Compensation for commuting in imperfect urban markets

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Abstract: We develop an urban equilibrium job search model where residential mobility is restricted due to the presence of residential moving costs. We presume a simple mono-centric model (firms are located in one location), but allow for imperfect labour markets. The model predicts that workers are compensated for commuting costs in the form of wages. As a result, rent gradients are less steep than predicted by standard urban theories that presume perfectly competitive markets. One of the consequences is that unemployed individuals who reside further from the CBD search less intensively for jobs.
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1. Introduction

Theories of urban residential location, which are based on perfect competitive labour and housing markets lead to predictions that are not always consistent with empirical evidence. We will focus here on two anomalies. First, these theories predict that wages depend on workplace location, but not on residence location (Muth, 1969).[1] However, this is not confirmed by empirical research: there is sufficient empirical evidence that at a particular workplace, workers' wages depend on residence location (for example, Zax, 1991; Hazans, 2003; see Kasper (1983) for a short review), suggesting the importance of labour market imperfections (e.g. bargaining power of firms) or housing market imperfections (e.g. moving costs).

An excellent example is Zax (1991) who identifies the effect of commuting time on earnings for employees of one firm located in the CBD of one city (Detroit, Michigan, USA). The research design is unique, because in the empirical analysis the workplace locations are the same for all employees. Zax (1991) shows that employees' wages depend on the residence location, essentially rejecting the assumption of a perfectly competitive labour market, and suggests that firms have labour market power, which induces firms to compensate employees for their commuting costs. He finds also that males receive higher wages and more compensation than females. To the extent that males have more labour market power, his results suggest thus that workers with more bargaining power (e.g. due to less discrimination or more residential mobility) receive higher wages *and* more compensation for commuting costs.

One may argue that the effect of residence location on wages, as for example identified by Zax (1991), may be a result of omitted variable bias related to the presence of unmeasured ability (an issue dealt with by Timothy and Wheaton, 2001). It is usually thought that high-ability workers commute further and earn higher wages. Kasper (1983) deals with this issue by employing another unique research design. The effect is estimated from a sample of one city (Glasgow, in the UK), where workers are *randomly relocated* within the city by a Housing Authority. The new location of residence was chosen by the Housing Authority, independent of location of workplace, and can be presumed to be exogenous. Kasper (1983) demonstrates that wages respond positively to increases in the commuting costs, also for those who do not change job, and that the increase is stronger for females than males (in contrast to the findings by Zax, 1991).

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[1] Zax (1991) argues that these theories implicitly assume that all workers at a particular workplace share the same residence location. Wages, given workplace, are invariant to residence location, because residence

Based on an analysis of cross-section data he finds similar results (although now the effect on the males' earnings is higher in line with Zax (1991)).

Another anomaly is that according to the standard theory, the price of housing services declines with the distance of residences from the centre to induce workers to choose locations at longer commuting distance (Muth, 1969). Because the theory presumes that workers do not receive compensation in the form of wages, workers receive full compensation in the housing market. However, this form of compensation, let alone full compensation, has to a large extent been empirically elusive (e.g. Dubin and Sung, 1987; Ball, 1973; Söderberg and Janssen, 2001).

This paper aims to address these deficiencies of urban theory by employing a model which explains that workers *at a particular workplace* (the Central Business District) are compensated by both wages and rents. This model is essentially a variant of the urban equilibrium search model as introduced in the literature by Wasmer and Zenou (2002). Our model takes labour market imperfections, imperfect residential mobility and wage bargaining between workers and employers into account.[2] More generally, the current paper can be interpreted as an attempt to understand commuting behaviour combining urban economics and job search theory. Job search theory is currently the main theoretical and empirical framework to analyse labour markets, building on the work of Stigler (1961, 1962). Search theory allows for market imperfections (lack of information, moving costs), and therefore avoids some of the problems associated with the standard urban economics model which assumes that markets are perfect (see Anas,

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location does not vary with workplace.

