

## **REFERRAL NETWORKS AND DISCRIMINATION** **Károly Takács<sup>1</sup>, Flaminio Squazzoni<sup>2</sup>, Giangiacomo Bravo<sup>3</sup>**

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### **Abstract**

The present study highlights that discrimination can be pervasive on the labor market also in the lack of average quality differences between members of different categories and also if neutral employers have the best intentions and strive for high quality workers on a perfectly competitive market. We demonstrate that discrimination is highest when employers base their decisions simply on their own experience. Hiring via social network contacts, which could either be by employing friends, using worker referrals, or business recommendations lower discrimination rates compared to the market composed of isolated employers. Thus, contrary to the common belief, referral hiring help markets to work more fairly and efficiently. We should not give too much credit, however, to arguments suggesting that the structure of business networks is detrimental for discrimination, as the network topology does not affect discrimination either in the short or in the long run. A much stronger effect is of aspiration levels that increase discrimination rates for a wide range of parameters, thus can explain why we observe stronger discrimination at top level jobs.

### **INTRODUCTION**

Employer discrimination is a term referring to the differential treatment of a certain social category, in particular in hiring, wages, and allocated jobs (Petersen and Saporta, 2004). Discrimination may be purposeful and motivated by prejudice (attitudes), stereotypes (beliefs), and racism (ideologies), but is distinct from these as it is, by definition, manifested in decisions (Quillian, 2006; Pager and Shepherd, 2008). Typically, only decisions and inequality in employment rate and wages can be observed, intentions and motivations by decision makers remain hidden.

Negative societal and economic consequences of discrimination are the reproduction of inequality (Reskin, 2000), sub-optimal market allocation, disinvestment incentives for disadvantaged groups (Allport, 1954; Arrow, 1973; Akerlof, 1976; Coate and Loury,

1993; Blau, Ferber and Winkler, 1998), reduction of social mobility and a provision of roots for stigmatizing and other forms of social conflict. Difficulties of groups who suffer from discrimination accumulate and there might be spillover effect across domains and time (Loury, 1977; Coate and Loury, 1993; Lundberg and Startz, 1998; Pager and Shepherd, 2008).

Discrimination is based on recognizable traits as gender, race or age that are the most salient social categories immediately encoded in case of any interaction (Fiske, 1998). In most situations, individual merits and abilities are difficult if not impossible to observe and judge promptly, and gathering additional information is very costly (Akerlof, 1976). When information is hard to collect, group reputation, prejudices, and average qualities are more likely used as proxies or indicators to estimate and judge the individual abilities of category members (Petersen, 2009; Heilman, 1995).

Discrimination is of *statistical* nature if it is based on *objective* differences of means (for instance, on differences between men and women in average emotional support for children, e.g., de Waal, 2005). Trusting a woman more than a man when searching for a baby-sitter is a result of “rational” statistical discrimination that is similar to the pricing practices of insurance companies based on hazard categories. In the case of pure statistical discrimination, each person of the same category is approximated to have the same ability that corresponds to the category average (Arrow, 1972). Statistical discrimination, however, is obviously not universal: people and institutions differ from each other in discriminative practices, and variation can be observed in how much they discriminate and also in whom they discriminate. They differ largely because they have different information they can rely on and are unaware of objective category averages. Employers have different experiences from the past and diverging access to pools of the labor force.

Employers have different ways to handle limited and asymmetric information. Signals such as educational attainment, suits for lawyers, smiles and jokes at an interview are used and are the bases for discrimination. The production of these signals by the applicants, however, require investments such as spending years and completing exams in education, paying for expensive suits, and maintaining a friendly character. These signals are often expensive, and are also costly to fake, which makes them credible sources of information (e.g., Frank, 2003; Spence, 1973; 1974; Gambetta, 2009).

The practice of statistical discrimination and discrimination based on signals is debatable from an egalitarian perspective and also from a welfare point of view. For instance, when only average abilities are considered, individuals with qualities higher than average are not motivated to invest in their skills, which leads to a societal suboptimum. If a category is deemed by discrimination as unqualified, then no incentive is given to become qualified, and the prophecy about differences between categories is self-fulfilling and prejudice is perpetuated (Allport, 1954; Arrow, 1973; Akerlof, 1976; Coate and Loury, 1993; Blau, Ferber and Winkler, 1998). These problems of statistical discrimination, signaling, and their welfare consequences have been studied extensively by economists and are also relevant for this study (Becker, 1971[1957]; Schulz, 1964; Welch, 1967; Arrow, 1972; Phelps, 1972; Akerlof, 1976; Cain, 1986; D’Amico, 1987; Yinger, 1998; Altonji and Blank, 1999; Winter, 2004).

The existence of statistical discrimination and relying on credible signals can be explained relatively easily. It is much more difficult to find reasons for the evolution and

maintenance of discriminative practices that occur when there are *no differences* in mean qualities. Discrimination in these cases exists could be attributed to social construction, which has largely been neglected in economic theory and makes sociological insights necessary. Discrimination that is prevalent in case of no average differences in quality is a deep societal problem that should be addressed more intensively. This study aims to address these non-obvious cases of discrimination. The main aim is to demonstrate how discrimination can emerge and be maintained in the lack of mean quality differences and considering *fair intentions* of employers by highlighting certain mechanisms that have been overlooked before. In particular, we address how social network mechanisms that are of key importance in hiring decisions relate to discrimination. With the use of agent-based simulations, we illustrate how and under which conditions social networks help to eliminate discriminative judgments and practices. In the following section, the background of this research topic and the research questions will be further elaborated.

## STRUCTURAL FACTORS AND NETWORK MECHANISMS OF DISCRIMINATION

In many cases, recognizable traits (gender, ethnicity, hair color) are irrelevant for job qualities or for behavior as there is no statistical basis for making a distinction between members of different categories. For instance, there is no evidence that hair color would make a difference in car driving or in task performance in secretary work. Blond women are still widely labeled to be clumsier, less effective and are subject to many derogating jokes (e.g., Benokraitis, 1997). Experiments demonstrate that disparagement humor leads to higher prejudice (Ford et al., 2008) and creates a normative climate of tolerance of discrimination (Meyer, 2001; Billig, 2001; Thomas and Esses, 2004; Ford and Ferguson, 2004).

It is also well known that women earn significantly less than men in many professions. Supply-side explanations of gender inequality in wages and career outcomes concentrate on women's choices, occupational preferences, lack of human capital, lower levels of job effort and career commitment (Polachek, 1981; Becker, 1985; 1991; McBrier, 2003), lower geographic mobility (McBrier, 2003), and on the risk of parental leave and shorter or interrupted work experience (cf. Albrecht et al., 1999). There is no doubt that women face greater constraints in their career related to family, marriage, and raising children (Bielby and Bielby, 1992; McBrier, 2003). There is documented evidence of discrimination, however, by employers. Employers tend to overrate men's credentials and performance and tend to underrate women's credentials and performance (Long, Allison, and McGinnis, 1993; Langton and Pfeffer, 1994; Witkowski and Leicht, 1995; Valian, 1998; McBrier, 2003).

As within-job wage discrimination has become illegal in many countries and it is relatively easy to document, it has a diminishing contribution to the gender wage gap; but allocative and valuative discrimination remain sources of wage differences (Petersen and Saporta, 2004; Bielby and Baron, 1986; McBrier, 2003). Allocative discrimination describes that women are allocated to occupations with a lower wage, and valuative discrimination covers that female dominated occupations also pay less if they require the same qualities as male dominated occupations. Women are often underrated also for their intelligence, despite most studies find no or very little difference in mean IQ scores of

men and women in the population (there is a significant difference, however, in the variation of IQ scores, which can explain statistical discrimination for jobs that require high intelligence; e.g., Baumeister, 2001). In certain cases, for example, discriminating members of lower castes or disallowing women to become priests, there is no statistical basis for discrimination, but discrimination is enforced by institutionalized traditions. There is no statistical basis and institutional enforcement, however, for instance, for the discrimination of blond women or short men (e.g., de Waal, 2005). People still act differently towards them, as if they were different with regard to their merits, skills or behavioral tendencies (e.g., Sherrow, 2006: 255). Moreover, although people are not forced or rewarded to do so, they help to maintain or even enforce prejudice and discriminative practices.

What holds for statistical discrimination, also holds in the lack of statistical differences: discriminative practice leads to suboptimal societal welfare. If different categories are judged differently, but members within a category are judged uniformly, then incentives are lost to invest in skills and other individual qualities that go beyond category averages. In the absence of efficient feedback mechanisms that would control for discriminative biases, members of the stigmatized category would only be motivated to reach the (falsely) believed average quality, which in turn would result in a self-fulfilling prophecy of differences between categories.

It is important to emphasize in advance that in this paper we will not investigate the deep socio-cognitive roots and mechanisms of discrimination that link prejudice, stereotypes and discrimination (e.g., England, 1992). We also not deal with socio-cognitive trigger mechanisms such as the black sheep effect (Marques and Paez, 1994; Barrera, 2008) or stigmatizing due to deviance (analyzed by labeling theory, see Becker, 1963; Loury, 1995), due to large perceived differences or due to heterophobia (Yzerbyt et al., 2000; Castano et al., 2002; Rydgren, 2004). Even more importantly, while we acknowledge the relevance of classical theories of ethnocentrism (Sumner, 1974[1906]; LeVine and Campbell, 1972; Brewer, 1981), of social identity and of social categorization in understanding the socio-cognitive origins of discrimination (e.g., Billig and Tajfel, 1973), our theoretical goals will be more sociological (a similar can be found in Petersen and Saporta, 2004). As implied by social identity and social categorization theories, members of one category use discrimination of members of the disadvantaged category to distinguish their category and membership in this category (Abrams and Hogg, 1990; Rabbie and Lodewijkx, 1994). In this process, in-group favoritism or more importantly, discrimination of out-group members is an integral part of social identity formation (Tajfel et al., 1971; Tajfel, 1981; 1982; Tajfel and Turner, 1979; 1986; Brewer, 1996). Different dynamics can be expected if members of the disadvantaged category would like to obey to the dominant norms and also discriminate their co-members on one hand (e.g., a mild response is to use self-effacing wit: Juni and Katz, 2001) and if all categories are driven by in-group favoritism on the other hand. The latter might have evolutionary origins as in-group members are documented to cooperate with each others while compete with out-group members in a wide range of settings (e.g., Richerson and Boyd, 2001; 2005; de Waal, 2005).

Social psychologists maintain that stereotypes are cognitive structures that are a normal part of perceptions about others, and serve as a shorthand to supplement our limited

information-processing resources (Ashmore and Del Boca, 1985; Bielby and Baron, 1986). A further cognitive constraint is that individuals have selected attention and are more likely to attend to and retain information that confirms their beliefs and to ignore information that contradicts their expectations (Hamilton, 1981). Such expectancy confirmation sequences have been predicted and demonstrated in experiments (Berger, Rosenholtz and Zelditch, 1980; Darley and Fazio, 1980).

In contrast, models in economics about statistical discrimination avoid assumptions such as prejudice. In fact, economists argue that segregations would not persist if beliefs were incorrect, since employers not sharing false beliefs would gain a competitive advantage (Arrow, 1973; Aigner and Cain, 1977). There is, however, little evidence that employers' practices reflect efficient and rational responses to differences in skills and turnover costs (Bielby and Baron, 1986).

### *Referral networks and labor market segregation*

Social identity formation, prejudice and stereotypes, intergroup rivalry and associated motives are certainly important for discrimination. Still, we set these into the background for a while and we intend to provide a sociological account of discrimination. We intend to demonstrate that structural factors and mechanisms can be responsible for the maintenance and for the breakdown of discriminative practices also in the absence of quality differences between groups and also if decision makers have no biased preferences. In particular, the key innovative aspect of this study is that it looks at the fundamental mechanisms originated in *social networks* that support or disrupt discrimination practices at hiring decisions (cf. Stovel and Fountain, 2009). Our basic idea is that discrimination can be understood as a consequence of different mechanisms in certain types of networks.

In a well documented case of job hiring, social networks, and weak ties in particular, play a very important role (Granovetter, 1973; 1974; Lin, Ensel, and Vaughn, 1981; Wegener, 1991). Social networks are important for accessing information on available jobs (Granovetter, 1974; Calvó-Armengol and Jackson, 2007), for who is getting hired and who is not (Bloch, 1994), and for what kind of conditions and salary is offered if accepted to a job (Petersen, 2009). While referrals are the sources of additional information that is difficult to be assessed otherwise (Fernandez, Castilla, and Moore, 2000; Elliott, 2001), they replace meritocratic processes in hiring and result in suboptimal allocations (Ioannides and Loury, 2004; Petersen, Saporta, and Seidel, 2000; Tassier and Menczer, 2008). The extended use of informal job search methods is believed to have a negative effect on the rate of mobility from low status to high status jobs (McBrier, 2003: 1212). If one of the groups have a better access to informal job search, then it is detrimental for the other group, as in the case of referrals from the "old boy network" in a wide range of fields (Rogers, 2000; McBrier, 2003).

When referral networks are in use and they are highly segregated, for instance, by ethnic group membership, they cause labor market segregation (Model, 1993; Tilly, 1998; Elliott, 2001). Disadvantaged groups, especially with language deficiencies, rely more likely on insider referrals than advantaged (majority) groups, which further downgrades their mobility chances (Elliott, 1999; 2001; Green, Tigges, and Diaz, 1999). Members of

a particular ethnic group in particular jobs will pass on information to and will recommend their friends with the same ethnic background. Therefore, the employment statuses of path-connected workers are correlated (Krauth, 2004; Calvó-Armengol, 2004; 2007). In case of segregated referral networks, groups with different reservation wages will receive different wages and firms can induce such segregation and discriminate between groups to increase their profit (Barr, 2009).

Micro level empirical observations document a quite extreme level of labor market segregation. Even within certain segments of the labor market there is further segmentation (Smith, 1983). Men and women in the same occupation are sorted into different organizations and segregated by job titles. One type of segregation that is observed frequently is that a given line of work is done exclusively by men in some organizational settings and by women in other. For instance, this is often the case with female waitresses and male waiters in restaurants (Bielby and Baron, 1986). In their sample, Bielby and Baron (1986) found that while all but 24 of the 290 establishments employed workers in a mixed occupation, only 144 enterprises employed both men and women. All others employed either men or women, but not both, which is also in line with the citation of Bielby and Baron (1986: 786-787) from Joan Walcott Scott about 19-century textile factories that the specific jobs done by men and women differed from mill to mill, but the separation of male and female work was almost universal. Even when men and women are not segregated occupationally, they are segregated organizationally. These forms of segregation cannot be explained by optimal choices of employers or by the voluntary choice of workers to work in segregated settings (Bielby and Baron, 1986). Bielby and Baron (1986: 781) conclude that statistical discrimination by employers has a far greater impact on segregation than labor supply constraints do.

Labor market segregation can occur also in the lack of qualitative differences between the groups. Tassier and Menczer (2008) assumed in their simulation workers without quality (which could also be looked as if they were equally qualified) and demonstrated the emergence of labor market segregation in a wide range of conditions with worker referrals. They have varied characteristics of the referral network and found that regular networks allowed for better containment of job information inside a group than random networks in a segregated population.

An interesting special case is when groups are unequal in their size. Size differences often lead to the disadvantage of the minority group. Segregated referral networks can explain how a minority group with equal or even higher qualities on average than the majority group would be subject to negative discrimination, if members of the majority group are also overrepresented among decision makers. On the other hand, it is known that minority groups tend to have less random networks than majority groups (Tassier and Menczer, 2008). Their network is more tightly knit (Portes and Sensenbrenner, 1993), which could compensate for a size disadvantage in referrals. In an agent-based study of workplace segregation that incorporates in the model an innate tendency of employers to discriminate, Abdou and Gilbert (2009) found that referral hiring might actually be beneficial for minority groups when the social network is highly segregated.

Referral networks can easily fuel self-reinforcing dynamics. Once some members of a social group are hired, they supply more and more recommendations. In a typical case

when social networks are segregated, in-group referrals will lead to a clear disadvantage of the out-group. It is also not much of a surprise that if one group occupies key decision making positions, such self-reinforcing dynamics will be triggered. For instance, because of an initial advantage, some groups could be concentrated in highly paid jobs while members of other groups are referred mainly to low-paid jobs, despite the lack of average quality differences between them. These arguments that do not assume that employers would be directly biased in favor of one of the groups lead us to formulate the following intuitive hypothesis about a possible relation between referral networks and discrimination:

Given that the social network of workers is segregated, the more important referral networks are in the hiring process, the more likely will be that individual employers stock up employees from the same group. We will refer to this objective appearance of discrimination as *micro level discrimination*. Micro level discrimination will more likely aggregate to disproportional hiring rates of the groups, which we will refer to as *discrimination at the macro level*, if one of the groups have a structurally advantageous position (e.g., they have an initial advantage in the job market). We will label this intuitive hypothesis as the “*worker referrals hypothesis*”.

#### *Information exchange among employers*

The worker referrals mechanism, but also the entire literature on referral networks is concerned primarily about referrals by workers. These recommendations, however, are not always taken seriously compared to recommendations coming *from other employers*. A survey of personnel officers found that recommendations from a manager was considered as much more important for hiring than objective signals such as high school grades (Crain, 1984; Rosenbaum et al., 1990; Spoonley, 2008: 27).

Research directions in new institutional economics (Williamson, 1975) and social network analysis (Granovetter, 1985; Uzzi, 1996; 1997) emphasize that relations between firms increase efficiency by increasing information and trust (Zucker, 1986; Rosenbaum et al., 1990; Uzzi, 1996). For employment, business contacts are important because these are sources that could judge the labor market potential of the employee properly. Although economic agents are opportunistic and therefore might give inflating recommendations in order to ruin the economic potential of their rival (Williamson, 1975; Rosenbaum et al., 1990), such opportunism cannot be expected from reliable and trustful business partners, who risk future loss of trade and collaboration by such behavior. The sources of recommendation can be judged to be reliable or not easier than worker referrals, as decision makers can take it into account if the referent is a direct competitor or partner, and can obtain available public information about the source. Employer recommendations, however, are studied surprisingly poorly in the literature, especially compared to their high relative importance in hiring decisions. Much less is known about how the structure of information exchange among employers affects labor market segregation and discrimination than about the impact of worker referrals.

It is in our major interest to find out if discriminative practices spread and are maintained via the recommendation network of employers. In the absence of perfect and complete information these network ties transmit information concerning previously employed

employees. Information exchange happens between chief executives of firms, human resource managers, public officials or academic professors during informal discussions, but also with a provision of recommendation letters. Rumor about exceptionally high performers and about absolutely unreliable workers spread quickly beyond the walls of the organization, which is a selection bias that might in itself create distortions in evaluation. Furthermore, if requested, reliable business partners often provide advice that is taken very seriously at hiring decisions. Close relations between firms make it also more likely that best employees, whose qualities could be directly observed during partnership, are tempted and seduced to start working at the partner company.

As a consequence of purposeful and unintended information exchange between employers, the typical career path of employees, in particular of best performers, is not on the „free market”, but through steps between partner companies. Without such partnerships, „treasures” of labor might get stuck at isolated firms. On the other side, employers who are central in their information networks can successfully employ a pool of workers with high quality, therefore the best workers will likely be concentrated at firms with central positions in employer networks.

Discrimination, however, is not a necessary by-product of this process as long as only information on individual qualities is exchanged. As social networks are largely segregated empirically, it follows from the worker referrals hypothesis that the stronger the role of social networks is in getting a job, the stronger the micro level discrimination and labor market segregation will be. We will conceptualize *labor market segregation* as the extent to which groups are concentrated at jobs offered by structurally related employers and excluded from jobs offered by other employers.

