

Abstract

Models of ‘modern monopsony’ based on job differentiation and/or search frictions seem to give employers non-negligible market power over their workers while avoiding the assumption of ‘classical monopsony’ that employers are large in relation to the size of the labour market that many labour economists find implausible. But, this paper argues that this is somewhat of an illusion because modern theories of monopsony do assume that labour markets are ‘thin’, although in a more subtle way than the classical models.

The paper also argues that there is evidence that labour markets are ‘thin’ in a way that gives employers some market power over their workers. It presents a model that combines both the job differentiation and search models of modern monopsony and derives predictions about the relationship between wages and commuting. The paper uses UK data to argue that there is good evidence for these predictions: that there is a robust correlation between wages and commuting distance that is the result of worker job search in a thin labour market, that those with longer commutes are not, on average, fully compensated for them and that there is substantial ‘wasteful’ commuting.

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The Real Thin Theory: Monopsony in Modern Labour Markets

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Introduction

I have recently written a book (Manning, 2003) arguing that our understanding of labour markets will improve if we think of employers as having some monopsony power over their workers. To many economists this seems a very odd thing to have spent the best years of your life doing as monopsony does not get a good press in much of labour economics. One of the reasons for this is that the word ‘monopsonist’ conjures up images in the minds of labour economists that seem irrelevant to most modern labour markets.

The definition of a monopsony in the Oxford English Dictionary is “a condition in which there is only one buyer for the product of a large number of sellers”, and the typical labour market example is a mining or mill town in the early days of the Industrial Revolution. Of course, even then there were very few (arguably none) labour markets in which there was literally only a single employer and workers always had some ability to move location so that one should not take the ‘mono-’ part of the prefix too literally. Better to think in terms of their being few potential employers within ‘reasonable’ distance of workers so that, from the perspective of a worker, the labour market appears to be ‘thin’. But, most economists are probably rightly sceptical that labour markets are ‘thin’ in the sense of there being few potential employers: the classic reference on this subject is Bunting (1962) who estimated employment concentration ratios for unskilled and semi-skilled workers in 1774 US labour market areas (typically a county) in 1948 and concluded that “the extent of concentration among private, profit-oriented firms in the not-skilled portions of the labour market is low” (Bunting, 1962, p. 112). While considerable time has passed since then, it is unlikely that the facts are very different now.

Classical monopsony could also occur when there are many employers but they collude in wage-setting so that there are only a few effective employers in the labour market.

Adam Smith strongly believed that employer collusion was a frequent outcome in labour markets: “we rarely hear, it has been said, of the combinations of masters, though frequently of those of workmen. But, whoever imagines, upon this account, that masters rarely combine, is as ignorant of the world as of the subject. Masters are always and everywhere in a sort of tacit, but constant and uniform combination, not to raise the wages of labour above their actual rate. To violate this combination is everywhere a most unpopular action, and a sort of reproach to a master among his neighbours and equals. We seldom, indeed hear of this combination, because it is the usual, and one may say, the natural state of things, which nobody ever hears of.” (Smith, 1986, p. 169). And, he then goes on to contrast this with the fact that combinations of workers “are always abundantly heard of” (Smith, 1986, p. 169). The view that employer collusion is widespread is also a very unfashionable view today though I suspect that Adam Smith’s assessment of the labour market commentators of his day applies also to the labour economists of today who are inordinately fond of writing papers about how workers collude to exercise market power while ignoring employer attempts to do the same. But, that is a subject for another day¹.

So, the two classical sources of monopsony power - a small number of and/or collusion among employers – both imply that labour markets are ‘thin’ and both do not seem particularly relevant to many labour markets today. But, the revival in interest in monopsony that has occurred in recent years (see Bhaskar, Manning and To, 2002, for a brief survey) is not based on these classical notions and appears, at first sight, to avoid the assumption that, from the perspective of individual workers, the labour market is ‘thin’. However, as will be seen, this appearance is misleading.

