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A tradable employment quota

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Abstract

Discrimination of women in the labor market requires appropriate policy interventions. Affirmative action policies typically advocate the introduction of an employment quota uniformly applied to all firms. In a heterogeneous labor market such a policy may yield avoidable welfare losses. We propose a tradable employment quota showing its effects on wages, employment, and welfare in a labor market with search frictions and taste discrimination. A tradable employment quota appears to be a viable alternative yielding superior labor market outcomes.

Keywords: tradable employment quota, affirmative action policies, taste discrimination, labor market, search and matching, agent-based model

JEL-Classification: J71, J78, C63

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1 Introduction

Affirmative action policies very often take the form of employment quotas. Norway introduced a quota in 2003 already. France, Iceland, and Spain have mandatory boardroom gender quotas forcing firms to have boards with 40% women by the years 2017, 2013, and 2015, respectively. German publicly listed firms subject to co-determination have to comply to a boardroom quota of 30% from 2016 onwards. Furthermore, the European Parliament passed a proposal by the European Commission to break the glass ceiling. According to this envisaged bill, European firms have to appoint female directors in order to make supervisory boards two-fifths female by 2020.¹

As it is very likely that a uniform employment quota imposes larger adjustment costs on some firms than on others the question arises whether the goal of paving the way for more female employment can be achieved at lower costs. In particular, as the size of women's labor supply is heterogeneous across occupations, sectors, and regions, some of the firms forced to fulfill a fixed quota will find it more difficult to hire women who match the vacancies than others. A more flexible instrument is called for that does not compromise on the overall goal of achieving a certain share of female employment. Such an instrument should allow firms to fall short of the quota if costs of compliance would become unreasonable, while allowing others to gain from employing relatively more women.

In this article we propose and analyze the labor market effects of a tradable employment quota. Borrowing from the experience with environmental regulation policies to combat excessive emissions, we suggest to implement a mechanism that efficiently achieves a fixed share of women working in relation to men. The idea is to issue permits to firms that give them the right to employ men and make these permits tradable. With such an affirmative action policy firms would only be allowed to employ men up to a number that matches the stock of permits that they hold. As a particular firm wants to employ an additional man it would only be able to do so by purchasing an additional employment right. Firms being in excess of permits because they find it more profitable to employ a woman than to hold a permit will want to sell this right. Trading of permits between those firms that want to buy and those firms willing to sell would yield a market price of a permit reflecting the profitability of employing an additional man. While the overall supply of permits of an issuing body would determine the share of female employment in the economy, single firms could adjust more flexibly and still comply.

We are aware of the fact that very often economists' ideas for resolving

¹See the European Commission Database on Women and Men in Decision Making.

societal issues do not find widespread support outside of their own community. Sometimes even fierce opposition arises and we would not be surprised if such a reaction emerges as a response to our proposal. The public discussion of affirmative action policies is very much centered on equity considerations. It appears to us that efficiency or the loss of efficiency is of secondary importance, maybe because policymakers or those whom they represent are not willing to trade equity for efficiency. On this background we believe that it is important to stress that our proposal does not question the equity related aim of improving women's participation in the labor market. Personally, we also think that this should be an important goal for policymakers. What we suggest here is, however, a policy measure that has the potential to achieve equity at a lower cost for society. The way that this may be achieved is via a market-oriented instrument.

We expect that recurring to market mechanisms to resolve equity issues may become another reason why our proposal could be dismissed by the broader public upfront. In fact, it has been reported that initially there was heavy opposition to the introduction of tradable carbon dioxide emission rights coming from environmental groups. The hostility towards a market-oriented instrument was mostly driven by moral or philosophical reasoning where it was argued that "It's Immoral to Buy the Right to Pollute" as the New York Times titled an article.² Similar objections may arise with respect to our proposal. Some critics may claim that it is immoral that firms can buy themselves out of the obligation to hire women by purchasing permits that allow them to employ men rather than women. We find it very difficult to resolve such kind of moral concerns. But we would like to point to a more recent discussion that has arisen as employment quotas got implemented. There is evidence that women feel stigmatized when their employer is subject to a quota (Heilman et al., 1992, 1997). The unease comes from the perception that fellow employees may think that a particular woman was only employed because of the quota policy rather than because of her qualification. Interestingly, in our proposal such a stigma is less likely to emerge because the mere fact that the employer chose to offer a contract to a woman signals appreciation. Alternatively, the employer could have employed a man by not selling a permit or buying an additional permit (which he did not do.)

In the context of environmental policies the use of tradable permits is based on Ronald Coase's idea that market participants may correct for negative externalities without the intervention of governments if legal rules of entitlement exist and transaction costs are negligible (Coase, 1960). Nega-

²See Sandel (1997).

tive externalities which are arising from production through the emission of health and climate damaging gases are corrected for by giving firms the right to pollute (or those affected by the emission the right for unpolluted air). Consequently, emissions are only allowed if costly permits are held so that firms are confronted with the socially relevant marginal costs of production rather than their private marginal costs only. It follows that production is extended up to the socially desirable level only. Moreover, the abatement of (environmentally) unhealthy substances takes place at the lowest costs possible. Those firms with relatively low marginal abatement costs will choose to invest in clean technologies and sell their permits, whereas the firms with relatively high marginal abatement costs will want to expand production by purchasing permits. It is the cost reducing feature of permit trading which we borrow for developing our proposal of an affirmative action policy that increases female employment shares at relatively lower costs than one would have with a uniform quota. As in the case of environmental policies, we expect that those firms which will find it inherently difficult to hire women will rather purchase permits than leave vacancies unproductive or costly retrain their newly hired employees, whereas those firms able to hire women will sell their permits. All these cost saving decisions of firms leading to trades on the permit market, however, should not jeopardize the goal of achieving an overall female employment rate set by policymakers and implemented by issuing a corresponding number of tradable employment permits.³

We would like to give some empirical evidence on the current situation with respect to female participation in advisory and executive boards of mostly publicly listed firms. Restricting to these figures for illustrative purposes may be justified by the recent policy moves that started to regulate this particular part of the labor market. With 16% the U.S. and the 27 (by 2007) EU member states fare equally in terms of female representation on firm boards. Japan, as another major industrialized country, has only 1% women on firm boards. A closer look into single European countries reveals a large dispersion of female representation. In the three countries with the largest representation almost every third member is female, a share which, however,

³We have been asked at various occasions whether our case of a discriminatory labor market entails some form of externality, which is then resolved through our proposed permit solution. In the sense that an externality is present whenever some economic agent's welfare is directly affected by the action of another agent (see, e.g., Hindriks and Myles, 2013) a discriminating firm does not constitute an externality. Choices of discriminating firms have effects on other agents' payoffs but they are mediated by prices, i.e. they are indirect or so-called pecuniary externalities. Thus, it is not an externality that we correct for with tradable employment rights, but we rather target the heterogeneous adjustment costs of firms that can be handled more efficiently through our proposal.

still falls short of Norway where a quota was introduced in 2003 already, forcing firms to comply by 2008. In the European countries that do worst less than one tenth of the positions are held by women. Interestingly, the countries doing relatively well in terms of female board membership hardly have women leading the board or being a CEO. Data for Germany allows for a closer look into the within country distribution of female representation. Again, we find a large variance between firms. Among the companies listed in the DAX (the major German stock market index), seven women served on the board of Henkel (a company producing personal care products) which was composed of 16 members at the time of data collection, while no woman was serving on the board of Fresenius (a medical care company).⁴

The introduction of a female board quota in Norway constituted a natural experiment that allowed for an analysis of firm reactions and their consequences more closely. At the time the law was introduced only 9% of women were on the boards of Norwegian firms. A legislated quota of 40% imposed a major change on the composition of Norwegian firm boards. Ahern and Dittmar (2012) use the pre-quota female representation across firms as an instrument for the changes of boards that followed the quota. For the days around the announcement of the law they find that stock returns fell by 3.52% for those firms with no female representation compared to firms that had at least one woman on the board. For the longer term, they estimate a decline in Tobin's Q of 12.4% as a response to a 10% forced increase in women representation on the boards. Overall they conclude that the imposed constraint had a large negative impact on firm value driven by the reorganizations of the boards. Drawing on the same policy change, Bohren and Staubo (2014) find that half of the firms that would have been affected by the gender quota chose to exit into another organizational form, thus avoiding exposition to the law. Also this piece of evidence suggests, at least indirectly, substantial costs of compliance that possibly could be diminished with a system of tradable permits to employ men.

In order to study whether a tradable employment quota is a feasible affirmative action policy and what labor market effects would possibly unfold we build a model that hosts a labor market and a market for permits. We study a labor market with a set of firms being allocated to multiple sectors. A fraction of the firms is characterized by taste discrimination against women as proposed by Becker (1957). The remaining fraction of firms is indifferent between hiring men and women. Workers have sector specific skills meaning that their productivity does not fully unfold unless they work in a sector that

⁴A table summarizing these figures and some additional information can be found in the Appendix (see Table 7).

requires precisely those skills. Female labor supply to sectors varies with the share of discriminating firms. In the words of Bergmann (1974) we assume “overcrowding” as firms systematically exclude women due to their distaste which ultimately leads to fewer women having invested in skills demanded by those firms. Firms post vacancies to which workers apply and are matched. In this framework taste discrimination leads to worse employment chances for women and lower wages. In order to balance this resulting gender gap we compare the labor market effects of two policies by studying the effects of a tradable as opposed to a non-tradable employment quota on welfare and various other labor market indicators.

Our main finding is that a tradable employment quota fares better in a heterogeneous labor market where firms are facing differentiated levels of female labor supply. The intuition why the tradable quota is superior is that given the heterogeneous labor supply of women, the degree to which firms are affected by a non-tradable quota varies, i.e. while firms residing in sectors with many women find it very easy to comply, the ones in sectors with less women find it more difficult. The tradable quota is a remedy for exactly this difference. It allows those firms facing high costs that would arise from a uniform quota to evade these costs by buying permits from those companies having an excess supply of permits because of the relatively higher labor supply of women to them. In a simulated version of our model we can disentangle the welfare effect of a tradable employment quota into changes of payoffs to firms and the wage sum and, furthermore, show how wages and payoffs change in discriminating and non-discriminating firms. This analysis shows that the advantage of the quota is mainly due to the fact that the tradable quota is a more flexible instrument and therefore better able to deal with an unequal female labour supply and discriminatory firms present in the market, without falling short of the equity goal of increasing female employment.