### *Aspiration level of employers*

If employers had low aspirations, they would easily be satisfied and likely re-hire their previous workers. Consequently, not much mobility could be expected on the labor market and choices would contain biases just by chance. Hence, we would not observe high discrimination rates at the macro level and discrimination would not change over time.

On the other hand, if employers had high aspirations, they would not be satisfied with their previous workers and would keep on searching for new workers in the hope of higher qualities. As they hired more new staff and are more desperate to hire new workers with high quality, the importance of signals and supplementary information such as group membership would become more important. Because of the larger role of supplementary information, we can expect higher discrimination rates for choosy employers who are not easily satisfied.

If group membership is taken into account immediately after the first experiences that are biased by chance in favor of one group, then search will continue only among the members of this group, which is a clear case of discrimination. Such generalizations are likely to take place as employers do not have an overview on the entire pool of available workers. If choosy employers are isolated, such random biases favor one group once and another at another time, hence the micro level discrimination will not necessarily aggregate to macro level discrimination. In short, we expect high aspiration levels of



firms to be responsible for higher micro level discrimination and labor market segregation, because for these positions, signals and supplementary information on group categories are more likely used than for mediocre jobs. We will label this intuition as the “*aspiration level*” hypothesis.

The “aspiration level” hypothesis has important implications for observed properties of the labor market and for labor market theories. For instance, it provides an explanation for the phenomenon why women are underrepresented especially in the top segment of jobs. Our explanation is alternative, or at least supplementary to the “glass ceiling” explanation.

### *The spread of group reputation*

Our goal is not simply comparing factors that contribute to discrimination at hiring decisions. We aim to compare different *mechanisms* that are responsible for discrimination. We do that in particular with reputation mechanisms.

The literature on reputation and social networks so far very much focused on *individual* reputation. Efficient *reputation* systems and image scoring help to overcome cooperation problems as this was demonstrated by a truly interdisciplinary research including sociologists, political scientists, economists, biologists, and computer scientists (Raub and Weesie, 1990; Bowles and Gintis, 1998; Nowak and Sigmund, 1998; Wedekind and Milinski, 2000; Conte and Paolucci, 2002; Boero et al. 2009). We know from this literature that certain network characteristics like structural holes are individually beneficial to achieve and maintain a good reputation (Burt, 1992; van de Bunt; Wittek, and de Klepper, 2005). It has also been shown how reputation motives can help to produce a dominance of false beliefs through a self-reinforcing process of collective belief formation (Kuran and Sunstein, 1999).

From the point of view of studying discrimination, it is more important that reputation is also formed about *groups*, mainly based on the available information about their members. In case of a hiring decision from unknown applicants, group reputation might be the sole basis of selection. As available information differs, group reputations might differ from employer to employer. Group reputations might largely be different from a statistical average and could indeed be systematically biased in favor of one of the groups.

Reputation is differentiated in the literature from image, which is a direct evaluation of others (Conte and Paolucci, 2002). Reputation is also a product of image by relevant others. Similarly, we will consider that group reputation is not acquired simply from direct experience, but it is also affected by the experience of relevant other employers.

Employers recommend individual workers to each other and exchange information about individual performances, but they cannot do this very extensively about each worker they employ. Key decision makers categorize individual employers and communicate their past employment experience, and share judgments and prejudices about group of employers. Hence, the social network of employers becomes also the channel of *spreading* group reputation. How high the reputation of a social category is for an employer depends on how high the reputation of this social category is for the friends of this employer.

When employers are isolates and base their decisions solely on their experience, decisions will very likely be biased in favor of one group or another. If employers exchange information about their individual workers, then the larger available pool of information decreases individual sampling biases. If group reputation also matters, that is when evaluation of group members of unknown quality is also based on the ongoing rumor about average group qualities, then individual sampling biases are further corrected and therefore we can expect more balanced and appropriate evaluations.

If the network structure allows for the preservation or even for the spread of initially biased group reputations, then these structural conditions characterize how discriminative practices emerge and spread in the population. For example, as there is an uneven distribution of qualities in the population, certain employers can be connected to members with lower qualities, and therefore they build up biased beliefs about this category. If these employers are in central or in broker positions, their prejudice can effectively spread and crowd out true beliefs.

One key network property that determines how quickly information reaches different parts of the network is average path length (Granovetter, 1973; Valente and Fujimoto, 2010). Social networks of employers that are characterized by long distances, clustering and low cohesion (weak interconnectedness between clusters, cf. Moody and White, 2003) are therefore natural embeddings for locally biased information. A research line concerning how unpopular norms can widely be accepted and enforced provides hints about the structural conditions of similar self-fulfilling prophecies (Heckathorn, 1990; Bikhchandani, Hirshleifer and Welch, 1992; Kuran, 1995; Binmore, 1998; Centola, Willer and Macy, 2005). This line of research finds that cascades of self-reinforcing support for highly unpopular norms cannot occur in fully connected networks, but if actors' horizons are limited to immediate network ties, unpopular norms can emerge and spread in the population (Centola, Willer and Macy, 2005).

Furthermore, we hypothesize that a highly centralized star network might be initially biased in favor of one of the groups because of the central employer, but this bias is quickly corrected, since not only the central actor influences the periphery directly (and bias their view), but also the periphery changes the view of the central employer (and correct his view). In a network with longer geodesic distances, such as in a line network, corrections take longer. But once information and reputation corrections travelled to all remote parts of the network, we should not expect any further change. In the long run, information balances and biased reputations disappear in any connected network. Hence, we expect a similar dynamic that can be observed in social influence models: if influence takes place, opinions converge and consensus is inevitable (French, 1956; De Groot, 1974; Berger, 1981).

Based on these arguments, we formulate the following “*group reputation*” hypothesis. If central and broker actors in the social network have a local information to the disadvantage of a certain category, then discriminative practices against members of this category can be experienced in a short term. In a connected network of employers, group reputation, however, will balance over time and there will be no differences in discrimination rates between different structures. The balancing process will be the longest in networks with large path lengths (for instance, in a line network).

Our long term prediction contradicts the findings of Lima, Hadzibeganovic and Stauffer (2009) and Moreira et al. (2006). These studies claim that the spread of favoritism towards similar others highly depends on the network topology and the associated heterogeneity of the population. By contrast, based on the analogy to opinion dynamics in networks we expect that employers develop a “consensus” about group reputations over time in any type of network as long as the network is a single component (cf. e.g., French, 1956). This does not exclude the possibility of discrimination, but we claim that its level will not be different by network topology as long as group reputation can efficiently travel through network ties.

The latter condition, however, is not always met. If employers do not process incoming information properly, then network properties *will* play an important role in spreading group reputation. Obstacles to the spread of true information and information distortion assist the development of local discrimination regimes. Cognitive biases of decision makers such as selective attention to top and bottom performers also make segregation of the labor market more likely. There will potentially be no discrimination at the aggregate level, but most employers still could be biased toward one or the other group, and hence there will be a high level of discrimination at the micro level and the labor market will be highly segregated.

The *group reputation* hypothesis is concerned about an ideal-typical case of perfect information dissemination. In case of high cognitive constraints on information processing, low cohesion and interconnectedness of the network of employers are expected to be responsible for variation in beliefs, which implies the stability of local discrimination regimes. This is going to be portrayed as high micro level discrimination and high labor market segregation. We will label this intuition as the “*biased reputation*” hypothesis.

### *Comparing different reputation mechanisms*

As soon as employees risk their own reputation by referrals, trustworthy recommendation systems that still favor in-group members but place top performers to top jobs could emerge. As the importance of worker referrals is higher, it will also become more likely that some referrals are not trustable as they refer to low-quality workers. If a feedback mechanism of *reputational responsibility* is present, employers can confidently rely on the referrals of their workers because there is a strong guarantee that insiders recommend high quality workers (Saloner, 1985; Fernandez, Castilla, and Moore, 2000; Elliot, 2001). Employees risk their reputation if they do otherwise and could even lose their jobs. The more their reputation is affected, the stronger will be the guarantee for reliable recommendations.

Reputational responsibility decreases the possibility of micro level discrimination and labor market segregation. The lack of reputational responsibility creates opportunities for partial referrals and is associated with higher micro level discrimination, which we will label as the “*reputational responsibility*” hypothesis.

### *Headhunters and gate-keepers of information*

So far, we have considered a labor market that is composed of a homogenous set of employers. We only allowed differences between employers with regard to their social network ties to employees and other employers. Although it is a crucial difference for acquiring information about possible employees, it does not truly reflect the large scale of heterogeneity we empirically observe in any segment of the labor market.

Keeping our model simple, we will not deal with all facets of possibly important differences, such as differences in specialization, size, turnover, internal organization, and market goals. As has been put forward, we concentrate on *structural* factors that might contribute to discrimination at hiring decisions.

One possible structural constraint is the presence of formal or informal gate-keepers who have extended information on workers and are connected to employers. Gate-keepers are powerful actors as they are brokers of information between different parts of the network (Granovetter, 1973; Burt, 1992; Valente and Fujimoto, 2010). In the labor market, gate-keepers could be headhunters, traveling salesmen, multinational companies with an exceptional overview on the various skills of the labor force at different locations, but could also be prominent actors who are central in their ethnic community. Gate-keepers spread information to employers, as employers do not have access to primary information. If gate-keepers exist on a market, then the group reputations they develop will be of crucial importance to how much discrimination can be expected. The relevance of their biased views has been demonstrated with real estate agents on the housing market (Ondrich, Ross, and Yinger, 2003; Pager and Shepherd, 2008) and with headhunters on the job market (Finlay and Coverdill, 2002).

Evidently, as long as gate-keepers simply gather and pass on information on individual qualities, and they are not biased, their presence does not imply discrimination. Problems arise if they also have limited information, and therefore rely on group reputations and act as if they would be aware of the true individual qualities of employees. In this case, the presence of gate-keepers enlarges micro level discrimination. In case of a selection bias among the relations of gate-keepers, macro level discrimination will also occur.

Prominent actors who are central in their ethnic community or group representatives play a similar role to headhunters due to the same structural reason. Assume that one representative has high qualities than another. After hiring the representatives, employers develop prejudice against members of the category with a low-quality representative and will rely on the referrals of the high-quality representative irrespective of the average qualities of the groups.

We summarize these intuitive arguments in the “*gate-keeper*” hypothesis: We expect that the presence of gate-keepers on a market leads to higher discrimination at the micro level, if gate-keepers do not simply gather and pass on information about individual qualities, but make reputational judgments about groups. In case their contacts are not a representative sample of employees, macro level discrimination occurs.

### *Schematic overview of hypotheses*

As we have discussed, discriminative practices have their roots in different mechanisms. Despite the crucial relevance of cognitive factors, in this study we concentrate on

sociological effects and try to illustrate the structural conditions that favor discriminative practices; and more importantly, the network conditions that make unbiased judgments and equal employment rates most likely. We do so by varying business network ties, referral ties, and social ties among workers. In particular, we build on the following intuitive hypotheses.

1. *Worker referrals* hypothesis: Considering a segregated social network of workers and perfectly neutral employers, the more important referral networks are in the hiring process, the more likely will the prevalence of micro level discrimination be on the market. Inequality in employment rates will also be observed if one of the groups have a structurally advantageous position.
2. *Aspiration level* hypothesis: We predict that aspiration levels of firms are responsible for higher micro level discrimination and labor market segregation, because for these positions, signals and supplementary information on group categories are more likely used than for mediocre jobs.
3. *Group reputation* hypothesis: If central actors in the social network have a local information to the disadvantage of a certain category, then discriminative practices against members of this category can be experienced in a short term. In a connected network of employers, group reputation, however, will balance over time and there will be no differences in discrimination rates between different structures. The balancing process will be the longest in networks with large path lengths.
4. *Biased reputation* hypothesis: In case of high cognitive constraints on information processing, low cohesion and interconnectedness of the network of employers are expected to imply micro level discrimination and high labor market segregation.
5. *Reputational responsibility* hypothesis: We expect that reputational responsibility decreases the possibility of micro level discrimination and labor market segregation.
6. *Gate-keeper* hypothesis: We expect that the presence of gate-keepers on a market leads to higher discrimination at the micro level, if gate-keepers do not simply gather and pass on information about individual qualities, but make reputational judgments about groups. In case their contacts are not a representative sample of employees, macro level discrimination occurs.

We will not deal with empirically relevant mechanisms and structural constraints that are self-explanatory: such as biased preferences, preferences for homogenous teams, and mechanisms that are related to social identity and intergroup rivalry. We will follow a stepwise model building strategy. We will aim to keep the model simple even after incorporating step by step the mechanisms we outlined above. Hence, we will not take further alternative explanations into account, such as socio-cognitive mechanisms related to social identity formation or to in-group cooperation. Such an unnecessary complication would not reveal the true nature and effect of mechanisms and structural constraints we are interested in. Moreover, our study will not assume the presence of a state or any external control body that could influence labor market processes. Hence, we seek solutions internal to the primary social order (cf. Coleman, 1990). In our simple agent-based model, we demonstrate how discrimination is maintained also in the lack of initial prejudice against members of certain categories. We will also explore whether worker referrals or employer referrals create more segregation and discrimination, under which conditions subtle initial differences spread and enlarged, what is the impact of key

structural parameters under different conditions, and what is the influence of changing the importance of different reputational mechanisms.

## THE MODEL

In our model, we will consider *job hiring decisions for fixed terms* on a stable labor market with a *fixed set of employers* complemented by a *fixed set of applicants (workers)*. Although job hiring is not the only terrain of discrimination, it can be characterized simpler than other areas. In particular, the hiring decision is binary and the outcome is apparent. Moreover, there is also empirical evidence that the discrimination issue is most important and probably most widespread at hiring decisions (Petersen, 2009; Lazear, 1991; Epstein, 1992). We presume, however, that most of our findings could be generalized to more complex situations, including also wage discrimination.

In practice, hiring decisions themselves could involve multiple layers of discrimination. Members of a certain category could have limited access to job information, could be hired disproportionately, or could be hired with worse conditions (Petersen, 2009). We will only concentrate on the second aspect and all jobs will be assumed to be identical.

We will consider one recognizable trait in the population of workers (e.g., gender) and two social categories of this trait (e.g., men and women) with a fixed category membership. We will present analyses for the case with equal number of workers in the two categories ( $N_1=N_2$ ). As we are only interested in the discriminative practices of employers, we will assume one-sided matching; where employers choose workers and workers automatically accept offers. We do not make any differentiation between jobs offered. This simplifying assumption is made as we are not interested in wage competition and in the behavior of the supply side of the labor market.

We will assume that workers vary in their quality, but characteristics of this variation are independent of group membership. Being more specific, we draw individual qualities from a uniform random distribution irrespective of group membership. We assume that individual qualities remain fixed and do not improve during employment. We vary *individual qualities* of workers on a single dimension on a scale of  $\{0, 1, \dots, 19\}$ . Hence, *there are no expected differences between the categories* in average qualities, in the variance of qualities, and in any characteristic of the quality distributions. Although the trait is truly irrelevant for matching, our analysis intends to demonstrate that discriminative practices can emerge and be maintained.

Individual quality information is never updated to a false score; therefore no biased evaluations are assumed. True qualities will remain known to the employer for a while after hiring (another parameter will determine how long). As a consequence, employers base their decision on information from an increasing pool until forgetting takes place. Forgetting is used also by other agent-based models with similar interests (e.g., Abdou and Gilbert, 2009). It is a necessary assumption to prevent the system from running into a market with full information, and reflects that people have limited capacities to process information (Miller, 1956; Cowan, 2001).

The goal of employers is to fill vacant positions in their firms. In each contract period (year), employers have to fill a predefined number of positions by hiring workers. For the sake of simplicity, employers fill up available positions sequentially; hence there are no complications from parallel applications. We assume that employers do not have

information about individual qualities of workers until they hire them. They can obtain, however, true information on individual qualities of previously hired workers from business contacts (employer recommendations). Business contacts will be characterized as mutual relations that are fixed over time. The number of business contacts will be determined by a density parameter.

As finding out true and perfect information about the quality of workers is highly expensive or even impossible, we assume that employers are expected to form and largely base their judgment on *reputation information about the social categories*. They make up group reputations as aggregations of individual quality information they have encountered and reputation information they receive from relevant business partners. Group reputations are therefore unique to each employer as they might be based on different experiences and different influences from others. Group reputations will be calculated as a weighted mean of individual experience (average quality of previously hired workers) and social influence from business partners (captured by a “group gossip” parameter  $g$  that is going to be manipulated). While, for instance, Cornell (1995) assumes that reputation information might be biased favoring in-group members, we do not build this strong assumption in the model as it might directly imply the expected results. We will assume that all employers are perfectly neutral and they do not belong to any of the groups. We initialize group reputation scores to be equal for every employer. We will not deal with status differences of jobs and we will not assume any primary form of prejudice that decision makers might have against members of a certain category. We will also not assume organizational attachment or any organization influences.

As the true qualities of workers are revealed in the process of employment, employers update their subjective group reputations each year. Note that all employers learn the true individual qualities from experience; hence employment always pushes the dynamics towards right judgments and away from discrimination.

We assume that there is a surplus of labor supply on the market: there are more workers than jobs in each period (the total number of jobs  $J$  exceed the total number of workers  $N_1+N_2$ ). Hence, there is unemployment on the market, and we will vary its level.

Besides business network contacts between employers and the career affiliation network that describes past employment (which is relevant as it is the basis of group reputations), we will also allow two further type of network ties: *worker referrals* and *acquaintances between employers and potential workers*.

Network ties between workers are important for hiring based on worker referrals. Employees who work already at the firm are in a position to recommend and help their unemployed friends getting a job at the same company. Note that friendship does not imply any correlation in quality. If the recommended worker turns out to be of low quality, the employer will hire somebody else and will update group reputations to the disadvantage of the category of the worker. Besides, due to the mechanism of *reputational responsibility*, we will also assume that bad referrals will also affect the employee who has provided the recommendation: in case of low-quality advice, she could also fall out of the pool of selection in the next contract period.

We will also allow acquaintances between employers and potential workers. It is important to emphasize that we will assume perfectly neutral employers who can have acquaintances from both groups with equal probability. Employer-worker ties will remain

fixed over time and as such, will be independent from work experience and worker quality. Acquaintances serve for employers as an unavoidable asset that they are obliged to use. Acquaintances receive priority, if they have not been employed before. They are re-employed if their quality exceeds the aspiration level of the employer and group reputation scores.

With regard to hiring decisions, we will make the following auxiliary assumptions. Just as in reality, we assume that employers give priority for workers whom they employed previously and have been satisfied with. We will assume that they re-hire their workers if qualities are above their aspiration level and are above group reputation scores. In this way, employers avoid unnecessary risks related to new employment. The support for incumbents is also a certain form of discrimination, but this is not the major scope of the present study.

To summarize, the hiring decisions of employers in a given contract period will be based on the following procedure. The procedure occurs in steps:

1. Employers check previous employees and re-hire them if they have a quality higher than the aspiration level and higher than group reputation scores. They will be re-hired in order of their quality.
2. If any jobs remain, acquaintances that are of unknown quality and unemployed will be picked randomly.
3. If any jobs remain, unemployed applicants recommended by business partners (employer contacts) are selected, if they have higher quality than group reputation scores and the aspiration level, in order of their quality.
4. If any jobs remain, acquaintances of business partners who are of unknown quality and unemployed will be picked randomly.
5. If any jobs remain, friends of workers who are of unknown quality and unemployed are picked a) randomly or b) in order of the quality of the referent.
6. If any jobs remain, workers who are of unknown quality and unemployed will be picked randomly from a group with higher reputation. If group reputations are equal, than a random unemployed worker with unknown quality is selected.

