Why do Ethnic Minorities Search Less? A Transport-Mode Based Theory

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Abstract

The aim of this paper is to show that different transport modes between whites and nonwhites lead to different search intensities. We develop a theoretical model in which whites mainly use cars to commute whereas nonwhites use public transportation. We show that, for both whites and nonwhites, living in areas where employed workers' average commuting time is higher yield the unemployed to search more than in areas with lower commuting time. Because of different transport modes, we also show that white unemployed workers search more intensively than nonwhites even if both live in areas where employed workers have exactly the same average commuting time. This is because using a faster transportation mode allows unemployed whites to accept jobs that are located further away and thus to have a higher area of search than nonwhites.

Key words: Commuting time, job access, search intensity.
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1 Introduction

(To be completed)

2 The general model

2.1 Model and notations

There is a continuum of workers and firms. The mass of workers is taken to be 1 and the mass of firms is $M > 1$. Following Salop (1979), we model heterogeneity by means of a circle along which both workers' and firms' locations are uniformly distributed on the circumference C of a circle of length 1 (see also among others Marimon and Zilibotti, 1999 and Hamilton et al., 2000). This is the geographical space and we denote by $0 \leq x_{ij} \leq 1/2$ the geographical distance between a worker located in i and a firm located in j.[1] It is assumed that workers are unable to change their residential location. One way to justify this assumption is that homes are less mobile than jobs (Manning, 2003).

At each moment of time, a worker can be either employed in a certain firm (or more exactly within a certain geographical distance from a firm) or unemployed. All unemployed workers search for a job and we assume that there is no on-the-job search. Similarly, at each moment of time, a firm can have either a filled position or an open vacancy (and in this case search for a worker). We denote by $u(i)$ the number of unemployed (or equivalently the unemployment rate) at location i and by $V(j)$ the number of vacancies at location j.

As in Marimon and Zilibotti (1999), we restrict attention to initial distribution such that the same proportion of workers are unemployed at all locations i, i.e. $u(i) = u$, $\forall i \in C$. It is easy to show (see Lemma 1 of Marimon and Zilibotti, 1999) that, in this case, a stationary equilibrium must have a uniform distribution of vacancies at all locations, i.e. $V(j) = V$, for all $j \in C$.

Time is continuous and workers live forever. A vacancy can be filled according to a random Poisson process. Similarly, unemployed workers can find a job according to a random Poisson process. In aggregate, these processes imply that there is a number of contacts (or matches) per unit of time between the two sides of the market that are determined by the following standard

[1] Because it is a circle of lenght 1 where distance is measured on both sides, the maximum distance between a firm and a worker is 1/2.

matching function:

$$M \equiv M(\overline{s}\, u, V) \tag{1}$$

Each unemployed worker has a search intensity equal to s, which is defined as how much effort he/she provides in the search process. Accordingly, $\overline{s}$ represents the average intensity of search of all the unemployed workers in the economy.

As usual (Pissarides, 2000), $M(.)$ is assumed to be increasing in both its arguments, concave and exhibits constant returns to scale. As a result, the probability of filling a vacancy per unit of time for a firm is given by:

$$\frac{M(\overline{s}\, u, V)}{V} = M\left(\frac{1}{\theta}, 1\right) \equiv q(\theta)$$

where $\theta = V/(\overline{s}u)$ is a measure of labor market tightness in search intensity units. Similarly, the probability of obtaining a job per unit of time for an unemployed worker with search intensity s is given by:

$$\frac{s}{\overline{s}} \frac{M(\overline{s}\, u, V)}{u} = s\, M\,(1, \theta) \equiv s\, \theta q(\theta)$$

By using the properties of the matching function, it is easy to see that

$$q'(\theta) < 0 \text{ and } \frac{\partial\left[\theta q(\theta)\right]}{\partial\theta} > 0 \tag{2}$$

since more vacancies increase the probability to find a job and decrease the probability to fill a vacancy.

Let us now focus of individual decisions. For simplicity we assume that the housing consumption is fixed and normalized to 1 for all workers (employed and unemployed). The land rent R paid by workers (employed and unemployed) has to be the same at each location since the number of unemployed and employed workers at each location is also the same. Furthermore, contrary to the standard result in urban economics where only one employment center prevails (see e.g. Fujita, 1989), here land rent does not depend on distance to jobs because jobs are distributed around the circle and, over their lifetime, *workers change jobs but not their residential location* so that distance to jobs change stochastically over time. As a result, at the steady state, the average time and physical distance to jobs is the same for all workers. As a result, the land rent R does not depend on distance to jobs and has the same value at each location.

We are now able to write the *instantaneous* utility function of both unemployed and employed workers. Assuming risk neutrality for all workers, the unemployed obtain the following instantaneous utility function:

$$b - R - C(s)$$

where b denotes the unemployment benefit, R, the land rent at each location and $C(s)$ is the total cost of searching for jobs. The latter encompasses the costs of buying newspapers, commuting contacting friends, phone calls, interviews, ... We assume that $C(0) = 0$, $C'(s) > 0$ and $C''(s) > 0$. For an employed working at a geographical distance x, his/her *instantaneous* utility function is given by:[2]

$$w(x) - R - T(x)$$

where $0 \leq x \leq 1/2$ denotes the distance between a residential location and a firm, $w(x)$ is the wage paid to workers at a distance x from the firm (this wage will be determined below) and $T(x)$ is the total cost of commuting as a function of the geographical distance to jobs. This cost is given by:[3]

$$T(x) = f + \tau w(x) t(x) \tag{3}$$

where f denotes the fixed cost of the transportation mode, τ a positive coefficient, $t(x)$ the time it takes to commute to jobs when residing at a distance x and thus $\tau w(x) t(x)$ represents the total time cost for a person residing at a distance x from his/her job. As usual in this type of model, the wage here represents the opportunity cost of time. We have

$$t(x) = \frac{x}{\mu} \tag{4}$$

where μ denotes the (average) speed of a trip to jobs. If one for example uses a car to go to work, then he/she has a higher fixed cost f but it takes less time to go to work (higher speed μ). As a result, one can measure distance

[2] As this will become clear below, the wage setting will be such that w is a function of x.

[3] This is the common way of modelling transport cost in the transport mode choice literature; see for example LeRoy and Sonstelie (1983) and Sasaki (1990). For simplicity and without loss of generality, we have omitted in (3) the variable part of the commuting cost (i.e. the pecuniary commuting cost).

Observe however that, in a more general model, the link between commuting costs and the wage paid is achieved through a labor-leisure choice, which implies that a unit of commuting time is valued at the wage rate (see, for example, Fujita, 1989, Chapter 2). However, such a model is cumbersome to analyze, and it is likely not to yield additional insights beyond those available from our simpler approach, which is consistent with the empirical literature that shows that the time cost of commuting increases with the wage (see, e.g. Small, 1992, and Glaeser, Kahn and Rappaport, 2000).

to jobs in terms of physical distance x (i.e. number of miles) or time distance $t(x)$ (i.e. hours). In other words, two workers using different transport modes, will not reach the same physical distance during the same time.