We analyze a simplified version of the model analytically and transpose a richer version of our framework into an agent-based simulation model to analyze whether a permit solution may actually work and what labor market effects might potentially emerge. Evaluating labor market policies using agent-based models has been suggested by Freeman (1998) already some time ago. Generally speaking an agent-based approach suits well for analyzing problems characterized by interacting heterogeneous agents. Moreover, agent-based modeling allows for a relatively detailed implementation of institutional arrangements. As we build a model with a sectoral structure hosting workers of different skill types to be employed by firms that may discriminate against women and, furthermore, will augment the labor market with a permit trading system, the agent-based approach seems to suit well for

our purposes. Our approach may also be subsumed under what Roth (2002, p.1341) called “design economics” where he argues that computational techniques should be seen as complementary to other tools applied to studying and designing markets, namely game-theory. One of the earliest attempts to analyze the effects of labor market institutions in an agent-based model can be found in Bergmann (1990). Others followed, with Tesfatsion (2001) working on wage setting or Neugart (2008) looking into training policies. Those and other contributions are surveyed in Neugart and Richiardi (2015).

Building our model we touch upon various strands of the literature. Women’s wages, employment opportunities or occupations may be affected by labor market discrimination in various ways. Becker (1957) suggested that men and women being treated differently can be explained by taste discriminating firms. A second, alternative explanation, is statistical discrimination (Arrow, 1973; Phelps, 1972) which postulates that employers discriminate on the basis of expected differences in average productivity between men and women. Empirical work long evolved separately along these two explanations (Guryan and Charles, 2013). Only in recent years efforts have been made to test taste based explanations of discrimination against explanations pointing at statistical discrimination (See, e.g., Altonji and Pierret, 2001; Knowles et al., 2001). The jury still seems to be out and we do not make an attempt to resolve the issue here. Finally, a third explanation, typically referred to as “occupational crowding” argues that women are systematically excluded from “male jobs” (Bergmann, 1974). The origins of overcrowding may lie in a social climate where young women are told that some jobs are not suitable for “girls” or discrimination might already take place at the stage of human capital acquisition (Mechtenberg, 2009). But it may also be the results of a feedback from the discriminatory behavior of firms that offer worse pay and job conditions (Blau and Kahn, 2000, p. 82) or the expected lower likelihood to get a top position (Stark and Hyll, 2014) leading to a deliberate decision by women not to invest into skills demanded by those discriminating firms. Drafting our model to analyze policies we heavily draw on the idea of taste discriminating firms and the feedback arising with respect to labor supply decisions by women.

Welch (1976) was probably among the first dealing with affirmative action policies from a theoretical point of view. One concern was to elaborate the consequences of a quota arising from skill bumping, i.e. the upgrading of skills of workers so that firms would comply to the affirmative action policy. Equal employment opportunities as one proliferation of affirmative action policies have been studied in the framework of a search and matching model of the labor market by Kaas and Lu (2010). They find that if an imperfectly monitored equal employment opportunity legislation is combined with an

equal pay obligation inequality increases.⁵ Contrary to them we do not look into a fixed quota but a tradable one.

Tradable permits solutions have gained widespread attention in the area of environmental policies (see, e.g., Stavins, 1998), but were also proposed as alternative policy instruments in the context of debt policies in the European Union (Casella, 1999), immigration (Moraga and Rapoport, 2014), birth control (De la Croix and Gosseries, 2009), or noise control at airports (Bréchet and Picard, 2010). With most of these proposals as with our application welfare consequences remain a theoretical discussion because the policy instruments were hardly implemented. The exceptions are, of course, the permit markets for carbon dioxide and sulfur dioxide. According to Schmalensee and Stavins (2013) these policy experiments mostly achieved the cost reducing goals. It is claimed that cost savings were at least 15 percent and perhaps even up to 90 percent compared with command-and-control approaches. While tradable permit solutions have been applied to other policy areas, there is, however, little to no work in the area of labor market policies.⁶ This contribution may be seen as a first step into the analysis of such kind of affirmative action policies.

In the following Section 2 we lay out our model and introduce the reader to the two affirmative action policies we are going to compare. As a benchmark for the simulation exercise we derive an analytical solution of a simplified version of our model with and without policies in Section 3. In Section 4 we introduce the reader to the parametrization and the simulation set-up. In Section 5 we present our results on the effects of a tradable employment quota in comparison with a non-tradable quota on welfare and other labor market indicators, and also report on various robustness tests. In the last section we conclude, discuss our proposal in relation to other policies, and point toward possible extensions.

2 The model

2.1 A general description

Our model consists of a labor market with heterogeneous firms, male and female workers, and a permit market. The labor market has a sectoral struc-

⁵Other contributions looking into the labor market consequences of equal pay legislation are Bowlus and Eckstein (2002); Coate and Loury (1993); Kaas (2009). Further search and matching models with taste discrimination but without policy analyses can be found in Black (1995); Lang et al. (2005); Rosen (2003).

⁶Winker (2000) sketches the idea of how collective wage agreements could be made more flexible using tradable permits.

ture where the sectors hosting the firms are allocated on a Salop circle (Salop, 1979), and the share of female workers differs in sectors.⁷

Firms sitting in a particular sector have distinct skill needs. Workers are equipped with different sector specific skills. A worker’s productivity unfolds fully if she is employed in a sector that matches her skills. Workers employed by firms in other sectors lose part of their productivity. Labor demand for each firm is fixed. Vacancies are posted and workers apply.

A fixed share of firms discriminates against women. Due to taste discrimination these firms will only employ women instead of men if wages of the former are sufficiently lower (or productivity is sufficiently higher). As a consequence of the taste discriminating firms and in accordance with theories of discrimination related to “occupational crowding” outlined earlier on, labor supply of women is modeled as being negatively correlated with the share of discriminating firms in a sector.

Firms send non-binding wage offers to the applicants with highest profitability. Workers know that the offer is not binding as the firm has to comply with an affirmative action policy once all workers decided on which offer to accept (if any).

Specifically, we consider two affirmative action policies. Under a non-tradable employment quota every firm is allowed to only employ a share of men that does not exceed the quota. Alternatively, we implement a tradable quota issuing permits that give a firm the right to employ men.

Once a firm knows about the gender composition of applicants who accepted its offers, it is able to determine the actual number of men it can employ (in relation to its female workforce) to comply with a fixed quota, or in the case of a tradable quota, how many permits it needs to purchase. Consequently, in both scenarios the affirmative action policies magnify the problem of coordination failure giving rise to labor market frictions (See, e.g. Petrongolo and Pissarides, 2001, sec. 3.2). Due to the policies, men may have to be turned down and vacancies stay empty.

The permit market is modeled with a central market maker to whom each individual firm submits its individual supply and demand schedule of permits. The central market maker aggregates these bids and asks and determines the market clearing price at which the permits are reallocated.

⁷The Salop model has been used as a framework for studying the effects of discrimination and labor market policies with imperfect competition by others before. Examples are Bhaskar et al. (2002), Bhaskar and To (2003), Kaas (2009), or Berson (2014). Contrary to the existing work we add tradable permits to a model of imperfect competition with discriminating firms whereas many of our other modeling assumptions are in line with respect to this strand of the literature.

2.2 Labor market environment

We consider a partial labor market where firms' fixed labor demand is derived from aggregate product demand. Firms reside in $s \in S$ sectors. Workers are equipped with skills for a specific sector k but may be employed at a firm in a sector other than k . A worker i employed at a firm in a sector requiring her specific skills unfolds full productivity A . Worker specific productivity $P_i(k, s)$ declines as she is employed in a more distant sector. Sectors are allocated on a Salop circle, i.e. a worker's productivity with specific skills in sector k , working in sector s follows

$$P_i(k, s) = \begin{cases} A - a \cdot |k - s| & \text{if } |k - s| \leq S/2 \\ A - a \cdot (S - |k - s|) & \text{else,} \end{cases} \quad (1)$$

with $0 < a < 1$, $k = 1, \dots, K$, and $s = 1, \dots, S$. As there are as many skill types as sectors we have $K = S$.

2.3 Workers

The fixed total labor supply of size I can be decomposed into a fraction σ of female workers and a fraction $(1 - \sigma)$ of male workers. The share of female labor supply may differ between sectors according to σ_k . A worker i has an individual reservation wage w_i^r that is drawn from a uniform distribution with support $[0, A]$ resulting in an upward sloping labor market supply curve.

Workers send out a fixed number m (with $m > 1$) of applications preferably to firms which value their sector specific skills. Unobservable characteristics orthogonal to workers' skill endowment make some sectors more attractive to a specific worker than others. Thus, she may send an application to a firm in a sector which does not value her specific skills most. More formally, we recur to a discrete choice specification postulating that worker i with specific skills for sector k sends out an application to a firm in sector \tilde{s} with probability

$$Prob_i(k, \tilde{s}) = \frac{e^{\lambda P_i(k, \tilde{s})}}{\sum_s e^{\lambda P_i(k, s)}}, \quad (2)$$

where $\lambda \geq 0$ drives the intensity of choice and the denominator sums up the exponential of worker specific productivities in all sectors.

Workers accept job offers with attached wage offers above their reservation wage w_i^r . If a worker receives more than one job offer, she chooses the job offer with the highest wage.

2.4 Firms

There is a total of L firms which we denote with $l = 1, \dots, L$. A firm l has J_l vacancies to fill. Each sector is populated with N firms. Overall, there is a share of $\mu > 0$ of discriminating firms. The share of discriminating firms may differ across sectors. We denote the share of discriminating firms in a sector s with $\mu_s > 0$. A discriminating firm has a dis-utility from hiring a female worker which is modeled with a discrimination coefficient d as suggested by Becker (1957). The firm l residing in sector s has payoffs calculated as the sum of the productivity net of the wage and the discrimination cost over all workers \tilde{J}_l it finally employs:

$$\pi_{l,s} = \sum_{\tilde{J}_l} (P_i(k, s) - d_{g,l} - w_{l,k,g,s}), \quad (3)$$

where $g = M, F$ is the gender of the worker. For discrimination costs we have $d_M = d_F = 0$ for a non-discriminating firm and $d_F > 0$ for a firm that discriminates against an employed woman.

Firms set male and female wages to maximize payoffs. Job offers conditional on the firm having to comply with the affirmative action policy are sent out including worker specific wage offers.

A firm finding a wage that maximizes payoffs faces the following trade-off: higher wage offers increase the likelihood that a vacancy can be filled and becomes productive. Higher wage offers, however, also increase the wage bill and depress payoffs. Firms learn given their past experience on payoffs and wage offers how to best place themselves on this trade-off. To this end, each firm runs regressions of payoffs per job offer on the wage offers of the past τ iterations. For a positively estimated slope coefficient $\hat{\beta}$, a firm l that resides in sector s will adjust the wage offer w^o for a worker coming from sector k and of gender g upwards by $\epsilon > 0$ in iteration t with respect to the previous iteration $t - 1$. For a negatively estimated slope coefficient the wage is adjusted downwards. Formally, we have

$$w_{l,k,g,s,t}^o = \begin{cases} w_{l,k,g,s,t-1}^o + \epsilon & \text{if } \hat{\beta}_{l,k,g,s,t} > 0, \\ w_{l,k,g,s,t-1}^o - \epsilon & \text{if } \hat{\beta}_{l,k,g,s,t} < 0, \\ w_{l,k,g,s,t-1}^o & \text{else.} \end{cases} \quad (4)$$

Wage offers are adjusted if they are within bounds $[0, A]$.

