

Search in Cities*

Yves Zenou^{†, ‡, §}

February 23, 2007 (Revised February 2, 2009)

Abstract: The aim of this paper is to expose the recent developments of urban search models which incorporate a land market into a search matching framework. Using these models, we will be able to explain why unemployment rates vary within a city, how city structure affects workers' labor-market outcomes, how unemployment benefits and the job-destruction rate affect the growth of cities and why workers living far away from job centers search less intensively and experience higher unemployment rates than those residing closer to jobs. We are also able to explain why, as compared to whites, black workers spend more time commuting to work but travel less miles and search for jobs over a smaller area.

Keywords: job search, urban land use, search intensity, spatial mismatch, automobile mismatch.

JEL Classification: D83, J15, J41, R14

*I'm grateful to Zvi Eckstein and two anonymous referees for very helpful comments.

[†]Stockholm University, Department of Economics, 106 91 Stockholm, Sweden. E-mail: yves.zenou@ne.su.se.

[‡]Research Institute of Industrial Economics (IFN), Sweden.

[§]GAINS, Le Mans, France.

1 Introduction

Why do unemployment rates vary within a city and, in particular, why are they so high in some specific areas? Does city structure affect the labor-market outcomes of workers? Does space create inefficiencies? Do unemployment benefits and the job-destruction rate affect the growth of cities? Why do workers living far away from jobs search less intensively and experience higher unemployment rates than those residing closer to jobs? Why do black workers experience higher unemployment rates than white workers in the same city? As compared to whites, why do black workers spend more time commuting to work but travel less miles and search for jobs over a smaller area?¹

These important questions cannot be answered in standard labor economics or urban economics. Indeed, labor economists do traditionally not directly incorporate space into their studies (see e.g. Layard et al., 1991; Pissarides, 2000; Cahuc and Zylberberg, 2004). Similarly, most urban models assume perfectly competitive labor markets and the issue of urban unemployment is not even discussed (see, in particular, Fujita, 1989; Fujita et al. 1999; Fujita and Thisse, 2002).

Thus, a theory that brings together labor and urban aspects is needed in order to be able to give some answers to the above questions. Search models solve for the steady-state unemployment rate.² Land use models tell us about the location of people in space. When these two are put together, we learn where unemployed and employed workers are located and how their search activity is influenced by the spatial nature of cities.

The aim of this paper is to expose the recent developments of urban search models. In most of these models, a land market is explicitly introduced in a search matching framework. The link between the land and the labor market is either realized through the average search intensity of unemployed workers or their area of search. Indeed, the latter depends on the location of unemployed workers in the city, which is endogenously determined in the land-use equilibrium. The location of workers, in turn, depends on the outcomes in the labor market.

We first develop a model (section 2) where workers choose their search intensity. We show that unemployed workers search less, the further away they reside from jobs. There is indeed a fundamental trade-off between short-run and long-run benefits of various location choices

¹These are well-documented stylized facts. See, in particular, Topel (1986), Eberts and Stone (1992), Blanchflower and Oswald (1994), Holzer et al. (1994), Ihlanfeldt and Sjoquist (1998), Crampton (1999), White (1999), Raphael and Stoll (2001) and Topa (2001).

²There is a vast literature on search and matching theory that emphasizes the importance of flows and search frictions in the labor markets (see the literature surveys by Mortensen and Pissarides, 1999; Pissarides, 2000; Rogerson et al., 2005; Yashiv, 2007).

for unemployed workers. Locations near jobs are costly in the short run (both in terms of high land rents and low housing consumption), but allow higher search intensities, which, in turn, increase the long-run prospects of reemployment. Conversely, locations far from jobs are more desirable in the short run (low land rents and high housing consumption) but only allow infrequent trips to jobs and hence, reduce the long-run prospects of reemployment. Therefore, for workers residing further from the job center, it is optimal to spend a minimal search effort whereas workers residing close to jobs provide a high search effort. In this model, three equilibrium urban structures emerge: unemployed workers reside close to or far away from jobs or they reside both close to and far away from jobs (core-periphery structure). With this model, we are able to explain why unemployment rates vary within a city and how the city structure affects the labor-market outcomes of workers. We are also able to explain why remote workers spend less effort in finding a job and why long-term unemployed workers are those residing far away from jobs. Indeed, because spatial frictions amplify search frictions, workers residing far away from jobs experience higher unemployment rates than those living closer to jobs. As a result, different unemployment rates will emerge within the same city. Finally, we show that space does not create additional inefficiencies beyond those created by search frictions. Indeed, the condition that guarantees that the market solution is Pareto optimal is the same in spatial and nonspatial models. The allocation of workers in space is thus optimal, a result already proved in previous research (Fujita, 1989).

Section 3 proposes two extensions of the benchmark model of section 2. First, we incorporate workers' skill heterogeneity and show that the wage increases with the size of the city, because the larger is the city, the better is the match between the diverse job requirements and the diverse labor pool. Then, we consider the case of high-relocation costs and show that these create additional frictions in the labor market.

Finally, in section 4, we use the different models described above to explain why ethnic minorities and whites experience different labor-market outcomes within the same city. If ethnic minority workers reside far away from jobs (because they are discriminated against in the housing market or because they want to live together even if this implies remote locations), then, as observed in most cities, they are stuck in locations that are badly connected to job centers, search less intensively, have a lower expected wage, and experience a higher unemployment rate than whites. We are also able to explain why, as compared to whites, black workers spend more time commuting to work but travel less miles and search for jobs over a smaller area.

2 The benchmark model

There is a continuum of ex ante identical workers whose total mass is 1 and a continuum of m ex ante identical firms. Among the workers, L are employed and U unemployed, so that $1 = L + U$. Observe that the unemployment rate u is here equal to U . The workers are uniformly distributed along a *linear, closed and monocentric* city. All land is owned by absentee landlords and all firms are exogenously located in the Central Business District (CBD hereafter) and consume no space. Workers are assumed to live infinitely and decide on their optimal place of residence between the CBD and the city fringe. There are *no relocation costs*, neither in terms of time nor money.

Let us describe the labor market. A firm is a unit of production that can either be filled by a worker whose productivity is y or be unfilled and thus unproductive. To find a worker, a firm posts a vacancy which can be filled according to a random Poisson process. Similarly, workers searching for a job will find one according to a random Poisson process. In aggregate, these processes imply there to be a number of matches per unit of time between the two sides of the market that are determined by the following matching function:³ $M(\bar{s}U, V)$, where \bar{s} is the average search efficiency of unemployed workers, and U and V are the total number of unemployed workers and vacancies. As in the standard search-matching models (Mortensen and Pissarides, 1999, and Pissarides, 2000), we assume that $M(\cdot)$ is increasing in both its arguments, concave and homogeneous of degree 1 (or, equivalently, have a constant return to scale). Thus, the rate at which vacancies are filled is $M(\bar{s}U, V)/V$. By constant returns to scale, this rate can be written as: $M(1/\theta, 1) \equiv q(\theta)$, where $\theta = V/(\bar{s}U)$ is a measure of *labor market tightness* in efficiency units and $q(\theta)$ is a Poisson intensity. Similarly, the rate at which an unemployed worker with search intensity $s(x)$ ⁴ leaves unemployment is given by:

$$a(x) = \frac{s(x)}{\bar{s}} \frac{M(\bar{s}U, V)}{U} \equiv s(x)\theta q(\theta), \quad (1)$$

which depends on his/her residential location x and \bar{s} . Here, when workers search more actively for jobs, their chance of leaving unemployment increases. Finally, the rate at which jobs are destroyed is exogenous and denoted by δ .

A steady-state equilibrium requires *simultaneously* solving an urban land use equilibrium and a labor market equilibrium. It is convenient to first present the former and then the latter.

³This matching function is written under the assumption that the city is monocentric, i.e. all firms are located in one fixed location.

⁴We will show below that search intensity s is a function of x .

2.1 Optimal search intensity

Each individual is identified with one unit of labor. Each employed worker goes to the CBD to work and incurs a fixed monetary commuting cost $\tau_L = \tau$ per unit of distance.⁵ When living at a distance x from the CBD, he/she also pays a land rent $R(x)$, consumes h_L units of land and z_L unities of the non-spatial composite good (which is taken as the numeraire so that its price is normalized to 1) and earns a wage w_L . There is no on-the-job search. Concerning unemployed workers, they also commute to the CBD but at different commuting cost per unit of distance, denoted by $\tau_U = s\tau$, $0 < s \leq 1$ where, for example, $s = 1/2$ implies that unemployed workers are searching every other day. We assume that all workers have identical preferences among consumption bundles of *land (housing)*, h_j , and *composite good*, z_j , for $j = L, U$, which can be represented by a log-linear utility:⁶

$$\Gamma(h_j, z_j) = h_j^\alpha z_j^\omega, \quad (2)$$

with $\alpha, \omega > 0$, where $\alpha + \omega < 1$. By maximizing (2) under the budget constraint for each type of worker $j = L, U$, we obtain the following indirect utility for each *employed worker* at x :

$$W_L(x) = \chi(w_L - \tau x)^{\alpha+\omega} R(x)^{-\alpha}, \quad (3)$$

where $\chi = [\alpha/(\alpha + \omega)]^\alpha [\omega/(\alpha + \omega)]^\omega$ and the following indirect utility

$$W_U(x) = \chi[w_U - s(x)\tau x]^{\alpha+\omega} R(x)^{-\alpha} \quad (4)$$

for each *unemployed worker* at x . In (4), w_U is the unemployment benefit and it is assumed that w_U is exogenously financed by taxpayers residing elsewhere (for example absentee landlords).⁷ The different steady-state value functions (i.e. Bellman equations) for employed and unemployed workers are thus given by:

$$rI_L(x) = W_L(x) - \delta [I_L(x) - I_U(x)] \quad (5)$$

$$rI_U(x) = W_U(x) + s(x)\theta q(\theta) [I_L(x) - I_U(x)]. \quad (6)$$

⁵Subscript L refers to employed workers whereas subscript U refers to unemployed workers.

⁶We assume a Cobb-Douglas instantaneous utility function since otherwise, we cannot obtain tractable results and closed-form solutions. If, for example, a CES utility function is used, then it is not possible to explicitly express the bid rent function and the model is extremely difficult to solve.

⁷In search-matching models, w_U is often interpreted as the utility of leisure (or home production).

Since there are no relocation costs, at any urban equilibrium it must be that $rI_L(x) = r\bar{I}_L$, $\forall x$, and $rI_U(x) = r\bar{I}_U$, $\forall x$. We have the following result (proved by Smith and Zenou, 2003a):

Proposition 1

- (i) *At each location x , there is a unique search intensity s maximizing (6).*
- (ii) *For any prevailing job acquisition rate, $\theta q(\theta)$, and constant lifetime values, \bar{I}_L, \bar{I}_U , the optimal search intensity function, $s(x)$, for unemployed workers is given for each location, x , by*

$$s(x) = \begin{cases} 1 & \text{for } x \leq x(1) \\ \frac{(\alpha+\omega)}{[1-(\alpha+\omega)]} \left[\frac{w_U}{(\alpha+\omega)\tau x} - \frac{r\bar{I}_U}{\theta q(\theta)(\bar{I}_L - \bar{I}_U)} \right] & \text{for } x(1) < x < x(\underline{s}_0) \\ \underline{s}_0 & \text{for } x \geq x(\underline{s}_0) \end{cases} \quad (7)$$

where

$$x(s) = \frac{w_U}{\tau} \cdot \frac{\theta q(\theta) (\bar{I}_L - \bar{I}_U)}{s [1 - (\alpha + \omega)] \theta q(\theta) (\bar{I}_L - \bar{I}_U) + (\alpha + \omega) r \bar{I}_U} \quad (8)$$

which is the unique inverse function of (7).