Denote by δ the job destruction rate, and by '0' the *unemployed state* and by '1' the *employed state*. Then, in steady-state, W_0 and $W_1(x)$, respectively the expected discounted lifetime utility of an unemployed worker and an employed worker living at a distance x from his/her job are given by the following Bellman equations:[4]

$$rW_1(x) = w(x)\left(1 - \tau\frac{x}{\mu}\right) - R - f - \delta\left[W_1(x) - W_0(s)\right] \tag{5}$$

$$rW_0(s) = b - R - C(s) + s\,\theta q(\theta)\left[2\int_0^{\widehat{x}}\left[W_1(x) - W_0(s)\right]dx\right] \tag{6}$$

where $r \in (0,1)$ is the discount rate and $\widehat{x}$ is the maximum geographical distance for which the unemployed accept to take a job (beyond $\widehat{x}$ all jobs will be turned down by the unemployed).

Let us comment these equations. Equation (5) has a standard interpretation. When a worker is employed today, he/she works at a distance x and he/she obtains an instantaneous (indirect) utility equals to $w(x)(1 - \tau x/\mu) - R - f$. Then, this worker can lose his/her job with probability δ and, in this case, experiences a reduction in intertemporal utility equal to $W_1(x) - W_0(s)$. Equation (6) has the following interpretation. When a worker is unemployed today, he/she provides a search effort of s and his/her instantaneous utility is $b - R - C(s)$. Then, he/she can obtain a job with a probability $s\,\theta q(\theta)$. However, this worker will not accept all job offers but only the ones that give him/her a higher intertemporal utility, i.e. all jobs at distance x for which $W_1(x) \geq W_0(s)$. Since $\widehat{x}$ is defined such that $W_1(\widehat{x}) = W_0(s)$, then all jobs that involve commutes at a higher distance than $\widehat{x}$ will be turned down. The term in bracket is multiplied by 2 because each worker considers the distance to jobs from both sides of his/her location. When this unemployed worker accepts a job offer at a distance x from his/her residential location, he/she obtains an increase in intertemporal utility equals to $W_1(x) - W_0(s)$.

We can also write the Bellman equations for the firm. The expected discounted lifetime utility of a firm with a filled job and a firm with a vacancy, respectively denoted by $F_J(x)$ and F_V, are given by:

$$rF_J(x) = y - w(x) - \delta\left[F_J(x) - F_V\right] \tag{7}$$

[4]For the model to make sense, we assume throughout that $1 > \tau/(2\mu)$ since this guarantees that $1 > \tau x/\mu$, $\forall x \in [0, 1/2]$.

$$rF_V = -\gamma + q(\theta)\left[2\int_0^{\widehat{x}}\left[F_J(x) - F_V\right]dx\right] \qquad (8)$$

where y is the productivity of a worker and γ denotes the firm's search cost per unit of time. The interpretation of (7) is similar to that of (5). Let us interpret (8). As it is written in (7), workers' productivity y does not depend on their distance to jobs x. As a result, all employed workers are identical from the firms' viewpoint. However, when a firm has a vacant job and pays γ to search for workers, it has a probability $q(\theta)$ to have a contact with a worker, but knows that workers with geographical distance greater than $\widehat{x}$ from them will always turn down a job offer. As a result, even though firms are indifferent to hire workers with different distance to jobs (since they all produce y), their area of research is limited to $\widehat{x}$ because they anticipate that beyond this distance workers will refuse to take a job.

2.2 Free-entry condition and labor demand

Firms enter in the market up to the point where they make zero (expected) profits, i.e. $F_V = 0$. Using (7) and (8), we have:

$$F_J(x) = \frac{y - w(x)}{r + \delta} \qquad (9)$$

$$2q(\theta)\int_0^{\widehat{x}} F_J(x)dx = \gamma \qquad (10)$$

This equation means that the (expected) value of a job is equal to the expected search cost, i.e. the cost per unit of time multiplied by the average duration of search for the firm.

Combining these equations yields

$$\int_0^{\widehat{x}} (y - w(x))dx = \frac{\gamma(r + \delta)}{2q(\theta)} \qquad (11)$$

For a given wage w, we can already examine here the relationship between $\widehat{x}$ and θ. By differentiating (11), we have

$$\frac{\partial\theta}{\partial\widehat{x}} = -\frac{y - w(\widehat{x})}{\gamma(r + \delta)q'(\theta)}2\left[q(\theta)\right]^2 > 0$$

This is quite intuitive. When the area of search increases so that workers are ready to accept jobs located further away, firms create more jobs (or equivalently more firms enter in the labor market) because they have more chance to fill up a vacancy (workers are less "picky" and F_V increases).

2.3 Wage determination

Let us now determine the wage setting. At each period, the total intertemporal surplus is shared through a generalized Nash-bargaining process between the firm and the worker. The total surplus is the sum of the surplus of the workers, $W_1(x) - W_0$, and the surplus of the firms $F_J(x) - F_V$. Since $F_V = 0$, at each period, the wage is determined by:

$$(1-\beta)\left[W_1(x) - W_0(s)\right] = \beta F_J(x) \tag{12}$$

where $0 \leq \beta \leq 1$ denotes the bargaining power of workers. In Appendix 1, we show that (12) is equivalent to:

$$w(x) = \frac{\beta\left(y + s\,\gamma\,\theta\right) + (1-\beta)\left[f + b - C(s)\right]}{1 - (1-\beta)\tau x/\mu} \tag{13}$$

which gives the bargain wage that each employed worker obtains depending on their distance to jobs. Observe that, for a given s, not surprisingly, the wage increases with labor market tightness θ since more vacancies or less unemployment increases the outside option of the workers. Observe also that, for a given θ, an increase in workers' search effort s does not always lead to higher wages. There are in fact two opposite forces at work. Indeed, when s increases, workers have more chance to find a job when unemployed and thus their outside option rises. However, their cost of search $C(s)$ also increases and this decreases their bargaining power. As a result, the net effect is ambiguous. Let us now comment the properties of this wage for a given θ and a given s (since these are endogenous variables that will depend in equilibrium on all the parameters). First, when the unemployment benefit b, the workers' productivity y, the fixed cost of transportation f or the workers' bargaining power β increases, firms increase the negociated wage because the outside option of workers is higher. Second, let us see the impact of distance x and transport mode μ on wages. When x, the distance to jobs increases, workers spend more time in commuting and thus their opportunity cost of time rises. As a result, firms have to increase wages to compensate workers for the increase in this cost. On the contrary, when μ increases (workers use faster transport modes), wages are reduced because the compensation is less due to lower opportunity cost of time.