Note that group reputations are compared with each other only in the last step, if nothing else works to fill the job. In this way, we create fair and unbiased employers in our model, who are interested in maximizing the quality of whom they hire. All major steps can and will be switched off and on, which makes a comparison of mechanisms possible. Furthermore, the sequence of steps is going to be varied. In particular, worker referrals (step 5) will be placed in front of employer recommendations (step 3).

Although contracts are set for a fixed period and hence there is a mass supply of labor on the market at the end of each period, our simulations will not allow that a single employer could quickly grab the best available workers. Employers will be selected in a random order to fill one of their jobs offered after each other. This procedure is repeated until vacancies are available.<sup>1</sup>

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<sup>1</sup> The agent-based model has been implemented in NetLogo (Wilensky, 1999) and is freely available at the Open ABM repository.



## OPERATIONALIZATION OF KEY CONCEPTS

In practice, discrimination is often hard to document in a single hiring decision. Aggregated numbers, however, tell us, if there are clear biases in the market in favor of one of the groups. There is no easy and simple way, however, to capture all aspects of *discrimination* in a single measure. The difference in evaluation (the monetary value that the employer is willing to pay for not employing a member of a certain category) is referred to as a discrimination coefficient by Becker (1971) and Arrow (1972). Their discrimination coefficient, however, implies that employers purposefully disregard members of a certain category and they are even willing to pay for this distinction. We claim that discrimination can also occur if employers have no internal motivation to discriminate.

We do not define discrimination based on evaluative differences, but as the *outcome* of the hiring process. First, we will use a *macro level discrimination index* that describes the observed inequalities in employment. For equal group sizes and no differences in average qualities, we define a macro level *discrimination index*  $\delta$  in a given contract period as:

$$\delta = \begin{cases} 1 - \frac{H_1}{H_2} & \text{if } H_1 \leq H_2 \\ 1 - \frac{H_2}{H_1} & \text{if } H_2 < H_1 \end{cases} \quad (1)$$

where  $H_1 \leq N_1$  is the number of hired workers from category 1. The index takes the value of zero when no discrimination takes place and the value of one when all jobs are filled with workers belonging to the same category.

Note that the discrimination index  $\delta$  has the following undesired property: if unemployment is low (the total number of jobs  $J$  exceed group size  $N=N_1=N_2$ ), then the index cannot take the highest value of 1 even in the case of perfect discrimination. Hence, if  $J \geq N$ , an adjusted discrimination index  $\delta^*$  should be used that is calculated as:

$$\delta^* = \begin{cases} 1 - \frac{H_1 - (J - N)}{H_2 - (J - N)} & \text{if } H_1 \leq H_2 \\ 1 - \frac{H_2 - (J - N)}{H_1 - (J - N)} & \text{if } H_2 < H_1 \end{cases} \quad (2)$$

The discrimination indexes  $\delta$  and  $\delta^*$  provide a good summary about the presence of discrimination in favor of one of the groups at the *macro* level. Their low value, however, does not necessarily mean the lack of discrimination at the level of firms. If all employers are perfect discriminators, and it is more or less random which group they discriminate, then the  $\delta$  index will provide a low value.

For this reason, we will use a *micro* level index of *discrimination*  $\delta_i$  to measure how much discrimination takes place locally. The  $\delta_i$  index simply compares the inequalities in employment at each individual employer and takes the average of the distortions. It is calculated for each employer the same way as  $\delta$ , and then these individual scores are averaged. It takes a zero value if nobody discriminates and takes the value of 1 if

everyone discriminates perfectly one or the other groups. In case of no differences in average qualities, we define  $\delta_i$  as:

$$\delta_i = \frac{1}{n} \sum_{i=1}^n \delta_{ii} \quad (3)$$

$$\text{where } \delta_{ii} = \begin{cases} 1 - \frac{H_{i1}}{H_{i2}} & \text{if } H_{i1} \leq H_{i2} \\ 1 - \frac{H_{i2}}{H_{i1}} & \text{if } H_{i2} < H_{i1} \end{cases} \text{ for employer } i,$$

where  $H_{i1}$  is the number of hired workers by employer  $i$  from category 1 and  $n$  is the number of employers.

Note that for uneven number of jobs (e.g., if all employers have 5 vacancies)  $\delta_i$  cannot take the zero value, because one or the other group is overrepresented at each firm. For instance, in case of 5 jobs per employers, the minimum value of the index is 1/3. We will also use the *variance of discrimination*  $\text{var}(\delta_i)$  at the micro level to measure how much discrimination varies locally.

As we have discussed before, structural reasons for discrimination are often closely related to *labor market segregation*. The labor market can be segregated also if employers do not belong to the same categories as workers or they have no group markers. Such segregation occurs if employers, who are densely connected to each other, employ members of the same group, while employers that are not so well connected to this subset employ members of the other group. A labor market segregation measure can be constructed in a way that one assumes that hired workers are the properties of employers, who are nodes in a business network. Then a network segregation index that compares similarity of neighboring nodes based on this property will give a measure of labor market segregation.

In case nodes with the same properties (same proportion of hired workers from each category) are connected and nodes that are dissimilar are not connected, the labor market segregation index should give the value of one. The higher the similarity between connected nodes, the higher the labor market segregation index should be. For a random network with a random employee composition the labor market segregation index should take the value of zero. It is, however, not the minimally segregated network. When perfectly dissimilar nodes are connected and perfectly similar nodes are not connected, the index should take the value of -1.

In case all nodes have the same employment strategy, then all nodes are similar and the index is meaningful if it takes a value close to zero. This also means that absolute similarities have to be taken into account and not relative similarities. Besides, it makes sense to compare the actual number of links to the expected number of links *given the overall proportion of employment for the different groups*. This means that labor market segregation will not be high if fair employers employing equal proportions from the different groups are densely connected to each other (although this means that highly similar nodes are densely connected), as workers of one category are not *concentrated* in segments of the network. The measurement in general is difficult because we want to suppress both the information on the concentration of workers and the similarity /

dissimilarity of employers in a single number. For purely the latter we could use an index of dissimilarity: the percentage of workers that need to be reclassified into different jobs in order to equalize the distributions (Duncan and Duncan, 1955; Bielby and Baron, 1986).

A known measure of concentration is the modified version of the Gini index by Carrington and Troske (1997: 406; Abdou and Gilbert, 2009: 182). This measures the deviation of the distribution of workers from different categories inside firms from random distribution. On the other hand, this index has the disadvantage that it does not take into account the connections between the firms (employers).

Taken these constraints into account, we proceed with the logical construction of the labor market segregation index as follows. Applying the logic of the Gini index, (1) we let workers to be randomly distributed among employers and explore this distribution. (2) For a given density of employer contacts we obtain a random network that connects employers that have the properties created by the random distribution. (3) In the constructed random network, the *pairwise similarity*  $e_{ij}$  of connected nodes is calculated and averaged ( $e^*$ ). This process (1-3) is repeated in a simulation several times, which (4) will provide the expected value of average pairwise similarity  $E(e^*)$  between the connected nodes.  $E(e^*)$  characterizes the idealtypical case of zero labor market segregation in a random graph with random distribution of employment strategies. (5) For a given network and employment profile, our labor market segregation index will be computed based on the difference between the observed average pairwise similarity ( $e$ ) and the idealtypical case  $E(e^*)$ , similar to the logic of the Freeman (1978) segregation index. Note, however that the original form of the Freeman segregation index:  $S = (E(e^*) - e) / E(e^*)$  is logically not applicable, because we can have meaningful values both for  $e < E(e^*)$  and for  $e > E(e^*)$ . Our index should take the value of 1 in case of perfect similarity ( $e=1$ ), the value of zero in case of expected similarity ( $e=E(e^*)$ ), and the value of -1 in case of perfect dissimilarity ( $e=-1$ ). Therefore, we will define a *labor market segregation index*  $S^*$  as:<sup>2</sup>

$$S^* = \begin{cases} \frac{e - E(e^*)}{1 - E(e^*)} & \text{if } e \geq E(e^*) \\ \frac{E(e^*) - e}{E(e^*) + 1} & \text{if } e < E(e^*) \end{cases} \quad (4)$$

For step (3), we need to determine how we conceptualize the *pairwise similarity*  $e_{ij}$  of connected nodes  $i$  and  $j$ . Denote the proportion of workers of category 1 hired by employer  $i$  by  $p_{1i}$  and the proportion of hired workers of category 2 by  $p_{2i}=1 - p_{1i}$ . As noted earlier, we need an absolute measure rather than a relative measure. Hence, if employers are perfectly similar ( $p_{1i}=p_{1j}$ ), then  $e_{ij}=1$ . If they are perfectly dissimilar ( $p_{1i}=1$  and  $p_{1j}=0$ ), then  $e_{ij}=-1$ . If one hires from both groups equally and the other hires from category 1 only ( $p_{1i}=p_{2i}$  and  $p_{1j}=1$ ), then  $e_{ij}=0$ . We calculate  $e_{ij}$  for the simplest case of equal group sizes as:

$$e_{ij} = 1 - 2|p_{1i} - p_{1j}|. \quad (5)$$

<sup>2</sup> The code written in NetLogo by the first author to calculate  $E(e^*)$  is available on request.

When we interpret  $S^*$ , we should take the actual density of the network into account. A low or high labor market segregation means nothing when employers are relatively isolated. For this reason, we will only compare labor market segregation between business networks of the same density.

Furthermore, a segmented network with low link-connectivity does not automatically imply a high value for the labor market segregation index  $S^*$ . It could very well be that in all network segments employers are mixed in their policy, which will rightly give a low labor market segregation index. On the other hand, if there is no labor market segregation that could also mean that every employer is a perfect discriminator. Hence, the labor market segregation index should be used together with the micro level discrimination index  $\delta_i$  for an appropriate description of structural inequalities.

## RESULTS

Results will be presented in the following structure. *First*, we demonstrate that discrimination and labor market segregation prevails as emergent phenomena even if there are no average differences between worker categories and employers are only interested to hire workers of high quality, and hence they are perfectly fair. We proceed with presenting results that are not related to network structure. In particular, we find general support for the *aspiration level hypothesis*. *Second*, we examine simulation results concerning structural mechanisms and hypotheses. Although many aspects are interrelated, we will roughly follow the sequence in which intuitive hypotheses were outlined in the theoretical introduction. We will explore step by step whether our intuitions that have been articulated in the worker referrals, group reputation, biased reputation, reputational responsibility, and gate-keeper mechanisms are internally valid or not. In addition, we will elaborate on mechanisms that originate in recommendations from business partners and we will analyze if there are any interaction effects of types of network embeddedness on discrimination and labor market segregation.

### *Emergence of discrimination on an atomized labor market*

We first consider a baseline scenario, in which there are no network effects. For each isolated employer, only private experience counts. The hiring decision comes down to a re-employment of workers with whom the employer has been satisfied and to new employment that replaces others. We assume in our hiring algorithm that employers are satisfied with workers above their aspiration levels and group reputation scores. The latter is assumed because rational employers would rather choose a random new worker with an unknown quality from a group for which she believes the average quality is higher than that of her current employee. In case of isolated employers, group reputation is based purely on own experience.

No discrimination or segregation is expected to take place in this atomized world. Still, employers hire members of one group only. That is, most employers are *perfect*

*discriminators*. Even more surprisingly, one can observe a fairly large disadvantage to one of the groups.

We immediately have two important emergent results. First, the emergence of high level of micro level discrimination and second, an unexpected consequence of macro level discrimination. For the latter, we have to note that with perfectly discriminating employers, the expected value of discrimination index  $\delta$  will be significantly different from 0. Consider that in the lack of any prejudices and initial differences, each employer randomly discriminates one of the groups. Consider an example with 10 employers each offering 5 jobs. There is no discrimination at all only in approximately quarter ( $\frac{10!}{5!5!}$ ) of the cases (Table 1). From the known properties of the binomial distribution, if all employers are perfect discriminators, the expected value of discrimination index can be derived.

Number of employers	probability	$\delta$
5+5	0.246	0
6+4	0.205*2	0.3333
7+3	0.1171*2	0.5714
8+2	0.0439*2	0.75
9+1	0.0097*2	0.8888
10+0	0.0009*2	1
Total	1	0.35535

Table 1. The expected level of discrimination index  $\delta$  in case of perfectly discriminating employers ( $n=10, J=50$ ) in an atomized market

More interesting question is that why do employers typically hire one type of workers only? Tables 2 and 3 represent two randomly generated examples of the hiring process by isolated employers. The first employer quickly becomes a perfect discriminator; the second employer also discriminates to a large extent. None of them have, however, an intention to discriminate. Note that group reputations are higher than average group qualities because only the best employees are kept in house (and other relations are forgotten).

Figure 1 provides a closer look at the micro process of development of perfect discrimination. We display expected distributions of hired workers on the quality scale in the simplest case of zero memory and isolation of the employer. Zero memory means that the employer can re-hire those who were employed in the current contract period, but does not recall any qualities from before.

In the first contract term, the expected distributions of qualities do not differ largely, because there are no differences between the groups. A subtle difference, however, will normally occur due to random sampling. This subtle difference will result in higher reputations for Group 1 and in the employment of two new workers from Group 1. The expected average quality of these new workers, however, will be below the average quality of workers from Group 2 who were kept in house in the second year. Hence, the reputation score of Group 2 will be higher and will result in the hiring of four new employees from Group 2. Yet again, the average quality of the new workers will be

below the reputation of Group 1, and therefore Year 4 will be characterized by another change of fortune. By the time of the fifth contract term, employees are selected from one of the groups, only. This is once more counterbalanced in Year 6, but there is no way back from perfect discrimination and a solidified difference in group reputations from Year 7 onward.

Year	1	2	3	4	5	6	7	8	9	10
Group 1	19	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>
	15	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	14	<i>17</i>	<i>17</i>
		<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	10	<i>17</i>	<i>17</i>
		1	<i>15</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	6	<i>17</i>	<i>17</i>
		0	<i>17</i>	<i>15</i>	<i>15</i>	<i>15</i>	<i>15</i>	6	<i>15</i>	<i>15</i>
Group 1 reputation	17	11.5	12.3	12.3	12.3	12.3	17	13.4	13.4	13.4
Group 2	14									
	12									
	7									
Group 2 reputation	11	11	11	11	11	11	11	11	11	11

Table 2: Qualities of hired workers over time by one employer in a random process  
*Note:* Re-employments are denoted by italics. Medium or low aspiration levels are assumed and a memory of 5 contract terms (years).

Year	1	2	3	4	5	6	7	8	9	10
Group 1	17	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>
	14	<i>14</i>	<i>14</i>	<i>14</i>	<i>14</i>	<i>14</i>	<i>14</i>	7		
	12	6								
	10	5								
		2								
Group 1 reputation	13.3	9.4	9.4	9.4	9.4	8.8	15.5	12.7	12.7	12.7
Group 2	12		<i>17</i>	<i>17</i>	<i>18</i>	<i>18</i>	<i>18</i>	<i>18</i>	<i>18</i>	<i>18</i>
			<i>10</i>	<i>12</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>	<i>17</i>
			4	18	17	17	17	17	17	17
									6	13
Group 2 reputation	12	12	10.8	12.2	13	13	13	16	14.5	14.2

Table 3: Qualities of hired workers over time by one employer in a random process  
*Note:* Re-employments are denoted by italics. Medium or low aspiration levels are assumed and a memory of 5 contract terms (years).

Hence, after quick switches in groups' fortunes, one group gains an overall dominance at the employer, which remains stable over time. Note that this is the *expected* sequence of employment and observed patterns will deviate from this expectations. The emergence of micro level discrimination due to the statistical sampling biases can occur even earlier.

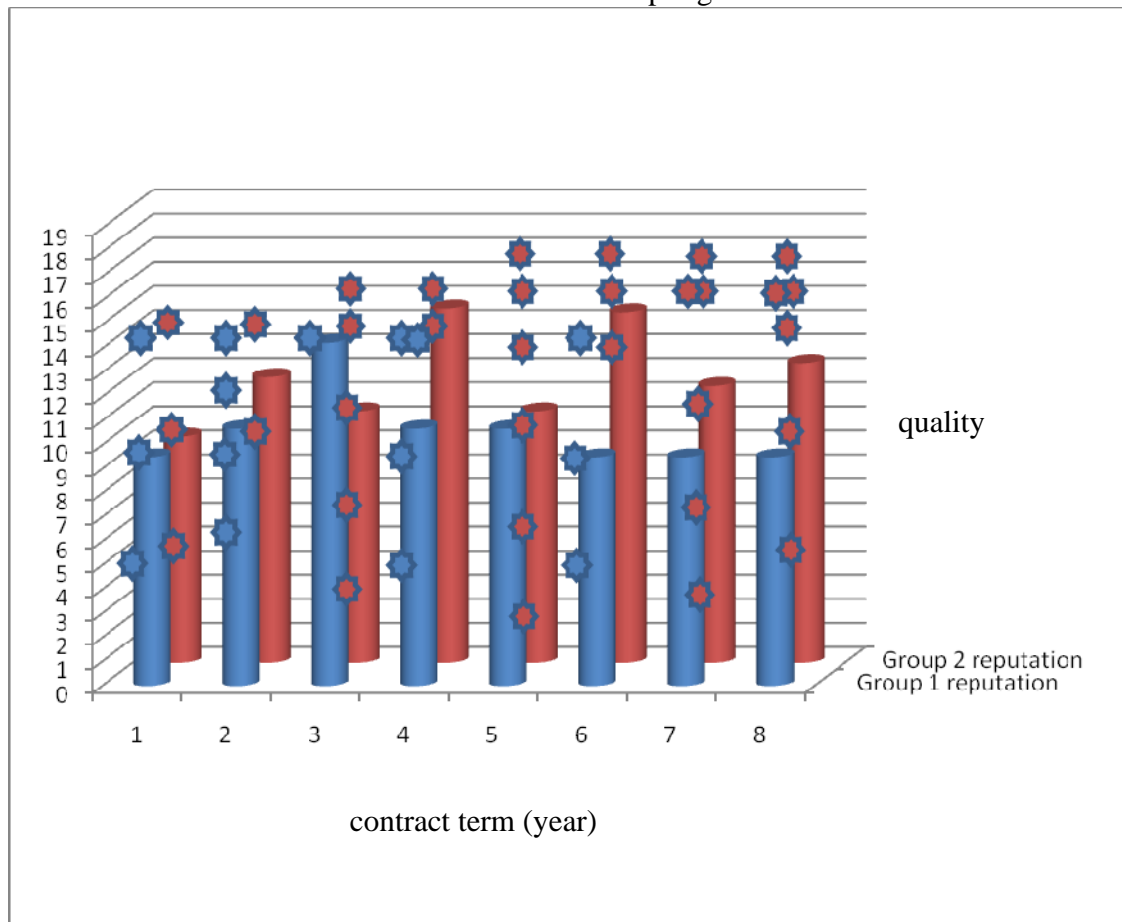


Figure 1. Expected composition of workers at a firm with zero memory and 6 jobs.  
*Note:* Colored bars indicate group reputations. Star symbols represent expected qualities of workers drawn from a random uniform distribution.

### *High desires – higher discrimination*

After demonstrating that discrimination can emerge in the lack of average quality differences between groups among perfectly neutral employers, we now turn to the results of our agent based simulations to test under which aspiration levels of employers will discrimination be the highest. In practice, high aspirations can originate in higher expectations about general quality of the labor force, but also from a demanding task and high wages. High aspiration levels are typical for high status jobs and for jobs where specialized knowledge or advanced skills are required.

