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ABSTRACT

Search in Cities*

We develop different spatial search models in which a land market is embedded into a standard search matching framework. The link between the land and the labour market is realized through the average search intensity of unemployed workers. We first develop a simple model where search intensity is exogenous. Because of this assumption, only one urban pattern emerges in which the employed reside close to jobs and the unemployed at the periphery of the city. We then extend this benchmark model by assuming that workers' search intensity negatively depends on their residential distance to jobs. This leads to two urban-land use patterns where the unemployed workers either reside close to or far away from jobs. Finally, we consider the case where the unemployed workers endogenously choose their search intensity and we show that they search less, the further away they reside from jobs. Apart from the two previous urban patterns, there is a third equilibrium that emerges, which has a core-periphery structure. In each model, we explore the labour market outcomes (job creation, unemployment and wages) of the different urban land use patterns.

JEL Classification: D83, J15, J41 and R14
Keywords: job search, search intensity, spatial mismatch and urban land use

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1 Introduction

There is a vast literature on search and matching theory that emphasizes the importance of flows in the labor markets (Mortensen and Pissarides, 1999, Pissarides, 2000). These models, now widely used in labor economics and macroeconomics, have highly enriched research on unemployment as an equilibrium phenomenon, on labor market dynamics and cyclical adjustment. The starting point of the analysis is to recognize that labor markets are characterized by search frictions. This means that it takes time for workers to find a job and for firms to fill up a vacancy so that unemployed workers and vacant jobs can coexist in equilibrium, a feature not possible in a standard Walrasian world (i.e. a frictionless world in which workers and firms can move costlessly and instantaneously between working and non-working). Because of these search frictions, the contacts between workers and firms depend on the market variables and the arrival rate of contacts for workers increases with the number of unemployed searchers while the arrival rate of contacts for firms increases with the number of vacant firms. A constant-return to scale function is a convenient way of capturing these properties, which is referred to as the "matching function" (Pissarides, 1979). Indeed, the matching function relates job creation to the number of unemployed, the number of job vacancies and the intensities with which workers search and firms recruit. It successfully captures the key implications of frictions that prevent an instantaneous encounter of trading partners.

However, in all these models the spatial dimension is absent. It is commonly observed in OECD countries that unemployment is unevenly distributed among cities. The incidence of unemployment varies between the regions of a country (Isserman et al., 1986, Gordon, 1987, Blanchflower and Oswald, 1994), between cities of different sizes and functions (Marston, 1985), between the inner and outer areas of cities and between the urban and rural areas. There are also stark spatial differences in incomes. For example, in the United States, the median income of central city residents is 40 percent lower than that of suburban residents.

The spatial concentration of unemployment and poverty make the workings of urban labor markets a vital concern of urban residents. Despite this, very few theoretical attempts have been made to better understand the working of the urban labor market and, in particular, urban unemployment and its spatial differences. Indeed, labor economists and macroeconomists traditionally do not incorporate space directly into their studies (see e.g. Layard et al., 1991; Pissarides, 2000; Cahuc and Zylberberg, 2004), even though there are some well-known empirical studies of local labor markets (see e.g. Holzer, 1989; Eberts and Stone, 1992). Similarly, in urban economics, despite numerous empirical studies, the theory of urban labor economics has been relatively neglected. In most advanced urban textbooks (see, in particular, Fujita, 1989; Fujita et al. 1999; Fujita and Thisse, 2002), it is mainly assumed throughout perfect competition in the labor market and the issue of urban unemployment is not even discussed.

The aim of this paper is to explicitly deal with the urban aspects of search-matching models. I will develop different spatial search models by introducing a land market in a standard search matching model. The link between the land and the labor market is realized through the average search intensity of unemployed workers. Indeed, the latter depends on the location of the 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. In order to understand the way the two markets operate, we first develop a simple model where search intensity is exogenous (section 2). Because of this assumption, only one urban pattern emerges in which the employed reside close to jobs and the unemployed at the periphery of the city. In section 3, we extend this benchmark model by assuming that workers' search intensity negatively depends on their residential distance to jobs. This leads to two urban-land use patterns where the unemployed workers either reside close to or far away from jobs. In section 4, unemployed workers endogenously choose their search intensity and we show that they search less, the further away they reside from jobs. Apart of the two previous urban patterns, there is a third urban equilibrium that emerges: the core-periphery equilibrium where the unemployed workers reside both close to (short-run unemployed workers) and far away (long-run unemployed workers) from jobs while the employed workers live in between them. In each model we explore the labor market consequences (job creation, unemployment and wages) of the urban land use pattern. Finally, in section 5, we discuss some extensions while in section 6 we show how these spatial search models can give some microfoundations to a well-known empirical observation: the spatial mismatch for minority workers between their residence and their workplace.

It has to be observed that this survey on spatial search is quite selective. In particular, we do not deal with the issue of migration between regions and search behaviors where the city is taken as a point in space and the focus is on *inter*-city equilibrium. Here we will investigate what happens within a city and thus focus on *intra*-urban equilibrium. Also, we do not present papers where the urban-land market is not explicitly modelled and where the search process of firms and the resulting matching between workers and firms are not explicitly taken into account. Finally, in order to facilitate the reading, we use the same model and the same notations throughout the paper.

2 The benchmark model

There is a continuum of ex ante identical workers whose mass is N and a continuum of M identical firms. Among the N workers, there are L employed and U unemployed so that $N = L + U$. The workers are uniformly distributed along a *linear*, *closed* and *monocentric* city. Their density at each location is taken to be 1. 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 be infinitely lived, risk neutral and decide their optimal place of residence between the CBD and the city fringe. There are *no relocation costs*, either in terms of time or money.

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 τ per unit of distance. When living at a distance x from the CBD, he/she also pays a land rent $R(x)$, consumes $h_L = 1$ unity 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 (that will be determined at the labor market equilibrium).[1] The budget constraint of an employed worker is thus given by:

$$R(x) + \tau\, x + z_L = w_L \tag{1}$$

Because of risk neutrality, we assume that preferences of all workers (including the unemployed) are given by $\Omega(z_L) = z_L$ so that the *instantaneous* (indirect) utility of an employed worker located at a distance x from the CBD is equal to:

$$W_L(x) = w_L - \tau\, x - R(x) \tag{2}$$

Concerning the unemployed, they commute less often to the CBD since they mainly go there to search for jobs. So, we assume that they incur a commuting cost $s\,\tau$ per unit of distance, where $0 < s \leq 1$ is a measure of search intensity or search efficiency; s is assumed to be exogenous. For example $s = 1$ would mean that the unemployed workers go everyday to the CBD (as often as the employed workers) to search for jobs. Observe that here we assume that unemployed workers need to go to the CBD to obtain information about jobs, that is why they commute there. If for example $s = 0$, which we exclude here, then they would never find a job. We would discuss alternative ways of gathering information about jobs below.

[1] The subscript L refers to the employed whereas the subscript U refers to the unemployed.

As a result, the *instantaneous* (indirect) utility of an unemployed worker residing at a distance x from the CBD is equal to:

$$W_U(x) = w_U - s\,\tau\,x - R(x) \tag{3}$$

Let us describe the labor market. A firm is a unit of production that can either be filled by a worker whose production is y units of output or be unfilled and thus unproductive. In order to find a worker, a firm posts a vacancy. A vacancy 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 that there is a number of contacts per unit of time between the two sides of the market that are determined by the following matching function:[2]

$$M(\overline{s}U, V)$$

where $\overline{s}$ is the average search efficiency of the unemployed workers, U and V the total number of unemployed and vacancies respectively. In this simple model, it is assumed that $s = \overline{s}$, so each worker provides the same search effort.[3] As in the standard search-matching model (see e.g. Mortensen and Pissarides, 1999, and Pissarides, 2000), we assume that $M(.)$ is increasing both in its arguments, concave and homogeneous of degree 1 (or equivalently has constant return to scale). Thus, the rate at which vacancies are filled is $M(sU, V)/V$. By constant return to scale, it can be rewritten as

$$M(1/\theta, 1) \equiv q(\theta)$$

where $\theta = V/(sU)$ is a measure of *labor market tightness* in efficiency units and $q(\theta)$ is a Poisson intensity. By using the properties of $M(.)$, it is easily verified that $q'(\theta) \leq 0$: the higher the labor market tightness, the lower the rate at which firm fill their vacancy. Similarly, the rate at which an unemployed worker with search intensity s leaves unemployment is

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

Again, by using the properties of $M(.)$, it is easily verified that $[\theta q(\theta)]' \geq 0$: the higher the labor market tightness, the higher the rate at which workers leave unemployment since there are relatively more jobs than unemployed workers. So here the higher the search intensity s

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

[3]The search intensity s will be endogeneized below.

(unemployed search more actively for jobs), the higher is this rate $s\theta q(\theta)$. Finally, the rate at which jobs are destroyed is exogenous and denoted by δ.

If, in this model, there are no frictions, then unemployment and vacancies disappear, and jobs are found and filled instantaneously. Indeed,

$$\lim_{\theta\to 0}\left[\theta q\left(\theta\right)\right]=\lim_{\theta\to +\infty} q\left(\theta\right)=0 \tag{4}$$

and

$$\lim_{\theta\to +\infty}\left[\theta q\left(\theta\right)\right]=\lim_{\theta\to 0} q\left(\theta\right)=+\infty \tag{5}$$

That is, if $\theta\to 0$, then the number of unemployed is infinite and thus firms filled their job instantaneously (no frictions on the firm's side), whereas if $\theta\to 0$, then the number of vacancies is infinite and thus workers find a job instantaneously (no frictions on the worker's side).

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

2.1 Urban land use equilibrium

Since there are no relocation costs, the urban equilibrium is such that, independently of their location x, all the employed workers enjoy the same level of utility W_L while all the unemployed workers obtain W_U. Bid rents[4] are respectively given by:

$$\Psi_L(x,W_L)=w_L-\tau\,x-W_L \tag{6}$$

$$\Psi_U(x,W_U)=w_U-s\,\tau\,x-W_U \tag{7}$$

They are both linear and decreasing in x. We have the following straightforward result:

Proposition 1 *With workers' risk neutrality, fixed housing consumption and fixed search intensity, the employed reside close to jobs whereas the unemployed live at the periphery of the city.*

[4]The 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 in order to achieve a utility level. See Fujita (1989) for a formal definition.

