Creaming Off and Hiring Discrimination *

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Abstract

A discriminating behavior in hiring does not only survive but also improves the welfare. This paper proves such a phenomenon by studying a simple labor matching model with a manpower-based friction in interviewing process. 'Creaming off' behavior by firms in matching is the key to this phenomenon; given that they cannot interview all of the workers, they intentionally classify identical workers into multiple groups, in order to cream off qualified workers efficiently from each group. Minority workers tend to enjoy higher employment rate from the discriminatory hiring. Testable cases in Japan and China are suggested.
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1. Introduction

Why does discriminating behavior remain in the labor market? This question has been a focal point of economists' interest since Becker (1957=1971) has pioneered in the field of labor discrimination research. Based on a model of competitive economy, he found that the effect of employers' 'tastes for discrimination' diminishes to zero if a part of employers have none of such a taste (*ibid.* Chapter 3). Then a natural question arises; what enables apparently discriminating behavior, such as those between male and female, young and old, whites and non-whites, and city residents and migrants, to survive in the market. Economists have asserted multiple causes such as incomplete information, statistical inference, and search friction.

This paper offers a new answer to this question. Particularly, the author shows that a certain kind of discriminatory hiring behavior appears and improves economic welfare in an economy with a matching friction. The author assumes that firms in the economy face a limited amount of manpower that they periodically input to interview unemployed job applicants. Such a limit may appear along with multiple distinct contexts. For an example, the economy is underdeveloped so that there are simply too many unemployed workers. For another, the majority of production depends on rather high level of technology so that firms need to carefully interview each applicant to distinguish whether he/she is qualified. Whichever, given that firms cannot interview all of the workers, they shall select the target of their interviews. Naturally, each firm is presumed to select statistically better source of qualified workers. Each firm, by classifying workers into multiple groups, tries to efficiently 'cream off' qualified workers from the barrels of unemployed applicants. This creaming off behavior is the source of discriminatory hiring.

When all the firms interview a particular group of worker earlier and the others later, they succeed to cream off more qualified workers from the set of unemployed workers than committing to egalitarian hiring behavior. If they commit to the latter, the group of interviewed and rejected workers return to the pool of unemployed workers and the density of qualified workers in the pool decreases. It worsens the efficiency of interviewing process that is held later on. Then, the policy of 'do not return skimmed milk into the barrel of fresh milk' is useful to avoid such a damage

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to efficiency. By classifying the workers into multiple groups and interviewing workers from each group once and all, they always interview 'fresh' pool of workers. This logic supports sequential discriminatory hiring behavior as welfare improving and strategically stable one.

Furthermore, non-economic force such as tastes or governmental regulation may make one particular type of discriminatory hiring likely to realize. In general, the firms do not necessarily prefer one style of discrimination to another. However, when some non-economic force conduct a propaganda for a particular style of discrimination, due to strategic complementarity of screening strategies, that particular style is likely to become unique equilibrium outcome.

The author verifies these points by studying a simple matching model with two sequential periods and a manpower limit in interviewing process. Workers in the economy have two types that are irrelevant to productivity. Each firm holds a finite density of manpower for interviewing, whose integral is assumed to be insufficient to interview the total amount of workers. Each firm selects its 'screening policy' for each period that determines which type of workers have priority to be interviewed by that firm. Then, sequential switch from one type of workers to another by all the firms becomes a stable subgame perfect equilibrium. Further, introducing firms with an adherent pattern of hiring, the author shows that a pressure by non-economic force toward a particular style of hiring, if sufficiently strong, specifies which type to be discriminated against. The author also investigates some distributive issues and shows that minority group of workers gain higher employment rate through the discrimination. Finally, the author suggests two testable cases in Japan and China.

As being mentioned above, Becker (1957=1971) has been awarded a plenty of academic responses and criticisms.[1] Arrow (1973) argues that entry by nondiscriminatory and more profitable firms drives out discriminatory and less profitable firms. Segregation may also equalize factor payments, though, that heavily depends on the complete information setting (Stiglitz 1973, 1985). If information on workers' productivity is incomplete, there appear possibilities of statistical discrimination; that is, employers shall prefer a group of workers that they may expect statistically more of qualified ones to the other groups (see Phelps 1972, Arrow 1973, Aigner and Cain 1977, and Coate and Loury 1993). Black (1995) has been a pioneer to explain persistent discriminatory wage setting based on search friction; discriminated workers' reservation wage is lower than the others given their poor employment opportunities due to discrimination. Rosen (1997), based on the urn-ball model in Blanchard and Diamond (1994), has argued that discriminatory hiring is unique equilibrium outcome when the ability information is incomplete. Rosen (2003) has proved that firms with a positive discrimination coefficient earn the highest profit in a search model. Arcidiacono (2003), studying an overlapping generations model with human capital investment, has shown that blacks may suffer from discrimination for a long time solely due to coordination failure among agents. Norman (2003) has pointed out that the statistical discrimination may contribute to the market efficiency by stopping 'free riding' in human capital investments.[2]

Compared with these literatures, this paper presents a style of welfare-improving statistical discrimination in hiring without depending on any structure of taste for discrimination, human capital investment, nor search friction. Arcidiacono (2003) and Norman (2003) are related with respect to interests in structural cause of and efficiency gain from discrimination. However, in the current analysis, the difference between groups arises not from human capital investments but from firms' hiring activity itself. In this sense, Masters (2009) is also closely related because he has studied the effect of firms' precision in interviewing on 'the average quality of the unemployment pool'. The creaming off discrimination in the current analysis occurs when the timings in which the average qualities of unemployed groups decrease are different across those groups.

[1] Cain (1986) offers a comprehensive survey on relatively earlier works.

[2] For other recent studies on the statistical discrimination, see, for example, Mailath, Samuelson, and Shaked (2000), Moro and Norman (2004), Altonji (2005), Antonovics (2006), Lange (2007), Bjerk (2008), and Fryer (2008).

This article is constructed as follows. Section 2 introduces the mathematical form of model. Section 3 is for analysis to verify the main results and other lemmas. Section 4 discusses testable cases, and Section 5 provides discussions on policy implication and future research. Section 6 summarizes the paper.

2. Model

The model is dynamic with two periods 1 and 2. A set of continuum resources, called workers, and a set of continuum firms are given. The firms and the workers are uniformly distributed with the size of F and L, respectively. Each period, firms are matched with unemployed workers.

Workers

The proportion q (< 1) of workers, i.e. the size qL of them, are *qualified*. No firm nor worker knows particular who of the workers are qualified. Note that each worker does not know whether herself is qualified or not. If a firm hires a *qualified* worker, they cooperatively produce the density v of pecuniary payoff. This is the only source of positive payoff in the current model. If the hired worker is not qualified, they cannot produce anything. Workers are split into two types, a and b. The types are irrelevant to worker's productivity. There are the size A of type a workers and the size B of type b workers, with $A + B = L$. For the notation, let us denote $A(t)$ and $B(t)$ $(t \in \{1, 2\})$ as the size of unemployed type a and b workers, respectively, at period t. It is assumed that $A(1) = A$ and $B(1) = B$. Further, let us define $q_t(k)$ $(k \in \{a, b\})$ as the proportion of qualified type k workers in the whole unemployed type k workers at period t. $q_1(k) = q$ for both types. Workers are resources and not players in the current model.

