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Statistical Discrimination and the Efficiency of Quotas

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Abstract

We develop a statistical discrimination model *a la* Cornel and Welch (1996) where groups of workers (males-females) differ in the observability of their productivity signals. We assume that the informativeness of the productivity signals depends on the match between the potential worker and the interviewer: when both parties have similar backgrounds, the signal is likely to be more informative. Under this "homo-accuracy" bias, the group that is most represented in the evaluation committee generates more accurate signals, and, consequently, has a greater incentive to invest in human capital. This generates a discrimination trap. If, for some exogenous reason, one group is initially poorly evaluated (less represented into the evaluation committee), this translates into lower investment in human capital of individuals of such group, which leads to lower representation in the evaluation committee in the future, generating a persistent discrimination process. We explore this dynamic process and show that quotas may be effective to deal with this discrimination trap. In particular, we show that introducing a quota allows to reach a steady state equilibrium with a higher welfare than the one obtained in the decentralized equilibrium in which talented workers of the discriminated group decide not to invest in human capital.

JEL classification numbers: J78, D82, K20.

Key words: Statistical discrimination, affirmative actions, quotas and signal accuracy.

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1 Introduction

Discrimination occurs when some workers are treated differently than others because of their personal characteristics, such as gender, race, age, nationality, sexual orientation, and so on, that are unrelated to their productivity (Arrow, 1973). One outcome of discrimination is under-representation in the labour market. Discrimination is not only leading to unequal outcomes, but it may also create efficiency losses: waste of talent, lack of incentives to invest in human capital by the discriminated group, inefficient allocation of resources. Affirmative action policies, such as quotas, have been proposed to reduce discrimination and achieve equality and/or efficiency. Their effectiveness is under scrutiny by a growing economic literature, mostly concentrated on the effects of gender quotas. Empirical research (see, among the others, Bertrand et al., 2014, Bagues et al., 2016) has reached no conclusive results on the effectiveness of gender quotas in reducing gender gaps in specific contexts (business, politics, academia) nor on the efficiency gains vis-à-vis the costs they may generate. The effectiveness of quotas in achieving equality depends on the extent to which quotas in decision-making positions translate into more balanced outcomes and smaller overall gaps - for example, if increasing women's representation in decision-making positions reduces overall gender gaps. As for efficiency, theoretically, quotas have an ambiguous effect. On one side, by reducing the inefficiency losses associated to discrimination, quotas may increase productivity and total welfare. On the other side, by restricting the set of candidates and imposing constraints to the selection process, they may generate economic costs. As a consequence, empirical analysis may reach different conclusions depending on the contexts and a theoretical assessment is needed to fully understand the mechanisms at work.

In this paper, we concentrate on the efficiency consequences of the introduction of quotas and provide a theoretical foundation for the argument that quotas introduced to reduce discrimination may generate efficiency gains and enhance welfare. The mechanism linking quotas to efficiency gains is intrinsecally dynamic, and passes through the increase in the incentives to invest in human capital created by the introduction of quotas in selection processes. These are typically non-neutral, because of discrimination.

Discrimination may depend on taste (Becker, 1957), if, for example, employers discriminate against women because of their prejudices against them, or on statistical inference (Phelps, 1972, Coate and Loury, 1993, Moro and Norman, 2004, Lazear and Rosen, 1990) if people do not have full information about an individual's relevant work characteristics and use group statistics as a proxy. We will focus on this statistical discrimination phenomenon in a context of imperfect information, in which firms are not adverse *per se* to women. In particular, we will analyze a statistical discrimination environment *a la* Cornel and Welch (1996). We study a perfect competitive labor market composed of a large number of identical employers and a pool of workers that belong to two different groups, for example men and women. There are no ex-ante productivity differences between the two groups. Workers' productivity is imperfectly observed by employers. We consider dimensions of the productivity that are difficult to assess: following Arrow (1973), Cornel and Welch (1996) and others, we can include among them steadiness, punctuality, responsiveness, leadership, effort in previous job experience or initiative. Employers are rational, as they are aware that both groups are ex-ante identical in terms of productivity and they are neutral, i.e. they do not have specific preferences for one particular group. However, employers have to infer the productivity of workers using interviews and other screening mechanisms. This assessment process is imperfect. The accuracy of these screening mechanisms may differ across groups, since employers can find it easier to learn the productivity of a worker with whom they share a similar background. This "homo-accuracy" bias may favor the group that is most represented in the evaluation committee and it is the driving force of the observed discrimination.

The idea that a differentially noisy signal about majority and minority candidates can bias the selection process toward majority candidates is already in Morgan and Vardy (2009). Building on this idea, and differently from this previous contribution, in this paper we endogenize two important elements: the specific human capital and the accuracy with which workers' productivity signals are observed. In the spirit of Arrow (1973) and Becker (1975), we assume that the specific human capital depends on the effort or investment of workers, and then on the incentives provided by the labor market. We also consider individuals who are heterogenous within groups, as the investment cost differs across workers. We assume that both groups are identical ex-ante, i.e. the distributions of human capital investment costs are the same in both groups. However in equilibrium it may happen that an individual of one group decides to invest, while another individual with the same investment cost in the other group decides not to do so. This is because the return of such investment in human capital depends on the observability of the productivity signal, which differs across groups.

We assume that the accuracy of productivity signals depends on the representation of each group in the evaluation committee: the higher is the proportion of one group in the evaluation committee, the more precise is the estimation of productivity of this group, and then the higher is the return of the human capital investment. This relationship suggests a dynamic link, since workers who are perceived as being high productive today, are more likely to be involved in future evaluation processes. In other words, the composition of the evaluation committee and the current observability of groups' productivity signals depend on the promotion and reward decisions taken in the past. Then, if for some exogenous reason one group is initially poorly evaluated, this translates into lower investment in human capital of individuals of such group, which leads to lower representation in the evaluation committee in the future, generating a persistent discrimination process. This discrimination trap is inefficient, because of the lack of investment in human capital by the talented workers (with relative low investment cost) of the discriminated group. We explore this dynamic process and show that quotas may be effective to deal with this discrimination trap. In particular, we show that introducing a quota allows to reach a steady state equilibrium that generates more welfare than the one obtained by the decentralized equilibrium.

The vaste literature on quotas has concentrated on its effectiveness in reaching equal representation for discriminated groups (Holzer and Neumark, 2006). Although being still a debated issue, equality is considered the natural justification for the introduction of quotas: they are a means to equalize opportunity in specific areas where a group face systematic barriers due to discrimination or persistent stereotypes (Holzer and Neumark, 2006). In the context of gender, the effectiveness of gender quotas in breaking the glass ceiling has been largely investigated. Many empirical studies show that gender quotas have shifted employment to women, but the magnitudes of these shifts are not necessarily large (see Leonard, 1990 and papers reviewed in Holzer and Neumark, 2006). Recent studies have proved that quotas are effective to give women more opportunities to reach top positions, thus leading to more equality between men and women, both on companies' boards (Kogut et al., 2014 for US; Engelstad and Teigen, 2012 for Norway; Profeta et al, 2014 for Italy) and on party's candidate lists in politics (De Paola et al., 2010). However the evidence is non conclusive. Some studies are skeptical about how substantial the changes are and how they may benefit the entire economy: to what extent do quotas induce a cascade mechanism which, at the end, reduces inequalities at all levels? Bertrand et al. (2014) find no evidence that the Norwegian board gender quota system had any impact on the reduction of gender gaps. Bagues and Campa (2015) find no impact of quotas in party's candidate lists on equal representation of male and female politicians. Bagues et al. (2016) find that in academia the gender composition of evaluation committees does not necessarily increase the chances for (existing) women to be promoted, thus limiting the effectiveness and desirability of gender quotas.

No previous paper has fully developed the argument that quotas may be justified based solely on efficiency reasons in a dynamic context.[1] Empirical suggestions in this direction however exist. Studies have found a positive impact of quotas on the quality of the representatives and on the performance outcomes (yet non uncontroversial results, see for a review Profeta et al., 2014). Experimental research has linked the existence of quotas to an incentive effect for risk-averse women to engage competition, with the consequence of enlarging the pool of talents from which to choose the more appropriate candidate, thus potentially improving the outcome of the selection (see Bertrand, 2011 for a review, Sapienza et al., 2009 and Niederle and Vesterlund, 2010).

The paper is organized as follows: next section describes the related literature on quotas and

[1] Coate and Loury (1993) link discrimination to employers' stereotypes about the productivity of workers. In this context, they show that temporary affirmative action policies may have ambiguous effects on the workers' investment incentives. On one side, protected workers may have more incentives to invest because of their higher chances, while, on the other side, if they perceive that affirmative action reduces the required standard, they may have less incentives to invest, thus reinforcing the initial stereotypes. Focusing on the accuracy of productivity rather than stereotypes we can fully exploit the efficiency gains of quotas.

on the selection process; section three develops the benchmark model; section four describes the theoretical equilibrium; section five introduces the policy of quotas; section six develops a simple dynamic model with a continuous of types and section seven concludes.