[2] The model introduced by Wasmer and Zenou (2002) presumes perfect residential mobility and predicts that workers receive full compensation in the housing market, but no compensation in the form of wages. Our model is also similar in spirit to the equilibrium search model introduced by Rouwendal (1998). In his

1982; Hamilton, 1982, 1989). The remainder of the paper is as follows. In section 2, the urban equilibrium model is introduced and analysed. Section 3 and 4 discuss extensions and compare the model with an equilibrium model with a different spatial structure. Section 5 concludes.

2. The basic job matching model

2.1 The job matching function

We presume a continuum of identical residences, which are homogeneously distributed over space. Firms are located in one location: the Central Business District (the CBD hereafter). The economy is linear and closed. Each residence is inhabited by one individual, who is either unemployed or employed. The unemployed search for jobs, the employed do not search (for an equilibrium model which includes on-the-job search, see Mortensen, 1994). The employed incur commuting costs t, which are proportional to distance. The commuting costs become known to the firm at the moment the unemployed job seeker and firm contact each other. A firm consists of only one job, which is either filled or unfilled. In order to fill a job, firms post a vacancy. When a firm with a vacancy and an unemployed contact each other, the job will be filled.[3]

Suppose there are L identical individuals in the labour force. We let u denote the unemployment rate and v denote the vacancy rate, defined as number of vacant jobs as a fraction of the labour force L. We assume the existence of a matching function that gives the number of matches between unemployed and firms per unit of time as a function of

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model the number of vacancies is exogenously given. The latter assumption is less appropriate to describe an equilibrium.

the number of unemployed uL looking for jobs and the number of firms looking for workers vL. The number of matches taking place per unit of time is given by $mL = m(uL, vL)$. The matching function is assumed increasing in both its arguments, concave, and has constant returns to scale. Empirical studies generally accept the assumption of an aggregate matching function with constant returns to scale, see Petrongolo and Pissarides (2001).

Given the matching function, the probability for a vacancy to be filled per unit of time, denoted as q, is defined. Given the constant returns to scale assumption, it follows that:

$$q = \frac{m(uL, vL)}{vL} = m(\frac{u}{v}, 1) = m(\frac{1}{\theta}, 1), \tag{1}$$

where θ = v/u. So, θ is a measure of labour market tightness, defined as the ratio of the vacancy to the unemployment rate. Thus, q, the rate at which vacancies become filled, depends negatively on the ratio of the vacancy to the unemployment rate, θ. Similarly, it can be seen that the rate at which unemployed become employed equals θq, where θq depends positively on θ (Pissarides, 2000). Note that we presume that θq does not depend on the location of the unemployed. Later on, we will relax this assumption.

2.2 Employed and Unemployed

An individual receives a wage w and incurs commuting costs t when employed, and

[3] So, we assume that given a contact, it is advantageous for both firms and job seekers to form a match. The conditions under which this behaviour is optimal are derived later on. We will demonstrate that these

receives unemployment benefits z when unemployed. To simplify notation, we presume that z equals zero. All individuals pay rent costs at the market price R(t). The commuting costs are exogenous to the worker. In contrast, the wage is endogenous. Given the value of the commuting costs t, firm and unemployed will bargain about the wage w, so w = w(t). The worker will not keep the job forever. The job will be destroyed at rate λ and the worker will then become unemployed. The discount rate is denoted as r.

Urban economic theory assumes the absence of residential moving costs and presumes that individuals can choose their residence freely (Fujita, 1989). Although the empirical literature on residential mobility has shown that moving costs are sufficiently high to deter residential mobility (see, among others, Boehm, 1981), this assumption can usually be justified when focusing on the residence location. When choosing the optimal location, moving costs are discounted over long periods, so the optimal location is hardly affected by the presence of moving costs. This assumption is however problematic when individuals experience changes in their characteristics *over time*. For example, individuals may experience a change in income, number of children, or, as in the current paper, in their labour market position. The absence of moving costs implies that any change in an individual's characteristic would induce a residential move.

