70% in Italy, and more than 80% in Poland. The proportion of part-time workers decreases as the educational attainments increase, as does also the relative percentage of involuntary part-time. The gender gap in part-time working is very significant. In 2011 on average across the 34 OECD countries 15-29 year-old women were more likely (6%) to have part-time jobs than men (3%). The relative proportion of involuntary part-time work, instead, is higher for men than for women.

Finally the analysis confirms that education rewards when looking for a job. Indeed, on OECD average in 2011, the proportion of unemployed among individuals between 15-29 years old was 14% between those with education levels less than ISCED 3, 8% among those with ISCED 3 qualifications and 6% among those with ISCED 5 or ISCED 6 educational attainments. As it has become the norm in most OECD countries to complete ISCED 3 levels of education, those who do not achieve this entitlement are less-favored when they enter the labor market. Indeed, in Ireland, the Slovak Republic and Spain, at least 25% of 25-29 year-olds who did not achieve an upper secondary school entitlement enter the NEET category. Moreover, the bearing of long term unemployment is negatively related to educational attainments.

5.2 Brain Drain Evidence

It is hard to get data regarding the brain drain issue as educational categories have not always been uniformly and clearly defined and because the protagonists of this process are changing and mutant and, thus, hard to identify (Commander *et al.*, 2004). Carrington and Detragiache (1998), although with many limitations, provides a snap-shot of the size of the high-skilled migrations. It is a common opinion that the brain drain has increased in size since the 1990s (Salt, 1997). Much attention has been attributed to the change of the interested sectors. For instance, around the 1960s and 1970s, the cornerstone of high-skilled migration pivoted around the migration of doctors, nurses and teachers from the less-developed countries. Although the migration of doctors is still an issue, as it is confirmed by the large percentages of foreign doctors in many OECD countries, skilled emigration has become far more diversified in terms of sectoral characteristics. In particular, in the 1990s the main sector involved was that of information and communication.

In Dobson *et al.* (2005) the authors perform an analysis of inflows and outflows of professional workers within the Australian case, hereinafter they infer that *Australia has experienced a substantial net gain of skilled persons from international movements.* The concern of those, especially academics, worried for the increase of outflows of highly-skilled individuals is justified by the fact that an high-skilled individuals diaspora has really taken place, this outflow though, is more than balanced out by the incoming specialized settlers or long-term visitors facilitated by the recent more favorable immigration policies. The same research paper reports some interesting lines regarding the European situation. In particular they affirm that *in 2002, six Europeans Nobel laureates*

demanded EU action to stem the brain drain to the US, demanding that research funds be doubled. They claimed that the EU's target to increase research funds from 2% to 3% of GDP by 2010 was inadequate (Hagan, 2002). The Ministry of Germany for Education and Research at that time denied though the significance of brain drain as a core issue (Stafford, 2003), indeed, Germany and France in 2004 started recruiting science students from other countries due to become EU members. It seems for instance that 70% Bulgarian science undergraduates were considering moving out after graduation (Scott, 2004). It seems also, from a survey of the German Research Foundation (DFG) fellowship recipients conducted in 2002/2003, that the majority, around 85%, returned home (Stafford, 2004a,b). It is clear, then, that if most German scientists return home and foreign ones are attracted from elsewhere, Germany does not have any brain drain issue, but it does, perhaps, have even a brain gain.

Differently from these first two examples that do not seem to suffer the brain drain issue, the phenomenon is still a relevant factor of the current global socio-economic situation. An important source for achieving brain drain evidences, which are in turn useful and necessary to implement well designed and bright migration policies, is OECD and UN (2013). From this document it is possible to gather an overview of the global migration flows and later narrowing the focus to high-skilled migration only. Perceiving the overall migration flows situation, indeed, is useful for better contextualizing the brain drain phenomenon as well.

In Westmore (2014) the author investigates the reasons behind migration flows, also he suggests that policy measures and increasing income in countries source of emigration might reduce the flows in the next decades. He states that *high (low) skilled migration appears to respond to developments in differentials at the upper (lower) end of the wage distribution.* Also, in the paper he confirms the past-literature outcome, that migration flows have a U-relationship shape with the economic development of the source country. This is to say that people from middle-income countries are more likely to emigrate because they do not face the budget constraints of extremely low-income country and, on the other hand, they do not have the same earning opportunities as in the high-income ones. It is possible, then, for some countries to see an increasing emigration even if the income level within the source country is increasing. Other influent factors in the emigration process are the so called *gravity factors.* Intuitively and confirmed by the empirical analysis shared borders, common languages and colonial relationships are positively connected to the migration flows. Adams Jr (2003) highlights how does proximity to OECD countries increase the size of high-skilled migration. Aging is negatively connected to migration flows (Hatton and Williamson, 2011; Bauer *et al.*, 1999), also because especially more developed countries are being more liberal with regards to young immigration as to face the aging problem of native population. Migration flows are driven as well by tax and benefits systems. Mytna Kurekova (2011) states that *countries with less generous welfare states have significantly higher shares of their workers leaving to work abroad.* On the political setting, it is to say that high levels of business regulation are negatively related to incoming flows of both high and low skilled immigrants, although there exists a contradictory effect. Significant business regulations

means on one side the country being more rigid and static, on the other hand a clear and serious regulation is symptomatic of a sane country in which institutions are credible. The labor market regulation is controversial as well, its effect indeed largely depend on the type of regulation and the migrants' skill level. That being said, the author concludes with a projection of the future migration flows up to 2060. Considering that the OECD projections for GDP in the developing countries foresee a convergence between the GDP per-capita of developing to developed countries (Johansson *et al.*, 2013), including in the analysis the evolution of the propensity to emigrate depending on the economic situation of the starting nation and the anticipated population he considers that the possibility of a reversing trend in the emigration flows is not to exclude, in particular with regards to the Euro area.

During the period 2000-2010, though, the total migrant stock has increased twice as fast (4.6 millions annually) than during the previous decade (2 millions annually). However, after 2010, the effects of the crisis have made the increase in migrant stock go down to about 3.6 million annually. The destinations have changed as well, southern Europe countries, for instance, have seen immigrants number decreasing due to the struggling economic conditions. Migrant workers, and in particular men, indeed, have been hard hit by the economic crisis, especially those working in the constructing services. Only less than 30% of the total migrants does not have a secondary school or higher degree, despite of this Adams Jr (2003) states that emigrants only entail a small proportion of the *best and the brightest* of most of source countries. This last aspect will be clarified better at a later stage and it is related to increasing absolute numbers of high-level graduates within the mentioned source countries. The situation presents geographical heterogeneity though, as in some countries the proportion of tertiary educated emigrated is extremely high.

Despite of the growth the number of international migrants remains relatively small compared to the global population. In 2013 they accounted for about 3.2% of the world population and to only 2.9% in 1990.

The settlement of migrants is not uniform, indeed, half of the overall number of migrants reside in ten countries. In order of importance in 2013 the United States of America (45.8 million or 20% of the global total), the Russian Federation (11 million), Germany (9.8 million), Saudi Arabia (9.1 million), the United Arab Emirates and the United Kingdom (7.8 million each), France (7.5 million), Canada (7.3 million), Australia and Spain (6.5 million each) hosted the largest number of international migrants. In parallel, the origins of migrants show considerable differences among regions. 50% of OECD migrants come from 16 countries, in range Mexico (11 millions), China (3.8 million), the United Kingdom (3.5 million), India (3.4 million), Poland (3.2 million) and Germany (3.2 million). The Philippines, Romania, Morocco, followed by Vietnam and Algeria, were among the main non-OECD countries of origin. Migrants from Latin America and the Caribbean and Asia together form more than half of the migrants moving to OECD countries, a con-cause for this aspect is the sharp increase in the past decade of migrants from the just mentioned regions, which increased respectively by 44% and 36%. European emigrants have largely increased as well (30%), due to the EU

enlargement and in 2010/2011 they accounted for around one third of the total migrants. It is the African migrant community though, the one that grew more than any other, reaching very high-percentages of growth such as 53% in the past ten years.

Talking about gender, women form about 48% of all international migrants. The proportion of female migrants is the highest in Europe, (51.9%), then Latin America and the Caribbean (51.6%), Northern America (51.2%), Oceania (50.2%), Africa (45.9%), and Asia (41.6%). The small proportion of female migrants in Asia is the result of the high demand for male migrant workers in the oil-producing countries of Western Asia.

Refugees amount to a relatively small proportion of the global migrant stock. In 2013, refugees were estimated to be around 15.7 million, about 7% of all international migrants. Nearly nine of every ten refugees in the world had found asylum in developing regions.

Talking more strictly about brain drain, it is to say that the number of tertiary educated immigrants in the OECD countries is rising sharply even though with strong regional and national differences. The rate is increased by 70% in the past decade, reaching 27.3 million in 2010/11. This amount represents about the 30% of the total migrants and one fifth of them is coming from India, China or the Philippines. About 4.7 million, or 17%, of the total high-skilled migration arrived in the past five years, mostly Asian migration. Also the number of high-skilled migrants from Africa is grown, reaching 2.9 millions in 2010/2011 and the number of Africans incoming within the last five years (450 000) is larger than that of Chinese (375 000), letting presuppose a further increase in the upcoming period. Summing up, in 2010/2011, one every nine persons born in Africa, one every thirteen persons born in the Caribbean and one in thirty persons born in Asia with a tertiary diploma lived in the OECD countries. Note that the data are biased downwards as it has been shown that the easiest way for high-skilled to emigrate is studying abroad (Martin Rovet *et al.*, 1998) and these people are not accounted in the numbers of migrant workers.

OECD data, that account for more or less the 85% of the brain drain worldwide phenomenon, are clearly underestimated as no non-OECD destination country is taken into account. Indeed by adding some available data regarding non-OECD countries the brain drain phenomenon appears to be much bigger, more than the double, for 13 countries and multiplied by more than 15 for other 20. The research work Carrington and Detragiache (1998) was made by taking into consideration foreign born individuals, aged 25 or more and an academic degree higher than high school. Three main issues may arise while running this study. Illegal immigration has a limited effect, as "brains" tend to emigrate legally. Secondly, very important is the issue of where the schooling has taken place, whether in the destination or in the home country. The age of emigration can be taken as a proxy of this fact. Finally exist issues of heterogeneity in terms of field, degree, occupation and so on.

The brain drain is more acute in countries with small populations and island states, but lower in populous non-OECD countries (Adams Jr, 2003). Among the countries more vastly affected by the high-skilled diaspora, Guyana is a prime example, close to 90% of highly skilled persons born in Guyana lived in OECD countries. In Barbados,

Haiti and Trinidad and Tobago more tertiary educated people live outside than inside the countries. The proportion of highly educated persons residing in OECD countries was also significant for Jamaica (46%), Tonga (44%), Zimbabwe (43%), Mauritius (41%), the Republic of the Congo (36%), Belize (34%), and Fiji (31%). In contrast very populous countries such as Brazil, China, India and Russian Federation had low emigration rates of the highly-skilled (below 3.5%). These results are confirmed by Carrington and Detragiache (1998), according to which the size of the origin country is negatively related to emigration. Moreover there are evidences that the most likely origin countries for emigrants are medium income nations, where there are incentives to study and emigrate and the budget constraints are less binding. Six major destination countries can be identified to cluster the 75% of the total brain emigration, these are USA, Canada, Australia, Germany, UK and France

Other non-OECD countries assume the role of sources of brain drain, Romania (109,000), Brazil (75,000) and Colombia (71,000). Also, Germany (169,000), the United Kingdom (165,000), Poland (165,000), France (147,000) and the United States (120,000) ranked among the main countries of origin of recent tertiary educated immigrants from within the OECD. Rather than the absolute numbers, it is more interesting analyzing the proportions. Figure 5.12 shows a map of origin countries of migrants with tertiary education. From this layout it is easy to evince that OECD countries loosing the highest proportion of high-skilled graduates are Austria, Ireland, New Zealand, Portugal and United Kingdom[13] .

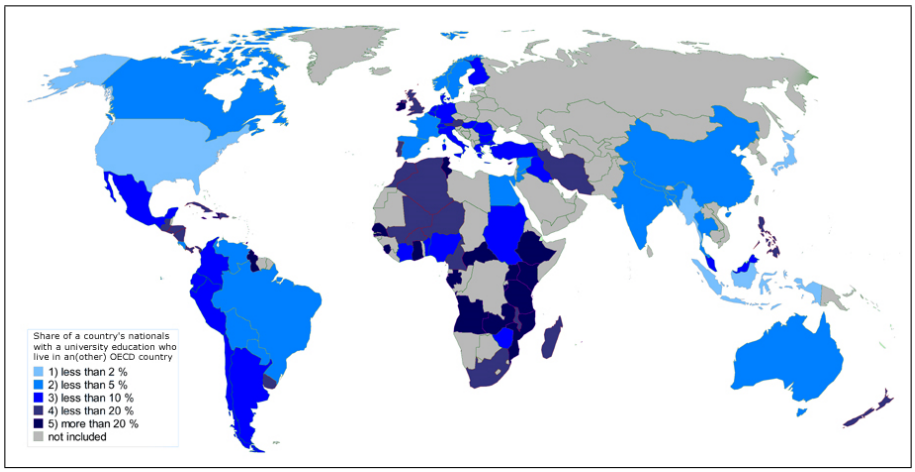

Figure 5.12: Share of a country's nationals with a University degree who live in another OECD country Source: OECD Database on Foreign Born and Expatriates, Employment, Labour and Social Affairs, 2006 and Cohen D. and M. Soto, 2001, Growth and Human Capital: Good Data, Good Results, OECD Development Centre WP n 179.

The brain drain increase in proportion of high skilled population is not uniform. In some countries it is sharply increased, while in others it even diminished. To clarify,

[13]No data available for Estonia, Hungary, Israel, Korea, Poland and Slovenia

it is better to say that in absolute numbers the amount of highly skilled emigrants has increased for any country of origin, it is true, though, that the educated population within the source countries may have increased as well so as to compensate or even overcome the brain drain phenomenon. It is the case, for instance, of Middle East and North Africa (MENA) countries which have strongly pushed for tertiary education in the last ten years. The widening of high-skilled individuals in populous countries, such as China, India or Indonesia, more than compensated the increase in the outflow of highly educated migrants. In contrast, the emigration rate of highly educated persons from smaller countries, such as the Republic of Moldova, Zambia and Zimbabwe, increased by more than 10 percentage points since 2000.

For most of the source countries, the emigration rate of the highly-skilled exceeds the total emigration rate reflecting the selectivity of migration by educational attainment, this has been proven to be true for 137 of the 145 countries of countries investigated. In 2010/11, Burundi, Lesotho, Malawi, Maldives, Mozambique, Namibia, Niger, Papua New Guinea, the United Republic of Tanzania, and Zambia had emigration rates of the highly-skilled which were more than 20 times the total emigration rates.

Among the push and pull factors, the research has shown that push factors are less important than pull ones (Mayda, 2010). In developing countries emigration is less sensitive to distance, it increases with religious fractionation at origin and decreases with the level of development. For developed countries, instead, emigration is less sensitive to geographical variables as distance and immigration policies in the destination countries.

Finally, gender issues exist. Indeed between 1960 and 2005 it has been noticed an increase in the feminine brain drain phenomenon from 46.8% to 49.6%. Highly skilled women have been found to be more responsive to pull factors than men (Docquier *et al.*, 2009, 2012). When the model is better specified, though, allowing to control for specific factors, such as family reunions, etc., this gap decreases. It is not completely clear why Carrington and Detragiache (1998) does not take into account the increase in feminine education as a joint cause for feminine increased brain drain. In many countries of origin, the share of tertiary educated women who were living outside their country of birth was higher than for men. This difference reached 10 percentage points in 2010/11 for the Maldives, the Republic of the Congo, Sierra Leone and Togo.

The share of individuals coming back to the origin country is important as well while analyzing the brain drain phenomenon. Borjas and Bratsberg (1994); Dustmann and Weiss (2007) estimated that the percentage of individuals coming back after 10/20 years lies around the 25%/30%, among which the majority falls into the brain drain category. The propensity to come back, though, strongly varies among countries and depends on many different factors, such as, for instance, the conditions of the labor market.

It is possible to deduce, then, that brain drain is a significant issue and large studies and research are necessary to better prevent it or respond to it.

Chapter 6

NetLogo Brain Drain Simulation

The following chapter is concerned with describing the main steps covered in the construction of the ABM. First we will consider a change of route followed to tripping over a mistake. It is interesting to report this step because it shows one of the most typical mistakes that can be done while designing a simulation. Later we will deal with the construction of the actual model. We first present the simple constructions of the simulation on which later have been added more complex features. Finally, in the last section we describe in detail the characteristics of the ABM model used as a powerful tool to investigate the dynamics of brain drain.

6.1 Redressing while Building a NetLogo Model

Creating an agent based simulation is no easy work. As it has been mentioned previously, the researcher has to build a plausible model, which permits both to get credible results and in which the outcomes are clearly readable and understandable. The model then should be a curbed representation of the reality, in which the main driving forces of the phenomenon under investigation take place. Also it has to be simple and legible. An ABM is a compromise between these two requirements. The reasons are apparent. If the simulation fails to take into account all the relevant factors of the studied course, it then misses the goal of providing useful insights, potentially interesting discoveries or innovative perspectives. It would be a very simplistic model with no concurrence in the reality. On the other hand, reality is complex. Phenomena, and in particular socio-economic processes, as the one under investigation within this research work, are complex. They encompass an enormous number of variables and significant factors. Without a selection of the most important and influential ones, an ABM would no longer be a model. It would be a completely true-to-life representation of the reality. But in this case, it would completely lose its role as an instrument of investigation, as the outcomes would be uncontrollable. The solution, as often, lies in the middle road.

Within this research work we investigate the phenomenon of brain drain and how does it influence the economic performance of the country of origin of the migrants. With this term we refer to the emigration from the native countries of individuals who

have largely invested in education. Commonly emigrants are accounted in the surveys of brain drain when they relocate after obtaining at least a master degree. An ABM that is trying to inspect such an event has to entail many different variables as many factors, indeed, are involved in the process. Initially, according to the author of this quest, the simulation should be mainly constructed over three phases. First, individuals have to decide whether to study or not, where studying is referred to as taking part to a master course. Second, looking at the surrounding environment, they choose whether to stay in their native country, or emigrate. Finally, if they have beforehand chosen to move abroad, they can eventually decide whether to come back or not.

6.1.1 A first attempt

The first construction of the NetLogo simulation was error-prone. It was indeed a clear example of what has been described above as an overly complicated simulation. Although not complete, the simulation was already uncontrollable. It was effectively stuck at the first stage of the programming, for matters of clarity, that in which agents decide whether to study or not. At this point, agents were already endowed with seven variables and a set of links. More, the environment was characterized by four factors. The majority of these variables was not fixed, but at user's disposal in order to perform experiments. The decision of whether to study or not was initially as a comparison of costs and benefits together with the influence of acquaintances and friends. It also involved environmental characteristics, such as the initial development of the origin country, the cost of education, the eventual possibility of emigration for countries with low levels of initial development and even a system of tax reductions. Later people where characterized by their income and ability, by their network and also by their optimistic or pessimistic attitude.

The main procedure was the following.

```
to Study
   ask people with [age = 19][
      if LowIncomeTaxReduction[ActivateProcedureISEE]
      BeInfluenced

       if Ability <= (0.3 * AverageAbility)
                [set SustainableCost (Budget - random Cost)]
       if Ability > (0.3 * AverageAbility) and Ability < (0.7 * AverageAbility)
                [ set SustainableCost Budget]
       if Ability >= (0.7 * AverageAbility)
                [ set SustainableCost  (Budget + random Cost) ]

      set SustainableCost (SustainableCost + Perspectives)
           ifelse ( 0.5 * SustainableCost ) >= Cost
                [ set color red  set Student 1] [set color black]]

   ask turtles [set Age (Age + 1)]
   Generate
   ask people with [Age = 25 and Student = 1]
                [set Graduate 1 set color green set Student 0]
   tick
   ]
end
```

Here, agents aged nineteen decide if it is worthy to invest in tertiary education. Eventually, the country they are living in may offer a system of tax reductions, which benefits low-income agents by subsidizing the University burden. This aspect is enclosed in the *ActivateProcedureISEE* which is named after the Italian system of classification for University duties exemption.

Later, the procedure goes on with the command *BeInfluenced*. This procedure is complicated, as it takes into account two main aspects. The former is related to the initial economic status of the country of origin. The intuition beyond, is that the more it is expanded, the larger it can offer good working perspectives to its citizens. That is why, if the *Development* of the country, which in the first stage is decided by the user through a slider on the interface, is larger than a certain level, the *Perspectives* of its inhabitants will be enhanced by a certain amount. This amount is randomly taken from a value that can be decided by the user. On the contrary, if the *Development* is low, the *Perspectives* will be reduced by a number drawn in the same way. It is not over. Indeed, it is possible that the country of origin is open to emigration, that is it allows its citizens to move abroad for working. As now the working perspectives are not limited to the only native country but to the world as a whole, obviously the citizens will have more reasons to invest in education. The second step of the *BeInfluenced* procedure takes into account acquaintances' links. It generates a set of links which interconnects the population. Then, if the percentage of individuals connected to the agents who are or have been studying is larger than the half of the total acquaintances network, this positively influences the *Perspectives* of the agent under investigation and vice-versa.

```
to BeInfluenced
  ifelse Development >= 50
   [set Perspectives random LevelOfHeterogeneity]
   [set Perspectives (- random LevelOfHeterogeneity)
     if OpenToEmigration
        [set Perspectives (Perspectives + random LevelOfHeterogeneity)]]

  create-links-with other people in-radius ((100 - Population) / 10)

  ifelse count people in-radius (100 - Population) / 10)
  with [Student = 1] >= 0.5 * count people in-radius (100 - Population) / 10)
     [set Perspectives (Perspectives + random LevelOfHeterogeneity)]
     [set Perspectives (Perspectives - random LevelOfHeterogeneity)]

end
```

The *Study* procedure continues by focusing on the *Ability* of the agents. The *Ability* of each citizen is distributed according to a normal around the mean *AverageAbility*, which is set by the user through a slider on the interface. Note that the variance as well is free to be chosen by the user. The variable *SustainableCost* is the amount of resources, which encompasses both economic, intellectual and opportunity costs, that each individual is willing to bear for education. The *Budget*, instead, is the amount of money each person is willing to address to education and it is generated following a Poisson distribution around a mean, which is stated by the user through a slider on the interface. The population then is divided among three groups, those with ability

lower than a certain percentage of the average one, those around the average and those above the average. For the first group the *SustainableCost* will be the *Budget* reduced by a certain amount, while for the latter one it will be the *Budget* increased by a certain amount. The intuition beyond is that underlying many labor economics models in which it is more costly for less education-inclined people to perform educational attainments.

The *SustainableCost* obtained in this way, is then added to the *Perspectives* and these two are then compared to the effective *CostOfEducation* of the country and in this way people decide whether to invest in education or not.

What happened is that this code was too complicated. Even controlling for bugs and errors was hard and time consuming because of the large amount of variables involved. Still, it was possible to continue on this way and prosecute by adding the following steps. But here came the intuition. Already at the first phase, outcomes are hard to read. The results are not clear nor immediate. By adding other processes, what will happen is a deepening in the intricacy of the phenomenon and an even more obscure readability of the achievements. More, performing experiments, would be a pernickety job.

For all these reasons the only possible decision was starting again. The new construction of the ABM would have followed the designed path provided by luminaries of the field, such as Axtell (2006), Gilbert (2004), Terna (2013) and many others mentioned in the previous chapter "Introduction of Agent-Based Modeling". According to them, the coding phase should start by clearly defining the purpose of the model. Successively it is possible to start programming by decisively keeping in mind what do we want to demonstrate. Finally programming should move from a simple skeleton of a program to which are added successively other characteristics and components. This is what has been done in the subsequent forms of the ABM.

6.2 Construction Steps of the Simulation

Learning from the mistakes mentioned in the section above, the construction of the NetLogo simulation has proceeded gradually. The following section sketches up two main progresses within the construction of the model. In particular it shows some evolution of the simulation, as to explain the operating procedure applied by the author. More, it is helpful in understanding changes in the construction of the model, which reflect variations in the perception of the phenomenon itself. In the first step, indeed, the simulation has been designed as a simple skeleton, to which adding, successively, more complex features. The second step tries to go further in the understanding of the issue by integrating more specific aspects and testing chances and correcting procedures, that have previously been designed in a too simplistic way.

6.2.1 First Step

As sketched above, the first step of the construction of the model has been very simplistic and rough. The idea, indeed, was to capture the main phases entailed in the brain drain phenomenon and outline them in a very simplistic way, as to recall their presence in

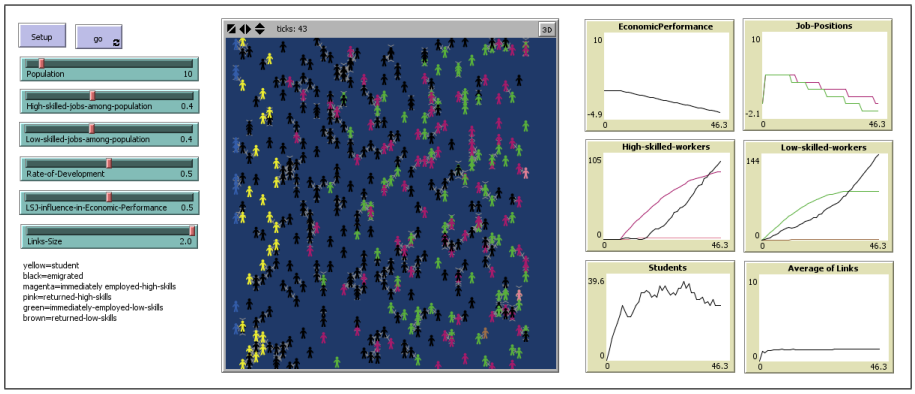

Figure 6.1: First Step

the phenomenon. The beefing up of the code has to be made gradually, upon reflection and intense study. Figure 6.1 shows the interface of the first step of the design of the NetLogo simulation of the brain drain phenomenon.

The code is made of five main procedures. The user chooses a number of people which will be born in every step/year aged nineteen, that is the age at which usually italian people choose whether to go to the University or not. Every agent has an ability, which is distributed according to a normal function with mean 0.5 and variance 0.5. People are connected through links, the size of which is decided by the user through a slider on the interface.

```
to Create-Links

    ask people [
      set friends-list []
      create-links-to other n-of (count people in-cone links-size 180)
            people in-cone Links-size 180
      let c count people - 1
      let world turtle-set people
      let m min [who] of world
      let b max [who] of world
      while [ c > 0 ] [
      while [b >= m ] [
      if in-link-neighbor? turtle b = true
          [set friends-list lput b friends-list]
      set c c - 1
      set b b - 1
      ]]
    ]
end
```

The patches are set so that it graphically appears as the people are living their working life by moving along the screen. The country offers a set of jobs differentiated between high and low skilled. These are provided in a proportion which is set by the user on the interface. People then choose whether to study or not. At this stage of the model, this procedure is still brutal, unrealistic and even undesirable. Obviously it will be modified in the future development of the code.

```
to Study

    ask people with [age = 19] [
    if ability >= 0.5 [set student 1 set color yellow]]
    ask people with [ age = 25 and student = 1]
         [ set student  0 set graduated  1]
    set students count people with [student = 1]

end
```

Subsequently, people who are not studying look for a working position that fits their abilities, which is a high-skilled position for graduated individuals and a low-skilled one for those who are not. If they find a job offer suitable for them they stay in the country, otherwise they emigrate.

```
to LookForWork

  ask people with [graduated = 1 and employed = 0] [
       ifelse high-skilled-jobs > 0
       [set high-skilled-jobs (high-skilled-jobs - 1)
        set employed 1 set color magenta]
       [set emigrated 1 set employed 1 set color black]]
  set h-g count people with [graduated = 1 and emigrated = 0]

  ask people with [student = 0 and graduated = 0 and employed = 0] [
       ifelse low-skilled-jobs > 0
       [set low-skilled-jobs (low-skilled-jobs - 1)
        set employed 1 set color green]
       [set emigrated 1 set employed 1 set color black]]
  set l count people with [student = 0 and graduated = 0 and emigrated = 0]

end
```

Once they are emigrated, if individuals find an available working position, which is appropriate for them, they go back home and start working in that place.

```
to Return

  ask people with [emigrated = 1 and graduated = 1][
    if high-skilled-jobs > 0[set high-skilled-jobs (high-skilled-jobs - 1)
       set returned 1 set color pink]]
  set h-r count people with [graduated = 1 and emigrated = 1 and returned = 1]
  set h-m count people with [graduated = 1 and emigrated = 1 and returned = 0]

  ask people with [emigrated = 1 and graduated = 0][
    if low-skilled-jobs > 0 [set low-skilled-jobs (low-skilled-jobs - 1)
       set returned 1 set color brown]]
  set l-r count people with
       [graduated = 0 and emigrated = 1 and returned = 1]
  set l-m count people with
       [graduated = 0 and emigrated = 1 and returned = 0]

end
```

Finally, the country is affected by the choices of its inhabitants. This procedure sets initially the number of jobs that will be offered the next year as the parameter x for high-skilled jobs and y for low-skilled jobs. In the first stage these parameters

are equal to the variables defined by the user through a slider on the interface. The user can decide how much do low-skilled-jobs count in the economic performance. After six ticks, that is after the first generation is graduated, the number of graduated who have never emigrated, that of graduated, emigrated and returned are summed to the product of low-skilled who are never emigrated plus low-skilled, emigrated and returned multiplied by the importance that low-skilled jobs play in the economic performance. If this number is larger than the number of people in the country multiplied by the rate-of-development, the economic-performance is positive, it increases of 0.1, the parameter for high-skilled-jobs increases by 0.01 and the parameter for low-skilled-jobs increases by 0.015, and vice-versa.

```
to Develop

  set high-skilled-jobs round(x * Population)
  set low-skilled-jobs round(y * Population)

  if  ticks >= 6 [
    ifelse (h-g+h-r+(LSJ-influence-in-Economic-Performance*(l-r+ l)))>=
        (Rate-of-Development * count people)
    [set EconomicPerformance (EconomicPerformance + 0.1)
       set x ( x + 0.01) set y ( y + 0.015)]
    [set EconomicPerformance (EconomicPerformance - 0.1)
       set x (x - 0.01)  set y ( y - 0.015)]
    ]

end
```

It is easy to see, that this version of the model is very limited and poor, with many important aspects being neglected. Still, it is judged by the author to be an improvement, as it is clear and easy to analyze. It defines the boundaries within which the final project will be confined and underlines the core underpinning that it will investigate.

6.2.2 Second Step

The second step adds some complexity to the simulation model. Figure 6.2 shows the interface of the program. It is clear that the differences from the previous version are huge, appointing some the division of the world into two countries, the important presence of the links and the many graphs used to investigate the behavior of the simulation. This step is based on nine main procedures, some of which are very similar to the ones of the previous model and thus will not be described in detail.

The studying procedure is much different from before, to the extent that people aged 19 decide whether to study or not on the basis of three main aspects. People of each breed look at the *EconomicPerformance* of the country they live in, if it is positive they set the variable *Outlook* as a value drawn from a normal distribution with mean 0.7 and variance 0.5. If, conversely, the *EconomicPerformace* is null or negative, they draw out the value from a normal distribution with the same variance but mean 0.3. More, they take into account their social network in terms of the proportion of studying friends. Finally they sum each of this variables to their *Ability*. Each of these three factors contributes to explain whether will the agent take part to University education or not.