It is optimal for workers to have constant search intensities close and far away from the CBD. Figure 1 describes what $s(x)$ looks like. There is a *non-linear decreasing* relationship between the residential distance to jobs for unemployed workers and their search intensity, s . In fact, unemployed workers living sufficiently close to jobs search every day, $s = 1$, whereas those residing far away provide a minimum search intensity, $s = \underline{s}_0$. Workers living in between these two areas experience a decrease in their search intensity from $s = 1$ to $s = \underline{s}_0$. The intuition runs as follows. There is a fundamental trade-off between short-run and long-run benefits of various location choices for unemployed workers. Indeed, locations near jobs are costly in the short run (both in terms of high rents and low housing consumption), but allow higher search intensities which, in turn, increase the long-run prospects of reemployment. Conversely, locations far from jobs are more desirable in the short run (low rents and high housing consumption) but only allow for infrequent trips to jobs and hence, reduce the long-run prospects of reemployment. Thus, for workers residing further away from the CBD, it is optimal to spend the minimal search effort whereas workers residing close to jobs provide a high search effort.

[Insert Figure 1 here]

For interior $s^*(x)$, i.e. the search intensity for workers living between $x(1)$ and $x(s_0)$, it is easily verified that it varies negatively with commuting costs τ , unemployment benefits w_U , and the lifetime value of the unemployed \bar{I}_U and positively with the hiring probability $\theta q(\theta)$ and the lifetime value of the employed, \bar{I}_L . The intuition is straightforward since when τ , w_U or \bar{I}_U is high and when $\theta q(\theta)$ or \bar{I}_L is low, workers reduce their search effort since either the costs of searching are too high or the rewards of searching are too low. Naturally, these results hold for a given θ and are not necessarily true in equilibrium since θ will, in itself, be a function of the different parameters like e.g. τ and w_U .

2.2 The different urban land use equilibria

Given this function $s(x)$, let us now determine the residential locations of all unemployed and employed workers in the city. The basic trade-off for employed workers is between commuting costs and housing consumption whereas for unemployed workers, commuting/search costs, housing consumption and search intensity are all of importance. To determine the urban land use equilibrium, we must define the bid rent function⁸ for each group of workers.

Given the utilities and the lifetime values above, we now define the equilibrium bid-rents. It follows from (5) that the bid rent function for employed workers at each location x is equal to:

$$\Psi_L(x, \bar{I}_U, \bar{I}_L) = \left[\frac{\chi(w_L - \tau x)^{\alpha+\omega}}{r\bar{I}_L + \delta(\bar{I}_L - \bar{I}_U)} \right]^{1/\alpha}. \quad (9)$$

This bid rent is decreasing in x but is not linear, which implies that more than two urban configurations can emerge. The bid rent function for unemployed workers is considerably more complex since it depends on the optimal search intensity level at each location. Using (6), we obtain the following bid rent function for unemployed workers at each location x :

$$\Psi_U(x, \bar{I}_U, \bar{I}_L) = \left[\frac{\chi[w_U - s(x)\tau x]^{\alpha+\omega}}{r\bar{I}_U - s(x)\theta q(\theta)(\bar{I}_L - \bar{I}_U)} \right]^{1/\alpha}, \quad (10)$$

⁸The bid rent is a standard concept in urban economics. It indicates the maximum land rent that a worker located at a distance x from the CBD is ready to pay to achieve a utility level. See Fujita (1989) or Zenou (2009a) for a formal definition.

where $s(x)$ is given by (7). It should be clear that the bid rents are calculated such that the lifetime utilities of both employed and unemployed workers, \bar{I}_U and \bar{I}_L , respectively, are spatially invariant. For example, compare an unemployed worker residing close to jobs and another unemployed worker living far away from jobs. The former has a lower search (commuting) cost and a higher chance of finding a job but consumes less land, whereas the latter has a higher search (commuting) cost and a lower chance of finding a job but consumes more land. The bid rent defined by (10) exactly compensates for these differences by ensuring that these two workers obtain the same lifetime utility, \bar{I}_U . However, it is not true for the current utility of unemployed workers $W_U(x)$ because, as can be seen in (4), the land rent does not compensate for $s(x)$. In fact, unemployed workers residing close to jobs have a lower current utility than those living far away from jobs because they provide more search intensity (indeed, using (4), it is easily seen that $W'_U(x) > 0$). However, because they are more actively searching for jobs, they have a higher chance of obtaining a job and thus, in the long-run, the short-run disadvantages are compensated for so that all unemployed workers obtain the same \bar{I}_U .

With the non-linear bid rents defined by (9) and (10), different urban configurations can emerge. Indeed, the land market being perfectly competitive, all workers propose different bid rents at different locations and (absentee) landlords allocate land to the highest bids. So, depending on the steepness of the bid rent functions (as captured by their slopes), at each location, employed workers can outbid unemployed workers or can be outbid by unemployed workers. An example of the equilibrium bid rent function is displayed in Figure 2. In particular, this figure illustrates a case where unemployed workers occupy both a central core of locations and a peripheral ring of locations, separated by an intermediate ring of employed workers. Other urban configurations may also emerge. For example, the unemployed can occupy the core of the city and the employed the suburbs. The reverse pattern may also prevail.

[Insert Figure 2 here]

Since we want to focus on interesting urban configurations where unemployed workers can outbid employed workers for peripheral land in equilibrium, we shall assume

$$w_L < \frac{w_U}{s_0}. \quad (11)$$

Proposition 2 *There is a unique equilibrium, which is of one of the three following locational patterns:*

- (i) *A central core of unemployed surrounded by a peripheral ring of employed,*

- (ii) A central core of employed surrounded by a peripheral ring of unemployed,
- (iii) Both a central core and a peripheral ring of unemployed separated by an intermediate ring of employed.

This proposition, proved by Smith and Zenou (2003b), shows that in a framework where workers' search intensity is endogenously chosen, the equilibrium is unique and of one of the three types specified in the Proposition. In the first (i), referred to as the *Integrated Equilibrium* (Equilibrium 1 depicted in Figure 3), unemployed workers reside close to the CBD, have high search intensities and experience short unemployment spells. In the second (ii), referred to as the *Segregated Equilibrium* (Equilibrium 2 depicted in Figure 4), the employed workers occupy the core of the city and bid away unemployed workers in the suburbs. In that case, the latter tend to remain unemployed for a longer time since their search intensity is quite low. Finally, the third case (iii), referred to as the *Core-Periphery Equilibrium* (Equilibrium 3 depicted in Figure 2), is when there are two categories of unemployed workers: those who are short-run unemployed reside close to jobs while those who are long-term unemployed live at the periphery of the city.

[Insert Figures 3 and 4 here]

For each equilibrium $k = 1, 2, 3$, we can calculate the steady-state labor equilibrium. The key variable that differs between the different equilibria is \bar{s}^k since its value depends on the average location of unemployed workers.

2.3 Steady-state equilibrium

The unemployment rate is defined by $u^k = U^k/N$. A steady-state labor market equilibrium $k = 1, 2, 3$ is a triple $(w_L^{k*}, \theta^{k*}, u^{k*})$ such that, given the matching technology $M(\cdot)$, all agents (workers and firms) maximize their respective objective function, i.e. this triple is determined by a wage-setting mechanism, a free-entry condition for firms and a steady-state condition on flows. This definition is related to that of the urban equilibrium through the average search intensity \bar{s}^k . Indeed, the equilibrium values of w_L^{k*}, θ^{k*} and u^{k*} depend on the urban configuration considered (equilibrium 1, 2 or 3) through \bar{s}^k , and the urban configuration that will prevail in equilibrium, in turn, depends on the equilibrium labor variables. Let us denote the expected lifetime utility of a filled job and a vacancy by I_F^k and I_V^k . If c is the search cost per unit of time and y is the product of a match, then, in steady-state, I_F^k and I_V^k can be written as:

$$rI_F^k = y - w_L^k - \delta(I_F^k - I_V^k) \quad (12)$$

$$rI_V^k = -c + q(\theta^k)(I_F^k - I_V^k). \quad (13)$$

We assume that firms post vacancies up to a point where $I_V^k = 0$. Using (12) and (13), we obtain, for each $k = 1, 2$, the following decreasing relationship between labor-market tightness and wages:

$$\frac{y - w_L^k}{r + \delta} = \frac{c}{q(\theta^k)}. \quad (14)$$

In words, the 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 a vacant job. So job creation θ^k is endogenous and determined by (14).

In 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, $I_L^k - I_U^k$, and the surplus of the firms, $I_F^k - I_V^k$. As a result, in each period, the wage is determined by:

$$w_L^k = \arg \max_{w_L^k} (I_L^k - I_U^k)^\beta (I_F^k - I_V^k)^{1-\beta}, \quad (15)$$

where $0 \leq \beta \leq 1$ is the bargaining power of workers. To have a closed-form solution of this wage, there must be a simple expression for $I_L^k - I_U^k$. Wasmer and Zenou (2002, 2006) assume housing consumption to be fixed and normalized to 1 for both employed and unemployed workers, i.e. $h_L = h_U = 1$, so that the instantaneous utility can be written as: $\Gamma(h_j, z_j) = \Gamma(1, z_j) = z_j$, for $j = U, L$. They also assume search intensity $s(x)$ not to be optimally chosen by unemployed workers but to be given by the following linear relationship:

$$s(x) = s_0 - s_a x. \quad (16)$$

This function (16) shares its main property with (7) since it is decreasing in x . Its main advantage is that it is a linear function of x , which implies that all bid rents are linear. This eliminates the core-periphery equilibrium (Figure 2) and only two equilibria prevail (described by Figures 3 and 4). In this formulation, s_a measures the marginal loss of information following an increase in distance to jobs. For search intensity to always be positive, we impose that $s_0 > s_a N$. By solving (15), Wasmer and Zenou (2002) obtain the following wage:

$$w_L^k = (1 - \beta) \left[w_U + (\tau_L - \tau_U) x_b^k \right] + \beta \left[y + (s_0 - s_a x_b^k) \theta^k c \right], \quad (17)$$

where x_b^k denotes the border between unemployed and employed workers with $x_b^1 = u$ and $x_b^2 = (1 - u)$. The first part of (17), $(1 - \beta) \left[w_U + (\tau_L - \tau_U) x_b^k \right]$, is what firms must pay to

induce workers to accept the job offer: firms must pay the unemployment benefit and exactly compensate for the difference in transportation costs between employment and unemployment. This is referred to as the *compensation effect*. The second part $\beta \left[y + (s_0 - s_a x_b^k) \theta^k c \right]$ is the part of the surplus obtained by workers. This is referred to as the *outside option effect*. The first effect is a pure spatial cost since $(\tau_L - \tau_U) x_b^k$ represents the space cost differential between employed and unemployed workers paying the same bid rent (i.e. at $x = x_b^k$) whereas the second effect is a mix of labor and spatial costs.

Let us now close the general model where the instantaneous utility function is given by (2) and workers' search intensity by (7). Since each job is destroyed according to a Poisson process with arrival rate δ , the number of workers entering unemployment is $\delta(1 - u_t^k)$ while those leaving unemployment are equal to: $\bar{s}^k \theta_t^k q(\theta_t^k) u_t^k$. The evolution of the unemployment rate is thus given by the difference between these two flows,

$$\dot{u} = \delta(1 - u_t) - \bar{s}^k \theta_t^k q(\theta_t^k) u_t \quad (18)$$

where $\dot{u} = du_t/dt$ is the variation in unemployment with respect to time t . In steady state, the rate of unemployment is constant and thus, these two flows are equal. We have:

$$u^{k*} = \frac{\delta}{\delta + \bar{s}^k \theta^{k*} q(\theta^{k*})}. \quad (19)$$

Equation (19) defines a downward sloping curve referred to as the Beveridge curves in the (u, V) space. The interesting feature of these Beveridge curves is that they are indexed by \bar{s}^k , which depends on the spatial dispersion of unemployed workers in equilibrium $k = 1, 2, 3$.