In the context of the labour market, the absence of moving costs implies that individuals move residence the moment they change their labour market position (from employment to unemployment or from unemployment to employment) (e.g. Wasmer and Zenou, 2002). This prediction is empirically implausible. For most individuals it is uneconomical to move residence the moment they become unemployed and to move again when they become re-employed, because the costs of moving exceed the benefits of

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conditions imply restrictions on the maximum commuting costs and therefore on the size of an urban area.

moving, viz. a temporary reduction in rent.[4] We presume therefore that individuals do not move residence the moment they become unemployed.

We assume that moving costs are absent for employed individuals following the standard assumptions of urban economic theory. In a competitive bidding market, unemployed workers who find a job will then move the moment they become employed and will not move residence again until the next job move. Hence, workers are expected to remain in the same residence for a period equal to the sum of the expected job and unemployment duration (which exceeds the expected unemployment duration many times). So, the assumption of the absence of moving costs can be justified on the grounds that the moving costs are discounted over a long period.

So, in essence, we presume that the existence of moving costs implies that individuals choose the optimal location for a period, which includes (at least) one spell of employment and one spell of unemployment.[5] The optimal location is chosen the moment the individual becomes employed.[6]

We denote by U(t) and W(t) the expected (discounted) lifetime income of the unemployed and employed respectively. The lifetime income of the employed can be written as:

$$rW(t) = w(t) - t - R(t) + \lambda(U(t) - W(t)). \quad (2)$$

[4] The expected duration of being unemployed is for most individuals only a couple of months.
[5] For a *non-urban* equilibrium search model which explicitly models commuting behaviour and residential moving costs, we refer to Van Ommeren and Rietveld (2002). They show, for example, that the probability of moving residence after accepting a new job is a negative function of the moving costs and a positive function of the expected employment duration.
[6] This assumption can be replaced by the (arguably less plausible) assumption that the optimal location is chosen the moment that the individual becomes *unemployed*, generating the same qualitative results.

The lifetime income of the employed is equal to the net wage - the wage minus the commuting costs – minus the rent plus the expected change in lifetime income due to the probability of losing the job. When the employed becomes unemployed, he / she will not move residence. The expected employment duration equals 1/λ.

When unemployed, the lifetime income of the unemployed can be written as:

$$rU(t) = -R(t) + \theta q(\max_{t'} W(t') - U(t)). \tag{3}$$

Interpretation of this Bellman equation is as follows: the unemployed pays rent equal to R(t) and has per unit of time a probability θq of becoming employed. At the moment the unemployed becomes employed, he / she will move to the location t', which maximises lifetime income W(t'). The expected unemployment duration equals 1/θq.

2.3 The bid rent function / optimal location

The moment the unemployed contacts an employer and decides to form a match, a new optimal residential location will be chosen to maximise lifetime income W(t'). Competition between unemployed job seekers who have just formed a match with an employer guarantees that all workers enjoy the same level of income, so W(t') = W, where W denotes the equilibrium lifetime income level. The new worker will move to another residence location, outbidding other workers. The optimal location is then determined by the maximum land rent that the employed worker is ready to pay to reach the equilibrium lifetime income level. Given equation (2), the bid rent of the employed, denoted as Ψ, is equal to:

$$\Psi(t,W) = w(t) - t + \lambda U(t) - (r+\lambda)W. \tag{4}$$

Using equation (3), which defines the lifetime income of the unemployed, the bid rent can be conveniently rewritten as:

$$\Psi(t,W) = \frac{r+\theta q}{r+\theta q+\lambda}(w(t) - t - rW). \tag{5}$$

Consequently, the bid rent function depends on the commuting costs t directly and indirectly (via wages). The marginal costs that a worker is ready to pay to be marginally closer to the CBD can be derived from the bid rent slope:

$$\frac{\partial\Psi(t,W)}{\partial t} = \frac{r+\theta q}{r+\theta q+\lambda}(w'(t) - 1) < 0. \tag{6}$$

The bid rent slope is negative (since $0 < w'(t) < 1$, which will be shown later on), and, importantly, less than one (in absolute value). Employed individuals are not fully compensated for the commuting costs in the housing market, because workers are partially compensated in the labour market ($w'(t) > 0$). This makes sense given the assumption of the presence of labour market bargaining power. When workers have bargaining power, they will receive compensation for commuting costs in the labour market, and, as a result, will need less compensation in the housing market. Further, the employed worker takes into account the likelihood to become unemployed *and to stay at* *the same location*. When unemployed, the individual will not commute to the CBD, so the employed will bid less for a location closer to the CBD (implied by the factor $(r+\theta q)/(r+\theta q+\lambda)<1$).