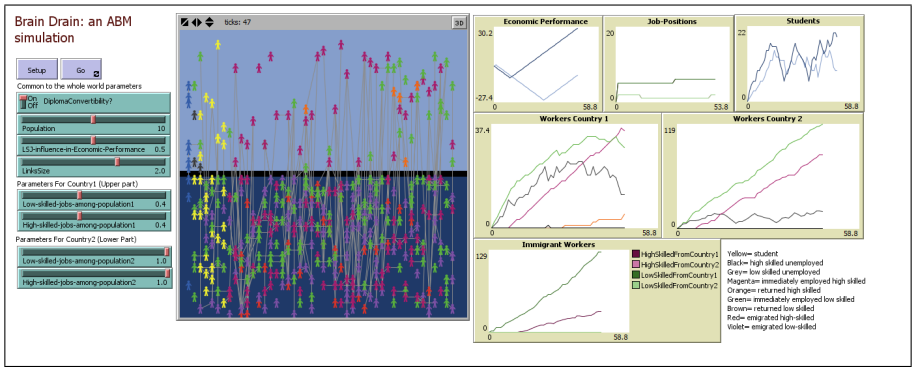

Figure 6.2: Second Step

Once students reach 25 years, they graduate. For every year they are studying, students cost one unit of money to the state.

```
to Study
   ask turtles with [age = 19] [
      let Average 0
      let Outlook 0
      let StudyingFriends 0
      let Identity 0
      let Indicator 0
      let Dummy 0

      ifelse breed = Ones
             [ifelse EconomicPerformance1 > 0
                [ set Outlook random-normal 0.7 0.71]
                [set Outlook random-normal 0.3 0.71]]
             [ifelse EconomicPerformance2 > 0
                [ set Outlook random-normal 0.7 0.71]
                [set Outlook random-normal 0.3 0.71]]
      foreach FriendsList
          [ set Identity item Indicator FriendsList
                    ask turtle Identity [if student = 1 [set dummy 1]]
                    if dummy = 1 [set StudyingFriends StudyingFriends + 1]
                    set dummy 0
                    set indicator indicator + 1
                    ]
      ifelse length FriendsList != 0 [
      set Average ( Ability + (StudyingFriends / length FriendsList) + Outlook )]
     [set Average (Ability + Outlook)]

      set Perspectives random-normal Average 0.71
      if Perspectives >= 1.5 [set student 1 set color yellow]]
   ask Ones with [student = 1][set MoneyFlow1 (MoneyFlow1 - 1)]
   ask Twos with [student = 1][set MoneyFlow2 (MoneyFlow2 - 1)]
   ask turtles with [ age = 25 and student = 1]
         [ set student  0 set graduated  1]
   set students1 count Ones with [student = 1]
   set students2 count Twos with [student = 1]
end
```

The *LookForWork* procedure is very similar to the one in the previous step. Differences arise from the fact that now two countries are involved and people who do not find

a suitable job do not immediately emigrate, but enter the unemployed category. Emigration, indeed, depends on the procedure *LookForWorkAbroad*. An interesting feature included in this version of the model is the possibility that the academic title achieved in the home country is not recognized, see the procedure *FindJobAbroadClosed*, and therefore spendable in the destination one. High-skilled workers, then, are relegated to accomplish working tasks that do not fit their degree of specialization. The return position is also slightly changed. It performs the same task as before, but, in addition it computes the amount of unemployed, which cost half a unit of money to the state for any year they stay in this condition. More, it states that, if there are available positions unfilled, this has a cost for the state, something like a lack of human capital to push growth and keep the level of production achieved. Finally the procedure *Develop* works largely as it has been already described in the previous section. It is clear that, although the large improvements achieved in the analysis of this complex phenomenon, the simulation is still overly simplistic and sometimes inaccurate. Much has to be added in terms of network structure and its influence. Also, some procedures need to be corrected, to better depict the reality trends.

```
to FindJobAbroadClosed

  let abscissa 0

  ask Ones with [student = 0 and unemployed = 1 and returned = 0 and emigrated = 0][
    if LSJ2 > 0[set LSJ2 ( LSJ2 - 1) set employed 1 set unemployed 0 set emigrated 1
      set abscissa xcor
      move-to one-of Country2 with [pxcor = abscissa]
      ifelse graduated = 1 [set color red][set color violet]
      ]]

  set l-m2 count Ones with [emigrated = 1 and employed = 1 and returned = 0]
  ask Ones with [student = 0 and employed = 1 and emigrated = 1 and returned = 0]
  [set MoneyFlow2 MoneyFlow2 + 1 * LSJ-influence-in-economic-performance]

  ask Twos with [student = 0 and unemployed = 1 and returned = 0 and emigrated = 0][
    if LSJ1 > 0 [set LSJ1 (LSJ1  - 1) set employed 1 set unemployed 0 set emigrated 1
      set abscissa xcor
      move-to one-of Country1 with [pxcor = abscissa]
      ifelse graduated = 1 [set color red][set color violet]
      ]]

  ask Twos with [student = 0 and employed = 1 and emigrated = 1 and returned = 0]
  [set MoneyFlow1 MoneyFlow1 + 1 * LSJ-influence-in-economic-performance]
  set l-m1 count Twos with [emigrated = 1 and employed = 1 and returned = 0]


end
```

6.3 The Final Model

The model designed within this research paper wants to roughly simulate the brain drain process in its three main components: human capital investment decisions, job search and the returning decision. It is not to forget the complexity of the issue as it is reasonable to assume agents' behavior to be strongly influenced by its own network. In the following

paragraphs are presented the three core procedures composing the final simulation model without forgetting the investigation of the influence of the network connections on the behavior of each agent. Shortly, the human capital investment decision will assess the agents' issue whether to undertake University studies or not. Agents make this decision with reference to three main factors, their ability, the economic performance of the country they live in and their network. The University might be endowed with exchange programs, such as for instance LLP Erasmus program, through which the agents could spend some time abroad. After finishing the University, for those who have chosen to invest in human capital, people have to start looking for a working position. The job search phase tackles with this question. Jobs are offered by the countries and they depend on the growing trend of the countries themselves. Agents are heterogeneous, that is some of them might be classified as *ambitious*, if they do always prefer to find a fitting job, no matter where is it set, otherwise they could be *mommy's boys*, if they prefer to stay in the origin country, no matter if this does imply settling for a non-fitting job. The economic outcome of any of these procedure is accounted for within the simualtion. Finally, the emigrated agents do confront a final decision, coming back to the native country or not?

6.3.1 Networks within the Model

The increased ability in communicating even in the distance has increased the emergence of networks together with the awareness that social relations do have an influence in most human life decisions. These two aspects combined with expanded amounts of available data and computer skills have enhanced the research regarding this field. In many scientific disciplines, such as economics, political science, sociology, physics and so on, understanding the network ruling a set of agents is highly important for understanding the decisional dynamics of each member and eventually set up a fitting response. Jackson (2014) presents a clear example of how does a serious network analysis clarify the decisional dynamics within a community. The author identifies two main aspects of a network, a *macro* level and a *micro* level. The former *plays primary roles in processes of diffusion and social learning, as well as in determining the extent to which disparate norms or cultures can exist within a given society.* In other words, it refers to the density of a network. The latter entails two core aspects, *centrality of a node* and *clustering*. The concept of centrality refers to the information individuals have access to, their behavior and how does their behavior affect that of other members of the community (Simmel, 1908; Katz and Lazarsfeld, 1970). Finally clustering, which reveals the degree of interconnection of a social network, is related to theories of *social capital*, see Coleman (1988) and Putnam (2000) and to the pace at which information spreads. In the same way Carvalho (2014) agrees on the significance of network relations on economic phenomena. Within his paper, he presents a microeconomic model where he studies the impact of the production network on the propagation of a shock within the network. Having a clear idea of the network, then, allows the organisms in charge to take a suitable response.

The combined use of ABM and NA for policy-making processes has been underlined

by Fontana and Terna (2014). Within their paper, indeed, the authors highlight the potential of combining these two powerful tools both for policy-makers, for deciding which policy is better to implement, and for citizens, who can then study the effectiveness of a particular policy. The authors state that *since it is easier to have network data (i.e. social network data) than detailed behavioral individual information, we can try to understand the relationships between the dynamic changes of the networks emerging from agent-based models and the behavior of the agents.* In Fontana (2012) the author affirms that key concepts of complex analysis such as heterogeneity, interaction, innovation and adaptation can bring new insights to the study of social phenomena. Indeed, the definition of a complex system itself, relies on the emergence of structures and patterns from a decentralized autonomous interaction. A combined use of ABM and NA, then, could bring important innovations to the policy analysis. NA helps ABM in being both simple in its structure and sophisticated in its outcomes. On the other hand, ABM help overcoming some limits of NA such as *dynamics* and the *behavior of nodes*.

Within the current research project NA is very relevant. For matters of clarity, then, it might be useful to more specifically define some core concepts of NA and this is done with reference to Mitchell (2009).

Networks are basically made of *nodes* and *links*. With the first term we refer to agents living within the simulation, who are connected to each other by a set of links. These might be *directed* or *undirected*, where the former means that the links do have a direction, while the latter refers to links without any direction. An example of the first case emerges if agent 1 is the mother of agent 2, which is true for one starting point and one destination point but not reversed, on the contrary in the second chance, if agent 1 is married to agent 2 this is true even vice-versa and this is an example of undirected link. Within this simulation model the used links are undirected as they are intended to simulate friendship relations. The *degree of a node* is the number of links coming into or out of that node. The *degree distribution* of a network, then, is the frequency of nodes within the network which has the same degree. The notion of *distance* within a network refers to number of intermediate nodes necessary to connect two individuals of the network. There are many possible *paths* for doing so, the *shortest path* is the path connecting two individuals, which involves the smallest number of halfway steps. In Milgram (1967), the author introduces the *small world property*, that seems to be valid in most of the real-world complex networks. In particular real world networks appear to have a few relatively long-distances, but most nodes are connected through short paths. Notably, he states that usually these distances are six degrees of separation, in other words this means that each individual is connected to any other individual through six intermediaries. This is possible through the so-called *hubs* of acquaintances. The idea of *clustering* is strictly connected to the concept of hubs, as it refers to the extent to which the connections of a node are respectively connected to one another, so it is the fraction of pairs of neighbors who are connected to each other. The *clustering coefficient* of the whole network is simply the average of the clustering coefficients of each node. The clustering coefficient might be significant in terms of how long does information take to travel from one part of the network to another. In Watts and Strogatz (1998), the authors

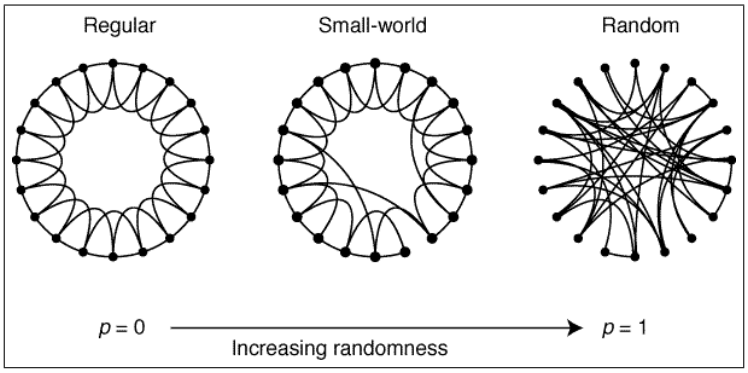

Figure 6.3: Network Examples

formalize the small-world network theory. What they did, basically is analyzing three different real complex networks and compute for each of them the clustering coefficient and the average distance. What they have found is that the small world model was better fitting the actual values when compared to a regular and a random structure, see figure 6.3.

Differently, Barabási and Albert (1999) investigate the aspect of scale-free structure also known as long-tailed distribution of networks. In figure 6.4 it is shown how does a scale-free network look like. In particular it follows a principle that could be summarized as *the rich gets richer*. An example of a scale-free network is the worldwide web. Within the internet network, a new web page will presumably link to another web page which already has many links, so as to increase the probability of being found. So the next time somebody creates a web page, the one already highly connected web page will be even more likely to be linked to because it has got even more links than before. This is called *preferential attachment*. The distribution of a scale-free network appears much as figure 6.5, that is strongly different from a Gaussian one, typical of a random distribution. In the latter case the distribution goes to zero very fast, that is most of the agents lie around the mean while it is very unlikely to find values that highly differ from the mean. On the contrary a *long-tailed* distribution goes to zero very slowly and, although most individuals concentrate around the mean, it is likely to find some others with very high degrees. More, the scale-free distribution is *fractal like*, that in a simplistic way means that at all scales it looks the same. It is an approximation to the mathematical fractals, and that is the reason why it has a power-law like distribution. Note that scale-free networks do have the small world property, that is high-clustering and low average distance between nodes. According to the authors of the mentioned paper many real world networks manifest scale-free distributions, but not all the researchers do agree, see for instance Clauset *et al.* (2009) and Fox Keller (2005).

The simulation model is largely based on the influence of networks on the brain drain phenomenon because following Terna (2014) we know that *complexity arises when agents, as parts of a whole, act and interact and the quantity of involved agent is relevant.* The network is not generated with a priori super-imposed features, such the small-world or

Figure 6.4: Scale-free Network

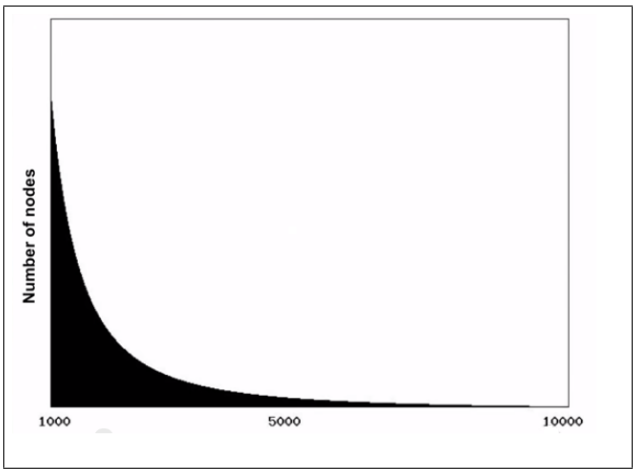

Figure 6.5: The Web's approximate degree distribution

the scale-free distribution. The links, indeed, are generated simply. When agents born, they are distributed randomly over a vertical line on the extreme left of the world. The links are set between two agents if their distance is less than the threshold decided by the user through a slider on the interface. The connections, then reflect the emergence of friendship relationships in the real world, where it is more likely for people to become friends if they happen to be in the same place for a while. More, when eventually moving abroad while studying or for working purposes, agents generate new sets of links, as it is reasonable to expect for an expatriate to generate new acquaintances. The network, then, influences some core procedures, in particular that of deciding whether studying or not and the returning decision. Also, the *sociability* of agents does affect the preference order of agents looking for a working position. It is interesting, then, to see whether this simply designed network does entail some special property. Quoting Fontana and Terna (2014) *the emergent network is not an objective but a consequence of interaction.* Differently from some research paper such as Gilbert and Hamill (2009) and De Caux *et al.* (2014), where the agents act to generate the network, within this research project, agents act following their internal rules and capabilities. In particular they take educational and working decisions according their internal rules and characteristics. The network emerges as a side effect, as it is in the real world.

6.3.2 The Interface

The interface of this last step of the model is shown in figure 6.6. As before, the interface presents some controls. We will browse them down in order to provide a clear understanding of the simulation. The *population* fixes how many people will be born at each tick, or year. The *population*, then, is spread equally among the two countries. The slider *LSJ-influence-in-economic-performance* determines the importance of the low skilled jobs in the economic output. This aspect takes inspiration from Moretti (2012), where the author assumes the presence of a multiplier of five for high-skilled jobs over low-skilled ones. As the mathematical procedure through which he reaches the number five is not clearly explained, but the underlying idea that high-skilled jobs may concur in generating low-skilled jobs is reasonable, we consider this hypothesis and allow the user for testing it by varying this parameter. *LinkSize* is the distance within which people establish connections to each other. As briefly mentioned above and as it will be extensively explained later, the network generated through the links is an important factor in many core procedures. The *MobilityThreshold* is a limit. Each agent, indeed is endowed with a *sociability* factor taken from a Poisson distribution with mean 10 and 10 degrees of liberty. The sociability factor, then, is negatively related to the *age* and positively related to the *education* and to the *mobility capital*, see Orru (2014). Within his research work, the author states that the moment in which people are more likely to emigrate for working reasons is just after concluding the tertiary education. *Mobility capital* refers to the stimulus to moving abroad given by the international experiences done meanwhile the University. The ABM allows the user to decide whether the possibility of studying exchanges is given to the students or not through the switcher *StudentMobility?*. The *sociability* of each agent then is turned into the *PropensityToLeave* of each agent by mul-

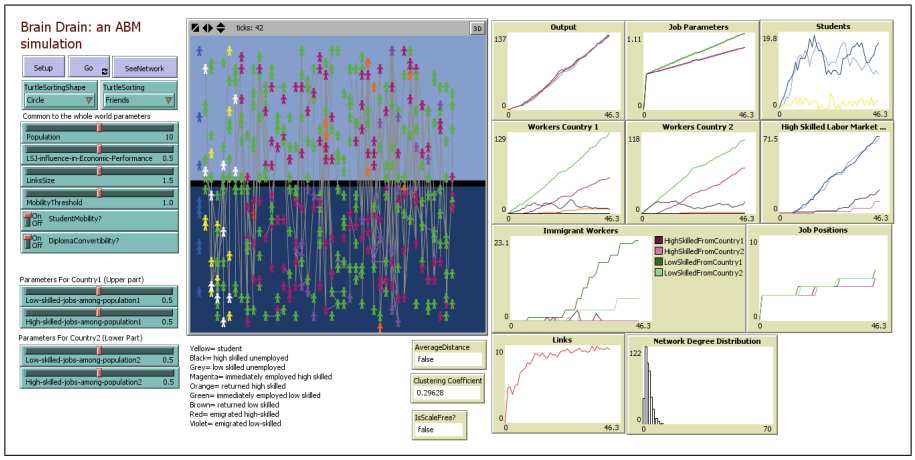

Figure 6.6: Third Step

tiplying it by 0.1. Now, each agent does have a particular level of *PropensityToLeave*, if this subjective value is larger or smaller than the *MobilityThreshold*, than the preference order regarding the working decision changes. Let us explain better. If an agent is more *mobile*, that is its *PropensityToLeave* is larger than the threshold, it is more ambitious, more willing to find a fitting job regardless of where it is located. On the contrary, an individual who is less mobile than the threshold does not really care so much about the job it will find, but rather on staying close to its comfort area. More, the *DiplomaConvertibility?* is the eventuality in which by emigrating the academic title is not accepted, or valued or convertible in the immigration country. The idea behind is reflecting the chance by which highly qualified individuals move to another country, but they are not employed within their field but banished to low skilled jobs because their academic degree is not acknowledged. For reference to this issue see Galarneau and Morissette (2008). Finally, the last parameters to be set by the user are the percentages of *high-skilled-jobs* and *low-skilled-jobs* in the two countries. These are the jobs that are initially offered by any of the two country for any of the two categories of jobs. If, for instance, we set the jobs values in *Country1* to 0.5 and 0.5 and the population is 10, this means that *Country1* will offer to its inhabitants $0.5 * (Population/2) = 0.5 * 0.5 * 10 = 2.5$, round to 3, working places of any type.

The procedures buttons are the *setup*, the *go* and the *SeeNetwork*. The former initialize the world, creating the two countries and starting the population and the jobs offers. The *go* procedure entails the dynamics of the simulation, it will be analyzed more in detail later. Finally, the latter enables the user to graphically see the network. By pressing that button, it is possible to get a vision of the network, which can be organized both as a circle, where agents are ordered according to the choice of the user, or as a tree, see figure 6.7

Now, let us move to the plots of the simulation. While the sliders and the switchers are useful to perform experiments on the dynamics of the simulation under various con-

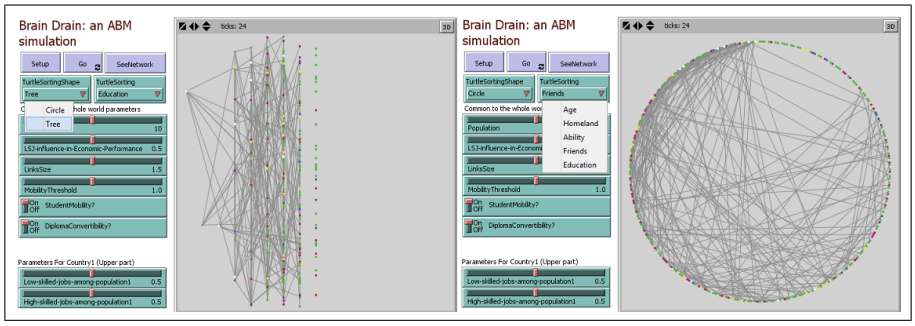

Figure 6.7: SeeNetwork

ditions, the plots are necessary to read the outcomes. *Output* represents the production of the two countries, where the brighter line refers to *Cuntry1* and the darkest to *Country2*. Note that this chromatographic choice will be valid in may representations. The red line, instead, shows the average output of the two countries.

Even though the job parameters, that is the percentages of any kind of job for any of the two countries are initialized exogenously, they evolve endogenously, depending on the economic performance of the two countries. The *JobParameters* plot represents this, the endogenous evolution of the percentages of jobs of the two types, violet for the high skilled and green for the low skilled, offered by the two countries. The *Job Positions* graph is strongly related to this concept. As the working positions are offered as a round of the parameter multiplied by half the population, they do evolve by steps. This last graph is the representation of the steps.

Easily to understand, the *Students* plot represents the number of students in any country. The yellow lines represent the students taking part to international mobility programs.

The *Workers Country* i plot, with $i = 1, 2$ represents the employment of all the people located on a specific country. The legend explains clearly enough the meaning of any line color[1]. This plot is useful to understand the characteristics of the working environment within a country, in terms of categories of jobs, unemployment, immigrant workers, returning workers and so on.

The *High Skilled Labor Market Matching* shows how does the job market fits the demand for high-skilled jobs, with blue lines representing fitting workers and the violet lines non-fitting ones.

The *Immigrant Workers* graph shows the numbers of immigrant workers for category. Note that for mismatching jobs, that is high-skilled conducting low-skilled jobs, the important is not the category of the worker, but the category of the job that the worker ends up performing.

Finally, the last representations are related to NA. The *links* graph simply refers to the average length of links. The *Network Distribution* graph represents the degree distribution of the network. Its shape is useful in analyzing the properties of the network

[1] A legend of the colors may be found in Appendix A

itself. Indeed, under some conditions the *degree distribution* of the network assumes interesting features. The *Centrality Distribution* graph, finally, shows the centrality distribution of the agents among the network. The monitor *ScaleFree?* shows when is the network exactly scale free. Other monitors show the *clustering coefficient* of the network, which, as we have already mentioned, does have implications on the transmission pace of information and the propagation of shocks within the network. Finally, the last but not least monitor shows, when possible[2], the *average distance* between nodes, that is the shortest number of intermediary steps between any of the nodes within the network.

6.3.3 Human Capital Investment Decisions

The investment in human capital and in particular in tertiary education is a premise for talking about brain drain, which as we have already explained, refers to the migrations of individuals who have attained at least a Master degree. Within this ABM people born aged 19, that is the time at which generally in Italy people decide whether to enroll in the University or not[3]. The decision is made on the basis of three main aspects, their ability, their network and the economic outlook of the country they live in.

With reference to the last factor, the procedure works in this way. People of each breed look at the *EconomicPerformance* of the country they live in, if it is above the average they set the variable *Outlook* as a value drawn from a normal distribution with mean 0.7 and variance 0.5. If, on the contrary, the *EconomicPerformace* is equal or below the average between the *EconomicPerformances* of the two countries, they draw out the value from a normal distribution with the same variance but mean 0.3. More, as following Jackson (2014)

> Consider the choice of an individual to pursue higher education or even just to participate in the labor force. The payoff from doing either of these is dependent on the decisions of a person's friends and acquaintances. For example, it is well-documented that social contacts play an important role in obtaining jobs. Thus, if the friends and acquaintances of an individuals are educated and employed, the individual has a greater incentive to become educated and be part of the work force as she or he will have greater opportunities to take advantage of the education and/or participation in the labor force.

The agents, then, count the proportion of friends who are studying.

Finally they sum up these first two values to their *ability* and we use this sum as mean for a normal distribution with variance 0.5. As each of the addend has an average of 0.5 and they are sum up, it can be expected the average of the sum to be around 1.5

[2]When not all the nodes are connected to each other, it is not possible to compute the average distance and the monitor reports false.

[3]Within this model are not taken into account late decisions of enrolling to the University, nor the abandon possibility. This last in particular could be an interesting future development of the simulation model.

and so the random normal, then if the number extracted is larger than 1.5 the individual under investigation studies.

```
to Study

ask turtles with [age = 19] [
      let Average 0
      let Outlook 0
      let StudyingFriends 0
      let Identity 0
      let Indicator 0


      ;EconomicPerformance

      ifelse breed = Ones
             [ifelse EconomicPerformance1 > AverageOutput
               [ set Outlook random-normal 0.7 0.71][set Outlook random-normal 0.3 0.71]]
             [ifelse EconomicPerformance2 > AverageOutput
               [ set Outlook random-normal 0.7 0.71][set Outlook random-normal 0.3 0.71]]

      ;Network
      foreach FriendsList [ set Identity item Indicator FriendsList
                            ask turtle Identity [if student = 1
                            [set StudyingFriends (StudyingFriends + 1)]]
                            set indicator indicator + 1
                            ]

      ifelse length FriendsList != 0 [
      set Average ( Ability + (StudyingFriends / length FriendsList) + Outlook )]
     [set Average (Ability + Outlook)]

      set Perspectives random-normal Average 0.71
      if Perspectives >= 1.5
       [set student 1 set color yellow set PropensityToLeave (PropensityToLeave + 1)]]

   ExchangePrograms

   set students1 count Ones with [student = 1]
   set students2 count Twos with [student = 1]

   ask turtles with [ age = 25 and student = 1] [ set student  0 set graduated  1]
end
```

If it is allowed by the switch *StudentMobility*, students can spend a period of time abroad[4] and once there, they generate a new set of links with the people met in those circumstances. Finally, once students reach 25 years, they graduate and they enter the working environment.

6.3.4 Job Search an the Returning Decision

This is one of the central procedures of the whole simulation model. Here people perform a job search which depends on their *PropensityToLeave*. This personal aspect, indeed, leads them to have different sets of preferences and, thus, a different job search.

[4]The possibility of doing exchange programs is given to any student, only those with high-enough levels of *Sociability* will effectively take part to them

In detail, we count the jobs offered for any kind of work in both of the countries under investigation. Later, the individuals may follow two different procedures, if their *PropensityToLeave* is above the *MobilityThreshold*, set by the user through a slider on the interface, they prefer to find a matching job, no matter if this implies moving. On the contrary, if their propensity to leave is low, they prefer to stay, no matter if this implies adapting to a non-matching job.

The flow works in the following way. If the *PropensityToLeave* of the agent is higher than the *MobilityThreshold*, the order of preferences is first *LookForMatchingJobInHomeCountry*, followed by a question. Is the *DiplomaConvertibility* activated? In other words, the agent is asking: "If I go abroad, will I be able to perform a fitting job or would I be deemed to perform a non-fitting one?" If the *DiplomaConvertibility* is present, the agent will then *LookForMatchingJobAbroad* and only later *LookForNonMatchingJobAtHome*. If *DiplomaConvertibility* is not activated, the agent would directly *LookForNonMatchingJobAtHome*. After these quests, if it is still unemployed, it will *LookForNonFittingJobAbroad*.

If, instead, the agent's *PropensityToLeave* is lower than the *MobilityThreshold*, the order of preferences is different. First, the agent will *LookForMatchingJobInHomeCountry*. Note that a fitting job in the home country is the Pareto optimal solution for any agent independently of its *PropensityToLeave*. Later the agent will *LookForNonMatchingJobAtHome*. Finally, if there is *DiplomaConvertibility* it will first *LookForMatchingJobAbroad* and if still unemployed after that it performs the *LookForNonFittingJobAbroad* procedure. If there is no *DiplomaConvertibility*, instead, it directly performs the *LookForNonFittingJobAbroad* task.

Finally, according both to their *PropensityToLeave* and their network, emigrated agents decide whether to come back or not. If their *PropensityToLeave* is higher than the *MobilityThreshold*, they will only come home for a matching job. If they have friends, they evaluate if they do have more friends in the foreign country or in the homeland and according to this, they decide whether to come back or not. If they do not have any friend, this decision will be random. If their propensity to leave is below the mobility threshold, then they could be willing to come back even for a non-matching job. If they have friends, the procedure is the same but for this last, just-mentioned aspect. If they do not have friends, they have a higher probability (0.8) of coming back home. To conclude, this procedure sums up all the variables accounting each category of workers, but these last steps are not reported below.

```
to WorkingProcedure

  ifelse count Ones != 0 [ask max-one-of Ones [age]

    [ set HSJ1 high-skilled-jobs set LSJ1 low-skilled-jobs ]][set HSJ1 0 set LSJ1 0]

  ifelse count Twos != 0 [ask max-one-of Twos [age]

    [ set HSJ2 high-skilled-jobs set LSJ2 low-skilled-jobs ]][set HSJ2 0 set LSJ2 0]

  let Identity 0
  let Indicator 0
  let LivingAbroadFriends 0
```

```
ask turtles [


  ifelse PropensityToLeave > MobilityThreshold[

        LookForMatchingJobInHomeCountry
        ifelse DiplomaConvertibility?
         [LookForMatchingJobAbroad LookForNonMatchingJobAtHome]
         [LookForNonMatchingJobAtHome]
        LookForNonMatchingJobAbroad

        ifelse length FriendsList != 0 [
          let origin homeland
          while [indicator < length FriendsList][
             set Identity item Indicator FriendsList
             ask turtle Identity [
               if (homeland = origin and emigrated = 1 and returned = 0) or
               (homeland != origin and emigrated = 0) or
               (homeland != origin and emigrated = 1 and returned = 1)
               [set LivingAbroadFriends (LivingAbroadFriends + 1)]
                set indicator indicator + 1]

              if LivingAbroadFriends / length FriendsList < 0.5
               [ReturnForMatchingJob]]]
      [if random-float 1 < 0.5 [ReturnForMatchingJob]]]

          [LookForMatchingJobInHomeCountry
           LookForNonMatchingJobAtHome
           ifelse DiplomaConvertibility?
            [LookForMatchingJobAbroad LookForNonMatchingJobAbroad]
            [LookForNonMatchingJobAbroad]

            ifelse length FriendsList != 0 [
              let origin homeland
              while [indicator < length FriendsList][
                set Identity item Indicator FriendsList
                ask turtle Identity [
                  if (homeland = origin and emigrated = 1 and returned = 0) or
                 (homeland != origin and emigrated = 0) or
                 (homeland != origin and emigrated = 1 and returned = 1)
                 [set LivingAbroadFriends (LivingAbroadFriends + 1)]
                  set indicator indicator + 1]

                 if LivingAbroadFriends / length FriendsList < 0.5
                  [ReturnForMatchingJob  ReturnForNonMatchingJob]]]
       [if random-float 1 < 0.28[ReturnForMatchingJob
                                                 ReturnForNonMatchingJob]]]
   ]

end
```

6.3.5 Developing

The *Develop* procedure monitors the output according to the individuals who have entered the production system. The output of each country is generated by the workers within the country. The contribution of low-skilled workers to the economic performance depends on the influence of low skilled jobs on the economy (LSJ-influence). This means

that it might happen that the contribution of one high-skilled to the output is larger than the one of a low-skilled. Later, if the output is growing compared to last year, the parameters regulating the percentage of jobs in the country are increased by a certain amount, 0.01 for high-skilled and 0.015 for low-skilled jobs. On the contrary, they are decreased by the same amount if the economy is performing worst than in the previous year.

```
to Develop

 let Production1 0
 let Production2 0

 set Production1 h-g1 + h-m1 + h-r1 + LSJ-influence-in-Economic-Performance * ( l1 + l-m1 + l-r1 )
 set Production2 h-g2 + h-m2 + h-r2 + LSJ-influence-in-Economic-Performance * ( l2 + l-m2 + l-r2 )

 set EconomicPerformance1 Production1
 set EconomicPerformance2 Production2

 ifelse EconomicPerformance1 >= OutputLastYear1 [
   ifelse EconomicPerformance1 = OutputLastYear1 [
     set ParameterAlpha1 (ParameterAlpha1) set ParameterBeta1 (ParameterBeta1)]
    [set ParameterAlpha1 (ParameterAlpha1 + 0.01) set ParameterBeta1 (ParameterBeta1 + 0.015)]]
 [set ParameterAlpha1 (ParameterAlpha1 - 0.01) set ParameterBeta1 (ParameterBeta1 - 0.01)]

 ifelse EconomicPerformance2 >= OutputLastYear2 [
   ifelse EconomicPerformance2 = OutputLastYear2 [
     set ParameterAlpha2 (ParameterAlpha2) set ParameterBeta2 (ParameterBeta2)]
    [set ParameterAlpha2 (ParameterAlpha2 + 0.01) set ParameterBeta2 (ParameterBeta2 + 0.015)]]
 [set ParameterAlpha2 (ParameterAlpha2 - 0.01) set ParameterBeta2 (ParameterBeta2 - 0.01)]

 ask Ones [ set high-skilled-jobs round(ParameterAlpha1 * 0.5 * Population)
      set low-skilled-jobs round(ParameterBeta1 * 0.5 * Population)]
 ask Twos [ set high-skilled-jobs round(ParameterAlpha2 * 0.5 * Population)
      set low-skilled-jobs round(ParameterBeta2 * 0.5 * Population)]


 if count Ones != 0 [ask max-one-of Ones [age]
     [set High1 high-skilled-jobs set Low1 low-skilled-jobs]]
 if count Twos != 0 [ask max-one-of Twos [age]
     [set High2 high-skilled-jobs set Low2 low-skilled-jobs]]
 set AverageOutput ((EconomicPerformance1 + EconomicPerformance2) / 2)
 set OutputLastYear1 EconomicPerformance1
 set OutputLastYear2 EconomicPerformance2

  end
```

6.3.6 Network Analysis

To conclude, we report the lines of the code analyzing the network generated within the simulation. For implementing the analysis we have made use of the NetLogo extension NW, which is included in the latest version of the program[5]. As it has been mentioned before when describing the plots on the interface, the analysis of the network generated within the simulation consists on examining various factors. We investigate the degree

[5]For further information see: https://github.com/NetLogo/NW-Extension

distribution, the centrality distribution and the clustering coefficient. We also analyze the properties of the network, such as the average path length or if it happens to be scale-free. Finally we look at the average length of links as an effect of migration flows. In the section devoted to the experiments, we will sometimes count the percentage of ticks on which the simulation happens to have interesting features, such as being scale-free or a small-world.

```
to AnalyzeTheNetwork

nw:set-context turtles links

  ;Frequency-Degree Distribution
  ask turtles [
    set Degree (length FriendsList)
    histogram [Degree] of turtles

  ;Average number of links
    let TotalLength 0
    set LinksNumber count links
    ifelse LinksNumber != 0 [ ask links [set TotalLength (TotalLength + link-length)]
      set AverageLinksLength (TotalLength / LinksNumber)]
    [ set AverageLinksLength  0]]

  ;Path-distance
  set PathDistance nw:mean-path-length

  ;ClusteringCoefficient
  set ClusteringCoefficient mean [ nw:clustering-coefficient ] of turtles

  ;Is Scale-free?
  ;The procedure checks if the number of nodes with degree k is proportional to (1/k-squared)
  set IsScaleFree? false
  let minK min [Degree] of turtle-set turtles
  let maxK max [Degree] of turtle-set turtles
  let CountTurtlesWithKLinks 0
  set k minK
  if minK != 0 [
    while [k <= maxK][
      set CountTurtlesWithKLinks (count turtles with [length FriendsList = k])
      if remainder CountTurtlesWithKLinks (1 / k * k) = 0 [
        set IsScaleFree? true]
      set k (k + 1)
      ]]


    ;Centrality
   ask turtles [set Centrality nw:betweenness-centrality]

end
```

Chapter 7

Experiments

In the following chapter we will make use of the simulation constructed to test the relevance of some factors on the issue of brain drain. In particular we will perform various simulations to analyze the effect of single variables or particular combinations of factors on the resultant dynamics of high-skilled migration flows.