2.5 Policies

We consider an affirmative action policy where every single firm has to employ at least $\bar{\sigma} \tilde{J}_l$ women where $\bar{\sigma}$ is the quota and \tilde{J}_l is the number of workers

employed at a firm l . In order to comply with the quota firms rank applicants by gender and payoffs. Again, the firm will send offers – which are declared conditional on the firm being able to comply with the quota – to the best workers taking into account the quota.

Alternatively, we simulate a market with permits for employing men. In this case, a firm is only allowed to employ as many men as it holds permits for employing male workers. There is a fixed number for permits C for the whole economy. Initially every firm gets an equal share of the total number of permits. These permits can be sold and bought at a central clearing agency. For the clearing agency, we consider a central market maker who collects ask and bid prices, determines the market clearing price in every period and reallocates the permits between the buying and selling firms.

If a firm owns permits, its offer curve for selling permits is constructed as follows. All unused permits are offered at reservation price zero. The offer of that single firm increases by one more permit at a price equal to the payoff of the least profitable male worker. The second least profitable worker determines the price of yet an additional permit. As we move to even more profitable workers the full schedule of the offer curve for that particular firm is derived.

Turning to the demand side the central market maker looks into a single firm that will ask for as many permits as there are more men employed than the firm holds permits currently. Permits are used to employ the most profitable male workers in the firm. The bid price for the first additional permit is the payoff of the most profitable male worker for whom the firm does not yet have a permit. The bid price for the second additional permit is the payoff of the second most profitable male worker for whom the firm does not yet have a permit, and so on.

3 Analytical solution

We solve a simplified version of the model analytically in order to pin down some of the mechanisms which will underlie our simulation results that are going to be presented in the later sections. To this end, we set the number of firms hosted by a single sector to $N = 1$ and let workers only apply to the firm of the sector to which their skill endowment fully matches. This implies setting $m = 1$, $Prob(k, \tilde{s}) = 1$, and $P(k, s) = A$. Essentially, we eliminate the part of labor market frictions arising through coordination failure in the process of applying and hiring of workers. For the moment we will also assume an even number of sectors S and jobs J at each firm, and an equal number of male and female workers $\sigma = 0.5$ in each sector summing up to

Table 1: A firm's profits without policies

w_l	$\phi(w_l)$	π_l	$\Delta\pi_l$
0	1	$2\phi(w_l)(A - w_l) = 2A$	
$\frac{A}{J/2}$	2	$4A - \frac{8A}{J}$	$2A - \frac{8A}{J} = 2A - \frac{1}{J}8A(\phi(w_l) - 1)$
$2\frac{A}{J/2}$	3	$6A - \frac{24A}{J}$	$2A - \frac{16A}{J} = 2A - \frac{1}{J}8A(\phi(w_l) - 1)$
...
$(J/2 - 3)\frac{A}{J/2}$	$J/2 - 2$	$6A - \frac{24A}{J}$	
$(J/2 - 2)\frac{A}{J/2}$	$J/2 - 1$	$4A - \frac{8A}{J}$	$-2A + \frac{16A}{J} = -2A + \frac{1}{J}8A(\phi(w_l) - 1)$
$(J/2 - 1)\frac{A}{J/2}$	$J/2$	$2A$	$-2A + \frac{8A}{J} = -2A + \frac{1}{J}8A(\phi(w_l) - 1)$

J workers. Furthermore, for each gender reservation wages are distributed according to $[0, \frac{A}{J/2}, 2\frac{A}{J/2}, \dots, (J/2 - 1)\frac{A}{J/2}]$. We denote with $\phi(w)$ male and female labor supply in a sector, respectively. Finally, we let there be no taste discriminating firms in the market ($\mu = 0$).

3.1 No employment quota

Labor supply for a firm l is upward sloping due to the distribution of reservation wages. In this monopsonistic setting a firm l chooses as many workers, and posts wages accordingly, to maximize profits. Let w_l be the wage paid by a firm l , then we may write for the firm's profits

$$\pi_l = 2\phi(w_l)(A - w_l), \quad (5)$$

i.e. a worker's productivity A less the wage paid times $\phi(w_l)$ male and $\phi(w_l)$ female workers.

Table 1 lists profits of a firm l (third column) as a function of the wage offer w_l and the corresponding labor supply $\phi(w_l)$. The firm will offer higher wages and expand production as long as profits are increasing in wages ($\Delta\pi_l > 0$). This gives optimal number of workers $\phi_l^* \equiv \phi(w_l^*)$ for firm l as a function of overall supply J , and optimal wages w_l^* picked from the distribution of reservation wages (such that the firm gets the optimal number of workers ϕ_l^*). Total output Y in this economy becomes

$$Y = S \cdot 2 \cdot \phi_l^* \cdot A. \quad (6)$$

3.2 Employment quota

What decisions will firms make if they are confronted with an employment quota that forces them to have a workforce where every second worker is female? A firm l in sector s still wants to have $2\phi(w_l^*)$ vacancies filled and offers w_l^* . It faces a labor supply of $\phi(w_l^*)$ women and $\phi(w_l^*)$ men and complies to the quota. Overall output in this economy is

$$Y^{ntq,eqFemDis} = S \cdot (\phi_l^* + \phi_l^*) \cdot A = S \cdot 2 \cdot \phi_l^* \cdot A. \quad (7)$$

Now, let us assume that women are not equally distributed over sectors S . Rather we inquire a labor market in which all women are allocated to sectors $s = 1, \dots, S/2$ and all men to sectors $s = S/2 + 1, \dots, S$. Although being subject to an employment quota, firms in “female” sectors will be able to fill all of their $2\phi_l^*$ profit maximizing jobs. Firms in “male” sectors will produce nothing due to the constraint imposed by the employment quota that half of the workforce has to be female. Output with an employment quota becomes

$$Y^{ntq,UneqFemDis} = S/2 \cdot 2\phi_l^* \cdot A + 0 = S \cdot \phi_l^* \cdot A < Y^{ntq,eqFemDis}. \quad (8)$$

3.3 A tradable employment quota

Alternatively to the non-tradable employment quota permits are issued that allow the firms to employ men now. We keep the assumption of an unequal distribution of women across sectors. In order to make a labor market with permits comparable to the one discussed without policies we issue $C = S \cdot \phi_l^*$ permits which is the number of male workers that all firms employed when maximizing profits. Initially, permits are equally distributed among firms. Thus, each firm is endowed with ϕ_l^* permits.

Firms in sectors $s = 1, \dots, S/2$ that face a female labor supply only can run all jobs $2\phi_l^*$ without using a single permit. For any permit price $p \geq 0$ they will be willing to sell their permits. Thus, overall supply of permits is $S/2 \cdot \phi_l^*$.

Firms in sectors $s = S/2 + 1, \dots, S$, facing a male labor supply only, have to purchase permits as they want to employ more men than they initially were allocated permits. The profit function of a firm l in a “male” sector becomes

$$\pi_l = \phi(w_l^p)(A - w_l^p) - (\phi(w_l^p) - \phi(w_l^*))p \quad \text{if} \quad \phi(w_l^p) - \phi(w_l^*) > 0 \quad (9)$$

where w_l^p is the wage paid by a firm l in a labor market with permits. The first part of the profit function constitutes the revenues of workers net of wage costs. The second part gives the costs of the permits that have to be bought in addition to the initially allocated number of permits.

Table 2 lists profits as a function of the permit price having substituted in the wage that has to be paid by a firm to draw on a certain labor supply. The table is drawn starting off with the wage w_l^* as the firm will never want to employ more workers than in the case where it did not face a permit requirement even if permits would be available for free.

As two men have equal reservation wages, a firm offering a marginally higher wage w_l^p will face a labor supply of two additional men. It may want to employ both of them or only one of them. By comparing profits it can easily be shown that they will always choose to employ two additional men as long as the product A net of the wage for the marginal worker is larger than the permit price.

Comparing profits of the firm for a labor demand of $\phi(w_l^p) = 2\phi(w_l^*)$ rather than $\phi(w_l^p) = 2\phi(w_l^*) - 2$ yields an upper permit price for the firm to be willing to employ $2\phi(w_l^*)$ of

$$A - (w_l^* - \frac{A}{J/2}) > p + \frac{A}{J/2}\phi(w_l^*). \quad (10)$$

For the firm to employ $2\phi(w_l^*)$ men the additional net product, i.e. the worker's productivity minus the wage to be paid has to cover the permit price plus the increase in the wage bill arising from the fact that all currently employed have to also receive the higher wage. As, moreover, the marginal profits are positive and increasing with lower demands for labor, the firm will demand $2\phi(w_l^*)$ workers if permit prices fulfill

$$\bar{p} = A - (w_l^* - \frac{A}{J/2}) - \frac{A}{J/2}\phi(w_l^*) > p. \quad (11)$$

Thus, for prices $0 \leq p < \bar{p}$ an exchange of ϕ_l^* permits between firms in "female" and "male" sectors is mutually advantageous.⁸ Firms in the "male" sectors will be able to purchase additionally needed permits to employ $2\phi_l^*$ men in total. With a permit market output becomes

$$Y^{tq,UneqFemDis} = S/2 \cdot 2\phi_l^* \cdot A + S/2 \cdot 2\phi_l^* \cdot A = S \cdot 2\phi_l^* \cdot A \quad (12)$$

3.4 Results

Comparing the output effects of the two policies gives

$$Y = Y^{tq,UneqFemDis} > Y^{ntq,UneqFemDis}. \quad (13)$$

⁸ $\bar{p} > 0$ as it is equal to the marginal product which the firm faces as it chooses the optimal wage without a policy constraint.

Table 2: A firm's profits facing male labor supply in a market with permits

Labor demand of firm l	w_l^p	π_l
$\phi(w_l^p) = 2\phi(w_l^*)$	w_l^*	$2\phi(w_l^*)(A - w_l^*) - \phi(w_l^*)p$
$\phi(w_l^p) = 2\phi(w_l^*) - 1$	w_l^*	$(2\phi(w_l^*) - 1)(A - w_l^*) - (2\phi(w_l^*) - 1 - \phi(w_l^*))p$
$\phi(w_l^p) = 2\phi(w_l^*) - 2$	$w_l^* - \frac{A}{J/2}$	$(2\phi(w_l^*) - 2)(A - (w_l^* - \frac{A}{J/2})) - (2\phi(w_l^*) - 2 - \phi(w_l^*))p$
$\phi(w_l^p) = 2\phi(w_l^*) - 3$	$w_l^* - \frac{A}{J/2}$	$(2\phi(w_l^*) - 3)(A - (w_l^* - \frac{A}{J/2})) - (2\phi(w_l^*) - 3 - \phi(w_l^*))p$
$\phi(w_l^p) = 2\phi(w_l^*) - 4$	$w_l^* - 2\frac{A}{J/2}$	$(2\phi(w_l^*) - 4)(A - (w_l^* - 2\frac{A}{J/2})) - (2\phi(w_l^*) - 4 - \phi(w_l^*))p$
...