The fact that wages increase with distance to jobs (or equivalently with commuting time) is a well-established empirical fact. For example, Manning (2003) using British data (the Labour force Survey for 1993-2001 and the

British Household Panel Survey for 1991-2000) shows that an extra hour of commuting each day is associated, on average, with an increase in wages of 27 log points. This is even more true for highly educated workers since those with more education and in the higher-status occupations are more likely to have both high wages and a long commute. These results are consistent with the ones found in the US. For instance, Madden (1985) uses the PSID to investigate how wages vary with distance to the CBD. She finds that, for all workers who changed job, there is a positive relationship between wage change and change in commute. Zax (1991), who uses data from a single company and regresses wages on commutes, also finds a positive relationship. For more evidence, see Small (1992) and White (1999).

Interestingly, from a theoretical perspective, few models have found this positive relationship between wages and distance to jobs. One exception is Zenou (2003), who, using an urban efficiency wage model, found a similar relationship. In his model, firms pay higher efficiency wages to remote workers to compensate them for their longer commute. Other models have found a positive relationship between wages and pecuniary commuting costs (see e.g. Wasmer and Zenou, 2002, who derive like here a bargain wage in search-matching framework).

2.4 Search intensity

We are now able to study the unemployed worker's decision of s (search intensity). Observe first that, when making this decision, the unemployed takes as given the unemployment rate u in the economy, the vacancy rate v in the economy, the average search intensity $\overline{s}$ (and thus $\theta = v/\overline{s}\,u$ the labor market tightness), the land rent where he/she lives R and the expected discounted lifetime utilities W_0 and $W_1(x)$.

The expected discounted lifetime utility of an unemployed worker is defined by (6). Using (30) in Appendix 1, it can be written as:

$$rW_0(s) = b - R - C(s) + s\,\gamma\,\theta\,\beta/(1-\beta) \tag{14}$$

Differentiating (14) with respect to s gives the following first order condition:[5]

$$-C'(s) + \gamma\,\theta\,\frac{\beta}{1-\beta} = 0 \tag{15}$$

The intuition of (15) is straightforward. For a given θ, when choosing s, the unemployed faces a fundamental trade-off between short-run and long-run benefits. On the one hand, increasing search effort s is costly in the short run (more phone calls, more interviews, etc.) since it decreases instantaneous utility, but, on the other, it increases the long-run prospects of employment since workers have a higher chance to obtain a job.

We can write an explicit solution for s. Indeed, (15) can be written as:

$$s(\theta) = C'^{-1}\left[\gamma\,\theta\,\frac{\beta}{1-\beta}\right] \tag{16}$$

with

$$s'(\theta) = \frac{\gamma\,\theta\,\beta/(1-\beta)}{C''(s)} > 0 \tag{17}$$

This is quite natural since higher job opportunities (i.e. more vacancies or less job seekers) induce workers to search more.

Since all individuals are all identical, all unemployed workers choose the same search intensity s given by (16). As a result, $\overline{s}$ the average search intensity is given by $\overline{s} = s$.

2.5 Maximum distance to jobs

We can finally determine the value of $\widehat{x}$, beyond which workers refuse to take jobs. It is given by

$$W_1(\widehat{x}) - W_0(s) = 0$$

or, equivalently, because of (12), by

$$F_J(\widehat{x}) = 0$$

Using (9), this is equal to

$$\frac{y - w(\widehat{x})}{r+\delta} = 0$$

[5] The second order condition is always satisfied since it is given by:

$$-C''(s) < 0$$

which, by using (13) can be written as:

$$y = \frac{\beta\,(y + s\,\gamma\,\theta) + (1-\beta)\,[f + b - C(s)]}{1-(1-\beta)\tau\widehat{x}/\mu}$$

This is equivalent to

$$\widehat{x}(s,\theta) = \frac{y - b - f + C(s) - s\,\gamma\,\theta\,\beta/(1-\beta)}{y\,\tau/\mu} \tag{18}$$

which is assumed to be strictly positive.

One of the most interesting result here is the relationship between $\widehat{x}$ and μ (for a given s and a given θ). It is easy to see that workers with faster transport mode (higher μ) are ready to accept jobs that are geographically further away than those who use slower transportation mode. The intuition is as follows. When μ increases, the time cost of travelling becomes lower, which increases the instantaneous utility. As a result, workers can extend their area of search and thus $\widehat{x}$ increases.

Now, If, for a given θ, we differentiate (18) with respect to s, we obtain:

$$\frac{\partial\widehat{x}(s,\theta)}{\partial s} = \frac{C'(s) - \gamma\,\theta\,\beta/(1-\beta)}{y\,\tau/\mu} \tag{19}$$

Indeed, when s increases, there are two effects on $\widehat{x}$. On the one hand, it increases the present cost of searching so that workers are induced to extend their area of search but, on the other, it increases their chance to obtain a job so workers become more "picky" and thus reduce $\widehat{x}$. The overall effect is thus ambiguous. However, if we evaluate this derivative at the optimal s, which is given by (15), then we see that one effect thwarts the other so that the net effect is nil.

Now, for a given s, we can differentiate (18) with respect to θ, and we obtain:

$$\frac{\partial\widehat{x}(s,\theta)}{\partial\theta} = \frac{-s\,\gamma\,\beta/(1-\beta)}{y\,\tau/\mu} < 0 \tag{20}$$

Indeed, for a given s, when θ increases, there are more opportunities in the labor market for workers since there are more vacancies and less unemployed. As a result, unemployed workers become more choosy and only accept jobs within a lower distance from their residence.

2.6 The steady-state equilibrium

Since each job is destroyed according to a Poisson process with arrival rate δ, the number of workers who enters unemployment is $\delta(1-u)$ and the number who leaves unemployment is $\overline{s}\,\theta q(\theta)\,u$. In steady state, the rate of unemployment is constant and therefore these two flows are equal (flows out of unemployment equal flows into unemployment). We thus have:

$$u = \frac{\delta}{\delta + \overline{s}\,\theta q(\theta)} \tag{21}$$

We can now write the set of equilibrium relations, except for the wage equation (13), since we substitute wages from (13) into the condition for the supply of jobs (11). The latter is now given by:

$$\int_0^{\widehat{x}} \frac{y(1-\beta)\left[1-\tau x/\mu\right] - \beta s\,\gamma\,\theta - (1-\beta)\left[b - C(s) + f\right]}{1-(1-\beta)\tau x/\mu} dx = \frac{\gamma(r+\delta)}{2q(\theta)} \tag{22}$$

We would like to focus on equilibria for which workers do not always accept job offers, i.e. $0 < \widehat{x}(s,\theta) < 1/2$. Using (18), it is easy to verify that this is equivalent to[6]

$$1 < \frac{y}{b - C(s) + f + \gamma s\theta\beta/(1-\beta)} < \frac{1}{1-\tau/(2\mu)} \tag{23}$$

Given this condition, Theorem 1 in Appendix 1 shows that there is a unique steady-state equilibrium $(u^*, \theta^*, s^*, \widehat{x}^*, w^*)$.