Our simulation results justify the validity of our intuitive arguments and provide support for the aspiration level hypothesis. Aspiration levels have a strongly pronounced effect on discrimination. Higher aspiration levels lead to higher discrimination not only at the micro, but also at the macro level (Figure 2). On one hand, there are no differences

between discrimination rates if low or medium aspiration levels are assumed. On the other hand, discrimination rates increase for high aspiration levels exponentially. This is a robust result across a wide range of parameter values.

When we introduce heterogeneity in aspiration levels among employers, then we observe higher discrimination than if all aspiration levels are set to a mean value. The reason is because there are agents with high aspiration level who push the index higher, while agents with zero aspiration level are not different from employers with a medium level of aspiration.

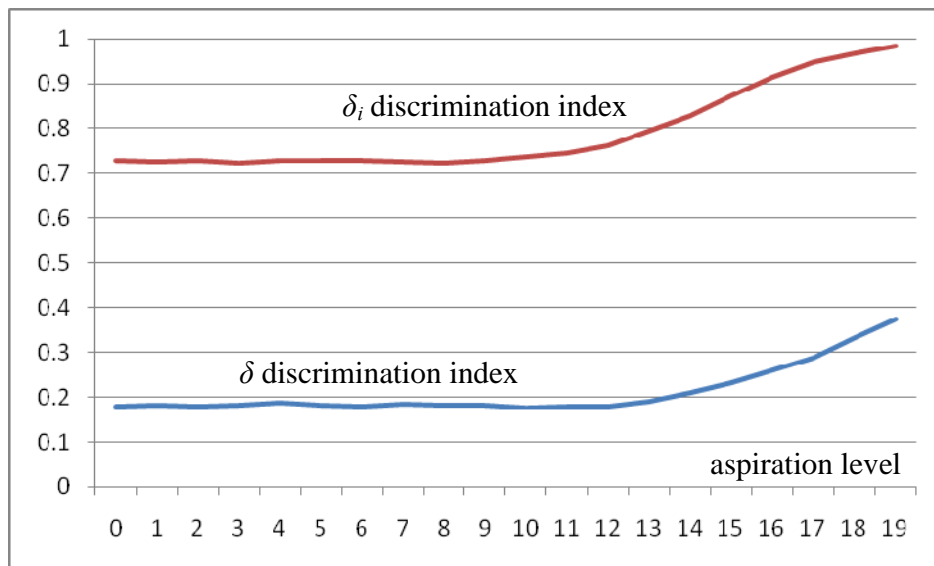


Figure 2. Average values of the  $\delta$  discrimination index (below) and average values of the micro level  $\delta_i$  discrimination index (above) across 1300 runs for each aspiration value (100 runs for each parameter combination), 26000 runs in total, averaged for different aspiration levels.

Notes: 15 employers, 6 jobs per employer, 200 workers, no business contacts, {1; 2; 3; 4; 5; 6; 7; 8; 10; 15; 20; 25; 30} years of memory, 100 years per run.  
[memoryaspiration3]<sup>3</sup>

Year	1	2	3	4	5	6	7	8	9	10
Group 1	10									

Group 1	10	10	10	10	10	10	10	10	10	10
---------	----	----	----	----	----	----	----	----	----	----

<sup>3</sup> To avoid mistakes simulation studies often suffer from, we have run millions of simulations across the parameter space. Simulation scenarios were in particular designed to test our main hypotheses, but also to justify lower level statements and to provide extensive robustness control. We have generated several simulation datasets each containing of a couple of ten thousands of simulation runs. Names in [ ] brackets refer to simulation datasets that were targeted to test the particular hypothesis or statement and are available by request from the authors. The full model will be available on the Open ABM repository at <http://www.openabm.org/node/6>.



reputation										
Group 2	19	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>
	17	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>
	15	13	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>	<i>19</i>
	10	6	17	17	18	18	18	18	18	18
		4	12	8	11	3	17	7	16	13
Group 2	15.3	12.9	13.7	13.5	13.7	12.8	14.5	13.8	14.3	14.6
reputation										

Table 4: Qualities of hired workers over time by one employer in a random process  
*Note:* Re-employments are denoted by italics. High aspiration level (18) is assumed and a memory of 5 contract terms (years).

The strong effect of aspirations can be explained as follows. The expectation is that all first employees will be unsatisfactory. Search goes on with changing fortunes until somebody is found with very high quality. This worker will be employed forever and will continue to bias group reputation scores in one direction, making it more likely that the next employee with exceptional qualities will also come from the same group. An example of the dynamic hiring process is displayed for an isolated employer in Table 4, where new workers have random qualities.

*Control variables: the level of unemployment, memory, and time horizon*

Before turning to our structural hypotheses, we explore the effect of control variables. We do this first because we would like to know in advance whether we can fix the values of these variables in later simulations when testing our main structural hypotheses. We find that for a fixed number of employers and jobs, a larger labor supply (higher unemployment, increasing competition for jobs) increases the discrimination index  $\delta$  [nworkerstofill2, nworkerstofill3, shortruns]. This result, however, is simply due to the calculation with  $\delta$ , instead of the adjusted discrimination index  $\delta^*$  in the range of  $J \geq N$ . With the use of the adjusted measure, there is no increasing effect of unemployment [nworkerstofill3]. The unadjusted discrimination index and the micro level discrimination index have low values for small unemployment, simply because almost everyone is employed, hence there are no differences in the employment rates.

Other important auxiliary parameters we need to explore concern time. It might be crucial for discrimination if employers remember for a long time a large set of individual qualities. Good memories intuitively would lead to lower discrimination. This can be expected as with longer memories, employers keep track of a larger sample of workers' quality. Hence, their estimation of the average quality of the two categories would become closer to reality, in which no average difference exists between the two groups. The results on Figure 3 and runs for other parameter combinations [densitymemory] demonstrate that there is a problem with this intuitive argument. There is no gradual effect of memory length on discrimination. There is a difference between no memory and a short term memory (the latter decreasing discrimination), but there is no significant improvement by having a long term memory.

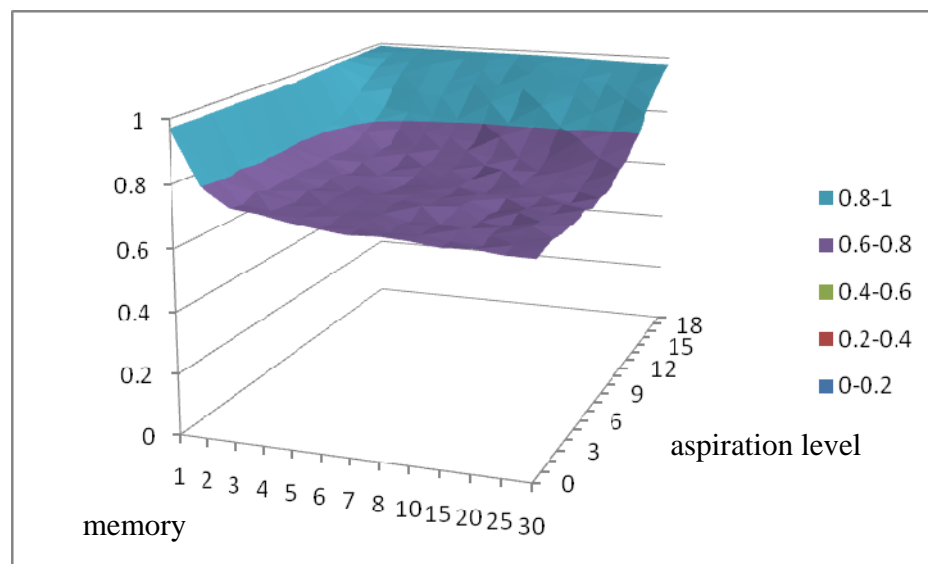
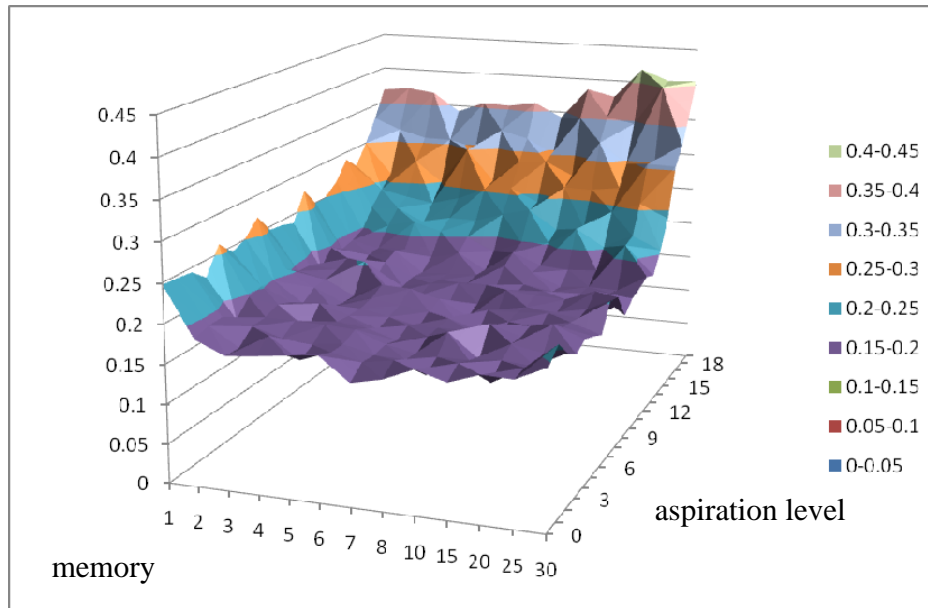


Figure 3. Average values of the  $\delta$  discrimination index (above) and the  $\delta_i$  discrimination index (below) across 100 runs for each parameter combination (26000 in total), averaged for different memory length (X axis) and aspiration levels (Y axis).

Notes: 15 employers, 6 jobs per employer, 200 workers, no business contacts, 100 years per run. [memoryaspiration3]

Similarly, one could expect that if we take a sufficiently long time perspective, individual employers might correct for their initial prejudices and biased experiences. The intuitive argument that individual employers correct for their false initial beliefs in the long run proves to be wrong (Figure 4). The micro level discrimination gradually increases over time for all memory levels [timeaspiration2] and for all aspiration levels [timeaspiration]. In the long run, all employers become perfect discriminators ( $\delta_i=1$ ).

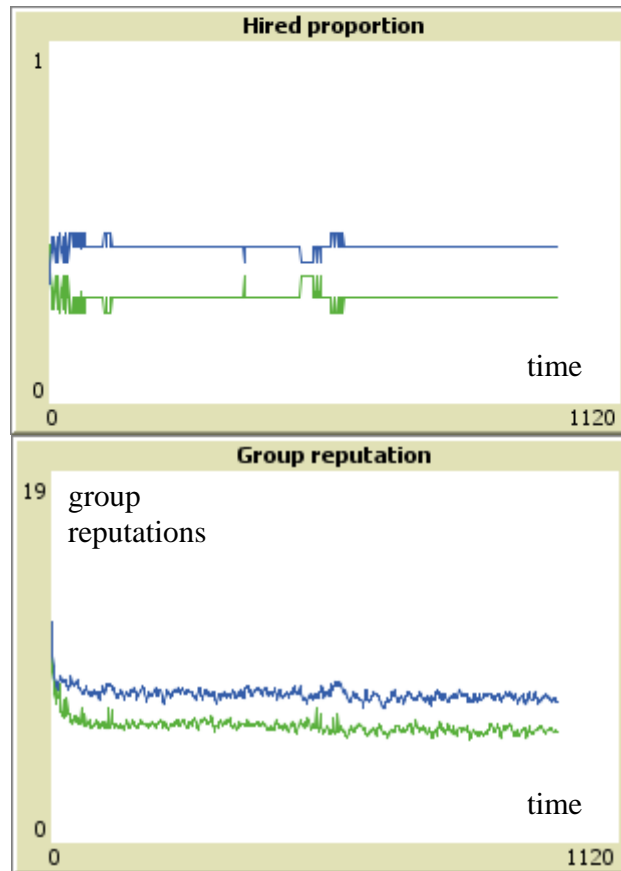


Figure 4. Hired proportions and average group reputations in a typical run over time.  
*Notes:* 15 employers, 5 jobs per employer, 200 workers, no business contacts, aspiration level of 19. [last run of timeaspiration]

Many studies on discrimination claim that structural opportunities at the start of the career are detrimental for later chances at the labor market. For instance, the disadvantage of women at the labor market is explained partly by their disadvantageous positions at the first entry to the labor market (McBrier, 2003). Women are more likely to be allocated to secondary jobs within professions (e.g., Rosenblum and Rosenblum, 1990). These jobs are characterized by limited opportunities (for both men and women) for upward mobility (Rosenfeld and Sørensen, 1979; McBrier, 2003).

Theoretical studies have also claimed that subtle initial differences or positional advantages are enlarged during the self-organizing dynamics and employment prospects of the groups will be persistently different (Calvó-Armengol and Jackson, 2004; 2007). For this reason, we have carefully checked the evolution of discrimination and labor market segregation over time. Besides, we have saved data from the first contract year and correlated them with later outcomes.

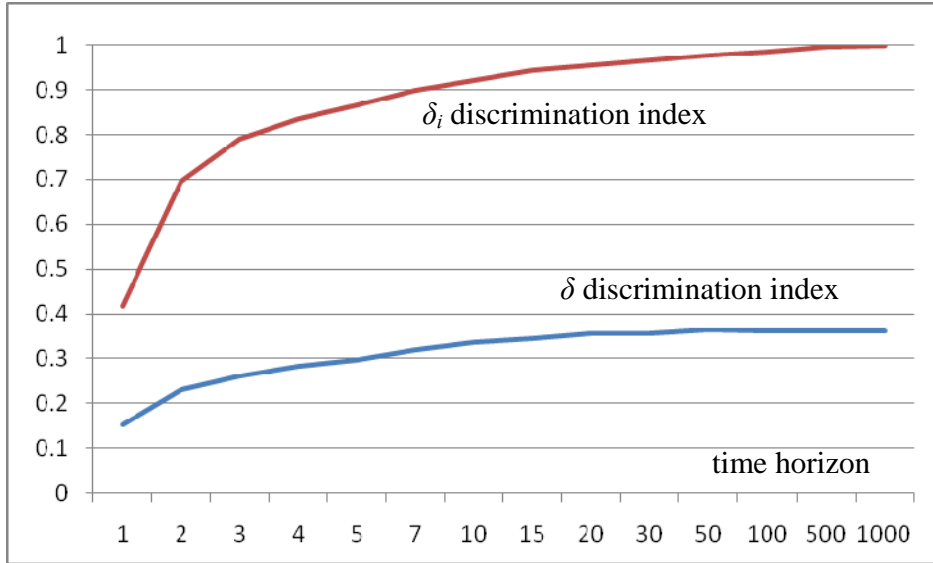


Figure 5. Average values of the  $\delta$  discrimination index (below) and average values of the micro level  $\delta_i$  discrimination index (above) across 1000 runs for each time horizon (X axis); 14000 runs in total.

*Notes:* 15 employers, 6 jobs per employer, 200 workers, no business contacts, maximum aspiration level (19), no worker referrals, {1; 2; 3; 4; 5; 6; 8; 10; 15; 20} years of memory. [timeaspiration2]

Results show that surprisingly, the initial discrimination index is basically independent of the final discrimination indexes [memoryaspiration3]. The initial index value does increase discrimination rates only for the short term (where the initial values have a significant weight in the average calculations) [butterfly2].

### *Social ties between employers and workers*

In the following step, we extend the baseline model by introducing social ties between employers and workers. We assume that employers give priority for known workers, but they do not re-hire them if their quality turns out to be low. We focus on enigmatic cases and we do not assume *any bias* in favor of any of the groups among the social ties. We assume that employers have the same probability to have a link to all workers in Group 1 and in Group 2. Note that this is a much more idealistic scenario than what the real world shows. We explore primarily how the extent to which employers rely on contacts to workers affects discrimination in this idealistic world. Hence, the key parameter we modify is *contact* between employers and workers, which we will operationalize as the density of the bipartite network).

Our simulation results show that hiring via social contacts between employers and workers surprisingly help to *diminish* discrimination (Figure 6). The more contacts employees have to employers and the more they rely on hiring via their social networks, the smaller the discrimination index is. The effect of density of the referral network is strongest for high aspiration levels.

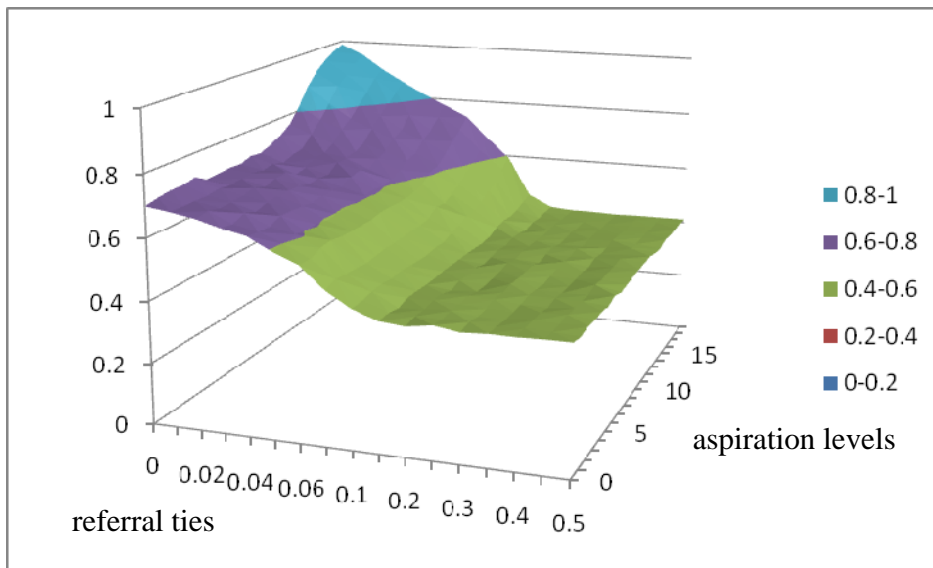
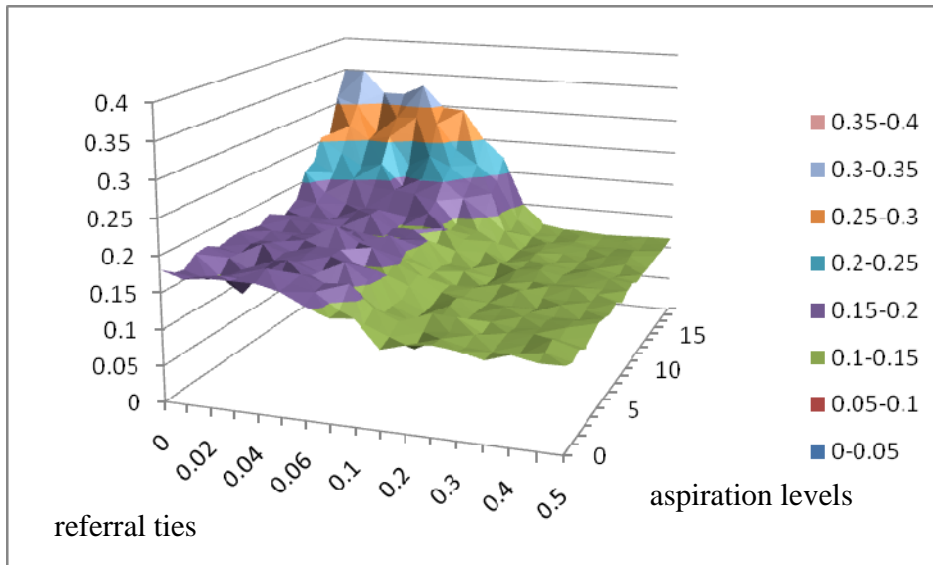


Figure 6. Average values of the of the  $\delta$  discrimination index (above) and of the  $\delta_i$  micro level discrimination index (below) across 100 runs for each parameter combination (34000 in total), averaged for the density of the bipartite referral network (X axis) and for different aspiration levels (Y axis).