7.1 Standard Configuration

As the aim of this chapter is understanding what effects, if any, in which direction and by how far do the involved variables have on the general outcomes, it might be useful to design a *standard configuration* with reference to which investigating the diverse resulting aspects of any variable. The standard configuration is designed as shown in table 7.1. This configuration entails the average values of the variables involved. The aim is not simulating a specific country or a particularly realistic starting point. It is a benchmark. By performing the experiments, successively, it is possible to adapt the initial conditions to some that are more easily found in reality or that reflect special conditions which might be very interesting to analyze. The analysis, finally, will be performed by comparing the more sought configurations to the standard one, by investigating diversities and similarities and by explaining them.

One last point, some variables of the model are cumulative. The economic performance, for instance, depends largely on the population on the country, the more working people there are, the more output is produced. It is inevitable, then, that these variables will be increasing until the world is full, which will happen after 46 ticks[1]. This aspect is important to be noticed because, although the pace at which cumulative variables increase is revealing of the dynamics of the model, the most interesting part of the analysis might reside in the dynamics after the world is completely full, that is after 46 ticks.

All the experiments will be performed over 150 ticks and the simulation will be repeated 3 times for reducing the randomness. The graphs presented are taken randomly

[1]People are born aged 19 and when they get 65, retirement age in many countries, they *retire*, that is they disappear from the simulation world. After 46 years, then, the population on the world is full. New born arrive for substituting the retiring agents.

Population	10
LSJ Influence in Economic Performance	0.5
LinkSize	1.5
MobilityThreshold	1
StudentMobility	Off
DiplomaConvertibility	Off
LowSkilled Jobs Country 1 (LSJ1)	0.5
HighSkilled Jobs Country 1 (HSJ1)	0.5
LowSkilled Jobs Country 2 (LSJ2)	0.5
HighSkilled Jobs Country 2 (HSJ2)	0.5

Table 7.1: Standard Configuration

from one of the simulations performed[2].

Figure 7.1 shows the resulting dynamics from the standard configuration performance. What arises is that there is no strong difference between the outcomes in the two countries. Indeed, they start from the same conditions and thus, the slight variations among the performances of the two countries depend on random factors and are not solid.

Labor market matching is satisfactory in both the countries, which means that the great majority of high-skilled workers are performing a fitting job.

Migration flows are null in the long run. Note that the values are extracted at the end of the simulation, which means that after 150 ticks, no migrant is found. This does not imply that in the dynamic of the simulation no migration flow has occurred. The intuition is that the countries are similar, with similar performances and thus alike job offerings, therefore, as *ceteris paribus* even the most ambitious agents prefer to stay in the native country, no migration flow occurs in the long run. Some migration flow has indeed taken place in the dyanimic, especially within the non-skilled labor market. Migration flows within this configuration has a strange shape characterized by peaks sometimes time-lasting. This configuration of the migration flows suggests the instability of the diversity within the performance of the two countries that impedes the birth of structured migration flows.

The proportion of students is highly variable in both of the countries.

The unemployment rate lies on average around 15%.

The average length of links is close to the initial level, set by the user on the interface, as no movement is occurring and no agent is displaced. Because of the scarcity of migration flows the network is not very connected. The clustering coefficient is rather

[2]All the available graphs can be found in the Experiments Appendix

low, it lies around 0.26. The average distance, that is the shortest path to connect any two nodes in the network, is false. This means that there are nodes that are totally disconnected from the network. This appears evident by looking at figure 7.2, where agents in the last row are totally separate from the rest of the network. Figure 7.2 shows also another perspective of the social network, where agents are sorted by homeland in the former case and by education in the latter. There appears to be a clear separation of the personal ties between the countries. The network, finally, is not scale-free.

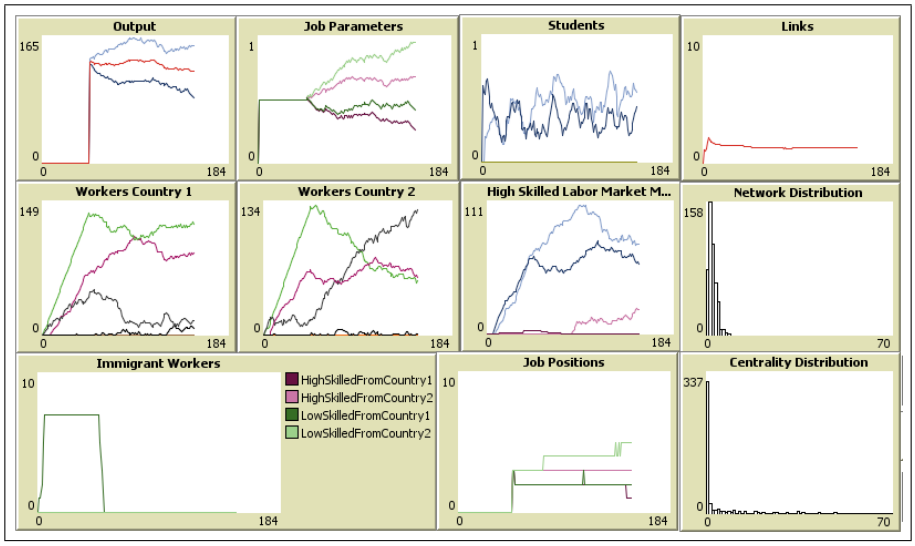

Figure 7.1: Standard Configuration Ensuing Performance

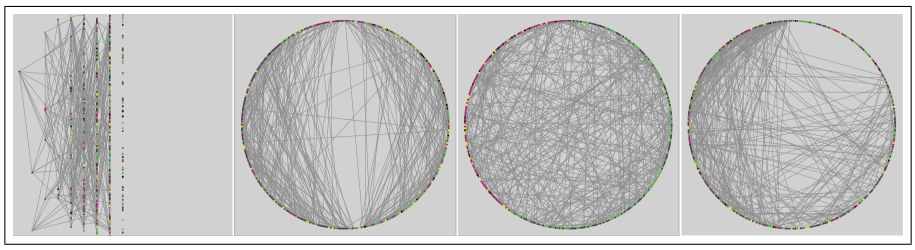

Figure 7.2: Network of the standard configuration represented first as an organogramm and as a circle sorted by homeland, education and friends

7.2 Investment in Human Capital

This section is concerned on understanding how do specific variables influence the process of investment in human capital within the simulation model. According to the design of the model, the studying decision depends on three main factors: ability, social network and economic output. Ability is not controllable by the user, so no test can be performed

with regards to this aspect. This is reasonable as ability is not observable in reality and also it is very harshly influenced by socio-economic or political measures. What is interesting to analyze, then, are the other two aspects. We will perform six experiments to achieve what is their role on the human capital investment decision.

The first test is about the influence of links size and is performed by reducing it to 0 and by enlarging it to 3. These two values modify the size and the characteristics of the social network. What we see from comparing the outcomes is that in the first case, where the network is strongly reduced, the economic output is on average smaller than when the social network is strengthened. This might depend on the positive influence of the social network on the human capital investment decision. By augmenting the social connections people appear to be intensely more penchant to studying, also high-skilled working positions contribute more[3] to the economic performance than low-skilled ones and this might explain the positive influence of the social network on the economic performance. A first consideration achieved from this experiment is that connection between individuals is positive for the community as a whole, it has positive externalities that influence education and economic output through education. The positive influence of the social network on economic output might depend also on the matching in the labor market which appears to be much larger in case of a stronger social network. The increased network, largely expanded on a spacial dimension as well, operates by augmenting the propensity to leave of the agents, which are, then, more ambitious, they prefer not to renounce to a fitting jobs. Figures 7.3 and 7.4 show the dynamics of the two simulations.

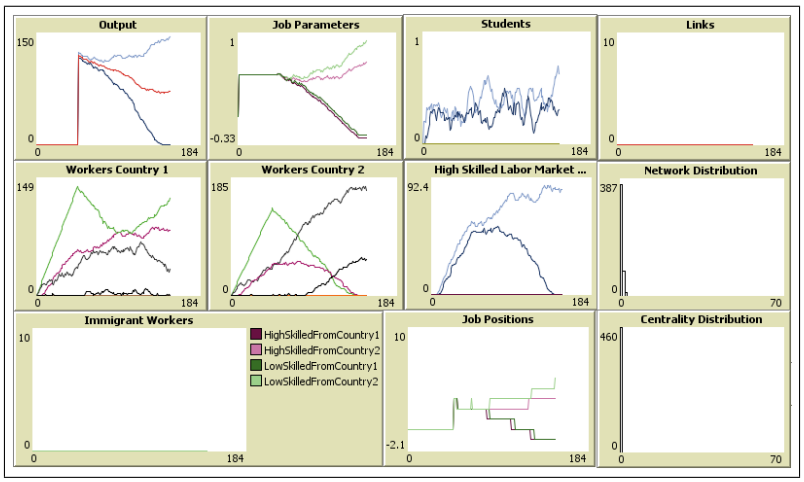

Figure 7.3: Human Capital Investment Decision Experiment 1.a

To conclude the analysis of this first case, figures 7.5 and 7.6 show the differences in the social networks generated within the two simulations. It is clear that in the first case the network is much more complex and inter-related. The clustering coefficient is rather

[3]Low-skilled works influence on economic performance is set equal to 0.5

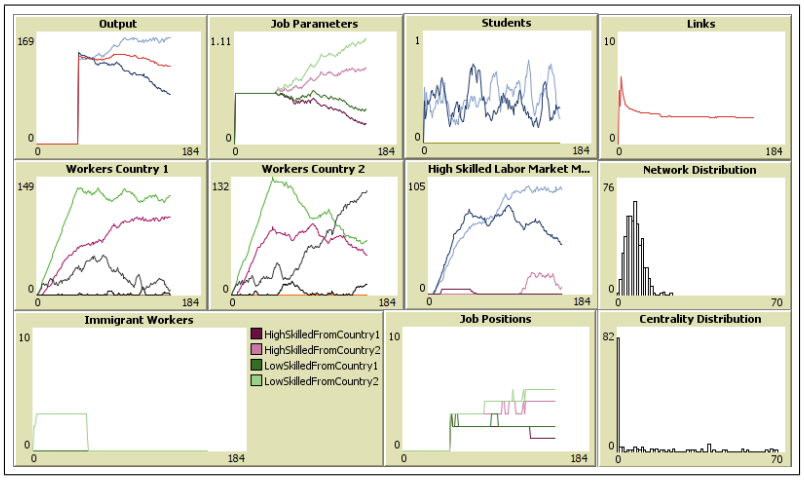

Figure 7.4: Human Capital Investment Decision Experiment 2.a

high in the second case, lying around 0.60, while it is extremely low in the first case (0.02). The average links length is much lower, close to 0 in the first case. This aspect depends on the fact that the amount of links is very limited. The degree distribution in the first case is not very interesting, as most of the agents do not have any connection. On the other hand in the second case the degree distribution appears to be much more diversified see figure 7.4. The centrality distribution is also much diversified, with the second case entailing some long-tailed distribution aspects, which means that some agent is a core node for the dynamics of the simulation.

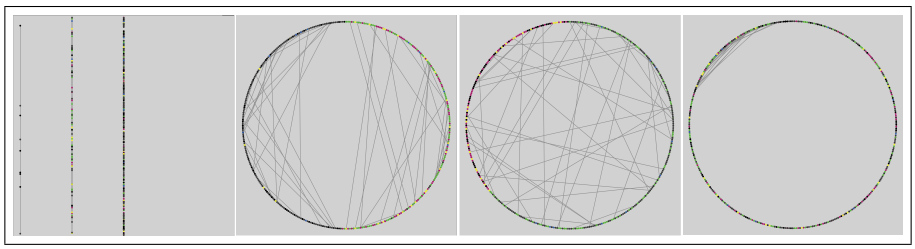

Figure 7.5: Network of the Human Capital Investment Decision Experiment 1 represented first as an organogramm and as a circle sorted by homeland, education and friends

The second experiment performed is about the relevance of population. Population indirectly affects the social network as well, as, if people are less numerous, they are more spread around the world and thus, links size equal, the network is less dense.

In proportion, the variable population seems to slightly negatively influence the proportion of studying agents, which partly contradicts what has been shown in the previous paragraph. Previously, indeed, we have mentioned that a stronger social network entails a positive influence on the investment in human capital decision. The contradiction,

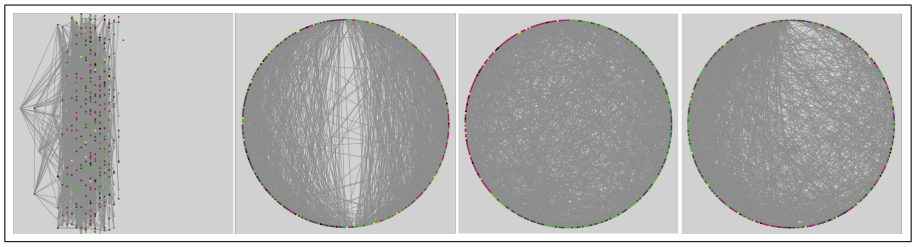

Figure 7.6: Network of the Human Capital Investment Decision Experiment 2 represented first as an organogramm and as a circle sorted by homeland, education and friends

though, is only partial as the networks generated in the two cases are very different. Within this example, in the most favorable case for network generation, that is that in which population is set to 20, the social network is still much less inter-connected that in the case with long links. This aspect can be slightly perceived by looking at figure 7.8 as compared to figure 7.6, by noticing that the clustering coefficient in this second experiment is lower than in the previous case and mostly by comparing the degree and the centrality distributions of the two variants shown in figure 7.10. Figure 7.7 shows the network in the less crowded world.

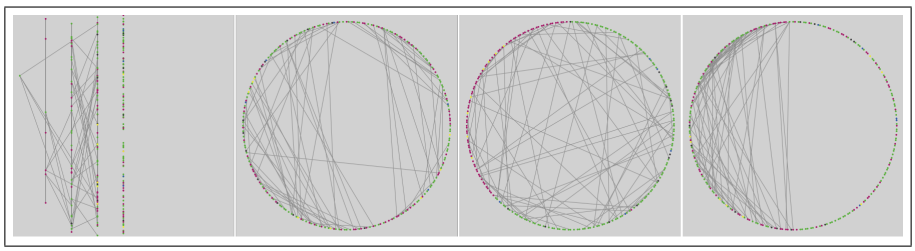

Figure 7.7: Network of the Human Capital Investment Decision Experiment 3 represented first as an organogramm and as a circle sorted by homeland, education and friends

The dynamics of the simulations can be seen in figures 7.9 and 7.10. It is clear that by enlarging the population the variables appear to have a more regular path, while with low population parameters they appear to be highly variant. The proportion of students, which is the investigated variable within this section strongly evidences this aspect.

The last experiment performed with regards to the human capital investment decision is referred to the available jobs, that influence the economic performance and consequently the expected benefit of studying. The experiments will be performed by differentiating the two countries, one offering a surplus of working positions and one just a few. The tests will be two, one in absence and one in presence of diploma convertibility

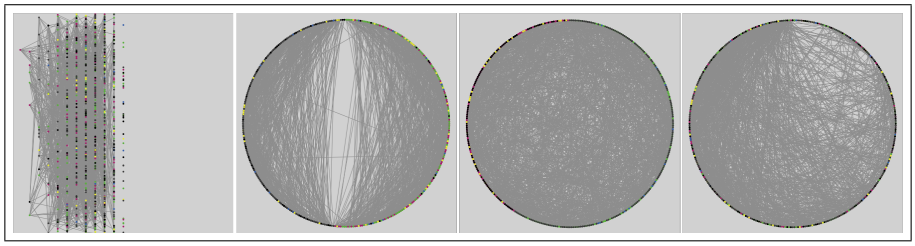

Figure 7.8: Network of the Human Capital Investment Decision Experiment 4 represented first as an organogramm and as a circle sorted by homeland, education and friends

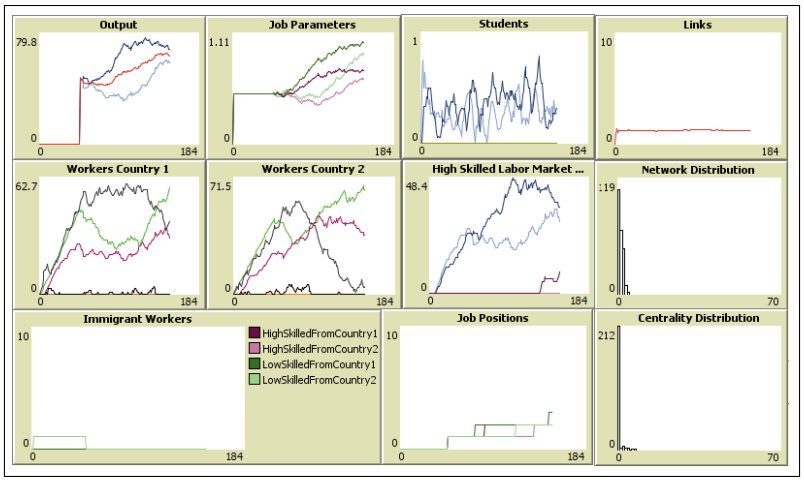

Figure 7.9: Human Capital Investment Decision Experiment 3.a

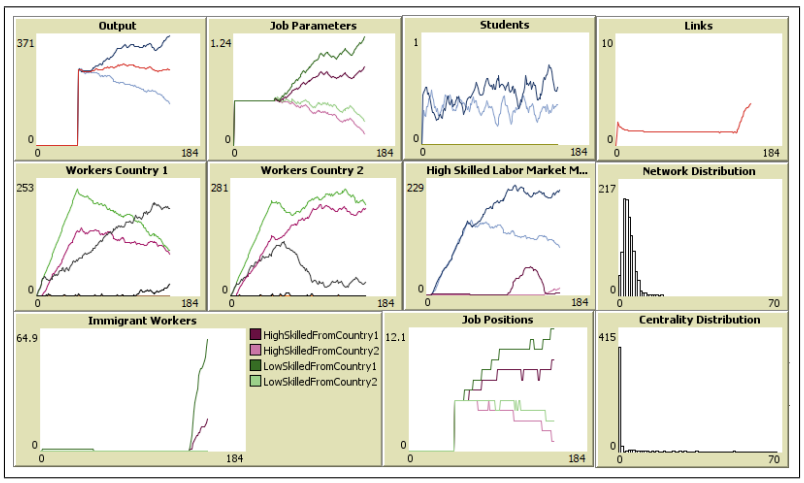

Figure 7.10: Human Capital Investment Decision Experiment 4.a

within the two countries[4].

An unequal distribution of working positions reduces the final economic output of the world as a whole. The negative performance of the less-favored country, indeed, reduces the aggregate output. The more favored country, instead, is facilitated by the lack of perspectives of the other one and somehow exploits the negative performance of its concurrent. This is mostly seen when degrees are convertible in the foreign country. The already highly richer country gets richer by exploiting migrating human capital from the less-favored one.

The percentage of students is slightly reduced in case of an unequal economic situation. The interesting factor though, is not the average between the two countries, but the fact that it is mostly reduced in the country with less favorable perspectives. The diploma convertibility option reduces the gap between the proportion of studying agents in the two countries.

Migrations are extremely larger and much more diversified in the second case, as the possibility of spending the degree abroad induces high-skilled workers from the less favored country to migrate. Figures 7.11 and 7.12 clearly show this aspect.

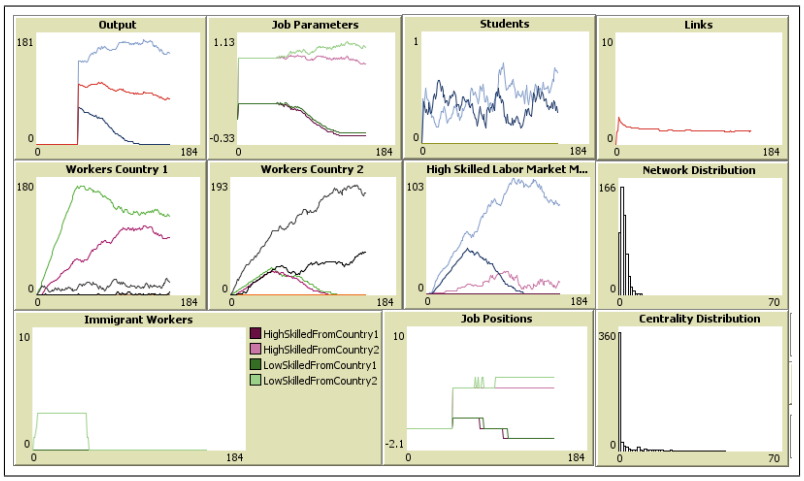

Figure 7.11: Human Capital Investment Decision Experiment 5.a

The networks generated within these last two experiments are very similar to each other as can be seen by the centrality and degree distributions and are represented in figure 7.13.

A concluding remark is that enlarging the population provides more homogeneous dynamic paths, which allow for a clearer investigation of the outcomes. In case of similar economic situations, a dense social network increases the economic output, the proportion of studying agents and the matching within the labor market. In case of unequal distribution, the average economic situation of the world as a whole is worsened. Inter-national differences start arising. In terms of economic output, the favored country

[4]See Experiments Appendix for more details regarding the configuration values

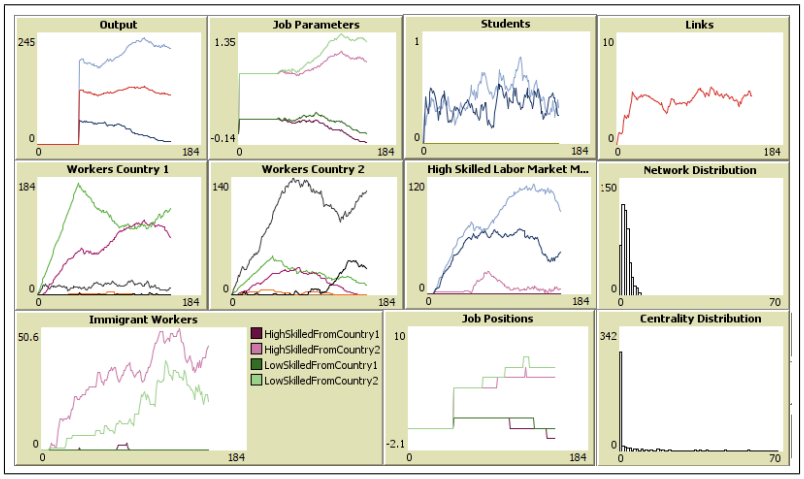

Figure 7.12: Human Capital Investment Decision Experiment 6.a

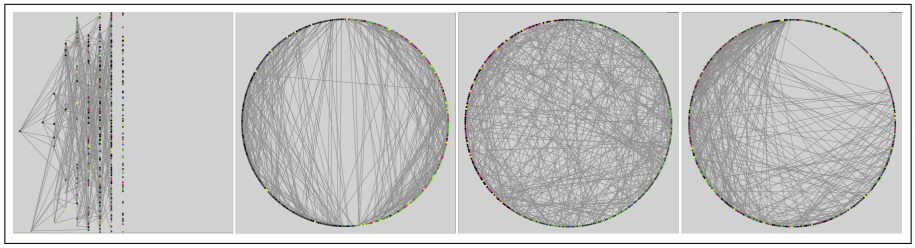

Figure 7.13: Network of the Human Capital Investment Decision Experiment 5 and 6 represented first as an organogramm and as a circle sorted by homeland, education and friends

enjoys the advantages coming from the lack of perspectives in the less-developed nation. More it does so if it lets incoming migrants exploiting their degree in the arrival country. The proportion of students is harmed as well by an uneven development. The distribution of students between the two countries is unbalanced in favor of the most advantages one, but the convertibility of degrees contributes to reduce this gap. Uneven economic starting points increase migration flows, which happen to be unidirectional from the poorer to the richer country. Migration flows are still scarce and only composed of non-qualified workers if diploma convertibility is not activated. On the contrary, when it is possible to exploit academic degrees abroad, the number of migrants start increasing and the flows start being composed by both skilled and non-skilled workers, where the former component is prevailing.

7.3 Network Analysis

It has been mentioned in the previous chapters that social networks play a core role in most socio-economic phenomena. Personal connections and relationships influence decisions in this simulation as well. In the previous section for instance it has be shown that a dense social network makes agents more inclined to studying. We will then perform four experiments to analyze how does the social network react to the variations in the involved variables[5]. First we will set up two extreme situations, one with a hugely thin social network and one with an extremely thick one. Later we will test a reduced migration rate on the last case by equating the economic departure. Finally we will test how does an opening, in terms of mobility programs during the University studies and convertibility of degrees, affect the outcomes of the standard configuration in terms of social network characteristics.

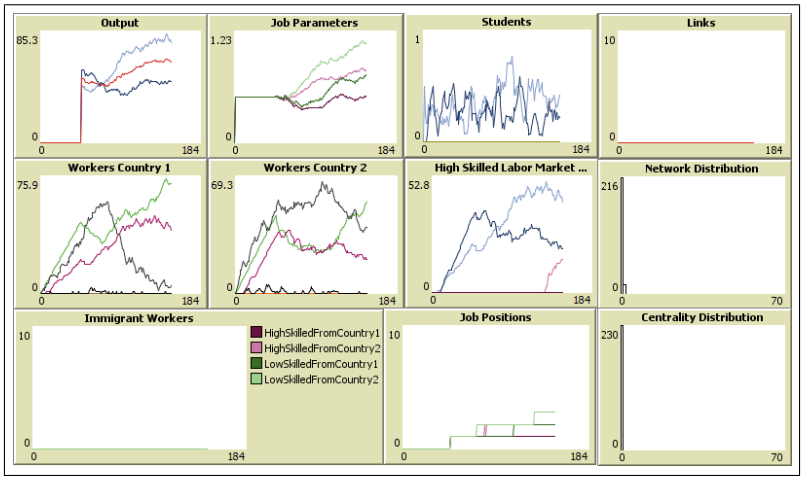

Figure 7.14: Network Analysis Experiment 1.a

[5]See Experiments Appendix for more details regrading the experiments configurations

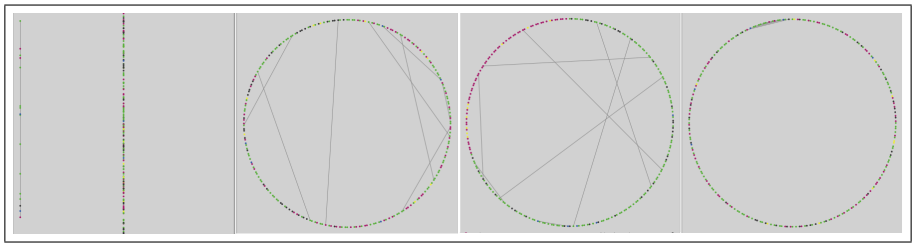

Figure 7.15: Network generated in the first network analysis experiment, represented first as an organogramm and as a circle sorted by homeland, education and friends

What emerges is that in case of an extremely thin social network, as compared to the standard configuration, the economic output is reduced. The parameters governing the creation of new working positions are slower. The percentage of students is lower. Matching in the labor market is strongly worsened, with higher percentages of high-skilled workers working in a low-skilled position. Migrations are null in the long run and agents are completely disconnected as shown by figure 7.15. The reasons behind this aggregate losses within the simulation world may be deriving from the lack of regulating and influencing role of the social network. The lack of a strong social network together with the low number of agents make dynamics highly variant, as shown by figure 7.14. The students proportion, for instance, only depends on the ability of agents, which is randomly chosen from a normal distribution, and the economic performance of the two countries.

Migration flows are null, both in the long run and within the dynamics. This aspect contribute to reduce the interconnections of the network. The process is actually circular. A few connections reduce the propensity to leave of agents, which migrate less and thus have less possibilities to increment the social connections. This lack of connections has an influence on the labor market matching as well, as, having a low propensity to leave, people are less ambitious and more likely to accept a non fitting working position rather than emigrate.

To conclude, we can consider that such a thin network could be realistic in representing very isolated areas. Outside from these areas, though the importance of the network in influencing socio economic processes can not be neglected. Eliminating this factor brings in the analysis extremely variant results hard to analyze. More, it has been shown here, that the lack of a well-structured social network is extremely damaging for the economies of the countries under investigation.

The next experiment, instead, is about the outcomes of a stronger social network. For this analysis has been added to the code a counter that identifies how many ticks during the simulation the social network has been both scale free or has had the small world properties[6].

[6]Note that these two eventualities may coincide. For having the small world properties, the network has to show a relatively high clustering coefficient, larger than 0,4, and a positive path distance, that is all the agents in the world being interconnected. No requirement has been placed on the size of the average distance, but the values observed always lie around 5 steps

Figures 7.16 and 7.17 show the resulting dynamics and social network of the simulation. It is evident that the social network is extremely interconnected, much more than in any of the previous tests. The reason is that the parameters have been settled in order to generate very frequent inter-connections. A crowded population, long links, an unequal economic situation, which induces labor mobility enhanced by the diploma convertibility, are the parameters on which we have played for performing this experiment. Finally the possibility of exchange programs during the University courses both enlarges the network of friends by adding foreign ones and augments the mobility capital of individuals that are successively more penchant to migrate and thus generate new social networks.

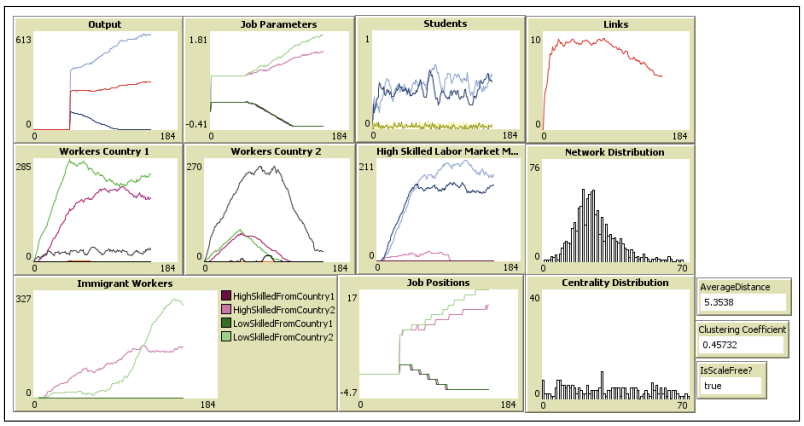

Figure 7.16: Network Analysis Experiment 2.a

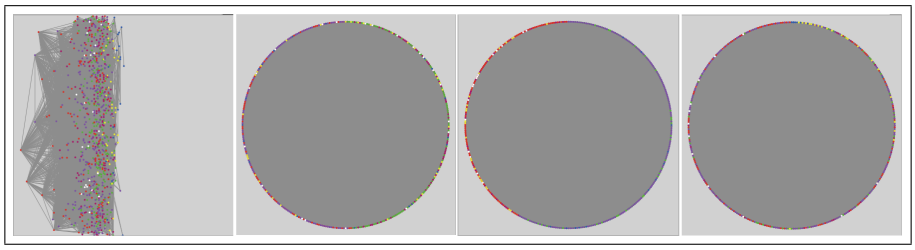

Figure 7.17: Network generated in the second network analysis experiment, represented first as an organogramm and as a circle sorted by homeland, education and friends

The outcomes of the simulation show that the economic output in presence of a strong social network is much higher than in the previous experiment. The percentage of studying agents is largely higher. This aspect is contrasting to what has been found in the previous section of experiments when performing the test of how does investment in human capital respond to an unequal economic starting point. In this case as well the point of departure is an unequal economic situation, which has previously been shown to negatively influence the proportion of studying agents. The joint action of the convertibility of degree and the strong social network is compensating and overcoming

the negative effect of an unjust starting point. Unemployment is strongly reduced. Matching in the labor market is improved. What we see, then is a strong improvement in comparison to the previous test. The comparison to the standard configuration is less impressive, but improvements can be found in terms of human capital investment and matching in the labor market.

Talking mores strictly about the social network it is to say that it resulted to be a scale free network for the 84% of the ticks of the simulation, indeed the network distribution is characterized by a long-tail as it is clear from figure 7.16. Also it is has shown characteristics of a small world network for the 82% of the ticks of the simulation. It is strange to notice that the clustering coefficient is not extremely high (0,45). The average length of links is very high, as mobility is strong. The centrality distribution seem to present a uniform distribution, although extreme values might have been excluded by the plot.

The next experiment starts from similar conditions to the previous one, the difference is the economic starting point of the two countries, that is equal in this case. The purpose is to test both the influence of the reduced migration flows on the social network and the effects on the economic output of this variation.