We can now calculate, in equilibrium, the average search intensity $\overline{s}^*$, the average distance to work $\overline{x}^*$ and the average commuting time $\overline{t}^*$. There are respectively given by (for the average time, we use (4)):

$$\overline{s}^* = s^* \tag{24}$$

$$\overline{x}^* = \frac{1}{\widehat{x}^*}\int_0^{\widehat{x}^*} x dx = \frac{\widehat{x}^*}{2} \tag{25}$$

$$\overline{t}^* = \frac{\overline{x}^*}{\mu} = \frac{\widehat{x}^*}{2\mu} \tag{26}$$

3 Whites versus nonwhites

We would like to use the previous analysis to explain unemployment rate, wage as well as search intensity differentials between whites and non-whites. Whites and nonwhites are totally identical except for the fact that they do not use the same transport mode. We assume that whites mainly use private modes

[6] Do not forget that we have assumed that $1 > \tau/(2\mu)$.

of transportation (cars) whereas nonwhites mainly use public transportation.[7] This is a reasonable assumption since, for example in the US, nonwhites (especially blacks) essentially take public transport to commute to their workplace whereas whites use more their cars. To be more precise, using data drawn from the 1995 Nationwide Personal Transportation Survey, Raphael and Stoll (2001) show that, in the US, 5.4 percent of white households have zero automobile while 24 and 12 percent of respectively black and Latino households do not hold a single car.[8] Even more striking, they show that respectively 64 and 46 percent of black and Latino households have one or zero car whereas this number was 36 percent for white households. In Great-Britain, using the 1991 Census data, Owen and Green (2000) show that people from minority ethnic groups are more than twice as likely as white people to depend on public transport for commuting journeys (33.2 versus 13.7 percent), with nearly three-fifths of Black-African workers use public transport to go to work. Furthermore, 73.6 percent of whites use private vehicle while this number is only 56.4 percent for ethnic minorities (and 39.6 percent for Black-African workers). Using the Labour Force Survey for England, Patacchini and Zenou (2003) find similar results. They show that the percentage of whites and nonwhites using coach, bus or British rail train to travel to work is 15% and 40.2% respectively and the percentage of whites and nonwhites using car or scooters is 79.1% and 57.7% respectively. On the other hand, the percentage of white and nonwhite active job seekers owning or using a motor vehicle is 75.8% and 55.4% respectively.

In our model, this implies that the total cost of commuting to jobs for whites and nonwhites are respectively given by:

$$T_W(x) = f_W + \tau w \frac{x}{\mu_W}$$

$$T_{NW}(x) = f_{NW} + \tau w \frac{x}{\mu_{NW}}$$

[7] Once again, the aim of this paper is not to explain why whites mainly use private vehicle while nonwhites use public transportation. This has already been done by LeRoy and Sonstelie (1983) and Sasaki (1990), whose explanations are based on income differences. In the present paper, we would to analyze the consequences of different transport modes on labor market outcomes for totally identical workers.

[8] These differences indicate that black and Latino households are disproportionately represented among households with no automobiles. Indeed, while black and Latino households were respectively 11.5 and 7.8 percent of all households in 1995, they accounted for 35 and 12 percent households with no vehicles.

where the subscripts W and NW refer respectively to whites and nonwhites. We assume: $f_W > f_{NW}$ and $\mu_W > \mu_{NW}$, i.e. cars used by whites have a higher fixed cost but are faster.

Because whites and nonwhites do not use the same transport mode, we also assume that they have separate labor markets. In this context, we would like to study the impact of different transport modes on white and nonwhite unemployment rates, wages and search intensities. For that, we consider the same environment as before and study two economies (or labor markets) that differ only on the fact that transport modes are not the same.

We have the following result.

Proposition 1 *Assume that white use cars and nonwhites public transportation to commute to work. Then, compared to nonwhites, whites search more intensively, have better opportunities in the labor market, experience a lower unemployment rate and obtain a higher wage. Furthermore, if*

$$(1-\beta)\widehat{x}^* y\tau/\mu < \beta s^*\gamma\theta^*\psi^* \qquad (27)$$

where ψ^* is the elasticity of μ with respect to θ^*, then white unemployed have a smaller area of search than nonwhites (i.e. lower $\widehat{x}^*$) and have a shorter mean time commute, i.e. $\overline{t}_W^* < \overline{t}_{NW}^*$.

Proof. See Appendix 2.

The following comments are in order. First, whites who use faster transport modes (higher μ) than nonwhites do search more intensively. Indeed, when whites decide s, they trade-off short run losses with long run gains. However, because they use a faster transport mode, the white unemployed anticipate that they can reach jobs located further away so they increase $\widehat{x}$. This in turn induces firms to create more jobs and thus it increases θ, which finally induce white workers to search more because of better opportunities (see (15)). Since all white workers behave the same way, their average search intensity is higher than that of nonwhites. Second, the effect on the labor market tightness is now straightforward. Indeed, because of a faster transport mode, whites have a higher $\widehat{x}$, which in turn induces firms to create more jobs so that θ increases. Third, whites' wages are higher because white workers have better outside option than nonwhites (because of higher θ and higher $\widehat{x}$).

Finally, the effect of μ on $\widehat{x}^*$ is interesting. Indeed, inspection of (18) shows that, for a given s and a given θ, a faster transport mode increases $\widehat{x}$ (this is what we have used in the first three comments of this proposition). This is because faster transport mode implies lower opportunity cost of time and thus workers are willing to accept jobs located further way. However, in equilibrium, one has to take into account not only this effect but also the indirect effect of μ on search intensity (since when μ increases, the effect on s is ambiguous; see (19)) and on labor market tightness (since when μ increases, firms anticipate that workers will accept jobs located further away and thus create more jobs, which in turn induce workers to more choosy and thus to reduce $\widehat{x}$; see (20)). It turns out that, when μ increases, only the effect of commuting time and labor market tightness matter (indeed the search intensity effect cancels out because when μ increases, workers search more but it also costs more) and condition (27) expresses this result. It says that if the commuting time effect (the left hand side of (27)) dominates the labor market tightness effect (the right hand side of (27)), then a rise in μ increases $\widehat{x}^*$. As a result, white unemployed workers will have a smaller area of research than nonwhites if (27) holds. Because of (26), the average time of commute will be shorter for whites since they use a faster transport mode and have a smaller area of employment if (27) holds.