Firms, matching, and interview

Each firm maximizes her total pecuniary payoff. For this purpose, each firm matches with and interviews multiple workers in order to distinguish who of them are qualified workers.

Each firm holds a finite density of manpower, which enables herself to be matched with and interview the density m of workers per period. It is assumed that $L > 2mF$.[3] At the beginning of period 1, each firm determines its *screening policies* for two periods from alternatives of $\{r, a, b\} \times \{r, a, b\}$. A policy profile (a, b), for example, implies that a firm takes the policies a and b for periods 1 and 2, respectively. r implies a random (equal) treatment for both types of workers. a (*resp.* b) implies a preferential treatment for type a (*resp.* b) workers. It is assumed that each firm takes r when the policy does not change its payoff.

For an arbitrary period $t \in \{1, 2\}$, let $F_r(t)$, $F_a(t)$, and $F_b(t)$ be the size of the firms that follow the policy r, a, and b, respectively. They satisfy $F_r(t) + F_a(t) + F_b(t) = F$. Each period, firms are matched with the size mF of workers, among the size L of them. Let us be more specific as the following. Each firm that takes the policy a (henceforth, a-firm) is matched with the density $\min\{m, A(t)/F_a(t)\}$ of type a workers and the density $\max\{0, m - A(t)/F_a(t)\}$ of type b workers. Each firm that takes the policy b (henceforth, b-firm) is matched with the density $\max\{0, m - B(t)/F_b(t)\}$ of type a workers and the density $\min\{m, B(t)/F_b(t)\}$ of type b workers. And Each firm that takes the policy r (henceforth, r-firm) is matched with the density $m \cdot \max\{A(t) - mF_a(t), 0\}/[\max\{A(t) - mF_a(t), 0\} + \max\{B(t) - mF_b(t), 0\}]$ of type a workers and the density $m \cdot \max\{B(t) - mF_b(t), 0\}/[\max\{A(t) - mF_a(t), 0\} + \max\{B(t) - mF_b(t), 0\}]$ of type b workers. Except for these condition on type-proportions, the rationing is random. As can be seen, this rationing system is efficient and a-firms (*resp.* b-firms) have priority over type a (*resp.* b) workers.[4]

[3]This condition is critical for the results. It implies that the economy is burdened with a substantial amount of structural unemployment. A typical situation is discussed in footnote 7.

[4]For this setting, it is presumed that the firms' screening policies are ex-ante observable (but not verifiable),

After the matching, each firm interviews her matched workers. Each qualified worker has the probability $1-\epsilon_2$ of being hired; $\epsilon_2 \in (0,1)$ is the probability of type II error when the firm formulates the alternative hypothesis that the current candidate worker is qualified. Each non-qualified worker, on the other hand, has the probability $\epsilon_1 \in (0,1)$ of being hired; in other words, the type I error. It is assumed that $1-\epsilon_2 > \epsilon_1$, which ensures the effectiveness of the interview test: $x(1-\epsilon_2) > x\{x(1-\epsilon_2)+(1-x)\epsilon_1\}$ $(\forall x \in (0,1))$.[5] These hired workers proceed into a wage bargaining process, which is described below. This hiring decision is hidden and purely bilateral; if a hired worker eventually leaves the firm, she becomes just an unemployed worker, who must be interviewed again in order to gain a job.[6]

Intuitively, the current model describes the firms' recruiting environment during their rather slack seasons. Each period in the model corresponds to a term including sequential activities, such as job advertisement, workers' application to the advertisement, application reviews, interviews, and hiring decision. Since each job advertisement incurs a substantial fixed cost, the number of periods cannot increase to infinity. The current number is set to be 2 for the sake of simplification. Further, since the recruiting process consumes the manpower of each firm, it tends to occur in rather slack seasons for the firm, with some appropriate limit to the scale and the time length.[7] Considering that the timings of slack seasons differ across industries, the firms and the workers in the current model correspond to those interested in similar industries with respect to business seasonality. It might be the case that the firms in period 1 are different from those in period 2; as can be seen later in the analysis, it does not change the results.

Bargaining and payoff

After each of the interviews, through the Nash bargaining process, each firm and each of its qualified workers bargain for the individual wage level. Let $R_t(k)$ $(t \in \{1,2\})$ be the type k worker's expected wage level when she rejects the current job offer. $R_2(k)$ is assumed to be 0 for both types.[8] Expected pecuniary payoff and the reservation value $R_t(k)$ are the thread points for the firm and the worker, respectively. Specifically, the wage level for the type k worker who is hired at period t is $w_t(k) \equiv \alpha \left(\frac{q_t(k)(1-\epsilon_2)}{q_t(k)(1-\epsilon_2)+(1-q_t(k))\epsilon_1} v \right) + (1-\alpha)R_t(k)$. $\alpha \in (0,1)$ is the bargaining power that is common to all the workers. Each worker accepts the job offer with the wage $w_t(k)$ as long as $w_t(k) \geq R_t(k)$.

At the end of period 2, each firm and its hired worker collaboratively try to produce their pecuniary payoff. It is assumed that the firm has to pay its workers her predetermined individual wage $w_t(k)$, whether she is qualified or not.[9]

As a summary, the figure below shows the events flow as a total.

so that the workers may choose firms with which policy to visit. Further, this formulation itself depends on the assumption $L > 2mF$.

[5]This inequality implies that a group hired through the interview is "thicker" than its generation group. It also implies that the interview decreases the density of qualified workers remaining unemployed in the labor market.

[6]Some readers might be puzzled with this somewhat complicated setting. It is necessary for two purposes. First, with q being smaller than 1, the proportion of qualified workers definitely decreases as the time goes on; it creates an incentive of "creaming off" for the firms. Second, with ϵ_2 being larger than 0, each worker may be potentially qualified even if she is once rejected by a firm, so that she keeps searching for job as long as she is unemployed.

[7]As mentioned, such a costly interviewing process appears in two distinct contexts. One is an economy whose hiring (legal) infrastructure is still underdeveloped. Another is an economy with highly developed technologies, wherein the firms have to check whether each applicant is substantially qualified for the tasks with technical contents. The latter skill-biased hiring is often observed in developed countries; see, for instance, Sasaki and Sakura (2005).

[8]Although this assumption is plausible for the current finite-horizon model, the author owes that it is restrictive simplification when you consider it as a reduced formulation of a stationary equilibrium of some dynamic model.

[9]Positive profit is ensured by the construction of $w_t(k)$.