Let us now define the urban-land use equilibrium. We denote the agricultural land rent (the rent outside the city or opportunity rent) by R_A and, without loss of generality, we normalize it to zero. We have:

Definition 1 *An urban-land use equilibrium with no relocation costs, fixed-housing consumption and fixed search intensity is a 5-tuple* $(W_L^*, W_U^*, x_b^*, x_f^*, R^*(x))$ *such that:*

$$\Psi_L(x_b^*, W_L^*) = \Psi_U(x_b^*, W_U^*) \tag{8}$$

$$\Psi_U(x_f^*, W_U^*) = R_A = 0 \tag{9}$$

$$\int_0^{x_b^*} \frac{1}{h_L} dx = L \tag{10}$$

$$\int_{x_b^*}^{x_f^*} \frac{1}{h_U} dx = N - L \tag{11}$$

$$R^*(x) = \max\left\{\Psi_L(x, W_L^*), \Psi_U(x, W_U^*), 0\right\} \quad \textit{at each } x \in (0, x_f] \tag{12}$$

Equations (8) and (9) reflect equilibrium conditions in the land market. Equation (8) says that, in the land market, at the frontier x_b^*, the bid rent offered by the employed is equal to the bid rent offered by the unemployed. Equation (9), in turn, says that the bid rent of the unemployed must be equal to the agricultural land at the city fringe. Equations (10) and (11) give the two population constraints. Finally, equation (12) defines the equilibrium land rent as the upper envelope of the equilibrium bid rent curves of all workers' types and the agricultural rent line. Since all N workers must consume 1 unit of housing each, and since there will be no vacant land inside the city in equilibrium, the distance from the CBD to the urban fringe must be given by $x_f^* = N$ and the border by $x_b^* = L$. As a result, the employed reside between 0 and L whereas the unemployed reside between L and N. Furthermore, for this equilibrium to exist (see e.g. Fujita, 1989), it has to be that the equilibrium land rent is everywhere continuous in the city.

By solving (8) and (9), we easily obtain the equilibrium values of the instantaneous utilities of the employed and the unemployed. They are given by:

$$\begin{aligned} W_L^* &= w_L - \tau\, x_b^* - s\tau \left(x_f^* - x_b^*\right) \\ &= w_L - \tau\, L - s\tau\, (N - L) \end{aligned}$$

$$W_U^* = w_U - s\tau\, x_f^* = w_U - s\,\tau\, N \tag{13}$$

The employment zone (i.e. the residential zone for the employed workers) is thus $(0, L]$ and the unemployment zone (i.e. the residential zone for the unemployed workers) is thus $[L, N]$. By plugging (13) and (13) into (8) and (9), we easily obtain the land rent equilibrium $R(x)$. It is given by:

$$R^*(x) = \begin{cases} \tau\ (L - x) + s\tau\ (N - L) & \text{for} \quad 0 \leq x \leq L \\ s\,\tau\ (N - x) & \text{for} \quad L < x \leq N \\ 0 & \text{for} \quad x > N \end{cases} \tag{14}$$

2.2 Steady-state equilibrium

We are now able to solve the labor market equilibrium and thus the steady-state equilibrium. The unemployment rate is defined by $u = U/N$. We have:

Definition 2 *A (steady-state) labor market equilibrium* (w_L^*, θ^*, u^*) *is 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 steady-state condition, a free-entry condition for firms and a wage-setting mechanism.*

In steady-state, the Bellman equations for the employed and unemployed are respectively given by:

$$rI_L = w_L - \tau\, L - s\tau\ (N - L) - \delta\, [I_L - I_U(s)] \tag{15}$$

$$rI_U(s) = w_U - s\,\tau\, N + s\theta q(\theta)\, [I_L - I_U(s)] \tag{16}$$

where r is the exogenous discount rate, and I_L and I_U denote the expected lifetime utility of an employed worker and a job seeker, respectively. The first equation that determines I_L states that an employed worker obtains today $W_L^* = w_L - \tau\, L - s\tau\ (N - L)$ but can loose his/her job with a probability δ and then obtains a negative surplus of $I_U(s) - I_L$. For the job seeker, $I_U(s)$ states that he/she obtains $W_U^* = w_U - s\,\tau\, N$ today but may find a job at rate $s\theta q(\theta)$, and then have a surplus equals to $I_L - I_U(s)$.

Let us denote respectively by I_F and I_V the intertemporal profit of a job and of a vacancy. If c is the search cost for the firm per unit of time and y is the product of a match, then, at the steady-state, I_F and I_V can be written as:

$$rI_F = y - w_L - \delta(I_F - I_V) \tag{17}$$

$$rI_V = -c + q(\theta)(I_F - I_V) \tag{18}$$

We assume that firms post vacancies up to a point where:

$$I_V = 0 \tag{19}$$

which is a free entry condition. From (19) and using (18), the value of a job is now equal to:

$$I_F = \frac{c}{q(\theta)} \tag{20}$$

Finally, plugging (20) into (17) and using (19), we obtain the following decreasing relation between labor market tightness and wages in equilibrium:

$$\frac{c}{q(\theta)} = \frac{y - w_L}{r + \delta} \tag{21}$$

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 search for the firm. So, firms' job creation is endogenous and is determined by (21).

Let us now determine the wage. 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, $I_L - I_U(s)$, and the surplus of the firms, $I_F - I_V$. As a result, at each period, the wage is determined by:

$$w_L = \arg\max_{w_L} (I_L - I_U(s))^{\beta}(I_F - I_V)^{1-\beta}$$

where $0 \leq \beta \leq 1$ is the bargaining power of workers. By solving this program, we obtain:

$$w_L = (1-\beta)\left[w_U + (1-s)\,\tau L\right] + \beta\,(y + cs\theta) \tag{22}$$

In search-matching models, the wage-setting curve WS (a relation between wages and the state of the labor market, here θ) replaces the traditional labor-supply curve. It is here given by (22). Let us interpret this equation. The first part $(1-\beta)\left[w_U + (1-s)\,\tau L\right]$, is what firms must pay to induce workers to accept the job offer: firms must exactly compensate the transportation cost difference (between the employed and the unemployed) of the employed worker who is the furthest away from the CBD, i.e. located at $x = x_b = L$. This is referred to as the 'compensation effect'. The second part $\beta\,(y + cs\theta)$ is the bargaining effect where workers obtain a part of the surplus. This is referred to as the 'outside option effect'. The first effect is a pure spatial cost since $(1-s)\,\tau L$ represents the space cost differential between employed and unemployed workers paying the same bid rent whereas the second effect is a mixed labor-spatial cost one. Furthermore, observe that θ has a positive impact on w_L, implying in particular that unemployment negatively affects wages. Finally, it is interesting to note that the search intensity s has an ambiguous effect on wages. On the one hand, when s increases, unemployed workers go more often to the CBD, so the difference in commuting costs between the employed and the unemployed is lower and thus firms need to compensate less the employed workers; thus wages decrease. On the other hand, when s increases, unemployed workers find jobs at a higher rate and their outside and wages increase.

Let us close the model. Since each job is destroyed according to a Poisson process with arrival rate δ, the number of workers who enter unemployment is $\delta(1-u)$ and the number who leave unemployment is $\theta q(\theta) s\, u$. The evolution of the unemployment rate is thus given by the difference between these two flows,

$$\dot{u} = \delta(1-u) - \theta q(\theta) s\, u \tag{23}$$

where $\dot{u}$ is the variation of unemployment with respect to time. In steady state, the rate of unemployment is constant and therefore these two flows are equal. We thus have:[5]

$$u^* = \frac{\delta}{\delta + s\theta q(\theta)} \tag{24}$$

It is easy to verify that $\frac{\partial u^*}{\partial \theta} < 0$. Indeed, a higher labor market tightness implies that workers leave unemployment at a faster rate and thus unemployment has to decrease for (24) to hold. Furthermore, by using (4) and (5), we easily obtain that:

$$\lim_{\theta \to 0} u^* = 1 \text{ and } \lim_{\theta \to +\infty} u^* = 0$$

When there are no frictions for workers, then nobody is unemployed ($u^* = 0$) while all workers have to be unemployed ($u^* = 1$) for firms to have no frictions. Now, by combining (21) and (22) and by observing that $L^* = N(1-u^*)$, the market solution that defines the equilibrium θ^* is given by:

$$y - w_U = \frac{c}{q(\theta^*)}\left[\frac{r + \delta + \beta s\theta^* q(\theta^*)}{1-\beta}\right] + (1-s)\,\tau N\,(1-u) \tag{25}$$

[5]Using (23), it is easy to show that:

$$\lim_{t \to +\infty} u_t = u^*$$

Thus, the steady-state u^* is a stable equilibrium.

2.3 Interaction between land and labor markets

By plugging the wage w_L, defined by (22), into (15), we have a steady-state equilibrium $R^*(x)$, I_L^*, $I_U^*(s)$, θ^*, u^* that is determined by five equations (14), (15), (16), (25), (24).

The key variable is θ^*, which appears everywhere. Compared to the standard job-matching model with no space (Pissarides, 2000, chap. 1), apart from the land market, the main difference resides in equation (25) and thus in the determination of the equilibrium job creation rate θ^*. Indeed, there is here one more term, $(1-s)\,\tau N\,(1-u^*)$, which comes from the wage equation (22) and corresponds to the spatial compensation that firms have to give to workers for them to accept a job. Interestingly, this term depends on an endogenous variable u^*, which here is a measure of distance to jobs since the worker who resides the furthest away from jobs is located at $L^* = N\,(1-u^*)$. This is why now the two equations (24) and (25) are linked together (this is not the case in Pissarides, 2000) and the comparative statics of θ^* will be affected. Indeed, by totally differentiating equation (25), we easily obtain:

$$\theta^* = \left(\underset{+}{y}, \underset{-}{w_U}, \underset{-}{c}, \underset{-}{r}, \underset{?}{\delta}, \underset{-}{\beta}, \underset{?}{s}, \underset{-}{\tau}, \underset{-}{N} \right) \tag{26}$$

where a question mark means that the sign is ambiguous. The effect of y, w_U, c and r are standard and can be found in Pissarides (2000). Indeed, an increase in productivity y or a decrease in unemployment benefit w_U, or in firms' search cost c, or in the discount rate r, or in workers' bargaining power β, leads to more job creation because more firms enter the labor market, anticipating higher expected profit. The new effects concern parameters that enter in the term $(1-s)\,\tau N\,(1-u^*)$. Take for example the job destruction rate δ. There are now two opposite effects, so the net effect on θ^* is ambiguous. Indeed, when δ increases, unemployment increases, which leads to higher job creation since firms need to compensate less workers in terms of wages ($(1-s)\,\tau N\,(1-u)$ decreases); the worker who is the furthest away is now closer to jobs. However, when δ increases, jobs are destroyed at a faster rate, which implies that less firms enter in the labor market and thus there are less job created. In Pissarides (2000), because the term $(1-s)\,\tau N\,(1-u)$ is absent, only the last effect prevails and thus an increase in δ always reduces job creation.

Take now the spatial variables s and τ. For the commuting cost τ, it is quite easy to understand the intuition since it enters only in $(1-s)\,\tau N\,(1-u)$. So, when τ increases, the spatial compensation in terms of wages increases and thus less jobs are created. For the search intensity s, it is more subtle because s affects both the spatial compensation and the efficiency of the labor market (the higher s, the lower the unemployment rate). The next effect is ambiguous. Indeed, an increase in search intensity reduces the unemployment rate. This has two effects. On the one hand, it decreases the spatial compensation of the wage but, on the other, it gives a better outside option for employed workers who require higher wages. The net effect on wages and thus on job creation θ^* is thus ambiguous. Once again, in Pissarides (2000, chap. 5) where search intensity is introduced, only the second effect is present so that higher s implies higher wages and thus lower θ^*.