Few empirical studies have tried to test these two last results. For the UK, McCormick (1986) has shown that, because of labour discrimination, ethnic minorities (Asian and West Indian workers) are ready to accept jobs at locations that would be unacceptable to whites in order either to avoid a spell of unemployment or an inferior occupation. This is what we obtain if (27) holds. Of corse, if discrimination was introduced in our model, then the McCormick's result will be even more true. Moreover, most studies have shown that the mean daily commute is lower for whites than for nonwhites (see e.g. Patachini and Zenou, 2003, for the UK and Chung et al. 2001, and Gottlieb and Lentnek, 2001, for the US.). This is what we obtained here because whites use faster transport mode and, if (27) holds, because they are on average closer to jobs than nonwhites.

We would like now to make comparisons within race. In particular, there has been an important debate about how access to jobs could be very harmful to unemployed workers, especially to nonwhites. This is the spatial mismatch hypothesis, initiated by Kain (1968). Most of this literature is empirical and the crucial element in the analysis is the accuracy of the measure of access to jobs. Since, obviously, the unemployed do not work, this measure is quite difficult (see in particular the excellent survey by Ihlanfeldt and Sjoquist, 1998). One direct measure of job access has been : "the mean commuting time of employed workers who live nearby". This has been used by, among others, Ihlanfeldt and Sjoquist (1990), Ihlanfeldt (1992), and Kasarda and Ting (1996). The intuition is as follows. If an unemployed worker lives in an area where the employed have long commutes, it implies that his/her connections to jobs are not good (for example the worker has low information about jobs) and thus this worker has a bad access to jobs. Therefore, he/she should experience higher unemployment rate. Let us see how this works in our model.

To measure the unemployed's access to jobs we use the employed's average commuting time in an area. Consider two areas, each of them being characterized by the economy we have just described; in particular, workers and firms are located on the circumference of a circle. The question we would like to answer is the following. If the transport mode is the same in the two areas (i.e. same f and same μ) and if we observe that, in area 1, the employed workers have a higher average commuting time than in area 2, i.e. $\overline{t}_1^* > \overline{t}_2^*$, what could we say in terms of differences in average search intensities, unemployment rates and wages? In other words, within each race (i.e. same transport mode), do we have a spatial mismatch in the sense that a bad access to jobs (as measured by the employed's average commuting time in the area) is harmful to the unemployed workers? The following proposition gives a clear answer to this question by showing that it implies that $\overline{s}_1^* > \overline{s}_2^*$.

Proposition 2 *If the employed's average commuting time in an area is a proxy for the unemployed's job access, then, within each race, a worse job access leads to higher (average) search intensity, lower unemployment and higher wages.*

Proof. See Appendix 2.

The intuition of this result is as follows. If we compare two areas where, in both, the employed workers use the same transportation mode (because there are of the same race) but, in area 1, we observe that their commute time is on average higher, then it must be that, in area 1, workers are accepting jobs that are located further away (i.e. $\widehat{x}_1^* > \widehat{x}_2^*$) and are thus less picky. This in turn implies that firms will create more jobs because they are more likely to fill up their vacancies (i.e. $\theta_1^* > \theta_2^*$) and therefore, unemployed workers will search more because they have more chance to obtain a job. This implies that the unemployment rate is lower and that wages are higher because workers have better outside option. As a result, areas with higher average commuting time (of the employed) should be characterized by higher average search intensity (of the unemployed), lower unemployment rate and higher wages.

This result is interesting in that it contradicts the empirical results of the spatial mismatch literature. Of course, our result is valid if and only if one controls for both race and transport mode. Therefore, either the employed's average commuting time is a bad measure of job access for the unemployed or the studies did not control for transport mode or the cities analyzed where mostly monocentric.

We can go further in the analysis of the spatial mismatch. We have the following result:

Proposition 3 *Assume that white use cars and nonwhites public transportation to commute to work. If we compare two areas, one predominantly white and the other predominantly nonwhite but in both workers have the same access to jobs, i.e. live in areas where the employed have exactly the same average commuting time, then in the 'white' area, the unemployment rate is lower, wages are higher, and the unemployed search more intensively than in the 'nonwhite' area.*

Proof. See Appendix 2.

This proposition is in some sense the dual of Proposition 2. Indeed, instead of fixing the transport μ and see the impact of different commuting time on search intensity, unemployment and wages, we here fix commuting time and evaluate the impact of different transport modes on labor market outcomes. If we are comparing white and nonwhite workers who both live in areas where the average commuting time of the employed is the same, i.e. whites and nonwhites have the same job access, then because of $\mu_W > \mu_{NW}$, it must be that whites are ready to accept jobs located further away than nonwhites, i.e. $\widehat{x}_W^* > \widehat{x}_{NW}^*$. This in turn implies that firms will create more jobs in the white labor market than in the nonwhite one, which in turn leads white unemployed workers to search more intensively than nonwhite unemployed workers. In other words, *faster transport modes broaden the spatial extent of search for whites.* The impact on the unemployment rate has a similar flavor. Because $\widehat{x}_W^* > \widehat{x}_{NW}^*$ firms create more jobs for whites, which increases whites' probability to find a job and thus reduces their unemployment rate. The same reasoning applies for wages.

So this proposition says that, if we control for job access, then because of different transport modes, whites search more intensively than nonwhites, experience lower unemployment rate and obtain higher wages.

4 Policy implications

The results of our model have strong policy implications. They suggest that subsidizing car ownership for ethnic minorities could have a substantial impact on their search activity and thus on their unemployment rate. This is a standard policy that has been advocated in the US (see e.g. Pugh, 1998) but rarely in Europe. Emprical evidence in the US and England seem to confirm the need of this policy. For the US, for example, Raphael and Stoll (2001) found that raising minority car-ownership rates to the white car ownership rate would considerably narrow inter-racial employment rate differentials. Similarly, for England, Patacchini and Zenou (2003), studying differences in search intensity between whites and nonwhites, show that giving to nonwhite workers the mean level of white car access would close the racial gap in search intensity by 37.8 percent.