What we achieve is that the outcome does only slightly differ and mostly in the distribution of the results rather than on the aggregate average. Aggregate output is higher than in the previous case, where the working positions were concentrated in the hand on one country only. In this test, instead, economic performance is rather equally spread among the two. Parameters generating new working positions follow the same path, with the average level being equal, but showing a strong inter-national difference in the previous case. In the first test, indeed, parameters generating working positions in the less-developed country resulted to be negative, that is job-destructing rather than job creating, but they were compensated by extremely high levels in the richer country.

The percentage of students is similar, slightly lower in the second test. The percentage of exchanging students is not affected by the starting economic performance in presence of such a thick social network.

In absolute numbers domestic workers are affected by the starting economic situation, with many more domestic workers existing in the most fair starting point. The matching in the labor market differs as well, with a more fair distribution in the second case and a perfect labor market matching in the long run. Finally, unemployment, existing for low-skilled workers only in this experiment, is lower than in the previous case.

As guessed, migration flows of both high-skilled and low-skilled are strongly reduced by an equal starting point. The origin of migrants is also affected as in the first case migrants are only originating from the less-developed country, while in the second one they are leaving from both the countries equally. Working migrants, extremely numerous in the first case, generate a large part of the aggregate output in the unfair starting point.

Talking more strictly about the social network, it is curious that the average links length and the clustering coefficient are higher in the second case, where, as mentioned, migrations are rarer. This aspect might depend on the presence of returning migration in the second case which enhances the average links length. Also, the bi-directional

migration entails an in increase in the links length as compared to a unilateral migration, which leads to a concentration on a smaller spatial dimension (the destination country) and consequently to a reduced size of the social connections. The network is scale-free the 79% of the ticks of the simulation and has the small world characteristics for the 77% of ticks[7]. The proportions are lower than in the previous case, because of the reduced migration flows. Figure 7.18 show the network generated within this experiment, in this representation it looks quite similar to the previous case. Figures 7.19 shows the degree and centrality distributions of the network. They appear to be very similar to the previous case, network distribution long-tailed configuration appears though to be slightly mitigated.

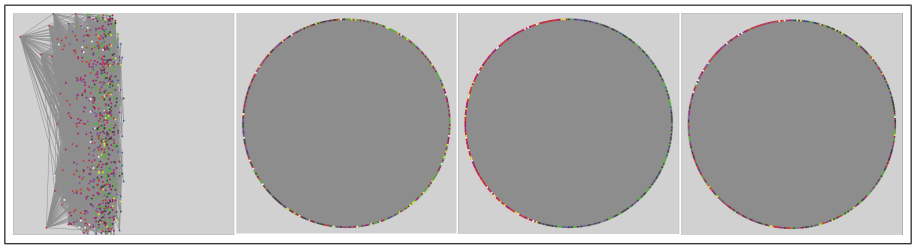

Figure 7.18: Network generated in the third network analysis experiment, represented first as an organogramm and as a circle sorted by homeland, education and friends

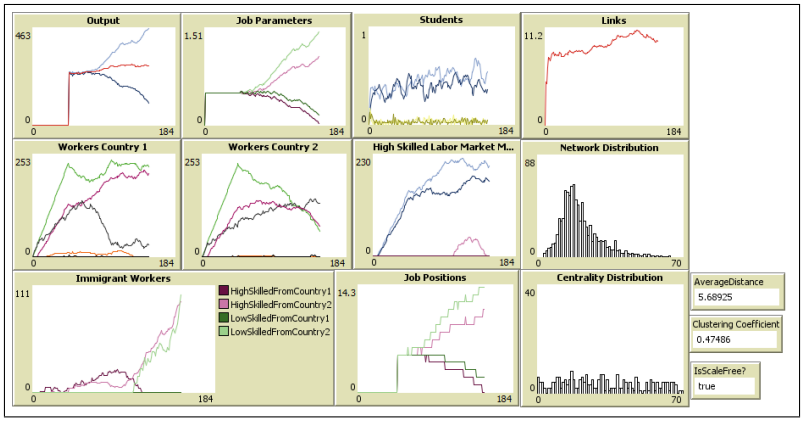

Figure 7.19: Network Analysis Experiment 3.a

The last experiment performed is a variation of the standard configuration, where migration flows are favored by exchange studying programs during the University and by the degree convertibility abroad. The results achieved by comparing this experiment to the standard configuration are that the aggregate economic output does not change significantly nor the percentage of students does. Exchange students exist in the second case and they allow for a more inter-connected social network as it is shown by figure

[7]Note that these two eventualities may coincide.

7.20, where, even when agents are sorted by homeland, the world appears to be fully communicant.

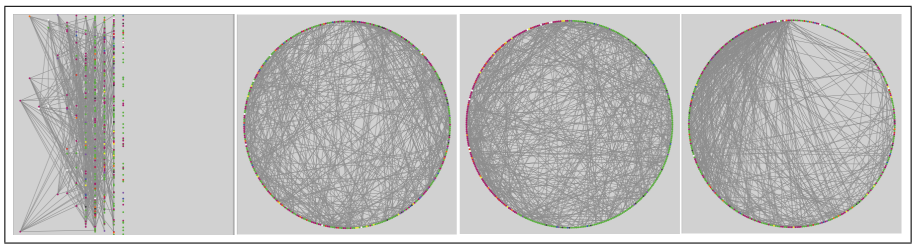

Figure 7.20: Network generated in the fourth network analysis experiment, represented first as an organogramm and as a circle sorted by homeland, education and friends

Unemployment is increased in this experiment, but it is compensated both by an increase in the matching in the labor market which pushes more agents to look for a fitting job rather than contenting themselves with non-fitting ones and by the migration flows, which bring into the countries new labor force. Average links length is much larger in the second case as migration produces an increase in the links length as people are physically moving from one country to the other. Also, migration produces an increase in the clustering coefficient which is raised by 5%.

The dynamics of this experiment can be seen in figure 7.21. A first evidence is the increasing trend of the average length of links. This is correlated to the increasing migration flows registered in this simulation that are much more considerable and time-lasting than in the standard configuration.

Through the analysis of the dynamics it is possible to evince that, although in the second case unemployment is slightly larger than in the standard configuration, it is declining, so it is reasonable to expect that it will decrease in the future. In the standard configuration, instead, it is increasing. In this experiment, also, it is possible to find patterns of returning migration flows.

Network distribution and centrality distribution are slightly different. Indeed, although they are characterized by a similar shape both in this test and in that for the standard configuration. The standard configuration shows a more Poissonian shape, with an extremely high number of people have extremely low connections; in this simulation the distribution is more homogeneous and the number of agents with higher numbers of connections is increased. Likewise, although centrality distribution is similar in both the tests, in the second case the number of agents with zero connections is strongly reduced.

Summing up the conclusions made within this section it is to say that an extremely thin social network is detrimental for the aggregate economy. It reduces output and University students, slows down the parameters generating working positions, worsens the matching in the labor market. It decreases the migration flows, makes the outcomes highly variant and hard to read and finally we think is not realistic as socio-economic processes are strongly driven by social connections. On the contrary, a thick and significant social network does frequently have likely characteristics such as scale-free and

Figure 7.21: Network Analysis Experiment 4.a

small world distributions. As compared to the previous case, it largely enhances the social output, increase the percentage of agents investing in human capital, decreases unemployment and increases the matching in the labor market. When slightly reducing the size of the social network by equalizing the economic starting points of the two countries, the network appears to be less-frequently characterized by the distributions mentioned above, but it does exhibit a more fair development, with workers, students, migrants and working opportunities more equally spread on the two countries. Finally, favoring migrations with simple strategies such as student mobility or degree convertibility allows for an increased realism in the social network, with centrality and degree distributions of the network being more diversified and people more connected between each other. Migration flows, all in all, foster labor market matching.

7.4 Migration Flows Analysis

The following section is concerned on analyzing what effects do some parameters have on migration flows[8]. We have already considered that unequal development, thick social networks, diploma convertibility and student mobility foster migration flows. Within this section we will perform four experiments in order to conclude the analysis with regards to migration flows. First we will test the effects of variating the mobility threshold, that is the limit on which the propensity to leave of each agent is confronted and preferences are ordered. If the latter is above the former, agents will be more ambitious, that is more willing to find a fitting job rather than content themselves with a non-fitting one just not to leave the native country. Finally we will test the influence of variating the mobility threshold in contexts of unequal starting point, where inequality is feeble. The purpose of this section is generating flows, migrating and returning. The issue of skilled

[8]See Experiments Appendix for details on the experiments configurations.

migration is also slightly investigated.

The first two tests are compared to the last experiment of the previous section, which corresponds to the standard configuration allowing, though, for student mobility and diploma convertibility[9]. This comparison is made in order to better isolate the effect of changing the mobility threshold.

What emerges is that aggregate output is slightly decreasing on the mobility threshold. So are the parameters generating working positions and, consequently, the working positions, reaching their minimum level when the mobility threshold is the highest. These three variables, indeed, always follow similar paths. One peculiarity, though, is that, apart from extremely low levels, low mobility thresholds generate an unfair distribution of the aggregate economic output between the two countries, which tends to be eliminated by increasing the threshold, see for instance the dynamics in figures 7.22 and 7.23.

The proportion of students is not related to the mobility threshold, nor is the proportion of exchange students.

Unemployment, which is mostly made of low-skilled workers, seem to be positively related to mobility, that is higher levels of mobility thresholds induce higher level of unemployment. A reasonable explanation might be, indeed, that a low mobility threshold together with an institutional open market expands the frontiers of labor research.

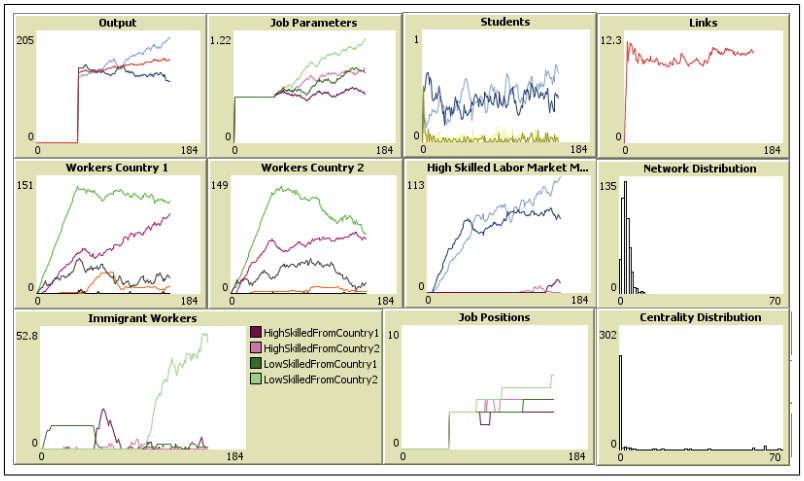

Figure 7.22: Migration Flows Analysis Experiment 1.a

It is interesting to analyze whether there is an effect of different mobility thresholds on migration flows. Returning flows are quasi-completely made of high-skilled migrants and are always very low and they are negatively related to the variable under questioning. The intuition is the following, by increasing mobility threshold, only those with higher *PropensityToLeave* will move out. These individuals, though, are also the less-likely to return, indeed their coming back decision is constrained by the finding of a fitting

[9]In the Comparative Table in Experiments Appendix it is called SCb

Figure 7.23: Migration Flows Analysis Experiment 2.a

working position in the home country. The mobility threshold affects the selection of migrants. When it is below 1, migration flows are mostly made of low-skilled migration. Low-skilled migration, though, although more variant, tends to decrease by increasing mobility, while the high-skilled one, although slightly, tends to increase. For high levels of the mobility threshold, then, high-skilled migration ends up being made mostly of high-skilled migration. Level 1 for the mobility threshold seems like the level at which migration changes from being mostly low-skilled to mostly high-skilled.

Another curious aspect is correlated to the links length, which is larger when mobility threshold is very high. Actually, the average links length remains quite constant for various levels of the mobility threshold, but it increases largely when the mobility threshold is at its maximum level. Clustering coefficient seem not to be affected by the mobility threshold. By comparing figures 7.22 and 7.23 it is possible to gather that centrality and degree distributions slightly differ, but the variation is very feeble.

Labor market matching follows a particular path, reaching the best situation, between those achieved in the experiments performed, when mobility threshold is at medium level (1), that is the same level for which returning migration is higher. On the contrary, non matching workers seem to be increasing in the mobility threshold.

Figure 7.24 and 7.25 show the networks generated within the two experiments, which appear to be very similar.

Experiments 3 and 4 test different levels of the mobility threshold in situations of weak economic inequality between the countries. To better understand the outcomes of the tests we have performed another experiment, called Experiment T in the tables, where the same inequality in the economic starting point together with student mobility and diploma convertibility is applied to the standard configuration[10].

What emerges is that output is generally lower than in the previous experiments. Output seem to depend on the mobility threshold, although the relationship is variant.

[10]See Experiments Appendix for a better specification of the configuration of Experiment T

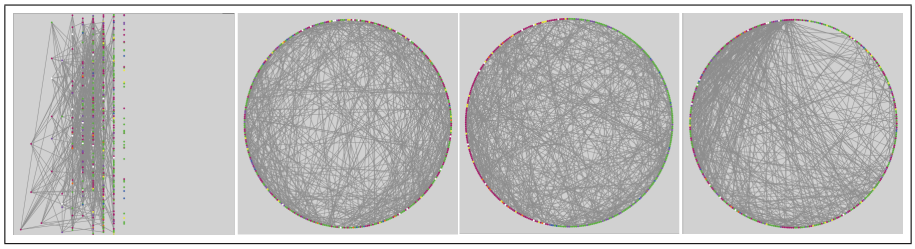

Figure 7.24: Network of the Migration Flows Analysis Experiment 1 represented first as an organogramm and as a circle sorted by homeland, education and friends

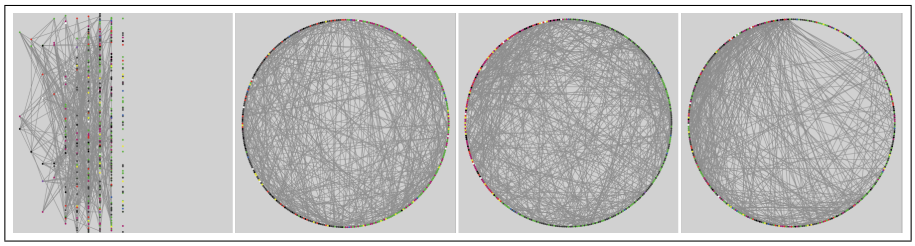

Figure 7.25: Network of the Migration Flows Analysis Experiment 2 represented first as an organogramm and as a circle sorted by homeland, education and friends

The aggregate output is stable for values of the mobility threshold between 0 and 1, it decreases dramatically when the mobility threshold assumes value 1 and starts increasing strongly after. This sharp increase might depend on the fact that, as before but here underlined by the unequal starting point, higher mobility threshold levels produce a fairer distribution of the aggregate output between the two countries in the long run, as can be clearly seen by comparing figures 7.26, 7.27 and 7.28. The job creating parameters work at increasing pace in the mobility threshold and so do the working positions generated. Exception is made for when mobility threshold is set at level 1 which produces the minimum parameters. The reason for these negative aspects connected to level 1 of the mobility threshold might be dependent on the fact that at this level mobility is not total and, at the same time, aggregate economy does not take advantage of the increased aggregate output generated by the convergence of the two economies. Also, another influent factor, might be that at this level migration flows are still not selected.

The students and exchange students' relation to the mobility threshold is not easy to achieve when the departure point is a slight economic inequality.

Analyzing unemployment, we find out that it is, as before, mostly made of low-skilled unemployment. It looks slightly decreasing in the mobility threshold, but it reaches its highest peak when the mobility threshold is set at 0,5. In these experiments unemployment is more differentiated between the two countries, in particular the more disadvantaged country shows higher levels of unemployment. High-skilled unemployment is only generated by the less-favored country. On average unemployment is higher than in the previous tests. Only for very high levels of mobility threshold unemployment

is lower than before, because, as we have mentioned, for high levels of the mobility threshold the economies converge and the variations generated by the initial inequality are removed.

Employment is increasing in the mobility threshold both for low and high-skilled workers. What emerges is that, in this context of departure from a slight economic inequality between the two countries, increasing the mobility threshold keeps constant the local high-skilled workers employed in the most favored country. Also, it augments the proportion of native high-skilled workers working in the less favored country. This might depend on the fact that we have considered that in the long run higher mobility thresholds tend to reduce the gap between the countries. In the same way, the proportion of native low-skilled workers in the most favored country is constant on the mobility threshold, while that of native low-skilled workers working in their native country is increasing. What we can consider from here is that higher levels of the mobility threshold help in reducing the gap between countries, allowing for a recovery of less-advantaged countries in confront to most favored ones.

The flow of returning migrants exist only for high-skilled workers. It is very low and, as before, it decreases when increasing the mobility threshold. No returning flow exist when the mobility threshold is null.

The flow of migrants is reasonably decreasing in the mobility threshold, for higher mobility thresholds, less migrants are moving from one country to the other. The mobility threshold, as before, helps in selecting the migrants. For levels below 1, most of the migrants are low skilled, while for higher levels most of the migrants are high-skilled.

Figures 7.29 and 7.30 show the networks originated in experiments 3 and 4. It seems that lower mobility thresholds produce better connected social networks, with thicker tangles of interpersonal relations. This appears also in figures 7.26 and 7.27 where both the degree and the centrality distributions indicate a better connected world and less people totally disconnected from the surrounding neighborhood. Higher mobility thresholds produce a fairer distribution of the economic output between the two countries, this reduces migrations and then the connection between the two countries and within the social network itself. The figures are showing the dynamics of the two simulations, where migration flows are smaller in size in experiment 4 rather than experiment 3. The better connection of the network in experiment 3, finally, may be lead back to the higher spacial concentration of individuals, indeed, if migration is unidirectional agents will end up concentrated in one country only. Being the space halved connections are facilitated and so is the concentration of the social network.

What we can consider from this analysis, then, is that the mobility threshold does have an influence on the outcomes of the simulation, although its effects are not always linear. Indeed, the mobility threshold operates in defining which is the preference order of each agents. The preferences, then, are subjected to many factors, internal and external to the agents, such as its innate attitudes and the availability of jobs in any of the two countries. What can be extracted, though, is that in the long run high levels of the mobility threshold reduce the flow of migrants. Not only, from the threshold 1 migrants are selected and migration flows start to be made prevalently by high-skilled

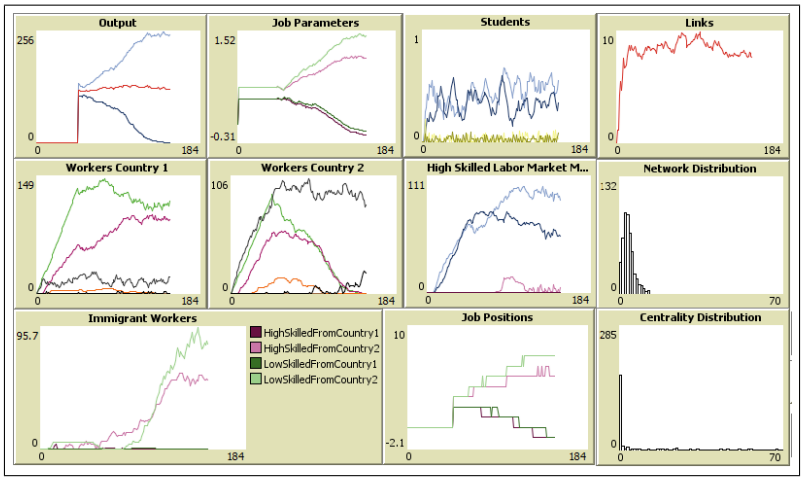

Figure 7.26: Migration Flows Analysis Experiment 3.a

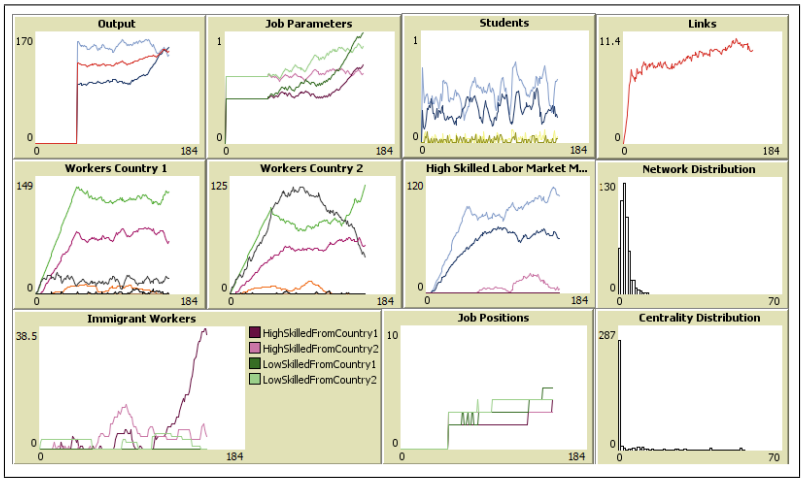

Figure 7.27: Migration Flows Analysis Experiment 4.a

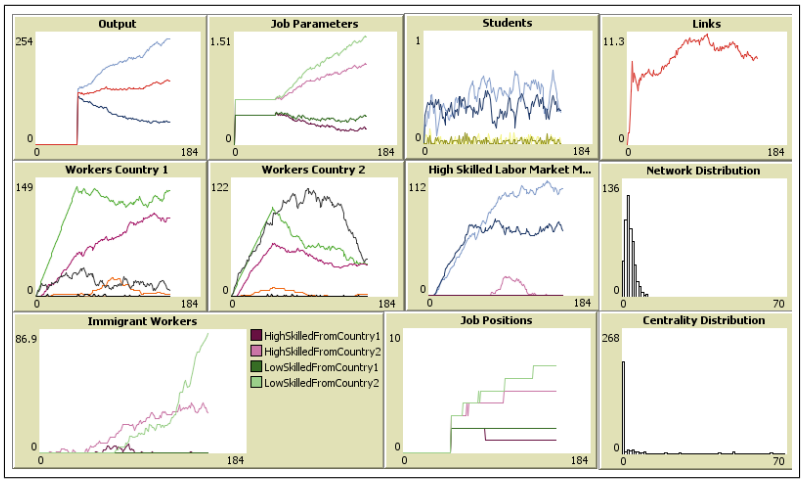

Figure 7.28: Migration Flows Analysis Experiment T

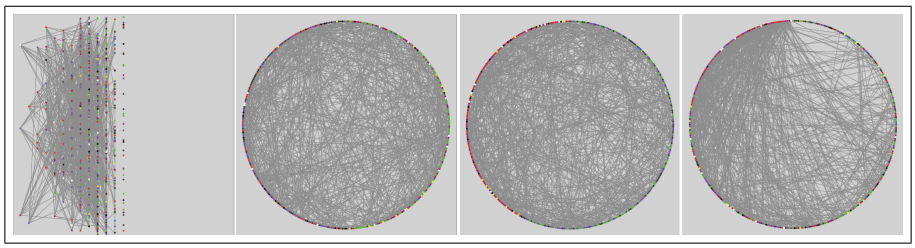

Figure 7.29: Network of the Migration Flows Analysis Experiment 3 represented first as an organogramm and as a circle sorted by homeland, education and friends

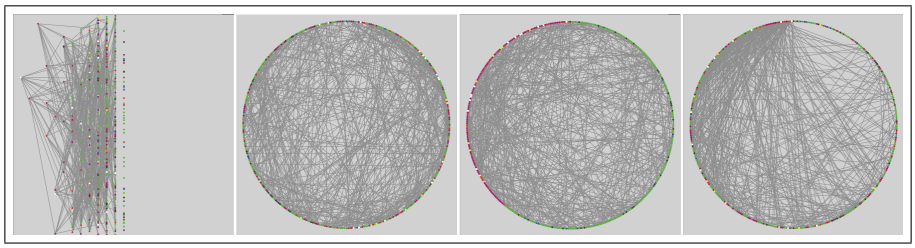

Figure 7.30: Network of the Migration Flows Analysis Experiment 4 represented first as an organogramm and as a circle sorted by homeland, education and friends

migrants. This happens because for higher levels of the thresholds, migration is favored for those agents with an higher propensity to leave, which is positively dependent on the achievement of a University degree and on the completion of an exchange program abroad, which is made while taking part to a tertiary level education. Also, higher levels of the mobility threshold favor the reduction of the gap between different economic performances of the countries, which is mostly noticeable if the departure point is unequal. Finally, increasing the mobility threshold reduces the returning flows of the migrants.

7.5 Economic Output Analysis

This section of experiments is concerned on understanding how is economic output affected by the influence of low-skilled jobs on the economics. In the theoretical foundations to the brain drain phenomenon, it has been mentioned the thesis of Moretti (2012) where he stated that high-skilled workers play a role in the economics generating a multiplier effect. Practically, one new high-skilled job generates five low-skilled jobs. This consideration might be read as a different relative importance of the two kinds of jobs for the economic production. As no mathematical foundation is advanced in support of this statement and the thesis itself is debatable, the simulation built in this research paper allows for testing it. Practically, by choosing one of the three levels of the influence of low-skilled jobs on the economics, the user decides if they do not involve any benefit, they count half of the high-skilled ones or they count exactly the same. Moretti's idea, anyway, is present in the job-creation procedure, as low-skilled jobs mutate much faster than high-skilled ones. In this section we will test the low skilled jobs influence on the economic performance in cases of equal departure conditions and closed economies and in cases of a slight unequal starting point with an open economy.

It does not make any sense comparing the output as it is obvious that for lower levels of influence of the low skilled jobs on the economic performance (LSJ-influence) output will be lower. It seems, though, that medium levels of the LSJ-influence produce a better resulting situation. The output is distributed in a more fair way between the two countries; parameters generating working positions are faster and the percentage of students is higher. As in any of the performed tests, unemployment is mostly made of low-skilled jobs. It increases when the LSJ-influence increases. In the same way the matching in the labor market seem to be worst in situations where the LSJ-influence is higher. Domestic workers, both high and low-skilled decrease while increasing the LSJ-influence.

Why favoring the economic performance through attributing more value to low-skilled jobs without diminishing that of high-skilled ones worsens the overall economic performance? From the dynamics shown in figures 7.31 and 7.32 it is possible to evince that in the second case output is vary stable and characterized by only very slight variations as compared to the first test. This homogeneous trend affects the pace at which parameters are generating jobs, which depends on the difference as compared to the previous year. If the output is stable, there is no need to generate more working positions. The number of jobs appears to be lower also for this reason. The low convergence of the

economic productions of the two countries in the long run also helps in damaging the overall situation. The lower percentage of students may depend on the less-connected network, which can be noticed both in the figures representing the dynamics of the tests and in figures 7.33 and 7.34, representing the networks generated between any of the simulations. The reduction in the percentage of students affects the matching in the labor market by reducing the propensity to leave of the agents. The better connection of the network in the first case depends on the higher number of migrants, which indeed appears to be increasing in the last years of the performance, while it happens to be null in the long run of the second test.

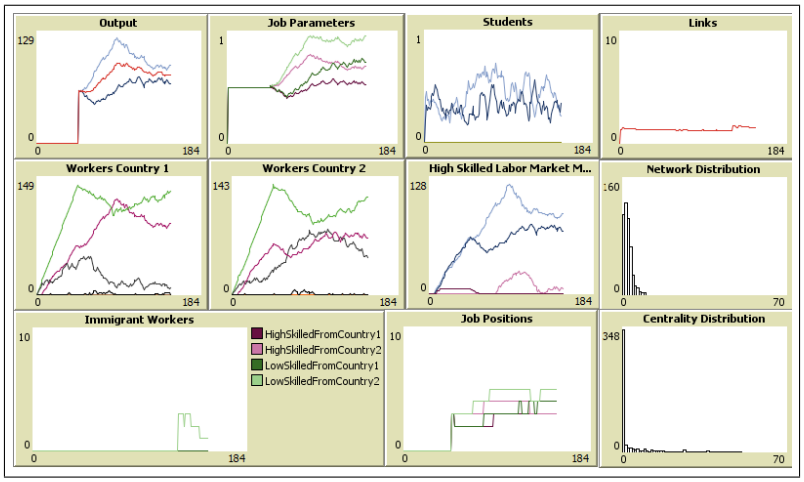

Figure 7.31: Economic Output Analysis Experiment 1.a

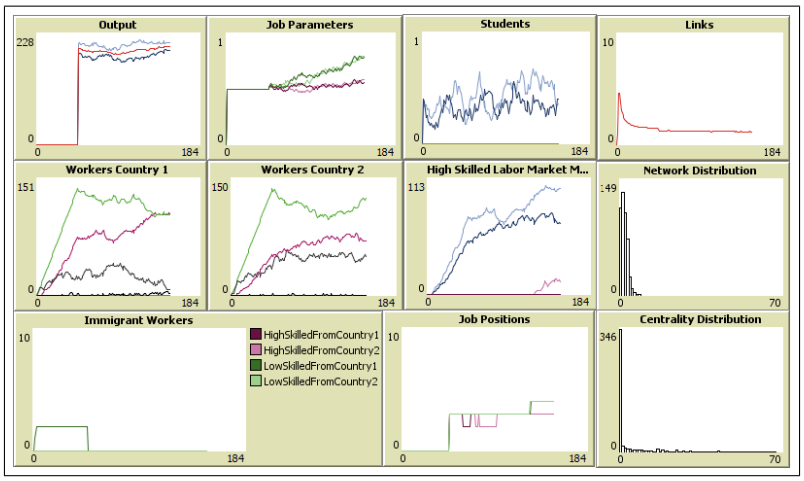

Figure 7.32: Economic Output Analysis Experiment 2.a

The second test shows that starting from slight unequal economic situations and in case of open economies, where citizens can take part to student mobility programs and

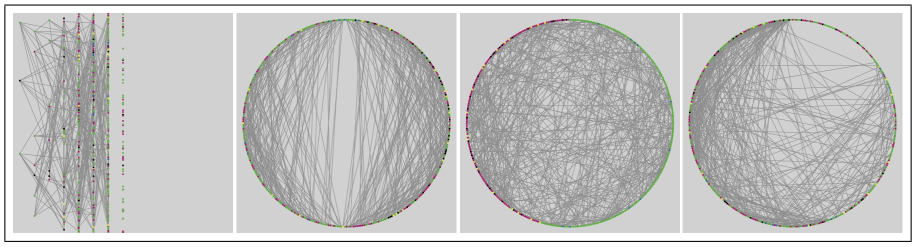

Figure 7.33: Network of the Economic Output Analysis Experiment 1 represented first as an organogramm and as a circle sorted by homeland, education and friends

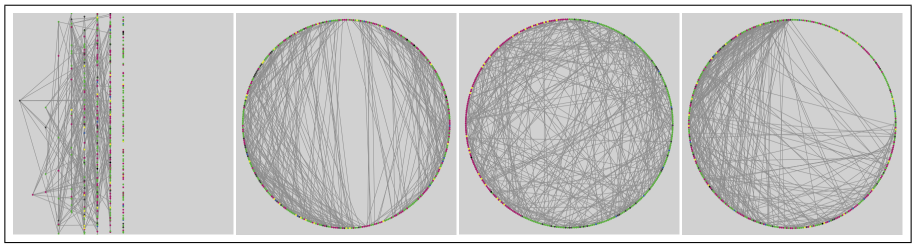

Figure 7.34: Network of the Economic Output Analysis Experiment 2 represented first as an organogramm and as a circle sorted by homeland, education and friends

can exploit their degrees abroad, the distribution of the aggregate economic output is more fair when the LSJ-influence is lower. Also, working positions are decreasing in the LSJ-influence. The aggregate amount of domestic workers, indeed, is decreasing in the LSJ-influence. Domestic workers are made of both high-skilled and low skilled, with the first category decreasing slower than the second one. Increasing LSJ-influence, finally, annihilates the flows of returning migrants, which is very low in any case and only made of high-skilled migrants.

Migration flows are mostly made of low-skilled workers. Only when the LSJ-influence is equal to 0,5 the number of high-skilled migrants is higher than that of low-skilled ones. This might depend also on the fact that variables are accounted in absolute numbers rather than as proportions. The number of high-skilled workers is lower than that of low-skilled ones and this may define the composition of the migration flows. Unemployment, as in all the previous experiments, is mostly made of unskilled workers. It increases the more the LSJ-influence increases. More, there is high-skilled unemployment only when the LSJ-influence is 1. Finally matching is slightly worsened by increasing LSJ-influence.

Students are decreasing in the LSJ-influence, while the proportion of exchange students is different from 0 only when the LSJ-influence is not 0,5.