2 Related Literature: The role of quotas

Existing studies have mainly concentrated on the effectiveness of quotas in reaching equality. While equity reasons are considered a plausible, yet debated, justification for the introduction of quotas, efficiency arguments have been mainly used by the opponents of quotas. Quotas are considered a costly policy: even when they are able to reduce gaps, they do so by equalizing outcomes rather than opportunities, by restricting the decision set of individuals, and thus at the risk of promoting less-qualified people, who very likely will perform poorly (Holzer and Neumark, 2006). However, since discrimination creates efficiency losses, such as waste of talent, lack of incentives to invest in human capital by the discriminated group and inefficient allocation of resources, in principle even a costly positive discrimination policy may be overall efficiency enhancing. Gender quotas may be linked to better performance outcomes (see Profeta et al., 2014 for a review). The evidence is however not fully conclusive: studies on Norway, a pioneer country in the introduction of gender quotas on boards of directors, show that, while the law has been effective in increasing the number of women on boards, it produced, for example, negative reactions by the market (Ahern and Dittmar, 2012). Positive reactions of the stock market to gender quotas are instead found in the Italian case (Ferrari et al., 2016).[2]

Our efficiency argument for the introduction of quotas is based on the dynamic functioning of the selection process. Quotas may be efficient if, in a context of discrimination, they break the persistent advantage of the dominant group, which is more represented in the evaluation committee and therefore better equipped to select similar people. Quotas are thus able to induce higher investment in human capital by the talented workers (with relative low investment cost) of the discriminated group in the future. Several contributions in different disciplines have shown the

[2] See also Adams and Ferreira (2009) and Adams and Ragunathan (2015).

existence of non-neutrality in the selection process. Goldin and Rouse (2000) find that moving to blind auditions in major American Orchestras, where the sex of the musicians cannot be observed by the evaluators, increases the likelihood that women advance in the hiring process and that they are eventually hired. In their exam of the factors, which influence evaluators when reviewing curricula vitae, Anders, Steinpreis, and Ritzke (1999) find that both male and female evaluators have a gender bias preferential toward male job applicants in the field of academic psychology. This discrimination against women may depend on the presence of stereotypes (Gorman, 2005) in selection criteria, which often include masculine characteristics (see also Reuben et al., 2010 in an experimental setting). In other words, there are well-established bias influencing the selection process, which are presumably difficult to remove without a strong intervention. Non-neutrality in the selection process may also derive from individual preferences: individuals may prefer people who are similar to them, since they are able to better assess their characteristics, and this may result, for example, in male evaluators preferring male candidates.[3] Even in absence of a clear preference for similar people, a "screening discrimination" may occur, as it is in general easier for individuals to screen people of similar background (Pinkston, 2003). As a result of this non-neutral selection process, men evaluators may tend to prefer male candidates. The direct evidence on this is however non fully conclusive (see Feld et al., 2013). In the context of academia, De Paola and Scoppa (2015) find that having a female evaluator increases the chances of women to be selected, while Bagues et al. (2016) find that the gender composition of scientific committees does not increase either the quantity or the quality of female candidates. In the managerial context, Bell (2005) finds that female executives have significantly higher chances of promotions in firms with a female CEO or female board chairman. Matsa and Miller (2010) find that having women on board of directors in previous years has a significant positive effect on the female share of top management.

[3]According to the general principle of "homophily", individuals prefer other people who are similar to them (McPherson et al., 2001), and "a contact between similar people occurs at a higher rate than among dissimilar people". This principle is key to the operation of network ties of every type. This concept, well-known from the ancient thought ("pares cum paribus facillime congregantur", Cicero - Cato maior de Senectute III.7) has been largely developed by social scientists since the 1920s and 1930s (Lazarsfeld and Merton, 1954). Gender has been recognized as one of the main dimensions of homophily (Ibarra, 1992). See also references in section 5.

3 The Benchmark Model

The economy is characterized by a perfect competitive labor market in which workers' productivity is imperfectly observed and there is a large number of identical employers (managers or evaluators). Workers (candidates) are risk neutral and their productivity depends on their investment decisions in human capital[4]. In particular, a worker decides whether to invest in human capital or not, i.e. $e \in \{I, N\}$. Investing entails a fixed cost $c \geq 0$, but leads to high productivity $\overline{\theta}$, whereas not investing entails no fixed cost but is linked with low productivity $\underline{\theta}$.

Workers may be one of three different types, depending on the size of the fixed cost in which they would incur in case they invest in human capital. With ex ante probability $\frac{1-\alpha}{2}$ the worker has a fixed cost $c = \infty$. As a consequence, independently of labor market conditions, this type of worker will never invest and he will always have low productivity $\underline{\theta}$. With probability $\frac{1-\alpha}{2}$, the worker has a fixed cost $c = 0$. This type of worker will always invest and, correspondingly, he will always have a high productivity $\overline{\theta}$. Finally, with a probability α, the worker has to incur in a intermediate fixed cost $\widehat{c}$, with $0 < \widehat{c} < \overline{\theta} - \underline{\theta}$. We denote these workers as "strategic" types, since their decision on investing in human capital will depend on the labor market conditions.

Workers learn their types before they decide whether or not to invest in human capital, and employers (or evaluators) do not observe workers' types. Workers' productivity (and the associated investment) is imperfectly observed by the employers. In particular, they observe the realization of one signal s, concerning the productivity of each worker. The signal's realization $s \in \{s_H, s_L\}$ depends on the underlying productivity of the worker, as follows:

$\Pr(s \mid \theta)$	$\overline{\theta}$	$\underline{\theta}$
s_H	1	$1-\gamma$
s_L	0	γ

That is, if the worker has high productivity, the signal will be s_H with certainty. However, if the productivity is low, there is some noise and thus the employer may observe both signal realizations. Notice that γ represents the accuracy of the signal, with a higher γ implying a more

[4] As we said in the introduction, we refer to non observable dimensions of human capital.

informative signal. More specifically, with $\gamma = 0$ the signal is non-informative whatsoever since employers always observe high realization s_H. On the contrary, with $\gamma = 1$ the signal is fully informative since it reveals the underlying productivity of the worker.[5]

The timing of the game is as follows.

1. Nature chooses the types of workers (the fixed cost c of acquiring human capital leading to high productivity).

2. Each worker chooses whether or not to invest in human capital and determines his productivity.

3. Nature chooses the signal $s \in \{s_H, s_L\}$ on the worker productivity according to the information structure described above. All employers receive the same signal.

4. Employers make their offers and, given the perfect competition assumption, workers receive their expected productivity.

4 The Market Equilibrium

As usual, we solve the game backwards and, thus, we start determining the expected salary of the workers. We have assumed a perfect competitive labor market, which implies that the expected salary coincides with the expected productivity of the worker. Namely:

$$w(s) = \underline{\theta} \Pr\left(\underline{\theta} \mid s\right) + \overline{\theta} \Pr\left(\overline{\theta} \mid s\right) = \underline{\theta} + (\overline{\theta} - \underline{\theta}) \Pr\left(\overline{\theta} \mid s\right). \quad (1)$$

On the one hand, if employers (or evaluators) receive signal s_L, the posterior probability that the worker has high productivity is zero. Then, $w(s_L) = \underline{\theta}$. If employers receive signal s_H, then they assign a positive probability that the worker has high productivity and they are willing to pay a higher salary, $w(s_H) = \underline{\theta} + (\overline{\theta} - \underline{\theta}) \Pr\left(\overline{\theta} \mid s_H\right)$.

Given these expected salaries, which will be the investment strategy chosen by workers in equilibrium? Or, in other words, under which circumstances the strategic workers are going to

[5]This model is similar to the credit reputation model of Diamond (1989).

invest in human capital? Solving the game and answering these questions require characterizing the Perfect Bayesian Equilibrium (PBE). As defined in Fudenberg and Tirole (1991), a PBE is a set of strategies and beliefs such that, at any stage of the game, strategies are optimal given the beliefs, and the beliefs are obtained from equilibrium strategies and observed actions using Bayes rule. Note the link between strategies and beliefs: the beliefs are consistent with the strategies, which are optimal given the beliefs.

Clearly, the choice will depend on the type of the worker: the type with $c = \infty$ will never invest, while the type with $c = 0$ will always do. We are then left to discuss what the strategic type with $0 < \widehat{c} < \overline{\theta} - \underline{\theta}$ is going to do. We have two equilibria in pure strategies.

4.1 The High Human Capital (HHC) Equilibrium

We denote as High Human Capital (HHC) the equilibrium in which the strategic worker chooses to invest. In equilibrium it must be that priors and beliefs are consistent with strategies. Then, in such a case, (and since, by assumption, the $c = 0$ type also invests), priors (beliefs of employers) are the following: the worker has high productivity with probability $\Pr\left(\overline{\theta}\right) = \frac{1-\alpha}{2} + \alpha = \frac{1+\alpha}{2}$, and low productivity with probability $\Pr\left(\underline{\theta}\right) = \frac{1-\alpha}{2}$. For the worker to be optimal to choose to invest, it must be that the expected salary (before the realization of the public signal) minus the cost when choosing to invest is larger than not to do it, that is

$$W_{HHC}\left(\overline{\theta}\right) - \widehat{c} \geq W_{HHC}\left(\underline{\theta}\right). \tag{2}$$

Notice that expected salaries depend on the productivity types (non directly on signals). In particular, the expected salary of a high productivity type is the following:

$$W_{HHC}\left(\overline{\theta}\right) = \Pr\left(s_H \mid \overline{\theta}\right) w^*_{HHC}(s_H) + \Pr\left(s_L \mid \overline{\theta}\right) w^*_{HHC}(s_L) = w^*_{HHC}(s_H)$$

Since $\Pr\left(s_H \mid \overline{\theta}\right) = 1$ and $\Pr\left(s_L \mid \overline{\theta}\right) = 0$. The expected salary of a low productivity type is the following:

$$W_{HHC}\left(\underline{\theta}\right) = \Pr\left(s_H \mid \underline{\theta}\right) w^*_{HHC}(s_H) + \Pr\left(s_L \mid \underline{\theta}\right) w^*_{HHC}(s_L) = (1-\gamma) w^*_{HHC}(s_H)$$

Since $\Pr(s_H \mid \underline{\theta}) = (1-\gamma), \Pr(s_L \mid \underline{\theta}) = \gamma$ and $w^*_{HHC}(s_L) = \underline{\theta}$, given our information structure, a bad signal realization is fully revealing. Finally, in order to save on notation, we have taken $\underline{\theta} = 0$.