The tradable employment quota is the superior policy instrument to the non-tradable quota when female labor supply is heterogeneous across sectors. Jobs that in male sectors are not productive, due to the employment quota constraint imposed on the firms there, turn productive as those firms can purchase permits that allow them to employ men.

3.5 Why move on with simulations?

In a next step, one may ask what happens to output in comparison of the two policies as we also allow for lower wage offers to women by discriminating firms, i.e. we have $\mu > 0$. Again, a strongly simplifying assumption may help to gain some intuition. Assume that all discriminating firms would be located in the “male sectors” and the non-discriminating firms in the “female sectors”. Then, we would have no wage effects at all arising from the taste discrimination and results would stay the same. Obviously, this particular assumption as the ones previously employed are very strong, perhaps even too strong to derive robust claims on the allocative effects of a tradable employment quota. A more realistic scenario is that a particular sector hosts discriminating and non-discriminating firms. Wage offers and hiring decisions of the non-discriminating firms will affect the discriminating firms and vice versa. Gender specific wages by the type of firm will emerge as well as gender specific employment rates. Moreover, firms unable to fill vacancies with workers fully matching their skill requirements will very likely start searching for workers in more distant sectors although those workers do not fully match in terms of their human capital endowment. As a consequence, the firms’ and workers’ decisions in a particular sector will have spill-overs on the labor market conditions of workers and firms in the adjacent sectors. In the following sections we will study those interrelated decisions and simulate the outcomes of the more general model introduced in Section 2. The intuition derived on the basis of the simplified model will help us to better understand the findings of the more general case.

4 Simulation set-up

4.1 Sequencing

The pseudocode outlined in Algorithm 1 gives the timing of the various actions for the simulated version of the model. A particular iteration starts with each firm l posting J vacancies. Workers apply to firms with a positive number of vacancies, with each worker sending out m applications. Firms

evaluate how high their wage offer should be to optimize on the trade-off of actually attracting workers and not letting the wage bill increase by too much. Firms make non-binding job offers obeying the non-tradable employment quota including the wage they are willing to pay to the most profitable applicants. Workers choose the job with the best wage offer conditional on it being above their individual reservation wage. Firms that were not able to hire enough women to fulfill the quota withdraw their offers to male workers.

For the case where we are looking into an economy with a tradable employment quota firms observe how many workers they are able to attract and compare their stock of permits with the number of male workers willing to work for them. Each firm draws its individual supply and demand schedule for the permits. The market maker aggregates these up and determines the market clearing price at which the permits are reallocated between firms. Firms not able to purchase the required number of permits for all the men who wanted to work for them withdraw their offers to the least profitable men.

Finally, the firms produce and observe their payoffs. At the end of each iteration all workers are dismissed and the cycle restarts.

4.2 Parametrization

We simulate a labor market with six sectors ($S = 6$) each hosting $N = 20$ firms. Each firm has $J = 10$ positions to fill. Total supply of workers is $I = 1,200$ and reservation wages are equally distributed on $[0, A]$. There is an equal number of male and female workers. When applying for jobs workers send $m = 5$ applications. A firm that fills a vacancy with a worker that has sector specific skills produces $A = 2$. The wage adjustment parameter $\tau = 10$ implies that firms learn over the past 10 iterations. They adjust wages from one iteration to the other with $\epsilon = 0.05$ which equals 2.5% of a worker's maximum productivity.

In one version of the simulation model firms do not discriminate ($\mu = 0$) and women are equally distributed across sectors ($\sigma = 0.5 = \sigma_k$). In the other version firms taste discriminate ($\mu = 0.5$ and $d_F = 0.5$). In the latter case, sectors are split into two types. There is one half of evenly numbered sectors where the share of taste discriminating firms is $\mu_s = 0.1$ and the share of female labor supply $\sigma_k = 0.7$. In the oddly numbered sectors the share of discriminating firms is $\mu_s = 0.9$ and the share of female labor supply $\sigma_k = 0.3$.

The parametrization for the policies is as follows. First we look into an affirmative action policy which prescribes every single firm to employ at least 50% women. Then, we introduce a tradable employment quota. 180 permits

Algorithm 1 Pseudocode of model implementation

```
create sectors
create workers
create firms
if tradable quota then
  distribute permits
end if
for  $t = 0$  to  $T$  iterations do
  for all firms  $l = 1$  to  $L$  do
    post vacancies
  end for
  for all workers  $i = 1$  to  $I$  do
    send  $m$  applications
  end for
  for all firms  $l = 1$  to  $L$  do
    adjust wage offer given past experience
    send non-binding job offers
  end for
  for all workers  $i = 1$  to  $I$  do
    if wage offer above reservations wage then
      accept best wage offer
    else
      decline
    end if
  end for
  if economy has tradable employment quota then
    for all firms  $l = 1$  to  $L$  do
      draft supply and demand schedules for permits
    end for
    central market maker aggregates supply and demand schedules
    central market maker determines market clearing price
    central market maker reallocates permits
  end if
  for all firms  $l = 1$  to  $L$  do
    if affirmative action policy is not fulfilled then
      firm withdraws offers to excess male workers
    end if
    produce
    dismiss all workers
  end for
end for
```

are equally distributed among the firms at the beginning of a run. Table 3 summarizes all these parameters.

Justifying the choice of parameters is inherently difficult as some of these parameters are hardly observable and empirical estimates are lacking. A firm’s taste for men is hardly measurable so that one has to recur to its consequences arising in terms of the wage differentials we observe between men and women. But even those raw differentials which often amount to about 25% lower wages for women (see, e.g., Altonji and Blank, 1999) have to be corrected for various other characteristics of the firms and workers. That skills and industry are among those control variables in empirical studies of wage differentials may be seen as justifying our assumption on the declining productivity of workers coming from adjacent sectors. The choice of parameters on workers’ application behavior was based on the notion of a labor market with frictions and adjusted such that workers apply mostly in their skill-specific sector but also consider adjacent sectors. The larger share of non-discriminatory firms coming with higher shares of female labor supply shall reflect the occupational crowding of women in sectors where they expect not to be discriminated. The quota policy parameter is in the range of the policies we actually observe or have been proposed in the ongoing policy debates (see our discussion in the introduction). Given the limited evidence and the stylized nature of the simulation model, it becomes most important to evaluate the findings against parameter changes which we do in a section on robustness (see 5.3) once the main results have been presented and discussed.

Each iteration t as described in the Pseudocode is replicated for $T = 1,010$ times. This we call a single run. Every treatment consists of 100 runs. For our analysis of the simulation outcome we record the average of the last 10 observations of every run. Thus, we have 100 observations for every treatment.

4.3 Difference-in-difference approach

A simple comparison of a tradable with a non-tradable quota would yield flawed results with respect to their labor market effects. Only if it was possible to issue the number of permits which exactly matches the restrictions that firms are facing from a uniformly applied quota the two policies would be comparable. However, as overall employment and the structure of employment by gender are endogenous this particular number of permits which makes the policies comparable cannot be determined in advance.

As a solution we apply a difference-in-difference approach to analyze the policy effects in comparison. Later on, in the robustness section we imple-

Table 3: Parameter choices

Parameters	
Number of sectors	$S = 6$
Number of firms per sector	$N = 20$
Vacancies per firm	$J = 10$
Full productivity	$A = 2$
Sectoral productivity decline	$a = 0.5$
Learning period	$\tau = 10$
Wage adjustment	$\epsilon = 0.05$
Number of workers	$I = 1,200$
Overall share of female workers	$\sigma = 0.5$
Number of applications per worker	$m = 5$
Intensity of choice	$\lambda = 1$
Share of discriminating firms	$\mu = \{0; 0.5\}$
Discrimination coefficient	$d_M = 0, d_F = 0.5$
Quota	$\bar{\sigma} = 0.5$
Number of permits	$C = 180$

ment an alternative approach. For now, the procedure will be to compare the difference of the variables of interest arising from a non-tradable employment quota comparing a labor market with an equal distribution of women and firms without discrimination to a labor market with an unequal distribution of women and of discriminating firms, with the difference between the same variables under a tradable employment quota. Denote with v the labor market variable of interest, with ntq the policy of a non-tradable employment quota, with tq the tradable employment quota, and with eq equally distributed female workers and firms and with $uneqDis$ unequally distributed female workers and discriminating firms across sectors. Then, the policy effect T writes

$$T = (v_{(ntq,eq)} - v_{(ntq,uneqDis)}) - (v_{(tq,eq)} - v_{(tq,uneqDis)}). \quad (14)$$

5 Simulation results

5.1 Baseline scenarios without policy

We start off with the version of our simulation model to which no policies, neither the tradable nor the non-tradable quota are applied and compare two cases. In one case, female workers and firms are equally distributed across all sectors, and there is no taste discrimination. In the other case, taste discriminating firms and workers are unequally distributed across sectors as explained in Section 4.2. The simulation results are shown using box plots drawing on the 100 observations for each treatment.

Figure 1 (a) shows the employment rates for both versions of the model. As expected male and female employment match on the left hand side as there are no discriminating firms and allocation of female workers and firms is homogeneous across sectors. Turning to the discriminatory version of the simulation model (*uneqDis*) reveals that male employment increases while female employment decreases. The employment pattern of the discriminatory version of the model is reflected in the wages by gender. Panel (b) shows that female wages fall short of the male wages. Note, that within this baseline scenario a quota could be a way to improve on the labor market prospects of women in the unequal case. However, we will argue that tradable permits will reach the same goal with lower distortions of welfare.