Figures 7.35, 7.36, 7.37 and 7.38 show the dynamics of the two simulations and the resulting social network. It is clear that the dynamic of the outputs of the two countries is more convergent in the first case, where the LSJ-influence is extremely low. This lack of convergence between the two countries slows down the aggregate pace at which working places are generated. In this case, indeed, the less favored country is deemed

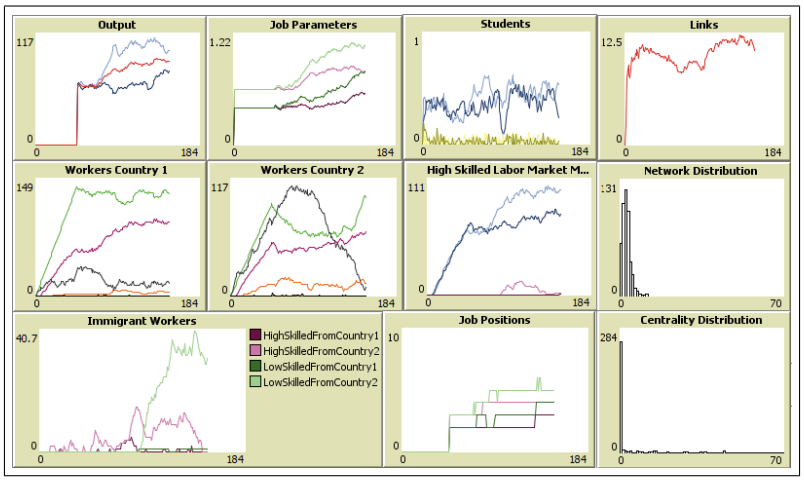

Figure 7.35: Economic Output Analysis Experiment 3.a

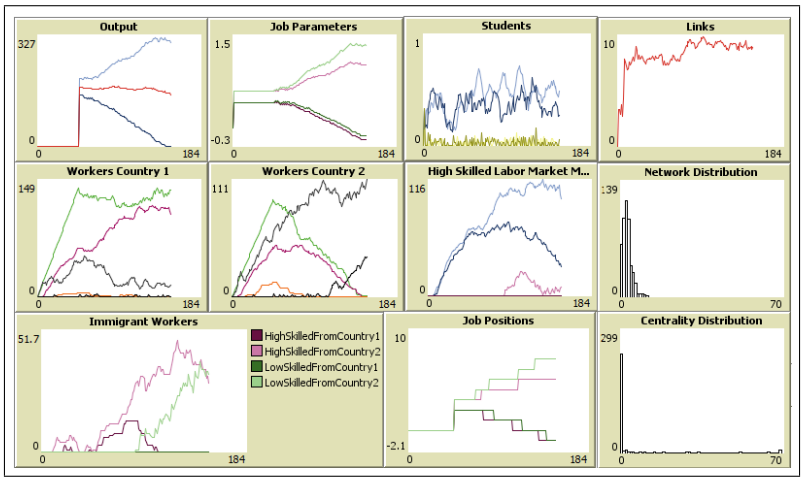

Figure 7.36: Economic Output Analysis Experiment 4.a

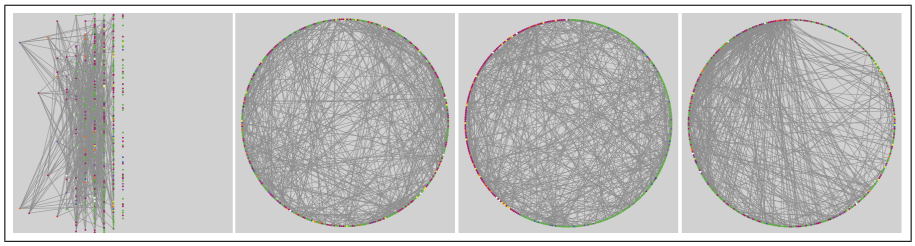

Figure 7.37: Network of the Economic Output Analysis Experiment 3 represented first as an organogramm and as a circle sorted by homeland, education and friends

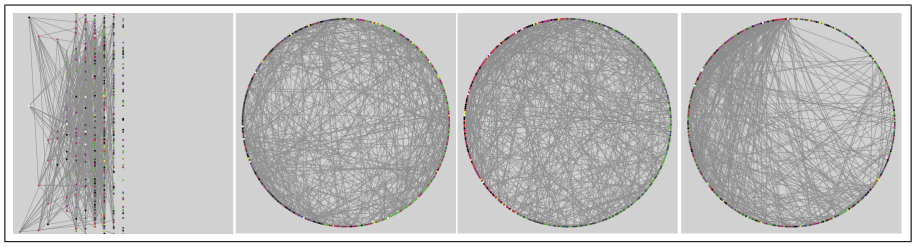

Figure 7.38: Network of the Economic Output Analysis Experiment 4 represented first as an organogramm and as a circle sorted by homeland, education and friends

to decline and it is not generating working positions anymore, it is even destructing the existing ones. This is why on average there are less working positions and less workers. Migrants are higher, because the large gap between the two countries induces people to migrate from one country to the other. The destiny of collapse of one country compared to the other erases any chance of returning migration. Returning migration, present in the test with null LSJ-influence, induces an increase in the average links-length, which are indeed higher in test 3. The increasing gap between the outputs of the two countries when enlarging the LSJ-influence conditions the unemployment levels and the matching in the labor market by worsening them. The outcomes of these experiments, then, confirm what has been suggested in the previous tests, with the unequal departure point emphasizing the effects of the LSJ-influence.

What we can deduce is that although the aggregate economic output is higher when the LSJ-influence is higher, this positive variation is only accounting. The economy performs because the two countries are deemed to follow different paths. On aggregate the economic situation is worst, with less working positions, domestic workers, worsening the labor market matching and increasing unemployment. The proportion of students is also negatively affected by high values of LSJ-influence. The proportion of students is also decreasing in the LSJ-influence. This outcome is counterintuitive but seem to support the Moretti's thesis.

7.6 Brain Drain

Once having tested each single variable separately it is possible to perform one final set of experiments on the issue of brain drain, which is the main matter of concern of this research work. From the previous experiments, we have achieved that the social network is more realistic when the world is crowded and links are long. In this context the network often appears to be scale-free or characterized by small world properties. A copious population also helps in making the dynamics more homogeneous, less variant and easier to understand. We have considered also that unequal economic departures, convertibility of the academic degrees and student mobility favor migration flows. Also we have deduced that the level of the mobility threshold helps in selecting the category of migrants. Finally we have gathered that lower levels of LSJ-influence help a more fair

distribution of the economic output in the long run and enhance returning migration flows.

Within this section we perform five experiments characterized by a thick network of social connections. On this network we test the influence of different levels of economic inequality departure, different configurations of economic inequalities and the influence of parameters such as the LSJ-influence. The mobility threshold is kept high (1,5) in order to select the migrants.

The network generated within any of these experiments is very thick as can be seen in figure 7.39. For this reason we will not enclose any more figure representing the network graphically, but we will rather concentrate on the network analysis by studying the parameters and the distributions characterizing the network itself.

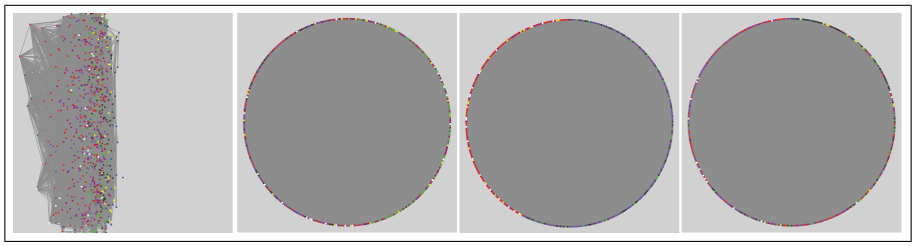

Figure 7.39: Network of the Brain Drain Analysis Experiment 1 represented first as an organogramm and as a circle sorted by homeland, education and friends

The first two experiments compare two situations of slight economic inequality for two different levels of the LSJ-influence[11]. What we achieve from this first experiment is that, as proven in the previous sections *ceteris paribus* high levels of the LSJ-influence worsen the overall economic situation. The distribution of the aggregate output between the two countries indeed worsens, the pace at which, on average, new working positions are generated decreases and so does the absolute number of working positions. Unemployment levels strongly increase wrapping up the high-skilled sector as well, which is not affected by unemployment in the test with lower levels of LSJ-influence, and increasing the proportion of low-skilled workers unemployed. Domestic workers decrease by increasing the LSJ-influence, this trend depends on the increased levels of unemployment. The matching in the labor market is worsened by the increased level of LSJ-influence on the economic performance, passing from a perfect long-run situation with no worker performing a non-fitting job in the long run to one in which the number of high-skilled workers performing a fitting job decreases and the ones performing a non-fitting job increases. Note that the reduction of the former depends both on the increased levels of unemployment, but also on the reduced proportion of students. Investment in human capital, indeed, together with the decision to take part to a student mobility program is negatively affected by high-levels of the LSJ-influence.

In the long run migrant workers strongly decrease when LSJ-influence is higher. To determine the reason behind this reduction in the size of migration flows it is useful to

[11]See Experiments Appendix for more specific definitions of the configurations

look at figures 7.40 and 7.41, which are showing the dynamics of the simulations. In the first case, where the LSJ-influence is lower, the economic performance of the two countries start to differentiate later. The most favored country does have a dominant position in both cases, but in the first one it allows for a slower decrease of the less-favored one. This can be seen both in the dynamics of the output, the job-parameters and the job positions. This prevalence, which appears to be so strong from the first ticks of the simulation, extends the number of migrants from the less to the most developed country. In the other case, where the gap increases slower, migration flows start increasing later in time, so in the long run, when the gap is large and migration flows have not yet taken place substantially they are higher in the former test than in the second one.

It is interesting to notice that migration flows in the former test increase largely when the unemployment level reaches its peak. Unemployment, then, decreases strongly as a large part of the unemployed are absorbed by the labor market of the most favored country. The arrival of numerous migrant from the less-developed country, though, seem not to affect the level of unemployment in the most developed one. This happens also in the latter test.

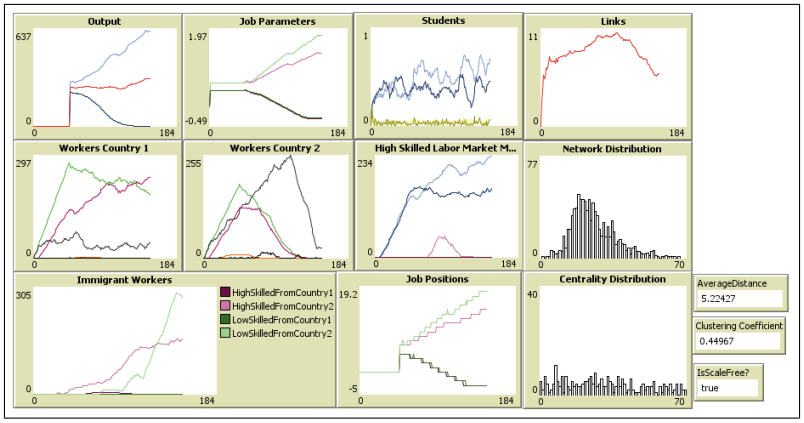

Figure 7.40: Brain Drain Analysis Experiment 1.a

A final remark is regarding the characteristics of the social network, which often appears to have interesting characteristics. It is respectively scale-free and a small world the 89% and the 86% of the times in the first experiment and the 88% and the 85% in the second one. This implies that in more than the 85% of ticks of the simulation the social network is realistic. Average links length is long as migration flows are considerable.

The second cluster of tests examines the outcomes of situations of strong economic inequality between the two countries in cases of different levels of LSJ-influence[12]. The economic departure point is very different, so it is unlikely for the two countries to converge in the long run, this aspect, though, might be mitigated by extremely low levels of the LSJ-influence, which has been shown to favor economic convergence in the long run.

[12]See Experiments Appendix for more details on the configuration of the experiments

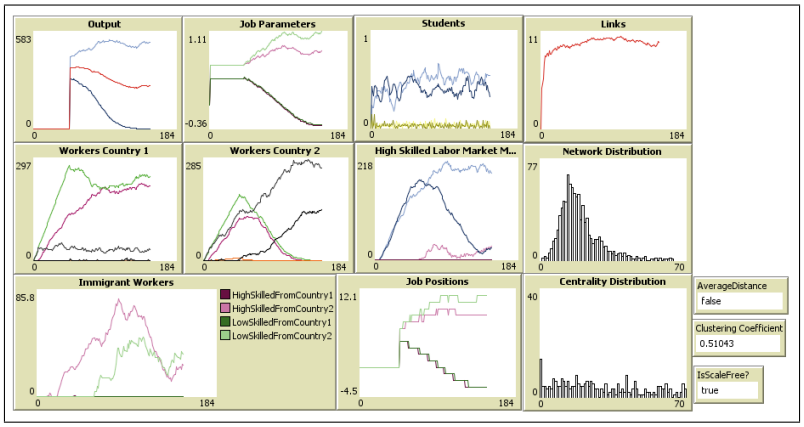

Figure 7.41: Brain Drain Analysis Experiment 2.a

As before, the difference in the economic performance of the two countries is reduced by decreasing the LSJ-influence. This is evident also by analyzing the parameters generating working positions, which on average appear to be slower in the first case. Not only, by looking at figures 7.42 and 7.43 it is possible to evince that in experiment three the pace at which new working positions are generated strongly differs between the two countries. In the less-favored country, indeed, parameters are rather job-destructing than job-creating, while in experiment four they are still positive although extremely lower than in the most favored country. This difference is reflected in the number of available working positions in the two countries. In experiment four they are more numerous and, relatively, more equally spread than in experiment 3. Obviously, this trend influences the dynamics of unemployment, which is extremely high in the former case, involving the high-skilled sector as well, and decreases subsequently in the latter experiment. Employment levels, also, show a negative correlation to the LSJ-influence. Domestic workers are much more present in aggregate in the latter experiment. This depends on all the considerations made above. Also, it depends, on the total absence of workers in the less-favored country in case of high LSJ-influence.

The proportion of migrants is higher in experiment 4. Not only, the flow of migrants is much more lasting in time. While in experiment 3 it looks that agents start emigrating as a boom in the end of the simulation, in experiment 3 migration is solid over time. The disadvantaged economic departure, though, together with a relatively high LSJ-influence do not favor the economic performance of the unfavored country, dooming the agents of this country to an unfortunate future, in which they will be forced to migrate. More, they will migrate in a big wave, rather than a soft ruffle. This will induce issues of overcrowding in the labor market of the destiny country. Not only, impressive wave of foreign migrants often entail strong social consequences, such as the emergence of issues of xenophobia and social exclusion. The proportion of students and the matching in the labor market are also worsened by the increase of the LSJ-influence.

In order to isolate the effect of different economic departure points, we can compare

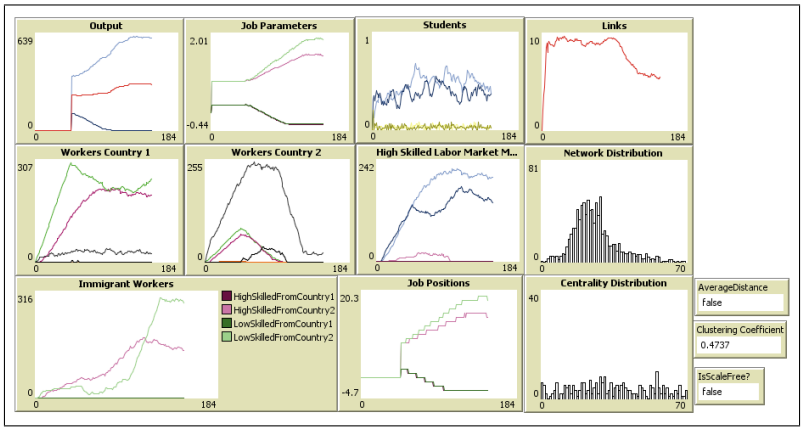

Figure 7.42: Brain Drain Analysis Experiment 3.a

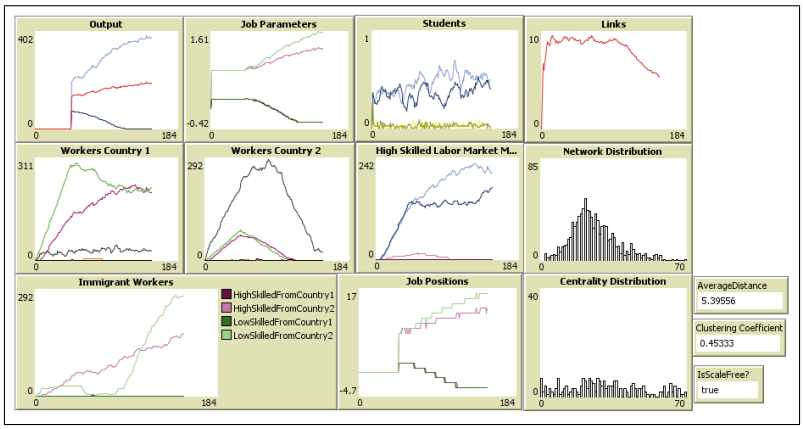

Figure 7.43: Brain Drain Analysis Experiment 4.a

the outcomes achieved in experiment 1 to that achieved in experiment 3. The configurations of these two tests are identical in anything but the distribution of the initial working positions. Slight inequality in the first case is compared to a solid one in the latter.

As it has been considered already more inequality produces lower levels of aggregate output. Also, obviously, the output is distributed in a less fair allocation between the two countries. Parameters generating working positions are negatively affected by increased inequality, and so are the total working positions available. Unemployment is significantly worsened as well, encompassing the high-skilled sector as well in the more unequal situation. This implies that the aggregate domestic workers are less numerous in the latter case. Such a worsening is depending on the strongly negative performance of the more disadvantaged country, which is inevitably performing extremely bad in the latter case. Element that is not, fortunately, ensured in the former case. The proportions of migrants and students are higher as well in the former case.

Experiment 5 is concerned with an unequal distribution of the working positions in the two countries differentiated not in the overall quantity, but in the kind of jobs offered. The two countries offer the same proportion of working positions, but Country1 offers more high-skilled jobs whereas Country2 offers more low-skilled positions. Experiment 6, finally, tests the outcomes in case of equal economic starting points.

What emerges from these last two tests is shown in figures 7.44 and 7.45.

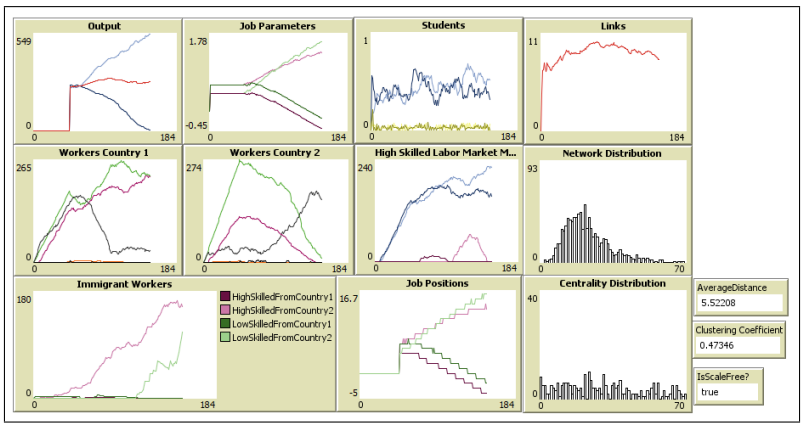

Figure 7.44: Brain Drain Analysis Experiment 5.a

In experiment 5 the country with abundance of high-skilled working positions as compared to low-skilled ones is performing much better than the other one. This depends also on the fact that the LSJ-influence parameters is set at 0.5. The international difference, though, is strong. The parameters generating new working positions are extremely different between the two countries, in the long run they appear to be negative in the country favoring low-skilled positions. The absolute number of working positions, obviously evidences this aspect. It is interesting to notice that numerous high-skilled workers trail the economy and produce an increase in the proportion of low-skilled work-

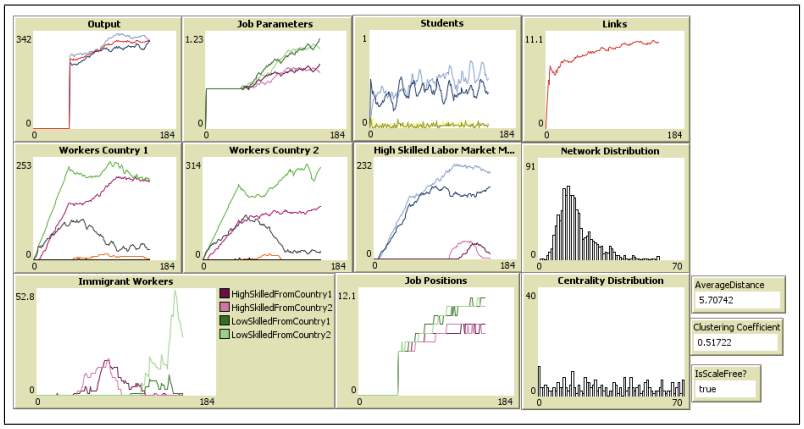

Figure 7.45: Brain Drain Analysis Experiment 6.a

ers as well, while the contrary does not happen. A consideration, then, is that investing in the creation of high-skilled working positions favors the economic performance of a country. The proportion of students, is also strongly and positively influenced by the numerous high-skilled working positions.

It is interesting to analyze the dynamics of the labor force between the two countries. In Country1, where high-skilled jobs are favored, the proportion of high-skilled and low-skilled workers is increasing almost monotonically. High-skilled workers are increasing slower because they need time to achieve their degree. Unemployment is high in the first period because of the lack of low-skilled working positions. When the economy starts evolving and generating new working positions, the unemployment level decreases as many unemployed find positions in the newly generated jobs. In Country 2, where low-skilled jobs are favored, it is evident the initial boom of low-skilled workers, whose absolute number is even higher than in the competing country, and the extremely low level of unemployment. The number of high-skilled workers, though, is low and struggles to increase. Note that high-skilled jobs are dragging the economy, as the LSJ-influence is different from 1. When the economy starts developing, the extremely low presence of high-skilled workers can not pull the economy in a proper way. The economic output starts decreasing and this produces a reduction in the working positions and a consequent increase of the low-skilled unemployment. In the latter phase the labor market matching conditions are wrecked as well, with some high-skilled agent performing low-skilled jobs, probably because of the shortage of qualified jobs. Migration flows start increasing and they are unidirectional.

The network generated within this test is solid. It appears to be scale-free the 90% of the ticks and a small world the 87% of times. The average links length is high, as the presence of migration in the long run enlarges the size of the links. The network distribution appears to be long tailed and the centrality distribution shows uniform characteristics.

So, to conclude, if Moretti is right and there is a multiplier of high-skilled jobs in

the economy country should invest in high-skilled jobs for pulling the economy. In the previous experiments we have shown the disastrous effects of the absence of such a multiplier and by thinking on the reality we consider the existence of this multiplier to be likely.

The last experiment, finally, shows what happens if the countries start from fair economic conditions. As we have already shown, a fair economic distribution enhances the aggregate output of the economy and strongly decreases the long term gap between the economic performance of the two countries. The parameters generating the working positions work faster and thus available working positions in the overall economy are more numerous.

The proportion of students seem to be slightly negatively related to the fair economic departure point, and so does the proportion of students performing an exchange project.

The aggregate level of unemployment is strongly reduced because the two economies are performing better, growing and therefore demanding more workers. There is no unemployment on the high-skilled sector. Also, unemployment is equally spread among the two countries, instead of being concentrated in one state only.

Domestic workers are very numerous, while in the long run the number of migrants is very low. This depends on the fact that since the two countries are performing similarly and offering more or less the same working conditions, agents are less motivated to move. Those who do it are just a few and maybe motivated more by labor market matching or by personal desires rather than job necessities. Flows of returning migrants are present as well, although smooth and, as before, more perceivable within the qualified sector.

Matching in the labor market is controversial. The number of matching workers, indeed, is increased, but so is the number of non-matching ones. This growth might be depending on the increase of the number of qualified workers and the reduced presence of unemployment. As compared to the outcomes of experiment 5, the proportion of high-skilled workers performing a fitting job is reduced while that of high-skilled workers performing a non-fitting job is increased. This might depend on the fact that if the two countries are both performing well they are both growing, new working positions are generated and everybody is able to take part to the labor market. The higher percentage of non-matching workers is taken away from the unemployment. Those workers which were unemployed in cases of unfair economic departure, here are yes taking part to the labor market, although not in the best conditions.

The network generated within this test is very thick and dense, figure 7.45 shows its centrality and the degree distribution. It is clear that individuals are very interconnected and each agent has many connections. The average links length is slightly longer than in the previous test because migration here is bidirectional. Also, returning migrants strongly increase the size of the links.

Summing up the conclusions of this experiment it is to say that a fair economic departure increases the aggregate output of the overall economy. The pace at which each of the two countries is growing is slower than in the case where only one is. This because, here migration flows are present but faint, each economy is mostly relying on the domestic human capital rather than on the foreign one. Domestic human capital

sometimes might not be enough for filling the total demand of workers of the market, while in the other case, where one country is disadvantaged as compared with the other, the more favored one can attract its labor force and fill up the domestic labor demand at the expenses of the country left behind. A developed high-skilled sector pushes the economic forward, therefore countries should invest on it. Finally, in any of the situations in which the economy started from uneven economi conditions, the exploitation of human capital of the less favored country by the most favored one deemed the poorer country to an unavoidable decline.

Chapter 8

Conclusions

This research is aimed at favoring the reflection on the high-skilled migration phenomenon. It wraps up the existing literature with regards to brain drain and provides an overview of the actual situation of the matter around the world (Chapters 5 and 6). In order to generate a powerful tool for examining the question under investigation, we have created an agent-based simulation. The model designed helps in better understanding the functioning, the decisional factors and the consequences of brain drain. It decomposes the phenomenon discovering its components, analyzing also some of those elements which have not been identified by most of previous research works, such as the influence of the social network. Finally, it helps in meditating how do specific factors influence the phenomenon and what are the outcomes in many various circumstances.

The main results emerging from the experiments performed are presented in the following lines.

Section 7.2 is concerned on understanding how do specific circumstances affect the investment in human capital decision. The paragraph shows that:

- enlarging the population provides less-variating and more understandable dynamics;
- in case of similar economic starting points, a dense social network improves the economic output, the proportion of studying agents and the matching within the labor market;
- uneven economic departures reduce the aggregate output and the overall proportion of students, distributing these outcomes unfairly around the world;
- uneven economic departures produce inter-national differences, with the favored country taking advantage of the lack of perspectives in the less-favored one. The exploitation of the disadvantaged country is higher if the migrants can employ their degrees in the arrival country (diploma convertibility) ;
- diploma convertibility enlarges migration flows and switches its components towards skilled migrants;

- diploma convertibility reduces inter-national gaps in the proportion of students generated by uneven starting conditions;
- migration flows foster labor market matching

By performing tests on the effects of different social networks we have achieved some interesting consideration, see section 7.3.

We consider that extremely thin social networks are not realistic, as socio-economic processes are strongly driven by social connections. On the other hand they could represent the existing cases of extremely isolated towns or areas. Strongly sparse social networks are detrimental for the aggregate economy, in particular they:

- reduce aggregate output;
- decrease the proportion of university students;
- brake the parameters producing new working positions;
- worsen the matching in the labor market;
- decrease migration flows;
- produce highly variant outcomes

On the contrary, when thick social networks appear:

- human capital investment is increased;
- migration flows are increased;
- labor market matching is improved;
- even starting points reduce migrations but make them bi-directional;
- even starting points produce returning migration flows, increase output, matching and reduce unemployments and distribute the outcomes equally between the two countries

We have also found out that extremely thick social network are more realistic, indeed, they frequently, more than 82% of times in case of uneven starting points and more than 77% of times in case of even, show scale-free or small world distributions. To conclude, we also noticed that allowing for University exchanges improves the social network and enhances the level of migration flows.

Section 7.4 deals with tests on the migration flows of agents. Among other things, these experiments clearly depend on the mobility threshold parameter. This variable affects the probability of migrating of each agent. In the real world mobility threshold can be seen as the correspondent to migration policies or incentives to migration, both incoming and outgoing. The effects of variating its level are not linear as the mobility threshold is the limit on which agents decide their set of preferences. This is then subjected to exogenous constraints. What we can achieve, though, is that:

- reasonably higher levels of mobility threshold produce less copious flows of migrants;
- by increasing the threshold, unemployment increases, because of the reduction in migration flows;
- by raising it, only high-skilled agents are willing to migrate;
- increments of the mobility threshold reduce the returning flows

These outcomes can be transposed to the reality. An obstruction to migration flows made by political institutions corresponds to an increase of the mobility threshold. This action lets only those or very desperate or very willing to migrate, while most of other agents quit their project. The mobility threshold, also, permits to choose the category of migrants; so an increase of the migration threshold can be seen as a sort of selection of the incoming migrants. Note that in many countries this aspect exist. Policies for incoming migrants tend to facilitate the entrance for qualified workers rather than non-skilled ones.

Section 7.5 performs experiments on the economic output resulting under different configurations. By testing the effects of variating the low-skilled jobs influence on the aggregate economy under various circumstances, we achieved that by augmenting the parameter the aggregate situation worsens:

- aggregate output increases;
- the economic output is distributed less-fairly;
- working positions decrease;
- labor market matching worsens;
- unemployment augments and encompasses the qualified component;
- the proportion of students diminishes

Finally, the last set of experiments, contained in section 7.6, considers the issue of brain drain more specifically. What emerges is that, as before:

- the aggregate output is higher in case of a fair economic departure;
- migration flows of high-skilled are thin and faint in case of equal starting conditions.
- the pace at which on average the two countries are growing is fast in case of uneven starting points, because the favored country is exploiting human capital migrating from the less-favored one;
- international gap is high in the uneven starting condition case, with one country performing extremely well, also because of the incoming human capital from the disadvantaged country, while the other one is failing to some extent slowly;

- returning migration flows in case of uneven economic development is very rare;
- economies with strong qualified sectors are deemed to perform better in the global competition

What can be considered, then, is that countries should invest in the high-skilled sector in order to keep their qualified human capital. More, we have shown that once the economic inequality is settled, it is very hard to solve it and find a convergence towards the positive performance of the advantaged country. It is even harder to attract back emigrated human capital, also considering the negative trend of the economic performance, which does not leave much space open for good working perspectives. Also, the creation of social networks in the destination country limits the coming back flows. On the other side, if one country happens to be in a position of dominance, it is more profitable for it attracting the human capital of the disadvantaged country. Also, the nation can play policies in order to select the incoming migrants. In this way its economy would perform extremely well, with extremely high growth rates, low unemployment, high labor market matching and so on. We have shown, though, that for the economy as a whole it would be convenient for both the countries to perform positively as this would lead to an increase aggregate output and faint migration flows moving from one country to the other more for personal attitude rather than necessity. Returning migrations would also exist in this case.

The results achieved within this paper turn out to be helpful and sometimes surprising. They are, though still preliminary and they need to be implemented in order to perform deeper analysis of the overall brain drain phenomenon. The simulation, for instance, has strong potentials and can be exploited in many further ways. It is, in fact, a valid policy tool and a powerful instrument to meditate on the issue of high-skilled migration flows. Among the potential political application of the simulation model we can mention:

- educational and schooling policies, by better implementing the investment in human capital decision, adding budget constraints, schooling support, extra earnings and benefits once entered in the financial market;
- analyzing the effects of schooling exchanges, which are extremely frequent especially in Europe[1]. These programs surely help in creating a unified European population, but they might have unexpected influences on the migration flows, especially those of high-skilled agents;
- investment and fundings to research, widening the model with the possibility of political intervention. Allowing for the possibility of investing in research may be useful in keeping domestic high-skilled workers or attracting foreign ones and produce higher economic output;

[1]See the Erasmus, Erasmus Placement, Leonardo Project etc.

- identifying and understanding the issue of isolation and finding adequate responses. We have seen that social networks do have an influence in the decisional process of agents. Not only, we have shown that faint social networks are negative for the economic output of the countries. This simulation, then, might be an additional tool for testing policies aimed at fighting social exclusion and isolation;

- migration, integration and working policies. We have seen that migrants increase the welfare of the destination country and mostly they do so if they can perform there the work they have studied for. Migration flows, though, are not all the same. The size of migration flows, their composition, the pace at which migrants are arriving in the country, acceptance of their degree on the domestic labor market, all these factors might be examined within this simulation model and diverse policies might be tested in order to find their potential outcomes.

These potential implementations of the simulation on the real world are still on the checklist. Sure the simulation model constructed need to be implemented and enlarged in order to better represent reality. Later researchers should reflect deep on some weak points of the model, for instance:

- the two categories of jobs only, that could be expanded to a most various, differentiated and realistic set of working chances,

- the shortage of any salary or budget constraint;

- the existence of one kind of relationship only;

- the presence of two countries only

These items are all categories of potential improvements of the model. Further development of the simulation might be done also through the co-usage of empirical data, trying to anticipate what will happen in the future economies, given some policies or testing different measures. We are still a long way from understanding all the components leading to the issue of brain-drain phenomena.

