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The impact of individual differences on network relations

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Introduction

1.1 Introduction

This book is about how differences between individuals impact their relationships. In particular, how inequality in people's benefits can be the by-product of social exclusion as it results from exchanges between heterogeneous individuals. People have characteristics that differentiate them; we are essentially heterogeneous. These differences can be a consequence of *who we are*: in our gender (men and women), our beliefs (religious and atheists), or our political affiliation (left or right wing), for example. Also, there can be differences regarding *what we can do*: in the contribution to a scientific project (researchers with specialized or general expertise), in the performance of a task in a firm (highly qualified or average employees), or in the generation of status (cool or unpopular friends).

Heterogeneity in the individual characteristics people have is of primordial importance at the societal level because (i) individuals relate to each other so that together they can achieve valuable goals, and in many cases (ii) people have a say on whom to relate with and to what extent. In this sense, heterogeneity can create differences in the opportunities actors have to relate between them. The more attractive a person is, in her social environment, the more opportunities she has to relate with others. Conversely, the less attractive a person is, the more likely she will be excluded from potential relationships with others. Therefore, the social environment (i.e. social network) that results, as a consequence of the choices people make, can be strongly influenced by differences in their individual characteristics. That is, differences between individuals in a society can lead to exclusion between those who have access to valuable goods and resources and those who do not have it. In consequence, this can lead to unequal distributions of benefits between the actors, given who they are.

For instance, when the relevant differences are in relation to what we can do, a natural example is a setting of scientific collaboration. When choosing whom to write a scientific paper with, researchers are likely to select partners depending on the expertise the poten-

tial co-authors have on the topic of the paper. If everyone is an expert in what they do, the network of relationships that is formed might not be the same as when some people are experts and others are not. Possibly, the specialized experts could be more attractive co-authors than the more generalist experts, so that the former have more co-authorship proposals and the latter end up being excluded by their colleagues. Thus, the existence of heterogeneity between individuals potentially results in social exclusion of the least attractive partners, and depending on the composition of the group of co-authors, we can expect the pattern of relationships and the outcomes achieved between them (e.g. the quality of the research paper) to vary. Exclusion then affects the well being of the researchers, for those who have less access to co-authorship opportunities are likely to achieve less benefit compared to researchers who have a richer pool of potential co-authors from which they can choose.

In other cases, where relevant differences regard who we are, a natural example is a coordination problem. There are multiple settings where people try to coordinate their behavior with their partners, and people's preferences influence their choices and relationships. In these cases, people are better off when they choose alike with those around them, and the more partners they coordinate their choice with, the better. For instance, if a person is choosing a technological product (e.g. two operative systems such as MacOS and Windows) and wants it to be compatible with her co-workers, her choice can change depending on how many of them are using the same technology or a different one (Vives, 2005). These interactions are known as coordination games, where a person's incentives to adopt a given behavior increase as more of those around her make the same choice. Because choosing a setting (e.g. a technological product) frequently implies that one cannot simultaneously choose a different one, then the pattern of behavior at the social level depends on who the people making the choices are. If every person has the same preference, it is likely that they can easily coordinate in choosing alike, and all would acquire the same technology. However, when there is heterogeneity (e.g. users of different technologies), a conflict in preferences can arise because individuals want to choose like others but they disagree on what the best choice is. Therefore, it is likely that Windows users might end up becoming MacOS users if many of the people they relate to are using MacOS. Thus, depending on who they are, people relate to some, by choosing their same setting, and segregate from (i.e. exclude) those who have chosen a different setting.

In essence, we define exclusion as a situation in which a focal actor does not exchange with one or more other exchange partners, when those others would prefer to exchange with the focal actor. Exclusion can come from different sources; heterogeneity of the potential exchange partners may be one of them. When exclusion becomes structural (i.e. the same actor repeatedly cannot exchange), inequality may be the result. That is, due to heterogeneity, exclusion can occur as the systematic non-participation in exchange by actors who have a specific characteristic. The very basic consequence of exclusion is the unequal distribution of gains between actors in a social setting. For this reason, we need tools that help us understand how and why people with certain characteristics are excluded.

Clearly, much sociological research has been devoted to showing how networks of relationships and patterns of behavior emerge at the macro-level (i.e. societal level) from the aggregation of the choices individuals make (Coleman, 1990). However, individual choices are not always isolated from the individual characteristics of the people who make them. On the contrary, because there are strategic interdependencies between the individuals, differences in who they are or what they can do influence individual decisions and thus influence the social outcomes. That is a main contribution of the work contained in this dissertation, investigating *how heterogeneity, expressed as differences in individual characteristics between people, affects exclusion and inequality in social networks?* For this, we study the emergence of the pattern of relationships, exclusion and unequal opportunities to access benefits, as a consequence of the micro-processes between heterogeneous actors. That is, we address the need to understand how these outcomes result from the basic mechanisms at the micro-level.