The employment and the wage effects are triggered by the introduction of discriminatory firms. First, due to their taste discriminating behavior those firms offer lower wages to women. Women who were willing to work at going labor market conditions withdraw from the labor market as wage offers decrease. Consequently female employment declines. Discriminatory firms looking for male workers to fill their vacancies will have to increase their wage offers to draw on an additional male labor supply. Male workers who did not choose to work formerly accept job offers now and, thus, male employment increases. Secondly, however, choices of the discriminatory firms have spill over effects on the behavior of the non-discriminating firms in the same and adjacent sectors. As can be seen in Figure 1 (c) the non-discriminating firms have a larger share of their vacancies filled than the discriminating firms. The difference in overall employment by the two types of firms arises as the discriminating firms have a substantially lower body of female workers. To the contrary, the non-discriminating firms employ significantly more female workers and less male workers. The non-discriminatory firms adjust their gender specific employment pattern as a response to the discriminatory behavior of their competitors. The gender wage gap (panel d) at discriminating firms reflects the dis-taste of those firms against women and manifests itself

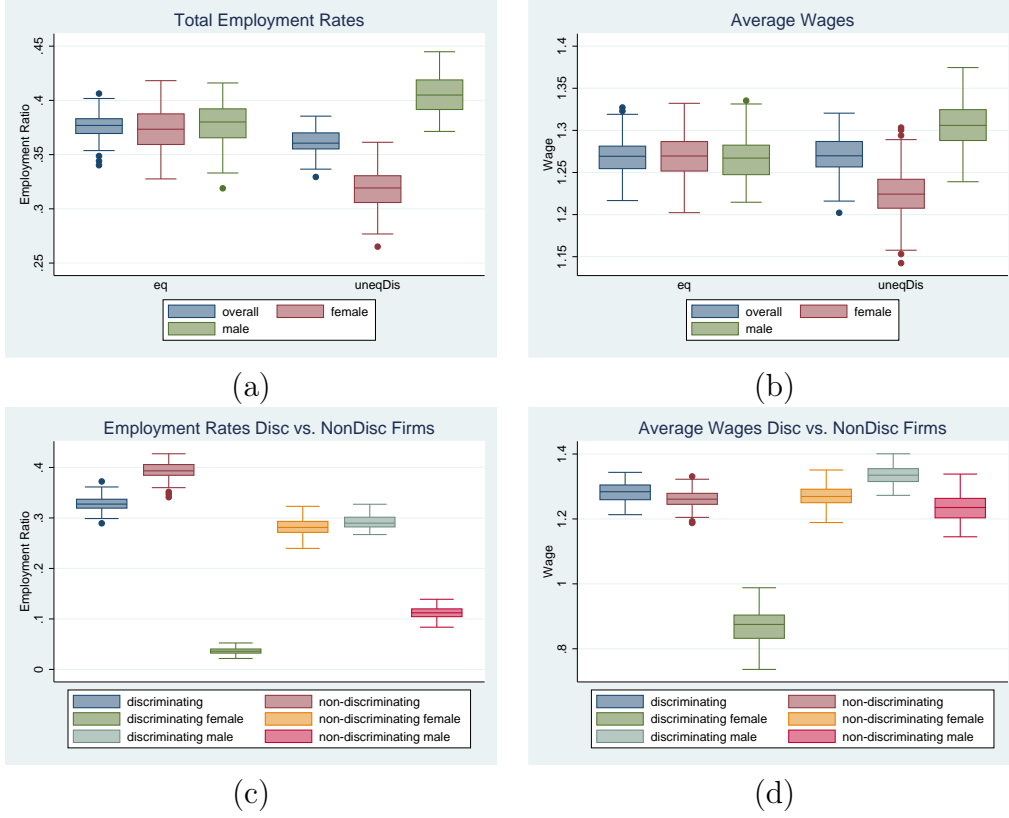


Figure 1: Employment and wage effects; (a) total employment rates by distribution of female workers and firms, (b) average wages by distribution of female workers and firms, (c) employment rates at disc. vs. non-disc. firms by gender, (d) average wages at disc. vs. non-disc. firms by gender.

in the employment pattern due to the distribution of the reservation wages of workers. A further consequence of the taste discriminating firms with respect to the wage pattern is that the non-discriminating firms pay lower male wages than the discriminatory firms because for them a female worker is a perfect substitute for a male worker.

Overall these simulations are in line with the findings of the existing literature on taste discrimination in search models of the labor market. As in Kaas (2009) and Kaas and Lu (2010) our simulation model generates employment segregation. The non-discriminating firms employ more women than men and the discriminating firms employ substantially more men. Comparable to Bowlus and Eckstein (2002) wages for women are lower than those for men. Moreover, we can relate to the search and matching model with het-

erogeneous reservation wages by Burdett and Mortensen (1998) who argue for the emergence of a wage dispersion in such frameworks. As we re-run our simulation model we do not get a single market wage, neither by gender nor by the type of firm for the 100 repetitions.

5.2 Policy evaluation

5.2.1 Trading of permits

Let us first look into the functioning of the permit market. Figure 2 shows a snapshot of the supply and demand schedules that the market maker is facing for a discriminatory labor market at a particular iteration. The downward sloping market demand stems from aggregating up the individual firms' demands for permits given prices. Similarly the upward sloping supply is the sum of permits that firms are willing to sell at given prices. As explained earlier, the market maker chooses the price where supply and demand schedules cross and reallocates the permits from those willing to sell at the market clearing price to those firms willing to buy.

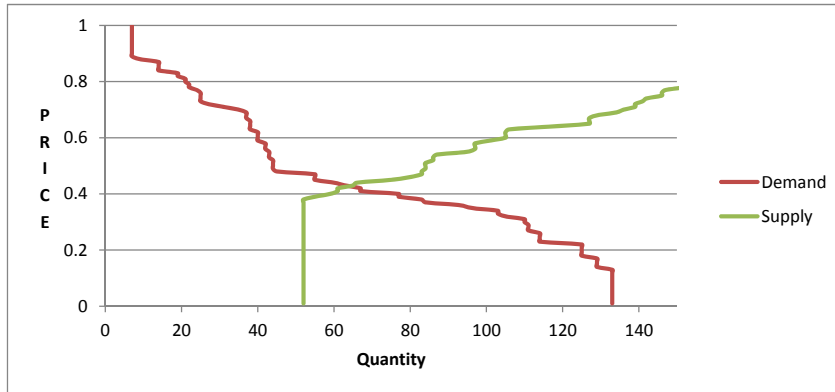


Figure 2: Bid-ask-diagram for permit trading market with an unequal female labor supply and discriminating firms across sectors at iteration 1,005.

The price for the permits and the traded volume as shown in Figure 2 refer to one iteration whereas the observations entering the box plots in Figures 3 (a) and (b) are the averages over ten iterations for the 100 runs. At the median about 64 permits are traded between firms. Prices are in the order of 0.44 which is slightly more than one fifth of the maximum productivity of a worker.

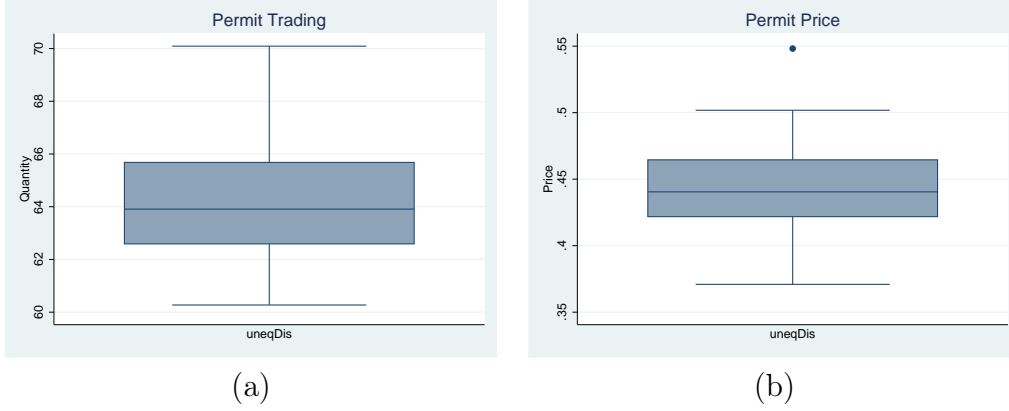


Figure 3: (a) Permit trading, and (b) permit prices

5.2.2 Welfare effects

We define welfare as the sum of all wages paid in the economy and all pay-offs accruing to firms. The welfare effects of the two policies using the difference-in-difference approach from equation (14) can be seen in Table 4. The first row shows a decline in welfare of 155 units as we move from a non-discriminatory labor market to a discriminatory labor market applying a non-tradable employment quota. Welfare also decreases for a tradable employment quota as we make the labor market discriminatory by 75 units. However, the decline is smaller so that the comparison of the welfare losses between the two policies (80) speaks for a tradable employment quota as the superior policy instrument.

These units may be interpreted in relation to total possible output. With 1,200 workers and a maximum per worker productivity of 2, the maximum of total units possible to produce in this economy is 2,400. Measured welfare falls short of the output potential due to the wage offers of profit maximizing firms below reservation wages which drives workers out of the market, and the allocation of workers to sectors where their productivity does not fully unfold. In Table 4 the output loss due to skill mismatch is calculated as the difference between actual output and the output that could have been achieved if all workers were employed in their own sector unfolding full productivity.

Overall the output loss due to skill mismatch is lower under the tradable quota. This is because firms can adjust to their labor market situation by engaging on the permit market, while under a non-tradable quota firms will try to fulfill the quota even if this means they have to hire somebody from a different sector. However, as we move from an equal to an unequal distribution of firms and workers over sectors the reduction in output loss due to

Table 4: Welfare analysis

	eq	uneqDis	diff	
non-tradable quota				
welfare	711.038	555.952	-155.086	
output loss due to skill mismatch	46.960	33.294	-13.667	
cost of distaste for women	0	23.425	23.425	
output loss due to unfilled vacancies	1,641.984	1,787.326	145.342	
output potential	2,400	2,400		
tradable quota				
welfare	772.798	697.779	-75.019	
output loss due to skill mismatch	40.479	31.803	-8.676	
cost of distaste for women	0	10.366	10.366	
output loss due to unfilled vacancies	1,586.686	1,660.038	73.353	
output potential	2,400	2,400		
				T(diff-in-diff)
				Std. err
welfare				80.067 *** 4.969
output loss due to skill mismatch				4.990 *** 0.752
cost of distaste for women				-13.060 *** 0.314
output loss due to unfilled vacancies				-71.989 *** 5.116

Note: *** denote significance at the 1% level.

skill mismatch is larger for the non-tradable quota. This is due to the fact that discriminatory firms are not able to hire women from other sectors as their distaste for women and the sectoral productivity decline induces them to offer too low wages to women from other sectors. Given the limited labor supply of women in their own sector, hiring women from neighboring sectors would be an option in order to fulfill the quota. However, the wages that these firms are able to offer are not attractive enough. Under a tradable quota such problems do not occur, as discriminatory firms in sectors with a smaller female labor supply will simply engage on the permit market. The payoff loss due to the distaste for women of discriminating firms is the wage equivalent of the distaste (d_F) multiplied with the female employment at discriminating firms. As there is less female employment at discriminating firms those costs decrease with a tradable employment quota. The largest effect on welfare of a tradable employment quota comes from a reduction of unfilled vacancies as the permits give firms a higher flexibility in terms of the gender composition of their workforce. The sum of these differentiated effects gives the welfare effect of the two policies in comparison.