Appendix A

Experiments Appendix

A.1 Notation

Color	**Legend**
Yellow	Student
White	Exchanging Student
Grey	Low-skilled unemployed
Black	High-skilled unemployed
Magenta	Immediately employed high-skilled
Orange	Returned high-skilled
Green	Immediately employed low-skilled
Brown	Returned low-skilled
Red	Emigrated high-skilled
Violet	Emigrated low-skilled

Table A.1: Legend of colors

Legend	List Of Variables
Output Country 1	EP1
Output Country 2	EP2
Average Output	AO
Parameter Generating High-Skilled Jobs in Country 1	PA1
Parameter Generating Low-Skilled Jobs in Country 1	PB1
Parameter Generating High-Skilled Jobs in Country 2	PA2
Parameter Generating Low-Skilled Jobs in Country 2	PB2
Students Country 1	S1
Students Country 2	S2
Exchange Students Country 1	ES1
Exchange Students Country 2	ES2
High-Skilled Workers Unemployed in Country 1	HighUnemp1
Low-Skilled Workers Unemployed in Country 1	LowUnemp1
High-Skilled Workers Immediately Employed in Country 1	h-g1
High-Skilled Workers Returned to Country 1	h-r1
Low-Skilled Workers Immediately Employed in Country1	l1
Low-Skilled Workers Returned to Country 1	l-r1
High-Skilled Workers Unemployed in Country 2	HighUnemp2
Low-Skilled Workers Unemployed in Country 2	LowUnemp2
High-Skilled Workers Immediately Employed in Country 2	h-g2
High-Skilled Workers Returned to Country 2	h-r2
Low-Skilled Workers Immediately Employed in Country2	l2
Low-Skilled Workers Returned to Country 2	l-r2
High-Skilled Matching Workers Country 1	HSMW1
High-Skilled Matching Workers Country 2	HSNMW1
High-Skilled Non-Matching Workers Country 1	HSMW2
High-Skilled Non-Matching Workers Country 2	HSNMW1
High-Skilled Workers Emigrated From Country 1	h-m2
High-Skilled Workers Emigrated From Country 2	h-m1
Low-Skilled Workers Emigrated From Country 1	l-m2
Low-Skilled Workers Emigrated From Country 2	l-m1
High-Skilled Working Positions in Country 1	High1
High-Skilled Working Positions in Country 2	High2
Low-Skilled Working Positions in Country 1	Low1
Low-Skilled Working Positions in Country 2	Low2
Average Links Length	ALL
Clustering Coefficient	Clustering

Table A.2: Legend and List of Variables

A.2 Standard Configuration

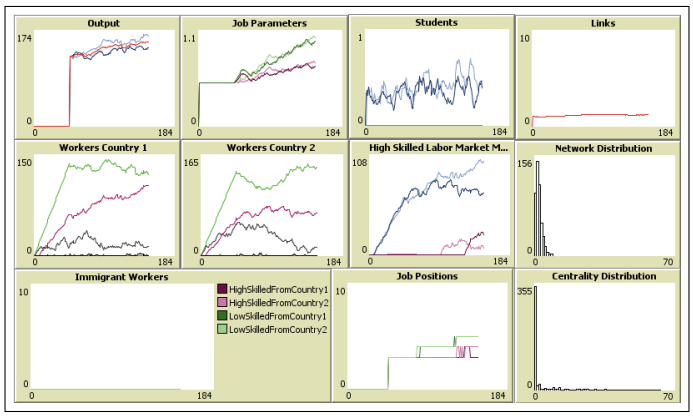

Figure A.1: Standard Configuration Experiment 2

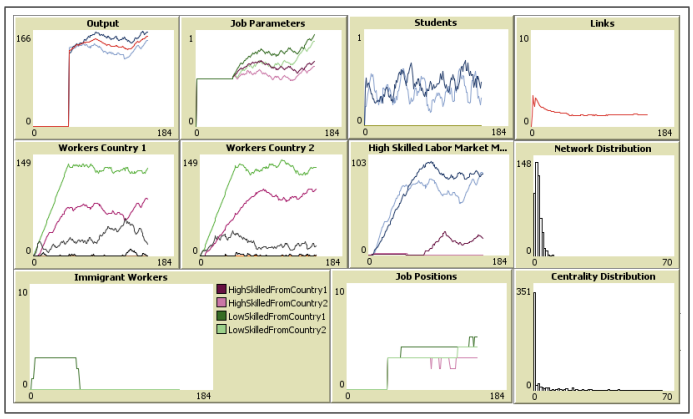

Figure A.2: Standard Configuration Experiment 3

Standard Configuration	**Average**
EP1	155,00
EP2	130,17
AO	142,58
PA1	0,68
PB1	0,95
PA2	0,54
PB2	0,78
S1	0,44
S2	0,42
ES1	0,00
ES2	0,00
HighUnemp1	2,67
LowUnemp1	15,67
h-g1	93,00
h-r1	0,00
l1	124,00
l-r1	0,00
HighUnemp2	0,67
LowUnemp2	51,33
h-g2	75,33
h-r2	0,00
l2	109,67
l-r2	0,00
HSMW1	86,67
HSNMW1	9,00
HSMW2	69,33
HSNMW2	9,00
h-m2	0,00
h-m1	0,00
l-m2	0,00
l-m1	0,00
High1	3,33
High2	2,33
Low1	4,67
Low2	4,00
ALL	1,22
Clustering	0,26

Table A.3: Standard Configuration Outcomes

A.3 Human Capital Investment

Variables	Exper1	Exper2	Exper3	Exper4	Exper5	Exper 6
Population	10	10	5	20	10	10
LSJ-influence	0,5	0,5	0,5	0,5	0,5	0,50
LinkSize	0	3	1,5	1,5	1,5	1,5
MobilityThresold	1	1	1	1	1	1
StudentMobility	off	off	off	off	off	off
DiplomaConvertibility	off	off	off	off	off	on
Low-Skilled-Jobs-1	0,5	0,5	0,5	0,5	0,8	0,8
High-Skilled-Jobs-1	0,5	0,5	0,5	0,5	0,8	0,8
Low-Skilled-Jobs-2	0,5	0,5	0,5	0,5	0,2	0,2
High-Skilled-Jobs-2	0,5	0,5	0,5	0,5	0,2	0,2

Table A.4: Configurations of the experiments on human capital performed.

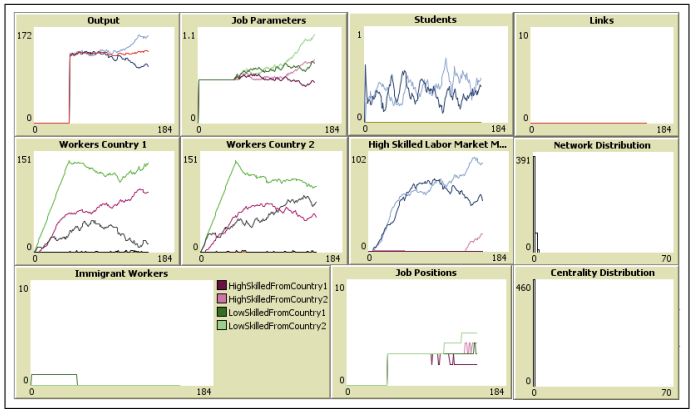

Figure A.3: Human Capital Investment Experiment 1.b

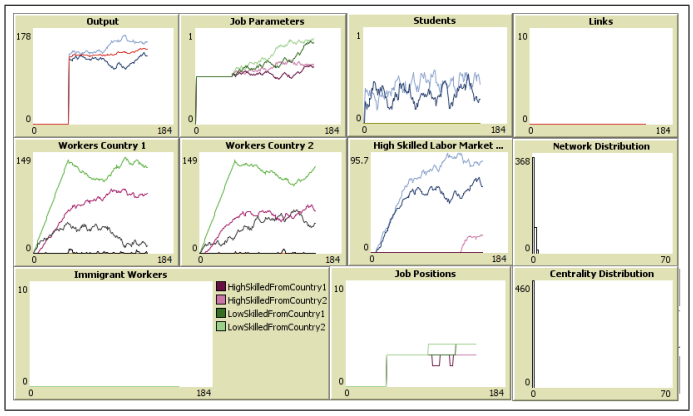

Figure A.4: Human Capital Investment Experiment 1.c

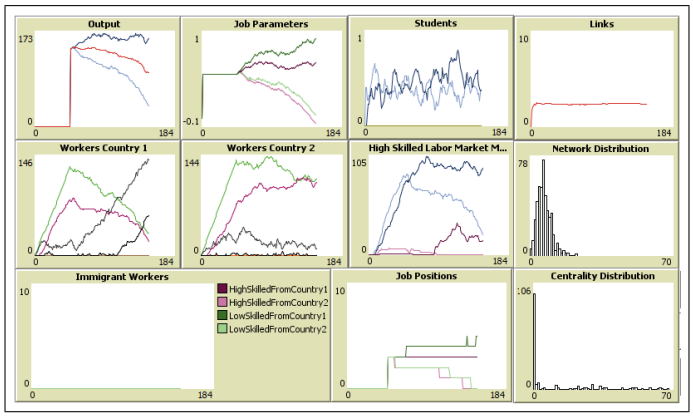

Figure A.5: Human Capital Investment Experiment 2.b

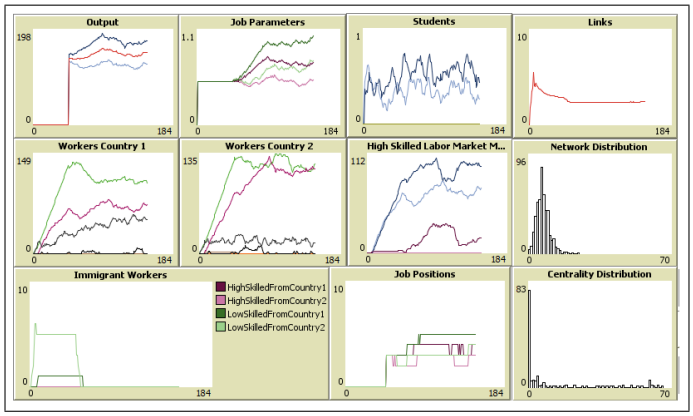

Figure A.6: Human Capital Investment Experiment 2.c

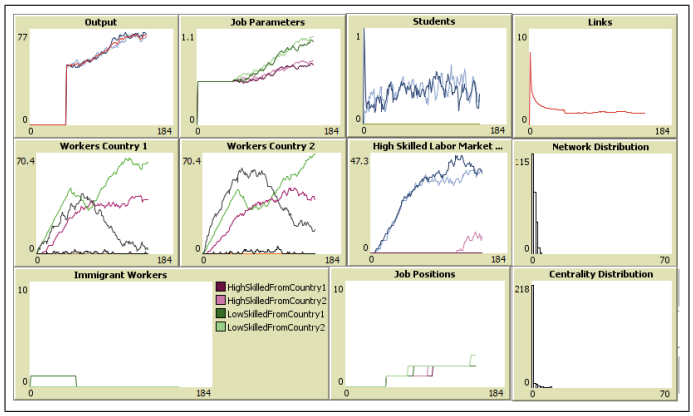

Figure A.7: Human Capital Investment Experiment 3.b

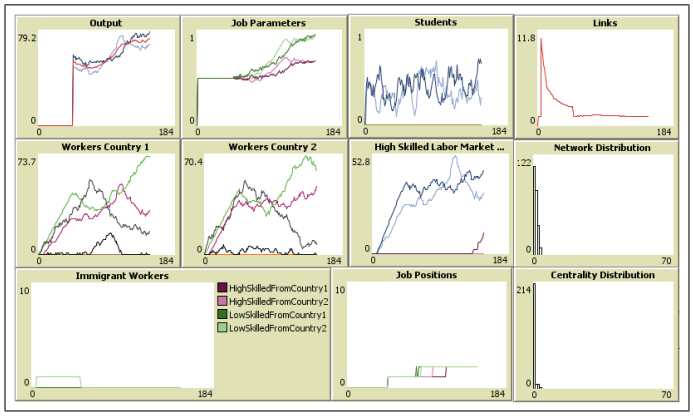

Figure A.8: Human Capital Investment Experiment 3.c

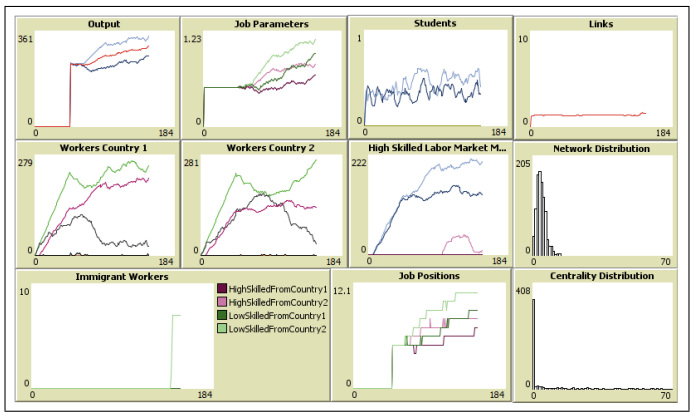

Figure A.9: Human Capital Investment Experiment 4.b

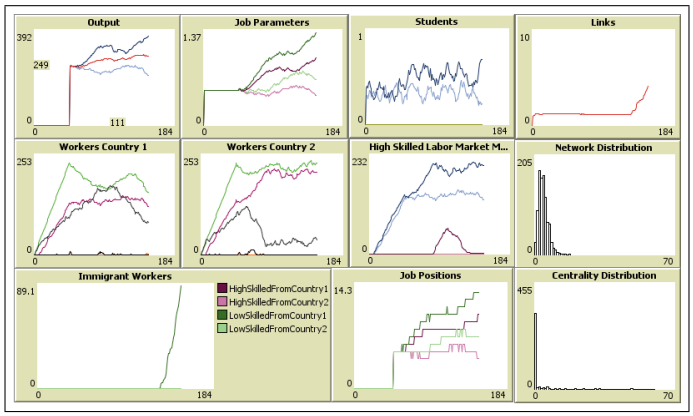

Figure A.10: Human Capital Investment Experiment 4.c

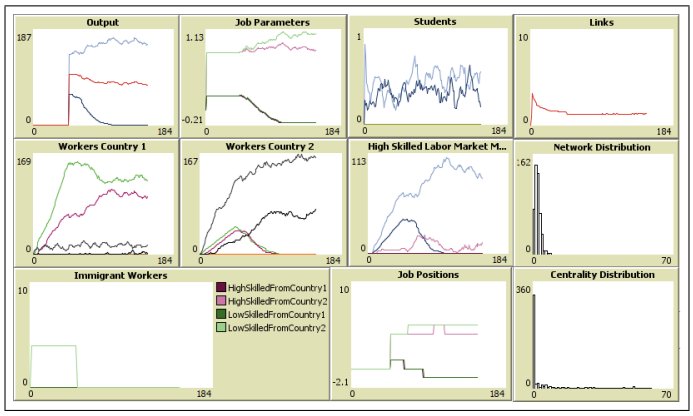

Figure A.11: Human Capital Investment Experiment 5.b

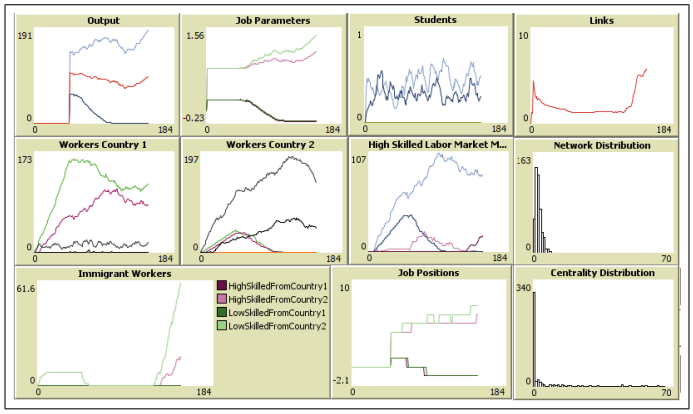

Figure A.12: Human Capital Investment Experiment 5.c

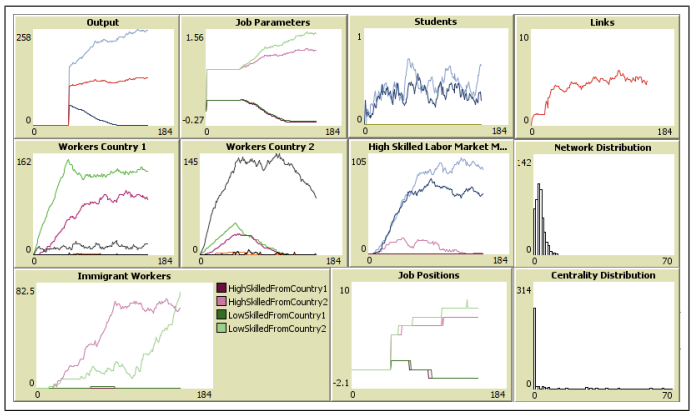

Figure A.13: Human Capital Investment Experiment 6.b

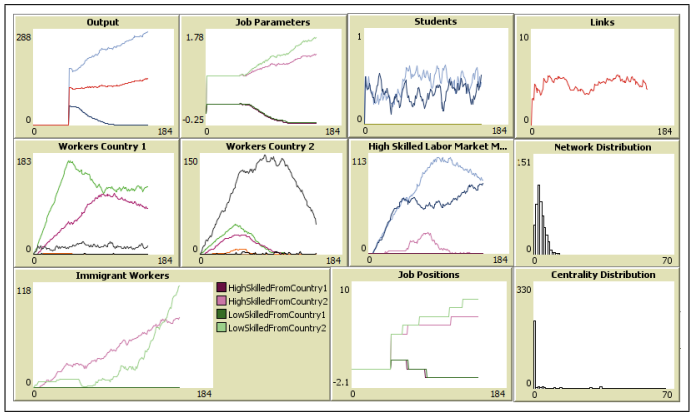

Figure A.14: Human Capital Investment Experiment 6.c

Comparative Table	SC	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
EP1	155,00	151,17	107,67	65,33	228,33	160,83	248,67
EP2	130,17	76,17	136,50	72,83	332,17	0,00	1,83
AO	142,58	113,75	122,08	69,17	280,25	82,17	125,17
PA1	0,68	0,67	0,24	0,69	0,45	0,67	1,12
PB1	0,95	0,94	0,60	0,95	0,68	1,14	1,44
PA2	0,54	0,13	0,52	0,70	0,83	-0,20	-0,18
PB2	0,78	0,45	0,76	0,98	1,16	-0,18	-0,14
S1	0,44	0,43	0,28	0,19	0,33	0,56	0,46
S2	0,42	0,21	1,24	1,04	0,51	0,24	0,27
ES1	0,00	0,00	0,00	0,00	0,00	0,00	0,00
ES2	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HighUnemp1	2,67	0,00	19,33	0,00	8,33	2,00	0,00
LowUnemp1	15,67	18,67	65,00	19,67	98,00	17,00	14,33
h-g1	93,00	87,33	64,00	33,33	142,33	88,33	86,67
h-r1	0,00	0,00	0,00	0,00	1,00	0,00	0,00
l1	124,00	127,67	87,33	64,00	167,67	120,33	131,00
l-r1	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HighUnemp2	0,67	18,67	4,00	0,00	0,00	64,33	10,67
LowUnemp2	51,33	94,67	47,00	9,33	33,67	154,67	83,67
h-g2	75,33	38,33	88,00	40,67	183,00	0,00	0,00
h-r2	0,00	0,00	0,00	0,00	0,00	0,00	0,00
l2	109,67	75,67	97,00	64,33	238,33	0,00	3,67
l-r2	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HSMW1	86,67	87,00	62,67	33,67	141,67	81,67	85,33
HSNMW1	9,00	11,67	2,00	2,67	7,67	7,33	1,67
HSMW2	69,33	38,33	77,67	39,33	181,33	0,00	61,67
HSNMW2	9,00	11,67	2,00	2,67	7,67	7,33	1,67
h-m2	0,00	0,00	0,00	0,00	5,67	0,00	0,00
h-m1	0,00	0,00	0,00	0,00	0,00	5,67	61,67
l-m2	0,00	0,00	0,00	0,00	48,67	0,00	0,00
l-m1	0,00	0,00	0,00	0,00	2,33	20,00	69,67
High1	3,33	3,33	2,33	2,00	4,33	4,67	5,67
High2	2,33	1,33	2,67	2,00	8,67	-1,00	-1,00
Low1	4,67	4,67	3,00	2,33	7,00	5,67	7,00
Low2	4,00	2,00	4,00	2,33	11,33	-1,00	-0,67
ALL	1,22	0,00	2,36	1,16	3,07	2,68	4,25
Clustering	0,26	0,02	0,60	0,14	0,51	0,29	0,35

Table A.5: Comparative Table of the Outcomes of the Investment in Human Capital Experiments

A.4 Social Network Analysis

Variables	Exper1	Exper2	Exper3	Exper4
Population	5	20	20	10
LSJ-influence	0,5	0,5	0,5	0,5
LinksSize	0	3	3	1,5
MobilityThreshold	1	1	1	1
StudentMobility	Off	On	On	On
DiplomaConvertibility	Off	On	On	On
Low-skilled-jobs 1	0,5	0,8	0,5	0,5
High-skilled-jobs 1	0,5	0,8	0,5	0,5
Low-skilled-jobs 2	0,5	0,2	0,5	0,5
High-skilled-jobs 2	0,5	0,2	0,5	0,5

Table A.6: Human Capital Experiments Configurations

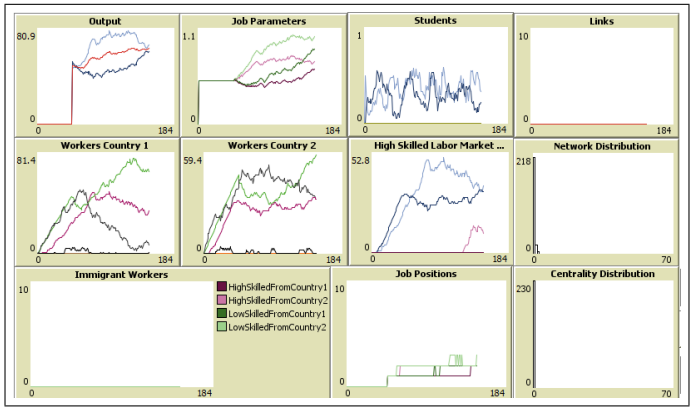

Figure A.15: Network Analysis Experiment 1.b

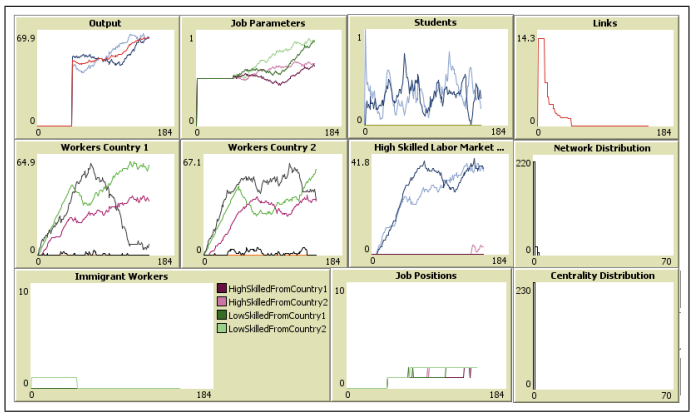

Figure A.16: Network Analysis Experiment 1.c

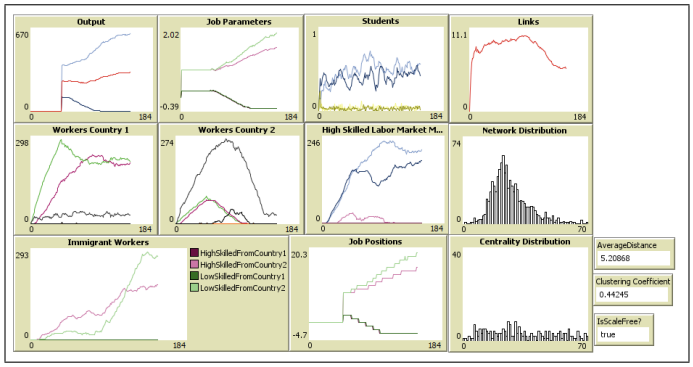

Figure A.17: Network Analysis Experiment 2.b

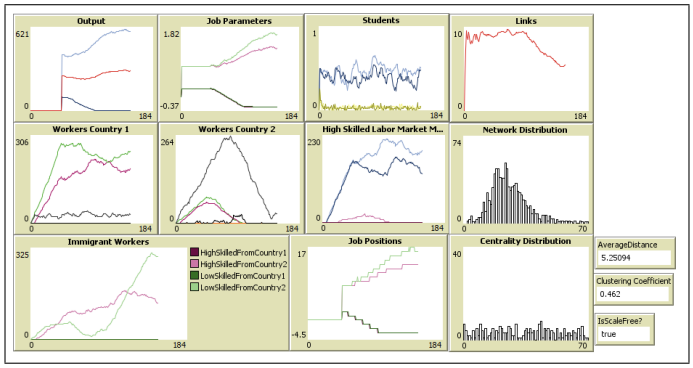

Figure A.18: Network Analysis Experiment 2.b

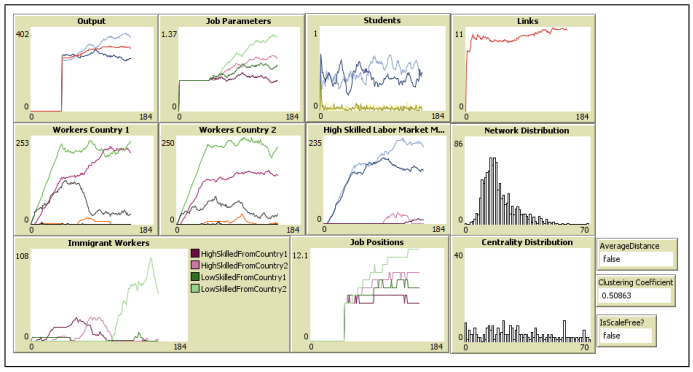

Figure A.19: Network Analysis Experiment 3.b

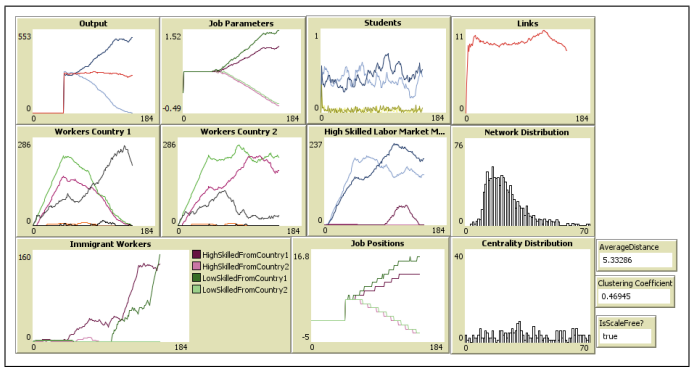

Figure A.20: Network Analysis Experiment 3.b

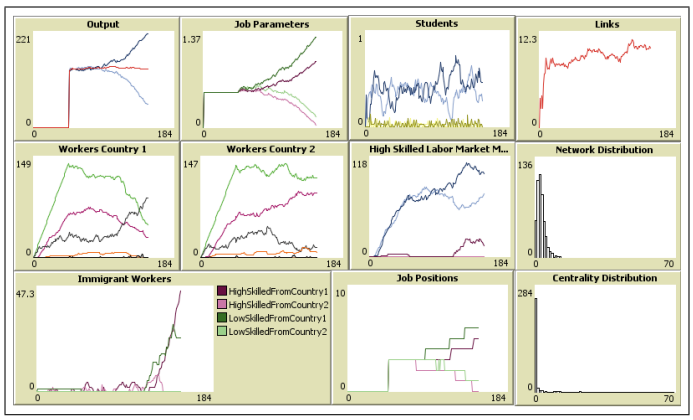

Figure A.21: Network Analysis Experiment 4.b

Test 2	CountScaleFree/ticks	CountSmall World/ticks
EXP1	0,82	0,79
EXP2	0,69	0,66
EXP3	0,91	0,89
Average	**0,81**	**0,78**

Table A.7: Proportion of ticks where the social network generated is Scale-Free and Small-World in the Second Experiments of Network Analysis

Test 3	CountScaleFree/ticks	CountSmall World/ticks
EXP1	0,87	0,84
EXP2	0,63	0,61
EXP3	0,89	0,87
Average	**0,79**	**0,77**

Table A.8: Proportion of ticks where the social network generated is Scale-Free and Small-World in the Third Experiments of Network Analysis

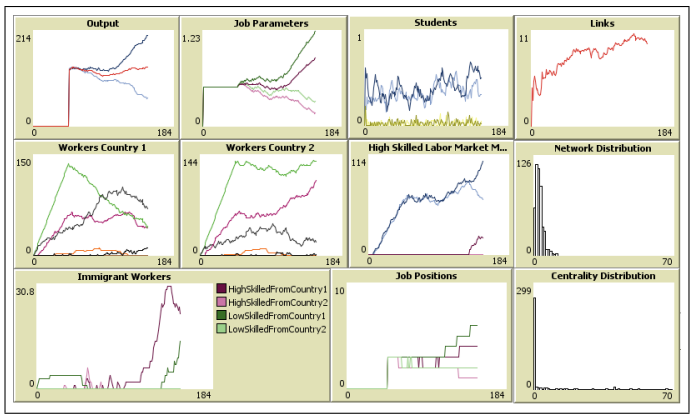

Figure A.22: Network Analysis Experiment 4.b

Comparative Table	SC	EXP1	EXP2	EXP3	EXP4
EP1	155,00	69,17	542,50	270,83	80,67
EP2	130,17	57,50	0,00	287,17	198,17
AO	142,58	63,33	271,25	279,00	139,42
PA1	0,68	0,72	1,22	0,54	0,08
PB1	0,95	1,00	1,57	0,79	0,42
PA2	0,54	0,43	-0,30	0,38	0,86
PB2	0,78	0,83	-0,30	0,80	1,18
S1	0,44	0,31	0,44	0,47	0,69
S2	0,42	0,24	0,44	0,33	0,15
ES1	0,00	0,00	0,03	0,03	0,02
ES2	0,00	0,00	0,02	0,02	0,03
HighUnemp1	2,67	0,33	0,00	0,00	3,67
LowUnemp1	15,67	6,33	25,67	85,00	59,33
h-g1	93,00	36,67	200,33	136,33	42,33
h-r1	0,00	0,00	0,00	0,33	1,00
l1	124,00	65,00	227,33	152,00	66,00
l-r1	0,00	0,00	0,00	0,00	0,00
HighUnemp2	0,67	0,00	42,00	0,00	0,33
LowUnemp2	51,33	36,00	88,00	64,67	15,67
h-g2	75,33	29,33	0,00	130,67	97,67
h-r2	0,00	0,00	0,00	1,00	7,33
l2	109,67	56,33	0,00	168,67	123,33
l-r2	0,00	0,00	0,00	1,00	0,00
HSMW1	86,67	37,00	197,67	182,00	65,67
HSNMW1	9,00	9,33	2,67	0,00	0,00
HSMW2	69,33	29,33	117,67	163,67	107,67
HSNMW2	9,00	9,33	2,67	0,00	0,00
h-m2	0,00	0,00	0,00	45,33	22,33
h-m1	0,00	0,00	117,67	32,00	4,33
l-m2	0,00	0,00	0,00	50,67	18,33
l-m1	0,00	0,00	221,67	52,33	0,00
High1	3,33	2,00	12,33	5,67	1,33
High2	2,33	1,67	-3,00	5,33	4,33
Low1	4,67	2,67	15,67	7,67	2,33
Low2	4,00	2,00	-3,00	8,00	5,67
ALL	1,22	0,00	4,08	6,30	6,65
Clustering	0,26	0,01	0,46	0,48	0,31

Table A.9: Comparative Table of the Outcomes of the Network Analysis Experiments

A.5 Migration Flows Analysis

Variables	Exper1	Exper2	Exper T	Exper3	Exper4
Popula	10	10	10	10	10
LSJ-infl	0,5	0,5	0,5	0,5	0,5
LinkSize	1,50	1,5	1,5	1,5	1,5
MobThr	0	2	1	0,5	1,5
StuMob	On	On	On	On	On
DipConv	On	On	On	On	On
LSJ1	0,5	0,5	0,6	0,6	0,6
HSJ1	0,5	0,5	0,6	0,6	0,6
LSJ2	0,5	0,5	0,4	0,4	0,4
HSJ2	0,5	0,5	0,4	0,4	0,4