*Notes:* 15 employers, 6 jobs per employer, 200 workers, no business contacts, 5 years of memory, no social ties among workers, 100 years per run. [acrossesrerun4]

Aspiration levels have the strongest effect on discrimination if there are only few social ties between employers and workers. The strong effect disappears completely if employers have an extended social network with workers (Figure 6). In the latter case,

employers hire new workers from their contacts and not from the market; hence their aspirations and group reputations become irrelevant for employment.

Without the use of social contacts, individual employers are strong discriminators. When they rely on an extended and unbiased social network, they are perfectly fair (Figure 6). In the latter case, they try out applicants from their large social network. This pool is large enough to find a sufficient amount of workers with the required skills. In short, social networks between employers and employees reduce information asymmetry, and as a consequence, also reduce discrimination.

### *Worker referrals*

Our intuitive hypothesis stated that if referral networks play an important role in job hiring, then segregated (and dense) social networks would lead to more discrimination at the micro level. To test this intuitive hypothesis, we have incorporated our model social network relations among workers. Employers, who previously hired a worker, could also select from the friends of this worker as a result of a referral mechanism. In the simulations reported here, we have implemented reputational responsibility in an extreme form: workers who recommended their friends with a quality lower than the aspiration level of the employer were deleted from the professional contacts of the employers (hence could not be re-hired directly). Note that later on, as a test of our intuitive reputational responsibility hypotheses, we compared this scenario with identical runs without reputational responsibility.

Furthermore, we assumed that social network relations among workers are segregated by group membership. As long as the required density allowed, the segregated social network among workers contained two components with an equal size. Within each component, ties were drawn randomly and with equal probability between each pair of workers.

Results show a qualitative difference between the situation in which the social network of workers is effective for referrals and in which they do not exist (left side of Figure 7). Discrimination quickly drops in the presence of worker referrals. For a given aspiration level, a further increase in the number of contacts between employers and workers has no further effect on discrimination.

For all densities of the social network of workers, the density of the bipartite referral ties to employers has *a strong effect* on discrimination. The denser the network, the lower the discrimination is. The strong effect in the macro level index is caused by the decreasing level of discrimination at the micro level (see bottom of Figure 7). In the absence of referral ties between employers and workers, under the depicted parameter values, there is almost perfect micro level discrimination, which is decreased to a fair level thanks to the worker referrals.

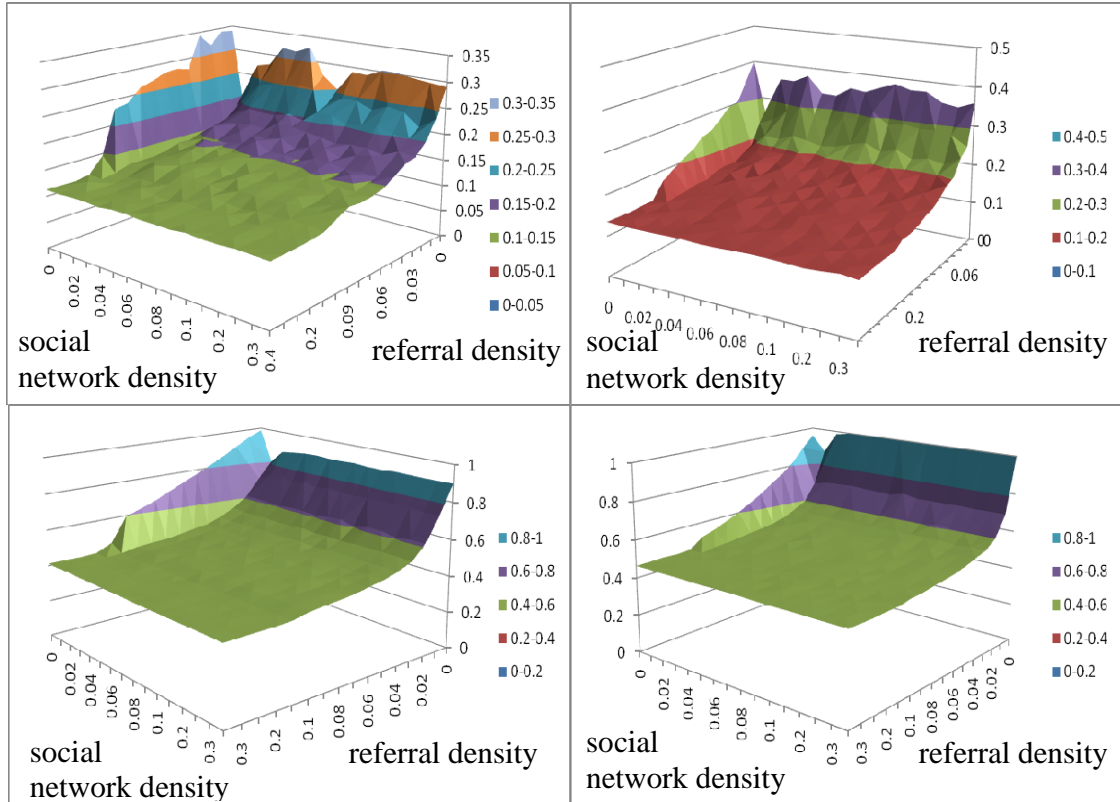


Figure 7. Average values of the  $\delta$  discrimination index (above) and of the  $\delta_i$  micro level discrimination index (below) across 100 runs for each parameter combination (51200 in total), averaged for the density of social networks among workers and for the density of the bipartite referral network between employers and workers without (left) and with (right) business connections.

*Notes:* 15 employers, 6 jobs per employer (left) and 5 jobs per employer (right), 200 workers, maximum aspiration level (19), no business contacts (left) and random business network with a density of 0.1333 (right), 5 years of memory, 100 years per run.  
[referralacrosses3, referralacrosses2]

There is a surprising interaction effect of worker social networks and aspiration levels. In the presence of worker ties that are used for recommendations, the aspiration level of employers becomes unimportant. Aspiration levels had a major impact on discrimination rates both at the micro and at the macro level in the absence of social network ties among workers. This effect, however, is completely extinguished if at least some workers can recommend others. Moreover, it does not matter, how dense the network among workers is, and how dense the referrals between employers and workers are. If they both exist (Figure 8 depicts an example with just a couple of referrals), the effect of aspiration levels disappears.

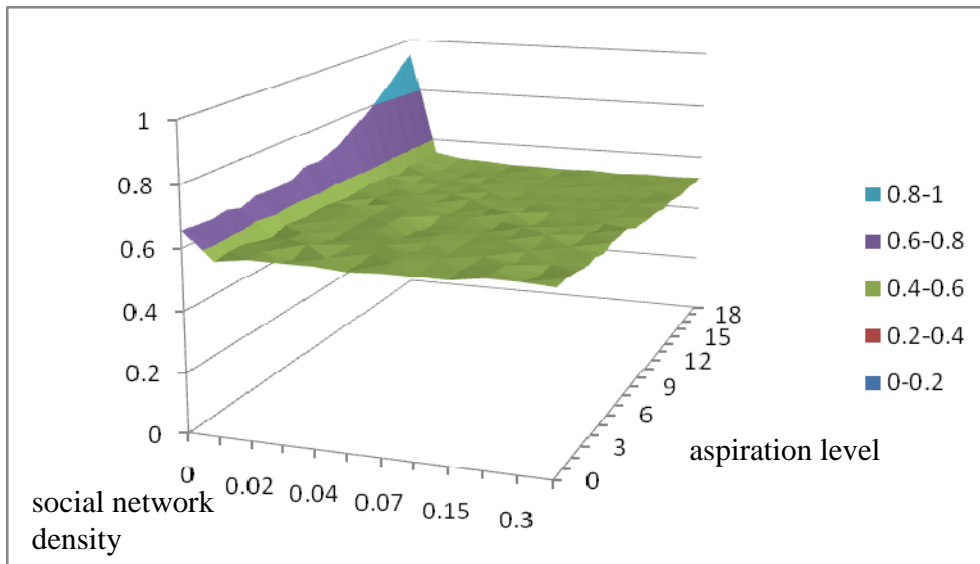
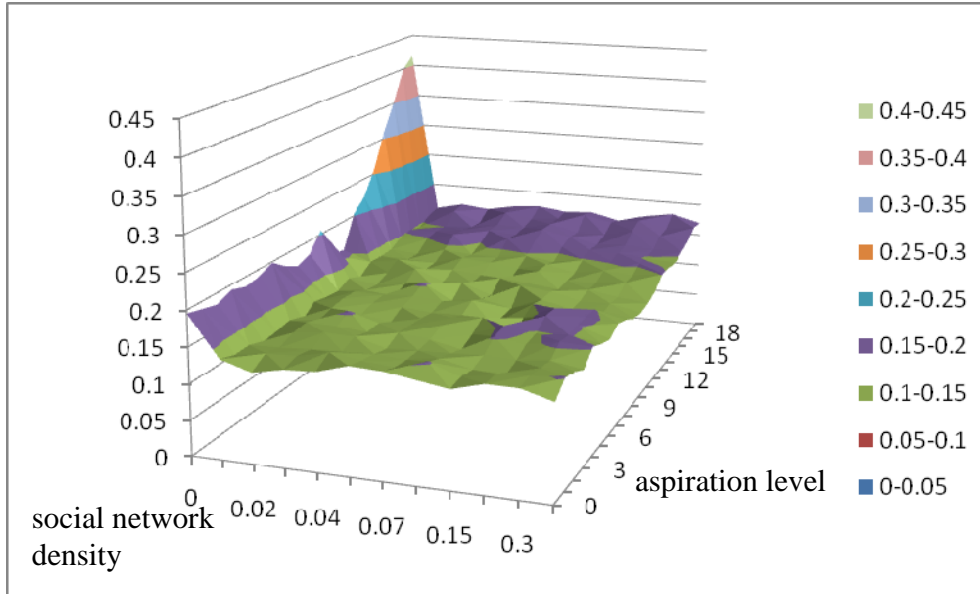


Figure 8. Average values of the  $\delta$  discrimination index (above) and of the  $\delta_i$  micro level discrimination index (below) across 100 runs for each parameter combination (24000 in total), averaged for the density of social networks among workers and for different aspiration levels among employers.

*Notes:* 15 employers, 6 jobs per employer, 200 workers, no business contacts, 30 years of memory, a random bipartite network between employers and workers with a density of 0.03, 100 years per run. [referralaspiration2]

*Network density of business contacts*



Let us now consider network ties among employers that are channels of transmitting information on worker qualities. As discussed earlier, we assume that employers are able to select from the employee pool of their direct business contacts. Hence, the density and structure of business contacts might be important for the level of discrimination experienced on the market. We manipulate density first.

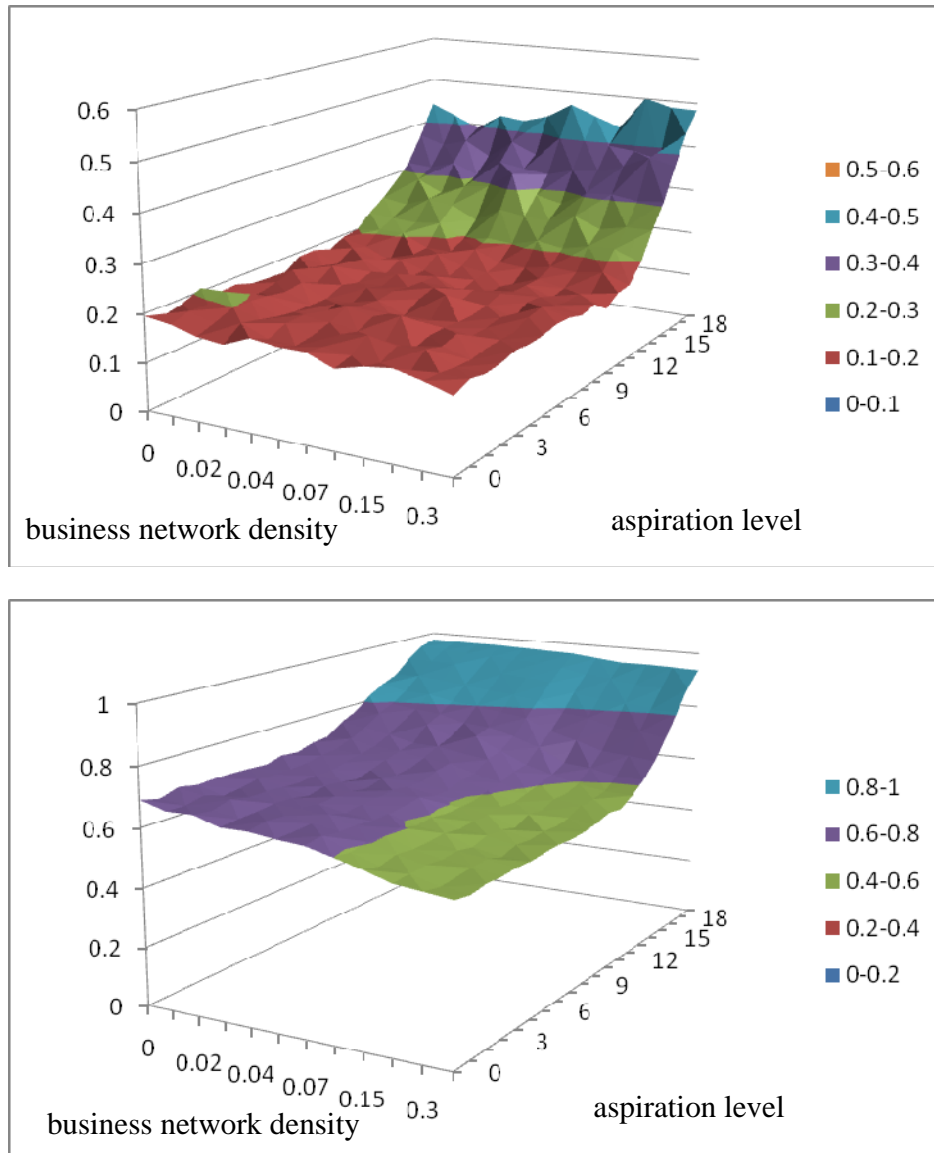


Figure 9. Average values of the of the  $\delta$  discrimination index (above) and of the  $\delta_i$  micro level discrimination index (below) across 100 runs for each parameter combination (24000 in total), averaged for the density of business networks among employers and for different aspiration levels.

*Notes:* 15 employers, 6 jobs per employer, 200 workers, random business network, no ties between employers and workers, 30 years of memory, 100 years per run.  
[densityaspiration100rerun]

We find again that for a wide range of parameter values, and in case of high aspiration levels in particular, employers are strong discriminators. As Figure 9 shows, business contact networks *decrease* discrimination at the micro level to a moderate extent. Small differences in the micro level discrimination index by the density of business contacts does not aggregate into differences in the macro level discrimination index. The effect of business networks is weak when compared to the major impact of aspiration levels [densityaspirationrerun4, densityaspirationrerun5] and worker referrals.

Business network density has a slight but robust positive impact on the macro level discrimination index for the highest aspiration level. This interaction effect has been reproduced also in simulations with a longer time horizon [densityaspiration100rerun, densityaspiration1000rerun]. It is an interesting result, because the individual discrimination index decreases by business network density also for the highest aspiration level.

### *The structure of business networks*

One of our intuitive hypotheses put forth a crucial role of central and broker actors in the business network for discrimination. We argued that central actors can rapidly create uniform beliefs in the business network. If these key actors have biased beliefs, then discrimination could spread easily. On the other hand, if central or broker actors in a business network are perfectly just, fair treatment is efficiently spread among employers. We also predicted that separate components and low cohesion of the business network would allow for the development of local regimes and labor market segregation, with a larger potential that local regimes will be different. Isolation (separate components) is expected to favor micro level discrimination, while other network properties could be relatively unimportant in a small network where information spreads quickly. The intuition that a business network with separate components will be largely different could be deduced from taking an analogy from social influence models (French, 1956; De Groot, 1974; Berger, 1981): consensual views could develop independently from each other in different components of the network.

In a small network, centralization could become unimportant as the central actor quickly obtains an overview on the entire labor market and rapidly corrects for initial biases. Hence, the biased initial judgment will not derail equal opportunities. Rapid feedback to the central actor can speed up the balancing of beliefs and fair treatment could evolve more rapidly in a centralized network than in a regular or a random network.

In our simulations, we have tested our intuitive arguments on centralization. We altered the structural properties of the business network to show how much harm centralized and segmented structures can make in the spread of biased beliefs. We have constructed different business network structures. *Star networks* were included as extreme cases of high centralization. In a star network, the first  $n-1$  links were drawn to the same employer (this corresponds to the density level we will compare in our presented analysis). When exploring cases of higher density, we added additional business ties randomly. *Regular networks* were included as extreme cases of low centralization. In a regular network, the first  $n-1$  ties were drawn to create a “line” network between the employers. If necessary, next links connected employers at a distance of 2 in a circle, then at a distance of 3, etc.

In the *2 segments network*, two components of equal size were created with an equal probability of all possible ties within the segments. That is, the components themselves were random networks. Similarly, in the network labeled as *regular components*, we created two separate components, but with a regular structure internally (e.g., a line and a circle for  $n-1$  links).

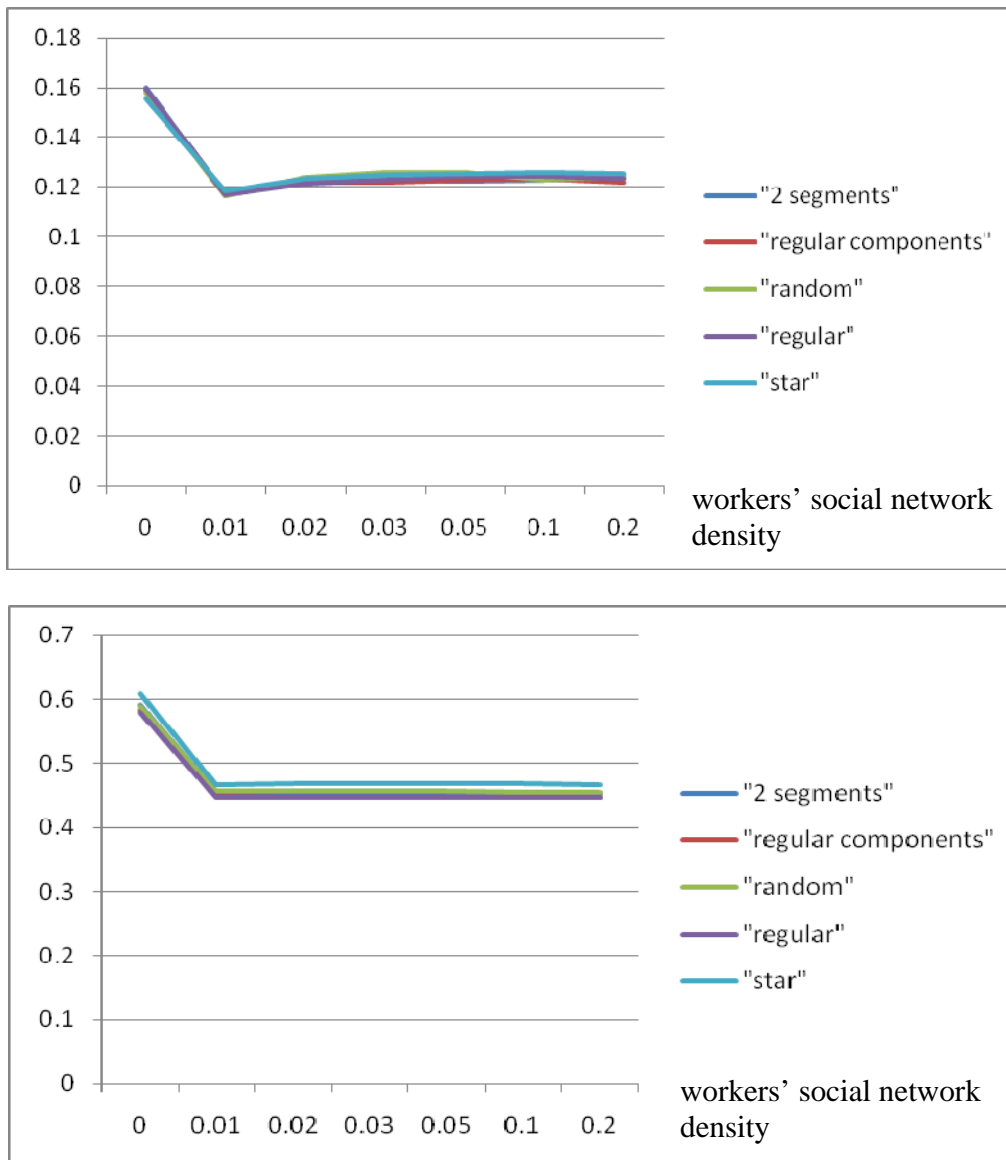


Figure 10. Average values of the  $\delta$  discrimination index (above) and the  $\delta_i$  discrimination index (below) across 100 runs for each parameter combination (126000 in total), for different social network density of workers (X axis) in different type of business networks.