One can identify two sorts of ‘modern monopsony’ models. First, there are the models that assume workers have full information and no mobility costs but that jobs are

¹ For example, the ‘ethnographic’ study of labour markets by Reynolds (1951) appears to reach much the same conclusion as Adam Smith: “each personnel manager knows that, if he steals a worker today, someone else will

differentiated in some way. Examples of this sort of model are Helsley and Strange (1990); Bhaskar and To (1999); Hamilton, Thisse and Zenou (2000) and Brueckner, Thisse and Zenou (2002). All of these models are based on the model of product differentiation of Salop (1979) in which both workers and employers are located at some point in characteristics space (typically modelled as a circle) but, because of fixed costs of firm creation, employers do not exist at all points so that employers have some market power. In these models, jobs might be differentiated by physical location or skill or any other plausible characteristic. But, in all of these models the extent of employer market power is related to how dense are employers in the characteristics space. When the characteristic space is geographical location, it is easy to see how this relates to the classical notion of 'thin' labour markets being the source of monopsony power. It does not take much imagination to see how these models effectively assume that labour markets are 'thin' when the characteristic space is defined in some other way. Of course, once one recognizes that workers care about, and jobs are distinguished by, a whole range of characteristics, one might argue that labour markets are much 'thinner' than they appear at first sight from a study like that of Bunting (1962) who focused only on a single dimension of employer heterogeneity (i.e. location). A good analogy is our view of the heavens: the stars appear close together but this is an illusion caused by projecting three dimensions onto two.

The second group of modern theories of monopsony are search models (the canonical versions of which are probably Albrecht and Axell, 1984 and Burdett and Mortensen, 1998). These models typically assume (in the interests of simplicity) that all jobs are identical but that it takes time and/or money for workers to change jobs. These search frictions inevitably give employers some market power, even if employers are infinitesimally small in relation to the market as a whole. The source of employer market power in this model appears to be the

steal from him tomorrow, and all have an interest in playing by the game." (p. 51)

‘reasonable’ assumption that a wage cut of a cent will not cause all workers to immediately leave the firm for employment elsewhere, and these models appear to avoid the ‘unreasonable’ assumption that labour markets are thin.

However, this appearance is misleading. For example, in the model of Burdett and Mortensen (1998), the extent of employer market power is determined by the rate at which job opportunities arrive relative to the job destruction rate: the lower the arrival rate of job offers, the more market power employers will have. But, from the perspective of a worker, a labour market in which, at any moment in time, there are only a few employers offering jobs, might reasonably be described as ‘thin’ even if there are a very large number of potential employers in the market as a whole.

So, it would seem that if one wants to argue that employers have significant market power, one cannot avoid arguing that, in the appropriate dimension, labour markets are ‘thin’ and that one can see evidence of this in various labour market phenomena.

Why are job opportunities hard to come by as assumed in search models? These models are typically set-up as if awareness of employers is imperfect, but this is not very plausible. It is not hard to find employers: just look them up in the yellow pages. It may be that workers are not all interested in all jobs (i.e. the job differentiation models have some element of truth in them) but it still would seem relatively easy to find employers for whom a worker is potentially interested in working. It is vacancies, not employers, that are hard to find. But, in models of monopsony the wage is below marginal product so that vacancies should not be hard to find as employers should be only too happy to employ workers who knock on their door. This fact that vacancy rates and durations are typically very low causes some to doubt the relevance of monopsony. However, as demonstrated in Manning (2003, Chapter 10) the stylized facts are not difficult to reconcile with the existence of substantial monopsony power once one recognizes that the creation of a job typically involves an ex ante

expenditure on capital and providing a market for the output that might be produced. Put simply, employers do not create jobs they do not expect to be able to fill. So, we should think of it as being vacancies not employers that are difficult to find. And the costs of establishing jobs give good reasons why vacancies are hard to find.

Where is the evidence that labour markets are ‘thin’? Manning (2003) argued that, if one opens one’s eyes, the evidence is all around: among other phenomena readily explained by employer market power are the existence of wage dispersion for identical workers, the correlations between employer characteristics and wages, part of the gender pay gap, employers paying for the general training of their workers, and the puzzling problem of finding disemployment effects of the minimum wage. But, in this paper, we focus on another aspect of labour markets that combines features of many of the different models of monopsony described above.

The first section presents a search model in which job opportunities arrive only occasionally and in which jobs are distributed in geographical space, thus combining elements of both the search and job differentiation models described above. It shows how these two sources of ‘thinness’ ultimately have very similar effects. It derives a number of predictions that are then tested (using British data) and evaluated against competing hypotheses.