The interaction between land and labor markets is thus captured by the comparative statics exercise of θ^* since the distance to jobs of the last employed worker is affecting wages and thus job creation θ^*. To study further the interaction between the two markets, observe that θ^* also affects both the employment and unemployment zones, and, as a result, the land rent $R^*(x)$ in the employment zone. Indeed, when θ^* increases, less people are unemployed and thus the employment zone is augmented while the unemployment zone is reduced. As a result, bid rents and thus $R^*(x)$ for the employed workers increase at each $x \in [0, x_b]$. We can study the comparative statics of $R^*(x)$ in the employment zone. We obtain:

$$R^* = \left(\underset{+}{y}, \underset{-}{w_U}, \underset{-}{c}, \underset{-}{r}, \underset{?}{\delta}, \underset{-}{\beta}, \underset{?}{s}, \underset{?}{\tau}, \underset{?}{N} \right)$$

The effects of each parameter on $R^*(x)$ can be derived from those of θ^* (see (26)). Observe however that the spatial variables s, τ, N have now an ambiguous sign because they affect both directly and indirectly (through θ^*) bid rents.

2.4 Welfare and efficiency

Let us study the welfare of this economy. The social welfare function is given by the sum of the utilities of the employed and the unemployed, the production of the firms net of search costs and the land rents received by the (absentee) landlords. The wage w_L as well as the land rent $R(x)$, being pure transfers, are thus excluded in the social welfare function. The latter is therefore given by:

$$\mathcal{W} = \int_0^{+\infty} e^{-rt} \left\{ \int_0^L (y - \tau x) dx + \int_L^N (w_U - s\,\tau\,x) dx - c\,\theta\,s\,u \right\} dt \tag{27}$$

The social planner chooses θ and u that maximize (27) under the constraint (23). In this problem, the control variable is θ and the state variable is u. The solution to this problem is given by:

$$y - w_U = \frac{c}{q(\theta)} \left[\frac{r + \delta + s\theta q(\theta)\eta(\theta)}{1 - \eta(\theta)} \right] + (1 - s)\,\tau N\,(1 - u) \tag{28}$$

In order to see if the private and social solutions coincide, we compare (25) and (28). We have the following result.

Proposition 2 *In a spatial search-matching model with fixed search intensity, where the employed reside close to jobs and the unemployed far away from jobs, the market equilibrium is efficient if and only if:*

$$\eta(\theta) = \beta \tag{29}$$

Condition (29) is referred to as the Hosios-Pissarides condition and is exactly the same as in the standard matching model with no space (Pissarides, 2000, chap. 8, Hosios, 1990). Indeed, in this model, market failures are caused by search externalities. As it is well-known, the land market is efficient (Fujita, 1989). Let us explain the search externalities. We have seen that the job-acquisition rate is positively related to V and negatively related to U whereas the job-filling rate has exactly the opposite sign. So, for example, negative search externalities arise because of the congestion that firms and workers impose on each other during their search process. Therefore, two types of externalities must be considered: *negative intra-group externalities* (more searching workers reduces the job-acquisition rate) and *positive inter-group externalities* (more searching firms increases the job-acquisition rate). As stated above, 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 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 $\eta(\theta)$ the elasticity of the matching function with respect to unemployment. Of course, there is no reason for β to be equal to $\eta(\theta)$ since these two variables are not related at all and, therefore, the search-matching equilibrium is in general inefficient. However, when β is larger than $\eta(\theta)$, there is too much unemployment, creating congestion in the matching process for the unemployed. When β is lower, there is too little unemployment, creating congestion for firms.

In our present model, we have exactly the same externalities (intra- and inter-group externalities). The spatial dimension does not entail any inefficiency so this is why the Hosios-Pissarides condition still holds, i.e. $\beta = \eta(\theta)$.

3 Search effort as a function of distance to jobs

So far workers' search intensity was exogenous and independent of residential location. There are strong evidence showing that distance to jobs do impact on search behavior. Several empirical studies on job search have indeed shown that distance to jobs deteriorates the information one has on job opportunities, and that job accessibility is crucial to get a job (see for example Rogers, 1997, Ihlanfeldt, 1997, Turner, 1997, Stoll, 1999). For example, Ihlanfeldt (1997) showed that Atlanta's inner-city residents are less able to identify the location of suburban employment centers than suburbanites and thus, have less information on those jobs. Turner (1997) showed that, in Detroit's suburbs, firms that resort to local recruitment methods have very few inner-city black applicants.

Using the models developed by Wasmer and Zenou (2002, 2006), we would like now to endogeneize s by assuming that

$$s(x) = s_0 - s_a x \tag{30}$$

where $s_0 > 0$ and $s_a > 0$. In order for the search intensity to be always positive, we impose that $s_0 > s_a N$. The linearity assumption will be very useful in the urban land use analysis. So, with this formulation, when workers are further away from jobs, they search less intensively. Moreover, $\overline{s}$, the aggregate search efficiency in a city will now depend on the average location of the unemployed since it is given by

$$\overline{s} = s_0 - s_a \overline{x} \tag{31}$$

By doing so, we are integrating even more the land and the labor market because now one will need to solve both markets simultaneously to obtain outcomes.

Because the model gets quite complicated, we will slightly change the way s was viewed in the previous section. Indeed, in section 2, the search intensity s was affecting both the number of trips to the CBD unemployed workers make to gather information there and the job acquisition rate. This was mainly because, the only way workers were gathering information about jobs, was by going to the CBD. Here we make the other extreme assumption that unemployed workers do not need at all to go to the CBD to obtain information about jobs. They obtain information either locally through newspapers, local employment agencies, etc., or through firms' adds, and it is not costly. So, basically, when someone is searching more intensively it means here that he/she is more actively searching for jobs by reading more newspapers or checking more often the adds. In this context, (30) states that distance to jobs negatively affects workers' search intensity because, by living further away, it becomes more difficult to obtain information about jobs and this has a discouraging effect on search intensity. In section 4 below, we will consider a more general model where s is endogenous and affects both the number of trips to the CBD and the job acquisition rate. Observe that in the present model unemployed workers still need to go to the CBD for shopping.

3.1 Urban land use equilibrium

Contrary to section 2, we cannot use the instantaneous utilities to solve the urban-land use equilibrium. Indeed, now, when workers decide how much to bid for land, they have to take into account the future prospects in the labor market since their location will partly determines it. The job-acquisition rate of a worker residing at a distance x from the CBD is, as above, given by:

$$a(x) = s(x)\theta q(\theta) = (s_0 - s_a x)\,\theta q(\theta) \tag{32}$$

but now depends on a worker's residential location x and on the average location of the unemployed since θ depends on $\overline{s}$. So, let us write the Bellman equations for the employed and unemployed workers. By denoting by τ_L and τ_U the commuting cost of the employed and unemployed workers respectively,[6] these equations are respectively given by:

$$rI_L = w_L - \tau_L x - R(x) - \delta\,(I_L - I_U)$$

$$rI_U = w_U - \tau_U x - R(x) + a(x)\,(I_L - I_U)$$

where $\tau_U < \tau_L$ because the unemployed workers go to the CBD only to shop while the employed workers go there to shop and to work. As stated above, the search intensity only affects the job acquisition rate $a(x)$ and not the commuting cost of the unemployed. The main difference is that the value of $\overline{s}$ will depend on the average location of the unemployed $\overline{x}_U$ and thus on the prevailing urban equilibrium. Since there are no relocation costs, the urban equilibrium is such that all the employed enjoy the same level of utility $rI_L = r\overline{I}_L$ as well as the unemployed $rI_U = r\overline{I}_U$. Bid rents can thus be written as:

$$\Psi_L(x, \overline{I}_U, \overline{I}_L) = w_L - \tau_L x + \delta\overline{I}_U - (r+\delta)\overline{I}_L \tag{33}$$

$$\Psi_U(x, \overline{I}_U, \overline{I}_L) = w_U - \tau_U x + a(x)\overline{I}_L - [r + a(x)]\,\overline{I}_U \tag{34}$$

These bid rents are linear (because $s(x)$ is linear in x) and decreasing in x. However, contrary to section 2, no clear urban pattern emerges because workers are trading off commuting costs and access to jobs. We have the following result.

Proposition 3

[6] In the previous section, we had: $\tau_L = \tau$ and $\tau_U = s\tau$.

(i) If

$$\tau_L - \tau_U < w_U \theta^1 q(\theta^1)(\overline{I}_L^1 - \overline{I}_U^1) \tag{35}$$

we have Equilibrium 1 in which the unemployed live close to jobs.

(ii) If

$$\tau_L - \tau_U > w_U \theta^2 q(\theta^2)(\overline{I}_L^2 - \overline{I}_U^2) \tag{36}$$

Equilibrium 2 prevails and the employed live close to jobs.

The unemployed workers would like to live close to jobs both because of their commuting costs and their unemployment duration (which is the inverse of $a(x)$). For the employed workers, it is only their commuting costs that drive their choice. Equation (35) states that if the differential in commuting costs per unit of distance between the employed and the unemployed is lower than the marginal expected return of search for the unemployed, then the unemployed workers bid away the employed workers and occupy the center of the city. If on the contrary (36) holds, then the employed live close to jobs while the unemployed workers reside at the outskirts of the city. Observe that these conditions depend on the endogenous variable θ that will be determined at the labor market equilibrium. So, at this stage, we do not know if both of them hold.

Given that conditions (35) and (36) hold, we have the following definitions:

Definition 3 *An urban land use equilibrium $k = 1, 2$ with no relocation costs, fixed-housing consumption and endogenous search intensity is a 5-tuple $(I_L^{k*}, I_U^{k*}, x_b^{k*}, x_f^{k*}, R^{k*}(x))$ such that:*

$$x_b^{1*} = N\, u^1 \qquad or \qquad x_b^{2*} = N\left(1 - u^2\right) \tag{37}$$

$$x_f^{k*} = N \qquad k = 1, 2 \tag{38}$$

$$\Psi_U(x_b^{k*}, \overline{I}_U^{k*}, \overline{I}_L^{k*}) = \Psi_L(x_b^k, \overline{I}_U^{k*}, \overline{I}_L^{k*}) \qquad k = 1, 2 \tag{39}$$

$$\Psi_L(x_f^1, \overline{I}_U^{1*}, \overline{I}_L^{1*}) = 0 \qquad or \qquad \Psi_U(x_f^2, \overline{I}_U^{2*}, \overline{I}_L^{2*}) = 0 \tag{40}$$

$$R^{k*}(x) = \max\left\{\Psi_L(x, \overline{I}_U^{k*}, \overline{I}_L^{k*}), \Psi_U(x, \overline{I}_U^{k*}, \overline{I}_L^{k*}), 0\right\} \quad at\ each\ x \in \left(0, x_f^k\right] \tag{41}$$

These two equilibria are illustrated in Figures 1 and 2.[7] The average search intensity in equilibrium k is equal to:

$$\overline{s}^k = s_0 - s_a \,\overline{x}^k \qquad k = 1, 2 \tag{42}$$

where $\overline{x}^k$ is the average location of the unemployed in equilibrium k. It is easy to verify that $\overline{x}^1 = N\, u^1/2$ and $\overline{x}^2 = N\,(1 - u^2/2)$. Since $\overline{x}_1^1 < \overline{x}^2$ (this is always true because $u^1 + u^2 < 2$), the average search efficiency in urban equilibrium 1 is always higher than in urban equilibrium 2, i.e., $\overline{s}^1 > \overline{s}^2$. This result is not surprising. Indeed, in the integrated city (equilibrium 1), the unemployed reside closer to the CBD than in the segregated city (equilibrium 2), and thus the rate at which they leave unemployment is on average higher.