5.2.3 Effect on employment, wages, and payoffs to firms

An alternative way of looking at these welfare measures is to split welfare in firm payoffs and the wage sum (see Table 5). Here we find that the wage sum is approximately twice as large as the payoffs to firms. When looking at the differences-in-differences result in the lowest third of the table we find that more than 70% of the effect of a tradable employment quota on welfare accrue to changes in the wage sum. This effect we can disentangle into an employment and a wage effect. The remaining effect on welfare is due to changes in the payoffs to the firms .

The drop in employment is less pronounced for the tradable quota as one moves from a non-discriminatory labor market to a discriminatory labor market if compared to the non-tradable quota. Why is that? Essentially, it is driven by the economic mechanisms that was already detected in the simplified version solved analytically. Without permits a firm wanting to produce may be constrained by the employment quota. There is a vacancy to be filled, and while there is no female applicant to fill the vacancy, a male worker would be willing to accept the job offer. However, the firm cannot employ him because the employment quota has to be obeyed. A tradable employment quota gives firms facing such a situation more flexibility. They may purchase a permit allowing them to employ an additional man, and they will do so as long as the additional male worker's profitability covers the price of the permit. Thus, more vacancies can actually become productive with a

Table 5: Effect on employment, wages, and payoffs to firm

	eq	uneqDis	diff
non-tradable quota			
payoffs	228.937	183.868	-45.069
wage sum	482.101	372.084	-110.017
empl.	0.316	0.255	-0.061
empl. female	0.452	0.388	-0.064
empl. male	0.180	0.123	-0.057
ave. wage	1.272	1.215	-0.057
ave. wage female	1.287	1.214	-0.073
ave. wage male	1.233	1.215	-0.018
tradable quota			
payoffs	266.377	242.537	-23.840
wage sum	506.421	455.242	-51.179
empl.	0.339	0.308	-0.031
empl. female	0.378	0.317	-0.061
empl. male	0.300	0.300	0.000
ave. wage	1.245	1.230	-0.015
ave. wage female	1.269	1.229	-0.039
ave. wage male	1.215	1.231	0.016
			T(diff-in-diff)
payoffs	21.228	***	1.959
wage sum	58.838	***	4.070
empl.	0.030	***	0.002
empl. female	0.003		0.004
empl. male	0.057	***	0.001
ave. wage	0.042	***	0.005
ave. wage female	0.034	***	0.006
ave. wage male	0.034	***	0.007

Note: *** denote significance at the 1% level.

tradable employment quota in a discriminatory labor market as reflected in the non-decline of the male employment rate for the tradable quota.

Moreover, for the tradable employment quota there is only a small wage effect while wages decrease for the non-tradable quota. Looking into the gender composition of the wage effect reveals that this occurs mainly because female wages decrease more for the non-tradable quota. As discriminating firms are facing a fixed quota they are required to hire women in order to balance their workforce. However, due to their distaste for women they are only willing to do this at a lower wage. This effect is non-existent for the more flexible tradable quota because discriminating firms can avoid to hire women by purchasing permits.

Finally, the increase in the employment rate also explains the effect of a tradable employment quota on payoffs as an otherwise unproductive vacancy is filled now.

One may even go further and analyze the distributional consequences of the two policies in comparison. How are the policies affecting wages paid at discriminating and non-discriminating firms, and do we observe effects on wages paid to workers employed in their own sector or in a sector which does not fully match their skills? Furthermore, how do the firms payoffs adjust with respect to the two policies in comparison. This is analyzed in Table 6.

Wages paid to workers who found jobs in the sector for which their skills match best decrease less if we move to an unequal distribution of firms and workers for the tradable quota if compared to the non-tradable quota. The same but larger effect can be observed for average wages of workers not employed in their own sector. Thus, there is some heterogeneity in the overall wage effect already detected in Table 4. Disentangling the overall wage effect along discriminating and non-discriminating firms reveals the following picture: the average wage of discriminating firms falls quite dramatically when moving from an equal to an unequal distribution with a non-tradable quota. This is because discriminating firms are forced to hire females, but pay much lower wages. For the tradable quota the share of females hired by discriminatory firms is quite low and thus the lower wages for females have a lower weight when calculating average wages. Actually, decomposing those wages by gender reveals that it is the wages paid to male workers by the discriminating firms driving this effect. Those firms are not constrained by a fixed quota anymore. Rather they are allowed to hire more men if they own the corresponding number of permits. But hiring those additional men requires to offer higher wages.

On average the discriminating firms have lower payoffs than the non-discriminating firms in both policy scenarios. This is due to their distaste for women and the lower wages they pay. As a consequence they draw on a

Table 6: Distributional effects

	eq	uneqDis	diff			
non-tradable quota						
ave. wage own sector	1.371	1.312	-0.059			
ave. wage other sector	0.937	0.828	-0.109			
ave. wage non-disc.	1.272	1.282	0.010			
ave. wage non-disc. female	1.287	1.301	0.014			
ave. wage non-disc. male	1.233	1.202	-0.031			
ave. wage disc.	<i>1.272</i>	1.004	-0.268			
ave wage disc. female	<i>1.287</i>	0.868	-0.420			
ave. wage disc. male	<i>1.233</i>	1.232	-0.001			
payoff disc.	<i>1.908</i>	0.680	-1.228			
payoff non-disc.	1.908	2.384	0.476			
tradable quota						
ave. wage own sector	1.331	1.308	-0.024			
ave. wage other sector	0.861	0.818	-0.043			
ave wage non-disc.	1.245	1.249	0.004			
ave. wage non-disc. female	1.269	1.274	0.005			
ave. wage non-disc. male	1.215	1.166	-0.049			
ave. wage disc.	<i>1.245</i>	1.202	-0.043			
ave. wage disc. female	<i>1.269</i>	0.862	-0.407			
ave. wage disc. male	<i>1.215</i>	1.256	0.040			
payoff disc.	<i>2.220</i>	1.646	-0.574			
payoff non-disc.	2.220	2.396	0.176			
				T(diff-in-diff)	Std. err	
ave. wage own sector				0.035	***	0.000
ave. wage other sector				0.066	***	0.000
ave. wage non-disc.				-0.006		0.005
ave. wage non-disc. female				-0.008		0.006
ave. wage non-disc. male				-0.018	**	0.008
ave. wage disc.				0.224	***	0.005
ave. wage disc. female				0.013	*	0.007
ave. wage disc. male				0.041	***	0.007
payoff disc.				0.654	***	0.016
payoff non-disc.				-0.300	***	0.020

Note: ***, **, * denote significance at the 1%, 5%, 10% levels, respectively. Entries in *italics* are approximated values for the firms which are currently non-discriminating but become discriminating firms for an unequal distribution of firms and workers.

smaller female labor supply which allows them to only fill fewer vacancies. The wedge between the payoffs of the discriminating and non-discriminating firms decreases with a tradable quota as the discriminating firms may purchase permits and thereby avoid idle vacancies due to their distaste for women. Relatively speaking, the discriminating firms profit from a tradable employment quota. It may be noteworthy at this point that looking into the distribution of payoffs to firms over time reveals that even the least profitable firms have non-negative payoffs (and will stay in the market.)

Comparing the results from the simulation model with what we derived earlier on within our analytical framework shows that similar economic mechanisms are driving the main outcomes. This is so although the simulation model rests on adaptively behaving firms and analytical results were derived under the usual assumption of rationally behaving firms. Rationality does not seem to be the crucial assumption being responsible for the effects of the two policies in comparison. Rather it occurs that adaptively behaving firms trying to find a wage offer which maximizes their profits is a somehow equivalent assumption to rationality in this context. One may even claim that it is also more appropriate as in a new policy environment firms will also have to find out for themselves how to behave best.

5.3 Robustness

We ran a series of robustness tests involving (a) the change of particular modeling assumptions, (b) changes of key parameters of our model, (c) a different initial allocation of permits to firms, and (d) an alternative evaluation of the effects of a tradable permit system when compared to a fixed quota. In all four instances we were interested in whether our main result of the positive welfare effect of a tradable employment quota prevails.

In our baseline model we let firms post wage offers to prospective workers without taking into account the upcoming costs that may arise with the need to purchase permits to employ men. Alternatively, one may imagine that firms make wage offers already taking into account that they may have to go to the permit market. To this end we ran a series of robustness tests where firms anticipate that they will have to hold permits in order to employ men and thus adjust the wage taking into consideration an estimate of the permit price. In particular, this estimated permit price p_t^e in period t was calculated as the average price over the last ten periods: $p_t^e = (\sum_{\tau=t-10}^{t-1} p_\tau) / 10$. It turned out that this led to lower wages and lower employment for men, while employment of women increased even further. Our main result, however, that a permit system is superior to a fixed quota was not affected.

In order to analyze whether our results are sensitive to changes in the

parametrization of the model we combined the two key policy parameters, i.e. the number of permits issued and the quota with all of the remaining parameters, one-by-one, and re-ran the simulations. The results of this exercise are summarized in Figures 4, 5, and 6. In all left columns of those figures we combine changes in the number of permits with one of the remaining parameters. In the right columns we combine changes in the quota with one of the remaining parameters. The grids are over three values of each parameter. The welfare effects of those nine parameter constellations are combined to a plane. The dark blue planes show the mean effect on the diff-in-diff welfare measure of 100 repetitions. Upper and lower planes in gray constitute the confidence intervals. The black dots refer to the diff-in-diff value for the welfare effect at the standard parameter constellation chosen in Table 5.

Figure 4 collects all parameters related to the adjustment behavior of agents and the number of iterations of each run. In order to exemplify how to read those graphs let us turn to Figure 4 (a). As we increase the number of iterations there is no change in the welfare measure which suggests that we have chosen an appropriate length for our simulation runs, i.e. one where the adjustment processes have worked themselves out. The flat plane furthermore indicates that this observation holds for the higher and also the lower value of permits. Turning to Figure 4 (b) replicates the analysis for a fixed quota showing that also in this case increasing the number of iterations does not alter the results. Changing the wage adjustment parameter or the learning period of the firms does not affect our main finding, either.

Figure 5 brings together parameters related to frictions in the labor market. Here, we were mainly interested in whether the number of applications sent out by the workers, their attachment to the skill-specific sector, and the closeness of sectors in terms of how suitable workers are for firms that come from adjacent sectors affect our simulation outcomes. Again, the results confirm our main findings.

Finally, Figure 6 assembles all robustness analyses related to parameters describing the discriminatory behavior of firms. This set of analyses may also be interpreted as a test on the robustness of the results given that firms' behavior may change over time. One could imagine that firms confronted with affirmative action policies or an evolving market reconsider their behavior and become non-discriminatory. Although we opted for a modeling of discriminatory behavior in the sense of taste discrimination, such behavior may, in particular, arise if one thinks of statistical discrimination as an alternative explanation of discriminatory behavior where firms may update their beliefs over time. Then the question arises whether a tradable quota system is still working. To this end, we alter the firms' costs of discrimination, the distribution of discriminatory firms over sectors, and the distribution of women

over sectors. Once more, the permit system yields welfare gains.