5 Conclusion

(To be completed)

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Appendix 1

Proof of (13)

By subtracting (6) to (5), we obtain:

$$\begin{aligned} & [W_1(x) - W_0(s)] \qquad (28) \\ = & \frac{1}{r+\delta}\left[w\left(1-\tau\frac{x}{\mu}\right) - f - (b - C(s)) - 2s\,\theta q(\theta)\int_0^{\widehat{x}}[W_1(x) - W_0(s)]\,dx\right] \end{aligned}$$

Plugging this value in (12) and using (9) yields

$$\begin{aligned} & (1-\beta)\left[w\left(1-\tau\frac{x}{\mu}\right) - f - (b - C(s)) - 2s\,\theta q(\theta)\int_0^{\widehat{x}}[W_1(x) - W_0(s)]\,dx\right] \\ = & \beta(y-w) \qquad (29) \end{aligned}$$

Now, using (12) and (9), we have

$$W_1(x) - W_0(s) = \frac{\beta}{1-\beta}\frac{y-w}{r+\delta}$$

which implies that

$$\int_0^{\widehat{x}}[W_1(x) - W_0(s)]\,dx = \frac{\beta}{1-\beta}\frac{1}{r+\delta}\int_0^{\widehat{x}}(y-w)dx$$

which, by using (11), is equal to

$$\int_0^{\widehat{x}}[W_1(x) - W_0(s)]\,dx = \frac{\gamma}{2q(\theta)}\frac{\beta}{(1-\beta)} \qquad (30)$$

Using (30), equation (29) can now be written as:

$$(1-\beta)\left[w\left(1-\tau\frac{x}{\mu}\right) - f - (b - C(s))\right] = \beta\,(y - w + s\,\gamma\,\theta)$$

which, after some manipulations, leads to (13). ■

Theorem 1 *Assume (23). Then, there exists a unique equilibrium* $(u^*, \theta^*, s^*, \widehat{x}^*, w^*)$, *in which* $0 < u^* < 1$, $\theta^* > 0$, $s^* > 0$, $0 < \widehat{x}^* < 1/2$ *and* $w^* > 0$.

The equilibrium equations are given by (21), (22), (16) and (18) for four unknowns u, θ, s and $\widehat{x}$ (the wage w has already been substituted in (22)). The model is recursive. There is one block formed by (22), (16) and (18) that gives the solutions for labor market tightness θ, search intensity s and maximum acceptance distance $\widehat{x}$. With θ, s and $\widehat{x}$ known, we obtain the equilibrium unemployment using (21) and the equilibrium wage using (13)

The first equilibrium equations that we have to solve are thus (22), (16) and (18). Since the two latter equations give explicit values of s and $\widehat{x}$, we can reduce these three equations into one. We have indeed:

$$\int_0^{\widehat{x}(\theta)} \frac{y(1-\beta)\left(1-\tau x/\mu\right) - \beta\, s(\theta)\, \gamma\, \theta - (1-\beta)\left[f + b - C(s(\theta))\right]}{1-(1-\beta)\tau x/\mu} dx = \frac{\gamma(r+\delta)}{2q(\theta)} \tag{31}$$

where $\widehat{x}(\theta)$ is defined by (18) and $s(\theta)$ by (16). Denote by

$$h(\theta, x) \equiv \frac{y(1-\beta)\left(1-\tau x/\mu\right) - \beta\, s(\theta)\, \gamma\, \theta - (1-\beta)\left[f + b - C(s(\theta))\right]}{1-(1-\beta)\tau x/\mu}$$

$$H(\theta) \equiv \int_0^{\widehat{x}(\theta)} h(x)dx$$

and

$$g(\theta) \equiv \frac{\gamma(r+\delta)}{2q(\theta)}$$

We have the following lemma.

Lemma 1

(*i*) *The function* $g(\theta)$ *is increasing and convex in* θ *and* $\lim_{\theta\to 0} g(\theta) = 0$ *and* $\lim_{\theta\to+\infty} g(\theta) = +\infty$.

(*ii*) *The function* $H(\theta)$ *is decreasing in* θ *and* $\lim_{\theta\to 0} H(\theta) > 0$.

Proof.

(*i*) By observing that $\lim_{\theta\to 0} q(\theta) = +\infty$, $\lim_{\theta\to+\infty} q(\theta) = 0$ and $q'(\theta) < 0$, then the results are straightforward to obtain by differentiating $g(\theta)$ with respect to θ.

(ii) First observe that

$$\frac{\partial H(\theta)}{\partial \theta} \equiv \int_0^{\widehat{x}(\theta)} \frac{\partial h(\theta,x)}{\partial \theta} dx + h(\theta,\widehat{x}(\theta))\frac{\partial \widehat{x}(\theta)}{\partial \theta}$$

We have

$$\int_0^{\widehat{x}(\theta)} \frac{\partial h(\theta,x)}{\partial \theta} dx = \frac{(1-\beta)C'(s)s'(\theta) - \beta\,\gamma\,[s(\theta)+s'(\theta)\,\theta]}{1-(1-\beta)\tau x/\mu}$$

which, using (15), is equal to

$$\int_0^{\widehat{x}(\theta)} \frac{\partial h(\theta,x)}{\partial \theta} dx = \frac{-\beta\,\gamma s(\theta)}{1-(1-\beta)\tau x/\mu} < 0$$

Using again (15), it is easy to see that:

$$\frac{\partial \widehat{x}(\theta)}{\partial \theta} = \frac{1}{1-\beta}\frac{-\gamma\,\beta s(\theta)}{y\,\tau/\mu} < 0$$

As a result, since $h(\theta,\widehat{x}(\theta)) > 0$, we have:

$$\frac{\partial H(\theta)}{\partial \theta} < 0$$

Finally, when $\theta = 0$, we have

$$H(\theta=0) = \int_0^{\widehat{x}(0)} \frac{y(1-\beta)\,(1-\tau x/\mu) - (1-\beta)(f+b)}{1-(1-\beta)\tau x/\mu} dx > 0$$

where

$$\widehat{x}(0) = \frac{y-b-f}{y\,\tau/\mu}$$

■

Using Lemma 1, it is clear that (31) has a unique solution given by θ^*. Plugging this value in (16) gives a unique s^*. Then, plugging θ^* and s^* in (18) yields a unique $\widehat{x}^*$. Finally, using these values and (24) in (13) and (21) leads to a unique w^* and u^*. ■

Appendix 2

Proof of Proposition 1

• First, let us show that

$$\frac{\partial s^*}{\partial \mu} > 0$$

Equation (16) can now be written as follows:

$$s^* = C'^{-1}\left[\gamma\,\theta^*(\mu)\,\frac{\beta}{1-\beta}\right]$$

By totally differentiating this equation, we easily obtain:

$$\frac{\partial s^*}{\partial \mu} = \frac{\gamma\,\beta/(1-\beta)}{C''(s)}\frac{\partial \theta^*}{\partial \mu} > 0 \tag{32}$$

To obtain this result, we need to show that

$$\frac{\partial \theta^*}{\partial \mu} > 0$$

The equilibrium variable θ^* is defined by (31) in which $\widehat{x}(\theta)$ and $s(\theta)$ are respectively defined by (18) and (16). If we use the notations above (i.e. in the proof of Theorem 1), then equation (31) is given by: $H(\theta) - g(\theta) = 0$. By totally differentiating this equation, we obtain:

$$\frac{\partial \theta^*}{\partial \mu} = -\frac{\partial H(\theta)/\partial \mu}{\partial H(\theta)/\partial \theta - \partial g(\theta)/\partial \theta}$$