1.2 Framework

To approach the problems of heterogeneity and social exclusion that this dissertation is concerned with, we study social networks. Social networks are comprised of social relationships people have and they provide a setting in which microlevel characteristics (i.e. who the actors are), microlevel choices (i.e. selection of partners) and macro-level outcomes (i.e. the structure of the social network and the distribution of gains and benefits) interact. In essence, studying the way actors choose to relate (or not) with others, in a social network, can be seen as an implementation of Coleman (1990)'s program to explain macro-level structures (i.e. patterns of network relations) through the individual actions and dyadic interactions that brought them about. In consequence, through the scope of social networks, we can study the influence that individual heterogeneity has on creating patterns of inclusion/exclusion in the relationships between individuals.

Overall, we focus on social networks where resources or opportunities are scarce. In terms of resources, this means that if a person is using them in one relationship, it prevents her from using them in another. So that when a researcher uses her resources (e.g. time and effort) in a project with a co-author, she cannot simultaneously use the same time to work in a different project with another co-author. Similarly, in terms of opportunities, this means that actors cannot choose different, and perhaps conflicting, conventions simultaneously. If a person acquires one operative system, she might not be able to simultaneously choose to use the other as well. These examples represent two ways in which social outcomes take place in networks where resources or opportunities are scarce: selection of partners and selection of settings. The choices of how (i.e. with whom) to use one's resources or what convention to adopt depend on the characteristics and decisions of the individuals in the social network (i.e. who they are and what can they do).

1.2.1 Productive exchange vs coordination settings

More concretely, we focus on two settings: productive exchange networks and coordination networks. The first setting of productive exchange relationships is understood as the type of interactions in which individuals combine their resources into a common pool and produce with them a joint outcome. The motivation individuals have, to do so, is that they can obtain better (i.e. more valuable) results for themselves than what they could have obtained separately. Think about the work of two researchers co-authoring a scientific paper (Jackson and Wolinsky, 1996). By combining their efforts the quality of their research is likely to be higher than if they had each written an article alone. The second setting, a coordination environment, is understood as the interactions where individuals aim to choose alike (i.e. behave similarly) with those around them because this improves their well-being. That is, a person's incentives to adopt a given behavior increase as more of those around her make the same choice. For instance, when two friends purchase compatible technologies (e.g. operative systems) they can do things together and share their knowledge of how to use their software better, by giving advice to each other (Galeotti et al., 2010). This would be more beneficial than if each of them had purchased incompatible technologies, which would forbid them from relating in this way.

For the two settings addressed, we focus on relevant individual characteristics, which can differentiate how actors influence outcomes at the social level. In productive exchange relationships, where individuals combine their resources and efforts into common projects, a key characteristic is the productive capacities of the people involved (e.g. the expertise of a researcher). This is a fundamental characteristic to be studied because even when two actors have the same resources, it is the ability to use the resources (e.g. their experience, accumulated knowledge, creativity) that can impact the outcomes that are achievable (Collins, 1990). Therefore, the productive capacity people have, influences with whom they choose to partner and whom they choose to exclude. That is, productive capacities influence the emergence of productive exchange networks.

In coordination settings, where actors derive benefit in choosing similarly to those around them, a key characteristic is their individual preferences over the available options. For instance, their political views when choosing to attend a protest or not; or the technologies they like or know how to use when choosing what operative system to purchase. Individual preferences are fundamental because they influence the level of support (pressure) a person needs to choose what she (dis)likes. If a person likes one technology more than the other, she will need less of her friends using the same technology (i.e. support) for her to purchase it, but she will require a larger number of friends choosing the product she dislikes (i.e. pressure) for her to buy it. Therefore, the individual preferences people have can influence the strength of pressure/support needed to choose one convention or another. That is, individual preferences influence the pattern of behaviors that result in coordination networks.

1.2.2 Assumptions

The general theoretical framework of this dissertation is based on the assumption that actors are purposive and rational. When deciding what relationships to form or what behavior to adopt, the underlying assumption is that actors are driven by incentives to benefit from their interactions (Becker, 1978; Hédstrom and Stern, 2008; Wittek et al., 2013). In this way, we use rational choice as our theory of action to model individual decision-making. This means that when choosing to co-author a paper, researchers do so because this can produce a valuable result for them. In the same way, when choosing to acquiring a specific technology, people do so because that is a beneficial choice for them.

The second main theoretical consideration in this dissertation is that actors' outcomes are interdependent (Fudenberg and Tirole, 1999; Schelling, 1978): the benefits actors get from their social relations depend on their own behavior and the behavior of others. Choices are strategically intertwined between them, so that outcomes depend on what an actor and those she relates with do. The quality and value of the research paper that two co-authors write depends on the involvement each of them has in their joint project. The benefit of attending a protest (or purchasing a technology) depends on how many of the people we want to coordinate with are choosing similarly or not. The outcome interdependence implies that rational actors will make their own behavior contingent on the (expected) behavior of others. In other words, outcome interdependence renders actors strategically interdependent.