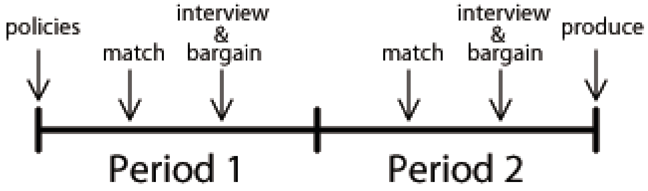

Figure 1

Treaters

As an extension module, the author introduces 'treaters.' Treaters are firms that adherently treat type a workers earlier. For a parameter $\delta \in [0, 1)$, the size δF of the firms are the treaters. From period 1 on, for common level ρ ($\in \{1, 2\}$) of periods, they take the policy a. Candidates of motive for their biased attitude are various. It may be the employers' taste or prejudice for a (against b); in this case, maybe $\rho = 2$. It may represent the effect of a governmental regulation on labor market, such as an employment protection regime; in this case, δ and ρ represents the degree of effectiveness and the time length of the regulation, respectively. Further, it may be some cultural or religious habit; δ represents the proportion of the holders of such a habit.

3. Analysis

Throughout the analysis, the equilibrium notion is the subgame perfect equilibrium. Further, there frequently appear expressions such that one type of workers (as a group) are *thicker* than another. Let the author define it briefly. Type a workers are *thicker* than type b workers at period t when $q_t(a)$ is larger than $q_t(b)$, vice versa. When the proportion is the same for both types, both types of workers are *equally thick*.

3.1. Basic model and results

As a benchmark, the analysis starts from the case without treaters; that is, $\delta = 0$. First, the author shows that an egalitarian hiring behavior is one of equilibria outcomes. If all the firms take the policy r every period, no firm has an incentive to deviate from the policy, because there appearrs no difference in 'thickness' between two types of workers.

Proposition 1

If all the firms take (r, r), that strategy profile is an equilibrium.

Proof: With this strategy profile, every period, every worker has the same probability of being interviewed. Then, at every period, both types of workers are equally thick and have the same level of $R_t(k)$ (and $w_t(k)$). Therefore, no firm discriminates for nor against any type of workers.∎

However, unfortunately, this egalitarian equilibrium is unstable. Suppose that a positive measure of firms are replaced with the treaters, with $\rho = 1$. This makes type b workers thicker than type a workers at period 2. The firms will voluntarily change their policies at period 2 to b. Further, this change increases $R_1(b)$. It implies the increase of $w_1(b)$, which induces the firms to change their policies at period 1 to a.

Meanwhile, there exist two stable equilibria with discriminatory behavior. The incentive of creaming off supports these equilibria. The key logic has appeared in the instability argument just above. If all the firms take (a, b) (*resp.* (b, a)), they voluntarily maintain their discriminatory policy schedules.

Proposition 2

If all the firms take (a, b) (resp. (b, a)), that strategy profile is an equilibrium.

Proof: The author focuses on the equilibrium (a, b) without loss of generality. The policy a at period 1 makes type b workers at period 2 thicker than type a workers. $R_2(k) = 0$ for all the workers, so that $w_2(k)$ is the same for all the workers. Therefore, the policy b at period 2 is the firms' best response. The policy b at period 2 makes $R_1(b)$ higher than $R_1(a)$. Since both types are equally thick at period 1, the firms voluntarily take the policy a at period 1.$\blacksquare$

Each firm voluntarily creams off better source of labor force. As a result, the creaming off activity becomes voluntary discrimination in hiring.[10] Further, the benefit from creaming off makes these equilibria stable. The equilibrium strategy (a, b), for example, is the firms' best response as long as the scale of perturbation in strategy is small enough for $R_1(b) > R_1(a)$ and $q_2(b) > q_2(a)$ to be satisfied.[11]

As is pointed out before, this existence does not depend on the setting that the firms at period 1 are the same firms to those at period 2. On one hand, influencing the levels of $R_1(k)$, the discriminatory screening at period 2 incurs the discriminatory response at period 1. On the other hand, affecting the levels of $q_2(k)$, the discrimination at period 1 induces that at period 2. There is no need of the same firms surviving through both periods.

Efficient Discrimination

These stable and discriminatory equilibria exhibit better welfare than the previous unstable and egalitarian one. In this sense, the creaming off discrimination is more efficient than the equal treatment. It is plausible when we consider that the firms as a whole conduct the creaming off in order to enjoy better matching in the former equilibria. To formally prove this assertion, the author has to define a welfare notion. Since the only source of positive payoff is matching between a firm and a qualified worker, the author simply defines the welfare as the total size of hiring of qualified workers. Further, the author names the equilibria in focus as the equilibrium (a, b), (b, a), and (r, r), respectively. Then, a trivial calculation proves the following proposition.

Proposition 3

Each of the equilibria (a, b) and (b, a) exhibits better welfare than the equilibrium (r, r).

Proof: See the Appendix A1.

The discriminatory equilibria exhibit higher welfare performance due to higher frequency of matching with relatively thicker type of workers, particularly at period 2. Since a positive measure of workers remain unmatched even at period 2, the firms can literally discriminatingly select thicker type of workers as their matching partners by controlling their screening policies appropriately. Such discriminative matching by firms, as a result, improves the hiring efficiency of the economy as a whole.[12]

Let the author note that this result crucially depends on the assumption $L > 2mF$. If this assumption is violated, rigorously if $mF\{q(1 - \epsilon_2) + (1 - q)\epsilon_1 + 1\} > L$ is satisfied, the creaming off behavior does not improve the welfare performance of economy. It is necessary for this welfare result that unmatched workers remain in the labor market at the final period. Only if there remains such unmatched workers, the firms can improve their total welfare performance by minimizing the size of thicker type of unmatched workers.

Surplus, wage, and employment

Finishing the welfare analysis, the author would like to focus on some distribution issues next. Particularly, three topics are discussed: the division of surplus between the demand side (firms) and the supply side (workers), the wage levels, and the employment rates. Each of main assertions in the discussions appears as a lemma.

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[10]This logic of creaming off discrimination is similar to that of "reverse discrimination" in Arcidiacono (2003). One important point of difference is that there occurs no coordination 'failure' by the firms in the current analysis.

[11]The readers can easily show that there is no other stable equilibrium.

[12]As is clarified later, there are three ranges of parameters according to which equilibrium outcome rigorously differ; explicitly, $(A \geq mF) \wedge (B \geq mF)$, $A > mF > B$, and $B > mF > A$. A part of the statements of results, however, omit this parameter issue, particularly when it does not make any qualitative difference in the results.

I. Division of Surplus

The author starts from the surplus comparison, with the simplest definition of surpluses as the following. The demand side surplus ($DS(j,k)$ $(j,k) \in \{(r,r),\ (a,b),\ (b,a)\}$) is defined as the integral of $v - w_t(k)$ for all the hiring contracts, respectively for each equilibrium. Similarly, the supply side surplus ($SS(j,k)$ $(j,k) \in \{(r,r),\ (a,b),\ (b,a)\}$) is defined as the integral of $w_t(k)$.