Notes: 15 employers, 10 jobs per employer, 320 workers, a density of 0.133 for the business network, a 0.03 density of ties between employers and workers, 5 years of

memory, a time horizon of 100 years, 100 runs for each possible integer aspiration level. [shortsegregation2, shortsegregationcircle].

Our striking result is that there is *no difference* in the discrimination rate between network types for any aspiration level and for any density of worker networks [shortsegregation4]. Not only networks that are single components have the same discrimination rate, but segmented structures (*2 segments* and *regular components*) are also not different with regard to discrimination from other networks (Figure 10). The lack of business network effects is confirmed in the presence and in the absence of referral contacts between employers and workers. While the density of employee-employer networks has an impact on discrimination, the type of the network of employers does not. Furthermore, contrary to our expectations, our simulations did not show qualitatively different results for the medium and for the long run [shortsegregation3]. Ultimately, the speed of convergence also did not differ between different business network types as discrimination rates were not different between business network types at any point of the dynamics [shortruns, shortaspiration]. There were also no differences in path dependence for any parameter combination. That is, the initial discrimination rate in a star network was not a better or worse predictor of the final discrimination index than in other type of network.

The first thing we should note that discrimination rates in the presence of business networks, employer-worker contacts *and* worker social networks are low, which is a reason for the lack of differences between business network types in itself. In the lack of worker referrals, however, discrimination rates are higher, but still there is no difference between different business network structures [densityaspiration100rerun2]. Our intuitive analogy to social influence models failed mainly because we cannot talk about *convergence* in group reputations among connected business partners. Individual experiences develop more independently than expected from the discriminations of business partners. If worker referrals are present and discrimination is low, individual fluctuations in the composition of hired workers are high. Pairwise similarity of hiring choices between business partners remains at a medium level. The choices of business partners are not independent; they are correlated always positively, but not strongly. In the lack of worker referrals, individual experiences drive more strongly towards perfect micro level discrimination. Micro level discrimination that in case of isolated employers switched in favor of one or the other group and then stabilized (Figure 1) is now subject to some influence from business partners. The result is that the same employer can switch from strong discrimination of one group to strong discrimination of the other. Furthermore, in the lack of referral networks and exchange of group reputations, pairwise similarity in all types of business networks drops to a value close to zero (and turns sometimes negative), which indicates that simply by merging available information on workers will not necessarily lead to correlated choices of employers.

We must therefore conclude that for a given density, with or without worker referrals, network centralization and segmentation of business contacts *do not make any difference* for discrimination. To test this conclusion more thoroughly, we have designed other types of business contact structures, including cohesive blocks, segmented blocks connected with a single bridge, and regular networks with some imperfections [circlematrixtable].

For a given density of  $n-1$ , we have not found notable differences in the discrimination measure  $\delta$ .

There are no differences between business networks also for larger networks ( $n=150$ ), for any aspiration level [shortrunlargemarket]. There is also no difference in the discrimination index between business network types under any levels of unemployment [networktype2, butterfly]. In short, it is a very robust result that network forms of employers *do not affect discrimination*.

If not in absolute values, we have at least expected a difference in the *variance of the discrimination* measure between business network types. We expected that the star network would have much higher variance than other networks, as the central actor with true beliefs efficiently spreads just treatment of the groups, while a central actor with false beliefs could contribute to large levels of discrimination.

This intuitive expectation has also been refuted. The discrimination index has the same variance in all type of business networks (the population standard deviation is close to 0.05 under the parameter conditions in Figure 10). Just like the value of the index, the variance of discrimination is stable for different densities of workers' social network, and it is only higher in the lack of such networks (but there is still no difference between business network types). The variance of discrimination index is not different by business network types at any aspiration level [shortsegregation2, shortsegregation3].

### *Network types and labor market segregation*

In addition to our paradoxical finding about the lack of business structure effects on discrimination, we have explored the effect of business network types on *labor market segregation*. Results contradict intuitions again as differences in  $S^*$  are very small and are not in the predicted direction (Figure 11). Based on intuition, we have expected the highest values of the index for segmented networks (*2 segments, regular components*). By contrast, we found the highest labor market segregation value in the star network both in the presence and in the absence of worker referrals [shortsegregation2, shortsegregation4, shortsegregationcircle, shortsegregation, largemarket, acrossesrerun, densityaspiration100rerun2]. Differences between network types with regard to labor market segregation are small, but significant and consistent through a wide range of parameter values [shortsegregation2, shortsegregation4, shortsegregationcircle, shortsegregation3, densityaspiration100rerun2]. Results highlight that it is not structural cohesion that makes a difference for labor market segregation. On one hand, the star network shows slightly higher labor market segregation as pairwise disagreement between connected pairs is most likely in this structure. On the other hand, regular networks minimize pairwise disagreement given a fixed density, being most capable of coordinating behavior locally.

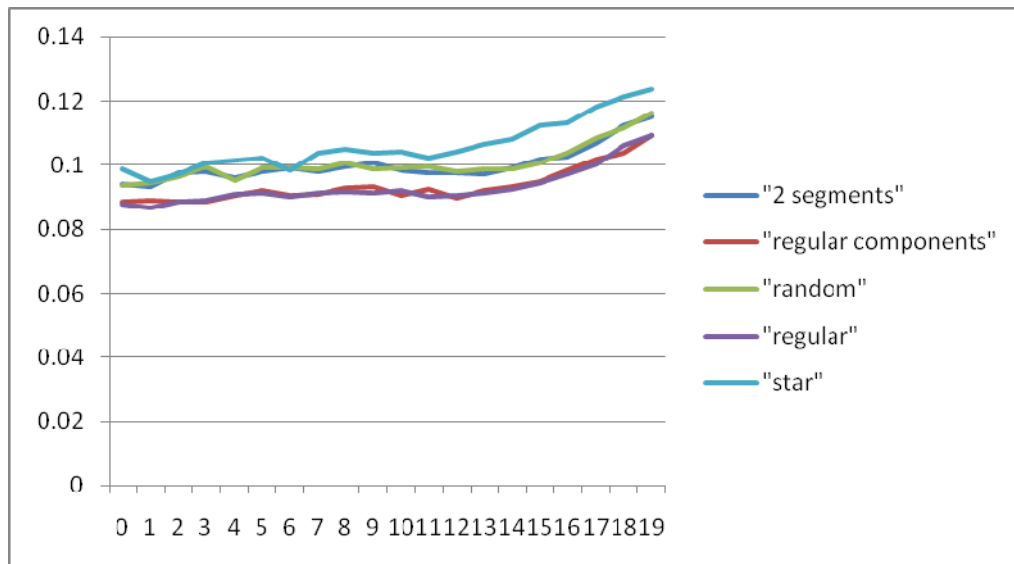
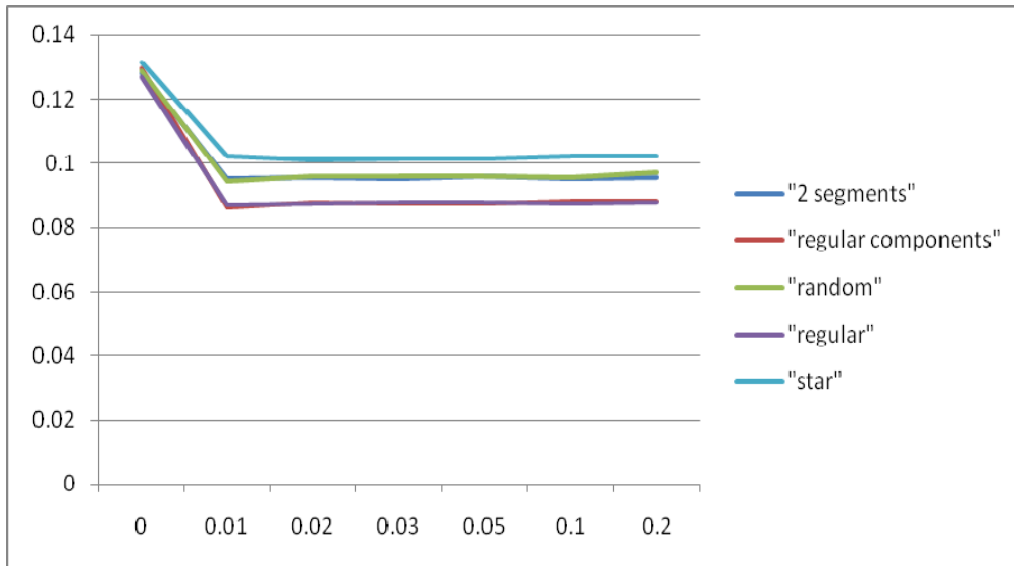


Figure 11. Average values of the *labor market segregation*  $S^*$  across 100 runs for each parameter combination (126000 in total), for different densities of workers' social network (above), and for different aspiration levels (below) in different type of business networks.

*Notes:* 15 employers, 10 jobs per employer, 320 workers, a 0.133 density of the business network, a 0.03 density of ties between employers and workers, 5 years of memory, time horizon of 100 years, 100 runs for each possible parameter combination (densities of workers' social network and aspiration levels are varied) [shortsegregation2, shortsegregationcircle, shortsegregation3].

### *The interplay of different networks*

One of our intuitive hypotheses linked worker referrals and labor market segregation. We expected that if worker referrals play an important role in job hiring, then individual employers will stock up labor force from one of the groups. That is, they will be perfect discriminators and the labor market will be strongly segregated (cf. Abdou and Gilbert 2009). We argued that if one of the groups have a structural advantage (e.g., have an initial advantage for the best jobs or have more references towards key employers or gate-keepers), then discrimination will also be observed at the macro level.

Our results show, however, that discrimination is not increased by a higher role of referral networks under any parameter combinations. Just the opposite, if perfectly neutral employers based their decisions largely on *referral networks*, it *helps to diminish discrimination*. The strong effect of referral networks and the strong and stepwise effect of workers' social network density displayed at the left side of Figure 7 prevail in any kind of business network [segregatedworkersreferraldensity, segregatedworkerscognitivebias]. Figure 7 reveals no major qualitative differences in the effect of referral networks and worker social networks in the lack and in the presence of business networks.

Furthermore, as Figure 12 shows, labor market segregation does not increase by the increasing importance of referral hiring. To the contrary, labor market segregation displays a relatively stable and fair value across the parameter values of referral density and social network density, except of the lack of these networks, when labor market segregation is highest. This can be explained as in the latter case, the business contact network is the sole information channel, which alone does not display such a strong balancing feature as with the help of referral networks.

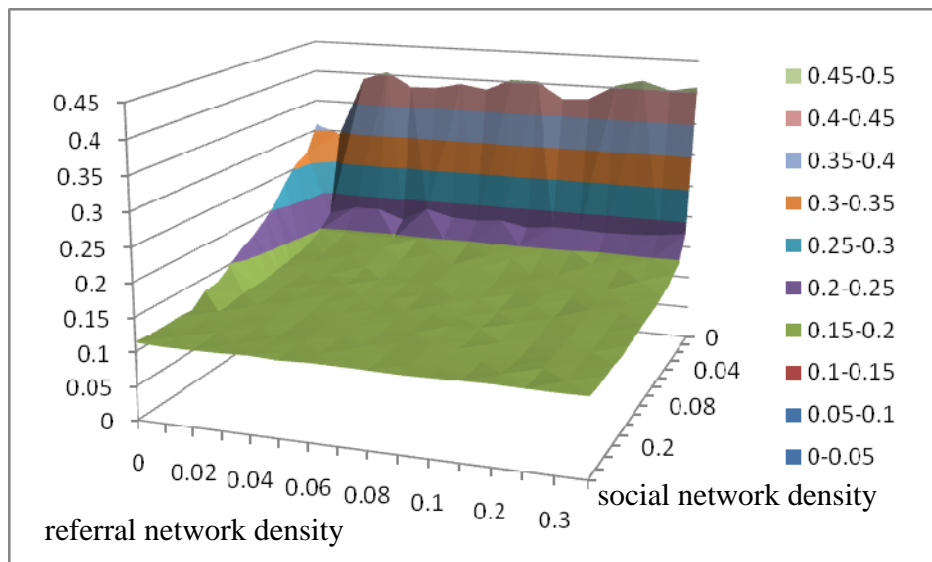


Figure 12. Average values of the *labor market segregation* index across 100 runs for each parameter combination (25600 in total), averaged for the density of referral networks between workers and employers and for the density of social networks among workers. *Notes:* 15 employers, 5 jobs per employer, 200 workers, random business network with a density of 0.1333, maximum aspiration level (19), 5 years of memory, 100 years per run. [referralacrosses2]

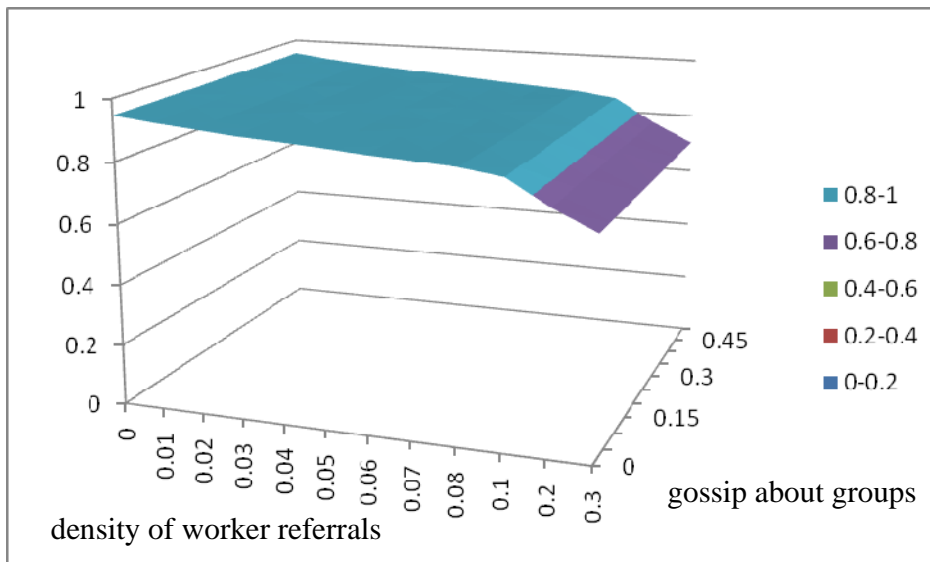
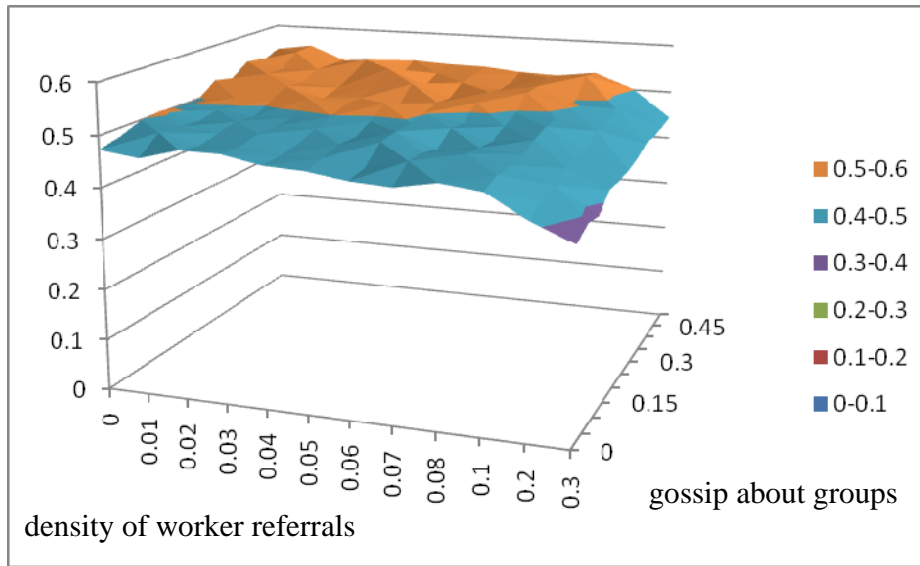
### *Exchange of group reputations*

As we have discussed, we do not merely analyze the effects of certain key parameters, but we also compare the impact of different reputation mechanisms on discrimination and labor market segregation. The results that have been displayed so far were based on a simple group reputation mechanism. In each contract period, group reputation was the simple mean of the qualities of previously employed workers within the memory window for each employer. We have already demonstrated that this simple reputation mechanism leads to high discrimination rates, in particular if employers are isolated and base their judgments purely on their own experience. High levels of discrimination are decreased, if worker referrals play a role in the hiring process. When we have added the possibility that employers have social ties to workers and give these ties a priority, discrimination rates have dropped.

We have also explored the possibility of information transmission about individual worker qualities via business contacts. We have assumed no costs and no biases related to business recommendations (or information leakage). Business contacts, however, only offered the possibility to hire from the employee pool of each other, group reputations have only been affected *after* hiring.

An alternative that we are now going to explore is that connected employers directly influence each other about group reputations. Group reputations will be assumed to be partly based on individual experience ( $1-g$ ) and on group reputation of business contacts ( $g$ ), where  $g$  determines the extent to which employers listen to the advice of their business contacts (gossip about groups). If no business contacts are present, then  $g=0$ . We assume that all business ties count equally.