In order to account for strategic interdependencies between actors, we approach the decision problems from a game theoretic angle. Game theory studies individual behavior when outcomes result from the interplay of decisions made by different actors (Fudenberg and Tirole, 1999). Furthermore, in the past decades, specific game theoretical tools have been developed to analyze the interaction of actors in networks (Goyal, 2007; Jackson, 2010; Vega-Redondo, 2007). That is, the strategic choices actors make, selecting with whom to relate or what convention to use, can be fruitfully modeled and analyzed through game theoretic tools.

Importantly, people differ in ways that are relevant for the outcomes of social relationships. Their individual differences pose an additional complication to the decisions actors make concerning with whom to relate or how to behave. It is not only the problem of finding a co-author and jointly using their resources in a common project. It is also the problem of choosing such a co-author from a pool of heterogeneous potential partners who differ in the way they can influence outcomes. Similarly, it is not only the problem of choosing one social setting or another, but to do so when the preferences of those we want to coordinate with might be in conflict with our own preference, regarding what the best setting to choose is.

For this reason, the third element, common in all chapters, is that actors are endowed with relevant individual characteristics for the problem at hand, and that they are heterogeneous in this respect. Heterogeneity is likely to affect the behavior of individual actors

and the emerging patterns of social relations. Therefore, we try to understand how the composition of the population, in terms of how heterogeneous it is, affects the decisions of partner selection and behavior. The first two common characteristics of all chapters, (i) rational actors and (ii) interdependent benefits, are standard elements in research on the strategic interaction in networks. The third element, heterogeneity, is the focal point of this dissertation, and the analysis of how it affects aggregate outcomes and influences social exclusions, is our main contribution.

In the remainder of this introduction we discuss how our studies relate to the existing work on productive exchange and coordination networks. Finally, we conclude by describing the general approach of the dissertation and present an overview of each chapter.

1.2.3 Productive exchange networks

One of the most prominent theoretical tools to study inequality and exclusion in social interactions, is social exchange theory (Blau, 1964; Cook and Emerson, 1978; Homans, 1958). Within the wide range of possible types of social exchange interactions, we study the case of productive exchanges (Molm, 1994a, 1997). Productive exchanges are social interactions in which actors join their contributions into a common pool to achieve a goal together, aiming at outcomes greater than the aggregation of what each could have attained separately (Cook and Cheshire, 2013, surveys the literature). Scientific coproduction is an example of productive exchange.

Research on social exchange has pointed to a conflict between the beneficial and detrimental elements that come out of exchanges between actors. On the one hand, there is the potential benefit of exchanging because of the complementarities that the relationship offers, so that actors have incentives to exchange. These exchanges can benefit them and society in a great way. On the other hand, inequality can increase if the benefits of the productive exchanges are distributed unequally. Moreover, because only those who are involved in the exchange relationship can benefit from it, being excluded and not having exchange partners can be a cause for increasing inequality (Komter, 1996, “principle of exclusion”).

As a consequence, inequality emerges between those who form successful productive exchanges and those who do not. For example, in the case of scientific co-authorship, it is possible that the presence of different potential co-authors leads to inequality through exclusion. If some of them can be more influential in guaranteeing a favorable result than others (e.g. a good paper), through their involvement in the productive exchange, it is likely that the former are perceived as more attractive partners. Thus, if scientists are able to choose with whom to collaborate in their joint research, the more attractive a partner is, the more likely she will be asked to be a co-author. Furthermore, scientists who do not find co-authors to work with may lose in scientific standing because they are less productive than their peers who do find co-authors to collaborate with (Jackson and Wolinsky, 1996; Merton, 1968; van de Rijt et al., 2014).

Identifying mechanisms and conditions that lead to inequality and social exclusion is a major theme in theoretical and empirical research on social exchange (Cook and Cheshire, 2013). There are different interrelated explanations for inequality and exclusion in exchange environments. The position of the actors in the network has been widely studied as one of them. It has been found that an actor's position is very influential in facilitating the exclusion of others and guaranteeing the inclusion of oneself in the most attractive exchanges (Skvoretz and Willer, 1993; Willer, 1999). Another explanation is related to the strategic use of power and how the use of coercion reduces the likelihood of unequal outcomes (Molm, 1990; Molm et al., 1999). A third relevant explanation regards the effect that initial inequalities have on resulting exclusionary network structures (Flache, 2001; Flache and Hegselmann, 1999). For instance, how actors who are initially endowed with more valuable resources are more attractive to others and end up receiving access to even more valuable benefits. We focus specifically on how differences in the abilities actors have to influence outcomes (e.g. their specialization in regard to the topic of a scientific paper), influence choices of partner selection (with whom to collaborate) and resource allocation (how to do so). These choices result in the emerging network structures where, due to their individual characteristics, some actors can end up excluded from the opportunities to interact with others. As a consequence, the benefit different actors gain can be distributed unequally. Studying individual differences can enhance our understanding of the micro-processes that lead to these outcomes.