2.4 Welfare and efficiency

Let us now proceed with the welfare analysis. The social welfare function is given by the sum of the utilities of employed and unemployed workers, the production of firms net search costs and the land rents received by the (absentee) landlords. The latter is given by:

$$\mathcal{W}^k = \int_0^{+\infty} e^{-rt} \left\{ \int_{employed} W_L(x) dx + \int_{unemployed} W_U(x) dx + (1 - u_t^k) (y - w_L^k) - c \theta_t^k \bar{s}_t^k u_t^k \right\} dt. \quad (20)$$

The first issue we address is the respective efficiency of the three types of land market configurations. Since there are no multiple equilibria in the land market, we cannot Pareto-rank the equilibria and it is therefore difficult to compare them. Nevertheless, we are able to investigate what happens to the welfare difference in the range of the parameters around the frontier separating the land market equilibria. Then, we focus on the efficiency and welfare analyses of each equilibrium.

Comparison of welfare between cities We first investigate the welfare and unemployment differences between the different cities. As for the wage, following Wasmer and Zenou (2002, 2006), we assume housing consumption to be fixed and normalized to 1 for both employed and unemployed workers, i.e. $h_L = h_U = 1$, and search intensity $s(x)$ to be given by (16). Let us determine the part of unemployment that is only due to spatial frictions. Since the analysis for equilibrium 1 is nearly identical, we only focus on equilibrium 2 where unemployed workers live far away from jobs. For simplicity, wages are assumed to be exogenous.⁹ In that case, θ^2 is constant and determined by (14). Using (19), the unemployment rate is given by:

$$u^2 = \frac{\delta}{\delta + \theta^2 q(\theta^2) [s_0 - s_a(1 - u^2/2)]}. \quad (21)$$

Let us further define:

$$u_0^2 = \frac{\delta}{\delta + \theta^2 q(\theta^2) s_0}, \quad (22)$$

the part of *unemployment that is independent of spatial frictions*, i.e. $s_a = 0$. By a Taylor first-order expansion for small s_a/s_0 , we easily obtain:

$$u^{2*} = u_0^2 \left[1 + \frac{s_a}{s_0} (1 - u_0^2) (1 - u_0^2/2) \right] = u_0^2 + u_\sigma^2, \quad (23)$$

where $u_\sigma^2 \equiv u_0^2 [s_a (1 - u_0^2) (1 - u_0^2/2) / s_0]$ is the *unemployment rate that is only due to spatial frictions* while u_0^2 is defined by (22). Observe that u_σ^2 is increasing in s_a/s_0 , the parameter representing the loss of information per unit distance, and null when $s_a = 0$.

To see how the welfare and unemployment rates vary across cities, let us proceed to a simple numerical resolution of the model. We use the following Cobb-Douglas function for the matching function: $M(\bar{s}^k u^k, V^k) = \sqrt{\bar{s}^k u^k V^k}$. This implies that $q(\theta^k) = 1/\sqrt{\theta^k}$, $\theta^k q(\theta^k) = \sqrt{\theta^k}$ and, whatever the prevailing urban equilibrium, the elasticity of the matching rate, defined as $\eta(\theta^k) = -q'(\theta^k)\theta^k/q(\theta^k)$, is equal to 0.5. The values of the parameters (in yearly terms) are the following: output y is normalized to unity. The relative bargaining power of workers is equal to $\eta(\theta^k)$, i.e. $\beta = \eta(\theta^k) = 0.5$. Unemployment benefits w_U have a value of 0.3 and the costs of maintaining a vacancy c are equal to 0.3 per unit of time. The commuting costs τ_L are equal to 0.4 for employed workers and $\tau_U = 0.1$ for unemployed workers. The discount rate is such that $r = 0.05$, whereas the job destruction rate is set to

⁹The extension to bargained wages is straightforward but much more cumbersome; see Wasmer and Zenou (2002, 2006).

$\delta = 0.1$, which means that jobs on average last ten years. Finally, s_0 is normalized to 1, thus implying that $0 \leq s_a \leq 1, \forall x \in [0, N]$.

The results are displayed in Table 1, where we have chosen to vary a key parameter s_a , **i.e.** the loss of information per unit of distance. This parameter s_a varies from a very large value 1 (where city 1 is the prevailing equilibrium) to a very small value 0.1 (where city 2 is the prevailing equilibrium). The cut-off point is equal to $s_a = 0.522$. The sign ‘-’ indicates the ‘limit to the left’, whereas the sign ‘+’ indicates the ‘limit to the right’.

Table 1. Comparison between cities

s_a	City	$u^{k*}(\%)$	$u_0^{k*}(\%)$	$u_\sigma^{k*}(\%)$	u_σ^{k*}/u^{k*}	θ^{k*}	x_b^{k*}	\bar{s}^{k*}	Welfare
1	1	6.86	6.64	0.22	0.03	1.98	0.069	0.966	0.715
0.75	1	6.85	6.69	0.16	0.02	1.95	0.069	0.974	0.714
0.6	1	6.85	6.72	0.13	0.02	1.93	0.069	0.979	0.714
0.55	1	6.85	6.73	0.12	0.02	1.92	0.069	0.981	0.714
0.525	1	6.85	6.73	0.15	0.02	1.92	0.069	0.982	0.714
0.522+	1	6.85	6.73	0.12	0.02	1.92	0.069	0.982	0.714
0.522-	2	12.4	6.73	5.65	0.46	1.92	0.876	0.511	0.712
0.52	2	12.4	6.74	5.63	0.45	1.91	0.876	0.512	0.712
0.5	2	12.1	6.82	5.31	0.44	1.86	0.879	0.530	0.713
0.25	2	10.0	7.81	2.20	0.22	1.39	0.900	0.763	0.727
0.1	2	9.15	8.35	0.80	0.09	1.20	0.909	0.905	0.732

The first interesting result is that when we switch from an integrated city (equilibrium 1) to a segregated city (equilibrium 2), for values very close to the cut-off point $s_a = 0.522$, the unemployment rate u^{k*} nearly doubles (from 6.85% to 12.4%). However, it should be clear that this result is mainly due to the spatial part of unemployment u_σ^k since the non-spatial part u_0^k is not at all affected by this increase. Indeed, when we switch from equilibrium 1, where unemployed workers are close to jobs and are very efficient in their job search ($\bar{s}^1 = 0.982$), to equilibrium 2, where the unemployed reside far away from jobs and are on average less active ($\bar{s}^2 = 0.511$), the spatial part of the unemployment rate changes the values from 0.12% to 5.65%. Another way of seeing this is to consider column 6 (u_σ^k/u^{k*}): the part of unemployment due to space increases from 2% to 46%. So the main effect from switching from one equilibrium to the other is that the search frictions are amplified by space and, consequently, there is a sharp increase in the unemployment rates. Thus, here spatial access to jobs is crucial for understanding the formation of unemployment in cities.

The last column of the table shows the value of welfare W^k when s_a varies. The result

is very striking: even though unemployment rates are higher in equilibrium 1 than in equilibrium 2, this does not imply that the general welfare of the economy is higher. Indeed, even though unemployed workers are better off in equilibrium 1 (lower unemployment spells and lower commuting costs), employed workers can, in fact, be worse off due to much higher commuting costs in equilibrium 1. In Table 1, it is interesting to see that in the vicinity of $s_a = 0.522$, switching from equilibrium 1 to equilibrium 2 does not involve any considerable change in the welfare level (from 0.714 to 0.712). Observe that this is just a numerical example and we do not have any general result. However, we are confident that it can be generalized since the same qualitative results have been obtained in the numerous simulations performed by us. Observe also that these numerical results could have been obtained for the more general model where search intensity was chosen and given by (7), as long as we had focused on urban equilibria 1 and 2.

Welfare within each city The shape of the city thus apparently has little impact on welfare since, in the segregated city, what is lost from lower search efficiency is gained through lower commuting costs. We now investigate the issue of the optimality of the decentralized equilibrium *within each land market equilibrium* for the case of a fixed search intensity function given by (16). The social planner chooses θ^k and u^k that maximize (20) under the constraint (18). In this problem, the control variable is θ_k and the state variable is u_k . Define $\eta(\theta^k) = -q'(\theta^k)\theta^k/q(\theta^k)$, i.e. the elasticity of the matching function in equilibrium k . Wasmer and Zenou (2002) show the following result:

Proposition 3 *In a spatial search-matching model with endogenous search intensity, for each urban equilibrium k , the market equilibrium is efficient if and only if:*

$$\eta(\theta^k) = \beta. \tag{24}$$

Condition (24) is referred to as the Hosios-Pissarides condition and is exactly the same as in the standard matching model without space (Pissarides, 2000, chap. 8, Hosios, 1990). Indeed, in this model, market failures are only caused by search externalities and the land market is thus efficient (Fujita, 1989). In fact, there are two types of search externalities that must be considered: *negative intra-group externalities* (when more workers are looking for a job, the workers' job-acquisition rate is reduced while when more firms are seeking to fill their vacancies, the firms' vacancy-filling rate is reduced) and *positive inter-group externalities* (when more workers are looking for a job, the firms' vacancy-filling rate is increased while when more firms are seeking to fill their vacancies, the workers' job-acquisition rate

is increased). For a class of related search-matching models, Hosios (1990) and Pissarides (2000) have established that these two externalities just offset one another in the sense that the search equilibrium is socially efficient if and only if the matching function is homogenous of degree one and the worker's share of surplus β is equal to $\eta(\theta^k)$, the elasticity of the matching function. Naturally, there is no reason for β to be equal to $\eta(\theta^k)$ since these two variables are not at all related and, therefore, the search-matching equilibrium is, in general, inefficient. In particular, when β is larger than $\eta(\theta^k)$, there is too much unemployment, thus creating congestion in the matching process for unemployed workers. When β is lower than $\eta(\theta^k)$, there is too little unemployment, thus creating congestion for firms.

In our present model, we have exactly the same search externalities (intra- and inter-group externalities). The spatial dimension does not entail any inefficiency which is why the Hosios-Pissarides condition still holds in each equilibrium, i.e. $\beta = \eta(\theta^k)$. Interestingly, when we consider the more general model where $s(x)$ is given by (7) and three urban equilibria prevail, the condition that internalizes the externalities on job creation is still (24). In terms of welfare, nothing changes when workers' search intensity is endogenized. This is not a surprising result since it was already obtained by Pissarides (2000, Ch. 8).

2.5 Discussion and stylized facts

This model can explain some of the stylized facts mentioned in the introduction. First, it is even clearer here how city structure affects workers' labor-market outcomes. We have three different city structures, described by Figures 2, 3, and 4, which imply very different labor-market experiences for workers. We also have a better understanding of why workers living far away from jobs search less intensively than those residing closer to jobs. This is simply because they have less incentives since their land rent and their housing consumption are low. There is also a new implication generated by this model: what is the impact of labor-market variables on the growth of cities? Indeed, since housing consumption is endogenous, city size is not equal to 1, i.e. the total population, but must include population density (which is the inverse of housing consumption).