Using Bayes rule[6], we obtain $\Pr\left(\overline{\theta} \mid s_H\right)$ and then, $w^*_{HHC}(s_H) = \frac{\overline{\theta}(1+\alpha)}{2-\gamma(1-\alpha)}$. Notice that the subindex HHC is required, since equilibrium strategies are consistent with priors beliefs, and consequently they also determine salaries. Moreover, when the realization of the signal is s_H, the equilibrium salary increases on the accuracy of the signal γ. This is because the higher the accuracy, the higher is the probability that the high realization signal comes from a high productivity worker.

Then, the incentive compatibility condition (2) becomes the following:

$$W_{HHC}\left(\overline{\theta}\right) - W_{HHC}\left(\underline{\theta}\right) = \gamma w^*_{HHC}(s_H) \geq \widehat{c}.$$

Plugging in the expression of $w^*_{HHC}(s_H)$, the necessary condition for the HHC equilibrium results:

$$\gamma w^*_{HHC}(s_H) = \frac{\gamma(1+\alpha)\overline{\theta}}{2-\gamma(1-\alpha)} \geq \widehat{c}. \tag{3}$$

where we recall that $\gamma \in [0,1]$. Notice that the LHS of the above inequality is increasing in γ and that, when $\gamma = 1$ (perfect information), the condition is just that the fixed cost is lower or equal than the gain in productivity, $\overline{\theta} \geq \widehat{c}$. Then, we can rewrite the incentive compatibility condition (3) in terms of γ, as follows:

$$\gamma \geq \underline{\gamma} = \frac{2}{(1+\alpha)\frac{\overline{\theta}}{\widehat{c}} + (1-\alpha)}. \tag{4}$$

If the level of accuracy of the public signal γ is large enough, strategic workers have enough incentives to invest in their human capital and the HHC equilibrium exists. Interestingly, the cut-off $\underline{\gamma}$ is increasing in $\widehat{c}$, and decreasing in $\overline{\theta}$ and α. In other words, the HHC is more likely to arise if the investment in human capital is more profitable ($\frac{\overline{\theta}}{\widehat{c}}$ increases), or if the proportion of strategic types is higher, since in equilibrium this increases the proportion of workers investing $\frac{1+\alpha}{2}$, making more valuable a high signal.

[6] Concretely

$$\Pr(\overline{\theta} \mid s^H) = \frac{\Pr(s^H \mid \overline{\theta}) \Pr(\overline{\theta})}{\Pr(s^H)}$$

where

$$\Pr\left(s^H\right) = \Pr(s^H \mid \overline{\theta}) \Pr(\overline{\theta}) + \Pr(s^H \mid \underline{\theta}) \Pr(\underline{\theta})$$

4.2 The Low Human Capital (LHC) Equilibrium

The analysis is analogous to the previous one. Suppose now that the strategic type chooses not to invest. Then, in such a case, priors that a worker has high productivity are $\Pr\left(\overline{\theta}\right) = \frac{1-\alpha}{2}$, whereas priors that a worker has low productivity are $\Pr\left(\underline{\theta}\right) = \frac{1-\alpha}{2} + \alpha = \frac{1+\alpha}{2}$. Let $w^{*}_{LHC}(s_H) = \overline{\theta}\Pr\left(\overline{\theta} \mid s_H\right)$ be the expected salary when the signal is high (s_H) and the strategic type firm has chosen not to invest. Using the bayes rule, we obtain $w^{*}_{LHC}(s_H) = \frac{\overline{\theta}(1-\alpha)}{2-\gamma(1+\alpha)}$. These salaries are linked to the accuracy of the signal. As in the previous case, when the realization of the public signal is low, the salary is zero, i.e $w^{*}_{LHC}(s_L) = 0$. Finally, the necessary condition for the strategic type to choose not to invest is that

$$W_{LHC}\left(\underline{\theta}\right) \geq W_{LHC}\left(\overline{\theta}\right) - \widehat{c} \tag{5}$$

For the same arguments than above, this is equivalent to the following:

$$W_{LHC}\left(\overline{\theta}\right) - W_{LHC}\left(\underline{\theta}\right) = \gamma w^{*}_{LHC}(s_H) \leq \widehat{c}.$$

Plugging the expression $w^{*}_{LHC}(s_H)$ in the incentive compatibility condition (5), we obtain the necessary condition for the LHC equilibrium in terms of the accuracy of the signal γ:

$$\gamma w^{*}_{LHC}(s_H) = \frac{\gamma(1-\alpha)\overline{\theta}}{2-\gamma(1+\alpha)} \leq \widehat{c}. \tag{6}$$

As in the case of the HHC equilibrium, the LHS of the expression is increasing in γ. In this case when $\gamma = 1$ (perfect information), the condition becomes that the fixed cost is higher or equal than the gain in productivity, $\overline{\theta} \leq \widehat{c}$. Analogously to the HHC equilibrium, we can rewrite the incentive compatibility condition (6) in terms of γ, as follows:

$$\gamma \leq \overline{\gamma} = \frac{2}{(1-\alpha)\frac{\overline{\theta}}{\widehat{c}} + (1+\alpha)}. \tag{7}$$

If the level of accuracy of the public signals γ is not sufficiently high, strategic workers have not enough incentives to invest in their human capital and the LHC equilibrium exists. As in the discussion of the HHC equilibrium, $\overline{\gamma}$ is increasing in $\widehat{c}$, and decreasing in $\overline{\theta}$. Contrary to the previous case, $\overline{\gamma}$ increases in α. The LHC is more likely to arise if the investment in human capital (captured by $\frac{\overline{\theta}}{\widehat{c}}$) is less profitable, or if the proportion of strategic types is higher, since in the equilibrium this decreases the proportion of workers investing $\frac{1-\alpha}{2}$, making less valuable a high signal.

4.3 Equilibrium Analysis

We have characterized the two possible equilibria in pure strategies of the game. The next step is to analyze the impact of the accuracy of the signal in the expected utilities.

LEMMA 1 *The expected utility of the strategic worker: i) in the HHC equilibrium -$W_{HHC}\left(\overline{\theta}\right)-\widehat{c}$- is increasing in the accuracy of the signal γ; and ii) in the LHC equilibrium -$W_{LHC}\left(\underline{\theta}\right)$- is decreasing in the accuracy of the signal γ.*

Lemma 1 shows that the accuracy has a positive effect when the strategic worker chooses to invest and negative effect in the low human capital equilibrium. Then, this is consistent with the previous result that the necessary condition for the HHC equilibrium -(3)- (LHC equilibrium-(6)-) is more (less) likely to be met when the accuracy of the signal is large.

The next proposition uses the incentive compatibility conditions of the HHC and LHC equilibria to provide a full characterization of the perfect bayesian equilibrium of the game in terms of the accuracy of the signal.

PROPOSITION 1 *When the level of accuracy γ is small, the only equilibrium is the LHC, whereas, when the level of accuracy is large enough, the only equilibrium is the HHC. For intermediate levels of accuracy, both HHC and LHC may arise:*

1. *if $0 < \gamma < \underline{\gamma}$ then a LHC equilibrium exists*
2. *if $\underline{\gamma} < \gamma < \overline{\gamma}$ then a LHC and HHC equilibrium exists (multiplicity of equilibria)*
3. *if $\gamma > \overline{\gamma}$ then a HHC equilibrium exists.*

The equilibrium characterization is illustrated in Figure 1.

[Figure 1 around here]

The characterization of the equilibrium depends on two facts: i) the salary linked with a high signal is higher in the HHC equilibrium, $w^*_{HHC}(s_H) > w^*_{LHC}(s_H)$. This is because, for a given γ, the probability that a good signal comes from a high productivity worker increases with the proportion of workers investing in human capital. ii) The incentives to invest in human capital increases with the accuracy of the signal irrespectively of the equilibria, i.e $W\left(\overline{\theta}\right) - W\left(\underline{\theta}\right) = \gamma w^*(s_H)$ is increasing in γ. The two facts (i) and (ii) yield to $\underline{\gamma} < \overline{\gamma}$ and, jointly with the incentive compatibility conditions (4) and (7), they fully characterize the perfect bayesian equilibrium of the game. We want to point out that making more profitable the investment in human capital (increasing $\overline{\theta}$ or decreasing $\widehat{c}$) decreases $\underline{\gamma}$ and $\overline{\gamma}$ and, consequently, it increases the likelihood of the HHC equilibrium, whereas increasing the proportion of strategic types α, decreases $\underline{\gamma}$ and increases $\overline{\gamma}$, thus enlarging the parameter space for which the multiplicity of equilibria exists.