We are now ready to examine the equilibrium location of the employed and unemployed. The market rent is given by R(t), and each individual takes it as an exogenous factor. Recall that W is the equilibrium lifetime income of the employed individual and $\Psi(t, W)$ is the maximum land rent costs an employed individual is willing to pay. Suppose now that the exogenous (agricultural) land rent at the fringe of the urban area is standardised to zero. This implies that t is an optimal location if and only if $R(t)=\Psi(t, W)$.

2.4 Job creation

Recall that all firms are located in one location. When opening a vacancy, firms do not know where the (next) job applicant who will fill the job is located or where the job applicant will move. When firms and unemployed contact each other and form a match, the unemployed will choose a new location and the commuting costs become known to the firm. The value of a vacancy, V, can be written as:

$$rV = -c + q(J^e - V), \tag{7}$$

where c denotes the firms' hiring costs. Vacancies are filled at rate q and J^e denotes the expectation of the job's net worth. The job's net worth is unknown to the firm, because the (new) residence location of the job applicant is unknown. However, the firm knows the distribution of commuting costs in the urban area, so the expected job's net worth is known.

The value of an occupied job is equal to the productivity level, denoted as p, minus the wage, w(t), taking into account that with a rate equal to λ the job will be destroyed. Hence, the value of the filled job can be written as:

$$rJ(t) = p - w(t) - \lambda J \text{ , or, similarly, } J(t) = \frac{p - w(t)}{r + \lambda} . \tag{8}$$

In equilibrium, all profit opportunities from new jobs are assumed to be exploited, driving rents from vacant jobs to zero, so V = 0. Note that job creation occurs based on the *expected* value of the filled job. This equilibrium condition determines the supply of vacancies, implying that:

$$J^e = \frac{p - w^e}{(r + \lambda)} = \frac{c}{q} , \tag{9}$$

where w^e denotes the expectation of the wage paid to the employee. This equation states that the expected capitalised net return of the job is equal to the expected value of the firm's hiring cost. This condition is usually referred to as the job creation condition (Pissarides, 2000).

2.5 Wage determination

The commuting costs are a drawing from a distribution determined by the size of the urban area. Given the commuting costs, the unemployed and firm bargain about the wage level. In equilibrium, job matches yield a local-monopoly surplus. We assume that the total surplus, equal to the sum of the workers' surplus, W-U(t), and the firms' surplus, J(t)-V, is shared according to the Nash solution to a bargaining problem, employing the following rule:

$$w(t) = \arg\max (W - U(t))^{\beta} (J(t) - V)^{1-\beta}, \tag{10}$$

where β is a measure of the workers' labour strength, other than the 'threat points' U and V. It can also be interpreted as the workers' share of the total surplus. We presume that 0<β<1. The first-order equation satisfies:

$$W - U(t) = \frac{\beta}{1-\beta}(J(t) - V). \tag{11}$$

In equilibrium V=0, so that the wage can be written as (see Appendix 1):

$$w(t) = (1-\beta)t + \beta p + \beta c\theta + \frac{(1-\beta)\theta q(R(t) - R^e)}{r + \theta q}, \tag{12}$$

where R^e denotes the expected rent. The expectation is taken from the perspective of the firm that does not know with certainty the location, and therefore the commuting costs, of a job applicant but knows the commuting costs distribution.