Another look at the right columns of all three Figures 4, 5, and 6 reveals that the welfare effects of a tradable quota relative to a non-tradable quota measured along the diff-in-diff methodology increases as the non-tradable quota becomes smaller. This result is driven by a lower difference in welfare for a fixed quota comparing an equal with an unequal distribution of firms at decreasing quotas (as the number of permits is unaffected by this change). A lower non-tradable quota increases welfare for an equal distribution of firms and women across sectors as it is easier for firms to meet this requirement. However, the increase becomes smaller as the quota is less binding (the slope when moving from a 60% quota to a 50% quota is steeper as compared to moving from a 50% quota to a 40% quota). For an unequal distribution of discriminating firms and women across sectors a less binding quota does not have the same effect on additional production. This is due to the discriminating firms offering lower wages because of their distaste for women, thus depressing female labor supply so that those firms will not be able to hire women which would allow them to fill vacancies with additional men even under a relaxed quota.

In our baseline simulation we allocated permits on a per-capita basis to the firms initially. One may wonder how alternative allocations of permits affect the results. We experimented with various other rules including a random and a highly skewed distribution of permits. As time evolves we get similar results in terms of welfare differences between the two policy instruments when compared to the per-capita rule.

Finally, we opted for an alternative evaluation of the policy effects. Rather than employing a diff-in-diff approach we modeled a government that endogenously adjusts the number of permits issued in every period so that policies become comparable. More specifically, for this robustness test permits are valid for only one period and the government every period issues a number of permits that would achieve a ratio of male to female employment compliant with a quota. What we expected from such an exercise is that on average welfare is higher for the policy simulations with tradable permits than with a fixed quota. And indeed, that is what the simulations showed which makes us more confident that the results are not driven by our methodology chosen to evaluate the policy effects.

6 Discussion

Discrimination of women (as well as other labor market groups) calls for affirmative action policies. In an economy where women's labor supply is

heterogeneous across sectors or regions, an employment quota applied uniformly to firms may cause avoidable costs to society. Firms located in sectors where the supply of female labor is relatively scarce may find it inherently difficult to comply with an employment quota whereas firms in other sectors where female labor supply is relatively strong will do better in terms of filling vacancies with female workers. Output losses may occur in sectors with relatively weak female labor supply as firms subject to the employment quota cannot fill up vacancies with men even if a woman cannot be found.

We propose and analyze a flexible quota solution. As we argue, a tradable employment quota gives firms additional flexibility to hire men if female labor supply is insufficient. By issuing permits to firms allowing them to hire men and making these permits tradable across firms, firms in shortage of women will not be forced to abandon output. Rather they will try to purchase a permit that allows them to hire a man up to the point where this additional man's profitability covers the costs of the permit. Equally, we will have firms in this market that will find it profitable to sell permits as they can easily fill their vacancies with women. An advantage of a tradable permit system is that it allows for a flexible adjustment at the firm level without having to compromise on the overall policy goal to achieve a certain share of female employment in the labor market. The scope of female employment in the economy can be managed at the aggregate level by issuing or withdrawing permits. Our results suggest that a market for a tradable employment quota may emerge, and that a more flexible policy solution is actually improving welfare. Those results have to be interpreted as arising from a comparison between two different policy measures trying to achieve higher female employment shares. Running our model without any restrictions on employer behavior yields higher welfare levels than what one gets in the policy experiments. From our point of view, however, a meaningful discussion of affirmative action policies starts from policy goal that female employment should improve, and then tries to answer the question which policy measures are most suitable to achieve this goal. Our exercise should be seen as a contribution in this spirit.

Although we did make an effort to implement features of the labor and permit market in considerable detail, we have been silent about the occupational or regional scope of a permit system. Given our discussion in the introduction on the recent moves to make shares of female workers legally binding for boards of firms, one may at first think of a permit market for that segment. In principle, however, we believe that a tradable employment quota would also work for other groups of occupations, may it be introduced nationally or for a set of countries (as it may work for other under-represented groups in the labor market).

An outcome of our analysis is that a tradable employment quota achieves an overall female employment rate at lower costs for society but results in an unequal distribution of women across firms. One may question such an outcome on the backdrop of a more normative assessment which posts that women should be equally represented also on a firm basis. In this case, evaluation of policies would certainly be tilted towards a non-tradable quota. Moreover, in a comparison of the two policies one might be inclined to favor a fixed quota if one believes that forcing firms to employ women may help to reduce prejudices against women as a possible cause of discriminatory behavior. We abstained from modeling such a feedback process as there seems to be no strong evidence currently available that points towards such a channel (see, e.g., Bertrand et al., 2010). Moreover, it is not clear to us if a fixed employment quota would only help changing preferences of “male” firms towards becoming more “neutral”. Actually, there is evidence reporting that women being protected by fixed employment quotas are stigmatized (Heilman et al., 1992, 1997). Thus, a fixed quota might actually lead to additional discrimination as women are disrespected by “ordinary” employees.

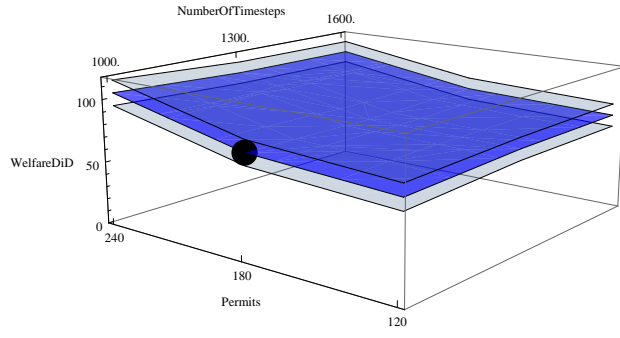
If Norwegian firms did not comply with the employment quota by January 2008 they were planned to be dissolved (Nygaard, 2011, p.23). Rather than forcing firms to go out of business, one may also think of an implementation where non-complying firms are fined. Whether such a fining system is functionally equivalent to a cap-and-trade system that we propose can be discussed very much along the well known lines of practical problems arising with the implementation of a Pigouvian tax.⁹ Very likely the marginal costs for employing women differ for firms which would require to install tailored penalties (or taxes). Collecting the necessary information and administrating such a system may be prohibitively difficult, and a permit trading system a viable alternative.

We also did not compare the two policies with respect to their medium or longer run consequences. Our focus was rather on how costs for firms that become subject to a uniform quota and have to change the gender composition of their workforce can be mitigated right after an affirmative action policy is introduced. While we have shown that within the short time horizon a tradable quota fares better it is also conceivable that a tradable quota is the better policy choice in the medium and longer run. It gives governments a flexible tool that allows them to react to changes in firms’ and workers’ behavior as time evolves by adjusting the supply of permits

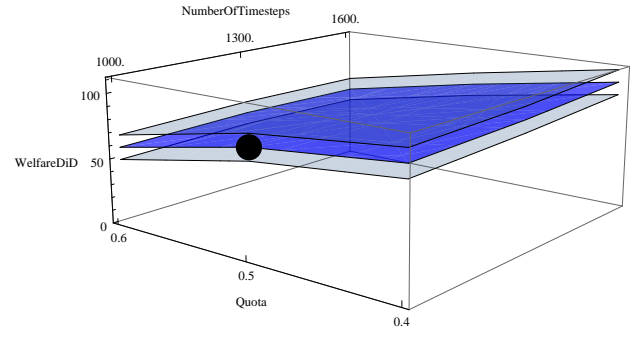
⁹Arguments for gender-based taxation have already been brought forward by Rosen (1977), Boskin and Sheshinski (1983), or, more recently, Alesina et al. (2011). There, differentiated taxes may also boost female employment at lower losses in welfare because labor supply elasticities differ between men and women.

and thereby the restrictions that firms are facing. Such a policy response could be easier to implement as changes of the law which seem to be quite often accompanied with intense public debates.

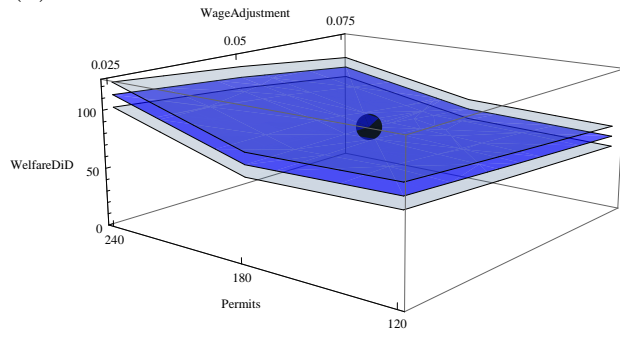
Our analysis and the results we derive rest on various assumptions we had to make. Although we ran robustness checks changing the parametrization of our model as well as the model implementation, one may be concerned about the partial nature of the model which abstracts from various feedback processes. In particular labor demand of firms is derived from a fixed product demand. Introducing a fixed or a tradable quota may, however, change the production costs of firms which firms may pass through to product prices. Thus, with heterogeneous firms relative prices and firms' market shares may change as a consequence of the policies. Actually, there is evidence on cost-pass through but estimated magnitudes to which extent this happens vary widely, see Goldberg and Hellerstein (2013) and Fabra and Reguant (2014) for two extreme cases. Given this rather large variety in estimates with a larger share of estimates finding relatively small effects of cost-pass through, we believe that a partial model should not bias our main results substantially. But it may be a worthwhile exercise to embed a comparison of affirmative actions policies in a macroeconomic model of the economy in future work, even more so as a larger share of firms becomes subject to these policies.