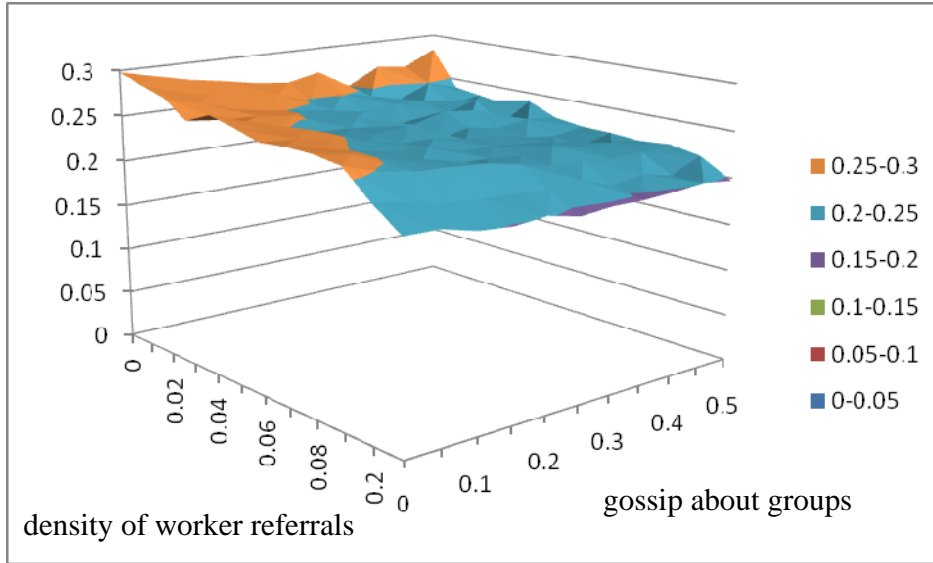


Figure 13. Average values of the  $\delta$  discrimination index (above), the  $\delta_i$  micro level discrimination index (middle), and the  $S^*$  labor market segregation index (below) across 100 runs for each parameter combination (52800 in total), averaged for the level of gossip about groups and for the density of worker referrals.

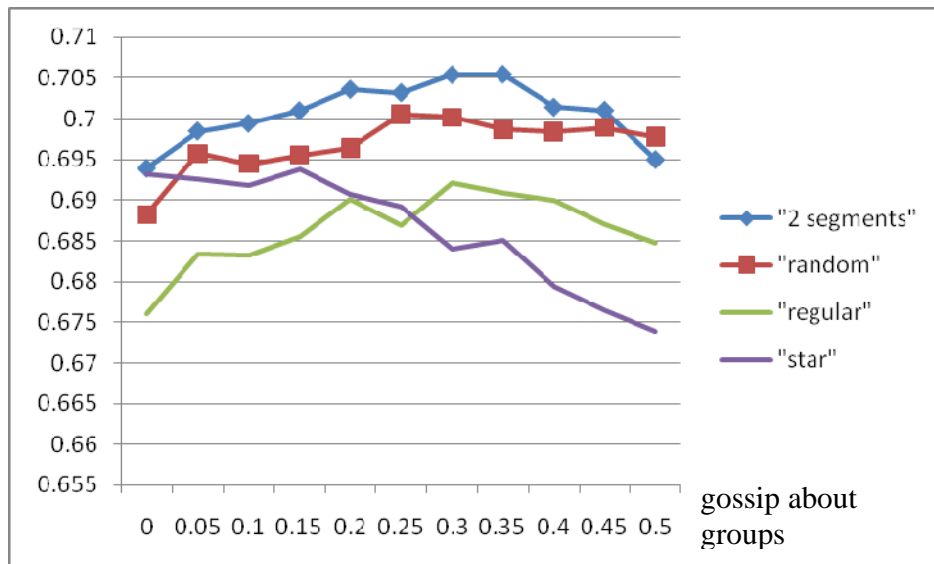
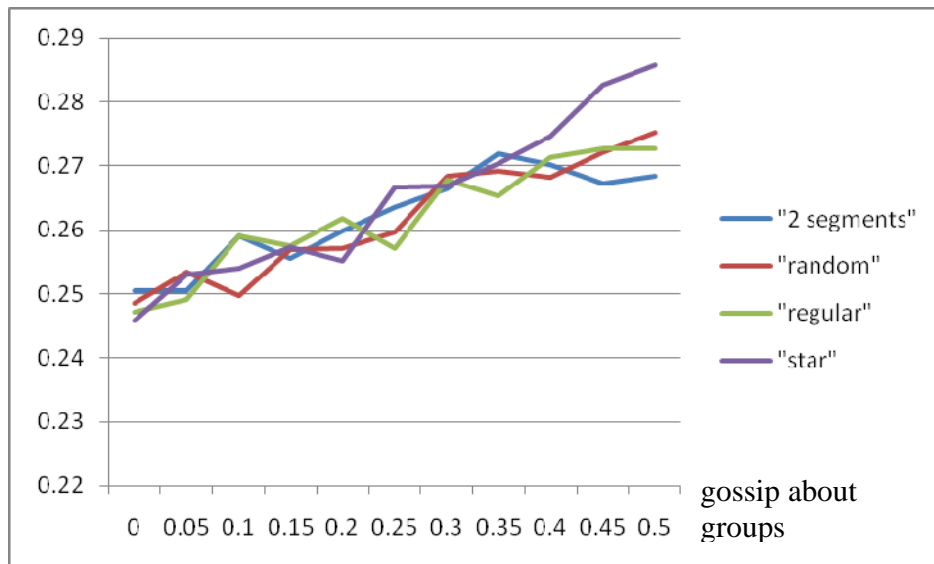
Notes: 15 employers, 6 jobs per employer, 200 workers, business network with a density of 0.1333 of different types {random, regular, star, and 2 segments}, no social network among workers, maximum aspiration level (19), 30 years of memory, 100 years per run. [groupgossip4]

We found only a small effect of group gossip ( $g$ ) on discrimination (Figure 13). Discrimination is largely unaffected by group gossip conditions [groupgossip2], which let us *reject our group reputations hypothesis*. The micro level discrimination index, in particular, is completely unaffected by varying the impact of business contacts on group reputations. Increasing  $g$ , however, has a tiny positive effect on  $\delta$  and a tiny negative effect on  $S^*$ .

In line with our intuitive arguments and with the results of Abdou and Gilbert (2009), we expected that exchange of group reputations in the presence of referral hiring will increase labor market segregation. Both in the presence and in the absence of referral hiring, for any aspiration level among employers, however, discrimination rates and labor market segregation are largely unaffected by group gossip conditions [groupgossip4; groupgossip22]. The small positive effect of  $g$  on  $\delta$  has been found only for the highest aspiration levels (shown in Figure 13) [groupgossip22].

The positive effect of group gossip on macro level discrimination in case of maximum aspiration levels is best pronounced in a centralized business network (Figure 14). The difference between the star network and other network types for a large weight of group gossip is small, but consistently found in a wide range of parameter conditions [cognitivebiases2]. It is also consistent that differences in the micro level discrimination index  $\delta_i$  are not in line with the macro level index; the star network is having the lowest micro level discrimination for high group gossip conditions (Figure 14,

[cognitivebiases2]). These results indicate that if business contacts have a strong influence on how group reputations are formed, then centralized networks create fair employers more likely, but contribute also more likely to distortions at the macro level, although both effects are pretty small. The differences between business network types with regard to labor market segregation are also minor, but the pattern that is depicted in Figure 14 can also be obtained in different parameter conditions [cognitivebiases2].



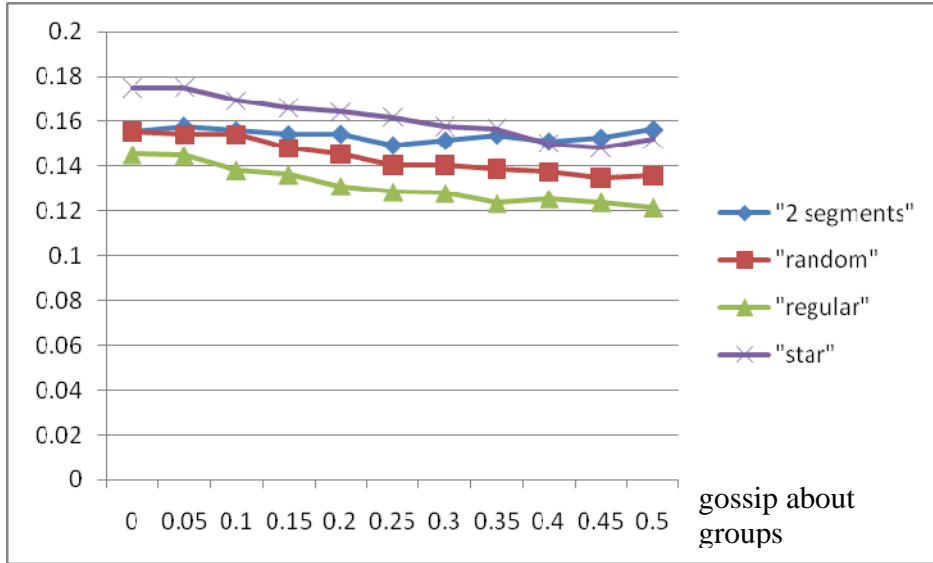


Figure 14. Average values of the  $\delta$  discrimination index (above), the  $\delta_i$  micro level discrimination index (middle) and *labor market segregation*  $S^*$  (below) across 100 runs for each parameter combination (52800 in total), averaged for the level of gossip about groups.

*Notes:* 15 employers, 6 jobs per employer, 200 workers, business network with a density of 0.1333 of different types {random, regular, star, and 2 segments}, no referrals between workers and employers; 30 years of memory, aspiration levels run from 1 till 19 in steps of 2; 100 years per run. [groupgossip22]

### Considering various reputation mechanisms

When introducing our model, we have discussed the steps we assumed how employers make hiring decisions. We considered an unbiased algorithm that values individual qualities. The algorithm consisted of steps, in which each step could and has been switched off and on, and results have been shown in the previous sections.

In addition, we have also varied the sequence of steps. In particular, worker referrals (step 5) were placed in front of employer recommendations (step 3). We have replicated otherwise identical scenarios [referraldensity and workersfirst, goodfriendreferrals and goodworkersfirst] with the different sequences of reputation mechanisms.

The surprising result is that the change in the sequence of reputation mechanisms did not bring any difference in the results. We found no difference between business network types in any of the cases. We also found no interaction effect of the sequence change with referral density.

We have continued to explore the role of different reputation mechanisms in discrimination. In the next step, we have introduced cognitive biases in reputation. Instead of taking the mean quality values of previously employed workers, we allowed employers to make various observational mistakes. First, we assumed that employers are more influenced by extreme qualities: as a calculation of group reputation, they used a weighted mean of qualities in which top quality weighted more (“top bias”), or they used

a weighted mean of qualities in which lowest qualities weighted more (“bottom bias”) or both. As a direct test of the *biased reputation hypothesis*, we have implemented simulation scenarios, in which we varied top bias and bottom bias, along with the weight of group gossip  $g$  across different business network types. After a careful exploration of these simulations, we have found no effect of cognitive biases on micro and macro level discriminations [cognitivebiases, cognitivebiases2]. Cognitive biases had no effect in the absence or in the presence of worker referrals and in any type of business network [segregatedworkers, reputationmechanisms]. Hence, we have to *refute our biased reputation hypothesis*.

In the simulation runs presented so far, we considered a severe form of reputational responsibility: in case of low quality recommendations, referents were excluded from employment irrespective of their quality. This implementation has been relevant in the co-presence of social ties between employers and workers and segregated worker networks. We explored, however, also less severe forms of reputational responsibility. As a contrast to the severe punishment for low quality recommendations, we implemented simulation runs with the same parameters in which workers were not punished at all for providing low quality recommendations.

Furthermore, in the simulation runs so far, recommendations from all known workers have been taken into account with the same probability. As another manipulation, we let recommendations to be evaluated in the order of quality of the referents (the word of best workers counted more). We intuitively expected that if this is paired with a radical deletion of professional ties who gave bad recommendations, then a contra-selection of best employees might take place.

Neither the absolute values of the indexes nor the qualitative conclusions from these manipulations differ radically from the picture we have seen before (e.g., in Figure 7). If priority is given to good workers, it *increases* discrimination slightly but consistently for a wide range of parameter values (see Figure 15). The effect is robust for different business network types and densities [goodfriendreferrals] and might have the same connotation as of the aspiration level hypothesis: a stronger strive for quality results in higher discrimination.

Reputational responsibility does not have a main effect on discrimination. The same general conclusions can be drawn with and without reputational responsibility. The density of the bipartite referral network has a strong negative impact on discrimination considering all types of reputation mechanisms (Figure 15). If social networks of workers play a role in the hiring process, then discrimination drops, except in the presence of extensive referrals, when there is no discrimination. If social networks are present, then their density is unimportant. Furthermore, there is an interesting and robust non-linear effect of social network density for the highest aspiration level in the lack of bipartite referrals: discrimination is highest in the complete lack and in the presence of sufficient ties among workers, and it is lowest if just a couple of ties are present. This non-linear effect is preserved for all network types, for all values of business network density, and both in the presence and absence of gossip about groups [goodfriendreferrals].

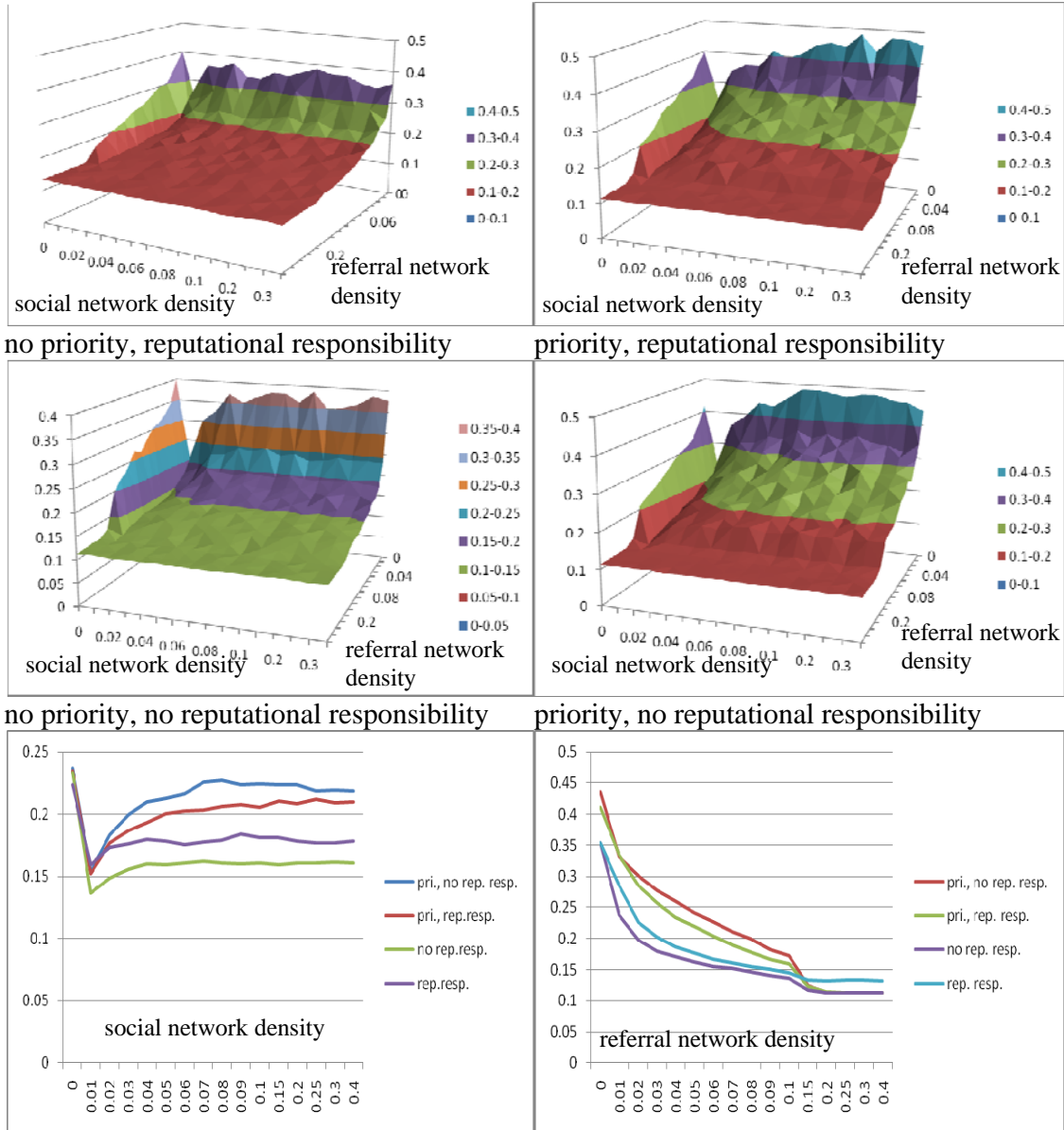


Figure 15. The effect of different manipulations of the reputational mechanism on the  $\delta$  discrimination index. The value of the index is depicted across 100 runs for each parameter combination (51200 for each part of the figure), averaged for the density of social networks among workers (summarized left below) and for the density of the bipartite referral network between employers and workers (summarized right below). On the left: mechanisms in which no worker has a priority for referrals, on the right: mechanisms in which recommendations by workers with a higher quality are taken first. Above: mechanisms with reputational responsibility, below: mechanisms without reputational responsibility.

Notes: The upper left part of the figure is a replication of Figure 7. 15 employers, 6 jobs per employer, 200 workers, random business network with a density of 0.1333; 5 years of

memory, maximum aspiration level of 19; with a 0.1 weight of group gossip or without,  
100 years per run.

[referralacrosses2                      referralacrosses2gf  
referralacrosses2nodie                  referralacrosses2gfnodie]

### *Gate-keeper hypothesis*

In the next step, we tested the internal validity of our gate-keeper hypothesis. We created centralized networks, in which central actors, who were employers themselves, acted as gate-keepers. This can be a representation of a labor market in which headhunters are present or a market in which only key employers have access to the general labor force and others build on the experience of key employers and follow their hiring policy.

In our model extension, we assumed a set of gate-keepers who had the same number of business ties and also the same likelihood of contact to each worker. There were no business ties among other employers, which guaranteed that central actors acted truly as gate-keepers. The bipartite network density parameter determined the number of links to gate-keepers, representing for instance the number of registrations at headhunters. Workers were randomly assigned to gate-keepers without an initial bias in favor of any of the groups.

In this extension, we were primarily interested in whether the presence of gate-keepers alters our main conclusions. We varied also the number of registered workers. Yet again to our surprise, we found only a very slight, negligible change in discrimination rates. Discrimination slightly increased in the presence of more gate-keepers, if referral ties were present in a sufficient number [gatekeepers, headhunters2].

The density of the bipartite referral network and of the social network among workers had the same effect as before also if gate-keepers controlled the hiring process. For all parameter combinations investigated, the effect of social network density occurred as an all-or-nothing effect: with zero density we observed much higher discrimination rates, but almost no differences between a density of 0.01 and 0.02. Similar to what we have seen in Figure 15, the drop in the discrimination rate between zero and 0.01 densities (the latter corresponds to as many ties as workers) is largest for the lowest level of referrals. Gossip about groups does not alter these conclusions [gatekeepers, headhunters2].

## SUMMARY OF RESULTS

Potentially, there are many processes behind the persistence of discrimination that are yet uncovered by social scientific research. This study concentrated on mechanisms that can significantly enrich existing explanations and can highlight that discrimination might exist also in the absence of statistical differences between the qualities of the groups and under the assumption of fair hiring decisions.

Most research on discrimination has addressed the reasons, maintenance, and consequences of statistical discrimination. The most difficult problems of discrimination are, however, those when discrimination is *not based on statistical differences*. Finding the underlying mechanisms and constructing a theoretical model that can explain these *enigmatic cases of discrimination* has been the *first* main theoretical aim and innovative

aspect of the study. In certain empirical cases, it is difficult to judge whether the observed inequality in hiring proportions is based on the difference in average qualities or discrimination is due to social construction (cf. Bielby and Baron, 1986; Falk and Zehnder, 2007; Ferraro and Cummings, 2007). In this paper, we have demonstrated that discrimination can exist also when the mean qualities of groups are the same and all employers are neutral and fair in the sense that they do not have any initial prejudices towards any of the groups. In our agent-based computation model, we tried to create as fair conditions as possible for an equal treatment of groups. Simulations, however, clearly showed that individual employers can quickly become perfect discriminators if they strive for quality and rely on their experiences. As employers (almost) exclusively hire members of one of the groups, we have a new explanation for the emergence of labor market segregation and a new answer to the problem why the labor market is largely segregated at the level of jobs.