Particularly, we focus on problems of knowledge-intensive joint production where actors' differences are expressed by their type of expertise in a certain domain; such as those in which researchers write scientific papers together. Knowledge intensive joint production occurs when a high degree of in-depth specialized knowledge of a particular domain is required to be optimally productive in collaborative work. A paradigmatic example of knowledge-intensive exchange is scientific co-production, but in certain realms like high-end technology, creative industries or the arts, highly specialized knowledge may be similarly relevant. In fact, as the complexity of technology and knowledge required to be productive progresses in many domains, knowledge-intensive joint production is becoming more and more important in those areas.

Arguably, for relationships that comprise knowledge-intensive production, an actor's degree of specialization is a key characteristic that can lead to fundamental differences in exchange outcomes. To model this, our analysis builds on earlier work about the role of actors' expertise in the generation of scientific knowledge (Collins, 1990; Collins and Evans, 2002, 2007; Sellinger and Crease, 2006). Essentially, this literature suggests that in knowledge-intensive production there are two main types of actors' expertise: generalist and specialist expertise. The first type of actor is an expert who has a general knowledge of the domain but cannot solve highly complex problems within a specific subarea of the domain. The benefit of generalist expertise is that it allows actors to be very effective in simpler or more general problems. However, the more the problem at hand demands specific knowledge, the less effective further investments of time and effort of a generalist will be. This is different for the specialist type of expertise. A specialist actor is proficient in a certain type of knowledge on a very specific subfield in her domain. The benefit of

specialist expertise is that it allows the specialists to perform a skilled practice of the task they are involved with, solving increasingly complex problems within that subfield. Technically, we can say that generalists have decreasing returns to their investments and specialists have increasing returns to their investments.

This difference can lead to inequalities in valuable outcomes, depending on whether the co-authors are specialized in the particular topic of the paper or not. Even if two potential co-authors were to invest the same level of effort into a joint collaboration, the partner with less expertise might not be able to match the expert's contribution. Thus, individual differences in the ways actors contribute to the joint outcome can lead to exclusion of less attractive partners, and to inequalities in what actors achieve. Thus, we study network emergence and how inclusion/exclusion occurs through multiple dyadic interactions between actors that can differ in what they can do to affect outcomes.

In many cases, patterns of relationships portraying social exclusion arise as a result of social exchange among unequal actors. For instance, exchange among unequal partners makes those who are wealthy in resources also highly attractive as exchange partners. Theoretical work (Flache, 2001; Flache and Hegselmann, 1999) illustrated how actors' search for attractive exchange partners can then entail a mechanism in which wealthy actors can choose from a wide range of potential exchange partners and therefore end up in the "core" of exchange networks, exchanging with each other in mutually highly beneficial interactions. Actors with relatively little resources are left to exchange with each other, in exchanges that are less beneficial for them. The consequence is a further increase in social inequality. Komter (1996)'s work on gift exchange can be seen as empirical illustration of this mechanism of social exclusion. She showed how "those who give many gifts, receive many gifts in return, but those who do not give much - often because their social and material conditions do not allow them to do so - are also the poorest receivers" (p. 299). More recently, Offer (2012) highlighted a similar process in the dynamics of personal networks among low-income families.

In conclusion, the degree of specialization is a particularly fundamental class of heterogeneity that helps understand patterns of relationships (i.e. inclusion/exclusion) in productive exchange networks in the realm of knowledge-intensive joint production. A main contribution of this dissertation is our aim to study how and under what conditions differences in the degree of specialization between actors lead to exclusion and inequalities. Specifically because it complements the exchange literature studying similar patterns due to differences in resources or position. As argued above, individual characteristics are an essential aspect of exchange and partner selection which therefore require attention and study.

Moreover, actors face the problem of choosing partners, which becomes complex given there is heterogeneity in their individual characteristics. Due to this, we also aim to answer the question of how actors solve the complex problem of choosing with whom to relate and in which way, when there is a pool of potential partners available and these partners influence outcomes differently. Consequently, connecting back to our interest of understanding how individual differences can lead to social exclusion and inequality, we

want to know what network structures emerge from the choices of the actors, influenced by their individual characteristics. We study these problems in Chapters 2 and 3.