Table A.10: Migration Flows Experiments Configurations

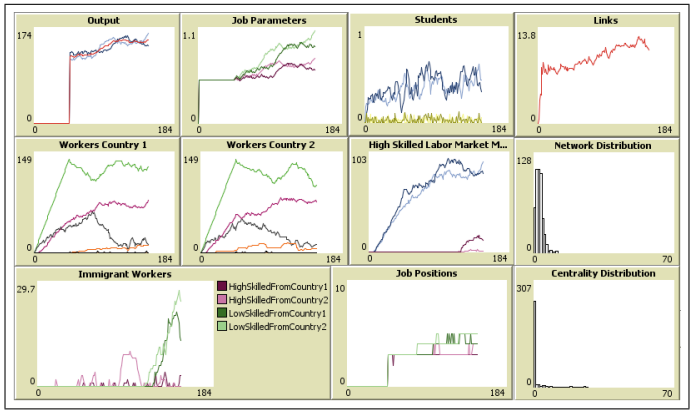

Figure A.23: Migration Flows Analysis Experiment 1.b

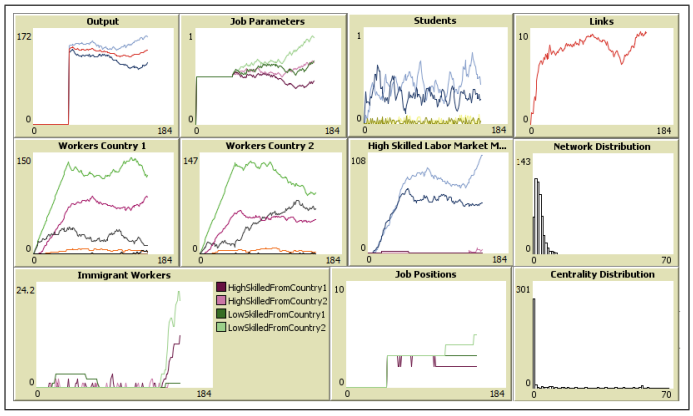

Figure A.24: Migration Flows Analysis Experiment 1.c

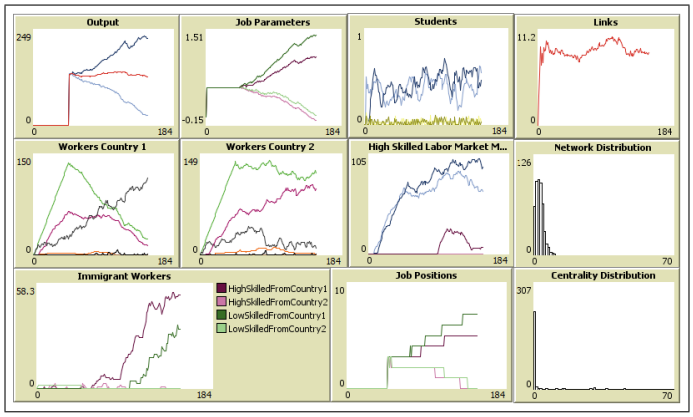

Figure A.25: Migration Flows Analysis Experiment 2.b

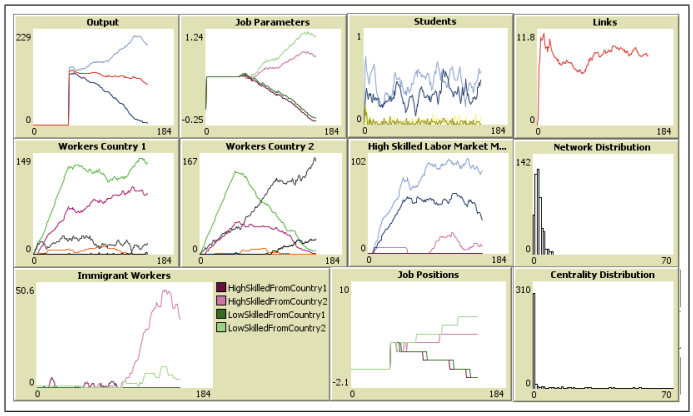

Figure A.26: Migration Flows Analysis Experiment 2.c

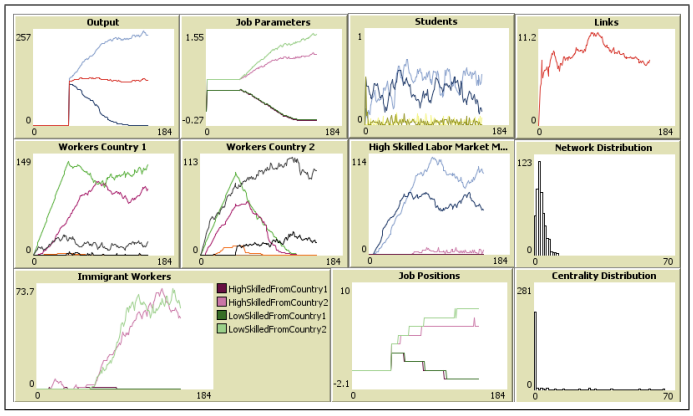

Figure A.27: Migration Flows Analysis Experiment 3.b

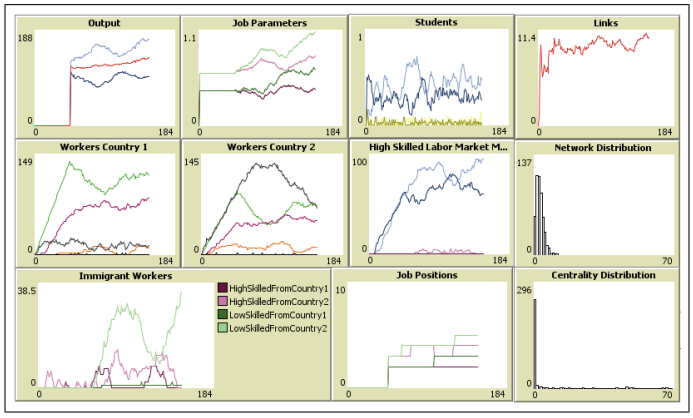

Figure A.28: Migration Flows Analysis Experiment 3.c

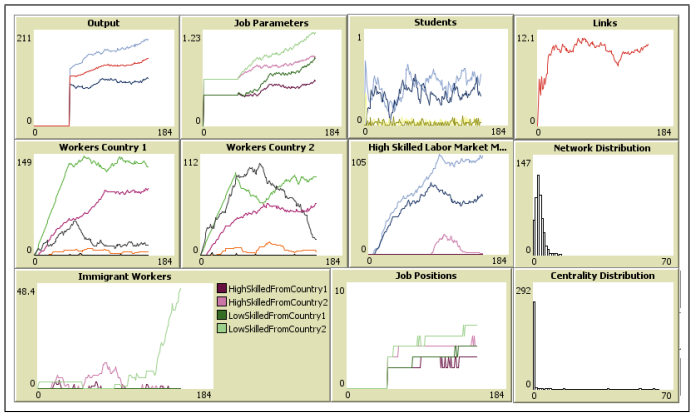

Figure A.29: Migration Flows Analysis Experiment 4.b

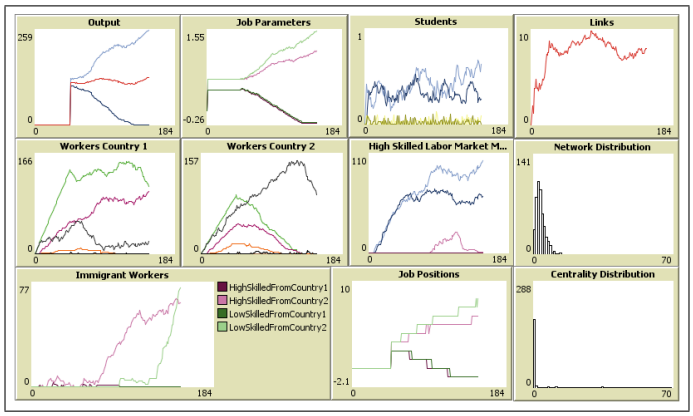

Figure A.30: Migration Flows Analysis Experiment 4.c

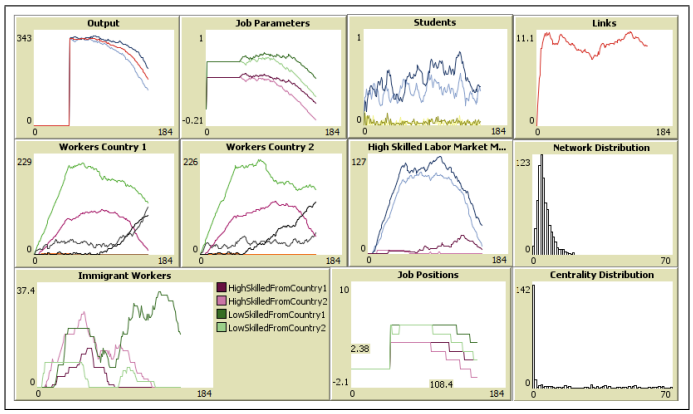

Figure A.31: Migration Flows Analysis Experiment 5.b

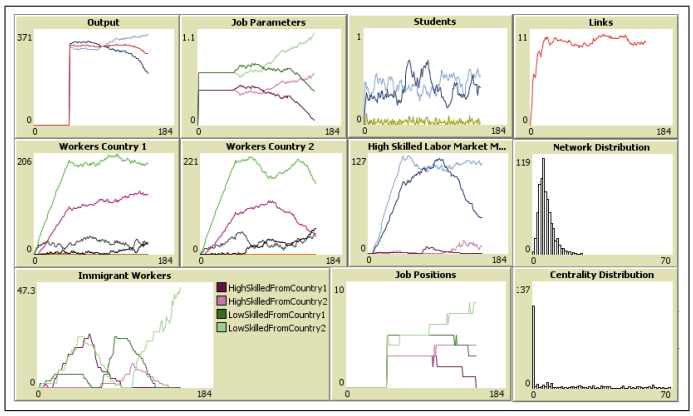

Figure A.32: Migration Flows Analysis Experiment 5.c

Comparative Table	SC	SCb	EXP1	EXP2	EXP T	EXP3	EXP4	EXP5
EP1	155,00	80,67	171,33	120,50	124,17	219,67	194,17	312,67
EP2	130,17	198,17	120,83	125,33	148,11	32,00	83,50	190,00
AO	142,58	139,42	146,08	122,92	136,14	125,83	100,17	251,33
PA1	0,68	0,08	0,74	0,26	0,36	0,99	0,69	0,44
PB1	0,95	0,42	0,70	0,65	0,59	1,32	1,19	0,88
PA2	0,54	0,86	0,37	0,48	0,57	0,02	0,35	0,06
PB2	0,78	1,18	0,77	0,71	0,89	0,12	0,55	0,39
S1	0,44	0,69	0,49	0,48	0,55	0,51	0,57	0,33
S2	0,42	0,15	0,24	0,41	0,27	0,25	0,27	0,28
ES1	0,00	0,02	0,05	0,03	0,03	0,03	0,07	0,03
ES2	0,00	0,03	0,01	0,01	0,02	0,03	0,02	0,03
HighUnemp1	2,67	3,67	1,00	0,67	1,78	0,00	0,00	38,67
LowUnemp1	15,67	59,33	14,67	46,67	40,22	18,33	18,33	51,00
h-g1	93,00	42,33	87,67	58,00	62,67	91,33	89,00	92,00
h-r1	0,00	1,00	8,00	3,67	4,22	3,33	1,67	0,00
l1	124,00	66,00	120,67	92,33	93,00	122,67	123,33	165,33
l-r1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
HighUnemp2	0,67	0,33	0,00	8,67	3,00	10,67	0,00	75,00
LowUnemp2	51,33	15,67	30,00	62,33	36,00	80,33	49,67	35,00
h-g2	75,33	97,67	64,67	53,00	71,78	16,33	36,33	42,00
h-r2	0,00	7,33	4,00	0,33	3,89	3,67	1,33	0,00
l2	109,67	123,33	88,33	93,00	101,55	23,67	67,67	141,67
l-r2	0,00	0,00	1,00	0,00	0,33	0,00	0,00	0,00
HSMW1	86,67	65,67	103,33	79,67	82,89	91,67	101,67	88,33
HSNMW1	9,00	0,00	1,67	4,33	2,00	3,33	2,00	4,00
HSMW2	69,33	107,67	69,00	62,33	79,67	54,67	59,67	41,67
HSNMW2	9,00	0,00	1,67	4,33	2,00	3,33	2,00	4,00
h-m2	0,00	22,33	5,00	20,00	15,78	0,00	12,00	0,00
h-m1	0,00	4,33	0,33	11,00	5,22	34,67	22,00	8,33
l-m2	0,00	18,33	5,00	11,00	11,44	0,33	0,00	6,33
l-m1	0,00	0,00	30,00	3,33	11,11	58,00	39,67	47,00
High1	3,33	1,33	3,67	2,33	2,44	4,67	4,33	3,33
High2	2,33	4,33	2,67	2,33	3,11	0,00	2,00	0,33
Low1	4,67	2,33	5,33	3,33	3,67	6,33	6,00	6,67
Low2	4,00	5,67	3,67	3,33	4,22	0,33	2,67	3,00
ALL	1,22	6,65	6,88	8,85	7,46	5,45	6,20	9,49
Clustering	0,26	0,31	0,30	0,29	0,30	0,33	0,32	0,48

Table A.11: Comparative Table of the Outcomes of the Migration Flows Analysis Experiments

A.6 Economic Output

Variables	Exper1	Exper2	Exper3	Exper4
Popula	10	10	10	10
LSJ-infl	0	1	0	1
LinkSize	1,5	1,5	1,5	1,5
MobThr	1	1	1	1
StuMob	Off	Off	On	On
DipConv	Off	Off	On	On
LSJ1	0,5	0,5	0,6	0,6
HSJ1	0,5	0,5	0,6	0,6
LSJ2	0,5	0,5	0,4	0,4
HSJ2	0,5	0,5	0,4	0,4

Table A.12: Configurations of the experiments on the economic output

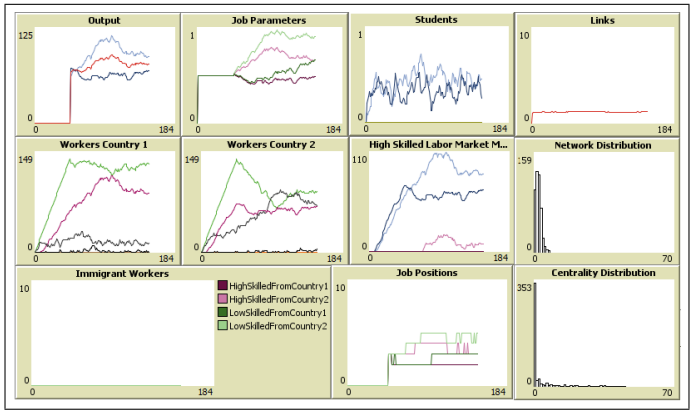

Figure A.33: Economic Output Analysis Experiment 1.b

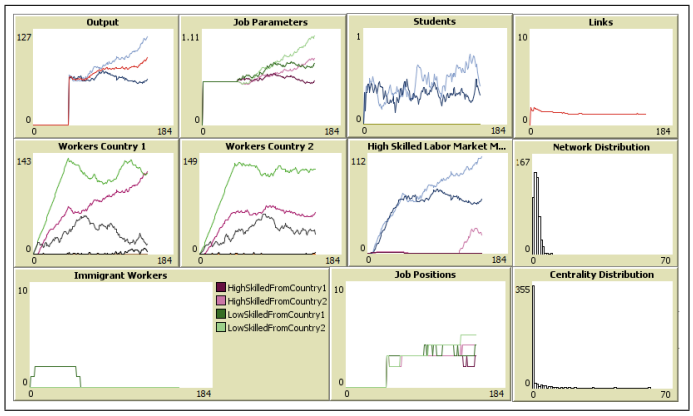

Figure A.34: Economic Output Analysis Experiment 1.c

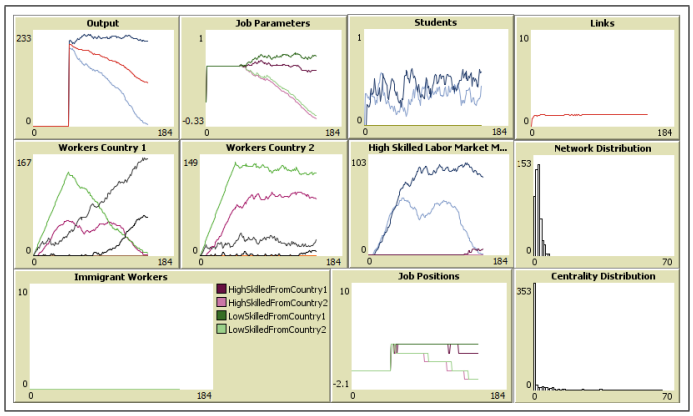

Figure A.35: Economic Output Analysis Experiment 2.b

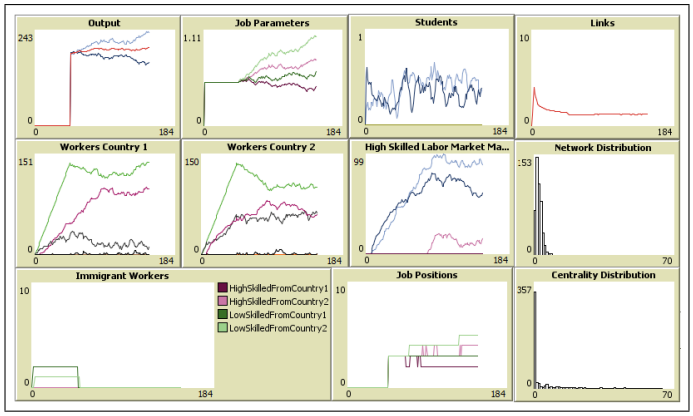

Figure A.36: Economic Output Analysis Experiment 2.c

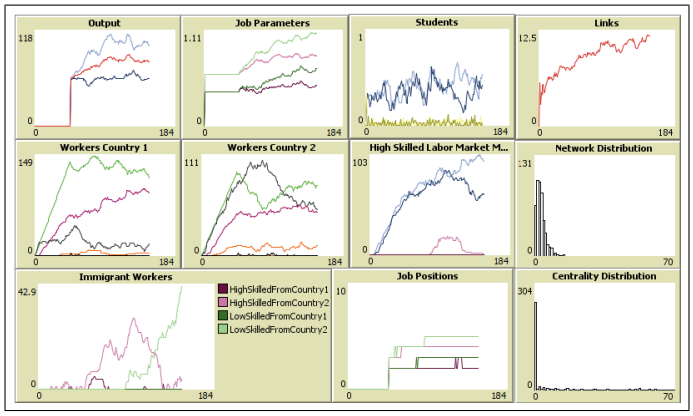

Figure A.37: Economic Output Analysis Experiment 3.b

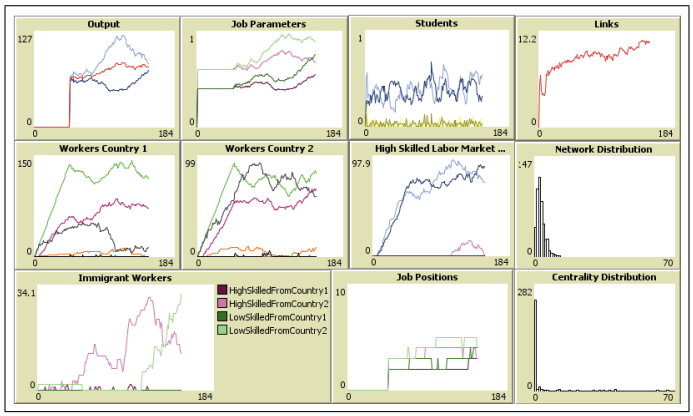

Figure A.38: Economic Output Analysis Experiment 3.c

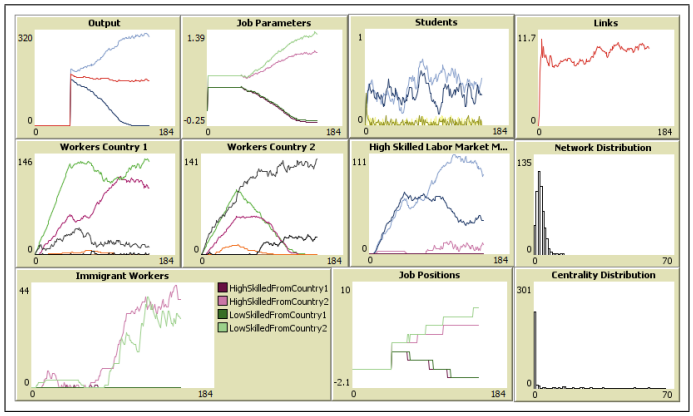

Figure A.39: Economic Output Analysis Experiment 4.b

Comparative Table	SC	EXP1	EXP2	EXP T	EXP3	EXP4
EP1	155,00	98,00	150,33	200,33	94,33	330,00
EP2	130,17	65,67	186,33	63,67	70,33	0,33
AO	142,58	81,83	168,33	132,00	82,33	165,17
PA1	0,68	0,71	0,37	0,70	0,56	1,09
PB1	0,95	0,97	0,55	1,21	1,01	1,43
PA2	0,54	0,04	0,31	0,20	0,53	-0,19
PB2	0,78	0,70	0,69	0,01	0,74	-0,16
S1	0,44	0,23	0,27	0,40	0,53	0,32
S2	0,42	0,20	0,31	0,26	0,32	0,30
ES1	0,00	0,00	0,00	0,00	0,02	0,02
ES2	0,00	0,00	0,00	0,00	0,02	0,02
HUnemp1	2,67	1,33	22,00	0,00	0,00	0,33
LowUnemp1	15,67	12,00	59,33	12,33	15,67	13,67
h-g1	93,00	98,00	68,33	82,67	86,00	95,33
h-r1	0,00	0,00	0,00	3,00	3,00	0,00
l1	124,00	125,33	82,00	130,67	119,67	131,00
l-r1	0,00	0,00	0,00	0,00	0,00	0,00
HUnemp2	0,67	2,33	2,33	0,67	0,00	21,00
LowUnemp2	51,33	48,00	45,33	77,67	39,33	100,33
h-g2	75,33	65,67	71,00	32,33	59,33	0,00
h-r2	0,00	0,00	0,00	4,00	11,00	0,00
l2	109,67	111,33	115,33	52,67	85,67	0,33
l-r2	0,00	0,00	0,00	0,00	0,00	0,00
HSMW1	86,67	93,67	64,00	85,33	89,33	89,67
HSNMW1	9,00	11,33	9,00	2,00	1,00	6,33
HSMW2	69,33	65,67	69,67	70,67	75,67	46,33
HSNMW2	9,00	11,33	9,00	2,00	1,00	6,33
h-m2	0,00	0,00	0,00	1,00	0,00	0,00
h-m1	0,00	0,00	0,00	34,33	5,33	46,33
l-m2	0,00	0,00	0,00	0,00	0,33	0,00
l-m1	0,00	0,33	0,00	30,00	34,67	57,33
H1	3,33	3,33	2,00	4,33	3,67	5,33
H2	2,33	2,67	2,33	1,33	2,67	-1,00
Low1	4,67	5,00	2,67	6,00	4,67	7,33
Low2	4,00	3,67	3,33	1,67	3,67	-1,00
ALL	1,22	1,24	1,19	5,45	9,27	8,20
Clustering	0,26	0,31	0,31	0,34	0,33	0,31

Table A.13: Comparative Table of the outcomes of the Experiments on the economic output

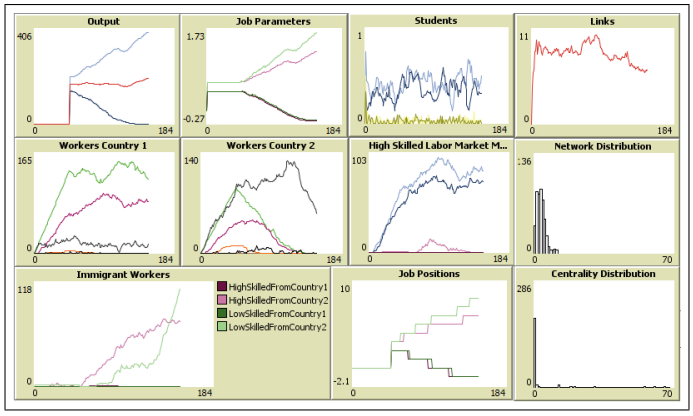

Figure A.40: Economic Output Analysis Experiment 4.c

A.7 Brain Drain

	Exper1	Exper2	Exper3	Exper4	Exper5	Exper6
Popula	20	20	20	20	20	20
LSJ-infl	0,5	1	0,5	0	0,5	0,5
LinkSize	3	3	3	3	3	3
MobThr	1,5	1,5	1,5	1,5	1,5	1,5
StuMob	On	On	On	On	On	On
DipConv	On	On	On	On	On	On
LSJ1	0,6	0,6	0,8	0,8	0,4	0,5
HSJ1	0,6	0,6	0,8	0,8	0,6	0,5
LSJ2	0,4	0,4	0,2	0,2	0,6	0,5
HSJ2	0,4	0,4	0,2	0,2	0,4	0,5

Table A.14: Configurations of the Experiments on Brain Drain

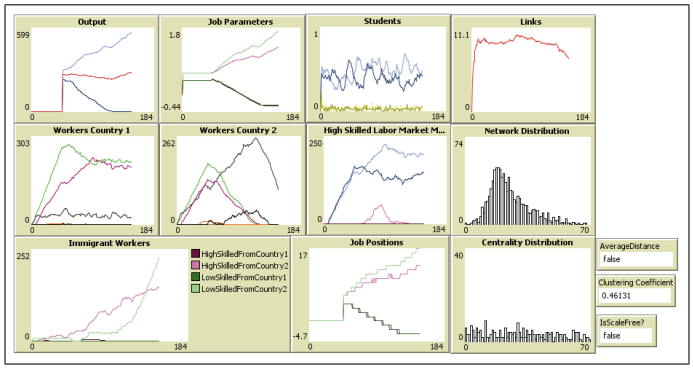

Figure A.41: Brain Drain Analysis Experiment 1.b

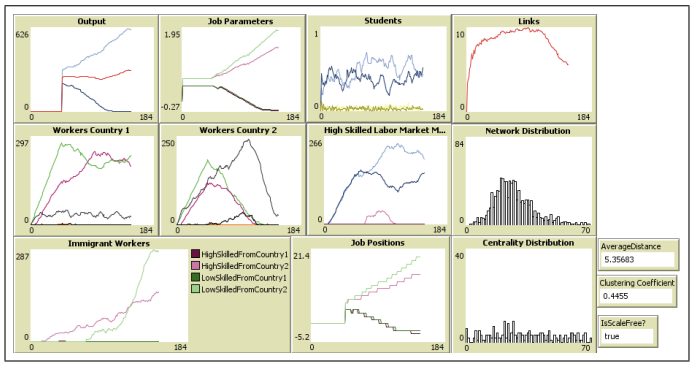

Figure A.42: Brain Drain Analysis Experiment 1.c

Test 1	Scale-Free	Small-World
Exp 1	0,88	0,83
Exp 2	0,92	0,90
Exp 3	0,86	0,85
Average	0,89	0,86

Table A.15: Proportion of ticks where the social network generated is Scale-Free and Small-World in the First Experiment of Brain Drain Analysis

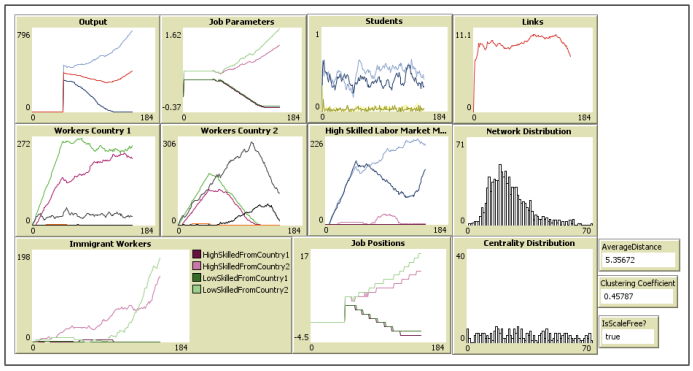

Figure A.43: Brain Drain Analysis Experiment 2.b

Test 2	Scale-Free	Small-world
Exp 1	0,88	0,85
Exp 2	0,81	0,80
Exp 3	0,93	0,91
Average	0,88	0,85

Table A.16: Proportion of ticks where the social network generated is Scale-Free and Small-World in the Second Experiment of Brain Drain Analysis

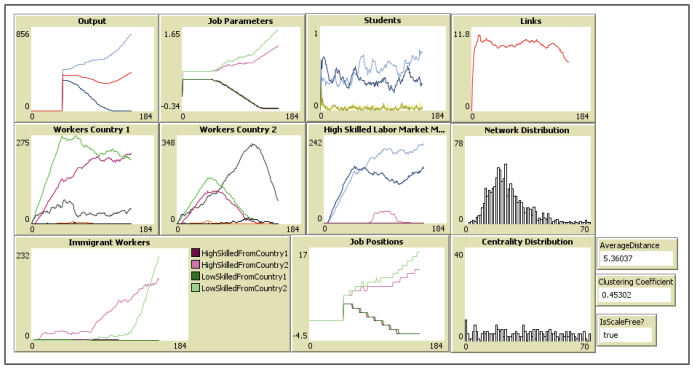

Figure A.44: Brain Drain Analysis Experiment 2.c

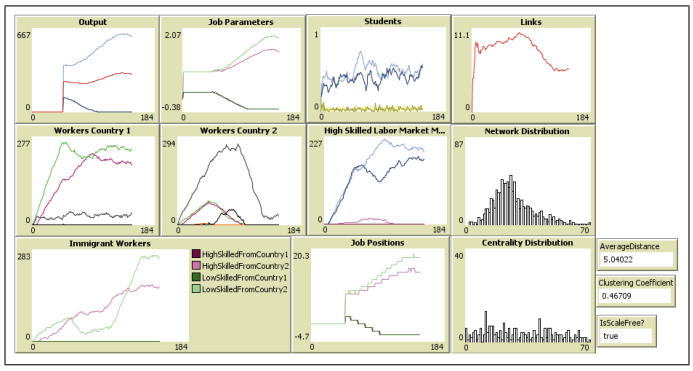

Figure A.45: Brain Drain Analysis Experiment 3.b

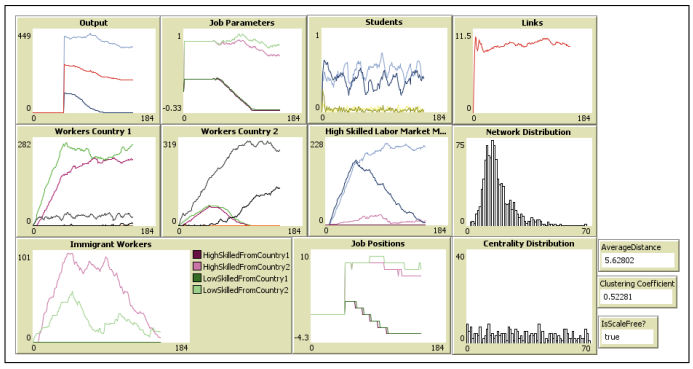

Figure A.46: Brain Drain Analysis Experiment 3.c

Test 3	Scale-Free	Small-world
Exp 1	0,91	0,89
Exp 2	0,89	0,86
Exp 3	0,87	0,85
Average	0,89	0,87

Table A.17: Proportion of ticks where the social network generated is Scale-Free and Small-World in the Third Experiment of Brain Drain Analysis

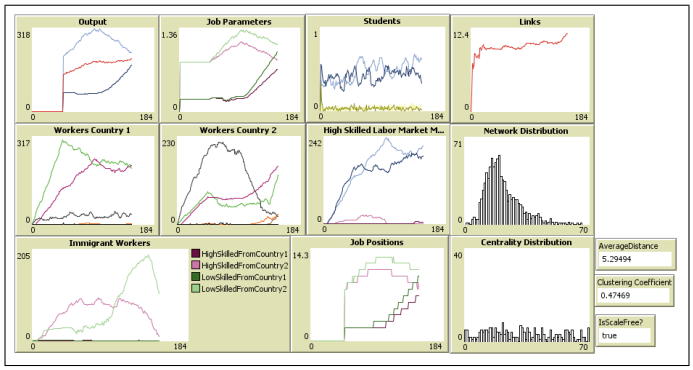

Figure A.47: Brain Drain Analysis Experiment 4.b

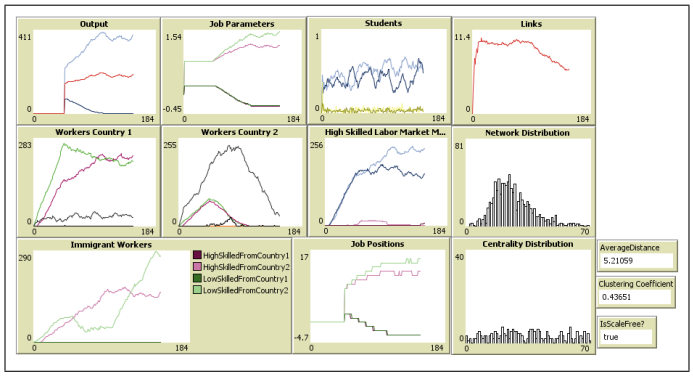

Figure A.48: Brain Drain Analysis Experiment 4.c

Test 4	Scale-Free	Small-world
Exp 1	0,89	0,87
Exp 2	0,88	0,86
Exp 3	0,82	0,81
Average	0,86	0,84

Table A.18: Proportion of ticks where the social network generated is Scale-Free and Small-World in the Fourth Experiment of Brain Drain Analysis

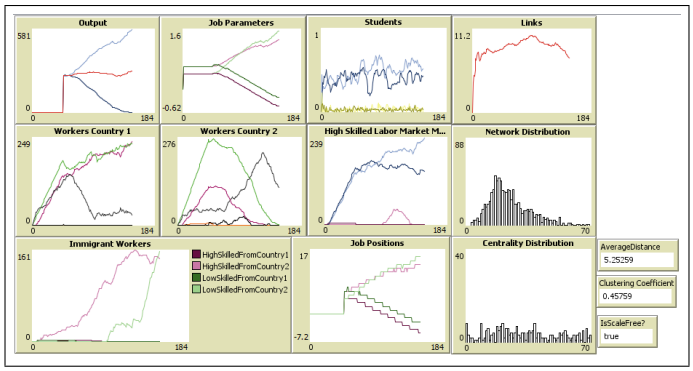

Figure A.49: Brain Drain Analysis Experiment 5.b

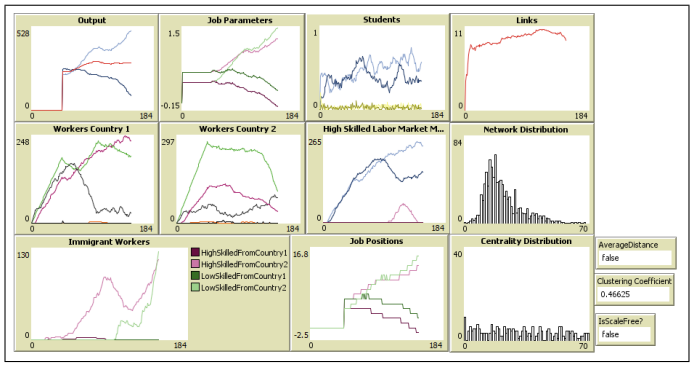

Figure A.50: Brain Drain Analysis Experiment 5.c

Test 5	Scale-Free	Small-world
Exp 1	0,88	0,85
Exp 2	0,92	0,89
Exp 3	0,89	0,87
Average	0,90	0,87

Table A.19: Proportion of ticks where the social network generated is Scale-Free and Small-World in the Fifth Experiment of Brain Drain Analysis