Equation (12) shows that the wage depends on commuting costs t, directly and indirectly via R(t). Interpretation of this effect is as follows. Conditional on the commuting costs, firms and job seekers bargain about the wage. The higher the commuting costs, the smaller is the worker's surplus from the match, which is equal to W-U(t), so the worker will ask (and receive) a higher wage to be compensated for the commuting costs. This direct effect of commuting costs on wages depends only on the bargaining power parameter β, and not on any other labour market variable. Further, equation (12) shows that the wage depends positively on the rent paid in the housing market. So, wages also compensate for the rent paid in the housing market. This can be contributed to the residential lock-in effect of moving costs, which induce the unemployed to reside in non-optimal locations. Equation (12) also shows that the wage is increasing in the productivity level and the average hiring costs per unemployed ($c\theta$ is equal to the hiring costs times the number of vacancies divided by the number of unemployed and can be interpreted as the average hiring costs per unemployed). Finally, note that the current interpretation of equation (12) is partial, because θ, R(t), R^e and q are endogenous variables.

The wage equation can also be written as (see Appendix 2):

$$w(t) = (1-\beta)t + \beta p + \beta c\theta - \frac{\beta(1-\beta)\theta q(t-t^e)}{r + \beta\theta q + \lambda}, \qquad (13)$$

where t^e denotes the expected commuting costs. So, keeping the expected commuting costs constant,

$$w'(t) = \frac{(1-\beta)(r+\lambda)}{r+\beta\theta q+\lambda} > 0\,. \tag{14}$$

Hence, the commuting costs compensation in the form of wages is positive, because of the residential lock-in effect of moving costs. In most labour markets the job finding rate θq is larger than the discount r and job quitting rate λ. Suppose a labour market with expected job durations of 6-7 years, and expected unemployment durations of 6 months, so λ equals 0.15 and θq equals 2. The annual discount rate r is usually assumed to be around 0.15. Pissarides (2000) argues that a reasonable value of β is 0.5 (so workers and firms have equal bargaining power), implying that the marginal compensation for commuting costs in the form of wage is 0.12. Thus, the model predicts that wage compensation for commuting is sizeable, and should be empirically relevant for the labour market.

The wage compensation for commuting depends on the chosen values of the parameters. In a market where workers have less (more) bargaining power, the marginal compensation in the form of wages is higher (lower). For example, when $\beta = 0.25$, marginal compensation is 0.28; when $\beta = 0.75$, marginal compensation is 0.07. This makes sense. Workers with more bargaining power will receive higher wages (a larger share of the surplus), so firms will be less 'willing' to compensate for the commuting costs. Consequently, according to the current bargaining model, workers who belong to groups which are disadvantaged in the labour market (for example, females, blacks), who have plausibly less labour market power, will receive lower wages and will receive *more* compensation for the commuting costs. This result is consistent with the panel data analysis of Kasper, 1983, but inconsistent with the cross-section analysis of of Kasper, 1983, and Zax (1991).

The marginal compensation for commuting costs depends negatively on the job finding rate of the unemployed (given the discount and quitting rate), because the job finding rate determines for how long unemployed workers are locked in by the residential moving costs. For example, keeping the assumption that β = 0.5, but the job finding rate is 1 (so the expected unemployment duration is one year), implies that the marginal compensation in the form of wages is 0.19.[7]

We have established now that workers are partially compensated for the commuting costs in the labour market. The consequences for the housing market can easily be derived. The bid rent slope equation can be rewritten as:

$$\frac{\partial \Psi(t,W)}{\partial t} = \frac{r+\theta q}{r+\theta q+\lambda}(w'(t)-1) = -\beta \frac{r+\lambda+\theta q}{r+\lambda+\beta\theta q} > -1. \quad (15)$$

Hence, the worker receives marginal compensation for the commuting costs in the housing market, which is less than one (in absolute value). Presuming again that β equals 0.5 (0.25), marginal compensation in the form of rent is 0.88 (0.72), which is clearly less than one. The rent gradient is therefore less steep than predicted by standard urban economics theory. In conclusion, the urban equilibrium job search model predicts that workers located in the CBD receive compensation for commuting costs both in the housing and labour market. Given reasonable values of the labour market parameters, the compensation in terms of rent tend to be larger than in terms of wages.