1.2.4 Coordination games on networks

One of the most prominent theoretical tools to study the emerging patterns of behavior and network structures in coordination interactions is the study of coordination games (Goyal, 2007; Jackson, 2010; Vega-Redondo, 2007). Coordination games are situations where people are better off by choosing alike with those around them, because they can benefit from it. By coordinating with others a person can share common experiences with them (e.g. in a social setting) or advice about how to use a particular technology. The difficulty (i.e. the coordination problem) is that there are at least two different options and it is not clear which one is going to be chosen by others (Bojanowski and Buskens, 2011; Corten and Buskens, 2010).

Research on coordination games has shown that there are beneficial and conflicting aspects in coordination interactions. On the one hand, there is a benefit to choosing alike with others, and the more one coordinates with others, the greater the benefit. On the other hand, the options one can coordinate on do not return the same benefits. In fact, a common feature in coordination games is that coordinating in one choice can be more beneficial than coordinating in the other. However, this is not straightforward because it tends to be the case that highly beneficial choices imply a higher risk of potential greater losses, if one fails to coordinate on them (Ellison, 1993; Kandori et al., 1993; López-Pintado, 2006; Morris, 2000; Young, 1993).

As a consequence, inequality in the benefits actors gain emerges because a person can only benefit from the relationships with those she is coordinating with. That is, coordinating on the same behavior results in excluding those others who choose a different behavior. Consider the example of two technological products, technology A which is commonly used, and a new technology B that is recently introduced. The new technology, B , is more expensive than the existing one, A , but also it is more efficient. In such a case, for an actor to switch from the existing technology to a more expensive but efficient one, she needs the support of those around her (i.e. coordinate with them), so that their benefit can be greater than if they stick to the traditional technology (Galeotti, 2010; Galeotti et al., 2010). Nonetheless, if she ends up acquiring the expensive technology alone, she will not have the same gains as if her friends had joined, and the cost is greater than that of staying with the technology she had. That is, she can only relate to those she coordinated her choice with, which in this case is none of her friends.

In game theoretic parlance, the product that is potentially more beneficial in coordination but gives a worse outcome (i.e. has a higher cost) in anti-coordination, technology B , is denoted as payoff-dominant. It is the case where the benefits (i.e. payoffs) actors can gain are the highest. The product where payoffs in coordination are not the highest but the losses in anti-coordination are not the worst, sticking to the existing technology A ,

is denoted as risk-dominant. As a result, a fundamental question in coordination games regards what will be the resulting pattern of behavior from the individual choices of the people involved, given that outcomes depend also on the choices of those around them (Granovetter, 1978). Essentially, because it is not clear which outcome is more likely to occur at the aggregate level (i.e. given the tradeoff between benefits and risk), a general question in the literature has been whether the payoff-dominant or the risk-dominant outcomes are more likely to take place. A persistent finding in the literature is that the most likely outcome is the risk-dominant (Ellison, 1993; Kandori et al., 1993; Young, 1993). Instead of aiming to get the highest payoffs by choosing a risky option, actors are more likely to focus on the less risky behavior at the expense of the benefits they can potentially gain.

To address the questions of what patterns of behaviors can result from the interaction of multiple actors in coordination networks, we focus on coordination games where there is heterogeneity in the preferences people have over the behaviors they can coordinate on. Differences in the way individuals benefit from coordinating in one behavior or another can arguably be a source of conflict for coordination games. That is, actors are better off by choosing the same as those around them (i.e. coordination) but have different preferences over which outcome they want to coordinate on (i.e. conflict). For instance, in our example of acquiring a technology, it is likely for actors to have different preferences over the products available. In such a case, the more technologically oriented, for instance, would prefer to acquire technology B and the rest would prefer to keep using the existing technology A , when keeping everything else constant. Importantly, because heterogeneity creates an environment of conflicting preferences, there is no clear trace towards payoff-dominant and risk-dominant outcomes in the pattern of behaviors that emerge. What is payoff-dominant to some (i.e. purchasing product B for the technological oriented actors) is risk-dominant for others (i.e. the less technologically oriented would rather keep using the product they know than face the risk of acquiring and new and expensive product), and vice versa. Thus, a crucial way to approach coordination games is by considering how differences in the preferences actors have over the conventions they can choose from, can influence the emerging pattern of behaviors.

A person's preference can have either a purely individual basis, but also a social one, such as norms and identities. The way we study heterogeneity in coordination games is by considering preferences based on a person's identity (Akerlof and Kranton, 2000; Tajfel and Turner, 1979): who she is. That is, depending on who a person is, she obtains more benefit from one behavior or another, when coordinating in her choice with those around her. The behavior that gives the highest benefit is denoted as the behavior she prefers. That is, a person's identity can generate her preferences over the behaviors she can choose from. For instance, what social setting a person chooses or what products to purchase. As a consequence, a determinant element of how inequalities and exclusion can arise in coordination games in networks is expressed by the interplay between the benefits of coordinating with others and a person's individual preference. If a person is surrounded by people choosing the behavior she does not prefer, it might be better for her to choose against her preference, so that she can gain more benefits from the relationships with others. Otherwise,

if choosing in accordance with one's identity but staying isolated, a person can end up with a worse outcome. This interplay between individual preferences and social influence has been modeled in coordination games in networks by thresholds functions (Galeotti et al., 2010; Granovetter, 1978; Hernández et al., 2013). For instance, when a person is deciding whether to acquire a specific technology or not, if more than a given number of her neighbors (i.e. the threshold) uses that technology, this person would purchase the new technology. Otherwise, she would keep using the existing technology.