To illustrate this issue, take equilibrium 2 (Figure 4) where unemployed workers reside far away from jobs and, for simplicity, assume that $x_b^* \geq x(\underline{s}_0)$ so that all unemployed workers provide a search intensity equal to $s(x) = \underline{s}_0, \forall x$.

Since the model becomes quite complicated, let us run some simple numerical simulations. We use the same assumptions and numerical values as in Section 2.3 with some differences due to the specificity of the model. First, as stated above, search intensity is now independent of distance and fixed to $\underline{s}_0 = 0.1$, which means that unemployed workers have a very low

search intensity (if employed workers search everyday, then unemployed workers search every ten days) because they all reside far away from jobs. As a result, by still assuming commuting costs τ to be equal to 0.4, we have: $\tau_L = \tau = 0.4$ and $\tau_U = \underline{s}_0\tau = 0.04$. Second, there are some new parameters which are set as follows: $\alpha = \omega = 1/4$. We obtain the following equilibrium values:

$$\theta^* = 10.46; u^* = 0.24; w_L^* = 0.85; x_b^* = 0.26; x_f^* = 0.30.$$

Not surprisingly, the unemployment rate is quite high (24 percent) because the unemployed workers, who reside far away from jobs, do not search very intensively.¹⁰ The wage is relatively high (85 percent of the productivity) and the replacement ratio, w_U/w_L^* , is relatively low (35 percent). Employed workers, who live between $x = 0$ and $x = x_b^*$, occupy 87 percent of the city. Indeed, even though 24 percent of the workers are unemployed, they occupy a smaller part of the city because their housing consumption is much smaller than that of employed workers. This is mainly due to the fact that wage w_L^* is very high as compared to the unemployed benefit.

Let us now examine how the labor market variables affect the size of the city, i.e. x_f^* . Figure 5 reports some of the simulation results (not all). First, when there is an increase in the unemployment benefits w_U , the size of the city also increases (Figure 5a), even if the effect on x_b^* is extremely small. Indeed, an increase in w_U raises the unemployment rate u^* because firms create less jobs (θ^* decreases) and, as a result, there is an increase in the housing consumption of unemployed workers. Thus, even though the employment area is not affected (the wage and housing consumption of employed workers increase but their number is still smaller), there is a sharp increase in the unemployment area which, in turn, increases the size of the city. In contrast, an increase in the firms' entry cost c or the job-destruction rate δ , reduces both the size of the city (Figure 5a) and the employment area. Indeed, wages and job creation are reduced while unemployment increases, which means that there is less competition in the land market and lower housing consumption for all workers. If we now look at the effect of search intensity $s = \underline{s}_0$ on x_f^* (Figure 5b), we have exactly the opposite results, i.e. both x_b^* and x_f^* increase because of lower unemployment and higher wages. However, this increase is not very important because job creation decreases since it becomes more expensive to hire workers. Finally, it is interesting to examine how commuting costs τ (which is a spatial variable) affect the growth of cities (Figure 5b). We find that both x_b^* and x_f^* decrease because of higher competition in the land market (access to the CBD becomes

¹⁰Note that the unemployment rate is much higher than that displayed in Table 1 because here $s(x) = \underline{s}_0 = 0.1, \forall x$ while, in Table 1, we had: $s(x) = 1 - s_a x$ with $s_a \in [0.1, 1]$.

more valuable), there is an increase in unemployment and job creation is reduced despite the increase in wages (firms need to compensate more workers for their commuting costs).

[Insert Figure 5 here]

2.6 Empirical evidence on the negative relationship between search intensity and job access

One of the main results of the benchmark model was the negative relationship between search intensity s and distance to jobs x (see (7)). In fact, there is strong evidence showing that distance to jobs has a negative impact on search behavior. Using data from the Labour Force Survey in England between 1994 and 2000, Patacchini and Zenou (2005) investigate the relationship between workers' search intensity and distance to jobs (as measured by the average commuting time of employed workers living in the same area and having similar skills as the non-employed). Once the influence of other observable and unobservable area-specific characteristics have been controlled for, they show that living in areas where the average commuting time of employed workers is longer makes the non-employed search less than in areas with a shorter commuting time. Rogers (1997) relies on unemployment insurance claim data for the Pittsburgh, Pennsylvania, metropolitan area in 1980 through 1986 to examine the impact of job accessibility on unemployment durations. Job accessibility is measured using two different employment-based indices that are each weighted by commuting times between the location of a household's residence and the location of jobs. She finds that a one-standard deviation increase in the mean value of job access decreases expected unemployment duration by about five weeks. Holzer et al. (1994) rely on data from the 1981 and 1982 US National Longitudinal Survey of Youth (NLSY) to estimate models explaining the log of unemployment duration for a sample of black and white youths. The authors find that job decentralization (which is a measure of bad access to jobs for blacks who mostly live in the central part of cities) is associated with increased unemployment durations.

To examine the link between unemployment duration and job accessibility, Dawkins et al. (2005) employ a unique version of the Panel Study of Income Dynamics (PSID) that provides information on the census tract and zip code of residence for each individual in the sample. Job accessibility is defined as the share of total MSA jobs located in each worker's zip code of residence. In the full model with the most extensive set of controls, they find that a one standard deviation increase in local shares of MSA jobs equates a roughly 9 percent reduction in unemployment durations.

Finally, Johnson (2006) uses the household and employer surveys of the US Multi-City Study of Urban Inequality (MCSUI) data set to investigate whether proximity to employment opportunities affects job search behavior and search duration and whether these effects vary with the extent of spatial frictions faced by searchers. For each respondent, geographical measures of job accessibility are developed using the spatial distribution of the sample of recently filled non-college jobs and net hires from the MCSUI Employer Survey. He found that job search behavior and job search outcomes are affected by the interaction of the degree of residential location constraints facing the job seeker and his/her proximity to employment opportunities.

3 Extensions

3.1 Skill heterogeneity

In the benchmark model, it was assumed that workers were identical in terms of skills. Sato (2001, 2004) develops a model which is similar to the benchmark model (without endogenous search intensity) but assumes workers to be ex ante heterogenous in terms of skills. Then, when a match occurs, workers pay all the training costs so that, ex post, every worker-firm pair reaches the same level of productivity, and all employed workers receive the same wage. Contrary to the benchmark model, Sato (2001, 2004) shows that there are two sources of inefficiency. First, as previously, there is a job-creation inefficiency where, depending on the value of workers' bargaining power, firms create too many or too few jobs as compared to the efficiency solution. Second, and this is new, there is another source of inefficiency due to training costs. Indeed, at the market solution, workers tend to refuse socially beneficial jobs because while workers bear all the training costs, the revenues from production are divided through bargaining between firms and workers.

One of the drawbacks of these papers is that, ex post, workers are identical and obtain the same wage. As a result, the urban land use equilibrium is as before and these models cannot explain the location of workers with different skills/incomes. Borrowing tools from the product differentiation literature, especially from Salop (1979), Helsley and Strange (1990), Kim (1990, 1991) and Brueckner et al. (2002), relax this assumption and we consider an urban matching model where workers and firms are ex ante and ex post heterogenous.¹¹ Helsley and Strange (1990) and Kim (1990, 1991) show that because of increasing returns to

¹¹See also Zenou (2009c) for an urban search model where workers are ex identical but ex post heterogenous due to different technological shocks that lead to endogenous job destructions.

scale and specialized production methods, as the number of workers in the market increases, there is an improvement in the average match between heterogeneous job requirements of firms and heterogeneous skill characteristics of workers. Thus, training costs decrease and net productivity increases as the size of the market increases. As a result, the wage rate increases with the size of the city, for the larger is the city, the better is the match between the diverse job requirements and the diverse labor pool.¹² Focussing on a different issue, Brueckner et al. (2002) show how heterogeneity in the skill space is mirrored in the residential-location choices of workers, thus drawing a connection between outcomes in the land and labor markets. In particular, low-skill workers have long commute trips, which yield a low wage net of training and commuting costs. Therefore, low skill workers are distant from firms in both skill and urban spaces. Because such workers thus live in the urban periphery, this model provides a rationale for the existence of *socio-economic ghettos*, occupied by workers who are socially and physically distant from their employers (Akerlof, 1997). This twofold segregation is found in a number of European cities, where high-income residents reside near the center and lower income workers live on the outskirts of the city.

3.2 Positive relocation costs

All models above assumed no relocation costs. Although this assumption is quite frequent in urban economics, its relevance may depend on the nature of the labor market. Indeed, when unemployment and employment spells are short (i.e. a U.S. style of labor market), it is not necessarily appealing: low-income households do not necessarily change their residential location as soon as they change their employment status. However, in a European context, long spells of employment and unemployment make it more likely that relocation and labor transitions coincide, in which case our benchmark assumption of absence of mobility costs is relevant.

Let us thus assume that relocation costs exist, are finite and denote the instantaneous amount of effort and money supported by moving individuals by C . To simplify this, we now consider s to be independent of distance and effort and wages to be exogenous and fixed at a level w .

Wasmer and Zenou (2006) show that, in equilibrium, there will be four groups of agents: the mobile employed and unemployed and the immobile employed and unemployed, respectively. Employed workers are said to be mobile (resp. immobile) when, hit by a job-

¹²See also Wheeler (2001) and Teulings and Gautier (2009) for similar models showing that urban agglomeration enhances productivity by facilitating the firm-worker matching process.

destruction shock, they decide to relocate to another part of the city (resp. stay in the same location). A similar definition of mobility can be adapted to the unemployed depending on the occurrence of a successful application to a job. Let us denote the border between the mobile and immobile employed, and the immobile and mobile unemployed by x^α and x^β , respectively. Wasmer and Zenou (2006) focus on urban equilibrium 2 and show that when there are positive relocation costs, this equilibrium can be described by Figure 6.

[Insert Figure 6 here]

If both total population and housing consumption are normalized to one, the areas where all mobile workers are employed and where the unemployed reside are given by x^α and $1 - x^\beta$, respectively, while the area where the immobile workers (employed and unemployed) live is $x^\beta - x^\alpha$. It can further be shown that:

$$x^\beta - x^\alpha = \frac{2C [r + s\theta q(\theta) + \delta]}{\tau_L - \tau_U}, \quad (25)$$

where, as previously, τ_L and τ_U constitute the monetary commuting cost per unit of distance for employed and unemployed workers. This is a key equation determining the size of the middle area and thus, the cost imposed by the full-mobility assumption. The size of the immobility area thus increases with C and with all turnover rates, and is reduced by the difference in commuting costs between employed and unemployed workers. The intuition is that to remain immobile, quick transitions in the labor market (so that waiting for another employment transition to remain in the same location is the best strategy) or low gains from mobility in terms of commuting costs must be expected.¹³

To conclude this part, it can be observed that relocation costs indeed change the derivation of the equilibrium. This adds an area in the middle of the city where employed and unemployed workers are immobile, pay the same rent, and continuously overlap. When the relocation costs disappear, we return to our previous equilibrium. This model has thus generalized the frictionless land market.

¹³See also Zenou (2009b) who develops a spatial search model where relocation costs are infinite so that individuals never change their residential locations.