[*Insert Figures* 1 and 2 *here*]

3.2 Steady-state equilibrium

We can now close the model as before. For each $k = 1, 2$, we have a free-try condition that gives the following labor demand curve:

$$\frac{c}{q(\theta^k)} = \frac{y - w_L^k}{r + \delta} \tag{43}$$

We can also determined a bargained wage, which is given by:

$$w_L^k = (1 - \beta)\left[w_U + (\tau_L - \tau_U)x_b^k\right] + \beta\left[y + \left(s_0 - s_a x_b^k\right)\theta^k c\right] \tag{44}$$

Equations (44) give the two wage-setting curves (WS_1 and WS_2), which are both positively sloped in the plan (θ_k, w_k). One can show that the curve WS_1 is steeper than WS_2 but the intercept of WS_1 is lower. The reason why WS_1 is steeper than WS_2 is the following. The slope of these curves represents the ability of workers to exert wage pressures when the labor market is tighter. Thus, for a given labor market tightness, a more efficient labor market, i.e. $\overline{s}^1 > \overline{s}^2$, leads to a higher wage pressure per unit of θ, thus a steeper WS_1 curve. The intercept is, however, higher in equilibrium 2 since when $\theta = 0$, the outside option effect vanishes and only the compensation effect remains. Since the same marginal worker is further away in equilibrium 2, he/she must have a higher compensation for his/her transportation costs.

We can finally determine a steady-state conditions on flows:

$$u^k = \frac{\delta}{\delta + \overline{s}^k \theta^k q(\theta^k)} \tag{45}$$

[7] Observe that the land use equilibrium in section 2 is also depicted in Figure 2.

The above equation defines in the (u^k, V^k) space a downward sloping curve referred to as the Beveridge curve. The interesting feature of this Beveridge curve is that it is indexed by $\overline{s}^k$, which depends on the spatial dispersion of the unemployed in equilibrium $k = 1, 2$. It can be shown that, in the plane (θ, w), the Beveridge curve in urban equilibrium 2 is always above the Beveridge curve in urban equilibrium 1. Indeed, a lower $\overline{s}^k$ is associated with an outward shift of Beveridge curve in the $u^k - V^k$ space because more vacancies are needed to maintain the steady-state level of unemployment. If s_a increases or s_0 decreases, the Beveridge curve is shifted away from the origin meaning that the labor market is less efficient. The same would arise if the city size increased: the unemployed would be further away.

By combining (43) and (44), we obtain the following market equilibrium:

$$y - w_U = \frac{c}{q(\theta^k)} \left[\frac{\delta + r + \theta^k q(\theta^k) \left(s_0 - s_a x_b^k \right) \beta}{1 - \beta} \right] + x_b^k \left(\tau_L - \tau_U \right) \tag{46}$$

If we define

$$\widehat{\theta} = \frac{1 - \beta}{\beta} \frac{(\tau_L - \tau_U)}{s_a \, c}$$

we have then the following result:

Proposition 4 *There exists a unique and stable steady-state equilibrium* $(I_L^{k*}, I_U^{k*}, x_b^{k*}, x_f^{k*}, R^{k*}(x), w_L^{k*}, \theta^{k*}, u^{k*})$, $k = 1, 2$, *and only the two following cases are possible:*

(i) If $\widehat{\theta} < \theta^{1*} < \theta^{2*}$, *urban equilibrium 1 prevails;*

(ii) If $\theta^{2*} < \theta^{1*} < \widehat{\theta}$, *urban equilibrium 2 prevails.*

These two possible cases (i) and (ii) are plotted in Figures 3 and 4, respectively . Inequalities in (i) and (ii) replace (35) and (36). Observe that multiple urban equilibria can never happen (i.e. having both a segregated and an integrated city) because, according to Proposition 4, the condition for multiple equilibria is $\theta^{2*} < \widehat{\theta} < \theta^{1*}$ and it can never be verified since the intersection of the labor demand curve with the wage setting curve never satisfies this condition. This is because $\widehat{\theta}$, defined initially as the intersection point between the two wage-setting curves, is also the critical value that determines which urban equilibrium prevails.

[*Insert Figures* 3 and 4 *here*]

3.3 Interaction between land and labor markets

The interaction between land and labor markets is partly due to the dependence of search efficiency on distance. To show that, we proceed *a contrario*: we assume first that wages are exogenous and $s_a = 0$. In this case, both markets are independent. When we relax exogenous wages and keep $s_a = 0$, then we are back to section 2 and there is a one-way interaction between markets: the labor market does not depend on the land market but the land market equilibrium depends on the labor market equilibrium through labor market tightness as workers locate in one configuration or the other depending notably on θ^*.

Finally, as soon as $s_a > 0$, one has a general equilibrium interaction between the two markets. Indeed, one of the key assumption of our model is that the search efficiency s of each worker depends on the distance between residence and the job-center, i.e., $s = s(x)$ with $s'(x) < 0$. This implies that the land and labor markets are interdependent. Indeed, on the one hand, the labor market strongly depends on the land market since the equilibrium values of u^{k*}, V^{k*} and θ^{k*} are affected by the value of $\overline{s}^k$. On the other hand, the land market strongly depends on the labour market since the inequality (35) or (36) determining the land market equilibrium configuration depends on the value of θ^{k*}.

The following table summarizes our discussion:

Table 1. Interaction between land and labor markets

	Exogenous wages	Endogenous wages
$s_a = 0$	No Interaction	Partial Interaction ($LME \rightarrow LE$)
$s_a > 0$	Complete Interaction	Complete Interaction

($LME \rightarrow LE$ means that the interaction is from the land market equilibrium to the labour equilibrium)

We pursue our analysis by determining the part of unemployment only due to spatial frictions. For simplicity, we only focus on equilibrium 2 where the unemployed live far away from jobs. We also normalize the total population so that $N = 1$. The analysis for the other equilibrium is straightforward since nearly identical. Let us start with exogenous wages. In this case, θ^2 is constant and determined by (43). By using (45), the unemployment rate is given by:

$$u^2 = \frac{\delta}{\delta + \theta^2 q(\theta^2)\left[s_0 - s_a(1 - u^2/2)\right]} \tag{47}$$

Let us further define:

$$u_0^2 = \frac{\delta}{\delta + \theta^2 q(\theta^2) s_0} \tag{48}$$

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

$$u^{2*} = u_0^2 \left[1 + \frac{s_a}{s_0} \left(1 - u_0^2\right) \left(1 - u_0^2/2\right) \right] = u_0^2 + u_\sigma^2 \tag{49}$$

where $u_\sigma^2 \equiv u_0^2 \left[s_a \left(1 - u_0^2\right) \left(1 - u_0^2/2\right) / s_0 \right]$ is the *unemployment that is only due to spatial frictions* and u_0^2 is defined by (48). Observe that u_σ^2 is increasing in s_a/s_0, the parameter representing the loss of information through distance to jobs and null when $s_a = 0$. Observe also that the pure frictional unemployment u_0^2 affects u_σ^2 in the following way:

$$\text{If} \quad u_0^2 < 1 - \frac{\sqrt{3}}{3} \approx 0.42 \ , \quad \text{then} \quad \frac{\partial u_\sigma^2}{\partial u_0^2} > 0$$

In general $u_0^2 < 0.42$ so that u_0^2 affects positively u_σ^2, showing the full interaction between land and labour markets. This is quite natural: higher 'spaceless' unemployment u_0^2 affects positively frictions due to spatial heterogeneity (this is a side-effect of the dispersion of space on the unemployed themselves, which increases the average distance to jobs).

Overall, compared to the non-spatial case, unemployment increases because of the loss of information due to spatial dispersion of agents and also because of the wage compensation of commuting costs. However, it also tends to decrease because of the outside option effect that reduces wages.

3.4 Welfare

Let us now proceed to the welfare analysis. The first issue we address is the respective efficiency of the two types of land market configurations. Since there are no multiple equilibria in the land market, we cannot Pareto-rank the equilibria and it is difficult to compare them. Nevertheless, we are able to investigate what happens to the welfare difference in the range of parameters around the frontier separating the two types of land market equilibria. We show in fact that the welfare difference between the two cities is very marginal so that a social planner does not necessarily want to impose the integrated city. We then focus on the efficiency and the welfare analysis of each equilibrium. We show that each equilibrium is in general not efficient and that a social planner can restore the efficiency using transportation policies.

Comparison of welfare between cities We first investigate the welfare of the city, and study how it varies in each urban configuration. For each city, we use the welfare function defined by (27).

To see how this quantity varies and if it can be compared across cities, let us proceed to a simple numerical resolution of the model. We normalize the total population to 1, i.e. $N = 1$. We use the following Cobb-Douglas function for the matching function: $d(\bar{s}^k u^k, V^k) = \sqrt{\bar{s}^k u^k V^k}$. 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: the 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. Commuting costs τ_L are equal to 0.4 for the employed, and $\tau_U = 0.1$ for the unemployed. The discount rate $r = 0.05$, whereas the job destruction rate $\delta = 0.1$, which means that jobs last on average ten years. Finally, s_0 is normalized to 1, implying that $0 \leq s_a \leq 1$.

We have the following results:

Table 2. 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

In Table 2, we have chosen to vary a key parameter s_a, the loss of information per unit of distance (remember that workers' search intensity is defined by $s(x) = s_0 - s_a x$). 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'.

The first interesting result of this table 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 is clear that this result is due to the spatial part of unemployment u_σ^k since the non-spatial one u_0^k is not at all affected by this increase. Indeed, when we switch from equilibrium 1, where the unemployed are close to jobs and are very efficient in their job search ($\overline{s}^1 = 0.982$), to equilibrium 2, where the unemployed reside far away from jobs and are on average not very active in their search activity ($\overline{s}^2 = 0.511$), the spatial part of unemployment changes values from 0.12 to 5.65. Another way to see this is to consider column 6 (u_σ^k / u^{k*}): the part of unemployment due to space varies from 2% to 46%. So the main effect from switching from one equilibrium to another is that search frictions are amplified by space and consequently unemployment rates sharply increase. So here the spatial access to jobs is crucial to understanding the formation of unemployment.

The last column of the table shows the value of the welfare $\mathcal{W}^k$ 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 in the first equilibrium. Indeed, even though the unemployed are better off in equilibrium 1 (lower unemployment spells and lower commuting costs), the employed can in fact be worse off because of much higher commuting costs in equilibrium 1. In the above table, it is interesting to see that at the vicinity of $s_a = 0.522$, switching from equilibrium 1 to equilibrium 2 does not involve much change in the welfare level (from 0.714 to 0.712).