On one hand, the demand side surplus definitely gains from the creaming off discrimination. As seen from the welfare analysis, the amount of hiring itself increases through the discrimination. Further, the terms of trade improves for the firms. Let us consider the equilibrium (a,b). By the discriminatory screening, the chances of second interview for type a workers, that is, the chances for the qualified type a workers at period 1 of being interviewed again at period 2, decreases. It implies the decrease of $R_1(a)$ and $w_1(a)$. Of course, simultaneously, $R_1(b)$ and $w_1(b)$ increases. However, the wage cost for firms in total decreases since the firms select cheaper labor force.

On the other hand, the supply side faces the trade-off between employment and payment. While the total amount of employment is larger when the creaming off is implemented, the workers' terms of trade deteriorates through the discrimination. Whether the supply side in total also enjoys the benefit from the discrimination depends on the workers' bargaining power (α). If the workers may claim sufficiently large proportion of the pecuniary payoff, their gain from the improved rate of matching overwhelms their loss from deteriorated terms of trade.

The following lemma summarizes the previous discussion.

Lemma 1

i) $DS(a,b) > DS(r,r)$ *and* $DS(b,a) > DS(r,r)$.

ii) There exists a value $\alpha_0 \in [0,1)$ *that satisfies* $SS(a,b) > SS(r,r)$ *if* $\alpha > \alpha_0$. *A similar result stands for* $SS(b,a)$.

Proof: See the Appendix A2.

Although the terms of trade for the supply side in total deteriorates due to the discrimination, it does not imply that the wage level for *each type* of worker should decrease nor that the income distribution becomes more unequal. Next discussion deals with these topics.

II. Wage

To begin with, the author represents the formulation of the wage level $w_t(k)$.

$$w_t(k) \equiv \alpha \left(\frac{q_t(k)(1-\epsilon_2)}{q_t(k)(1-\epsilon_2) + (1-q_t(k))\epsilon_1} v \right) + (1-\alpha)R_t(k).$$

It can be verified that $w_t(k)$ is an increasing function of $q_t(k)$ and $R_t(k)$.

In order to discuss the type-wise wage level, the author defines $w_t(k;x,y)$ ($k \in \{a,b\}$, $(x,y) \in \{(a,b),(b,a),(r,r)\}$) as the (offered) wage level for type k qualified worker at period t in the equilibrium (x,y). Furthermore, in the current discussion, we have to distinguish three ranges of parameters, according to which there appear some $w_t(k;x,y)$ such that the measure zero of type k workers receive $w_t(k;x,y)$ at period t. Henceforth, as an abbreviation, the author writes $w_t(k;x,y)$ is *relevant* (*resp. irrelevant*) when a positive (*resp.* zero) measure of type k workers are offered $w_t(k;x,y)$ at period t. Those ranges in focus are, explicitly, (i) $\min(A,B) \geq mF$, (ii) $A > mF > B$, and (iii) $B > mF > A$.[13] In all the cases, $w_t(k;r,r)$ is relevant for $k \in \{a,b\}$ and $t \in \{1,2\}$; rather, the parameters affect the relevancy of $w_t(k;a,b)$ and $w_t(k;b,a)$. In the first case, $w_1(a;a,b)$, $w_2(b;a,b)$, $w_1(b;b,a)$, and $w_2(a;b,a)$ are relevant. In the second case, $w_1(a;a,b)$, $w_2(a;a,b)$, $w_2(b;a,b)$, $w_1(a;b,a)$, $w_1(b;b,a)$, and $w_2(a;b,a)$ are relevant. And in the third case, $w_1(a;a,b)$, $w_1(b;a,b)$, $w_2(b;a,b)$, $w_1(a;b,a)$, $w_2(a;b,a)$, and $w_2(b;b,a)$ are relevant.

[13] $mF \geq \max(A,B)$ does not stand since $L = A + B > 2mF$ is assumed.

The order of those wage levels generally differs across the parameter cases, except that $w_t(a;r,r) = w_t(b;r,r)$ for all the cases. Therefore, the author discusses each case separately in the following. Since the workers' types a and b are substitutable, the author fixes his focus on the comparison of the equilibria (r,r) and (a,b).

In the first case, $\min(A,B) \geq mF$, $w_1(a;a,b)$ is lower than $w_1(a;r,r)$ because in the equiulibrium (a,b) the type a workers do not have any chance of second interview. Their $R_1(a)$ is equal to zero in the equilibrium (a,b), with $q_1(a) = q$ for both equilibria. While each type a worker's terms of trade worsens from the discrimination, that of type b worker improves due to the increase of $q_2(b)$. Since, in the equilibirum (a,b), the type b workers' first opportunities of interview are at period 2, $q_2(b) = q$. In the equilibrium (r,r), $q_2(b)$ is less than q, with $R_2(b) = 0$ for both equilibria. Therefore, $w_2(b;a,b) > w_2(b;r,r)$. For both types of workers, the interview opportunity is once and for all, which implies $w_1(a;a,b) = w_1(b;a,b)$.

In the second case, $A > mF > B$, the order is quite similar to that in the first case. Points of difference are that $w_1(a;a,b) > w_2(b;a,b)$ and that $w_2(a;a,b)$ is relevant. Since type a workers have opportunities of interview at period 2 in the equilibrium (a,b), $R_1(a) > 0 = R_2(b)$, which implies $w_1(a;a,b) > w_2(b;a,b)$. However, the probability of gaining $w_2(a;a,b)$ is rather lower than that for $w_2(a;r,r)$. Then, with a similar logic to that in the previous case, it can be shown that $w_1(k;r,r) > w_1(a;a,b) > w_2(b;a,b) > w_2(k;r,r)$ $(k \in \{a,b\})$. $w_2(a;a,b)$ is the lowest among the relevant wage levels because at period 2, remaining type a workers just have been intensively skimmed off, so that $q_2(a)$ is even lower than that in the equilibrium (r,r).

In the third case, $B > mF > A$, $w_1(k;r,r) > w_1(a;a,b) > w_2(b;a,b) > w_2(k;r,r)$ still stands. Instead of $w_2(a;a,b)$, $w_1(b;a,b)$ is relevant. $w_1(b;a,b)$ is the highest among the relevant wage levels, since at period 1 in the equilibrium (a,b), type b qualified workers have a strong bargaining position such that their type is the main target of interview at next period.

Lemma 2

i) If $\min(A,B) \geq mF$, $w_1(k;r,r) > w_1(a;a,b) = w_2(b;a,b) > w_2(k;r,r)$ $(k \in \{a,b\})$.

ii) If $A > mF > B$,

$w_1(k;r,r) > w_1(a;a,b) > w_2(b;a,b) > w_2(k;r,r) > w_2(a;a,b)$ $(k \in \{a,b\})$.

iii) If $B > mF > A$,

$w_1(b;a,b) > w_1(k;r,r) > w_1(a;a,b) > w_2(b;a,b) > w_2(k;r,r)$ $(k \in \{a,b\})$.