In conclusion, when people do things together (i.e. cooperate) they frequently need to adopt a certain technology or a set of behaviors or conventions. However, this is problematic. On the one hand, choosing the same behavior as others is better than choosing a dissimilar one. On the other, people may differ in their preferences over different behaviors. Differences in individual preferences, which result in conflict about what behavior to adopt, are an essential class of heterogeneity. These differences can help us understand what the micro-processes that lead to different patterns of behaviors in coordination games are. By means of this, we can study how and under what conditions the differences in individual preferences can make actors choose the behavior they dislike. And therefore, whether it is possible that all actors behave in the same way, in settings with conflicting preferences. That is, we want to understand the conditions that can lead to social exclusion in the choice between different conventions and its effect of the benefits actors gain from their choices (i.e. risk or payoff dominant outcomes), when actors differ in their individual preferences over the different choices. We study these problems in Chapters 4 and 5.

1.2.5 Coordination problems vs coordination games

As a final comment, we want to clarify in more detail the difference between coordination problems and coordination games. In both of the settings studied, Coordination and Productive exchange, there are coordination problems.

In a productive exchange, individuals want to coordinate their choices of collaboration and their investments of resources with others. For example, researchers want to use their resources (e.g. time and effort) between projects with different co-authors, and they face a coordination problem because a collaboration only takes place if both parties involved decide to work together. Therefore, in a pool of many potential co-authors, there is a coordination problem of choosing with whom to collaborate while also being chosen by that same partner. Specially, because the outcomes actors can achieve depend on the resources allocated by others as well.

In coordination games (e.g. acquisition of different technologies) the underlying coordination problem amounts to choosing conventions (i.e. behaviors), and the benefits a person gains increase as more of those around her make the same choice. For instance, choosing a social setting (e.g. a manifestation, a party, purchasing a technology) implies the problem of coordinating or not with those around us. As the number of our friends making use

of the technology increases, the better for us to share it with them, and thus the higher the benefit of choosing that behavior. In conclusion, in both settings there are coordination problems, however only one is considered a coordination game, while the other is a productive exchange.

1.3 Approach

To study strategic interactions in networks we integrate the techniques from research in economics, in our modeling, looking at explaining network relations (Goyal, 2007; Jackson, 2010; Vega-Redondo, 2007, survey this literature). More recently, sociologists have further built on and advanced this line of modeling (Braun and Gautschi, 2006; Dogan and van Assen, 2009; Dogan et al., 2009). In this line of work, it is assumed that behavior in networks, whom to relate with and how to do so, is driven by goal directed individual actions. These actions are chosen by rational and strategic decision makers, who consider the interaction between their choices and the choices of those around them, as determinants of their benefits.

By means of the theoretical modeling of rational actors who interact strategically, we are able to study the problem of how individual differences in the characteristics of the actors can influence the emerging patterns of behavior and networks of relationships. Specifically, how these differences affect the inclusion/exclusion of others in their relationships and lead to inequality in the benefits actors gain in the social network. Game theory allows for the systematic derivation of propositions on behavior in strategic situations. In this direction and following Coleman (1990), our game theoretical analysis allows us to fully consider how the macro-level and microlevel interact in social environments, as those of productive exchanges and coordination games.

For all four of our studies, the composition of the population of actors, expressed by differences in their individual characteristics (heterogeneity), influences the way actors perceive their potential interactions with others (bridge assumption). The individual characteristics of the potential co-authors a researcher has, influences her incentives to form co-authorships with some or others, and the involvement they are willing to put into each research project. Similarly, the characteristics of those others influence our incentives to behave in a certain way. Thus, they influence how we perceive our potential benefits of attending to one social event or another, and the choices we make. As mentioned above, the assumption is that purposive rational actors make these choices aiming to gain benefit from them (theory of action). When multiple actors interact in social networks, the aggregation of all their strategically interdependent choices can lead to particular patterns of relationships (i.e. network structures), which can in turn result in unwanted, unequal outcomes between actors, so that some perceive greater benefits than others. Possibly due to the choices actors make to relate to some but not to all others (transformation assumption).