4 Can space explain why black workers perform poorly in the labor market?

4.1 Spatial mismatch

The different models developed in this article can provide some mechanisms explaining why black workers, who tend to live far away from jobs, experience a high unemployment rate. This is known as the “spatial mismatch hypothesis”. Indeed, first formulated by Kain (1968), the spatial mismatch hypothesis states that residing in urban segregated areas that are distant from and poorly connected to major centres of employment growth, black workers face strong geographic barriers to finding and keeping well-paid jobs. In the US context, where jobs have been decentralized and blacks have remained in the central parts of cities, the main conclusion of the spatial mismatch hypothesis is that distance to jobs is the main cause of high unemployment rates. Since Kain’s study, hundreds of others have been conducted trying to test the spatial mismatch hypothesis (see, in particular, the literature surveys by Ihlanfeldt and Sjoquist, 1998; Ihlanfeldt, 2006). The usual approach is to relate a measure of labor-market outcomes, typically employment or earnings, to another measure of job access, typically some index capturing the distance between residences and centres of employment. The general conclusions are: (a) poor job access indeed deteriorates labor-market outcomes, (b) black and Hispanic workers have worse access to jobs than white workers, and (c) racial differences in job access can explain between one-third and one-half of the racial differences in employment.

Despite this huge empirical literature, few theoretical models have been proposed (for a survey on the theoretical literature, see Zenou, 2006 and Gobillon et al., 2007). The models developed in this paper provide the two following mechanisms for why distance to jobs can have adverse labor-market outcomes for ethnic minorities:

(i) Workers’ job search efficiency may decrease with the distance to jobs. Indeed, Wasmer and Zenou (2002) show that workers living far away from jobs have less chance of finding a job because they obtain poor information on distant job opportunities. Observe that the social isolation of inner-city neighborhoods can also have an impact on local social interactions and thus explain the lack of good job contacts. Indeed, since high-poverty neighborhoods are usually poorly connected to job centers and characterized by low employment rates, black workers who live in these neighborhoods may have few friends who are employed and can help them find a job (Topa, 2001; Selod and Zenou, 2006; Bayer et al., 2008).

(ii) Workers residing far away from jobs may not search intensively. Indeed, in section

2, we have seen that since housing prices decrease with distance to jobs, distant workers feel less pressured to search for a job in order to pay their rent. In this context, spatial mismatch can be the result of optimizing behavior by labor market participants, since the unemployed can choose low amounts of search and long-term unemployment. This implies that the standard US-style mismatch arises because inner-city blacks choose to remain in the inner-city and only search little. They do not relocate to the suburbs because the short run-long run gap is sufficiently large to make locations near the jobs too expensive.

It should be clear that using mechanisms (i) and/or (ii), it can easily be understood why, in the same city, ethnic minorities experience higher unemployment rates than workers from the majority group. Indeed, if ethnic minorities reside far away from jobs for some reason (because they are discriminated against in the housing market or because they want to live together), they will search less intensively because they either have less information about jobs or it is optimal to do so. As a result, they will leave unemployment at a slower rate and thus, experience higher unemployment rates.

By highlighting these two mechanisms, we have learned how distance to jobs affects the labor-market outcomes of ethnic minorities. This is important because it leads to interesting policy implications. Since search frictions and job access are the main culprits in creating spatial mismatch, improvements in the efficiency of the matching function (better information, better market structure organization) and/or in the transportation infrastructure will reduce unemployment. Furthermore, if the local government could “move” minority workers closer to jobs, this would improve their outcomes. In that case, “Moving to Opportunity” programs (such as the so-called Gautreaux program)¹⁴ are just the correct policy device for reducing mismatch, rather than lowering search costs in some other way.

All models so far have used the monocentric city paradigm. One question naturally arises. Would polycentric city configurations overturn the main location results in the paper? There are, in fact, very few papers with a complete analysis of land and labor markets in a non-monocentric city.¹⁵ We will here develop a search model proposed by Coulson et al. (2001) with two job centers, the Central Business District (CBD) and the Suburban Business

¹⁴By giving housing assistance (i.e. vouchers and certificates) to low-income families, the MTO programs help them relocate to better and richer neighborhoods. The results of most MTO programs (in particular for Baltimore, Boston, Chicago, Los Angeles and New York) show a clear improvement in the well-being of participants and better labor market outcomes (see, in particular, Ladd and Ludwig, 2001; Katz, Kling, and Liebman, 2001; Ludwig, Duncan, and Hirschfield, 2001; Rosenbaum and Harris, 2001; Kling and Katz, 2005). Observe that the MTO programs are not targeted at minority families (such as blacks) but rather at poor families. But this is a good example of an integration policy since the two are correlated.

¹⁵Exceptions include Smith and Zenou (1997), Brueckner and Zenou (2003) and Coulson et al. (2001).

District (SBD). This models also aims at explaining the spatial mismatch hypothesis.

Consider a continuum of heterogeneous (in terms of disutility of commuting) workers who reside in each of the two locations (CBD or SBD) and a continuum of firms that provide vacancies in each of the two locations. Even if workers' residential location is fixed, they are free to search for work in either (or both) locations and commute to work if employment is found outside the zone in which they are domiciled. The authors assume that the firms' entry cost c is higher in the CBD than in the SBD. This captures the fact that jobs have been decentralized in the United States, so that it is less costly to create a job in the suburbs. Explanations include cheaper land prices in the suburbs, lower taxation, lower labor costs, lower production costs, etc.

Proposition 4 *If the difference in entry costs between the CBD and SBD is sufficiently large, then there exists a unique steady-state search equilibrium in which none of the SBD unemployed workers search for a job in the CBD while CBD unemployed workers search for a job in both centers. In that case, the labor market equilibrium is such that:*

- (i) *the unemployment rate is higher for central city residents than for suburban residents;*
- (ii) *the vacancy rate in the CBD is lower than that in the SBD;*
- (iii) *workers in the suburbs earn a higher wage than those in the CBD.*

As can be seen from this proposition, in equilibrium, the city has the features associated with the spatial mismatch hypothesis. Let us give the intuition for this result.

A higher entry cost for CBD-firms implies that these firms will enter less in the labor market (and thus create less jobs) than SBD-firms. As a result, the contact rate for workers searching in the CBD will be lower than in the SBD, while the contact rate for firms in the CBD will be higher than in the SBD.

Thus, in steady-state, workers with a high disutility of commuting will only search in the area where they live while those with a low disutility of commuting will search in the area where they do not reside. Thus, there is a threshold disutility value \tilde{d}_j at each location $j = CBD, SBD$ for which all workers with a disutility lower than \tilde{d}_j will search in the other area while the others will search in their own area. The threshold value \tilde{d}_j is clearly influenced by these contact rates. When the difference in entry costs between the CBD and the SBD is sufficiently large, which means that the worker-contact rate in the CBD is much lower than in the SBD and the firm-contact rate is much higher, it is never profitable for SBD workers to commute to the CBD while the reverse is not true.

Moreover, since the vacancy rate inversely depends on the firm-contact rate while the unemployment rate inversely depends on the worker-contact rate, results (i) and (ii) follow. As concerns the wage, since the entry cost is higher in the CBD, there is a direct negative effect on the wage because of the enhanced bargaining power of firms. In addition, as we have seen, the higher entry cost in the CBD reduces the entry of firms in the CBD and reduces the equilibrium worker-contact rate, which also reduces the wage (by weakening each worker's bargaining strength). These two effects work in the same direction, thus implying an unambiguous lower wage level in the CBD (result (iii)).

Observe that search frictions are also crucial in explaining the results of Proposition 4. Indeed, as the search frictions vanish, all firms enter the SBD labor market and no workers are employed in the CBD. This implies that differential entry costs together with nontrivial search frictions are sufficient to generate spatial mismatch.

What are the policy implications of this model? Since differential entry costs and search frictions are the main culprits in creating spatial mismatch, as above, improvements in the efficiency of the matching function and/or in the transportation infrastructure will reduce unemployment. A policy consisting of reducing the differential in the fixed entry cost between areas could also be effective in reducing spatial mismatch. Such policies have been implemented in the United States and in Europe. Indeed, in the US, the enterprise zone programs (Papke, 1994; Boarnet and Bogart, 1996; Mauer and Ott, 1999; Bondonio and Engberg, 2000; Bondonio and Greenbaum, 2007) consist of designating a specific urban (or rural) area, which is depressed, and targeting it for economic development through government-provided subsidies to labor and capital. Such policies have also been implemented in Europe. In France, for example, any firm desiring to set up in a depressed area ('zone franche') is exempt from taxes but 20 percent of its workforce must consist of local workers.

4.2 Automobile mismatch

While the spatial mismatch hypothesis could explain why black workers residing far away from jobs experience adverse labor-market outcomes, it cannot explain other crucial aspects of the spatial labor market of black workers. Indeed, if it is true that black workers in general reside further from jobs than whites, they do, however, (i) spend more time commuting to work, (ii) travel less miles to go to their jobs and (iii) search for jobs in a smaller area (see e.g. Holzer et al., 1994, and Raphael and Stoll, 2001). It is difficult to fully understand these facts without introducing mode choices in the explanation. Some researchers have even put forward the idea of an *automobile* or *transportation mismatch* rather than a spatial mismatch to understand the adverse labor-market outcomes of black workers in the United States (see,

in particular, Taylor and Ong, 1995). Since most blacks use mass transit,¹⁶ the choice of transportation is indeed crucial, in particular in large American metropolitan areas where public transportation is usually not that good (see e.g. Pugh, 1998).¹⁷ Mass transit is a much slower means of transport than private cars in the United States, not only because buses are slower but also due to the unreliability of the transit system that causes workers to frequently miss transfers and the fact that many areas are difficult to reach by public transport. In 2000, in the United States, the average commuting time by public transit was about twice as high as by car (47.7 versus 24.1 minutes; see Kawabata and Shen, 2007).

Based on Gautier and Zenou (2008), we would like to develop a spatial search model that can explain stylized facts (i), (ii) and (iii). This paper uses the same framework as the models developed in Section 3.1. Indeed, following Salop (1979), Gautier and Zenou model workers' and firms' *heterogeneity* using a circle along which workers and firms are uniformly distributed over its circumference C of length 1. However, in contrast to Section 3.1, the circle represents *geographical space* and not skill space and there is a continuum of job centers. To only focus on the role of car access, they consider a framework where firms have *no taste for discrimination* and ex ante, blacks and whites are located *at the same distance to jobs*.

Apart from the color of their skin, the only difference between black and whites is an initial wealth difference. The authors show that if this difference is sufficiently large, black workers will always choose public transportation while whites will afford to have cars. Since

¹⁶Using data drawn from the 1995 Nationwide Personal Transportation Survey, Raphael and Stoll (2001) show that in the US, 5.4 percent of the white households have no automobile while 24 and 12 percent of the black and Latino households, respectively, do not own a car. Even more striking is that they show that 64 and 46 percent, respectively, of the black and Latino households only have one or zero cars, whereas this number was 36 percent for white households. Using the 1991 Census data, Owen and Green (2000) show that in Great-Britain, 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 using public transport to go to work. Furthermore, 73.6 percent of the whites use a 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 (2005) find similar results.

¹⁷Naturally, there are important variations in the quality of public transportation systems both between and within cities. Indeed, within the U.S., public transportation in most large metropolitan areas is better than in small metropolitan areas, suburban, or rural areas. Furthermore, in most large U.S. metropolitan areas, transportation systems are at least as good as in most other metropolitan areas with the exception of a few Western European countries which heavily subsidize public transport. There are also large differences in public transport within large metropolitan areas in the U.S. (Pugh, 1998). For example, public transport in New York is clearly much better than public transport in Phoenix.

the set of jobs that can be reached by car is larger than the set that can be reached by public transportation, whites find jobs faster and experience shorter unemployment spells. Living far away from one's job could, in principle, signal car ownership but not if home location is either unobservable or not verifiable (i.e. workers can always provide fake addresses). Employers do observe the worker's type (black or white) and since whites on average have a better bargaining position, they earn higher wages. In equilibrium, Gautier and Zenou (2008) show that as compared to whites, blacks (*i*) do not own a car, (*ii*) experience higher unemployment rates and longer unemployment spells, (*iii*) earn lower wages, (*iv*) on average spend more time commuting to work, (*v*) on average travel less miles to go to their jobs and (*vi*) search for jobs over a smaller area.