Proof: See the Appendix A2.

With respect to equality of compensation, comparison of the egalitarian equilibrium and the discriminatory equilibrium is rather complicated. For the majority of workers, the discriminatory equilibrium, somewhat contradictorily, exhibits more equal compensation distribution. For all the parametric cases, $w_1(k;r,r) > w_1(a;a,b) \geq w_2(b;a,b) > w_2(k;r,r)$ $(k \in \{a,b\})$ stands. However, depending on the parameters, a minority (but positive measure) of workers may receive extremely high or low wage. On one hand, the egalitarian equilibrium may be more preferable than the discriminatory one because the discrimination sometimes lowers the minimum of the relevant wage level. However, on the other hand, it can be said that the discrimination enhances the employment by lowering the wage levels and therefore contributes to the equality of compensation for the workers as a whole.

III. Employment Rate

Let us denote $e(k;x,y)$ as the employment rate for type k workers in the equilibrium (x,y); the rate itself is calculated as the size of hired type k workers divided by the size of type k workers as a whole. The analysis on the employment rate for total workers is redundant and therefore omitted, since its result is clearly seen from the welfare comparison.

As a consistent tendency, with respect to the employment rate, the majority type of workers tend to suffer from the loss due to the discrimination. That is because the discriminatory screening offers an excessive priority for the minority type, from the viewpoint of the majority type. For example, suppose that the type a workers are overwhelming majority relatively to the type b workers, with $\min(A, B) \geq mF$. If the hiring manner is egalitarian, most of the hired workers will be of type a, with the same employment rates for both types. However, in the equilibrium (a, b), the size mF of each type of workers are interviewed; in this case, just a half of the hired workers are type a. Then, the minority type b of workers definitely enjoy a higher employment rate under the discriminatory screening.

Lemma 3

i) Suppose $\min(A, B) \geq mF$. *There exists* γ (> 1) *such that* $e(a; a, b) > e(a; r, r)$ *(resp.* $e(b; a, b) > e(b; r, r)$*) if and only if* $\gamma > A/B$ *(resp.* $\gamma > B/A$*).*

ii) Suppose $A > mF > B$. *There exists* $\gamma_0 > 0$ *such that* $e(a; a, b) > e(a; r, r)$ *if and only if* $\gamma_0 > A/B$. *There exists* μ^* *such that* $\gamma_0 > 1$ *if* $mF/L > \mu^*$. $e(b; a, b) > e(b; r, r)$ *stands without any additional condition.*

iii) Suppose $B > mF > A$. *There exist* μ_1 *and* μ_2*, which satisfy* $0 < \mu_1 < \mu_2 < 1/2$ *and the following characteristics. If* $mF/L \in [0, \mu_1]$, $e(b; r, r) > e(b; a, b)$. *If* $mF/L \in (\mu_1, \mu_2)$*, there exists* $\gamma_1 \in (1, \infty)$ *such that* $e(b; a, b) > e(b; r, r)$ *if and only if* $\gamma_1 > B/A$. *If* $mF/L \in [\mu_2, 1/2]$, $e(b; a, b) > e(b; r, r)$. $e(a; a, b) > e(a; r, r)$ *stands without any additional condition.*

Proof: See the Appendix A3.

As being seen above, if type k workers' size, say K, satisfies $1/2 > K/L$, their employment rate is better in the creaming off hiring system than in the egalitarian hiring system. The behavior of the majority's employment rate is, on the other hand, somewhat complicated. Depending on the parameters, the majority workers might also enjoy higher employment rate in the discriminatory system. In such a case, their size must be sufficiently close to that of minority.

Robustness

As a final of this subsection, the author discusses two topics on the robustness of the previous results.

First, the readers might suspect that the main results shall be vulnerable in a dynamically extended version of the current model: that is, a model with more periods. Faithfully speaking, the answer is yes and no, depending on the specific manner of such an extension. If the manpower limit for interviewing process keeps to be relevant in the economy, then the results keep to be established. As being mentioned first in the analysis, the main results depend on the assumption that L is sufficiently large compared to mF: that is, $L > \{1 + q(1 - \epsilon_2) + (1 - q)\epsilon_1\}mF$. With this condition, the firms always have an incentive to tap from better type-group of the workers, and the welfare improves through such creaming off discrimination. Roughly speaking, $L > 2mF$ is sufficient for the results. Therefore, even if the number of periods becomes n (> 2), as long as $L > nmF$ is satisfied, the result is robust; with a presumption of some appropriate perturbation on the strategy profile, the egalitarian equilibrium (if any) shall be always unstable due to possible existence of the discriminating firms.

Further, the workers might wait patiently to be employed in an infinite horizon model because, with some settings, they shall face the same hiring opportunities each period. If we assume perfectly patient workers in the infinite horizon setting, the answer may be positive. However, with some cost of delay in hiring, negative. If we assume some practical damage from the delay such as time discounting, poor social security, or finite lifetime of workers,[14] then the workers are likely to compete for earlier employment.

For the distribution issues, a part of the results is quantitative in the sense that it depends

[14] It might be noteworthy that Arcidiacono (2003) also has considered the workers with a finite lifetime.

on the specific analytical form of the current model. While the lemmas 1 and 2 are qualitative results, the statements in lemma 3, particularly ii) and iii), heavily depend on the form. The behavior of employment rate of the minority type-group is independent from the specific form, though, that of the majority type-group is model-dependent.

Second, it might be unclear why the firms do not increase the amount of their manpowers or lower their qualification thresholds (in other words, raise the level of q) in order to evaluate more applicants. The current model implicitly presumes a situation wherein the constraint on interviewing process endogenously determine the level of m. The manpower limit also limits the amount of firm's total laborforce, so that the manpower for the interview is naturally limited stationarily. Lowering the level of q, while increasing the employment, tends to lower the average level of pecuniary payoff v. Again implicitly, the level of q is presumed to be at an endogenously determined level due to this trade off.

3.2. Treaters

In the foregoing analysis, types a and b have been completely substitutable; the stable equilibria (a, b) and (b, a) have always coexisted. Now, the author discusses a possibility that some non-economic factor such as taste, prejudice, cultural attitude, and/or employment protection policy, may determine a unique stable equilibrium. Specifically, the author introduces the treaters; that is, henceforth, it is assumed that $\delta > 0$. To simplify the analysis, in this subsection, it is assumed that $\min(A, B) \geq (1 + \delta)mF$.