First, it is argued that this model can explain the positive relationship between wages and commuting distance as the result of workers in ‘thin’ labour markets, trading off wages and distance. The second section shows that part of the observed relationship between wages and commute can be explained in this way.

Secondly, it is argued that workers will not, on average, receive full compensation for longer commutes so that utility is falling, on average with the length of commute. Evidence from job separations in the third section of the paper is consistent with this prediction.

Finally, it is argued that the model can explain the existence of ‘wasteful’, ‘excess’ or ‘cross’ commuting’, the phenomenon by which we see some workers living in A and working in B while apparently identical workers do the opposite, something that could not happen in a frictionless labour market. This phenomenon is well-known in the urban economics literature but less well-known in labour economics. The fourth section argues that this is a real phenomenon and is another piece of evidence that labour markets are ‘thin’.

To sum up, this paper argues that modern theories of monopsony do effectively assume that labour markets are ‘thin’ though the reasons for this are more subtle than in classical monopsony. And, it argues that one should not be ashamed of making that assumption as the empirical evidence suggests that labour markets are ‘thin’ in the sense of there being few employment opportunities available at any moment in the immediate geographical locality of a worker.

1. A Simple Model of Worker Search in Geographical Space

In this section, I present a model of a labour market in which jobs are characterised by wages and location (both of which workers care about) but job opportunities arrive only occasionally (see Simpson, 1992, for another analysis that has taken this approach). To keep matters simple (though none of the results derived below depend on it) assume that every point in space has the same level of employment, the same level of population and wage offer distribution². This is obviously not a realistic assumption but the purpose is to derive predictions about how, even in such a labour market, one would expect to observe a positive

² One might wonder why a labour market in which employers have market power inevitably has wage dispersion. There are some appealing models e.g. Burdett and Mortensen (1998) that have equilibrium wage dispersion among identical employers but the source of this result is the rather implausible assumption that all workers will change jobs for an infinitesimally small wage rise. It is better to think that wage dispersion exists for other reasons. Imagine that all employers at a particular location face the same supply curve of labour but

relationship between wages and commuting time even though there is no intrinsic relationship between location and wages.

Suppose that workers get utility from log wages, w , but dislike having to travel a long time, t , to work. Suppose that utility, v , is given by:

$$v = w - \alpha t \quad (1)$$

so that α is a measure of how much travel time is costly. α can also be interpreted as a measure of how, from the perspective of workers, plentiful are potential employers within ‘reasonable’ commuting distance and so can be interpreted as a measure of ‘classical’ monopsony. To keep matters simple, we assume that workers are unable to change their residential location³. This can be justified by the fact that homes are less mobile than jobs: approximately 20% of workers have job tenure less than a year compared to 10% with residential tenure of less than a year.

Job offers consist of a wage from a particular employer at a particular location. Assume that the wage offer distribution is given by $F(w)$ which is independent of employer location because, with the assumption of uniformly distributed workers and employers, there is no reason to think otherwise.

Assume that job offers at a distance t from the worker arrive at a rate I independent of whether the worker is currently employed or not. As on- and off-the job search are equally effective the reservation utility level will be given by b , the utility obtainable when out of work. The assumption that job offers are uniformly distributed over distance means that the

are themselves heterogeneous e.g. in productivity. Different employers will choose different points on the labour supply curve and the consequence of this will be wage dispersion.

³ It would be interesting to consider the optimal residential location of workers if there is a fixed cost of moving: in the model used here it will be in the interests of workers to move their home to their job only if the wage is above a critical level as low-wage jobs are not expected to last long.

arrival rate of any job offer at all is infinite but the arrival rate of job offers at a commuting distance that is sensible for the worker to consider is finite.

Denote by $I(v)$ the arrival rate of job offers that offer utility v . If this job is at distance t then it must be offering a wage $(v + at)$. Hence, $I(v)$ must satisfy:

$$I(v) = I \int_0^{\infty} f(v + at) dt \quad (2)$$

Changing the variable of integration to w we have that:

$$I(v) = \frac{I}{a} \int_v^{\infty} f(w) dw = q [1 - F(v)] \quad (3)$$

where $q \equiv (I/a)^4$. q is a composite measure of the extent of frictions in the labour market that combines both the arrival rate of job offers and the costs of distance. Note that labour markets can be ‘thin’ in this set-up either because there is monopsony in the ‘classical’ sense of their being few employers within reasonable commuting distance (α is high) or in the ‘modern’ sense of opportunities to change job being hard to find (λ is low).