As stated above, results (*iv*) and (*v*) are well-documented features of the spatial labor market of blacks and white workers. Indeed, even though blacks are, on average, further away from jobs, they live closer (in miles) to jobs when they are employed but spend more time traveling. The time cost per mile traveled is thus substantially higher for blacks than for whites. There is indeed a difference between *commuting distance* and *commuting time*. In the central city in the United States (where a large fraction of blacks live), travel times are quite long, even over shorter distances, especially for people relying on public transportation. For example, in 1995, the average commuting distance for workers using private transportation was twelve miles, as compared to thirteen miles for those reliant on public transportation. However, commuting times were more than twice as long for public transit than for those who used private vehicles – twenty-two minutes as compared to forty-two minutes (Hu and Young, 1999). Results (*iv*) and (*v*) are due to the lack of car access among the black population.

In this context, investments in public transport can have a substantial impact on the search activities of low-income workers and thus, on their unemployment rate.¹⁸ Indeed, if labor participation for black workers is affected by poor access to job locations and poor worker mobility, and if public transportation services are designed to effectively link workers with areas of concentrated employment, then an increased access to public transit should yield higher levels of employment, in particular for blacks (Sanchez, 1998, 1999; Blumemberg and Manville, 2004). Alternatively, programs that help job takers (especially blacks) obtain a used car – a secured loan for purchase, a leasing scheme, a revolving credit arrangement – may offer real promise and help low-skill workers obtain a job. This is a standard policy that has been advocated in the United States. Stoll (1999) shows that increasing the access of blacks and Latinos to cars will lead to greater geographic job search. Using data from

¹⁸See Zenou (2000) for a first urban labor model where a public transportation policy is explicitly considered.

the UK, Patacchini and Zenou (2005) find similar results. They find that for a given time distance to jobs (measured by the average commuting time of the employed in a given area), unemployed white workers search more intensively than unemployed black workers. They also show that giving the mean level of white (time) distance to jobs and white car access to black workers would close the racial gap in search intensity by 50.31 percent. Raphael and Stoll (2001) also found that raising minority car-ownership rates to the white car ownership rate would considerably narrow inter-racial employment rate differentials (see also Raphael and Rice, 2002, and Gurley and Bruce, 2005, who found positive effects of car access on employment). Moreover, if one believes that the low rate of car ownership among black families is driven by discrimination in the automobile insurance and credit markets, the government should enforce anti-discrimination laws preventing such behavior.

5 Concluding remarks

In this article, we have exposed different models that improve our understanding of urban spatial structures and commuting patterns and show how they can be useful in explaining the stylized facts mentioned in the introduction. However, this literature on urban search models is very recent and there are some open questions that need to be answered in the future. First, in none of these models were employed workers allowed to search for jobs (i.e. on-the-job search) to improve their current wages. This is an important feature of labor markets, especially in Europe, where plenty of workers find a job while already employed (Cahuc and Zylberberg, 2004). As shown by Burdett and Mortensen (1998), including on-the-job search has important consequences for the wage distribution and, as a result, for the location of workers in cities. Second, we have seen that the market solution of (spatial) search models is not efficient because of search externalities. Policies like zoning (Fischel, 1985), which impose land-use regulation (e.g. limiting the height of buildings or lot coverage), could, in principle, restore efficiency. Third, it is well documented that social networks play an important role in searching for and finding a job (Ioannides and Loury, 2004). It is also well documented that social interactions are very localized (Bayer et al., 2008). Therefore, it would be interesting to develop a model where the interaction between the social and the urban space takes place. This will help us better understand why ethnic minorities have difficulties finding a job. Indeed, if they are segregated and separated from business centers and their only source of job information is provided by their neighbors who are themselves unemployed, then the chance of escaping unemployment will be very low. These are exciting areas of research that we leave to the future.

References

- [1] Akerlof, G., 1997. Social distance and social decisions. *Econometrica* 65, 1005-1027.
- [2] Bayer, P., Ross, S.L., Topa, G., 2008. Place of work and place of residence: Informal hiring networks and labor market outcomes. *Journal of Political Economy* 116, 1150-1196.
- [3] Blanchflower, D.G., Oswald, A.J., 1994. *The Wage Curve*. MIT Press, Cambridge, MA.
- [4] Blumemberg, E., Manville, M., 2004. Beyond the spatial mismatch hypothesis: Welfare recipients and transportation policy. *Journal of Planning Literature* 19, 182-205.
- [5] Brueckner, J.K., Thisse, J-F., Zenou, Y., 2002. Local labor markets, job matching and urban location. *International Economic Review* 43, 155-171.
- [6] Brueckner, J.K., Zenou, Y., 2003. Space and unemployment: The labor-market effects of spatial mismatch. *Journal of Labor Economics* 21, 242-266.
- [7] Burdett, K., Mortensen, D.T., 1998. Wage differentials, employer size, and unemployment. *International Economic Review* 39, 257-273.
- [8] Cahuc, P., Zylberberg, A., 2004. *Labor Economics*, MIT Press, Cambridge, MA.
- [9] Coulson, E., Laing, D., Wang, P., 2001. Spatial mismatch in search equilibrium. *Journal of Labor Economics* 19, 949-972.
- [10] Crampton, G.R., 1999. Urban labour markets. In: Cheshire, P., Mills, E.S. (Eds.), *Handbook of Regional and Urban Economics*, Vol. 3, Elsevier Science, Amsterdam, pp.1499-1557.
- [11] Dawkins, C.J., Q. Shen, Sanchez, T.W., 2005. Race, space, and unemployment duration. *Journal of Urban Economics* 58, 91-113.
- [12] Eberts, R.W., Stone, J.A., 1992. *Wage and Employment Adjustment in Local Labor Markets*. W.E. Upjohn Institute for Employment Research, Kalamazoo.
- [13] Fischel, W.A., 1985. *The Economics of Zoning. A Property Rights Approach to American Land Use Controls*. Johns Hopkins University Press, Baltimore.
- [14] Fujita, M., 1989. *Urban Economic Theory*. Cambridge University Press, Cambridge.

- [15] Fujita, M., Krugman, P., Venables, A.J., 1999. *The Spatial Economy. Cities, Regions, and International Trade*. MIT Press, Cambridge, MA.
- [16] Fujita, M., Thisse, J-F., 2002. *Economics of Agglomeration. Cities, Industrial Location, and Regional Growth*. Cambridge University Press, Cambridge.
- [17] Gautier, P.A., Zenou, Y., 2008. Car ownership and the labor market of ethnic minorities. CEPR Discussion Paper No. 7061.
- [18] Gobillon, L., Selod, H., Zenou, Y., 2007. The mechanisms of spatial mismatch. *Urban Studies* 44, 2401-2427.
- [19] Gurley, T., Bruce, D., 2005. The effects of car access on employment outcomes for welfare recipients. *Journal of Urban Economics* 58, 250-272.
- [20] Helsley, R.W., Strange, W.C., 1990. Matching and agglomeration economies in a system of cities. *Regional Science and Urban Economics* 20, 189-212.
- [21] Ioannides, Y.M., Loury, D.L., 2004. Job information networks, neighborhood effects, and inequality. *Journal of Economic Literature* 42, 1056-1093.
- [22] Holzer H.J., Ihlanfeldt, K.R., Sjoquist, D.L., 1994. Work, search, and travel among white and black youth. *Journal of Urban Economics* 35, 320-345.
- [23] Holzer, H.J., Reaser, J., 2000. Black applicants, black employees, and urban labor market policy. *Journal of Urban Economics* 48, 365-387.
- [24] Hosios, A., 1990. On the efficiency of matching and related models of search and unemployment. *Review of Economic Studies* 57, 279-298.
- [25] Hu, P.S., Young, J.R., 1999. *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*, Federal Highway Administration, US Department of Transport, Washington, DC.
- [26] Ihlanfeldt, K.R., 1997. Information on the spatial distribution of job opportunities within metropolitan areas. *Journal of Urban Economics* 41, 218-242.
- [27] Ihlanfeldt, K.R., 2006. A primer on spatial mismatch within urban labor markets. In: Arnott, R., McMillen, D. (Eds.), *A Companion to Urban Economics*. Blackwell Publishing, Boston, pp. 404-417.

- [28] Ihlanfeldt, K.R., Sjoquist, D., 1998. The spatial mismatch hypothesis: A review of recent studies and their implications for welfare reform. *Housing Policy Debate* 9, 849-892.
- [29] Immercluck, D., 1998. Job proximity and the urban employment problem: Do suitable nearby jobs improve neighbourhood employment rates? *Urban Studies* 35, 7-23.
- [30] Johnson, R.C., 2006. Landing a job in urban space: The extent and effects of spatial mismatch. *Regional Science and Urban Economics* 36, 331-372.
- [31] Kain, J., 1968. Housing segregation, negro employment, and metropolitan decentralization. *Quarterly Journal of Economics* 82, 175-197.
- [32] Kawabata, M., Shen, Q., 2007. Commuting inequality between cars and public transit: The case of San Francisco Bay area, 1990-2000. *Urban Studies* 44, 1759-1780.
- [33] Kim, S., 1990. Labor heterogeneity, wage bargaining, and agglomeration economies. *Journal of Urban Economics* 28, 160-177.
- [34] Kim, S., 1991. Heterogeneity of the labor market and city size in an open spatial economy. *Regional Science and Urban Economics* 21, 109-126.
- [35] Layard, R., Nickell, S., Jackman, R., 1991. *Unemployment. Macroeconomic Performance and the Labor Market*, Oxford University Press, Oxford.
- [36] Madden, J.F., 1985. Urban wage gradients: Empirical evidence. *Journal of Urban Economics* 18, 291-301.
- [37] Manning, A., 2003. The real thin theory: Monopsony in modern labour markets. *Labour Economics* 10, 105-131.
- [38] Mortensen, D.T., Pissarides, C.A., 1999. New developments in models of search in the labor market. In: Card, D., Ashenfelter, O. (Eds.), *Handbook of Labor Economics*, Vol. 3, Elsevier Science, Amsterdam, pp. 2567-2627.
- [39] Owen, D., Green, A.E., 2000. Estimating commuting flows for minority groups in England and Wales. *Journal of Ethnic and Migration Studies* 26, 581-608.
- [40] Patacchini, E., Zenou, Y., 2005. Spatial mismatch, transport mode and search decisions in England. *Journal of Urban Economics* 58, 62-90.