A beneficial and necessary element of research on social interactions is to empirically test,

complement and extend theoretical studies. One way of empirically testing theoretically-derived predictions can be done through laboratory experiments. The experimental testing of the theoretical models is also a fundamental aspect of this dissertation. The experiments serve to unravel the understanding of the pervasive question of this dissertation: what are the effects of heterogeneity in individual characteristics on the way actors behave and what are the likely outcomes that emerge from the aggregation of the individual choices? Do the choices of the actors exclude others from interacting with them? Do these outcomes result in interactions that are affected by inequalities? To investigate this, we use experimental methods as traditionally used in economics (Camerer, 2003; Kagel and Roth, 1995; Plott and Smith, 2008, provide surveys of the literature).

A common trait of this type of experimental methodology is that interactions are motivated by financial incentives. Subjects are paid to participate in the studies, but their earnings depend on their individual choices and also on the choices of those they interact with in the experiment. The financial incentives are one of many advantages that laboratory experiments offer. In addition, a very useful possibility of laboratory experiments is that researchers can control conditions and manipulations to focus on the particular aspects of interest while keeping other aspects fixed. For instance, in our work we are interested in the effect of individual characteristics of the actors on the choices of selecting with whom to relate and how to do so. To implement this in the lab, it is possible to artificially create individual characteristics expressed in the effect of a subject's contribution to a productive exchange (e.g. degree of specialization), or in the benefit that a subject gains by coordinating with others in one action or another (i.e. individual preferences). We do this while controlling for all other individual characteristics of the subjects, given they interact through computer terminals and the interactions are anonymous.

Experimental work on networks is growing fast. Especially because the study of network relationships in laboratory experiments allows for a greater understanding of how individuals form relationships and choose behavior in strategic network settings. In addition, these individual decisions are also easy to integrate into studying the macro-level outcomes. Thus, experimental research allows for the understanding and assessment of the interplay between individual choices and aggregate outcomes, which is of great benefit for problems of social networks such as those studied in this dissertation. Kosfeld (2004) provides a survey of network experiments.

In conclusion, experimental methods and game theoretic models go hand in hand and complement each other. This provides a fruitful and valuable interaction of two aspects of the same interest, understanding the effect of heterogeneity in networks and identifying conditions for exclusion and inequality from it. Therefore, in this dissertation we develop theoretical models and also empirically assess predictions from these models by means of laboratory experiments.

1.3.1 Overview of the four studies

In what follows, a summary of the four studies is provided. The four studies in this dissertation contribute to the understanding of how heterogeneity in the individual characteristics of the actors affects their behavior and choices in network settings, and how from their study we can understand the micro-processes that lead to social exclusion and inequality. The four chapters are grouped into those studying productive exchange networks; comprising a theoretical study (Chapter 2) and an experimental study (Chapter 3). Second, those chapters studying coordination networks; comprising a theoretical study (Chapter 4) and a theoretical and experimental study (Chapter 5). We conclude the dissertation in Chapter 6 with a summary of the main findings and suggestions for further research.

Chapter 2 presents a theoretical study of productive exchange networks in which the interactions portray situations of knowledge-intensive coproduction. A model is proposed where actors, endowed with resources, differ in the degree of specialization they have regarding the task they want to carry out. Some are generalists and others are specialists, and this influences the way their resources affect outcomes. Actors can choose their partners and also the allocation of resources to each relationship they form. Although multiple possible stable states can be characterized analytically (i.e. resulting outcomes in terms of behavior and network structures), we study two types of outcomes that can result from the choices actors make.

First, we consider which stable outcomes can emerge when purposive actors can make only individual changes regarding their relationships. That is, if actors find that they would be better in a different situation, the only changes they have access to are those that they can achieve by unilateral actions (i.e. Nash equilibria). This is particularly relevant to understand the dynamics of networks because in situations of productive exchange, relationships are usually formed by mutual agreement of the parties involved but are dissolved by unilateral decisions.

The second stable outcomes include the possibility that pairs of actors pursue profitable outcomes by making changes together (i.e. Pairwise stable Nash equilibria). This means that if two actors are not in a relationship together, they can improve by mutually agreeing on it, while in the first type of outcomes they cannot. In our model we investigate how exclusion of potential partners and inequalities in the benefits acquired by the actors depend on the differences in the degree of specialization between them and on the way they can affect outcomes (i.e. unilateral or bilateral deviations).

Chapter 3 presents an experimental study that aims to empirically understand how actors deal with the complex coordination problem that arises in relationships of productive exchanges in networks. In situations in which actors decide with whom to form a relationship and how much of one's resources to allocate into each productive exchange, there is great risk due to the fact that the formation of relationships requires mutual involvement. Therefore, while the potential gains of exchanging together is greater than what actors can achieve alone, if the counterpart does not get involve in the coproduction, the potential

losses of failing are also substantial. This becomes more difficult when there are multiple partners to choose from, and even more cumbersome when partners can differ in the way they can influence outcomes (e.g. heterogeneity in their degree of specialization). That is, our aim is to understand what the strategies are that subjects use to solve their coordination problems, and whether these choices can lead to stable collaborative relationships between them.