In order to consider an economy with the treaters, we have to examine the equilibrium notion because a part of the firms' policies are constrained. Fortunately, we do not have to change the equilibrium notion itself; the notion of subgame perfection is still sufficient for the analysis. However, on the other hand, we have to re-define what the notation such as an equilibrium (x, y) indicates. If $\rho = 1$, a profile of (equilibrium) policies (x, y) is a profile such that the non-treaters take the strategy (x, y) and the treaters take the strategy (a, y). If $\rho = 2$, a profile of (equilibrium) policies (x, y) is a profile such that the non-treaters take the strategy (x, y) and the treaters take the strategy (a, a).

First, let us consider the case wherein $\rho = 1$. Each treater in this case have an opportunity of free action at period 2. Typical of such treaters are those firms with both discriminative thought and economic interest. They do not want to give up the benefit from creaming off and just want to treat their favorite type of workers better (with respect to their wages).

On one hand, straightforwardly, the equilibrium (a, b) exists with no further parametric condition. If both the treaters and the non-treaters take the policy a at period 1, then all the firms voluntarily take the policy b at period 2 and the strategy profile (a, b) in the previous subsection is reproduced. The equilibrium (b, a), on the other hand, needs an additional constraint on parameters for its existence; that is, δ must be sufficiently small. If δ is so large that $q_2(b) > q_2(a)$ is satisfied, all the firms voluntarily deviate to take the policy b at period 2. Further, with a positive measure of the treaters, the equilibrium (r, r) no longer exists. Even if the non-treaters take (r, r), the treater's policy a at period 1 makes (r, r) suboptimal for each firm.

Lemma 4

Suppose $\rho = 1$ and $\delta > 0$. The equilibrium (a, b) always exists. The equilibrium (b, a) exists if $\frac{A}{A+B} > \delta$.

Proof: See the Appendix A4.

Second, for the case wherein $\rho = 2$, the author just simply states that there also exist two discriminatory equilibria, (a, b) and (b, a), and a certain upper bound of δ for the existence of the equilibrium (b, a). The logic in this case is the same to that in the previous lemma and therefore the author omits the detail.

Intuitively we may regard the treaters as (anonymous) activists who conduct a practical propaganda of one style of hiring discrimination. If the effect of propaganda is sufficiently strong, the other firms follow their voice, judging based on the economic efficiency. Note that the treaters in the equilibrium (b, a) is conspicuous. In this equilibrium, an observer such as government may easily find out the treaters among the group of firms since they take clearly different policy from those of the non-treaters at period 1. The treaters in the equilibrium (a, b), on the other hand, are under the cover of the others. It is impossible for any observer to spot them since all the firms are apparently identical.

4. Implications for Testable Cases

The previous results can be summarized in two points. First, if a labor market holds the friction in interviewing process, even if it has none of search friction, discriminatory hiring behavior appears as the outcome of stable equilibrium and it shows better welfare performance than the egalitarian behavior. Second, if the firms treat the minority preferentially, the wage level and employment rate for the minority tend to be better than those for the majority.

According to these points, typical testable cases of the current model are those with developed labor market and apparently discriminatory preferential treatment for some minority.[15] The target of test shall be the distribution of wages and jobs, and furthermore, if possible, the efficiency performance of discriminating firms. The author wishes to suggest two typical cases: that is, i) the labor market in Japan with preference for newly graduated persons and ii) the urban labor market in China with (institutional) preference for urban residents, in comparison with rural immigrants.

In Japan, the firms' hiring sections have prima-facie taste for new university graduates. It is frequently pointed out that those over 25 can be hired by large companies only through a certain irregular mid-way hiring process (called *chuto saiyo*), not on the regular basis (*teiki saiyo*), and such irregular opportunities are often worse with respect to compensation. This kind of cohort effect in Japan youth employment experientially well-known and has been often empirically verified (see Ohta, Genda, and Kondo 2008, Kambayashi and Kato 2009, Mitani 1999, and Mitani 2008). With respect to hiring per year, the firms generally hire more of the mid-way workers than the new graduates (Ministry of Labor 2009). It implies that the firms know the productivity of mid-way workers well and therefore this discrimination does not seem to be based on groundless prejudice. Explanation by learning model seems not necessarily to work (see, for example, Ariga et al. 1999). In total, the new graduates as minorities seem to enjoy their privileged status. Then, application of the current model may shed a light on possibility of market-structural cause of this hiring discrimination.

Growing rural-to-urban migration have been a substantial phenomenon in Chinese economy and society since its drastic reform in 1979 (for a comprehensive review, see Zhao 2005). Although the rigid residence regulation through the *hukou* system has loosened in last decade, there still remains clear labor market segregation on both institutional and economic basis (Knight, Song, and Jia 1999, Cai 2001, Huang and Pieke 2003, Demurger et al. 2006). Particularly, in urban area, a dualism between rural migrants and city residents is observed (Wang and Zuo 1999, Meng and Zhang 2001, Maurer-Fazio and Dinh 2004, Lu and Song 2006). A researcher may be able to investigate some stability of this segregation based on the current model; the institutional barriers against rural migrants correspond to the existence of treaters. Further, Fan (2002) points

[15] In contrast, the current model does not explain well the harsh discrimination against the black people in the US. For that purpose, see, for example, Arcidiacono (2003) and/or Rosen (2003).

out that permanent migrants have recently manifested as 'the most privileged and successful elites, followed by nonmigrant natives, and finally by temporary migrants at the bottom of hierarchy.' This finding is consistent with the current result on wage distribution.

5. Other Discussions

As a policy implication, the current result poses a suspicion against the relevancy of those anti-discriminative legislative schemes. The Anti Discrimination Act, for example, might punish just the profit maximization behavior by the firms. Even if there is no firm with discriminative taste nor dispersion in the workers' ability in the economy, market-wise hiring discrimination might appear as the result of optimization. Further, in some cases, you cannot distinguish the firms' optimization from the taste-based discrimination.[16] The affirmative action against the creaming off discrimination incurs nothing or the opposite discrimination: that is, the shift of equilibrium from discriminatory one to discriminatory another. Some explicit population-based quota system might dispel the discrimination, while yielding some second-best welfare performance.[17]

The author wishes to offer two ideas of possible extensions. One is an application to sector-wise discrimination. Another is an analysis of some dynamic version. First, the logic in the current results can be applied to consider sector-wise hiring discrimination. Suppose a public sector and a private sector exist in a city. There lives city residents and rural (temporary) migrants in that city and both of them are workers. The public sector is famous among the workers due to its higher productivity, and therefore vacancies in the public sector tend to be occupied earlier than those in the private sector. If the public sector (i.e. the firms at period 1) prefers the city residents and the private sector (at period 2) prefers the migrants, this discrimination behavior may be stable and market-wise efficient. Second, an analysis of some infinite horizon version of the current model may offer a basic theoretical tool to investigate interactions between migration and labor market development. On one hand, the increase of labor force tend to incur the creaming off discrimination. On the other hand, the efficiency gain through the discrimination may attract more inflow of labor force. However, the inflow might stop when the wage gap due to the discrimination discourages migrants.