- [41] Patacchini, E., Zenou, Y., 2006. Search activities, cost of living and local labor markets. *Regional Science and Urban Economics* 36, 227-248.
- [42] Pissarides, C.A., 2000. *Equilibrium Unemployment Theory*, Second edition, MIT Press, Cambridge, MA.
- [43] Pugh, M., 1998. Barriers to work: The spatial divide between jobs and welfare recipients in Metropolitan Areas. Discussion Paper 8/98, The Brookings Institution, Center on Urban and Metropolitan Policy.
- [44] Raphael, S., Rice, L., 2002. Car ownership, employment, and earnings. *Journal of Urban Economics* 52, 109-130.
- [45] Raphael, S., Stoll, M.A., 2001. Can boosting minority car-ownership rates narrow inter-racial employment gaps? *Brookings-Wharton Papers on Urban Economic Affairs* 2, 99-145.
- [46] Rogers, C.L., 1997. Job search and unemployment duration: Implications for the spatial mismatch hypothesis. *Journal of Urban Economics* 42, 109-132.
- [47] Rouwendal, J., Van Ommeren, J., 2007. Recruitment in a monopsonistic labour market: Will travel costs be reimbursed? Tinbergen Institute Discussion Paper No. 07-044/3.
- [48] Rogerson, R., R. Shimer, Wright, R., 2005. Search theoretic models of the labor market: A survey. *Journal of Economic Literature* 43, 959-988.
- [49] Salop, S., 1979. Monopolistic competition with outside goods. *Bell Journal of Economics* 10, 141-156.
- [50] Sanchez, T.W., 1998. Equity analysis of personal transportation system benefits. *Journal of Urban Affairs* 20, 69-86.
- [51] Sanchez, T.W., 1999. The connection between public transit and employment. The cases of Portland and Atlanta. *Journal of the American Planning Association* 65, 284-296.
- [52] Sato, Y., 2001. Labor heterogeneity in an urban labor market. *Journal of Urban Economics* 50, 313-337.
- [53] Sato, Y., 2004. City structure, search, and workers' job acceptance behavior. *Journal of Urban Economics* 55, 350-370.

- [54] Selod, H., Zenou, Y., 2006. City-structure, job search, and labour discrimination. Theory and policy implications. *Economic Journal* 116, 1057-1087.
- [55] Smith, T.E., Zenou, Y., 1997. Dual labor markets, urban unemployment and multicentric cities. *Journal of Economic Theory* 76, 185-214.
- [56] Smith, T.E., Zenou, Y., 2003a. Spatial mismatch, search effort and urban spatial structure. *Journal of Urban Economics* 54, 129-156.
- [57] Smith, T.E., Zenou, Y., 2003b. Spatial mismatch, search effort and urban spatial structure. CEPR Discussion Paper No. 3731.
- [58] Stoll, M., 1999. Spatial job search, spatial mismatch, and the employment and wages of racial and ethnic groups in Los Angeles. *Journal of Urban Economics* 46, 129-55.
- [59] Stoll, M., Raphael, S., 2000. Racial differences in spatial job search patterns: Exploring the causes and consequences. *Economic Geography* 76, 201-223.
- [60] Taylor, B.D., Ong, P.M., 1995. Spatial mismatch or automobile mismatch? An examination of race, residence and commuting in US metropolitan areas. *Urban Studies* 32, 1453-1473.
- [61] Teulings, C.N., Gautier, P.A., 2009. Search and the city. *Regional Science and Urban Economics*. Forthcoming.
- [62] Topa, G., 2001. Social interactions, local spillovers and unemployment. *Review of Economic Studies* 68, 261-295.
- [63] Topel, R.H., 1986. Local labor markets. *Journal of Political Economy* 94, S111-S143.
- [64] Turner, S., 1997. Barriers to a better break: Employer discrimination and spatial mismatch in metropolitan Detroit. *Journal of Urban Affairs* 19, 123-141.
- [65] Van Ommeren, J., van der Vlist, A., Nijkamp, P., 2006. Transport-related fringe benefits: Implications for moving and the journey to work. *Journal of Regional Science* 46, 493-506.
- [66] Wasmer, E., Zenou, Y., 2002. Does city structure affect job search and welfare? *Journal of Urban Economics* 51, 515-541.

- [67] Wasmer, E., Zenou, Y., 2006. Equilibrium search unemployment with explicit spatial frictions. *Labour Economics* 13, 143-165.
- [68] Wheeler, C.H., 2001. Search, sorting, and urban agglomeration. *Journal of Labor Economics* 19, 879-899.
- [69] White, M.J., 1999. Urban areas with decentralized employment: Theory and empirical work. In: Cheshire, P., Mills, E.S. (Eds.), *Handbook of Regional and Urban Economics*, Vol. 3, Elsevier Science, Amsterdam, pp.1375-1412.
- [70] Yashiv, E., 2007. Labor search and matching in macroeconomics. *European Economic Review* 51, 1859-1895.
- [71] Zax, J.S., 1991. Compensation for commutes in labor and housing markets. *Journal of Urban Economics* 30, 192-207.
- [72] Zenou, Y., 2000. Urban unemployment, agglomeration and transportation policies. *Journal of Public Economics* 77, 97-133.
- [73] Zenou, Y., 2006. Urban labor economic theory. In: Arnott, R., McMillen, D. (Eds.), *A Companion to Urban Economics*. Blackwell Publishing, Boston, pp. 418-439.
- [74] Zenou, Y., 2009a. *Urban Labor Economics*, Cambridge University Press, Cambridge.
- [75] Zenou, Y., 2009b. High-relocation costs in search-matching models: Theory and application to spatial mismatch. Unpublished manuscript, Stockholm University.
- [76] Zenou, Y., 2009c. Endogenous job destruction and job matching in cities. *Journal of Urban Economics*. Forthcoming.