5 Statistical Discrimination

The previous section is devoted to explain the relationship between incentives to invest in human capital and the informativeness of the workers' productivity signals. We now move to the core of our paper by investigating how the accuracy of the productivity signals is determined by the selection process in a setting in which there are different types of workers. Consider that workers belong to one of the following two groups: group m, for example males, and group f, for example females. We assume that ρ is the proportion of individuals of group m and and therefore $(1-\rho)$ is the proportion of individuals of group f. For simplicity, and for a more direct interpretation of our results in terms of discrimination, we assume that $\rho = \frac{1}{2}$. These two groups may differ in the accuracy of their productivity signals in the following way. We assume that the salaries and hiring decisions of workers are done by the selection committees. The representation of each worker's group in these selection committees determines the accuracy of the signals of such particular group. In what follows we formalize this idea.

Let ϕ^m be the proportion of male managers in the selection committee, and ϕ^f the proportion of females, where $\phi^m + \phi^f = 1$. Let γ^m and γ^f be the accuracy of the productivity signal of male and female workers respectively. The next key assumption determines the way in which the accuracy of productivity signals depends on the composition of the evaluation committee.

Assumption 1 *$\gamma^m = h^m(\phi^m, \phi^f)$ with $\frac{\partial h^m}{\partial \phi^m} > 0$ and $\frac{\partial h^m}{\partial \phi^f} < 0$, while the opposite occurs for $\gamma^f = h^f(\phi^f, \phi^m)$, $\frac{\partial h^f}{\partial \phi^m} < 0$ and $\frac{\partial h^f}{\partial \phi^f} > 0$.*

We label this as the "homo-accuracy" assumption: the accuracy of each group of workers is increasing in the proportion of such group in the evaluation committee, and consequently decreasing in the proportion of the other group. For tractability, we also make the assumption of symmetry, $\gamma^m = h^m(\phi^m, \phi^f) = \gamma^f = h^f(\phi^{f\prime}, \phi^{m\prime})$ if $\phi^m = \phi^{f\prime}$ and $\phi^f = \phi^{m\prime}$. Then we can use the same function $h()$ for both groups. Furthermore, using that $\phi^m = 1 - \phi^f$ we can rewrite all the functions as a function of proportion of female in the selection committee ϕ^f. In particular, $\gamma^f = h(\phi^f)$ and $\gamma^m = h(1 - \phi^f)$ with $\frac{\partial h(x)}{\partial x} > 0$.

How the "homo-accuracy" assumption works in the real world can be drawn from the empirical literature of non-gender neutrality in selection process and the evidence collected by these studies. Generally speaking, we refer to the concept of "screening discrimination", which occurs when employers are less able to evaluate the ability of workers from one group than from another (Aigner and Cain, 1977; Lundberg and Startz, 1983; see a review in Altonji and Blanck, 1999). Cornell and Welch (1996) show that, even when employers do not have preference for similar people, they favour promotion of people of the same type, since they can judge job applicants' unknown qualities better when candidates belong to the same group. In other words, they can better distinguish good and bad individuals in a population of similar people. As a consequence, the measurement error for a given evaluator is smaller when the considered people have a similar cultural background. Bagues and Perez-Villadoniga (2012) show that in a multidimensional framework of statistical discrimination where the accuracy of evaluators depends on how knowledgeable they are in each dimension, candidates who excel in the same dimensions as the evaluator tend to be preferred. This is because evaluators can assess knowledge more accurately at those dimensions where they are more knowledgeable, and thus they will consider more important the signals in these dimensions. Lavy (2008) compares data on blind and non-blind scores that high school students receive on matriculation exams in their senior year in Israel and finds that the grades obtained in non-blind tests are sensitive to the characteristics of evaluators. In the context of gender, Pinkston (2003) find strong evidence that employers receive less-accurate initial signals from women than from men, even when comparing men and women in the same job. A recent experiment by Ferrari et al.(2015) find that, although on average there is no bias *per se* in favour of a group in the promotion process in companies, the evaluators assign different weights to signals such as occupational experience and education of a male and female candidate. They find that the informativeness of the productivity signals depends on the match between the candidate and the evaluator, which in turn may be captured by having the same gender. The accuracy in evaluating candidates of a different gender may depend on the existence of gender segregated networks, gender segregated tasks in jobs, or on the presence of gender stereotypes. Although Bagues et al. (2016) find no evidence that these mechanisms are in action in specific contexts of promotions in academia, they may still be crucial in evaluations affected by unconcious bias on unobservable dimensions of productivity. Accuracy may also depend on differences in language, communication styles and perceptions, which make it easier for a person to evaluate personal skills and attitudes of people of their same gender and to believe these characteristics to be relevant for the position (Lang, 1986). This concept has been studied by a large socio-linguistic literature: differences in verbal and non-verbal communication styles between groups of different race or gender may affect economic and social outcomes (Canary and Dindia, 2009; Scollon et al., 2011).[7]

In short, there is a supportive evidence that males (females) evaluate in a more accurate way males (females). We introduce this fact in our framework by considering that the probability that a low productivity type of some group is promoted (a type II error decision) is decreasing in the

[7] These communication barriers across genders that exist in the workplace (Angier and Axelrod, 2014) have been associated to discrimination in the labour market (Lang, 1996) and to the selection process of women at top positions (Flabbi et al., 2014).

proportion of such group in the evaluation committee, $\Pr(s_H \mid \underline{\theta}_m) = 1 - \gamma^m$ is decreasing in ϕ^m (since $\gamma^m = h^m(\phi^m, \phi^f)$ is increasing in ϕ^m). Consider for instance the following mechanism. The committee decisions are taken by a qualified majority voting rule, and the "quality" of the votes of committee members depends on their match with the group of the candidate.[8] In particular, focus on the case that the committee is evaluating a low productivity male candidate. Let $G_m(x \mid \underline{\theta}_m)$ and $G_f(x \mid \underline{\theta}_m)$ the distribution of positive votes that the candidate received by the committee members of males and females respectively. The core of our assumption can be translated, for example, into that the both distribution functions are ordered according to the first order stochastic dominance, i.e $G_m(x \mid \underline{\theta}_m) \geq G_f(x \mid \underline{\theta}_m)$. If this is true, the number of votes of this low productivity worker and then his possibility of promotion negatively depends on the proportions of committee members of his group.

Assumption 1, jointly with Proposition 1, delivers the classical result that the group that has a larger proportion in the evaluation committee has more incentives to invest in human capital.

PROPOSITION 2 *If $\phi^f < \frac{1}{2}$ then, $\gamma^m > \gamma^f$ and then: i) males invest more in human capital than females, ii) men's wages are higher.*

In words, the group that has a smaller proportion in the evaluation committee has a noisier signal of her productivity and then it has: i) less incentives to invest in human capital and ii) a lower wage, meaning that female high types $\overline{\theta}$ receive lower salaries than men high types $\overline{\theta}$. Hence, statistical discrimination may lead to an inefficient allocation of resources, since it discourages investment in human capital. At the same time, it induces an unfair distribution of salaries, because individuals with the same productivity are paid differently depending on whether or not they belong to the group that it is more represented in the evaluation committee.

[8] Of course, many other voting and bargaining mechanisms are used to take committee decisions. More importantly, in this example and in the motivation of our mechanism, we are focusing on direct effects, sincere voting and "better" voting when types of the candidate and committee member coincide. Bagues et al (2016) shows empirically that there may exists relevant indirect effects. For example, committee members belonging to majority may abstain or disregard their private information when they are evaluating a minority candidates (the swing voter's effect of Feddersen and Pesendorfer (1996)). When the minority is better represented in the committee, members of the majority may be more willing to participate actively in the decision over minority candidates.

5.1 The Role of Quotas

In this setting, using quotas in the selection committees may alleviate the distributional conflict between the minority and majority groups. Our goal is to analyze whether introducing quotas could restore the allocation efficiency. Therefore, we take a normative approach and focus on characterizing policies that maximize total production. In our simple setting, in which we assume that $\overline{\theta} \geq \widehat{c}$, the efficient allocation requires (if it is feasible) that in both groups the strategic workers invest in human capital (i.e both groups are in the HHC equilibrium). As we will see below, the feasibility of having the two groups in the good equilibrium HHC depends on the *accuracy function* $h(x)$ that maps the composition of evaluation committees into the accuracy of productivity signals.

In order to understand how quotas may change the equilibrium and modify the total output, it is useful to consider the following example represented in Figure 2.

[Figure 2 around here]

Figure 2 represents the signal accuracy of each group as a function of the proportion of females in the selection committee. In this example, the proportion of female managers in the evaluation committee is sufficiently low to be in the bad equilibrium LHC (point a), while the males are in the good equilibrium HHC (point b). The quota policy leading to an increase in the proportion of women in the evaluation committee has two opposite effects: on the one hand, it increases the precision of the signal from females (increasing their incentive to invest); on the other hand, it reduces the precision of the productivity signal of males (decreasing their incentive to invest). Therefore, if we start from an economy where most of the managers in the evaluation committee are men, the introduction of a quota of women (i.e. increasing ϕ^f and γ^f, and reducing γ^m) will be efficient if the first effect dominates the second one. In our simple discrete model, this would happen if we get that women (with intermediate cost) may find attractive to invest in human capital, while keeping the incentive of men in investing in human capital. Formally, this optimal quota ϕ^{*f} satisfies $\gamma^f = h(\phi^{*f}) \geq \underline{\gamma}$ and $\gamma^m = h(1 - \phi^{*f}) \geq \overline{\gamma}$.

In other words, the introduction of a quota is an improvement in efficiency if males are still in the HHC equilibrium (i.e. $\gamma^m > \overline{\gamma}$) and females move to the region where HHC equilibrium may exists (i.e $\gamma^f > \underline{\gamma}$). In Figure 2, this is represented by moving from point (a, b) to (a', b').