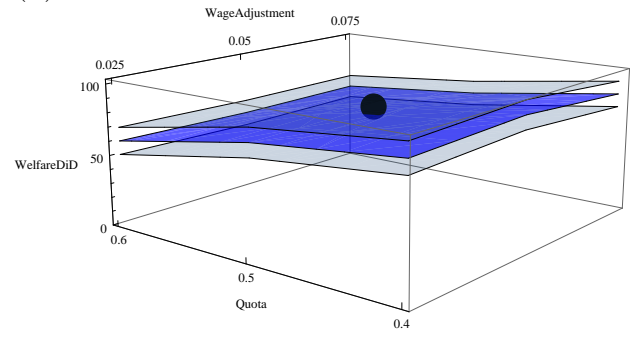
(a)



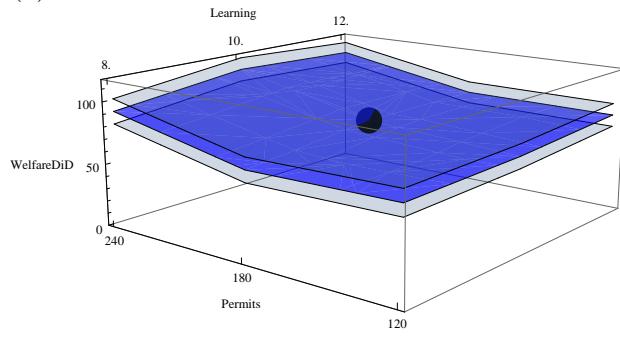
(b)



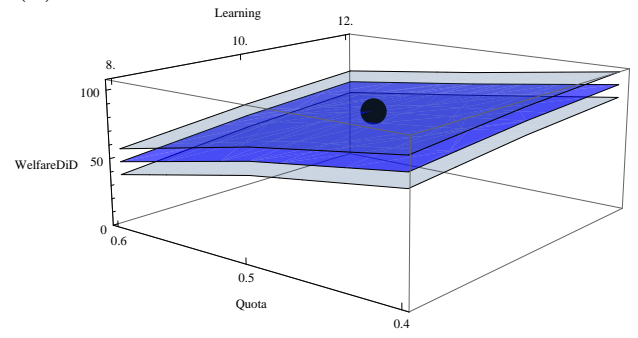
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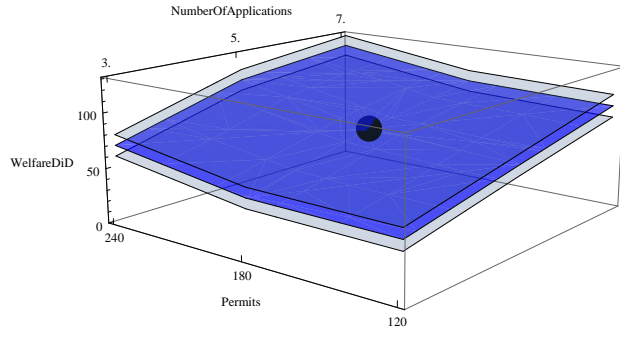


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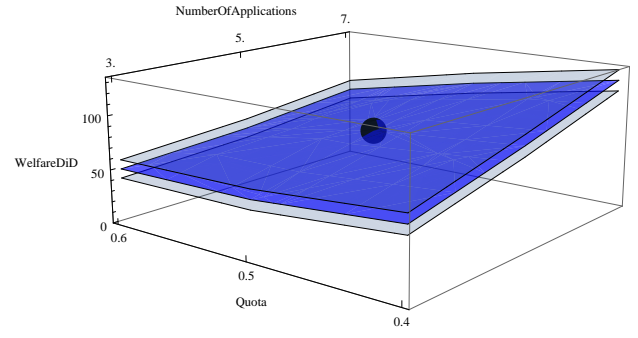


(f)

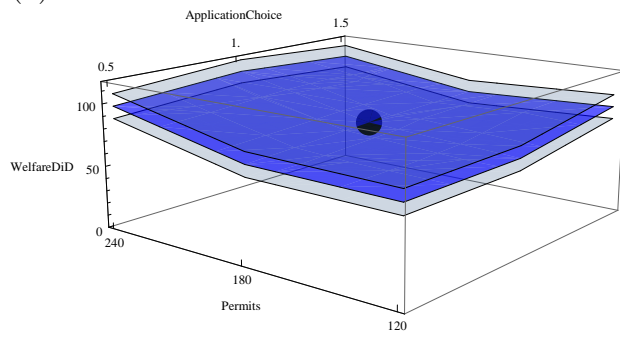
Figure 4: Robustness with respect to dynamic behavior of agents



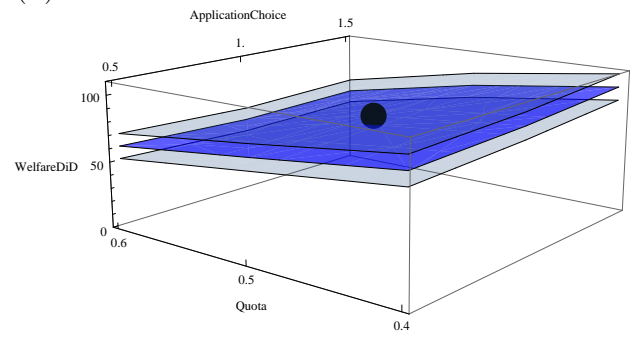
(a)



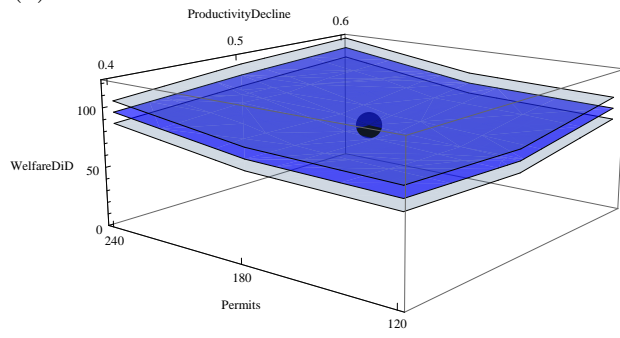
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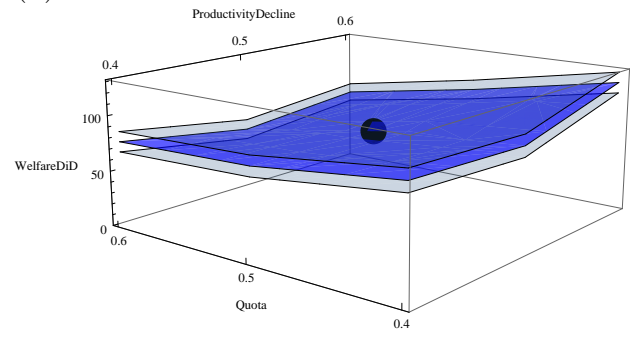
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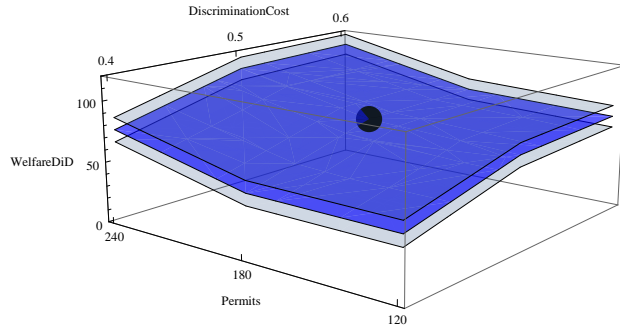


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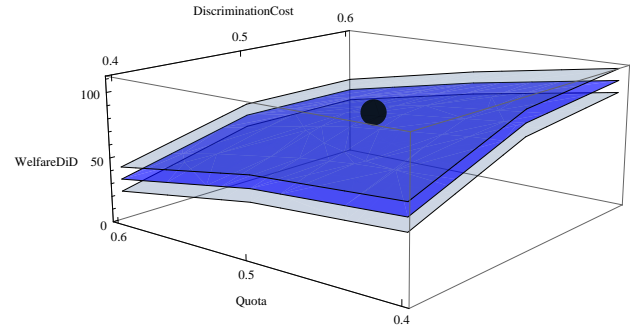


(f)

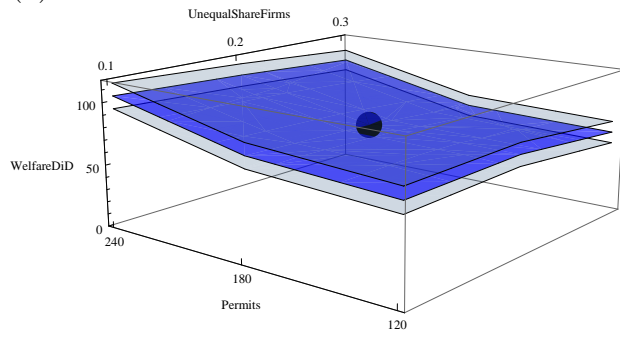
Figure 5: Robustness with respect to labor market frictions and heterogeneity



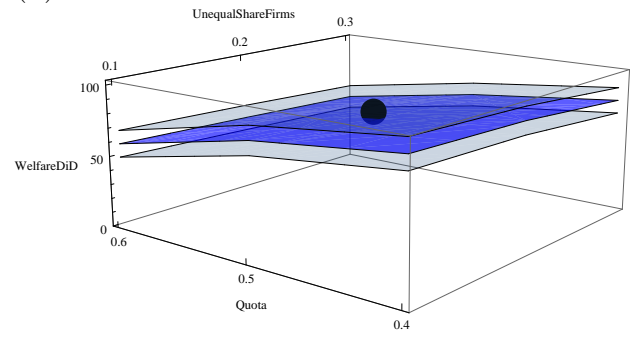
(a)



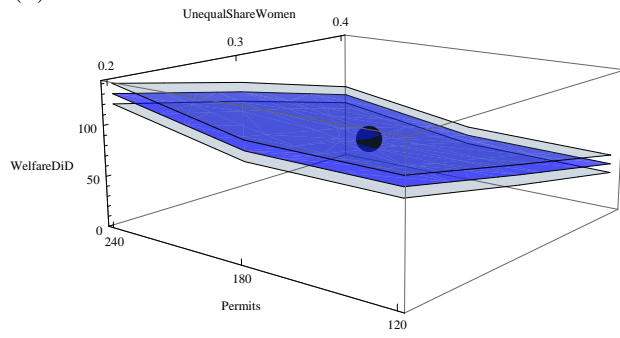
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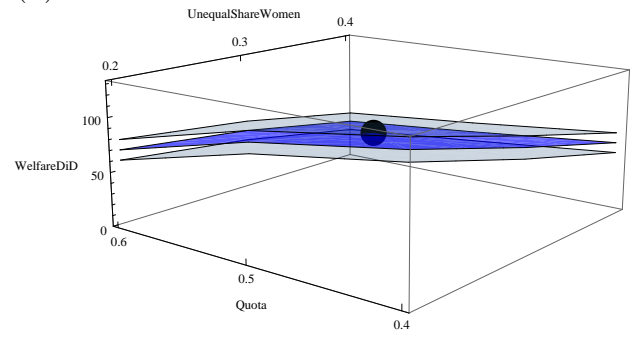
(c)



(d)



(e)



(f)

Figure 6: Robustness with respect to extent of discrimination

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Appendix

Table 7: Women on boards

Country	Members of board			Board chairs [%]	CEOs [%]
	Ave. share [%]	Min [%]	Max [%]		
USA (a)	16				
Japan	1				
EU-27	16			3	2
Finland	29			4	0
Latvia	28			13	3
Sweden	26			0	4
...					
Germany	18	0 (b)	44 (b)	3	0
...					
Portugal	7			0	0
Hungary	7			0	0
Malta	4			0	5
Norway (c)	39				

Data source: European Commission Database on women and men in decision making for 2012 if not otherwise stated. (a) European Commission: Women on boards - Factsheet 2, Gender equality in member states; (b) Der Spiegel 48/2013, p.74; (c) Ahern and Dittmar (2012, p.143).