Figure 1. Optimal Search Intensity

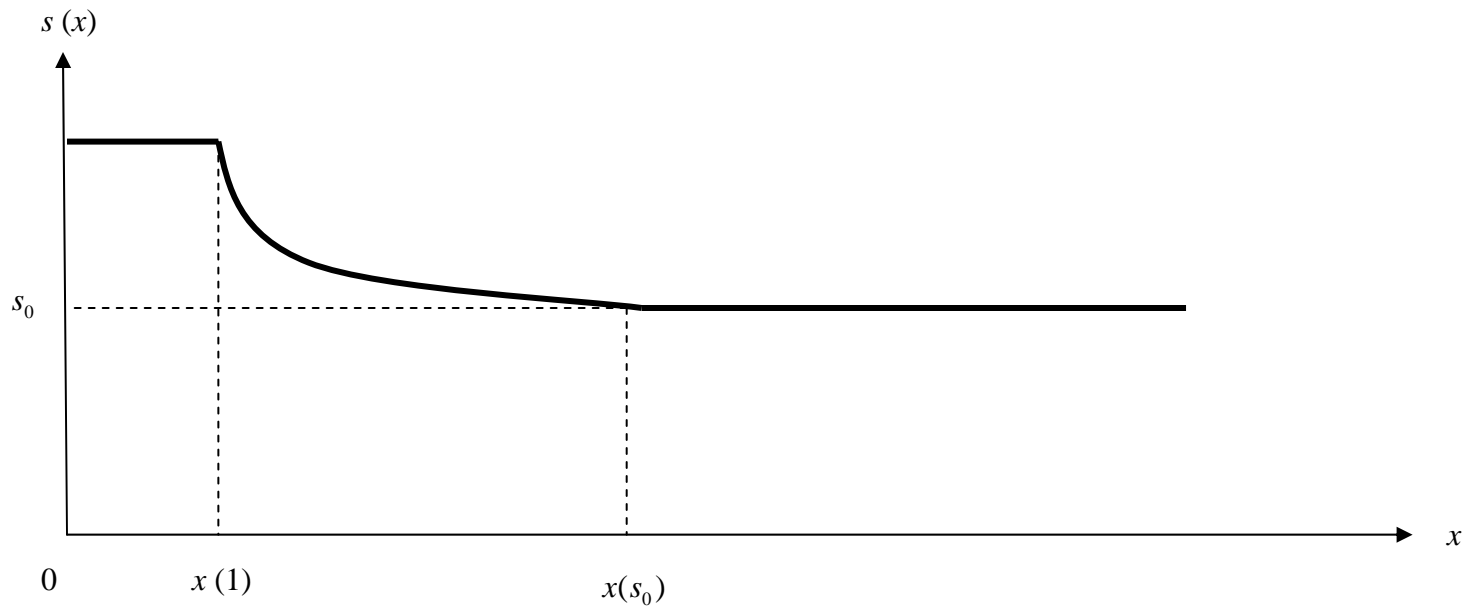


Figure 2. Urban Equilibrium 3: The Core-Periphery Equilibrium

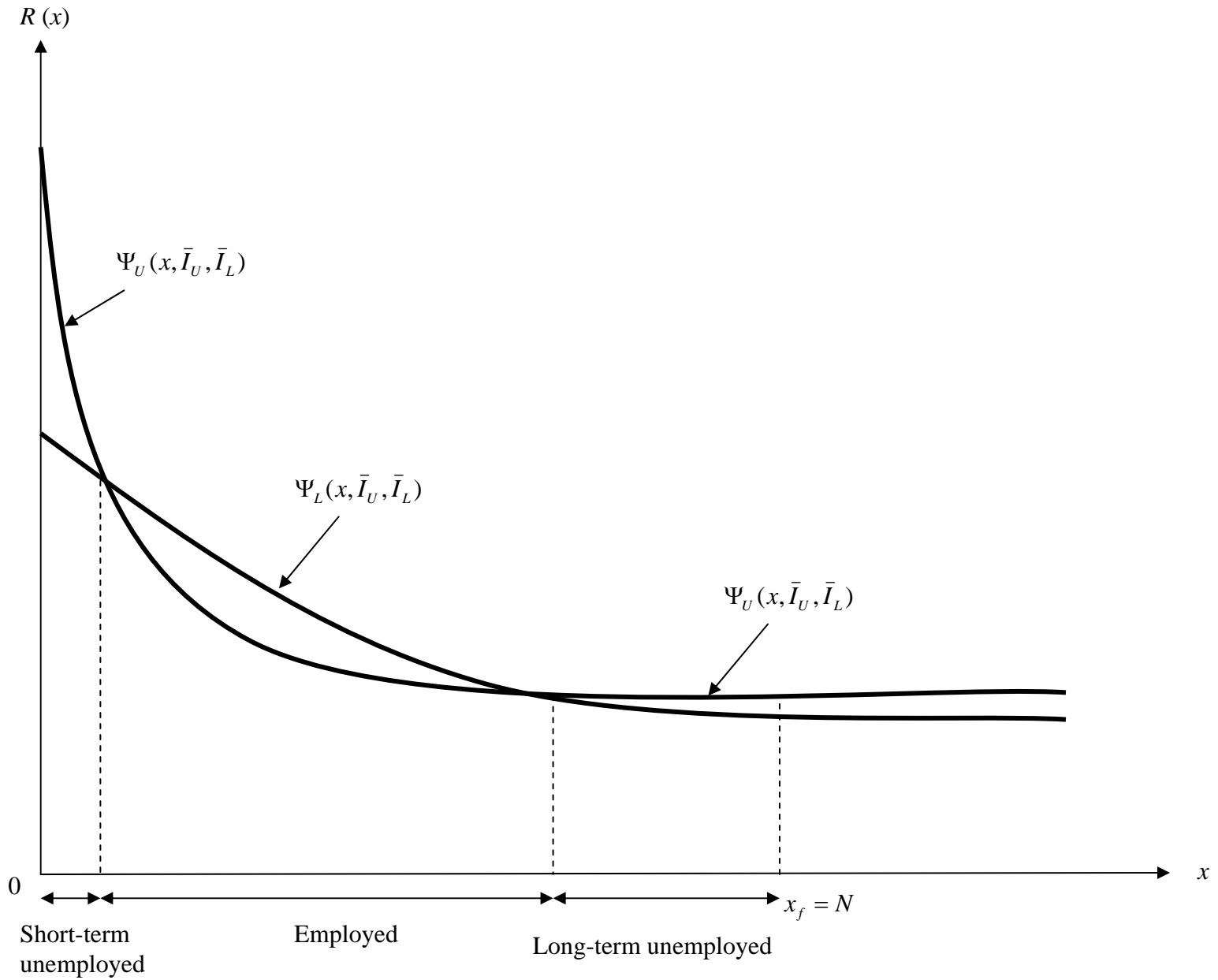


Figure 3. Urban Equilibrium 1: The Integrated City

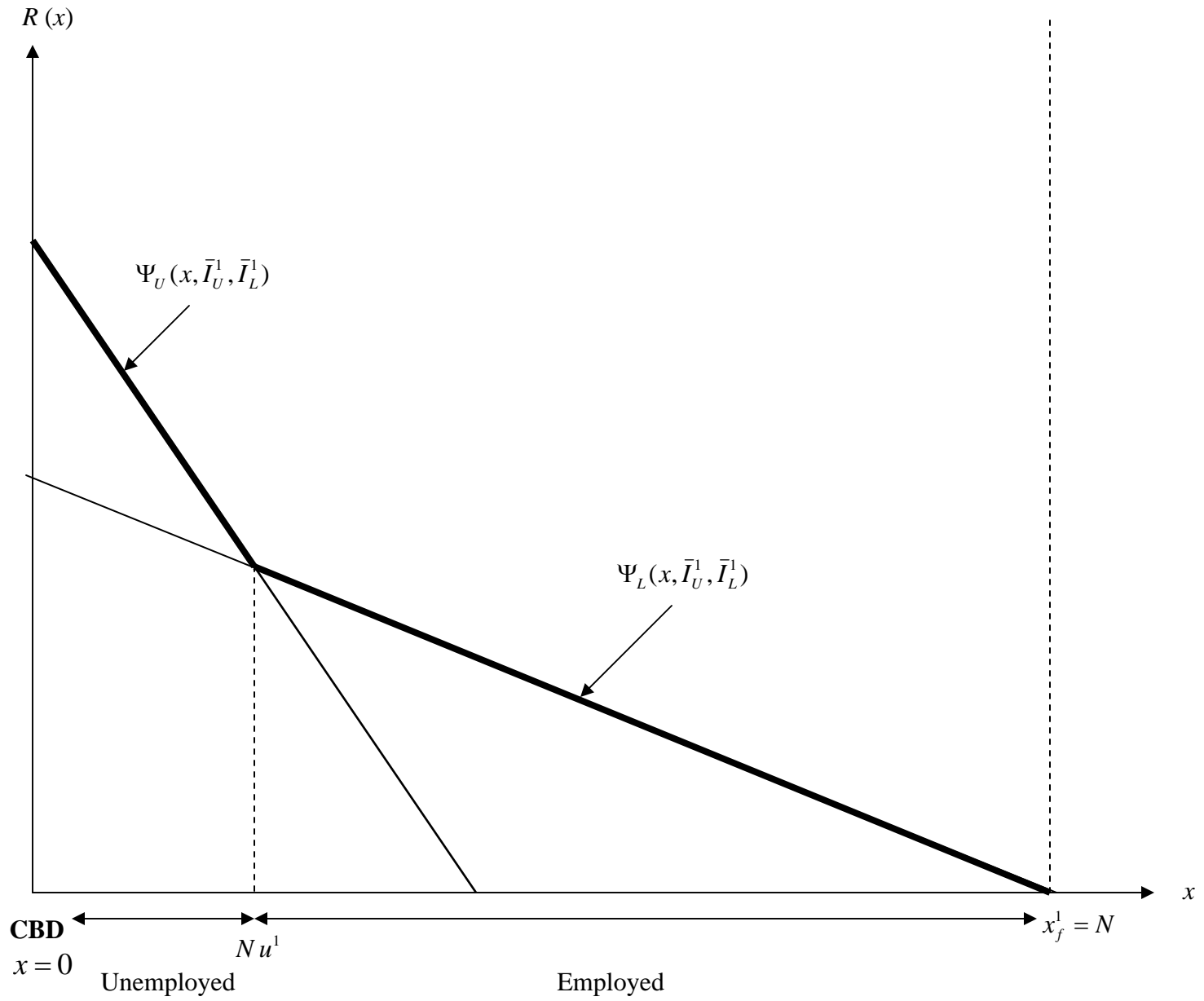


Figure 4. Urban Equilibrium 2: The Segregated City

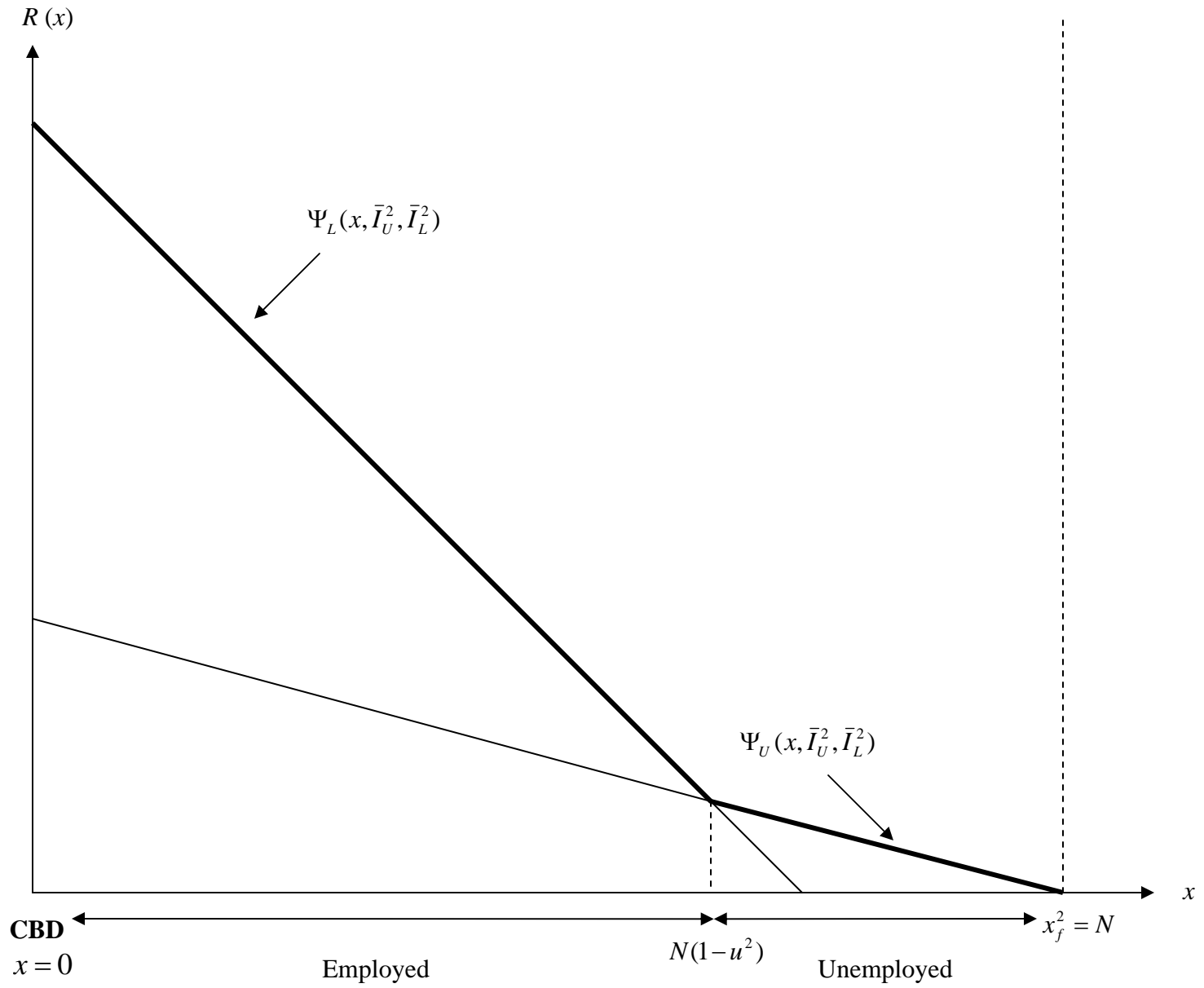


Figure 5a. Impact of labor-market variables
on the growth of cities

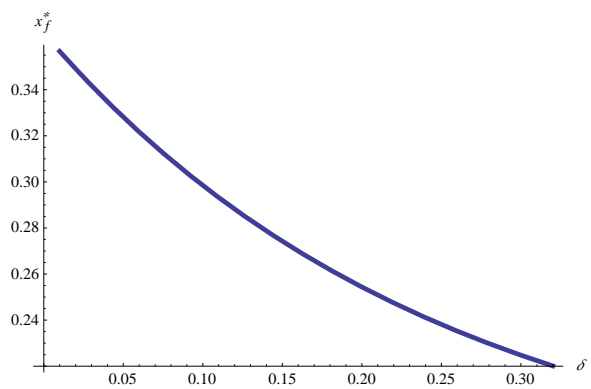
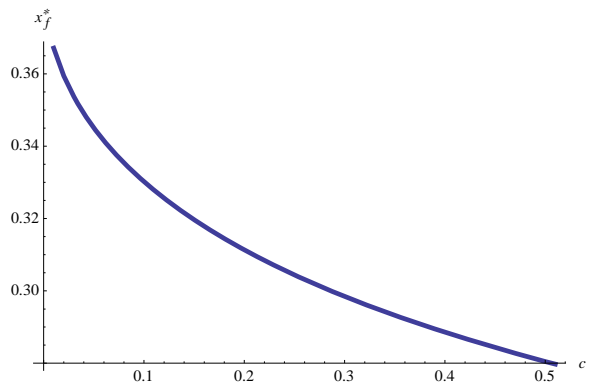
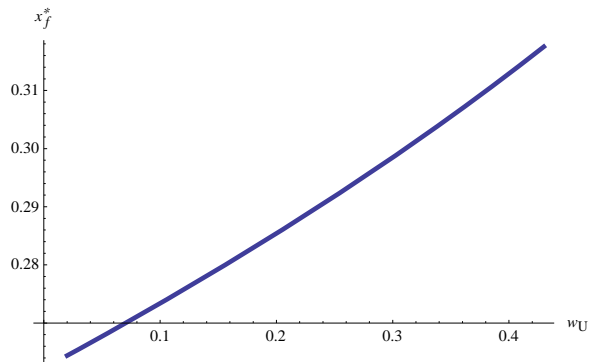


Figure 5b. Impact of search intensity and commuting costs on the growth of cities

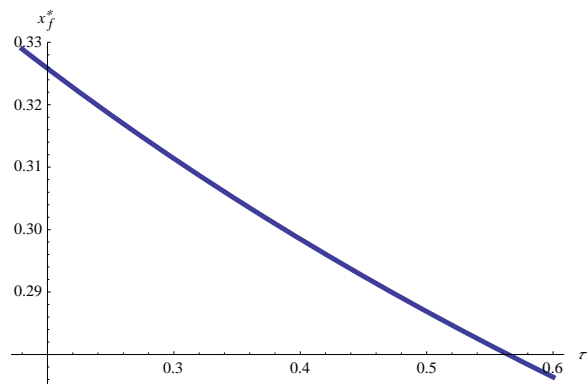
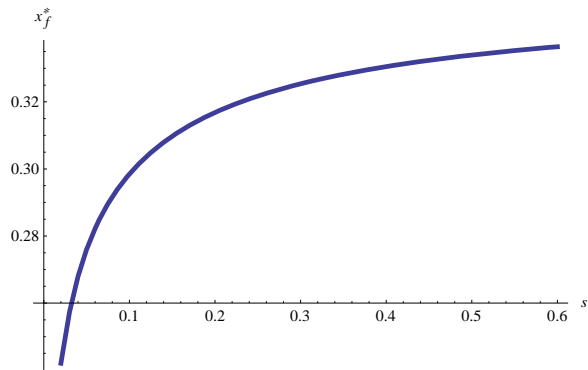


Figure 6. Urban equilibrium 2 with mobility costs