Welfare within each city The shape of the city has thus 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.*

In our present model, we have exactly the same externalities (intra- and inter-group externalities) as in the previous section. The spatial dimension does not entail any inefficiency so that it is easily verified that, for each equilibrium $k = 1, 2$, Proposition 3 still holds.

4 Endogenous search intensity and housing consumption

So far, we have assumed that search intensity was either exogenous or depending on distance to jobs. In the present section, based on Smith and Zenou (2003a), we would like to derive endogenously the search behavior of workers and show under which condition their search intensity depends on distance to jobs.

In this section, workers' search intensity s affects both the number of trips to the CBD and the job acquisition rate. So, when an unemployed worker wants to obtain information about jobs, he/she needs to go to the CBD. Also, here workers' search intensity s is interpreted as the fraction of commutes to the CBD and thus s is between $s_0 > 0$, its minimum value and 1. If $s = 1$, then the unemployed go to the CBD as often as the employed workers, that is every day.

4.1 The model

We assume that all workers have identical preferences among consumptions bundles (h, z) of *land* (*housing*), h, and *composite good*, z, representable by a log-linear utility

$$\Gamma(h, z) = h^{\alpha} z^{\omega} \tag{50}$$

with $\alpha, \omega > 0$, where it is also assumed that $\alpha+\omega < 1$. By solving the maximization problem under budget constraint, we can derive the following indirect utility

$$\Omega_L(x) = \chi(w_L - \tau x)^{\alpha+\omega} R(x)^{-\alpha} \tag{51}$$

for each *employed* worker at x, where $\chi = [\alpha/(\alpha+\omega)]^{\alpha}[\omega/(\alpha+\omega)]^{\omega}$ and the following indirect utility

$$\Omega_U(s, x) = \chi(w_U - s\tau x)^{\alpha+\omega} R(x)^{-\alpha} \tag{52}$$

for each *unemployed* worker at x, where in this case s is now included as a relevant choice variable. The different Bellman equations are thus given by:

$$rI_L = \Omega_L(x) - \delta\left[I_L - I_U(s, x)\right] \tag{53}$$

$$rI_U(s, x) = \Omega_U(s, x) + s\theta q(\theta)\left[I_L - I_U(s, x)\right] \tag{54}$$

Since there are no relocation costs, at any urban equilibrium it has to be that $rI_L = r\overline{I}_L$ and $rI_U(s, x) = r\overline{I}_U$. Unemployed workers optimally choose s^* by maximizing (54). We obtain:

$$r\frac{\partial I_U(s, x)}{\partial s} = -\chi\tau x\left(\alpha+\omega\right)\left(w_U - s\tau x\right)^{\alpha+\omega-1} R(x)^{-\alpha} + \theta q(\theta)\left(\overline{I}_L - \overline{I}_U\right) = 0 \tag{55}$$

There is a fundamental trade-off between short-run and long-run benefits for an unemployed worker. On the one hand, increasing search effort s is costly in the short run (more commuting costs) but, on the other, it increases the long-run prospects of employment. We have the following result:

Proposition 5

(*i*) *At each location x, there is a unique search intensity s that maximizes (54).*

(*ii*) *For any prevailing job acquisition rate, $\theta q(\theta)$, and constant lifetime values, $\overline{I}_L, \overline{I}_U$, the optimal search intensity function, $s(x)$, for unemployed workers is given for each location, $x \in [0, \frac{w_U}{s_0 \tau})$, by*

$$s(x) = \begin{cases} 1 & \text{for} \quad x \leq x(1) \\ \frac{(\alpha+\omega)}{[1-(\alpha+\omega)]} \left[\frac{w_U}{(\alpha+\omega)\tau x} - \frac{r\overline{I}_U}{\theta q(\theta)\left(\overline{I}_L - \overline{I}_U\right)} \right] & \text{for} \quad x(1) < x < x(s_0) \\ s_0 & \text{for} \quad x \geq x(s_0) \end{cases} \tag{56}$$

where

$$x(s) = \frac{w_U}{\tau} \cdot \frac{\theta q(\theta)\left(\overline{I}_L - \overline{I}_U\right)}{s\left[1-(\alpha+\omega)\right]\theta q(\theta)\left(\overline{I}_L - \overline{I}_U\right) + (\alpha+\omega)\, r\overline{I}_U} \tag{57}$$

which is the unique inverse function of (56).

It is optimal for workers to have constant search intensities close and far away from the CBD. Figure 5 describes $s(x)$. There is a *non-linear decreasing* relationship between the residential distance to jobs of the unemployed and their search intensity s. In fact, individuals living sufficiently close to jobs search every day, $s = 1$, whereas those residing far away provide a minimum search intensity, $s = s_0$. Workers living in between these two areas see a decrease in their search intensity from $s = 1$ to $s = s_0$. The intuition runs as follows. As stated above, there is a fundamental trade-off between short-run and long-run benefits of various location choices for the unemployed. 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 allow only infrequent trips to jobs and hence reduce the long-run prospects of reemployment. Therefore, for workers residing further away from the CBD, it is optimal to spend the minimal search effort whereas workers residing close to jobs provide high search effort. Compared to the previous section, we have endogeneized the relationship between s and x and given a mechanism that explains why search intensity is a decreasing function of distance to jobs.

[*Insert Figure* 5 *here*]

For interior $s^*(x)$, that is search intensity for workers living between $x(1)$ and $x(s_0)$, we can perform a comparative statics exercise. An interesting and non-standard result is that, when the unemployment benefit w_U increases, workers' search intensity s^* also increases. For the same reason, we have the contrary result for the commuting cost per unit of distance τ since $\partial^2\Omega_U(s,x)/\partial s\partial w_U \leq 0$. So, when transportation becomes cheaper (for example because of transportation subsidies or better public transportation), then unemployed workers search more intensively. Another interesting result is about land rent. For a given x, an increase in land rent $R(x)$ increases search intensity since $\partial^2\Omega_U(s,x)/\partial s\partial R \geq 0$. Finally, not surprisingly, an increase in the labor market tightness increases search intensity.

4.2 The different urban land use equilibria

We have determined the optimal search intensity of the unemployed at each location in the city (Proposition 5). Knowing this function $s(x)$, one may ask where do the unemployed and the employed locate in the city? The basic trade-off for the employed is between commuting costs and housing consumption whereas for the unemployed, it is between commuting/search costs, housing consumption and search intensity (and thus duration of unemployment). As usual, in order to determine the urban land use equilibrium, we have to define the bid rent function of each group of workers.

Given the utilities and lifetime values above, we now define the equilibrium bid-rents. It follows from (53), that the bid rent function for employed workers at each location, $x \in [0, w_L/\tau)$, is equal to:

$$\Psi_L(x,\overline{I}_U,\overline{I}_L) = \left[\frac{\chi(w_L-\tau x)^{\alpha+\omega}}{r\overline{I}_L+\delta\left(\overline{I}_L-\overline{I}_U\right)}\right]^{1/\alpha} \tag{58}$$

As usual, this bid rent is decreasing in x but is not anymore linear, which implies that more than two urban configurations can emerge. The bid rent function for unemployed workers is considerably more complex, in that it depends on the optimal search intensity level at each location. Using (54), we obtain the following bid rent function for unemployed workers at each location, $x \in [0, \frac{w_U}{s_0\tau})$:

$$\Psi_U(x,\overline{I}_U,\overline{I}_L) = \left[\frac{\chi\left[w_U-s(x)\tau x\right]^{\alpha+\omega}}{r\overline{I}_U-s(x)\theta q(\theta)\left(\overline{I}_L-\overline{I}_U\right)}\right]^{1/\alpha} \tag{59}$$

where $s(x)$ is given by (56). An instance of this (piecewise continuously differentiable) bid rent function is shown in the bottom half of Figure 5, where the curve represents a typical 'slice' through the two-dimensional rent surface.

It should be clear that the bid rents are calculated such that the lifetime utilities of both the employed and the unemployed workers, respectively, $\overline{I}_U$ and $\overline{I}_L$, are spatially invariant. Compare for example 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 to find a job but consume less land whereas the latter has a higher search (commuting) cost and a lower chance to find a job but consume more land. The bid rent defined by (59) exactly compensates these differences by ensuring that these two workers obtain the same lifetime utility $\overline{I}_U$. This is not true for the current utility of the unemployed $\Omega_U(s, x)$ because, as can be seen by (52), the land rent does not compensate for $s(x)$. In fact, the unemployed residing close to jobs have a lower current utility than the ones living far away from jobs because they provide more search intensity (indeed, using (52), it is easy to see that $\Omega_U'(x) > 0$). However, because they provide more search intensity, they have a higher chance to find a job, and thus in the long-run they compensate the short-run disadvantage so that all unemployed workers obtain the same $\overline{I}_U$.

With the non-linear bid rents defined by (58) and (59), 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 different steepness of the bid rents (as captured by their slopes), at each location, the employed can outbid the unemployed or can be outbidden by the unemployed. An example of the equilibrium rent function is shown in Figure 6. In particular, this figure illustrates a case where unemployed workers occupy both a central core of locations and a peripheral ring of locations about the CBD, 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* 6 *here*]

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

$$w_L < \frac{w_U}{s_0} \tag{60}$$

Proposition 6 *In equilibrium there are exactly three possible 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 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 endogeneously chosen, different urban equilibrium configurations can emerge. In the first one (i), referred to as the *Integrated Equilibrium* (Equilibrium 1 depicted in Figure 1), the unemployed reside close to the CBD, have high search intensities and experience short unemployment spells. In the second one (ii), referred to as the *Segregated Equilibrium* (Equilibrium 2 depicted in Figure 2), the employed occupy the core of the city and bid away the unemployed in the suburbs. In that case, the latter tend to stay 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 6), is when there are two categories of unemployed workers: the short-run ones who reside close to jobs and the long-term ones who live at the periphery of the city.

For each equilibrium $k = 1, 2, 3$, we can calculate the steady-state labor equilibrium, which is still defined as in Definition 2. The key variable that differs between equilibria is clearly $\overline{s}^k$ since its value depends on the average location of the unemployed.

4.3 Long-term unemployment and the urban space

It is easy now to interpret this model in terms of short-run versus long-run unemployment. Indeed, as stated above, looking at the core-periphery equilibrium described in Figure 6, one can see that workers who reside close to jobs are short-run unemployed while those living farther away are long-run unemployed. The intuition of this result is as follows. When choosing their optimal level of effort, the unemployed workers equalize their marginal gain (which is the probability generated by one more interview times the surplus when leaving unemployment) and their marginal loss (which is the marginal commuting cost of searching for a job). Then, because search effort marginally costs more further away from jobs, individuals search less in remote places and thus their probability to find a job decreases with distance to jobs. In that case, even though all the unemployed enjoy the same utility level, the ones who reside close to the employment center experience *short unemployment* spells because their search efficiency is very high whereas those who live further away are *long term unemployed* since their probability to find a job is quite low. Indeed, either workers reside in remote areas, are long run unemployed, live on welfare but pay very low land rents or reside close to jobs, experience short unemployment spells but pay a very high land rent. Thus, *space (or location) makes workers heterogeneous in terms of access to employment:*

those who are further away from jobs experience longer unemployment spells (see e.g. Rogers, 1997 for empirical evidence).