We emphasise here that we have presumed imperfect labour markets where employers have bargaining power, so $\beta < 1$. By comparison, the assumption of perfect competitive labour markets (so $\beta = 1$) would imply that workers receive a wage equal to the productivity level. Hence, in the case of perfect competitive labour markets, wages are not a function of commuting costs, so workers are not compensated in the form of wages, and workers are fully compensated in the form of rents.

2.6 Equilibrium

In the steady state, the proportion of individuals who enter unemployment, $\lambda(1-u)$, must be equal to the proportion who would leave unemployment, θq. So, the unemployment rate can be written as

$$u = \frac{\lambda}{\lambda + \theta q}. \tag{16}$$

The expected wage, w^e, can be written (using equation (12)) as:

$$w^e = (1-\beta)t^e + \beta p + \beta c\theta. \tag{17}$$

As can be seen above, the *partial* effect of expected commuting costs on the wage is positive (keeping labour market tightness constant). In equilibrium however, an

[7] Empirical evidence indicates that the unemployed's job finding rate relative to the quitting / firing rate is higher in Japan than in the United States. This suggests that in Japanese urban areas compensation for

increase in the expected commuting costs decreases labour market tightness (and increases unemployment; the effect on vacancies is undetermined). This can be demonstrated by incorporating the expected wage equation (17) into the job creation condition (9):

$$(1-\beta)(p-t^{e})-\frac{(r+\lambda)c}{q}=\beta c\theta. \tag{18}$$

Equation (18) can be solved uniquely for θ given t^e. Given θ, the equilibrium unemployment rate u is determined (see equation (12)). So, the full equilibrium has been defined. The *overall* effect of higher expected commuting costs on the expected wage can be demonstrated using Figure 1. The wage curve is an increasing function of labour market tightness, whereas the job creation curve implies a negative relationship between the wage and labour market tightness. The job creation curve does not depend on the expected commuting costs (see (9)), whereas the expected wage curve shifts up where the job entry costs increase (see (17)). Consequently, the overall effect of higher expected commuting costs is an increase in the expected wage. The negative effect on labour market tightness and therefore the positive effect on unemployment follow from the same figure (the effect on the vacancy rate can be shown to be ambiguous).[8]

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commuting in the form of wages should be lower than in the United States.

[8] We have presumed that each contact between firm and unemployed generates a job match (see section 2.1). This puts a limit on the maximum commuting costs and therefore size of the urban area. The maximum commuting costs acceptable to the unemployed job seeker, denoted as t^m, are defined by the condition that W-U(t^m) = 0. When t exceeds t^m, the job seeker will reject the match. This condition implies that J(t^m) = 0, so w(t^m) = p (see equation (11) and (8)). Given the relationship between commuting costs and commuting distance, and given the land size of one residence, the size of the urban area is determined. For

3. Search and spatial mismatch

Employing equations (8) and (11), and noting that w depends positively on t, it can be easily seen that W-U(t) and J(t) are both a negative function of t and U(t) is a positive function of t. The latter occurs because the unemployed residing further away from the CBD pay lower rents. The implication is that unemployed job seekers located further from the CBD are better off and have an incentive to search less intensely than those located closer to the CBD.[9] To examine this issue, let us presume that search costs, σ, vary with search intensity, s, optimally chosen by the unemployed,[10] and that the unemployed matching probability is an increasing linear function of search intensity, so q' > 0 and q'' = 0. A justification of the latter assumption can, for example, be found in the work of Pissarides (2000).[11]

We assume that the cost function σ is a convex function of s. Search intensity is chosen by the unemployed worker to maximise the lifetime utility U(t,s), where U(t,s) can be written as follows:

$$rU(t,s) = -\sigma(s) - R(t) + \theta q(s)(\max_{t'} W(t') - U(t,s)) \,. \tag{19}$$

The worker chooses the intensity of search to maximise U(t,s). The optimal s* satisfies:

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example, if the unit travel costs are one, and the size of the residence is equal to one, the fringe of the urban area must be located at a distance from the CBD, which is less than t^m.