The *second* main innovative aspect of the study has been a focus on mechanisms that origin in *social networks*. Social networks are highly relevant for discriminative norms and practices as they are the source of information and influence that change beliefs, attitudes, and behavior. Network relations affect prejudice, the practice of discrimination, and the spread of discrimination among employers. In the hiring process, different social networks play a role. Previous research, however, dealt only with worker referrals (e.g., Tassier and Menczer, 2008). Empirical studies have demonstrated that referral networks play a crucial role in getting a job in various labor markets (e.g., Granovetter, 1973; 1974; Lin, Ensel, and Vaughn, 1981; Wegener, 1991; Bloch, 1994; Fernandez, Castilla, and Moore, 2000; Rogers, 2000; Elliott, 2001; McBrier, 2003). These studies did not sufficiently highlight a distinction between two distinct components of referral networks: connections among job seekers on one hand and connections that link employers and their potential workers on the other. Therefore, the different roles these connections and their structure might play have remained unrevealed in previous research. As the social network of workers is typically segregated, labor market segregation is an obvious consequence of an extended use of referral hiring. The contact structure between employers and workers, however, is more than just the reflection of the current employment relations, and therefore might accentuate social segregation, and can even be a potential source of consistent discrimination. In addition, largely neglected in previous research, business networks are also important sources of recommendations. Network ties among employers are information channels that help to maintain discrimination practices or help to assure fair judgments.

Based on the existing literature on social network effects and on our intuitions, we have formulated intuitive hypotheses about key structural factors and mechanisms on discrimination and labor market segregation. Our expectations were formulated for an ideal world, in which no differences exist between the mean qualities of groups and all employers have the virtue to treat groups equally and seek labor that meets their standards. This is the setting we should use to highlight that not only statistical differences and built-in preferences and prejudices can be responsible for large levels of inequalities in the employment rates of different groups.

Our *worker referral hypothesis* stated that if worker referrals play an important role in job hiring, then micro level discrimination might arise and the labor market will be strongly segregated. We argued that if one of the groups have a structurally advantageous position



in the worker-to-employer referral network (e.g., have an initial advantage for the best jobs or have more references towards key employers or gate-keepers), then micro level discrimination will be aggregated to employment inequality at the macro level.

Our agent-based model has revealed an unexpected and strong effect of worker referrals *in the opposite direction*. If worker referrals exist, discrimination rates drop. Even if they come from a segregated social network of workers, worker referrals reduce discrimination compared to the situation when employers just base their decisions on their own judgment or on business recommendations. Furthermore, an increased density and segmentation of the social network of workers does not contribute to higher discrimination either in the presence or in the absence of dense worker-to-employer referrals. It seems to be a robust emergent result that discrimination is strongest in the complete absence of worker referrals.

Our conclusions downgrade the predominantly negative view on social network effects on labor market efficiency. Social networks, if used in the hiring process, decrease discrimination as well as labor market segregation. The reason is that in case of fixed term contracts and a continuing need of re-employment, referral networks that have a *balanced composition* are able to correct for the random biases in individual experiences of employers.

We found also no negative effect of business recommendation networks. We have expected that discrimination will not be a by-product of the exchange of information between employers as long as only information on individual qualities is exchanged. This intuition has been confirmed by our agent-based model. In our *group reputation hypothesis*, we predicted, however, that the exchange of group reputations (gossip about groups) will have an effect on discrimination rates. We found that values of the discrimination indexes did not differ through group-gossip conditions. We have not found a cascading spiral of false beliefs in any type of business network.

Intuitively we argued that if central and broker actors in the business network have local information to the disadvantage of a certain category, then discriminative practices can be experienced in a short term. We argued that in a connected network of employers, group reputation will balance over time and there will be no differences in discrimination rates between different structures. The balancing process, we claimed, will last the longest in networks with large path lengths (for instance, in a line network). This set of our intuitive expectations has been disconfirmed. On average, largely different business networks did not show differences in the rate and in the spread of discrimination. All type of business networks resulted in the same level of discrimination and labor market segregation. This is certainly an interesting result and highlights that similar to other situations, there might be an all or nothing effects of networks, while no effects of network topologies (e.g., Cohen, Riolo, and Axelrod, 2001; Boero, Bravo, and Squazzoni, 2010).

In addition, we found no support for the *biased reputation hypothesis*. We expected that cognitive constraints paired with low cohesion and interconnectedness of the network would be responsible for variation in beliefs and for labor market segregation. Contrary to our expectations, in our simulations, there was no effect of cognitive constraints on discrimination and also no interaction with network properties.

Furthermore, we expected that if *gate-keepers* exists on the market and they do not simply gather and pass on information about individual qualities, but make reputational judgments about groups, then it leads to higher labor market segregation. Just like with

other types of business network structures, however, we have found no such effect in our simulations.

We also formulated an intuitive hypothesis about the effect of *aspiration levels* on discrimination. We argued that high aspiration levels of firms will be responsible for higher discrimination, because in a desperate search, signals and supplementary information on group categories are more likely used. We have found strong support for this intuitive hypothesis. Aspiration levels had a high impact on discrimination rates under a wide range of parameter values. The emergent relationship between aspirations and discrimination is obtained because if firms have higher aspiration levels, they more frequently fire employees and tend to base their group judgments on the few workers that satisfy their needs. Our results imply a potential alternative answer to the problem of higher discrimination at the top of the hierarchy: in addition to the persistence of a glass ceiling and longer career ladders, discrimination rates at the top can also be higher because aspirations of employers are higher.

In addition, we also compared discrimination rates and labor market segregation assuming variations in the reputation mechanisms. The order in which business recommendations and worker referrals were considered by employers did not matter at all for discrimination. If priority in referrals has been given to good workers, it contributed to slightly higher discrimination rates through a wide range of parameter values. We received no support, however, for our *reputational responsibility hypothesis*.

In short, our major conclusions demonstrate that verbally formulated intuitions, even if they sound firm and logical, might easily contain internal inconsistencies. Intuitive arguments can lead to misleading implications due to their imprecision (e.g., Macy and Willer, 2002). The rigor of formal steps and explicit assumptions in agent-based models corrects for such inconsistencies of intuitive arguments and highlights the true macro implications that follow from well defined micro assumptions (Coleman, 1964). By implementing an agent-based model, we also had a methodological contribution to the ‘state of the art’ of research in the field of discrimination. , but offer a huge potential to broaden our limited insight into social mechanisms that maintain discrimination practices (for relevant examples, see Calvó-Armengol and Jackson, 2004; Abdou and Gilbert, 2009; Stovel and Fountain, 2009). Our conclusions highlight that agent-based simulations do not only correct for the internal inconsistencies of verbally formulated intuitions, but can also largely supplement our sociological understanding of discrimination that is now provided mainly by macro data, surveys, field experiments and case studies.

## DISCUSSION

Employers act differently towards persons with different traits, as if they had different qualities. For instance, they use observable traits such as gender and race “as inexpensive screening devices when hiring for jobs, particularly skilled jobs, in the belief (correct or not) that race and sex status are, on average, related to productivity. Individual workers are stereotyped as qualified or not, with more attention given to their membership in a race or sex group.” (Kaufman, 2002: 550).

Discrimination at hiring decisions have far reaching consequences. Differences in wages can largely be the result of differential hiring (Petersen, 2009; Stinchcombe, 1990).

Hiring decisions also have a long term consequence for later career success (McBrier, 2003). Differences in hiring rates between groups contribute to differences in social mobility, career success and wages, and solidify status inequality.

The present study intended to enrich existing theories about discrimination from a new perspective: it aimed to model mechanisms based on social network relations. It tried to find answers under which structural configurations discrimination practices are likely to occur and under which structural conditions they can be best avoided. These questions are appropriate as they address relevant, but previously largely overlooked aspects of discrimination. Discrimination practices in the times of increased migration movements, however, continue to exist in all countries. A study that tackles this problem successfully can contribute to the conservation of human values and to the enrichment and stability of the integration of societies.

Our major conclusions highlight that high aspiration levels and isolation of employer decisions largely increase discrimination. Our other major result is that in a labor market with perfectly fair employers, *all kinds of networks* help the fight against discrimination.

Although it has rarely been done before in a single social simulation study, re-implementation can radically improve the validity of results and help to discover problems and might also contribute to improvements in the details of the simulation design. We have taken such an exercise and re-implemented the basic model in Repast.<sup>4</sup> Important difference between NetLogo and Repast is the order in which agents are chosen for action. In NetLogo, it is always a random order and also interaction partners are selected randomly with different seeds. In Repast, this is not the default feature. In qualitative terms, we could successfully reproduce our results of the basic model that contained business networks and the aspiration level mechanism. The successful replication implies that randomization of agent actions does not bias our results.

We based our conclusions on a simple model that assumed informational asymmetry between employers and employees; which is realistic as the quality of employees is unknown at the time of application and will only be learnt during employment. In our agent-based model we assumed that hiring decisions are one-sided and are always made by the employers. For the sake of simplicity, we assumed that employees always accept the first job they have been offered and there is no differentiation by wages. We can alternatively view this as the market is perfect in the sense that employers always offer clearing wages that are acceptable to all candidates. This means that employers with higher aspiration levels *should* offer higher wages. We have assumed that there is one recognizable trait in the population (e.g., gender) and two categories (e.g., men and women). These simplifications can easily be relaxed in subsequent model development.

As we modeled the dynamics of hiring decisions as a one-sided process, we have neglected all potential mechanisms that origin from the labor supply side and can contribute to the emergence of discrimination. For instance, in our model, we did not capture worker preferences for jobs or for same-sex working environments and did not include sex-labels that are attached historically to jobs (Tyack and Strober, 1981). In exchange, the simple one-sided matching model we opted for has potential implications also for other social phenomena, in particular for situations characterized by the problem

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<sup>4</sup> Programming was done by Claudio Gandelli.

of asymmetric information on quality. These could be consumer choice and political choice in which products and parties are analogous to workers in our model.

Simplicity implied that the model can be used generally, but limited the external validity of our conclusions to empirical cases of discrimination. Most importantly, we have not dealt with the cognitive foundations of discrimination (for a review, see Pager and Shepherd, 2008) in this study, but purely concentrated on structural mechanisms that can result in discrimination in case of employers who are perfectly unbiased and prejudice-proof. It is truly remarkable that despite not taking into account cognitive foundations of discrimination, we still found a highly discriminating market.

The neutral and fair employers in our model do not intend to discriminate, they just happen to develop discrimination due to structural reasons. Empirically observed discriminative behavior is also not necessarily purposeful. Tags, group markers, and prejudices are cognitively built in our mind. They unconsciously or partly unconsciously produce biased decisions (Crocker, Major, and Steele, 1998; Ridgeway, 1997; Fiske, 1998; Reskin 1998; 2000; McBrier, 2003). On the other extreme, discrimination is put to the extreme, institutionalized, and publicly enforced in the case of Nazi Germany or the apartheid regime in South Africa (van den Berghe, 1990). This study did not aim to determine the cognitive roots of problems or the origins of the public enforcement of discrimination. In this paper, we have dealt with discrimination as an unintended and uninstitutionalized process, in which employers base their judgment impartially on their own experience and referrals from their social network and it results in an emergent macro-phenomenon of discrimination.

There might be, of course, many other relevant *structural* mechanisms and constraints that increase discrimination on the labor market. Some mechanisms might accentuate the effects we have found. For instance, in a hierarchically organized labor market, employers of different organizations can base their judgments on the hierarchical positions of applicants have in their current organization. For external selection, they use the hierarchical position and group reputation as two sources of information. As the hierarchical position already to a certain extent could reflect differences in group reputations, discrimination is further increased. Furthermore, if no jumps are possible in a hierarchical structure, then quick careers of high quality individuals are out of the question. The limited availability of top level jobs create congestions at certain levels that further hinders equal opportunities and help the stability of current discrimination regimes.

Not only members of the groups are labeled as “appropriate” or “inappropriate” for certain tasks, but also jobs and tasks are labeled as “appropriate” or “inappropriate” for certain groups, such as for blacks or whites, women or men (England, Kilbourne, and Herbert, 1994; Moss and Tilly, 1996; 2001; Reskin and Roos, 1990; Reskin and Padavic, 1999; Ridgeway, 1997; Kaufman, 1986; 2002). This queuing mechanism makes the hierarchical effects even stronger: top level jobs will be labeled as appropriate for whites and men. Labeling jobs is a similar process to group reputation and statistical discrimination, although updates are less likely based on experience, because workers who are in these jobs are not motivated to update job position reputations as it ensures them higher status.

Furthermore, employers might prefer to assemble a homogenous group in order to decrease chances of conflicts within the organization and maintain a harmonic

organizational climate (cf. e.g., Jehn, 1994; Jehn, Northcraft and Neale, 1999; Harrison et al., 2002). First, this might result in allocative discrimination, in which members of a certain category are hired for less prestigious jobs (Petersen and Saporta, 2004). Second, the employers have an interest to substitute minority members with members of the majority group since it is more likely that they will be able to compose a homogenous group that saves them from potential conflict and might lead to higher performance (Jehn, 1994; 1995). Already a few employers with such motives could generate labor market segregation with crowding out members of other categories. The result is discriminative only if first entrants are dominantly members of the same category and due to team-work incentives, also low-quality members of this category are favored.

There is a further argument from the employer's point of view to build extensively on worker referrals and compose a homogenous team. Referrals and similar others will be more likely to help the newcomer in the organizational socialization process and thereby boost productivity (Grieco, 1987; Fernandez, Castilla, and Moore, 2000; Elliot, 2001). Obviously, not only employers, also employees could have preferences for homogenous work units. Such preferences play without doubt an important role in labor market segregation and result in a self-explanatory dynamics.

We have assumed that employers are perfectly neutral and do not belong to any of the groups. Obviously, introducing group affiliations for employers result in much stronger segregating and discriminating tendencies. Even in this case, structural parameters that describe the interconnectedness of groups could be particularly important for the maintenance of prejudice and discrimination practices. The classical and recent social psychological literature on prejudice and discrimination has for long recognized and demonstrated the key role of *contact* on reducing prejudice and helping intergroup relations (Allport, 1954; Ellison and Powers, 1994; Pettigrew, 1998; Dovidio, Gaertner and Kawakami, 2003; Pettigrew and Tropp, 2006). The relevance of the structure of contacts, however, has largely been neglected by this literature (cf. Flache and Mäs, 2008). For the dissemination of true beliefs, exposure to members of the other category will be important and network segregation will contribute to the preservation of discriminative practices (cf. Takács, 2001; 2002; Abdou and Gilbert, 2009). Hence, we can expect that with salient group categories, segregated social networks would lead to more discrimination.

As we have already discussed, hiring of employees is not a one-sided process. Workers are proactive job seekers; they stand up from their current jobs, and reject offers. A subsequent model extension should go in this direction. In a dual matching process, contacts provide job seekers with information on employment opportunities and insider information on job quality. This information can also be biased and hierarchical, which creates labor market segregation and self-selection by job seekers.

Other possible extensions are the consideration of multidimensional quality (different skills), where employers possibly discriminate in different dimensions; or the introduction of biases in information transmission. The model could also be extended to more social categories that can resemble e.g., race or ethnicity. Only slight modifications are necessary to study the effect of minority group size (with the necessary adjustment of the dependent variables) and the internal structure of minorities (cf. e.g., Abdou and

Gilbert, 2009; Tassier and Menczer, 2008); the effect of varying contract lengths and as a consequence, queuing and promotion chains; the role of turnover (cf. Abdou and Gilbert, 2009); or of initial prejudices. The reputation mechanisms assumed in our paper could also be elaborated further. One could possibly introduce group reputation scores that depend also on the quality of referrals and a more sophisticated transmission of reputational beliefs. A more advanced attempt that would be of a character of growing artificial societies (Epstein and Axtell, 1996) would be to reward employers who hired better workers with “economic growth” such that they can hire more employees in subsequent contract periods. The resulting economic system could be analyzed by different measures of market efficiency, market concentration, and hierarchy.

Heterogeneity could also be introduced in the updates of agents. Not all employers learn the same way from personal experience, and some might even have a tolerant attitude towards members of a group with a lower reputation in the hope of future benefits. One could study different social learning mechanisms and tolerance thresholds that could be efficient in minimizing prejudice and discriminative practices.

The learning mechanism that is of highest relevance for the study of social network effects is *social learning* (e.g., Bandura, 1977; Conte and Paolucci, 2001). Social learning can take simple forms of social facilitation and imitation (see e.g., Bravo, 2008; Rendell et al., 2010), but it can also be more sophisticated and allow individuals to selectively copy and internalize part of beliefs and belief systems. Individuals only partly base their judgment on their own experience, they learn from relevant others and also form socially desirable responses in order to maintain their social acceptance by relevant others (e.g., Kuran and Sunstein, 1999). The question of who is relevant makes the study of social network effects unavoidable. Certain structures of social influence imply efficient dissemination of true beliefs, while other structures support the conservation of discrimination practices via social learning mechanisms. Social learning might facilitate true beliefs, but also facilitate a quick adoption of false beliefs in different network configurations (Centola, Willer, and Macy, 2005). Hence, social learning has an impact that is conditional on the network relations on reaching a collective optimum (for analogous findings see Chang and Harrington, 2005). A similar result could be obtained for reputation effects, which would be especially contrasting with the well documented positive effect of reputation building on cooperation. The social psychological literature on social identity and intergroup relations at least would suggest that reputation can be maintained by holding true beliefs, but also be built up by adjusting beliefs that might be false and discriminating toward less relevant others. For the derivation of exact hypotheses about the effect of reputation building and social learning mechanisms, and of their interactions, agent-based modeling is necessary.

A study on discrimination would not provide an adequate representation, if it would not cover the deeply rooted conflicts that characterize opposition of social groups that are distinguished by a single trait and gain their identity from this distinction. Therefore, the baseline model could also be extended in a way to concentrate on cases where discrimination is aligned with segregation and intergroup rivalry. In such cases, discriminative practices have feedback effects on the network structure. Individuals are likely to strengthen ties that are self-reinforcing and abandon ties with negative connotations. This results in a segregation of social contacts that in turn increases pressure towards applying discriminative practices and enforcing discrimination norms.

A subsequent agent-based model could seek the route out of this spiral and analyze the viability of tolerance and tolerant network formation. The conditional success of tolerant strategies that go against learned beliefs and handle others equally or even positively discriminate members of other categories could be analyzed. Intuitively, positive discrimination is expected to be rarely successful in case of strong intergroup categorization and rivalry. It is difficult to find a rationale for actors to behave tolerantly and apply positive discrimination voluntarily, especially during tense intergroup relations. Tolerant actors face disapproval of their locality for not obeying to discriminative practices. Tolerant network formation is a farsighted network strategy that is based on short-term sacrifices in order to gain long-term benefits from a collective optimum of non-discrimination. The viability of tolerance is expected to depend strongly on the exact network structure, especially on the structure of intergroup contacts and on the auxiliary assumptions on individual far-sightedness. The far-sightedness of central and broker actors is a necessary condition of the way out of the spiral of segregation and discrimination. As successful strategies are expected to be relatively complex, there is a long further way to go with using agent-based simulation as an adequate tool for the exploration of mechanism related to discrimination.

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