Now consider the employment rate. Workers who are not in employment will only accept offers that give a level of utility above b , the reservation level. Using (3) the arrival rate of job offers that are above b is given by:

$$m = q \int_b^{\infty} [1 - F(v)] dv = q S(b) \quad (4)$$

⁴ Also, note also that the job offer arrival rate in (3) depends on the cumulative density function and not the density function $f(w)$ as it does in the traditional set-up.

where we define:

$$S(v) \equiv \int_v [1 - F(x)] dx \quad (5)$$

Hence, if jobs end at a rate δ , the non-employment rate, u , will be given by:

$$u = \frac{d}{d + qS(b)} \quad (6)$$

Obviously, a higher cost of travel will be associated with a higher non-employment rate as it worsens the utility offer distribution. Ideas that a lack of jobs in a locality can explain the low employment rates of the residents have been behind the ‘spatial mismatch’ hypothesis in the U.S (see Kain, 1968 or Holzer, Ihlanfeldt and Sjoquist, 1994 inter alia) that the lower employment rates of blacks can be explained, at least in part, by the lack of jobs in the areas where they live.

But, this paper is more concerned with how wages and utility vary with commuting. Some answers are contained in the following Proposition.

Proposition 1:

- a. the wage distribution across workers is increasing in the commute (in the sense of first-order stochastic dominance) if the wage offer distribution satisfies the condition that $\ln[1-F(w)]$ is concave in w .

- b. the distribution of utility across workers is decreasing in the commute (in the sense of first-order stochastic dominance) if the wage offer distribution satisfies the condition that $\ln f(w)$ is concave in w .

Proof: See Appendix.

It should be emphasized that the conditions provided in this Proposition are sufficient not necessary (and are common in deriving comparative statics results in search models – see Burdett, 1981) and that these comparative statics are what one might expect. Jobs at all locations have a common reservation utility level so, as the commute rises, the reservation wage also rises to off-set the greater cost of commuting. Hence, we might expect that the distribution of accepted wages is increasing in the commute, the complication arising from the fact that jobs have ‘weights’ that depend on the utility offered in the distribution of wages across workers.

Similarly as the commute rises, the distribution of utility offers falls as the wage distribution is assumed to be unaltered. But, as the reservation utility level remains the same, the main effect of this is for a higher fraction of job offers to be rejected. The condition given in part (b) then provides a condition under which the truncated utility distribution is declining in distance.

One can interpret the result in Proposition 1 in the following way. The process by which workers trade-off wages and commute results in an implicit compensating differential. It is implicit because wage offers are assumed not to vary with the location of firms or workers. But this compensation is, on average, less than complete: workers who travel longer distances to work tend to be worse-off.

What happens in this labour market as frictions disappear and the labour market becomes ‘thick’. One can model this as a labour market in which $q \rightarrow \infty$. The average

commute time will go to zero and every worker will receive the highest wage offer in the market. This is the result of the assumption that jobs and homes are evenly spread in geographic space. While this is a convenient assumption for demonstrating how a relationship between wages and commute time can emerge even in a labour market where there is no intrinsic relationship between wages and location, urban economics has largely been concerned with the analysis of markets in which jobs and homes are located at different points in space. In testing the predictions of Proposition 1, it is important to bear in mind the predictions of these urban economics models.

Whether the predictions of Proposition 1 are supported by the data is the subject of the following sections.

2. Empirical Correlations Between Wages and Commutes

The model of the previous section predicts that we would expect to see a positive relationship between wages and commutes. This hypothesis is investigated using two British data sources, the Labour Force Survey for 1993-2001 and the British Household Panel Survey for 1991-2001. In the autumn quarter of every year, the Labour Force Survey asks about average travel-to-work time and the method of transport. The BHPS asks similar questions in every wave.