[9] Further, it suggests that firms may vary their search intensity spatially so that they have a higher probability of contacting an unemployed job seeker close to the CBD. We will ignore this aspect here.

[10] Note that this assumption differs from Wasmer and Zenou (2002) who presume that search effort depends on the distance between job seeker and firm.

[11] Pissarides (2000) presumes that a worker transfers from unemployment to employment at rate $\theta q(s) = s.m(\bar{s}u, v)/\bar{s}u$, where $\bar{s}$ denotes the average search intensity level which is exogenous to s.

$$-\sigma'(s^*) + \theta q'(s^*)(\max_{t'} W(t') - U(t, s^*)) = 0 \,. \tag{20}$$

It follows that the optimally chosen s* is a negative function of t (since $\partial U/\partial t > 0, \sigma'' > 0$ and $q'' = 0$). Hence, the unemployed residing further from the CBD will search less intensively[12] and the expected unemployment duration (equal to $1/\theta q(s^*(t))$) will be longer for those individuals located closer to the CBD. In the steady state, the proportion of individuals at t who enter unemployment $\lambda(1-u(t))$, must be equal to the proportion at t who leave unemployment, $\theta q(s^*(t))u(t)$. So, the unemployment rate at t can be written as: [13]

$$u(t) = \frac{\lambda}{\lambda + \theta q(s^*(t))} \,. \tag{21}$$

It follows that the unemployment rate is lower for individuals residing closer to the CBD.[14] The reason is that unemployed individuals who reside closer to the CBD pay higher rents, and search therefore more intensively for jobs. This result provides an explanation for the positive unemployment gradient found, for example, in the work of Vipond (1980; 1984) and, more generally, sheds new light on the mismatch literature which presumes that bad job access worsens employment opportunities (Holzer, 1991).

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[12] A similar result has been obtained by Myers and Philips (1979) in a partial equilibrium model and has been *assumed* by Wasmer and Zenou (2002).

[13] The average unemployment rate u in the urban area is defined by integrating the local unemployment rate u(t) over the size of the urban area.

[14] Note that given the absence of moving costs, the model would predict that the unemployment rate is invariant over space as shown by Wasmer and Zenou (2002).

4. Spatial structure and compensation

In the empirical urban economics literature, the extent to which workers are compensated for commuting costs has extensively been investigated (starting with Muth, 1969). Far less attention has been given to the implications of *urban structure* for compensation. Let us therefore compare results derived above with the results of a similar labour market model given a *continuum* of identical firms, so spatial variations in rents are absent, which characterises a non-urban area. In this case, the wage equation can be written as: $w(t) = (1-\beta)t+\beta p+\beta c\theta$ (see Van Ommeren and Rietveld, 2002). So, the marginal compensation for commuting costs in the form of wages in non-urban areas is equal to $1-\beta$, which exceeds the marginal compensation in urban areas (see (14)). This is intuitive, because in urban areas, workers are also compensated by rents. This finding appears to be consistent with empirical studies. For example, it has been reported that firms located in large cities tend to reimburse less than those located elsewhere. In the United Kingdom, firms located in London are 50% less likely than firms located outside London to offer a contribution to individual commuting expenses at the moment of recruitment (RCI, 2001), although firms in London pay higher wages.

5. Conclusion

We set out to analyse an urban equilibrium model presuming imperfect labour markets (bargaining power, search behaviour) and allowing for residential moving costs aiming to explain the empirical observation that for workers at a particular workplace (in the current model, the CBD), wages depend on residence location and therefore on commuting costs (Zax, 1991). Labour market imperfections (for example, search costs) and bargaining between workers and employers play an essential role in the model. In contrast to models that exclude (labour) market imperfections, but in line with the empirical literature, workers are partially compensated for the incurred commuting costs. We demonstrate that labour market power determines the extent to which workers can shift the burden of commuting expenses onto their employers, but, maybe surprisingly, the model predicts that workers belonging to groups which have more labour market power will receive higher wages but less compensation for commuting costs (since due to the higher wages, the firm's surplus is less).