Consider the case in which the accuracy function is linear, in particular $\gamma = h(x) = x$. Then, the conditions for the improvement in efficiency described in the Figure 2, $1-\phi^{*f} \geq \overline{\gamma}$ and $\phi^{*f} \geq \underline{\gamma}$, can be summarized as follows:

$$\underline{\gamma} + \overline{\gamma} \leq 1 \tag{8}$$

It is important to note that this condition is easier to hold when the productivity of the investment in human capital increases (increasing $\overline{\theta}$ or decreasing $\widehat{c}$). This condition guarantees that males remain in the good equilibrium HHC, and females move from the bad equilibrium to the multiplicity region. In order to be sure that both groups are in the good equilibrium, the feasibility condition (8) becomes more demanding: $1 - \phi^{*f} \geq \overline{\gamma}$ and $\phi^{*f} \geq \overline{\gamma}$, which is equivalent to $2\overline{\gamma} \leq 1$.

5.2 The Optimality of Quotas

The previous discussion has two important caveats. First, we want to consider a large set of accuracy functions. More importantly, for obtaining a normative result over quotas, we need to state what would be the outcome in absence of quotas, and how quotas would change this outcome. In this subsection, we address these two caveats and we show that, under some conditions, introducing quotas may lead to a more efficient allocation of resources.

We focus on a particular family of accuracy functions $h(x) = x^\beta$, for $\beta \in (0, \infty)$. This specification allows us to discuss how the curvature of the functions affects the market equilibrium, as well as the performance of the quotas. As we discussed above, if we increase the proportion of one group in the evaluation committee (i.e we increase the accuracy of the productivity signals of such group), we decrease the representation of the other group. The balance of these effects over total welfare depends on the curvature of the accuracy functions. The more concave the function is, the more likely it is that moving to a more equalitarian representation in the selection committee increases welfare.

In order to define what would be the outcome in absence of quotas, we need to introduce some assumption on how the evaluation committees are formed.

ASSUMPTION 2 *The representation of each group in the evaluation committees coincides with the proportion of workers of such group into the set of high productivity workers.*

As our model at this stage is static, we interpret assumption 2 as making a steady state analysis. In the next section, we extend our model to a dynamic setting where the representation in the evaluation committees in period t depends on the proportion of high productivity workers in period $t-1$.

Since we assumed that investing in human capital is efficient, $\overline{\theta} \geq \widehat{c}$, we can denote as equalitarian first best an equilibrium in which both groups are in the good equilibrium HHC (i.e $\gamma^m > \overline{\gamma}$ and $\gamma^f > \overline{\gamma}$). As the sizes of the initial population of males and females are assumed to be the same, by assumption 2 this implies that the composition of the evaluation committees is also completely equalitarian, $\phi^f = \frac{1}{2}$. Next Lemma states for which functions in the family under consideration we have that $h(\frac{1}{2}) \geq \overline{\gamma}$.

PROPOSITION 3 *For accuracy functions as $h(x) = x^\beta$, the equalitarian first best equilibrium is feasible if $\beta < \beta^* = \frac{\ln \overline{\gamma}}{\ln \frac{1}{2}}$.*

According to our previous intuition, the first best can be implemented as long as the accuracy function is "concave enough".[9] This means that if $\beta > \beta^*$ the equalitarian first best is not feasible, and this cannot be obtained by any quota policy. This is because, if we impose equalitarian representation in the selection committees, the accuracy of the productivity signal will be not large

[9]Notice that $\beta^* \in (0, \infty)$. This is because $\overline{\gamma} \in (0,1)$. If the cost of investment in human capital is 0, then $\overline{\gamma} = 0$ since all strategic workers will invest in human capital independently of γ. In that case $\beta^* = \infty$, meaning that the equalitarian first best is feasible for all accuracy functions $h(x) = x^\beta$. On the contrary if $\widehat{c} = \overline{\theta} = 1$, there is no gain in investing in human capital independently of γ. This implies that $\beta^* = 0$, which means that the equalitarian first best is not feasible for any accuracy functions $h(x) = x^\beta$.

enough to provide sufficient incentives to guarantee that all workers are in a good equilibria HHC. Under such circumstances, asymmetric selection committees may maximize the total investment in human capital, by concentrating the effort in one of the groups and sacrificing the other.

Consider now that we are in a asymmetric equilibrium, in which males are in the HHC and females are in the LHC. In this asymmetric equilibrium, the proportion of males and females educated are $\frac{1+\alpha}{2}$ and $\frac{1-\alpha}{2}$ respectively. Then, by assumption 2, the composition of the evaluation committees is also asymmetric. Concretely, in this asymmetric equilibrium, the proportion of females (males) in the selection committees is $\phi^f = \frac{1-\alpha}{2}$ ($\phi^m = \frac{1+\alpha}{2}$). Then, if i) $(\frac{1-\alpha}{2})^\beta < \overline{\gamma}$ and ii) $(\frac{1+\alpha}{2})^\beta > \overline{\gamma}$, the asymmetric equilibrium may arise and persist. From similar computation than Proposition 3, condition i) is equivalent to $\beta > \beta_L^* = \frac{\ln \overline{\gamma}}{\ln \frac{1-\alpha}{2}}$ and condition ii) is equivalent to $\beta < \beta_H^* = \frac{\ln \overline{\gamma}}{\ln \frac{1+\alpha}{2}}$, where $\beta_L^* < \beta_H^*$. Then if $\beta \in [\beta_L^*, \beta_H^*]$ both conditions are satisfied and the asymmetric equilibrium may arise. It is easy to show that the maximum β required for the equalitarian first best being implementable lies in the interior of this interval, i.e $\beta_L^* < \beta^* < \beta_H^*$. Using this fact, we can show that introducing quotas may restore efficiency under some circumstances.

Proposition 4 *For accuracy functions as $h(x) = x^\beta$, if $\beta \in [\beta_L^*, \beta^*]$ the asymmetric equilibrium may arise and persist, and it is feasible to achieve the equalitarian first best by imposing an equalitarian system of quotas.*

Multiplicity of equilibria is a known feature of statistical discrimination settings. Proposition 4 shows that a system of quotas may play a role in avoiding being traped in an inefficient equilibrium (women are underrepresented in higher hierarchies and selection committees$\Rightarrow$noiser productivity signals and lower incentives to invest in human capital$\Rightarrow$women are less promoted and underepresentated in committess). However, as shown by the next proposition, it is also true that, for alternative constellation of parameters, imposing an equalitarian system of quotas may reduce welfare.

Proposition 5 *For accuracy functions as $h(x) = x^\beta$, if $\beta \in [\beta^*, \beta_H^*]$ the asymmetric equilibrium* *may arise and persist. but imposing an equalitarian system of quotas may reduce total investment in human capital.*

The intuition behind this proposition is as follows. In the asymmetric equilibrium, males are in the good equilibrium HHC and females in the bad one, LHC. Imposing an equalitarian quota would lead the groups to levels of accuracy below the threshold $\overline{\gamma}$, making it possible for both groups to be in the bad equilibrium, LHC.

This result is in line with the evidence that shows that affirmative action policies may not be effective if the "context" is not favorable, for example because prejudicial attitudes are too strong and difficult to change with these measures, or because specialization in jobs comes from men and women having different preferences for particular types of works (Sloane et al., 2005). In these circumstances, the reduction of gender inequality in the labor market may still be desirable, but some degree of gender segregation can be accepted, and thus the optimal level of job segregation remains to be defined. Affirmative action policies may not be efficient in these contexts (Myers, 2007). Given the complex combination of factors which contributes to define gender segregation in the workplaces (culture, skills, preferences, family relationships, on top of discrimination), which may make affirmative action policies not effective in some circumstances, the evidence also shows that there is a high persistence in gender segregation in the labor market, and that the reduction of gender segregation in the short term appears very limited (Cohen, 2013; England, 2010).

Next section extends this model along two dimensions and shows the robustness of the previous results. We will consider a continuous distribution of costs and a simple dynamic version of the static model.

6 A Simple Dynamic Model with a Continuous of Types

We start by considering a simple dynamic version of our model, where the human capital investment decisions of period $t-1$ determines the composition of the evaluation committee and the accuracy for each population group at period t. In particular, we assume that among workers who have invested in human capital at $t-1$, a representative percentage of each group becomes part of the evaluation committee at t. We also consider that the fixed cost of investing in human capital, $c \geq 0$ is independently distributed according to a continuous uniform distribution function G over $[0,1]$.

Every stage of the dynamic game is identical to the static model described in the previous section. A new cohort of workers of measure one is born every period. Every cohort is composed by two identical ex-ante groups (i.e. with the same size and the same distribution of talent cost $G(.)$): group m and group f. All workers learn their types c, and take their decisions over investing or not in human capital. Beside the new distribution of types, most of the workers work for only one period before retirement and they face the same trade-offs as we have analyzed before. An infinitesimal but representative proportion of educated workers of both groups are promoted to the evaluation committee in the second period.[10] Then, the only intertemporal link in the model is through the selection committee's composition. As we said above, we are assuming that the percentage of each group, m and f, in the selection committee at period t is the same as the proportion of each group among the workers that have been invested in education at period $t-1$. The idea behind this assumption is that workers hired at period $t-1$ reveal their true type at the end of the period and only high productivity workers are part of the selection committee at period t. Then, let ϕ^f_{t-1} be the proportion of females among the group of workers that have invested in human capital at $t-1$. Following assumption 1 the accuracy of the productivity signals of females at period t is given by $\gamma^f_t = h(\phi^f_{t-1})$ and consequently determined by the labor market equilibrium at period $t-1$.