6. Conclusion

Through this paper we have established a simple labor matching model with the manpower-based friction in interviewing process, which has exhibited a pattern of welfare maximizing hiring discrimination. Assuming the existence of some remaining uninterviewed workers, the firms discriminate a group of workers from the others in order to 'cream off' their workers more efficiently. The minority side of workers tend to enjoy higher employment rate due to the discrimination. If some non-economic force makes a large part of the firms conduct the practical propaganda of one style of hiring discrimination, that style becomes the unique equilibrium outcome. The results pose a suspicion against the relevancy of the anti-discriminative legislative schemes. The author has suggested two testable cases as Japan youth employment and China urban labor market.

Appendix

A1. Proof of Proposition 3

Let us focus on comparison between equilibria (r, r) and (a, b). Each period, not depending

[16] Epstein (1992) shows a rich set of cases wherein discrimination is reasonable in the sense that it enhances efficiency of some system.

[17] On unsolved questions about the affirmative action, see Fryer and Loury (2005). Moro and Norman (2003) shows a a possibility that the affirmative action may harm the intended beneficiaries. Fryer (2007) points out that the explicit quota exhibits better welfare performance than implicit ones.

on equilibrium, the size mF of the workers are matched with and interviewed by the firms.

In the equilibrium (r, r), the size $mFq(1-\epsilon_2)$ of qualified workers are hired at period 1. Simultaneously the size $mF(1-q)\epsilon_1$ of the non-qualified workers are hired. Then, the size of unemployed workers at period 2 is $L - mF\{q(1-\epsilon_2) + (1-q)\epsilon_1\}$. The size of unemployed and qualified workers is $qL - mFq(1-\epsilon_2)$. Therefore, the size of hired qualified workers at period 2 is $mF\frac{qL-mFq(1-\epsilon_2)}{L-mF\{q(1-\epsilon_2)+(1-q)\epsilon_1\}}(1-\epsilon_2)$. Totally, the welfare of equilibrium (r, r) is:

$$mFq(1-\epsilon_2)\left[1 + \frac{L - mF(1-\epsilon_2)}{L - mF\{q(1-\epsilon_2) + (1-q)\epsilon_1\}}\right].$$

In a similar way, the welfare of equilibrium (a, b) can be calculated. It takes different value according to three distinct ranges of parameters: $\min(A, B) \geq mF$, $A \geq mF > B$, $B \geq mF > A$.

$$\text{If } \min(A, B) \geq mF,\ mFq(1-\epsilon_2) \cdot 2.$$

$$\text{If } A \geq mF > B,\ mFq(1-\epsilon_2)\left[1 + \frac{B}{mF} + \frac{mF - B}{mF}\frac{A - mF(1-\epsilon_2)}{A - mF\{q(1-\epsilon_2) + (1-q)\epsilon_1\}}\right].$$

$$\text{If } B \geq mF > A,\ mFq(1-\epsilon_2)\left[1 + \frac{B - (mF - B)(1-\epsilon_2)}{B - (mF - B)\{q(1-\epsilon_2) + (1-q)\epsilon_1\}}\right].$$

It can be proved that each of them is largers than the welfare of equilibrium (r, r). For the second case, the proof depends on the assumption that $L > 2mF$.

A2. Proof of Lemma 1 and Lemma 2

The formulation of the wage level $w_t(k)$ is

$$w_t(k) \equiv \alpha\left(\frac{q_t(k)(1-\epsilon_2)}{q_t(k)(1-\epsilon_2) + (1-q_t(k))\epsilon_1}v\right) + (1-\alpha)R_t(k).$$

The author uses the definiton of $w_t(k; x, y)$ ($k \in \{a, b\}$, $(x, y) \in \{(a, b), (b, a), (r, r)\}$) in this subsection. Further, the author additionally defines $q^{(1)} \equiv q(1-\epsilon_2) + (1-q)\epsilon_1$ and $q^{(2)} \equiv q(1-\epsilon_2)^2 + (1-q)\epsilon_1^2$. For example, $q(1-\epsilon^2)/q^{(1)}$ indicates the ratio of qualified workers in a group of hired workers at period 1. $q^{(2)}/q^{(1)}$ indicates the probability that a worker who is offered a job at period 1, rejecting that job, is again offered a job if he/she is fortunately matched with a firm at period 2. In the same manner, for an arbitrary $q_0 \in (0, 1)$, the author may define and use the notation such as $q_0^{(1)}$ and $q_0^{(2)}$. Then the following results are obtained.

$$w_1(k; r, r) = \alpha v(1-\epsilon_2)\left\{\frac{q}{q^{(1)}} + \frac{mF}{L - mFq^{(1)}}\frac{q^{(2)}}{q^{(1)}}(1-\alpha)\frac{q_2(k; r, r)}{q_2(k; r, r)^{(1)}}\right\},$$

$$w_2(k; r, r) = \alpha v(1-\epsilon_2)\frac{q_2(k; r, r)}{q_2(k; r, r)^{(1)}},$$

$$DS(r, r) = (1-\alpha)vmF(1-\epsilon_2)\left(q - \frac{mF}{L - mFq^{(1)}}q^{(2)}\alpha + q_2(k; r, r)\right),$$

$$SS(r, r) = \alpha vmF(1-\epsilon_2)\left\{q + \frac{mF}{L - mFq^{(1)}}q^{(2)}(1-\alpha) + q_2(k; r, r)\right\},$$

where $q_2(k; r, r) = \dfrac{Lq - mFq(1-\epsilon_2)}{L - mFq^{(1)}}$.

i) If $\min(A, B) \geq mF$,

$$w_1(a; a, b) = w_2(b; a, b) = \alpha v\frac{q(1-\epsilon_2)}{q^{(1)}},$$

$$DS(a, b) = (1-\alpha)vmF(1-\epsilon_2) \cdot 2q, \quad SS(a, b) = \alpha vmF(1-\epsilon_2) \cdot 2q.$$

ii) If $A \geq mF > B$,

$$w_1(a; a, b) = \alpha v(1-\epsilon_2)\left\{\frac{q}{q^{(1)}} + \frac{mF - B}{A - mFq^{(1)}}\frac{q^{(2)}}{q^{(1)}}(1-\alpha)\frac{q_2(a; a, b)}{q_2(a; a, b)^{(1)}}\right\},$$

$$w_2(a;a,b)=\alpha v(1-\epsilon_2)\frac{q_2(a;a,b)}{q_2(a;a,b)^{(1)}},\quad w_2(b;a,b)=\alpha v(1-\epsilon_2)\frac{q}{q^{(1)}},$$

$$DS(a,b)=(1-\alpha)vmF(1-\epsilon_2)\left\{q-\frac{mF-B}{A-mFq^{(1)}}q^{(2)}\alpha\frac{q_2(a;a,b)}{q_2(a;a,b)^{(1)}}+q_2(a;a,b)\frac{mF-B}{mF}+q\frac{B}{mF}\right\},$$

$$SS(a,b)=\alpha vmF(1-\epsilon_2)\left\{q+\frac{mF-B}{A-mFq^{(1)}}q^{(2)}(1-\alpha)\frac{q_2(a;a,b)}{q_2(a;a,b)^{(1)}}+q_2(a;a,b)\frac{mF-B}{mF}+q\frac{B}{mF}\right\},$$

where $q_2(a;a,b)=\dfrac{Aq-mFq(1-\epsilon_2)}{A-mFq^{(1)}}$.