One of the main implications of the model is that due to residential moving costs, rent gradients are less steep than predicted by standard urban theories in line with a range of empirical studies (Dubin and Sung, 1987). Using a theoretical urban economics model with multiple employment centres, Crane (1996) and Turnbull (1998) both obtained a similar result when presuming future job site uncertainty and the presence of residential moving costs that constrain households to live in the same place. In these models, the residential location is based not only on where the current job is located, but also on the expectation of where future jobs will be located. Although our model is quite different from the models of Crane (1996) and Turnbull (1998), in particular, we presume wage bargaining and only one employment centre, these models share the assumption of imperfect residential mobility and labour market imperfections. This suggests that the introduction of residential moving costs combined with labour market imperfections may be fundamental to our understanding of the relationship between urban labour and housing markets and the implications for commuting compensation. Furthermore, according to our model, the presence of residential moving costs explains why unemployed individuals who reside closer to the CBD search more intensively for jobs, because these moving costs induce these individuals to pay higher rents for which they are not compensated in equilibrium. This contributes to our understanding of the relationship between poor job access and unemployment as discussed in the mismatch literature (Holzer, 1991). To conclude, we call for a better understanding of residential moving costs on wages, unemployment and rents in urban markets. Our study should be seen as a first step towards this goal. More realistic models, for example urban models that include on-the-job-search, endogenous firm location and congestion, may be needed to confirm our results.

Appendix 1: The wage equation

Equation (11) implies that:

$$W - U^e + U^e - U = \frac{\beta}{1-\beta}\frac{p-w}{r+\lambda}, \tag{A1}$$

where U^e denotes the expected lifetime income of an unemployed job seeker (the expectation is taken from the perspective of the firm that does not know the commuting costs of the new employee). The expected lifetime utility of an unemployed job seeker can be calculated combining (3) and (11), taking expectations using (9).

$$rU^e = -R^e + \frac{\beta\theta c}{1-\beta}. \tag{A2}$$

From equation (3) it follows that:

$$U - U^e = -\frac{R - R^e}{r + \theta q}. \tag{A3}$$

Equation (2) can be rewritten as:

$$W - U^e = \frac{w - t - R + \lambda(U - U^e) - r + U^e}{r + \lambda}. \tag{A4}$$

Substituting (A2), (A3) and (A4) into (A1), reveals that:

$$\frac{w - t - \frac{\beta\theta c}{1-\beta} - \lambda \frac{R - R^e}{v + \theta q}}{r + \lambda} + \frac{R - R^e}{r + \theta q} = \frac{\beta}{1-\beta}(p - w) \,. \tag{A5}$$

Reordering gives us wage equation (12).

Appendix 2: Rewriting the wage equation

$$R - R^e = \frac{r + \theta q}{r + \theta q + \lambda}(w - w^e - (t - t^e)) = -\frac{r + \theta q}{r + \beta\theta q + \lambda}\beta(t - t^e), \tag{B1}$$

since $w-w^e-(t-t^e) = ((1-\beta)-1)(t-t^e)+(1-\beta)\theta q(R-R^e)/(r+\theta q)$. Substituting (B1) into (12) gives (13).

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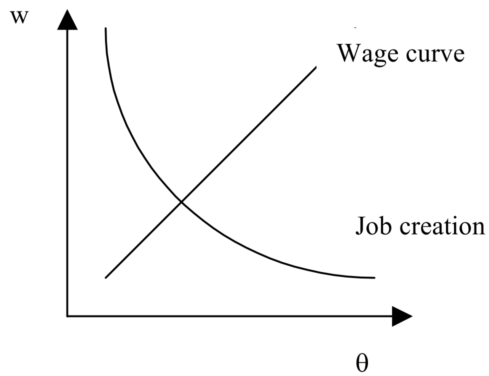

Figure 1