5 Extensions

5.1 Gathering information about jobs

So far, the way workers gathered information about jobs was mainly by commuting to the CBD. Imagine now the following. Each unemployed individual commutes to the center to gather information about jobs. This is not the only way to obtain information since one can also obtain job information by buying newspapers or calling friends. However, each return trip from the residential location to the employment center allows the worker to have some additional information that is not accessible without going to the center (for example, looking at some ads that are locally posted or having interviews with employment agencies that are located in the center).

If τ and ϕ denote respectively the *pecuniary* and *time* cost per unit of distance to commute to the employment center, then for the unemployed workers the total cost per return trip of gathering information about jobs in the employment center is given by:

$$\tau\, x + \phi\, x \tag{61}$$

We can now determine the *total* cost of gathering information about jobs at a distance x from the employment center. It is given by:

$$(\tau + \phi)\, e\, x \tag{62}$$

where $0 \leq e \leq 1$ is the search-effort rate provided by each unemployed worker. For example, $e = 1$ would be searching every day while $e = 1/2$ would be searching every other day. Obviously the higher e the more often the unemployed worker has to travel to the employment center to gather information about jobs. In this formulation, x is a measure of job access (how "well" the unemployed worker is connected to jobs) while e is a measure of search intensity (how many hours per day the unemployed worker spends in searching for a job).

In this context, the budget constraint of an unemployed worker living at a distance x from the employment center is equal to:

$$w_U = z + R(x) + C(e) + (\tau + \phi)\, e\, x \tag{63}$$

where $C(e)$ denotes all searching costs that are not distance-related. The latter encompasses the costs of buying newspapers, making phone calls, etc. We assume that $C(0) = 0$, $C'(e) > 0$

and $C''(e) > 0$. In this formulation, the total cost of searching is thus $C(e) + (\tau + \phi)\, e\, x$, which encompasses both search costs that are not distance-related and costs that involve commuting to the employment center.

Let us now focus on employed workers. He/she has the following budget constraint:

$$w_L = z + R(x) + (\tau + \phi\, w_L)\, x \tag{64}$$

The time cost of commuting for an employed worker residing at a distance x from the CBD is $\phi\, w\, x$; in accordance with empirical observation, it increases with income. As usual, w_L is the opportunity cost of leisure (even though this is not explicitly modelled here). The Bellman equations for unemployed and employed workers can be written as:

$$rI_U = w_U - C(e) - (\tau + \phi)\, e\, x - R(x) + \theta q(\theta)\, s(e)\, (I_L - I_U) \tag{65}$$

$$rI_L = w_L\, (1 - \phi\, x) - \tau x - R(x) - \delta\, (I_L - I_U) \tag{66}$$

The unemployed worker located at a distance x chooses e^* that maximizes his/her intertemporal utility (65). The first order condition yields:

$$\theta q(\theta)\, s'(e^*)\, (I_L - I_U) = C'(e^*) + (\tau + \phi)\, x \tag{67}$$

By totally differentiating (67), we obtain:

$$\frac{\partial e^*}{\partial x} = \frac{\tau + \phi}{\theta q(\theta) s''(e^*)(I_L - I_U) - C'(e^*)} < 0$$

and thus

$$\frac{\partial s}{\partial x} = s'(e^*) \frac{\partial e^*}{\partial x} < 0$$

Our previous results are thus robust to different search costs. It is easy to check that the employed workers' bid rent is linearly decreasing in x while the unemployed workers' one will be decreasing and convex in x. We will have again the three urban configurations described in Proposition 6 and the labor-market analysis can be carried through.

5.2 Positive relocation costs

The models developed above had 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 by C the instantaneous amount of effort and money supported by moving individuals. To simplify, we consider now that s is independent of distance and effort and that wages are 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. Employed workers are said to be mobile (resp. immobile) when, hit by a job-destruction shock, they decide to relocate to another part of the city (resp. stay at 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 by x^{α} and x^{β} the border between the mobile and immobile employed, and the immobile and mobile unemployed, respectively. Then, the equilibrium can be described by Figure 7.

[*Insert Figure* 7 *here*]

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

$$x^{\beta} - x^{\alpha} = \frac{2C\left[r + s\theta q(\theta) + \delta\right]}{\tau_L - \tau_U} \tag{68}$$

where, as before, τ_L and τ_U are the monetary commuting cost per unit of distance of the 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 the employed and the unemployed workers. The intuition is that, to remain immobile, one has to expect fast 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.

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

5.3 Endogenous acceptation rule

One interesting extension is to assume that workers are ex ante heterogenous in terms of idiosyncratic characteristics, for example productivities. Sato (2001, 2004) provides such a model. The model is basically the same as in section 2, with one major difference: when an unemployed worker becomes employed in a firm, the worker must bear a training cost ψ. It is assumed that ψ is match-specific and is determined stochastically, i.e. ψ is a random variable whose cumulative distribution function $G(\psi)$ is defined on the support $\left[0, \overline{\psi}\right]$. A worker does not know his/her ψ until he/she contacts a firm. When a contact occurs, an endogenous job acceptance rule will determine if the worker will accept a job or not. After the training, every worker-firm pair attains the same level of productivity, so that all employed workers receive the same wage. The expected lifetime utility of workers (15) and (16) can now be written as:

$$rI_L = w_L - \tau\, L - s\tau\ (N - L) - \delta \left[I_L - I_U(s)\right] \tag{69}$$

$$rI_U(s) = w_U - s\,\tau\, N + s\theta q(\theta) \left[\mathbb{E}_\psi \left(\widehat{I}_L\right) - I_U(s)\right] \tag{70}$$

where $\widehat{I}_L = \max\left[I_L - c, I_U(s)\right]$ and $\mathbb{E}_\psi\left(\widehat{I}_L\right)$ is the expectation of $\widehat{I}_L$ with respect to c. So the only equation that changes is equation (16), which is now given by (70), because of match-specific training costs where $\mathbb{E}_\psi\left(\widehat{I}_L\right)$ represents the change in expected utility when an unemployed worker comes into contact with a vacant job. For firms, the Bellman equations (17) and (18) become:

$$rI_F = y - w_L - \delta(I_F - I_V) \tag{71}$$

$$rI_V = -c + q(\theta)\,\Pr(\text{accept})(I_F - I_V) \tag{72}$$

where Pr(accept) is the probability that the match is accepted by a worker when a firm contacts a worker. If one denotes by $\widetilde{\psi}$, the threshold value above which workers refuse to accept a match, i.e. the reservation training level of a worker, then it can be defined as:

$$\widetilde{\psi} = I_L - I_U(s)$$

This is because when an unemployed worker is offered a job then he/she compares the expected value of this job, i.e. $I_L - \psi$, and the expected value of staying unemployed, i.e. $I_U(s)$. In that case, we have:

$$\Pr(\text{accept}) = F\left(\widetilde{\psi}\right)$$

and

$$\mathbb{E}_{\psi}\left(\widehat{I}_L\right) = \int_0^{\widetilde{\psi}} (I_L - \psi) f(\psi) d\psi + \int_{\widetilde{\psi}}^{\overline{\psi}} I_U(s) f(\psi) d\psi$$

The urban equilibrium is as before and described by Figure 1. Sato (2004) shows that if $\widetilde{\psi} \geq \beta (y - w_U) / (r + \delta)$, then there exists a unique steady-state equilibrium. This guarantees a possibility of sufficiently high training costs and excludes the case that, for some θ, workers accept any jobs. There are three interesting results that link the urban and labor markets. First, an increase in the commuting cost τ, decreases both the reservation training level $\widetilde{\psi}$ and the labor market tightness θ, but increases the unemployment rate u. Indeed, higher commuting costs make workers more selective, which leads them to reduces their reservation training level. Firms then create less jobs and thus unemployment increases. Second, an increase in the city size N decreases both the reservation training level $\widetilde{\psi}$ and the labor market tightness θ, but increases the unemployment rate u. The intuition is similar to the one with commuting costs since bigger cities imply (on average) higher commuting costs for workers. Finally, an increase in the search intensity s decreases $\widetilde{\psi}$ only if the commuting cost τ is small. Indeed, as workers search more intensively, firms create more jobs but the difference in the cost of living between the employed and unemployed decreases. The net effect depends on the value of the commuting cost.

6 Discussion: The spatial mismatch hypothesis

The different models developed in this article can provide some microfoundation to the fact that black workers, who tend to live far away from jobs in the United States, experience 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 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 stayed 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 labour-market outcomes, typically employment or earnings, to another measure of job access, typically some index that captures the distance between residences and centres of employment. The general conclusions are: (a) poor job access indeed worsens labour-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 racial differences in employment.

Despite this huge empirical literature, few theoretical models have been proposed (for a survey on the theoretical literature, see Gobillon et al., 2005, Zenou, 2006). The models developed in this paper provide the two following mechanisms for why distance to jobs can have adverse labor-market outcomes:

(*i*) Workers' job search efficiency may decrease with distance to jobs. Indeed, in section 3, we have shown that, for a given search effort, workers who live far away from jobs have fewer chances to find a job because they get less information on distant job opportunities. Observe that the lack of information generated by distance to jobs can also involve local social interactions. The key intuition is that in a neighborhood far from jobs, all workers are affected by distance so that the unemployment rate in the neighborhood is high. It is thus more difficult for each individual to rely on personal connections to refer them to jobs and unemployment is further exacerbated (Mortensen and Vishwanath, 1994, Calvó-Armengol, 2004, Calvó-Armengol and Zenou, 2005, Selod and Zenou, 2006).

(*ii*) Workers residing far away from jobs may not search intensively. Indeed, in section 4, we have seen that housing prices decrease with distance to jobs, and thus distant workers feel less pressured to search for a job in order to pay their rent.

The empirical evidence is consistent with the models's findings. Concerning (*i*) Rogers (1997) and Immergluk (1998) argue that, for informational reasons, the workers who reside close to jobs remain unemployed for a shorter period of time. Stoll and Raphael (2000) show that whites have a better job-search quality than blacks because they search in areas where employment growth is higher and that the difference in spatial job search quality between whites and blacks explains nearly 40% of the difference in their employment rates. Holzer and Reaser (2000) show that less educated black males (who search less in the suburbs) are less likely to be hired in the suburbs. They attribute this result to low information flows (but also to higher costs of applying). Concerning (*ii*), using English sub-regional data, Patacchini and Zenou (2006) empirically confirm that living in areas where rents are higher induces workers to search more for a job: a one-standard deviation increase in housing prices raises search intensity by about one third of a standard deviation.