iii) If $B\geq mF>A$,

$$w_1(a;a,b)=\alpha v(1-\epsilon_2)\frac{q}{q^{(1)}},\quad w_2(b;a,b)=\alpha v(1-\epsilon_2)\frac{q_2(b;a,b)}{q_2(b;a,b)^{(1)}},$$

$$w_1(b;a,b)=\alpha v(1-\epsilon_2)\left\{\frac{q(1-\epsilon_2)}{q^{(1)}}+\frac{mF}{B-(mF-A)q^{(1)}}\frac{q^{(2)}}{q^{(1)}}(1-\alpha)\frac{q_2(b;a,b)(1-\epsilon_2)}{q_2(b;a,b)^{(1)}}\right\},$$

$$DS(a,b)=(1-\alpha)vmF(1-\epsilon_2)\left\{q-\frac{mF-A}{B-(mF-A)q^{(1)}}q^{(2)}\alpha\frac{q_2(b;a,b)}{q_2(b;a,b)^{(1)}}+q_2(b;a,b)\right\},$$

$$SS(a,b)=\alpha vmF(1-\epsilon_2)\left\{q+\frac{mF-A}{B-(mF-A)q^{(1)}}q^{(2)}(1-\alpha)\frac{q_2(b;a,b)}{q_2(b;a,b)^{(1)}}+q_2(b;a,b)\right\},$$

where $q_2(b;a,b)=\dfrac{Bq-(mF-A)q(1-\epsilon_2)}{B-(mF-A)q^{(1)}}$.

It can be easily shown that $DS(a,b)>DS(r,r)$ for each case. Note that $SS(r,r)$ is decreasing function of α with the infimum of $\alpha vmF(1-\epsilon_2)\{q+q_2(k;r,r)\}$. It can be shown that $SS(a,b)>SS(r,r)$ for each case if $\alpha=1$. By continuity, there exists α_0 in the statement. Noting that $q/q^{(1)}$ is increasing function of q, the result of lemma 2 is straightforwardly obtained.

A3. Proof of Lemma 3

Not depending on the parameters, $e(k;r,r)=\frac{mFq^{(1)}+mFq_2(k;r,r)^{(1)}}{L}$.

First, suppose $\min(A,B)\geq mF$. $e(a;a,b)=\frac{mFq^{(1)}}{A}$, $e(b;a,b)=\frac{mFq^{(1)}}{B}$. Solving $e(a;a,b)>e(k;r,r)$, we have $\gamma\equiv\frac{q^{(1)}(L-mFq^{(1)})}{Lq^{(1)}-mFq^{(2)}}>\frac{A}{B}$. It can be shown that $q^{(2)}>{q^{(1)}}^2$ so that $\gamma>1$. Solution of $e(b;a,b)>e(k;r,r)$ is $\frac{q^{(1)}(L-mFq^{(1)})}{Lq^{(1)}-mFq^{(2)}}>\frac{B}{A}$.

Next, suppose $A>mF>B$. $e(a;a,b)=\frac{mFq^{(1)}+(mF-B)q_2(a;a,b)^{(1)}}{A}$, $e(b;a,b)=q^{(1)}$. $e(b;a,b)>e(k;r,r)$ always stands. Solving $e(a;a,b)>e(k;r,r)$, we have:

$$\frac{(1-\mu q^{(1)})\{(1-\mu)\mu q^{(2)}-\mu^2{q^{(1)}}^2\}}{(1-2\mu)q^{(1)}-(\mu-2\mu^2)q^{(2)}-(\mu-2\mu^2){q^{(1)}}^2+\mu^2(1-\mu)q^{(1)}q^{(2)}-\mu^3{q^{(1)}}^3}>\frac{A}{B}\ \text{ where } \mu=\frac{mF}{L}.$$

The LHS is positive and converges to $\frac{2-q^{(1)}}{q^{(1)}}$ (>0) when $\mu\to\frac{1}{2}$. By continuity, there exists some μ_0 in the statement.

Third, suppose $B>mF>A$. $e(a;a,b)=q^{(1)}$, $e(b;a,b)=\frac{(mF-A)q^{(1)}+mFq_2(a;a,b)^{(1)}}{B}$. $e(a;a,b)>e(k;r,r)$ always stands. Solving $e(b;a,b)>e(k;r,r)$, we have:

$$(1-\mu)(1-\mu q^{(1)})\{\mu q^{(2)}-(1-\mu)q^{(2)}\}$$
$$>\{(1-2\mu)q^{(1)}-(\mu-2\mu^2)({q^{(1)}}^2+q^{(2)})\mu^3q^{(1)}q^{(2)}+(\mu^2-\mu^3){q^{(1)}}^3\}\tfrac{B}{A}.$$

The LHS is positive iff $\mu>\frac{{q^{(1)}}^2}{{q^{(1)}}^2+q^{(2)}}$. The RHS is decreasing to μ and positive when $\mu=\frac{{q^{(1)}}^2}{{q^{(1)}}^2+q^{(2)}}$. Further, the LHS is increasing to μ if $\mu\geq\mu_0$. Then, defining $\mu_0\equiv\frac{{q^{(1)}}^2}{{q^{(1)}}^2+q^{(2)}}$, $\exists\mu_1,\ \mu_2\in(\mu_0,1/2)$ such that $\mu_1<\mu_2$, the RHS equals to the LHS if $\mu=\mu_1$, and the RHS equals to

0 if $\mu = \mu_2$. As a result, if $\mu \in [0, \mu_1)]$, $e(k;r,r) > e(b;a,b)$. If $\mu \in (\mu_1, \mu_2)$, there exists some $\gamma_1 \in (0,1)$ such that $e(b;a,b) > e(k;r,r)$ if and only if $\gamma_1 > B/A$. If $\mu \in [\mu_2, 1/2)$, $e(b;a,b) > e(k;r,r)$.

A4. Proof of Lemma 4

Let us focus on the existence condition of equilibrium (b,a) (the proof for the equilibrium (a,b) is in the main body). The condition is $q_2(a) > q_2(b)$ with $q_2(a) = \frac{Aq - mF\delta q(1-\epsilon_2)}{A - mF\delta q^{(1)}}$ and $q_2(b) = \frac{Bq - mF(1-\delta)q(1-\epsilon_2)}{B - mF(1-\delta)q^{(1)}}$. Noting that $1 - \epsilon_2 > q^{(1)}$, the solution is $\frac{A}{A+B} > \delta$.

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