In Lemma 1, we have shown that $\partial H(\theta)/\partial\theta - \partial g(\theta)/\partial\theta < 0$. Let us show that $\partial H(\theta)/\partial\mu > 0$. We have

$$\frac{\partial H(\theta)}{\partial \mu} = \int_0^{\widehat{x}(\theta)} \frac{\partial h(\theta, x)}{\partial \mu} dx + h(\theta, \widehat{x}(\theta))\frac{\partial \widehat{x}(\theta)}{\partial \mu}$$

Now, it is easy to verify that

$$\int_0^{\widehat{x}(\theta)} \frac{\partial h(\theta, x)}{\partial \mu} dx$$

$$= \int_0^{\widehat{x}(\theta)} \frac{(1-\beta)\tau x\,[\beta y + s(\theta)\,\gamma\,\theta) + (1-\beta)(f + b - C(s(\theta)))]}{\mu^2\,[1-(1-\beta)\tau x/\mu]^2} > 0$$

Furthermore, since $\partial\widehat{x}(\theta)/\partial\mu > 0$ then $h(\theta, \widehat{x}(\theta))\partial\widehat{x}(\theta)/\partial\mu > 0$. As a result

$$\frac{\partial \theta^*}{\partial \mu} = -\frac{\partial H(\theta)/\partial \mu}{\partial H(\theta)/\partial \theta - \partial g(\theta)/\partial \theta} > 0 \tag{33}$$

Since $\overline{s}^* = s^*$, this implies that

$$\frac{\partial \overline{s}^*}{\partial \mu} > 0 \tag{34}$$

- Second, let us show that both

$$\frac{\partial u^*}{\partial \mu} < 0 \text{ and } \frac{\partial V^*}{\partial \mu} > 0$$

For that we have to use (21). By differentiating (21), we obtain:

$$\frac{\partial u^*}{\partial \mu} = \frac{-\delta}{[\delta + \overline{s}^*\, \theta^* q(\theta^*)]^2} \left[\frac{\partial \overline{s}^*}{\partial \mu} \theta^* q(\theta^*) + \overline{s}^* \frac{\partial \left(\theta^* q(\theta^*)\right)}{\partial \theta^*} \frac{\partial \theta^*}{\partial \mu} \right]$$

which, by using (2), (34) and (33), is strictly negative.

For V, we use the fact that

$$\theta^* = \frac{V^*}{\overline{s}^* u^*}$$

which implies that

$$V^* = \theta^* \overline{s}^* u^*$$

Differentiating this expression gives

$$\frac{\partial V^*}{\partial \mu} = \left[\frac{\partial \overline{s}^*}{\partial \mu} \theta^* + \overline{s}^* \frac{\partial \theta^*}{\partial \mu} \right] u^* + \theta^* \overline{s}^* \frac{\partial u^*}{\partial \mu}$$

$$\begin{aligned}
&= \frac{\partial \overline{s}^*}{\partial \mu} \theta^* u^* + \overline{s}^* \frac{\partial \theta^*}{\partial \mu} u^* - \frac{\theta^* \overline{s}^* \delta}{[\delta + \overline{s}^*\, \theta^* q(\theta^*)]^2} \left[\frac{\partial \overline{s}^*}{\partial \mu} \theta^* q(\theta^*) + \overline{s}^* \frac{\partial \left(\theta^* q(\theta^*)\right)}{\partial \theta^*} \frac{\partial \theta^*}{\partial \mu} \right] \\
&= \frac{\partial \overline{s}^*}{\partial \mu} \theta^* \left[u^* - \frac{\theta^* \overline{s}^* \delta}{[\delta + \overline{s}^*\, \theta^* q(\theta^*)]^2} q(\theta^*) \right] + \overline{s}^* \frac{\partial \theta^*}{\partial \mu} \left[u^* - \frac{\theta^* \overline{s}^* \delta}{[\delta + \overline{s}^*\, \theta^* q(\theta^*)]^2} \frac{\partial \left(\theta^* q(\theta^*)\right)}{\partial \theta^*} \right] \\
&= \frac{\delta}{\delta + \overline{s}^*\, \theta^* q(\theta^*)} \left[\frac{\partial \overline{s}^*}{\partial \mu} \theta^* \left[1 - \frac{\theta^* q(\theta^*) \overline{s}^*}{\delta + \overline{s}^*\, \theta^* q(\theta^*)} \right] + \overline{s}^* \frac{\partial \theta^*}{\partial \mu} \left[1 - \frac{\theta^* \overline{s}^*}{\delta + \overline{s}^*\, \theta^* q(\theta^*)} \frac{\partial \left(\theta^* q(\theta^*)\right)}{\partial \theta^*} \right] \right] \\
&= \frac{\delta}{\delta + \overline{s}^*\, \theta^* q(\theta^*)} \left[\frac{\partial \overline{s}^*}{\partial \mu} \theta^* u^* + \overline{s}^* \frac{\partial \theta^*}{\partial \mu} \left[1 - (1 - u^*) \rho \right] \right]
\end{aligned}$$

where $\rho > 0$ is defined as:

$$\rho = \frac{\partial \left(\theta^* q(\theta^*)\right)}{\partial \theta^*} \frac{\theta^*}{\theta^* q(\theta^*)}$$

By using the properties of the matching function, it is easy to verify that $\rho < 1$ (see e.g. Pissarides, 2000). As a result this expression is strictly positive and thus $\partial V^* / \partial \mu > 0$.

We have thus shown that

$$\frac{\partial u^*}{\partial \mu} < 0 \text{ and } \frac{\partial V^*}{\partial \mu} > 0 \tag{35}$$

• Third, let us show that

$$\frac{\partial w^*}{\partial \mu} > 0$$

Let us differentiate (13). Using (15), we have

$$\begin{aligned}\frac{\partial w^*}{\partial \mu} &= \frac{\beta\,\gamma \partial\theta^*/\partial\mu\, s^*\left[1-(1-\beta)\tau x/\mu\right]}{\left[1-(1-\beta)\tau x/\mu\right]^2} \\ &\quad + \frac{\beta\,(y+s\,\gamma\,\theta)+(1-\beta)\left[f+b-C(s)\right]}{\left[1-(1-\beta)\tau x/\mu\right]^2}\beta\tau x/\mu^2\end{aligned}$$

which is clearly positive.