To address this problem we develop a stylized experiment using an exchange game derived from Chapter 2. Groups of four actors play the game with the same potential partners for 20 periods. Our experimental treatments use differences in the individual characteristics (e.g. degree of specialization) to vary the way actors can solve severe coordination problems. This is expressed by the number of *stable* outcomes they can reach (i.e. equilibria), for they reflect in turn how likely is that the collaborative relationships are sustainable between different subjects along time. This is a very useful approach even for a simple setup as that of our game. In our game there are four actors, each of them deciding how to use 10 units of resources. Resources can be used in joint projects with any (or all) of the three potential partners and in an individual project alone. There are 286^4 possible ways of choosing (around six billion). Thus, the strategies actors choose to relate between them is not trivial. In particular, this chapter focuses on the issue of coordination and equilibrium selection, and our theoretical hypotheses are based on the likelihood that stable resulting configurations can emerge. That is, on the likelihood that actors can sustain collaborations with others along time.

Chapter 4 presents a theoretical study of coordination in networks when actors have conflicting preferences. Interactions in this study portray situations in which actors have individual identities that influence their inclination to adopt one behavior or another, but aim to behave alike with those around them. Thus, if two actors are interacting and their preferences are in conflict, each has incentives to choose the same as the counterpart, for this makes them better off, but they have a conflict over which behavior is the one they want to coordinate on.

A model is proposed in which actors, embedded in a network of social relationships, can choose how to behave from a set of two possible choices. There are two general classes of stable outcomes. Either all actors coordinate in the same choice, so that behavior in the social network is specialized in a single action, or some actors choose one action and others choose the other, so that behavior is hybrid and both choices co-exist in the social network. As actors differ in their preferences, they do not attain the same payoffs depending on the action chosen by them and by those around them in the social network. Thus, the interplay, between the gains an actor obtains by coordinating with others and her individual preferences, can lead to inequalities in the benefits actors can achieve. In this direction, our model provides a very simple framework to understand how inequalities between actors depend on how heterogeneous in preferences the network is. The simplicity of our model allows us to also consider the opposite case in which actors aim to anti-coordinate (i.e. differentiate) with those around them.

Furthermore, a key contribution of this chapter is that we compare two classes of stable

outcomes in which actors do not have incentives to change their behavior unilaterally: equilibria. In the first case actors are informed about the identities of all others around them, so that they choose how to behave, while knowing what those around them prefer (i.e. Nash equilibria). This first consideration is fundamental to understand the effect of conflicting preferences on network relationships. In the second case actors know their individual preference and have an idea of how the population is composed, but cannot directly observe the identity of those around them (i.e. Bayesian Nash equilibria). This assumption is more realistic than that of complete information, especially for larger sizes in the population.

Finally, Chapter 5 proposes a model that extends the theoretical work in Chapter 4 and develops an experimental study of the findings from the model. Particularly, the extension of the theoretical model is on the way network relationships occur. In Chapter 4 the focus is on the effect of conflicting preferences in network games, so that network relationships were not part of the individual decisions of the actors but given exogenously to them. In Chapter 5 we relax this assumption, and model situations in which actors can choose what behavior to adopt and who they want to interact with.

Thus, in our model, actors play a coordination game with multiple partners and can decide who those partners are. We study stable outcomes in which actors can deviate unilaterally (i.e. Nash equilibria) and also in pairs (i.e. Pairwise stable Nash equilibria). In our model we investigate how exclusion of potential partners and inequalities in the benefits acquired by the actors depend on the level of heterogeneity in the network.

The second part of this chapter presents the results of a laboratory experiment that tests the analytical results of the model. Particularly, groups of 15 actors play a coordination game and choose with whom to form a relationship and what behavior to adopt from two possible choices. Actors earn higher benefits by coordinating on one action or another, depending on their preference. Based on this scheme of incentives, we design three experimental treatments that vary the level of conflict in the network, due to the level of heterogeneity in the population. The treatments are labeled as no conflict if all actors have the same preference, low conflict if there is a significant majority of actors with one preference and a very small minority of actors with the opposite preference, and high conflict when majority and minority are not too different in size. Our experiment studies under what conditions segregation between actors results from the level of conflict in their preferences. For this we consider the interplay between the incentives an actor has to choose the behavior she prefers, and the incentives an actor has to choose alike with those around her. In addition, we study whether the resulting pattern of connections leads to inequality in actors' earnings.

As a final note, it is necessary to point out that each chapter in this dissertation was written as a separate and independent research paper. This comes with a positive and a negative consequence. The very positive one is that each chapter is self contained and can be read independently of the others. The not-so-positive factor is that some concepts and terms used might vary between chapters.