Test 6	Scale-Free	Small-world
Exp 1	0,86	0,83
Exp 2	0,89	0,87
Exp 3	0,90	0,89
Average	0,88	0,86

Table A.20: Proportion of ticks where the social network generated is Scale-Free and Small-World in the Sixth Experiment of Brain Drain Analysis

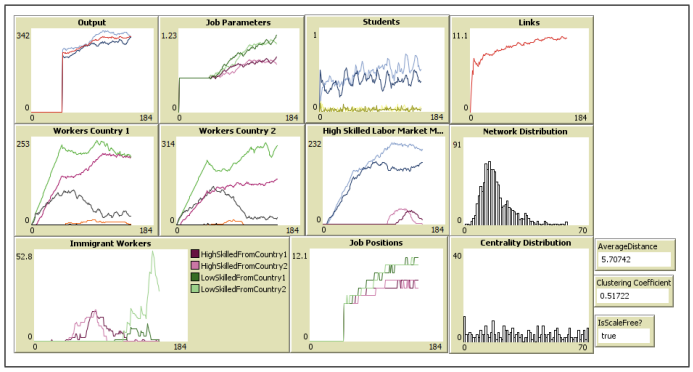

Figure A.51: Brain Drain Analysis Experiment 6.b

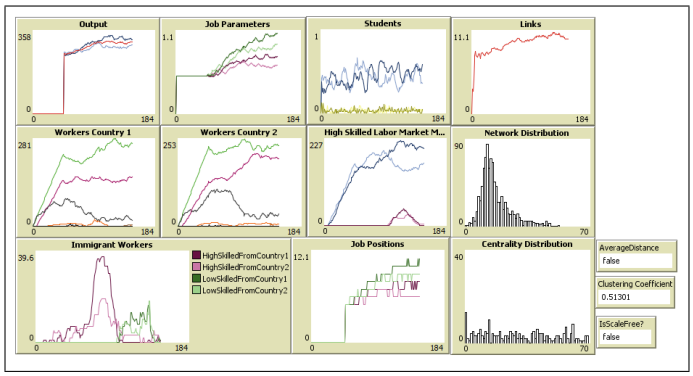

Figure A.52: Brain Drain Analysis Experiment 6.c

Comparative Table	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
EP1	599,00	690,00	520,00	328,33	540,83	289,67
EP2	0,00	0,00	0,00	59,33	33,50	327,00
AO	299,50	345,00	260,00	193,83	287,17	308,33
PA1	1,36	1,08	1,13	1,09	1,31	0,68
PB1	1,80	1,43	1,22	1,39	1,53	0,97
PA2	-0,28	-0,29	-0,30	0,05	-0,31	0,80
PB2	-0,26	-0,27	-0,29	0,14	-0,05	1,12
S1	0,53	0,53	0,41	0,54	0,53	0,38
S2	0,46	0,31	0,43	0,40	0,33	0,45
ES1	0,02	0,01	0,05	0,04	0,03	0,03
ES2	0,04	0,02	0,01	0,01	0,04	0,03
HUnemp1	0,00	0,33	2,00	0,00	0,00	0,00
LowUnemp1	32,67	34,33	31,00	31,00	28,67	20,33
h-g1	209,67	213,00	199,67	215,00	230,33	167,00
h-r1	0,00	0,00	0,00	0,67	0,00	3,67
l1	210,67	229,33	248,67	210,33	214,00	225,33
l-r1	0,00	0,00	0,00	0,00	0,00	3,00
HUnemp2	0,00	52,33	44,67	0,00	0,00	0,00
LowUnemp2	52,00	153,00	109,00	24,33	124,00	28,67
h-g2	0,00	0,00	0,00	50,67	13,33	187,67
h-r2	0,00	0,00	0,00	8,67	0,00	3,33
l2	0,00	0,00	0,00	43,00	40,33	248,00
l-r2	0,00	0,00	0,00	8,00	0,00	0,00
HSMW1	209,67	203,00	197,00	215,67	230,33	171,33
HSNMW1	0,00	10,00	3,67	0,00	0,33	6,67
HSMW2	153,00	106,00	104,33	169,67	151,00	191,00
HSNMW2	0,00	10,00	3,67	0,00	0,33	6,67
h-m2	0,00	0,00	0,00	0,00	0,00	0,67
h-m1	153,00	106,00	104,33	112,67	137,67	0,00
l-m2	0,00	0,00	0,00	0,00	0,00	22,67
l-m1	262,00	141,67	183,33	218,00	131,67	9,67
H1	13,67	10,67	11,33	11,00	13,00	6,67
H2	-3,00	-3,00	-3,00	0,33	-3,33	8,00
Low1	18,00	14,33	14,33	14,00	15,33	9,67
Low2	-2,67	-2,67	-3,00	1,33	-0,67	11,33
ALL	6,17	8,00	6,73	7,62	8,20	10,04
Clustering	0,45	0,47	0,49	0,45	0,47	0,51

Table A.21: Comparative Table of the Outcomes of the Experiments on Brain Drain

Appendix B

Research Material Appendix

B.1 Appendix: Bhagwati and Hamada (1974): Intergration of international high-skilled labor markets and unemployment

In Bhagwati and Hamada (1974) the authors bestow to the neoclassical first-wave analysts the merit some important progresses in the brain drain phenomenon study, such as discovering the form of the objective function to be specified. On the other hand they repudiate from the beginning the conclusion that their forerunners had come to, that is the idea of brain drain not being detrimental for the source country. Intuitively, taking away labor from the origin country, loosing the progressive tax effect through which the country could partly recovers the cost of education invested in the talent emigrated and especially in presence of human capital externalities and wage rigidities, brain drain can only be a source of accretion of the international gap.

To better investigate the phenomenon, they elaborate the following value-theoretic model which studies the welfare effect of the brain drain in underdeveloped countries.

Assume two commodities m_1 and m_2 and their outputs being M_1 and M_2. These latter are produced through the following production functions with i=1,2, which possess the standard properties including twice differentiability and linear homogeneity:

$$M_i = F_i(L_i) \tag{B.1}$$

where L_1 is the quantity of high-skilled workers employed only in producing m_1, and L_2 is the quantity of unskilled workers employed only in producing m_2. Diminishing returns to L_i with i= 1, 2, are postulated. The country is small in Samuelson's sense, that is the commodity price ratio is exogenously set and m_2 is the numeraire. As it is often seen in the underdeveloped countries, elite's real wages to be fixed in accordance to the wage-level of equivalent categories in more developed countries (Sunkel, 1972; Jolly and Seers, 1970), the real wage for high-skilled workers is fixed at $\bar{w}_1$ in m_2 units. More, through the so-called *leap frogging process*, that is that phenomenon in which the lowest wages get pulled up by the highest, the real wage for low-skilled is set at $\bar{w}_2$. The market equations, then can be written as:

$$\Delta F_i/\Delta L_i = \bar{w}_i/\pi or L_i = g_i(\bar{w}_i/\pi) \tag{B.2}$$

U_i and N_i with i= 1, 2 represent respectively high-skilled and low-skilled unemployed and high-skilled and low-skilled labor supply. We have then three balance equations:

$$L_i + U_i = N_i \tag{B.3}$$

$$N_1 + N_2 = \bar{N} \tag{B.4}$$

with $\bar{N}$ representing the fixed labor supply. It is now necessary to investigate how will the population divide among educated and non-educated. The authors assume expected high-skilled real wage to be larger than the expected low-skilled one. Let the expected wage Ew be the average wage for it, respectively:

$$Ew_i = \bar{w}_i(L_i/N_i) \tag{B.5}$$

Assuming education to be state-financed, the equilibrium condition is then:

$$Ew_1 = Ew_2 \tag{B.6}$$

Note that in this model there are three sources of inefficiencies, the two rigid wages and the provision of free education. By correcting for all of them, the economy would reach a Pareto-optimal solution with full employment of labor. The authors carry on with the analysis by focusing on four main possible scenario and evaluating their consequences. The first study is performed in the case of an increase in w_1, asked by the highly-skilled elite willing to integrate to the foreign high-skilled workers. The second case investigates the so-called *leap-frogging* process. In the third case, the authors examine the effect of emigration of high-skilled individuals to areas with higher expected wages for specialized workers. Moving finally to the fourth case, the combination of both the emigration of high-skilled workers and the consequent rise in the domestic real wage for high-skilled workers is investigated. Summing up the results of this analysis, it is shown that even without externalities the emigration of educated labor can easily induce negative consequences for both national income, per-capita income and employment.

The authors then prosecute by changing the assumptions of the model, allowing for the internalization of the cost of education, that is letting people pay for their own education, and for the payment by the foreign country of the cost of education of the immigrants. In the first case, since the employment in each sector does only depend on the wage, this variation will produce no effect. On the contrary it is influent in determining the proportion of individuals choosing education. The authors suggest that the more internalization of the cost of education, for any given level of $\bar{w}_1$, $\bar{w}_2$ and Z (exogenous emigration of educated labor), the more employment and income level will be improved. This does not imply, though, that internalization does reduce the negative effect of brain drain in the model. More, they show that even in the short-run scenario, or by introducing competitive labor market for non-skilled jobs, so that only high-skilled

real wages are rigid, or by letting the destination country pay the cost of education for high-skilled immigrants does not vary the outcomes achieved in the previous section.

The authors then show what are the welfare implications of brain drain and the integration of international labor markets. To do this it is necessary to clearly specify a welfare function. In contrast with the previous neoclassical analysis of the brain drain (Grubel and Scott, 1966; Johnson, 1967), five factors are deemed to be relevant. National income, level of emigration, level of educated/professional manpower, unemployment and income distribution are all included in the following welfare function designed by the authors:

$$U = U(Y, Y/N, Z, N_1, L_1/N_1, L_2/N_2, (\bar{w_1}L_1 + \bar{w_2}L_2)/Y) \tag{B.7}$$

They perform, then, one particular taxonomy exercise, that is studying the effects of a tax on emigration. This tax is charged annually to all of those who have emigrated. The expected effects on those left behind are a *direct effect* of the tax on revenue, that can be seen as a sort of redistribution towards those left behind, and an *indirect effect*, which operates by modifying the levels of the expected wages. Assuming T as the poll tax paid by emigrants (Z), the tax revenue will be TZ. As T changes, the tax revenues will be changed by:

$$Z(1 - {\eta_f}^T) \tag{B.8}$$

with ${\eta_f}^T$ being the elasticity of emigration with respect to the poll tax. The *revenue effect* will be positive or negative depending on this elasticity. To understand the indirect effect, the authors assume that only the expected wages are negatively influenced by the tax. They show, then, that an increase in T will always decrease the supply of high-skilled workers in the long run. A sufficient, but not necessary, condition for the impact of both the effects on the welfare of those left behind to be positive is that ${\eta_f}^T < 1$.

B.2 Haque and Kim (1995): Impact of migration on income and growth

In Haque and Kim (1995), the authors designed a model which sketches human capital flight. The world considered is made of two identical countries in each of which the same number of heterogeneous individuals lives two overlapping generations. In each of the countries, growth is driven by human capital accumulation. Technology is linear. In the first period agents decide whether to acquire education or not, in order to improve their salary situation for the second period. Once they have acquired education they decide whether to stay or migrate to the other country. The two countries have different tax policies and therefore there exists a wage differential between the two. The cost of emigration is the same for both educated and not. Wage differential is higher for higher skilled, therefore it is more profitable for them to emigrate. Here the authors do not take into account that even if less profitable, less skilled individuals may come from very hopeless situations and therefore the emigration perspective is good even if non-profitable[1]. The analysis, then, proceeds by examining the growth rates of the source and the destination countries. Finally they study the effects of tax-financed political subsidies to education and in particular they try to understand whether it is profitable for a country open to migrations to invest in high education or if it might be better to invest on lower educational levels. There is no population growth and without migration, the two nations are inhabited by the same number of citizens. Each agent maximizes

$$U(c_{t,t}, c_{t,t+1}) = u(c_{t,t}) + \beta u(c_{t,t+1}) \tag{B.9}$$

where c_t is the consumption during period τ of an individual born at t and β is the subjective discount factor.

In each country an equal number of heterogeneous agents are born in each t with the same level of human capital, h_t, which can differ across countries. When agents are young, they can not emigrate, but they can decide whether to invest v_j of time in education or not. Education is provided free of charge, it is subsidized by the government. Education subsidies increase with the average of human capital as $E_t = \alpha H_t$ where α is the subsidy ratio. When young, an agent faces a budget constraint such as

$$c_{t,t} = (1 - r_d)w_t(1 - v^j)h_t + \alpha h_t \tag{B.10}$$

where r_d is the rate of wage tax in the home country[2] and w_t is the domestic real wage rate at time t. By allowing for education subsidies, the budget constraint slightly changes. In particular the authors consider two kinds of subsidies often found in practice. The first is a subsidy proportional to the time spent in education. The second one is an lump sum, independent from the time spent in education. The considered subsidy, therefore, can be re-written as a sum of this two kinds of financing. The budget constraint can therefore be re-typed as

$$c_{t,t} = (1 - r_d)w_t(1 - v^j)h_t + (av^j + c)h_t \tag{B.11}$$

[1] No budget constraint considered.

[2] r_f in the foreign one

In the second period of life agents can decide whether to work abroad or in the source country. Because of adaptation difficulties and search costs, the authors assume that the capacity at which agents provide work abroad is a proportion $q \in (0,1)$ of their full capacity. This assumption is limiting. Indeed it does not allow for increasing in adaptation, as it should be reasonable to guess. The effective labor abroad can therefore be written as

$$h_{t+1}^{f,j} = qh_{t+1}^{j} \tag{B.12}$$

The cost of immigration, given by immigration policies, cost of transportation and so on, is assumed to be independent of human capital and equal to T_t. Moreover, it changes over time proportionally to the average of human capital, as $T_t = \gamma h_t$ as job search in a new environment takes time and foregone wages while migrating are proportional to human capital. The wage after tax for an adult agent is therefore

$$c_{t,t+1} = (1 - r_d)w_{t+1} + 1h_{t+1}^{j}l_d^{j} + ((1 - r_f)w_{t+1}^{f}qh_{t+1}^{j} - \gamma h_t)l_f^{j} \tag{B.13}$$

where l_d is a dummy variable, equal to 0 if the agent works abroad and to 1 if if works in the source country. The dummy variable l_f works in the opposite way. For simplicity, the authors assume no financial markets. Human capital is a linear function of the time spent in education adjusted for the capability of learning. This is represented by the parameter δ^j, which is different for any agent. However the distribution of δ^j is identical across countries. Human capital accumulation can be written as

$$h_{t+1}^{j} - h_t = \delta^j v^j h_t \tag{B.14}$$

where v^j is the time spent in education and h_t is the human capital with which all individuals are born, which is equal to the average of skills of the parents. This implies an intergenerational externality, that allows for positive growth.

Firms are operating in perfect competition and they have constant returns to scale. The production function is equal to $y_t = Ah_t$, where h_t is the effective unit of labor employed and A is the marginal product of effective labor. Firms choose A in order to maximize the firm value, therefore $A = w_t$. Before-tax wage, then, is constant and identical across countries. Differences in labor productivity across countries may exist if there is some kind of technology which is hard to be transferred. The authors assume $A^f = \lambda A$, where A^f and A represent the marginal product of labor on foreign and domestic countries respectively.

In the quoted model, the government only collects taxes and re-distributes them through education subsidies, for this reason it is subjected to a budget constraint. In the construction of the model there are no financial markets, individuals only attain inter-temporal consumption smoothing through investments in human capital. Note that De Gregorio and Kim (1994) analyzed the role of the market in this model and what they have found is that by allowing domestic market to operate does not substantially change the results of this paper.

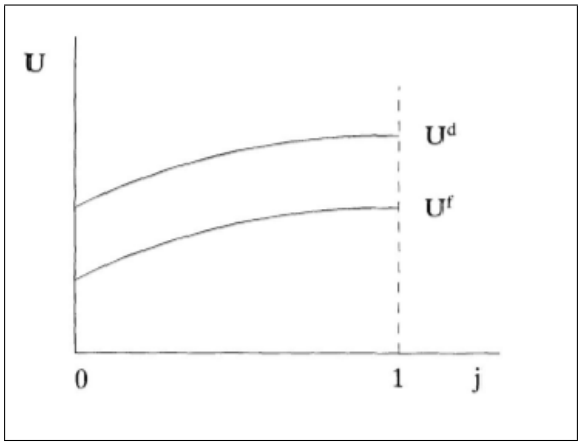

Figure B.1: Case of no migration

With the introduction of migration, agents' decision making will crucially depend on the location chosen to live in old age, since the after tax wage varies across countries. First the authors analyze the case in which the agents take decisions on the optimal level of education, given the location of residence in the second period of their lives. What they get is that both the inter-temporal budget constraint, after tax rate of return and relative consumption and the optimal choice of education may be written as a function of the location of residence. Moreover they find out that an agent would invest more in human capital if it migrates rather then if it stays at home.

The second problem to be solved is that of finding the optimal residence choice given the utility derived as a function of residence. The authors call the utility of an agent working at home U_d and that of an agent working abroad U_f. Depending on the relative utilities, the optimal solution for residence will be $l_d = 1$ or 0. U_d and U_f depend on many factors. First the ability of the agent to achieve human capital, which is heterogeneous among the agents, and so will be their decisions. Also, they depend on the wage tax rates, education subsidy rates, fixed costs of immigration and language similarity. Starting from this point, three are the main possible outcomes. First the case where all the agents will stay working at home. In this case it is clear that $U_d < U_f$ for any agent, see figure B.1. This may depend on any of the factors mentioned below. In particular the case where γ is infinite, which is an infinite cost of immigration, is the case of perfect labor immobility.

The second case is that in which all agents move to the foreign country to work. This implies that $U_f > U_d$ for any agent, see figure B.2, which, as before may arise from many different variables. In particular, the case in which γ is equal to zero represents perfect labor mobility.

Finally, the most interesting case is that in which some agents emigrate to work in the foreign country and some do not. In this case it can be said that if $(1 - r^f)q\lambda > (1 - r^d)$ and the parameters γ, q and λ are in some intermediate range, there exists an individual j^* with ability δ^* who is indifferent between staying and emigrating. Individuals with

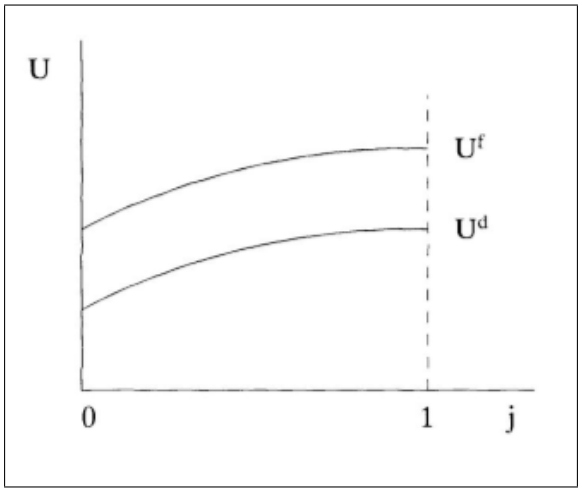

Figure B.2: Case of total migration

learning abilities higher than j^* will choose to emigrate, while those with lower abilities will choose to stay. It can be proved that the slope of U_d is greater than that of U_f, then it follows that for $j < j^*, U_d > U_f$ and vice-versa, see figure B.3.

The intuition behind this mechanism is that as migration costs are constant and independent of ability and human capital accumulation, while wage differential is increasing in these two variables, it is more profitable for highly educated people to emigrate. Their advantage, indeed, will be large enough to compensate for the expenses. The j^* individual determines the fraction of human capital that stays in the source country and therefore $(1-j^*)$ represents the human capital flight. The value δ^* indicates the average level of human capital that stays in the economy. The average human capital which will stay in the economy, will determine the growth of the source country. By computing the value for individual j^*, it is possible to deduce the effect that the variables taken into consideration play on it. The equilibrium human capital flight ratio $(1 - j^*) \in (0, 1)$ decreases with the cost of migration γ and the tax rate in the foreign country r_f. On the other hand it increases with the assimilation parameter q[3], the relative level of foreign technology λ, the subsidy rates a and c, the average level of educational abilities m and the domestic tax rate r_d. Finally, it is important to note that in equilibrium j^* does not depend on h_t, which means that independently of any circumstance a constant fraction of the population will migrate to the other country in any t.

The outcome of human capital flight in this model can be summarized by saying that the brain drain implies a permanent reduction of per-capita income growth in the source country. The magnitude of this phenomenon is proportional to the percentage of the population which has migrated. On the other hand, if it is the destination country under investigation, what is observable is very interesting. The growth rate will be affected by

[3]It would be interesting who notice how does this parameter change by repeating the game and allowing for adaptation

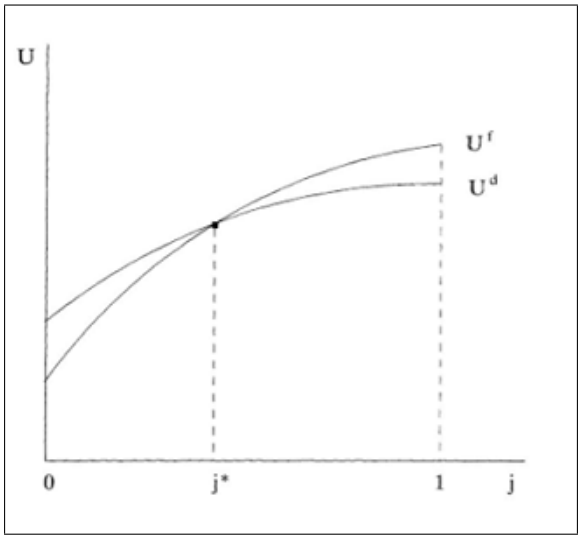

Figure B.3: Case of partial migration

brain immigration and the sign and the amplitude of this influence will depend on the evolution of the average ratio levels of human capital. Indeed, if the incoming individuals can provide a higher human capital than the average of that present in the receiving country, they will then increase the growth pace at which the destination country is proceeding. Anyway their positive effect will be reduced over time. On the contrary, if the average human capital level of the incoming agents, although the highest is the source country, is lower than that in the destination country, their arrival may damage the growth rate. However, as the source country will see its growth rate reduced, the relative growth rate of the receiving country will increase. In the long run emigration can lead to differences in the steady state income per-capita. Indeed, once a stable the ratio (h_t^E/h_t^I) reaches a stable value, may emerge different level of income per-capita across countries.

The model puts forward the following deduction. In absence of brain drain, a tax financed increase in education which preserves the fiscal balance will enhance the future growth rate of the country. On the other hand, if the country is open to emigration, such a policy may have negative effects. In the presence of brain drain, human capital flight will reduce the effect on growth on education subsidies. Also, the increase in governmental taxes to finance education subsidies will enlarge the brain drain phenomenon.

It is interesting to analyze also the differences between the two kinds of subsidies taken into consideration. In both a closed and an open economy, a proportional subsidy leads to higher growth rather than a lump sum subsidy. Finally the authors take into consideration another kind of subsidy, which is a proportional up to a certain level and then takes different values beyond that level. In the framework of this model, the growth maximizing subsidy would be an instrument which is proportionate up to level δ^* and 0 beyond that level. The intuition beyond this is that with a proportionate subsidy only,

those who will benefit of the higher subsidy will then migrate and therefore they will not increase the country growth although they have participated in limiting the budget spending. On the other hand, financing lower levels of education, will slightly increase average human capital in the country, so enhancing growth, but not enough for the beneficiaries to find it profitable to emigrate.

B.3 Appendix: Beine *et al.* (2001): Brain Drain and Economic Growth

In this paper the authors focus on the effects of the prospects of migration in human capital accumulation. The idea is that two contrasting effects play an important role. An ex-ante effect enhancing human capital accumulation because of the higher returns in other countries, and an ex-post drain effect, due to the actual emigration of high skilled workers. A beneficial brain drain is possible if the first effect dominates. The rationale behind this study is that in a country with an *inadequate growth potential*, the incentives to achieve a higher education may not be strong enough. The possibility of migration could, therefore, enhance the proportion of educated people. Finally, not all of them who will get an education will be willing or managing to emigrate, and therefore it is not given, as a great part of the previous literature is asserting, that brain drain is necessarily negative. The paper is very interesting as it provides both a wide theoretical and empirical analysis of the phenomenon. Anyway it is only slightly related to the topic analyzed in this work, as here the term brain drain is not only referred to those very highly skilled professional we are interested in, but it is centered on the emigration of those people who have an education higher than the local average.

The model presented represents a small open economy occupied by two-period living individuals. In the first stage individuals decide whether to acquire education or not. This decision will influence their productivity in the future. At each period of time, individuals show different abilities to learn and this aspect is a warranty of heterogeneity. Country growth is achieved through the transmission of knowledge between generations and therefore the average education of adults in the country is very important.

The productive sector is characterized by competitively behaving firms that use capital K_t and labor H_t to produce a composite good in quantity Y_t. The production function shows constant returns to scale. Therefore we can write $Y_t = F(K_t, H_t)$ and $y_t = f(k_t)$, where k_t is the capital per efficient hour worked.

Each individual i of generation t is endowed with an initial level of inherited human capital h_t. Lately everyone can decide whether to invest a fraction of the time in education ($e_t^i = \bar{e}$) or not ($e_t^i = 0$). In the second period, individuals level of human capital will be depending on the time spent in education and the capability to learn. Therefore, it can be summarized in this formula $h_{t+1}^i = [1 + a^i e_t^{i\beta}]h_t$ with $0 < \beta < 1$ and a^i is a parameter of individuals' ability uniformly distributed on the probability space $[\underline{a}; \bar{a}]$. The authors assume that human capital is transferable and rewarded an higher return abroad. With w is considered the exogenous relative return to education, net of any migration cost, so there is no possibility for convergence in productivity levels. The expected productivity for emigrants in a foreign country is therefore represented by equation B.15

$$h_{t+1}^i = [1 + wa^i e_t^{i\beta}]h_t \tag{B.15}$$

Educational requirements are necessary but not sufficient to emigrate. Indeed, many other factors may play a role in the decision of emigrating or not, such as destination country immigration policies, source countries emigration policies, family reasons and so

on. People will be able to emigrate with probability p. Furthermore, the authors assume that the probability of emigrating depends solely on the achievement of some educational threshold and not on individuals' productivity, as the first is better observable. Agents are risk neutral and maximize expected life income. The condition of the critical agent, that is the one who is indifferent whether to invest on education or not is the following equation B.16

$$a_E = \frac{\bar{e}^{i-\beta}(i+r)}{\phi(p,w)} \tag{B.16}$$

where r s the discount factor. The ability of the critical agent, a_E, is higher if the possibility of emigrating is zero, while it drastically decreases if the probability is one, but note that in that case there will not be educated people in the source country.

The authors then analyze how can migration opportunities influence growth in the source country. As it has already been mentioned, the source of growth is the intergenerational transfer of knowledge, that is entirely spread to the younger generation. The equilibrium growth rate is directly proportional to $(1-p)$ that is the proportion of educated who stay home, but it is a decreasing function of a_E, that is a decreasing function of p. This clearly shows the two opposite effects mentioned initially. By allowing for a benchmark economy without possibility of emigrating, the authors find the conditions under which brain drain is beneficial. What they found out is that, if there is growth in the origin country, brain drain is beneficial for the source country if and only if the probability of migration satisfies the following condition:

$$pxZ(p) = p(Ap^2 + Bp + C) < 0 \tag{B.17}$$

With $A = (w-1)^2$;$B = (w-1)(\frac{\bar{a}^2 - a_F^2}{\bar{a}_F} + 3 - w)$,$C = \frac{\bar{a}^2 - \bar{a}_F^2}{\bar{a}_F} - 2(w-1)$

From the theoretical model, two main aspects can be deduced. Migration prospects increase the number of people who are willing to get education. The growth rate of the origin country is positively dependent on the number of educated individuals who stay there and negatively affected by those who emigrate. The authors have continued the analysis through an empirical study which aims at assessing the empirical value of the theoretical results achieved. Some issues have been found while dealing with data. In particular there are no qualitative analysis of emigrants, which can be used to identify their schooling achievements. Furthermore even the size of the emigration phenomenon is not easily computable, as source and destination countries data are quite different. Furthermore, there are specification issues, regarding the endogeneity of migrations and the non-linear relation between human capital accumulation and migration prospects. The authors have also introduced public education expenditures and remittances as control variables.

The results arising from this study are generally according with the theoretical model. In particular there exists a strong and positive correlation between wage differential and migration and a strong and negative correlation between population size and migrations, that seems to confirm the bindingness of immigration policies and situation of uncertainty in which agents make decisions. Note for instance, that the immigration

policies in USA only allow per-determined quotas of immigrants from each country to enter. The quotas are independent from the dimension or the population of the source country, and therefore they happen to be more binding for more populated countries. The analysis reinforces the idea that incentive effects of migration provided by the theoretical model can not be rejected. Finally the experiments performed show a positive correlation between capital accumulation and growth.

B.4 Appendix: Axtell (2006): Coordination in Transient Social Networks

The example they make regards a reduction in the retirement age in the USA, the authors try to explain why did it take around three decades for agents to adapt to the new situation. It would not be possible to be so if the citizens were totally informed rational agents. Other academics have tried to answer by attributing optimization problems to be solved by the agents. This explanation is not very realistic as agents have been proved not to be good at solving backward induction problems. The authors, therefore, rely on two main factors as key aspect in modeling population behavior: imitative behavior and social interactions. Note that ABM is particularly useful in studying heterogeneity, bounded rationality, non-equilibrium situations and spatial processes.

There are three categories of agents: rational, random and imitators. The first ones behave as if they were *homo economicus* and they retire at the first possible age. The second ones retire randomly at a fixed probability p. The third category collects the majority of agents who retire following an imitative behavior. The agents are divided into 81 age cohorts. Each cohort contains C agents, therefore the total is $C81 = A$. At each time t, each agent is activated exactly once and, if eligible for retirement, but not retired yet, it decides whether to retire or not.

Each agent is endowed with a social network. This is a list of agents specified randomly and fixed over time. The size of this network, S, is drawn randomly from $U[a, b]$. The extent, E, is how far below and above the age of the agent its network goes. This value is randomly drawn from $U[0, c]$. Networks may overlap or not.

Each imitator has within its network a percentage f of colleagues which is eligible for retirement and has retired. Each agent is endowed with an imitation threshold τ. Practically the imitator decides to retire if $f >= \tau$, otherwise it keeps on working. This behavior can be thought as a process of maximizing utility, where utility is given by coordination. The state of population can be re-written as $x \in [working, retired]^A$. We consider individual i. N_i is its social network. Its utility function can be written as $U_i(x) = \sum_{j \in N_i} u(x_i, x_j)$. U_i is the payoff function of the social network game.

Initially the authors focus on two extreme cases. The first is a situation in which there is a large percentage of rational agents and the second where this percentage is much smaller. By keeping all the other factor constant, e.g. population size, C,τ, p and so on, what is achieved is that efficiency is reached in both cases. The difference resides in the pace and in the path the population follows. In the first case, indeed, the trend is monotone, while in the second it appears to be much more confusing.

To get quantitative results it is necessary to perform many times[4] the computational model for a specific situation, and successively examine the influence of some particular varying aspect. The authors therefore set up a standard configuration and then analyze the effect of each variable on the transition time. The size of the cohort, C, has been proved to have no effect on the transition time.

By testing the percentage of random agents, it can be deduced that with values of 0

[4]each standard configuration has been performed 50 times

or 5 per-cent, a definite percentage of rational agents is necessary for efficiency to arise. Given that this percentage exist, then the transition time decreases with the increase of random individuals.

With reference to τ, it is important to note that this parameter needs to discretely variate, in order to affect transition time, therefore the authors have performed a different analysis. Holding τ still in average, they have tested what is the effect of making it more heterogeneous. The outcome is that by increasing τ's variance, transition time decreases. This is due to the fact that if the variance is larger, more individuals will have low values for the imitation rate and they will influence other agents to retire.

The following test has been performed with reference to S and to its variance, first separately and then combined. If the size of S increases, holding its variance constant, the transition time increases. The time required to adequate to a group, increases with the size of the group. With reference to S's variance, as it increases, the transmission time decreases, although the effect is week. The combined effect of these two opposing influences is that if both S and its variance increase, then transmission time increases very rapidly.

Finally the last test is computed on the effect of the extent of the social network E. As E increases, the transition time decreases, as the agents are influenced by older colleagues, that are more likely to retire.

By simulating what has happened in 1961 in the USA, the authors now reduce the age of eligibility for retirement from 65 to 62. Moreover they set up the obligation to retire at 70. This last measure will increase the pace of achievement of the 65-rule. Once the 65 rule is achieved, the authors introduce the policy mutation. According to the analysis already performed what is expected is that transition time will decrease with the increase of the percentage of rational agents in the population. On the other hand there exist a positive relation between transition time τ, S and E, although this last outcome seems to be contradicting the considerations made before. According to the simulation model, it takes between twenty or thirty periods to achieve an efficient result, more or less like in reality where it took around thirty-five years to the population to move towards the new 62 years standard.

It is reasonable that population is divided into sub-groups where some is more aware of the surrounding circumstances than another. For instance the authors have divided the population into two subgroups, where in one none is rational, while the ten per cent of the second group is. The two groups are connected through networks. Suppose that the 90% of the agents composing the network of an agent coming from the first group is composing by members of the same sub-population, while the remaining 10% is composed by members of the other group. This last percentage is called the coupling population. The authors have shown, that even in this conditions, it is possible to achieve efficiency. It is not high the percentage of coupling needed to the non-rational sub-group to conform to the efficiency standard.

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