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Figure 1. Urban equilibrium 1 (The integrated city)

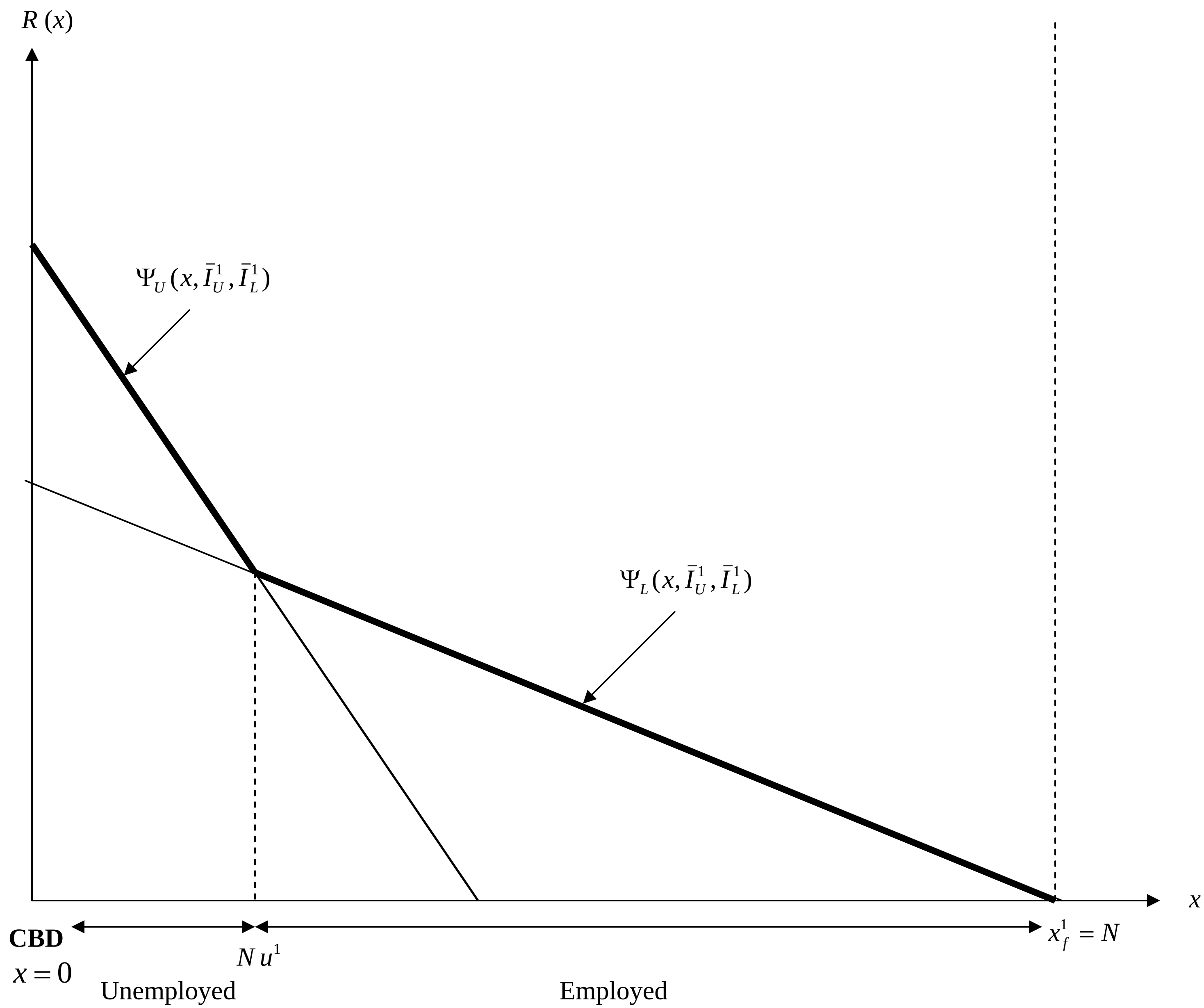

Figure 2. Urban equilibrium 2 (The segregated city)