• Fourth, let us show that if (27) holds, then

$$\frac{\partial \widehat{x}^*}{\partial \mu} > 0$$

Equation (18) can now be written as follows:

$$\widehat{x}^* = \frac{y-b-f+C(s^*)-s^*\,\gamma\,\theta^*\,\beta/(1-\beta)}{y\,\tau/\mu}$$

By totally differentiating this equation we obtain:

$$\begin{aligned}\frac{\partial \widehat{x}^*}{\partial \mu} &= \frac{\left[C'(s^*)\partial s^*/\partial\mu - \gamma\,\beta/(1-\beta)\left[\partial s^*/\partial\mu\,\theta + \partial\theta^*/\partial\mu\,s^*\right]\right](y\,\tau/\mu)}{(y\,\tau/\mu)^2} \\ &\quad + \frac{\left[y-b-f+C(s^*)-s^*\,\gamma\,\theta^*\,\beta/(1-\beta)\right]y\,\tau/(\mu^2)}{(y\,\tau/\mu)^2}\end{aligned}$$

By further manipulating this equation and by using the value of $\widehat{x}^*$, we easily obtain:

$$\frac{\partial \widehat{x}^*}{\partial \mu} = (1-\beta)\widehat{x}^* - \frac{\beta s^* \gamma \theta^* \psi^*}{y\tau/\mu}$$

where

$$\psi^* = \frac{\partial \theta^*}{\partial \mu}\frac{\mu}{\theta^*} > 0$$

• Finally, if

$$(1-\beta)\widehat{x}^* < \frac{\beta s^* \gamma \theta^* \psi^*}{y\tau/\mu}$$

then $\partial\widehat{x}^*/\partial\mu < 0$ and since $\overline{t}^* = \widehat{x}^*/(2\mu)$ with $\mu_W > \mu_{NW}$, we have: $\overline{t}_W^* < \overline{t}_{NW}^*$.

■

Proof of Proposition 2

Let us first show the impact on average search intensity $\overline{s}^*$. Take two areas with the same μ. Assume that, in area 1, the employed have a higher commuting time than in area 2, i.e. $\overline{t}_1^* > \overline{t}_2^*$. Then, using (26), it is easy to see that it implies that $\overline{x}_1^* > \overline{x}_2^*$ and $\widehat{x}_1^* > \widehat{x}_2^*$ (since μ is fixed). This in turn implies that firms will create more jobs (or equivalently will enter more in the labor market), i.e. $\theta_1^* > \theta_2^*$ since they are more likely to fill a vacancy because the maximum distance to accept a job is higher in area 1. To see this point, we have to differentiate (22). Let us use the same notation as in Lemma 1, where this entry equation is written as:

$$\int_0^{\widehat{x}(\theta)} h(x)dx - g(\theta) = 0$$

where $H(\theta) \equiv \int_0^{\widehat{x}(\theta)} h(x)dx$. Then, by differentiating (22), we obtain:

$$\frac{\partial\theta}{\partial\widehat{x}} = -\frac{H(\widehat{x})}{\partial H(\theta)/\partial\theta - \partial g(\theta)/\partial\theta}$$

In Lemma 1, we have shown that $\partial H(\theta)/\partial\theta - \partial g(\theta)/\partial\theta < 0$, and, since $H(\widehat{x}) > 0$, then $\partial\theta/\partial\widehat{x} > 0$.

Furthermore, $\theta_1^* > \theta_2^*$ implies that $s_1^* > s_2^*$ (see (17)) since better opportunities increase search intensity, which in turn leads to higher average search intensities, i.e. $\overline{s}_1^* > \overline{s}_2^*$. This argument can of course be generalized to any number of areas with different commuting times.

Second, let us show the impact on u^*. Take two areas with the same μ. Assume that, in area 1, the employed have a higher commuting time than in area 2, i.e. $\overline{t}_1^* > \overline{t}_2^*$. Then, using (26), it is easy to see that it implies that $\overline{x}_1^* > \overline{x}_2^*$ and $\widehat{x}_1^* > \widehat{x}_2^*$ (since μ is fixed). As we have seen above, this in turn implies that $\theta_1^* > \theta_2^*$. Now, using (21), which defines u^* in the steady-state equilibrium, it is easy to verify that

$$\frac{\partial u^*}{\partial\theta^*} = -\frac{\overline{s}\,\delta}{\left[\delta + \overline{s}\,\theta q(\theta)\right]^2}\frac{\partial\left(\theta^* q(\theta^*)\right)}{\partial\theta^*} < 0$$

using (2). As a result, $\theta_1^* > \theta_2^*$ implies that $u_1^* < u_2^*$. This argument can also be generalized to any number of areas with different commuting times.

Finally, let us show the impact on w^*. Take two areas with the same μ. Assume that, in area 1, the employed have a higher commuting time than in area 2, i.e. $\overline{t}_1^* > \overline{t}_2^*$. Then, using (26), it is easy to see that it implies that $\overline{x}_1^* > \overline{x}_2^*$ and $\widehat{x}_1^* > \widehat{x}_2^*$ (since μ is fixed). As we have seen above, this in turn implies that $\theta_1^* > \theta_2^*$. Now, using (13), which defines w^*, it is easy to verify that

$$\frac{\partial w^*}{\partial \theta^*} > 0$$

As a result, $\theta_1^* > \theta_2^*$ implies that $w_1^* > w_2^*$. This argument can also be generalized to any number of areas with different commuting times. ■

Proof of Proposition 3

Let us first show the impact on average search intensity $\overline{s}^*$. We are comparing two areas with the same $\overline{t}^*$, i.e. $\overline{t}_W^* = \overline{t}_{NW}^*$ but with different transportation mode, i.e. $\mu_W > \mu_{NW}$, i.e. whites use faster transportation mode than nonwhites. Then, using (26), it is easy to see that it implies that $\overline{x}_W^* > \overline{x}_{NW}^*$ and $\widehat{x}_W^* > \widehat{x}_{NW}^*$ (since $\overline{t}^*$ is the same). This in turn implies that firms will create more jobs in the white labor market than in the nonwhite one , i.e. $\theta_W^* > \theta_{NW}^*$ (see the proof of Proposition 2) since the two labor markets are different. Finally, $\theta_W^* > \theta_{NW}^*$ implies that $s_W^* > s_{NW}^*$ (see (17)) since better opportunities increase search intensity, which in turn leads to higher average search intensities, i.e. $\overline{s}_W^* > \overline{s}_{NW}^*$.

Let us now show the impact on u^*. Take two areas with the same $\overline{t}^*$, i.e. $\overline{t}_W^* = \overline{t}_{NW}^*$ but with different transportation mode, i.e. $\mu_W > \mu_{NW}$. Then, using (26), it is easy to see that it implies that $\overline{x}_W^* > \overline{x}_{NW}^*$ and $\widehat{x}_W^* > \widehat{x}_{NW}^*$ (since $\overline{t}^*$ is the same).. As we have seen above, this in turn implies that $\theta_W^* > \theta_{NW}^*$. Now, using (21), $\theta_W^* > \theta_{NW}^*$ implies that $u_W^* < u_{NW}^*$ (see the proof of Proposition 2).

For wages, we have exactly the same reasoning. ■