[10]By assuming that the number of workers participating to committees is infinitesimal, we are ignoring the impact over the incentives at $t-1$ of rents earned by workers participating in an evaluating committee at t. Taking these rents into account would foster the investment in education at period $t-1$, but it would not change qualitatively any of our results.

We first characterized the static perfect bayesian equilibrium for a continuous distribution of fixed costs. In order to do that, we take as given the accuracy of the productivity signal of an arbitrary population of workers with a fixed costs of acquiring human capital distributed according to a uniform distribution in the interval $[0, 1]$, $c \sim G(.) = U[0, 1]$. The characterization of the market equilibrium follows the same procedure as in the discrete case. There is however an important difference: while in the case of discrete types, multiplicity of equilibria arises, in the continuous case, there is only one equilibrium characterized by a unique marginal type $\widehat{c}$. In this equilibrium, the marginal type is indifferent between investing or not in human capital, where higher types (lower types) prefer not investing (investing). Using this feature of the equilibrium, we characterize the marginal type, $\widehat{c}$, as follows:

$$W\left(\overline{\theta}\right) - \widehat{c} = W\left(\underline{\theta}\right). \tag{9}$$

Where $W\left(\overline{\theta}\right)$ $(W\left(\underline{\theta}\right))$ is the expected wage of a worker that invest (not invest) in human capital. The computation of the expected salary is analogous to the discrete case, that is $W\left(\overline{\theta}\right) = w(s_H)$ and $W\left(\underline{\theta}\right) = (1-\gamma)w(s_H)$, where the expected wage is equal to the expected productivity of the worker $w(s_H) = \overline{\theta}\Pr(\overline{\theta}|s_H)$. We can rewrite the equation (9) as follows:

$$\begin{aligned} \overline{\theta}\Pr(\overline{\theta}|s_H) - \widehat{c} &= (1-\gamma)\overline{\theta}\Pr(\overline{\theta}|s_H) && (10) \\ \widehat{c} &= \gamma\overline{\theta}\Pr(\overline{\theta}|s_H) && (11) \end{aligned}$$

Using that all types with c lower than $\widehat{c}$ invest in human capital, and those with higher costs do not invest, we obtain from bayes rule $\Pr(\overline{\theta}|s_H) = \frac{G(\widehat{c}_t)}{G(\widehat{c}_t)+(1-\gamma_t)(1-G(\widehat{c}_t))}$. Plugging this expression into equation (11) and simplifying we obtain:

$$\frac{1-\gamma_t}{\gamma_t} = \frac{G(\widehat{c}_t)}{\widehat{c}_t}\left(\overline{\theta} - \widehat{c}_t\right)$$

As c is uniformly distributed on $[0, 1]$, the indifferent type $\widehat{c}_t$ is also the proportion of educated workers in the population $G(\widehat{c}_t)$. Using this, we can explicitly define the indifferent type, $\widehat{c}_t$, as a function of the accuracy level γ_t.

$$\widehat{c}_t = \overline{\theta} + 1 - \frac{1}{\gamma} \tag{12}$$

Note that the above expression is negative and then, not well defined if $\gamma_t < \gamma_L = \frac{1}{1+\overline{\theta}}$. For values γ_t smaller than γ_L, there is no worker that invests in human capital.[11]

This equilibrium is consistent with the results of the static and discrete model. If $\gamma = 1$ (i.e. perfect information) the worker invests in skills if $c \leq \overline{\theta}$ and the proportion of skilled workers is increasing on the accuracy of their productivity signal. To save on notation we set $\overline{\theta} = 1$.

We move to analyze the statistical discrimination problem in this continuous setting. As before, let ϕ^f_{t-1} ($\phi^m_{t-1} = 1 - \phi^f_{t-1}$) be the proportion of females (males) in the selection committee at period $t-1$. We also assume that γ^f_t (γ^m_t) is increasing (decreasing) in ϕ^f_{t-1}

$$\begin{aligned} \gamma^f_t &= \frac{1}{2} + \frac{1}{2} h(\phi^f_{t-1}) \\ \gamma^m_t &= \frac{1}{2} + \frac{1}{2} h(1 - \phi^f_{t-1}) \end{aligned}$$

where $h(\phi)$ is increasing (can be concave or convex) and with $h(0) = 0$ and $h(1) = 1$. Note that we have added $\frac{1}{2}$ in order to guarantee that $\widehat{c}_t$ is always well defined. As in the previous model, if $\phi^f < \phi^m$ then $\gamma^f < \gamma^m$, women invest in human capital less than men and they obtain on aberage lower wages by productivity.

6.2 Efficient Composition of the Selection Committee

In this subsection, we characterize the optimal composition of the selection committee ϕ^{f*} that maximizes total welfare at the steady state, $\phi^j_{t-1} = \phi^j_t$. Note that there is only one control variable ϕ^f. The proportion of females in the evaluation committee determines the accuracy of the productivity signal of both groups, which in turns, determines the proportion of educated workers in both groups. In this setting, total welfare depends not only on the proportion of educated workers in both groups, but also on the cost of the investment in human capital incurred by the

[11] Technically, this result is driven by the fact that the marginal productivity of the investment in education of the worker, $\gamma\overline{\theta}\Pr(\overline{\theta}|s_H)$ is an increasing function of the indifferent type $\widehat{c}$, and the slope of such function is 1 when $\gamma_L = \frac{1}{1+\overline{\theta}}$, and smaller than 1 for lower γ, implying that the only equilibrium point is 0.

educated workers. In particular, total welfare depends on the proportion of educated workers in both groups c^j (since we have normalized the productivity of educated workers to 1) and their cost of investment in human capital $\int_0^{c^j} c^j g(c^j)dc^j$. Then, ϕ^{f*} is characterized by the solution of the following maximization problem:

$$
\begin{aligned}
\phi^{f*} &\in \arg\max \left\{ \left[c^f - \int_0^{c^f} c^f g(c^f) dc^f \right] + \right. \\
&\qquad \left. \left[c^m - \int_0^{c^m} c^m g(c^m) dc^m \right] \right\} \\
\text{s.t. } c^f &= 2 - \frac{1}{\gamma^f} \text{ and } c^m = 2 - \frac{1}{\gamma^m} \\
\text{where } \gamma^f &= \frac{1}{2} + \frac{1}{2}h(\phi^f) \text{ and } \gamma^m = \frac{1}{2} + \frac{1}{2}h(1-\phi^f)
\end{aligned}
$$

In the discrete model, the only objective was to maximize the total proportion of educated workers. In the present setting what also matters is who invest in human capital. Welfare maximization requires that workers with the lower cost of investing in human capital invest, independently of the group they belong to.

Next proposition shows the efficient composition of the selection committee and provides a sufficient condition for such efficient composition being completely egalitarian.

Proposition 6 *If $h(\phi^f)$ is concave the efficient solution is $\phi^{f*} = \phi^{m*} = \frac{1}{2}$.*

Proposition 6 provides a sufficient condition for the equalitarian composition of the selection committee to be efficient when, as it is in our case, the talent is equally distributed among groups. The intuition is as follows. The indifference curves of the social planner over the proportion of educated workers among groups are convex as the standard consumer preferences. On the one hand, for a given number of educated workers, she always prefers an equalitarian distribution among both groups, since in such way she minimizes the total workers' investment in human capital. On the other hand, when the accuracy function $h(\phi^f)$ is concave, an equalitarian composition of the evaluation committee maximizes the total number of educated workers in the population.

As the preferences of the social planer and the "screening technology" go in the same direction, an equalitarian composition of the evaluation committee (leading to an equalitarian distribution of educated workers in the steady state) is the efficient solution when $h(\phi^f)$ is concave. On the contrary, if $h(\phi^f)$ is convex, a non egalitarian composition of the selection committee may maximize the total number of educated workers. This is because the marginal impact of increasing the representation of one group in the evaluation committee over the accuracy function is increasing in the current proportions of members of this group in the evaluation committee. Then, there is a trade-off between preferences of the social planner and the feasibility imposed by the "screening technology".

We now turn to characterize the solution of the problem for our leading example of accuracy functions $h(x) = x^\beta$. As it is shown in the proof of Proposition 6, the equalitarian composition of the selection committee is always a solution of the first order condition of the problem independently of the curvature of the $h(x)$. However, only if $\beta \leq \beta_H^d = 2.53$ the second order condition is negative, and therefore the equalitarian composition is optimal.[12]

Figure 3 plots the efficient solution when $h(\phi) = \phi^\beta$ for different values of β . Note that having all members of one group educated is always feasible in this example, since $h(1) = 1 \rightarrow \gamma^f = 1 \rightarrow c^f = 1$. The figure illustrates that the efficient solution is equalitarian as long as the convexity of the accuracy function is relative small. When the convexity is relative large, $\beta > 2.53$, the "screening technology" effect dominates and the efficient solution is an unequal composition of the selection committee.

[figure 3 around here.]