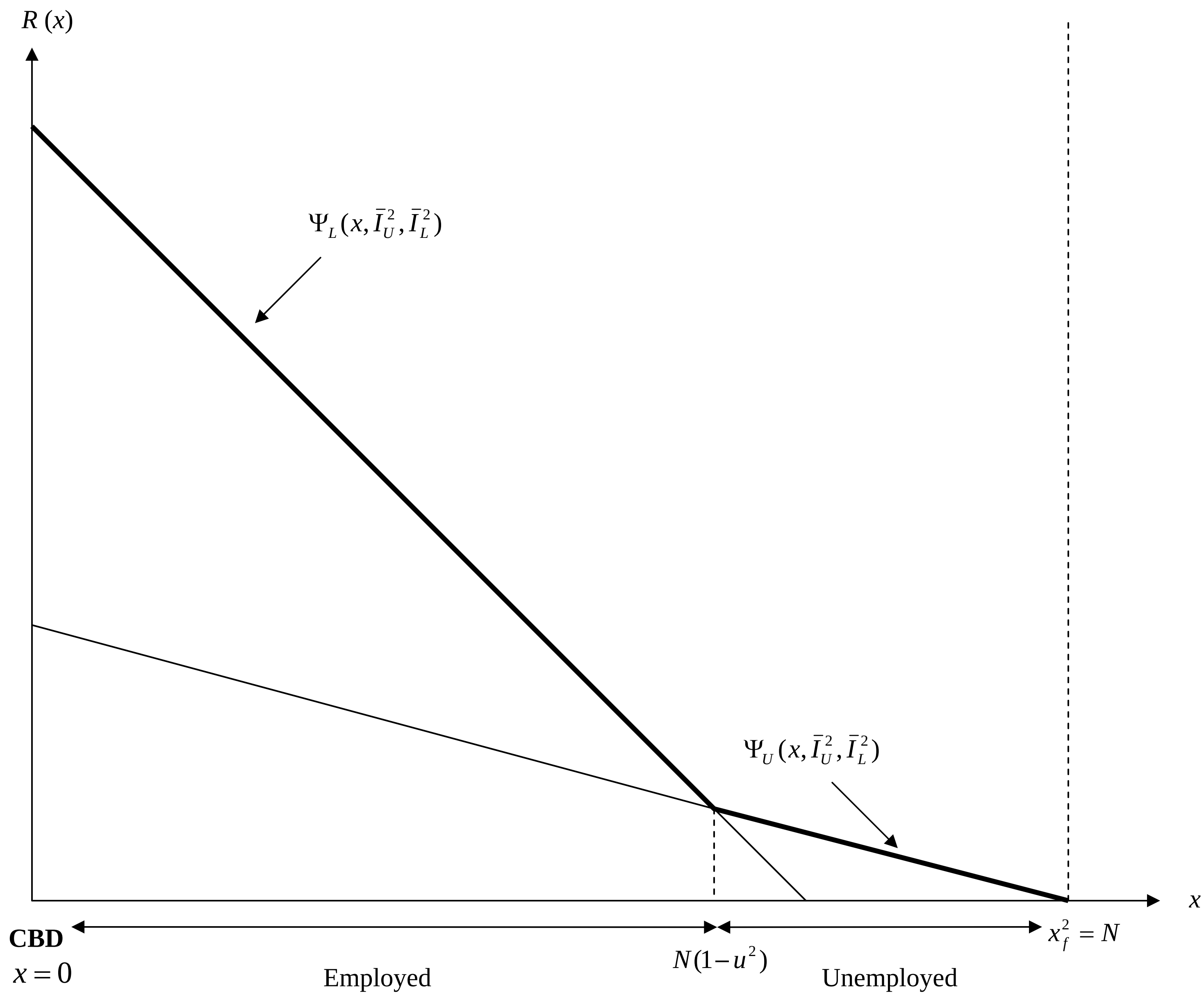

Figure 3. Steady-state labor equilibrium 1

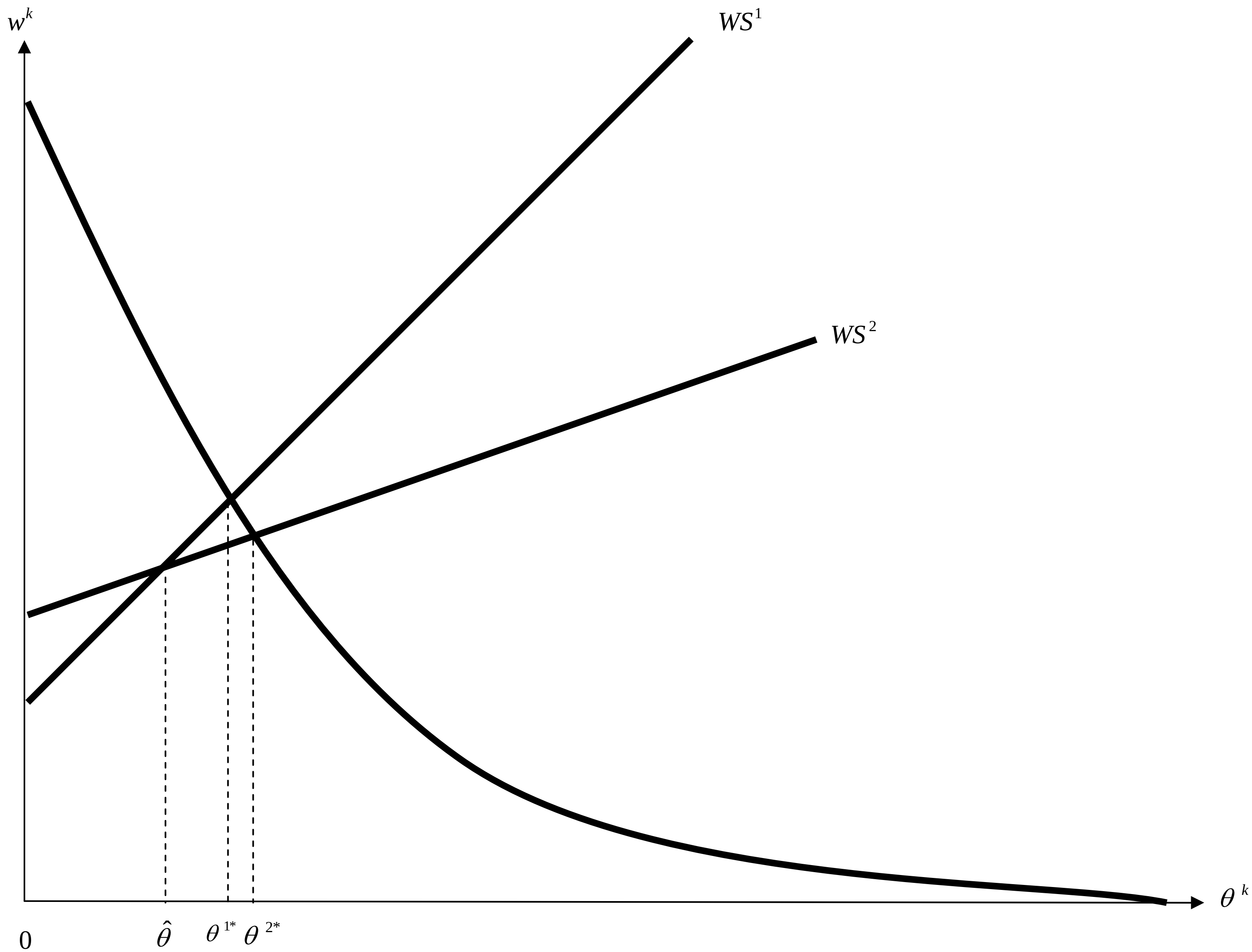

Figure 4: Steady-state labor equilibrium 2

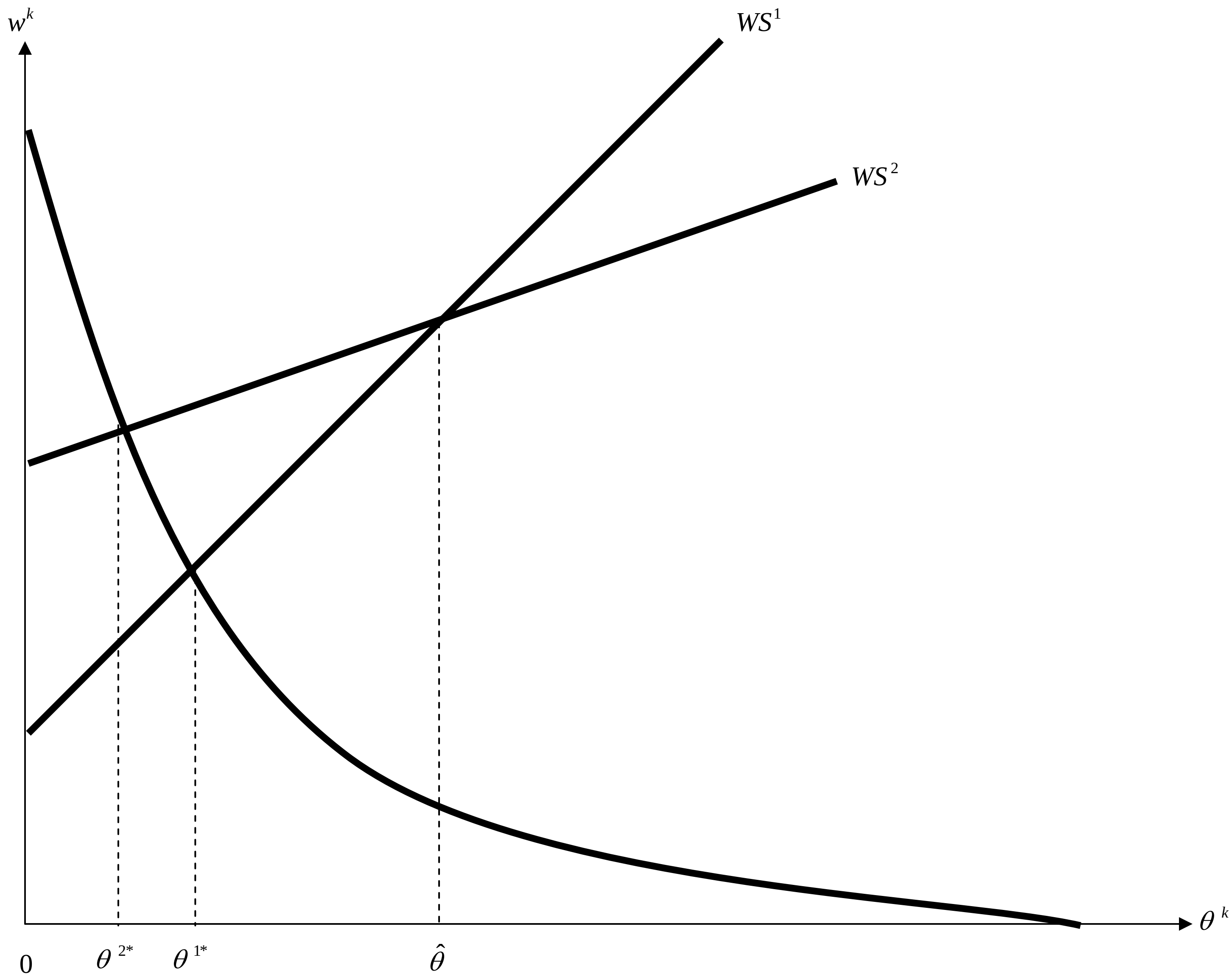

Figure 5. Optimal search intensities

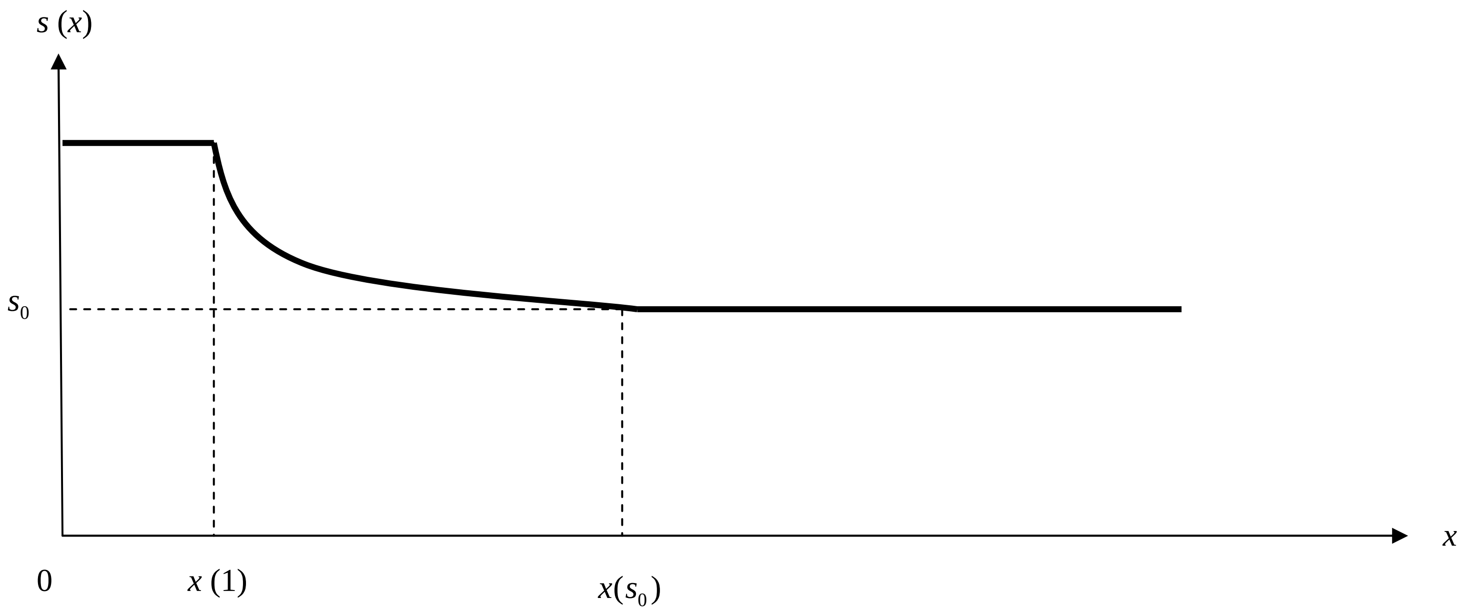

Figure 6. The core-periphery equilibrium

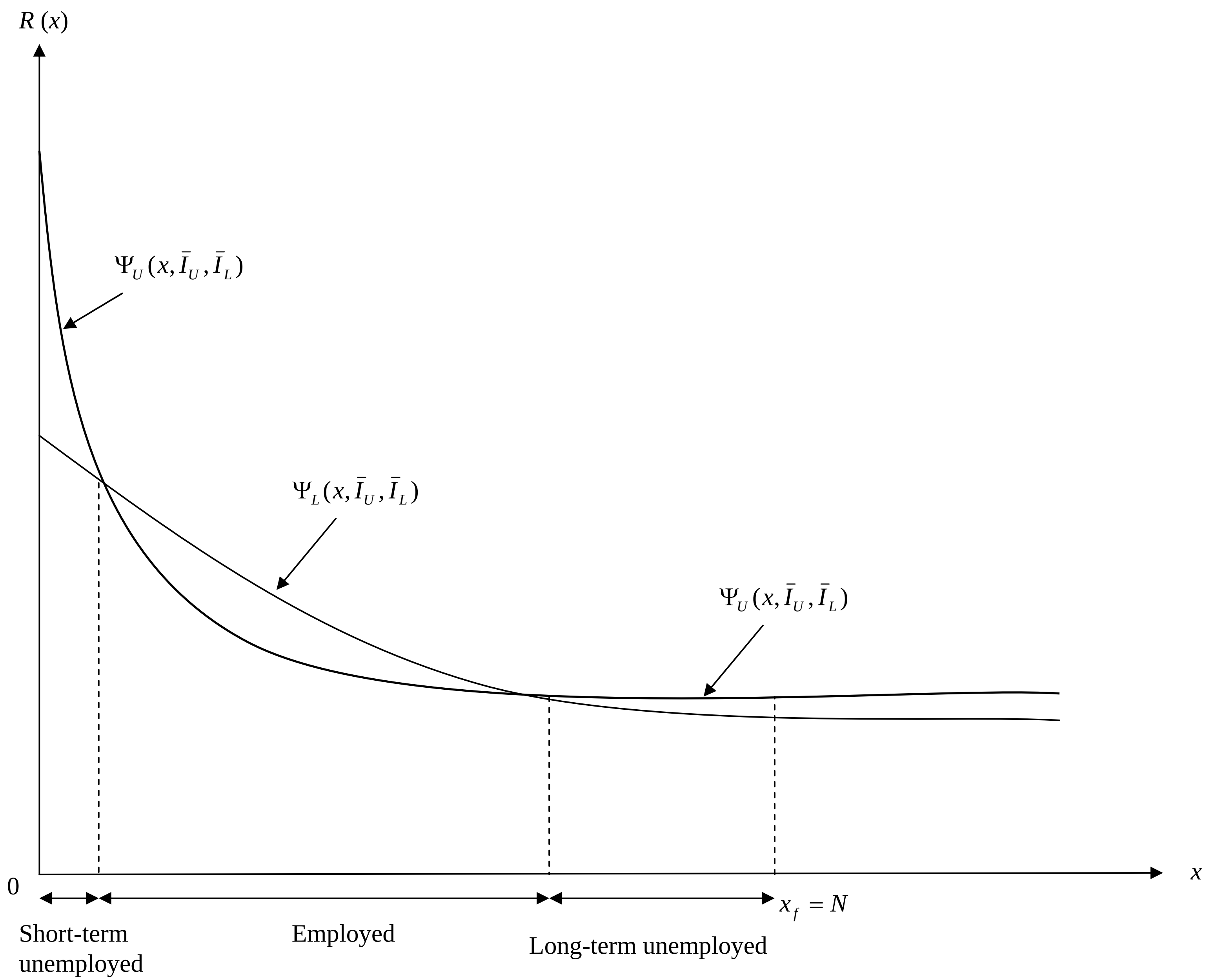

Figure 7. Urban equilibrium with mobility costs