In both data sets the mean daily commute is about 45 minutes. The unconditional distribution of daily commutes is presented in Table 1: the distribution is very similar for both the LFS and BHPS. We truncate the distribution at 3 hours per day as there are a handful of extremely large daily commutes reported that otherwise have a disproportionate impact on the results.

Table 2 presents some estimates of the correlation between log hourly wages and commutes⁵. The first row shows the estimate when the only regressor in the earnings function is the length of commute. The coefficient implies that an extra hour of commuting each day is associated, on average, with an increase in wages of 27 log points.

The next row then introduces other regressors: first, regional dummies, then employer variables and finally personal variables. These tend to reduce the size of the coefficient on the commute though it is the introduction of the personal characteristics that has the biggest impact and, among the included personal characteristics it is education and occupation that play the most important role. Those with more education and in the higher-status occupations are more likely to have both high wages and a long commute. There is a sense in which the model of the previous section predicts this: as the wage offer distribution rises, one can show that expected commute will rise (see Proposition 2 in the Appendix) basically because the maximum distance that workers are prepared to travel is increasing in the average level of wages. This is consistent with the evidence cited in Simpson (1992) that, even when high-skill workers both live and work in suburban areas, they are less likely to live in the areas where they work.

With all the controls included, an hour-long daily commute is associated with wages that are 7-9% higher. Is this effect large or small? To benchmark it, consider what would be predicted from theory. Suppose, that the only cost of commuting is the loss of time. If the wage associated with a commute of t is W then utility can be written as $v(WH, L-t-H)$ where H is hours of work and L is total available time. If we log-linearize this utility function we have that:

$$dv = H v_y dW - v_L dt \quad (7)$$

⁵ Note that Proposition 1 is only about correlations and not about causality: this should be borne in mind in interpreting the results here.

This can be written as:

$$dv \propto dw - \frac{v_L}{Wv_y H} dt \quad (8)$$

where $w = \ln(W)$. Furthermore, if one thinks of hours of work as being a free choice for the worker then we will have $(v_L/v_y) = W$ so that (8) can be written as:

$$dv \propto dw - \frac{1}{H} dt \quad (9)$$

If workers were fully compensated for longer commutes then the coefficient on commuting in an earnings equation where the dependent variable is the log of hourly earnings should be one over the daily hours worked so an 8-hour day should be associated with a coefficient on the commute of 0.125⁶. The actual coefficient is of this order of magnitude but somewhat smaller, perhaps suggestive of utility falling as distance from work increases.

While these estimates are consistent with the model presented in the previous section, they are also consistent with a number of other hypotheses. The rest of this section argues that, while there may be some truth in some of these other explanations, a sizeable part of the relationship between wages and commute is best explained as the outcome of a process of search in a thin labour market.

The first alternative hypothesis is simply that more able workers choose, on average, longer commutes (as shown in Proposition 2 in the Appendix) essentially because their higher wages make commuting longer distances worthwhile (see also, Benito and Oswald,

⁶ This formula appears more frequently in the transportation literature as the trade-off between weekly earnings and the commute should be the hourly wage – see Small (1992) for a discussion of results on the implied value of time in this literature.

1999⁷). The inclusion of education and occupation as controls in the earnings function reduces the size of the coefficient on the commute as the better-educated tend to live further from work. If observed worker quality has this effect then it may be that unobserved worker quality can explain all the correlation. One way to deal with this criticism is to control for individual fixed effects and to see whether, on average, changes in commute time are related to changes in wages.

The fixed effect estimators are presented in the fifth row. The coefficient on commute is much smaller than previously. But, there are a number of reasons to think that this might be contaminated with measurement error. First, we only want to look at changes in commute time caused by changes in job and not that caused by changes in residence (though this is not a problem for the LFS as it is address-based) or from changes in method of travel to work or in changes in ease of transportation. The sixth row of Table 2 restricts attention to job movers for whom the change in the commute is likely to have a higher signal-to-noise ratio and finds a larger coefficient on commuting time.