Next proposition summarizes these numerical results

[12]The cut-off point β_H^d is obtained by evaluating the second order condition on the equalitarian composition of the selection committee, and after that making the second order condition equal to 0:

$$\beta_H^d(\beta_H^d - 1)(\frac{1}{2})^{\beta_H^d - 2}(1 - (\frac{1}{2})^{\beta_H^d})(1 + (\frac{1}{2})^{\beta_H^d}) - (\beta_H^d)^2(\frac{1}{2})^{2\beta_H^d - 2}2(2 - (\frac{1}{2})^{\beta_H^d}) = 0.$$

It can be shown that for β lower than β_H^d, the second order condition is negative. On the contrary, for β higher than β_H^d, the second order condition is positive and then the equalitarian composition is a minimum.

Proposition 7 *For accuracy functions as $h(x) = x^{\beta}$, if $\beta < \beta_H^d$ the equalitarian allocation $\phi^{f*} = \phi^{m*} = \frac{1}{2}$ is efficient.*

In a nutshell, the efficient steady state allocation depends on the preferences of the social planner that favors an equalitarian distribution of educated workers and the curvature of the "screening technology" $h(\phi)$ that determines the feasible set of educated people of each group $\left(c^m, c^f\right)$. With concave $h(\phi)$, no discriminatory allocation leads to a higher aggregate human capital, $c^m + c^f$. For a sufficiently high convexity of $h(\phi)$, the opposite happens.

6.3 Decentralized Dynamic Equilibrium and the Role of Quotas

Finally, we want to explore whether or not the decentralized dynamic equilibrium is efficient. We focus on a simple dynamic link between periods. We are assuming that the proportion of females in the selection committee ϕ_t^f is given by the proportion of females among the educated workers in $t-1$. Concretely:

$$\phi_t^f = \frac{c_{t-1}^f}{c_{t-1}^m + c_{t-1}^f} \text{ and } \phi_t^m = \frac{c_{t-1}^m}{c_{t-1}^m + c_{t-1}^f}$$

Using the characterization of the marginal types $\widehat{c}_t^f = 2 - \frac{1}{\gamma_t^f}$ and the assumption of the "screening technology", $\gamma_t^f = \frac{1}{2} + \frac{1}{2} h(\phi_t^f)$, we can derive the dynamic equation between the proportion of females in the evaluation committee (state variable) in periods $t-1$ and t.

$$\phi_t^f = \frac{1}{1 + \frac{1 + h(\phi_{t-1}^f)}{h(\phi_{t-1}^f)} \frac{h(1 - \phi_{t-1}^f)}{1 + h(1 - \phi_{t-1}^f)}} \tag{13}$$

Next proposition states that the dynamic equation (13) has at least three steady state equilibria.

Proposition 8 *There exist three decentralized equilibria, $\phi_t^f = \phi_{t-1}^f = \phi_{EE}^f$; i) $\phi_{EE}^f = 1/2$; ii) $\phi_{EE}^f = 1$; and iii) $\phi_{EE}^f = 0$.*

Note that the equalitarian allocation is always a decentralized equilibrium independently of the shape of $h(\phi)$. However it is crucial to determine the stability of such equilibrium in our dynamic model, and how this stability depends on the curvature of the "screening technology" $h(\phi)$. In order to do that, we focus on our leading example $h(\phi) = \phi^{\beta}$.

Proposition 9 *For accuracy functions as $h(x) = x^{\beta}$, i) There exist a cut-off point $\beta_S^d \backsimeq 1.3833$ such that if $\beta < \beta_S^d$ the equalitarian equilibrium is stable; ii) if $\beta \in [\beta_S^d, \beta_H^d]$ the equalitarian equilibrium is efficient but unstable. Therefore imposing an equalitarian system of quotas may increase total welfare.*

Next figure illustrates part i) of Proposition 9 for two particular values of β.

[Figure 4 around here]

Part ii) of Proposition 9, and the characterization of the efficient allocation in Proposition 7 show us that there is a range of parameters for which the equalitarian allocation is efficient but it cannot be sustained in a decentralized equilibrium. In particular, for $\beta \in [\beta_S^d, \beta_H^d]$ the equalitarian allocation (which is the first best) is never achieved in the decentralized equilibrium when the initial point (or status quo) is not equalitarian. In this case, introducing a quota can restore efficiency.

To sum up, we first proved in an static setting that a quota system may help sustain the equalitarian efficient allocation. Then, we extended the analysis in order to consider dynamic implications of our model. In this setting, the stability of the efficient equalitarian allocation is crucial: when the conditions over the screening technology for this stability are not met, a system of quotas can make the equalitarian efficiency allocation achievable. In a nutshell, we show that the decentralized equilibrium in the labor market can generate an inefficient trap for women. As they are underrepresented in higher hierarchies and selection committees, their productivity signals turn out to be less accurately observed, thus generating lower incentives to invest in human capital (and to compete for promotions), and reinforcing their initial underepresentation. A quota system targeted to restore the equalitarian composition of committees may overcome this inefficient trap, improving the allocation of talent in the economy and enhancing total welfare.

7 Conclusions

This paper has studied a statistical discrimination model *a la* Cornel and Welch (1996) with two important features. Firstly, productivity is endogenous, since it depends on the investment of workers in specific human capital. Secondly, the reward of this investment, and consequently the incentives to invest, depends on the observability of the productivity. We consider workers in two different groups which, although identical ex-ante, generate productivity signals of different accuracy. More specifically, due to the "homo-accuracy" bias, the group that is most represented in the evaluation committees generates more accurate signals, and consequently has a greater incentive to invest in human capital. In this setting, we show that, if the evaluation committees are initially not equalitarian, this could translate into a persistent discriminatory trap, where the less represented group in the evaluation committees has less incentives to invest and is then less productive. We show that this is an inefficient equilibrium, since there is a waste of talent in the discriminated group. Quotas imposed on evaluation committees are shown to be an effective mechanism to restore efficiency.

We undertake the analysis both in a static and in a dynamic setting. In both environments, the shape of the screening function represents the key element in the analysis. We consider a particular family of accuracy functions with different degrees of convexity. In both the static and dynamic settings, the equalitarian allocation is efficient as long as the accuracy function is not too convex. If the accuracy function is very convex, it is efficient to concentrate the screening in one group. Similarly, the equalitarian allocation represents a decentralized equilibrium when the accuracy function is not too convex. However, the first threshold of convexity is larger than the second one, and this creates inefficiencies and the potential room for introducing quotas.

This analysis sheds light on the relevance of possible "homo-accuracy" bias as captured by our accuracy function. Our model is the first theoretical analysis which explains why the existence of biased selection process, a fact which is supported by some empirical evidence, may lead to inefficiency, which, in turn, may be alleviated by the introduction of quotas. At the same time, our analysis raises new empirical questions: How is the screening process conducted in reality? More precisely, how are the decisions taken within the evaluation committees? Are these processes very "concave", meaning that a small representation of the minority group eliminates most of the bias, or do they exhibit convexity, requiring large representation in order to get a substantial improvement in the screening process?

Finally, following Becker (1975), in our context human capital corresponds to any stock of knowledge or characteristics the worker has (either innate or acquired) that contributes to his or her "productivity". Some of these characteristics are observable, as the years of schooling, but many others are not, such as training, investing in learning new skills (or perfecting old ones) while on the job, or attitudes towards work. In this paper we have focused on these unobservables factors, assuming that observable characteristics are equal among groups. In fact, in most of the countries women invest even more than men in the observable characteristics of human capital, such as years of schooling. Consistently with the results of our paper, women may decide to invest more than men in observable characteristics, because the returns on investment in non observable characteristics are more risky or uncertain in a world dominated by men.

8 Appendix

Proof of Lemma 1: The expected utility of the strategic worker in the HHC equilibrium, is equal to $W_{HHC}\left(\overline{\theta}\right) - \widehat{c} = w^*_{HHC}(s_H) - \widehat{c} = \frac{(1+\alpha)\overline{\theta}}{2-\gamma(1-\alpha)} - \widehat{c}$. Where $\frac{(1+\alpha)\overline{\theta}}{2-\gamma(1-\alpha)}$ is increasing in γ. For the same token in the LHC equilibrium, $W_{LHC}\left(\underline{\theta}\right) = (1-\gamma)w^*_{LHC}(s_H) = \frac{(1-\gamma)(1-\alpha)\overline{\theta}}{2-\gamma(1+\alpha)}$. Where

$$\frac{\partial W_{LHC}\left(\underline{\theta}\right)}{\partial \gamma} = (1-\alpha)\overline{\theta}\frac{\alpha-1}{(2-\gamma(1+\alpha))^2} < 0$$

■

Proof of Proposition 1: Immediate from the arguments in the main text. ■

Proof of Proposition 2: Part i) follows from the equilibrium characterization in Proposition 1. Part ii) this is because $w^*_{HHC}(s_H)$ and $w^*_{LHC}(s_H)$ are higher than $w^*_{HHC}(s_L) = w^*_{LHC}(s_L) = 0$, and by Part i) men have more incentives to invest in human capital (and consequently obtain a better signal). Moreover, even for high signal realization, $w^*_{HHC}(s_H)$ and $w^*_{LHC}(s_H)$ are increasing in γ. This implies that controlling for productivity, female high types $\overline{\theta}$ receive lower salaries than men high types $\overline{\theta}$. ■

PROOF OF PROPOSITION 3: If both groups are in HHC, then the proportion of males and females with high productivity is the same, and consequently the proportion of both groups in the evaluation committee as well, $\phi^m = \phi^f = \frac{1}{2}$. Then, the condition for both groups (males and females) to be in the HHC is $(\frac{1}{2})^{\beta} > \overline{\gamma}$. Let β^* be implicitly defined by $(\frac{1}{2})^{\beta^*} = \overline{\gamma} \Rightarrow \beta^* = \frac{\ln \overline{\gamma}}{\ln \frac{1}{2}}$, as $(\frac{1}{2})^{\beta}$ is decreasing in β, if $\beta < \beta^*$ then the condition of $(\frac{1}{2})^{\beta} > \overline{\gamma}$ is satisfied. ■

PROOF OF PROPOSITIONS 4 AND 5:

We know that $\beta^*_L = \frac{\ln \overline{\gamma}}{\ln \frac{1-\alpha}{2}} < \beta^* = \frac{\ln \overline{\gamma}}{\ln \frac{1}{2}} < \beta^*_H = \frac{\ln \overline{\gamma}}{\ln \frac{1+\alpha}{2}}$ (because the absolute value $\left|\ln \frac{1+\alpha}{2}\right|$ is decreasing in α). For the discussion in the main text, if $\beta \in [\beta^*_L, \beta^*]$ the decentralized asymmetric equilibrium is feasible, and by Proposition 3 if $\beta < \beta^*$ the equalitarian first best equilibrium is achievable. Then, imposing an equalitarian system of quotas may turn the inefficient asymmetric equilibrium into the equalitarian first best equilibrium. On the contrary, if $\beta \in [\beta^*, \beta^*_H]$ the equalitarian first best equilibrium is not feasible, but as $\beta < \beta^*_H$, one population group may be in HHC equilibrium with certainty. Imposing an equalitarian system of quotas may lead both groups to the multiplicity of equilibria region, reducing the overall investment in human capital and total welfare. ■

PROOF OF PROPOSITION 6: The first order condition is

$$(1 - \frac{2h(\phi^f)}{1 + h(\phi^f)})\frac{h'(\phi^f)}{(1 + h(\phi^f))^2} = (1 - \frac{2h(1-\phi^f)}{1 + h(1-\phi^f)})\frac{h'(1-\phi^f)}{(1 + h(1-\phi^f))^2}$$

it is convenient to express the FOC as

$$\frac{(1 - \frac{2h(\phi^f)}{1+h(\phi^f)})\frac{1}{(1+h(\phi^f))^2}}{(1 - \frac{2h(1-\phi^f)}{1+h(1-\phi^f)})\frac{1}{(1+h(1-\phi^f))^2}} = \frac{h'(1-\phi^f)}{h'(\phi^f)}$$

The LHS is decreasing in ϕ^f, the RHD is increasing if $h'' < 0$ and decreasing if $h'' > 0$.

Then there is only one possible solution if $h'' < 0$, and this is that $h(1 - \phi^f) = h(\phi^f)$ and $(1 - \phi^f) = \phi^f = \frac{1}{2}$. In fact, $(1 - \phi^f) = \phi^f = \frac{1}{2}$ is always a solution of the FOC, but whether or not this is the optimal solution of the problem depends on the second order condition.

The second order condition is also satisfied when $h(\phi^f)$ is concave since all terms are negative.

$$\left[(1-\frac{2h(\phi^f)}{1+h(\phi^f)})\frac{1}{(1+h(\phi^f))^2}\right]' h'(\phi^f)+\left[(1-\frac{2h(\phi^f)}{1+h(\phi^f)})\frac{h''(\phi^f)}{(1+h(\phi^f))^2}\right]+$$
$$-\left[(1-\frac{2h(1-\phi^f)}{1+h(1-\phi^f)})\frac{1}{(1+h(1-\phi^f))^2}\right]' h'(1-\phi^f)+\left[(1-\frac{2h(1-\phi^f)}{1+h(1-\phi^f)})\frac{h'(1-\phi^f)}{(1+h(1-\phi^f))^2}\right]$$

This concludes the proof. ■

PROOF OF PROPOSITION 7: It is implied by the arguments provided in the main text. ■

PROOF OF PROPOSITION 8: It is a direct proof, using equation 13 and that $h(1) = 1$ and $h(0) = 0$. ■

PROOF OF PROPOSITION 9: i) The dynamic equation (13) for $h(\phi) = \phi^\beta$ can be rewritten as follows

$$\phi_t^f = \frac{1}{1+\frac{1+(\phi_{t-1}^f)^\beta}{(\phi_{t-1}^f)^\beta}\frac{(1-\phi_{t-1}^f)^\beta}{1+(1-\phi_{t-1}^f)^\beta}} = f(\phi_{t-1}^f,\beta) \tag{14}$$

We are interested in the stability of the equalitarian equilibrium. As the dynamic equation $\phi_t^f = f(\phi_{t-1}^f, \beta)$ is continuous and differentiable, the condition for the equalitarian equilibrium being stable is that the slope of f is lower than 1 when $\phi_{t-1}^f = \frac{1}{2}$:

$$\left.\frac{\partial f(\phi_{t-1}^f,\beta)}{\partial \phi_{t-1}^f}\right|_{\phi_{t-1}^f=\frac{1}{2}} = \frac{\beta}{1+(\frac{1}{2})^\beta} < 1$$

As the slope $\left.\frac{\partial f(\phi_{t-1}^f,\beta)}{\partial \phi_{t-1}^f}\right|_{\phi_{t-1}^f=\frac{1}{2}} = \frac{\beta}{1+(\frac{1}{2})^\beta}$ is increasing in β and equal to 1 for $\beta_S^d \backsimeq 1.3833$, we can state that the equalitarian equilibrium is stable as long as $\beta < \beta_S^d$. ii) The second part of the Proposition is a direct implication of part i) and Proposition 7. ■

9 References

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1 Figures

Figure 1: Proposition 1

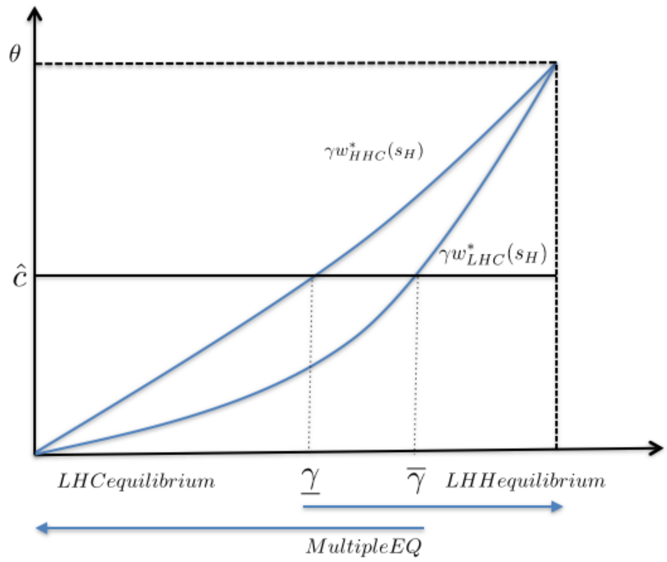

Figure 2: The Role of Quotas

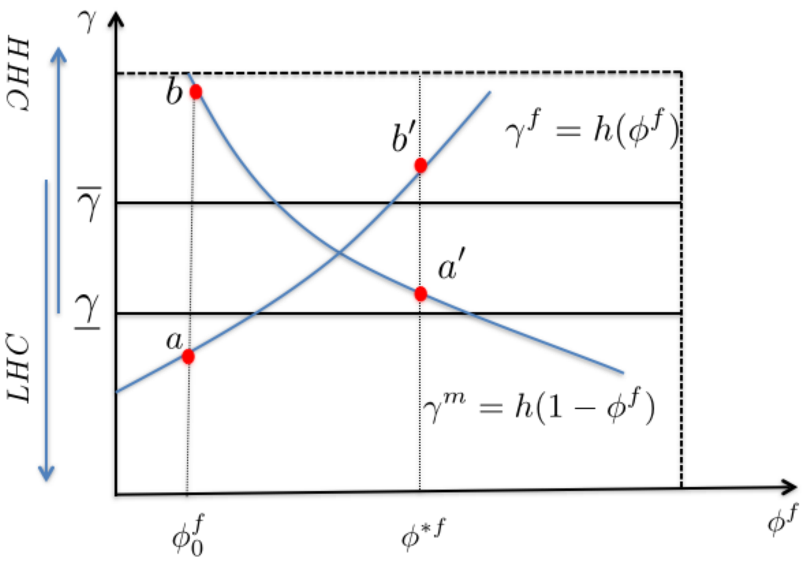

Figure 3: Efficient Composition of the Selection Commetee

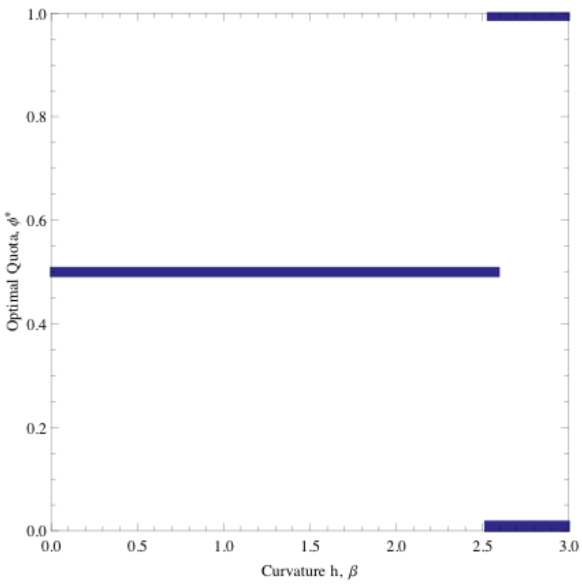

Figure 4: Stability of the Decentralize Equilibrium