These results are consistent with those reported in a number of papers in the urban economics literature that look at the relationship between wages and commutes. Madden (1985) uses the PSID to investigate the existence of ‘wage gradients’, how wages vary with distance from the central business district (CBD). However, the actual variable used is not distance of the job from the CBD but distance of the job from the residence. She regresses change in length of commute on the change in wages for those who changed their jobs only, changed their jobs and residence and for those who changed their residence only. For all those who changed jobs there is a positive relationship between wage change and change in

⁷ Benito and Oswald (1999) also use the BHPS but run a regression of commute on log wages (i.e. do the reverse regression) and try to identify the demand for commuting by instrumenting the wage. They reach the conclusion that those with higher wages dislike commuting. However, my experimentation suggests that their results are extremely sensitive to specification.

commute (note that this can be interpreted as a fixed-effects estimate), exactly as we find in our data sets.

Zax (1991) uses data from a single company and regresses wages on commutes, finding a positive relationship. He interprets this result as being evidence of an explicit compensating differential paid by employers to workers with long journey-to-work times. But, the interpretation is rather implausible on both theoretical and empirical grounds. In a competitive labour market, employers should pay the same wage to all identical workers irrespective of their length of commute: otherwise they would only want to employ workers with short commutes and, if the market is competitive there is no reason why an individual employer would not be able to do this. This theoretical prediction of the competitive model also seems in line with everyday experience that suggests that asking for a pay rise because one has moved further away from work is unlikely to be successful. A more plausible interpretation of the Zax results is that it picks up the fact that higher-level occupations are likely to have high wages and high commutes (his regressions have only rudimentary controls for occupation).

Holzer, Ihlanfeldt and Sjoquist (1994) include measures of both commute time and distance (separately and jointly) in wage equations. For whites they find positive returns to both time and distance while for blacks there are larger returns to distance but smaller returns to miles.

But, while these papers find empirical results consistent with ours, their interpretation of them is different and is based on different theoretical explanations to be found in the urban economics literature. This literature suggests a number of hypotheses that might explain the correlation between wages and commute.

First there is one explanation based on the endogeneity of household location. In the classical urban economics model of a monocentric city in which all employment is based in

the CBD, workers of different quality will receive different wages. They will then choose to live at a certain distance from the CBD and, given that all employment is at the CBD, the household location determines the length of commute. For households with higher wages there is a trade-off between the higher demand for housing which, given that rents decline with distance from the CBD, makes them choose to live in the suburbs with a long commute and the fact that their time is more valuable which makes them want to live in the inner-city with a short commute. The 'US' pattern is thought to be that those with higher wages will choose to live further from the CBD while the 'EU' pattern is often thought to be the reverse (see Brueckner, Thisse and Zenou, 1999, for a recent discussion of this phenomenon).

It is simple to examine the explanatory power of this hypothesis as both the LFS and BHPS are household-based surveys, sampling all individuals within the household. As all individuals within a household must reside at the same location, one can control for location by estimating models with household fixed-effects. The results of doing this are reported in row 7 of Table 2. The coefficient on commuting is virtually unchanged from the individual regressions implying that within households those with a longer commute tend, on average to have higher wages. One could even argue that this estimate understates the true effect as there is an incentive for households to locate near the job of the high-earner given that the shadow value of their commuting time is higher⁸.

While the empirical findings above cannot be explained away by models in which all workers work in the CBD, they can be more readily explained by models in which some employment is at locations away from the CBD⁹. There has been discussion of this case in the urban economics literature. Associated with every location will be a wage for a given type of worker so that an individual worker will face a wage $w(t)$ for a commute of distance t

⁸ White (1977) presents a theoretical model that claims to explain why women have shorter commutes. But, this theoretical result derives from the assumption that housing is cheaper at female places of work than male.

and the actual commute will then be chosen to maximize utility $w(t) - at$. Wages in the CBD will typically need to be higher to compensate workers for the longer commute they need to make to go there, so that there is what is called a ‘wage gradient’¹⁰.

This result is normally derived for the case of workers with identical travel costs in which case the wage gradient must fully compensate workers for longer commutes. But, suppose that there are variations in travel costs, even among individuals of identical ability. As the model is based on the assumption of a competitive labour market, wages will be the same for workers of a given ability at a given location even if there are differences in travel costs. The model then predicts that, given household location, the relationship between wages and commute should be the same for those with different levels of travel costs, the only impact of higher travel costs being that a shorter commute is chosen¹¹. In contrast, the search model of the previous section would predict that the relationship between wages and commute should be stronger for those with higher travel costs.

How can we identify workers with different travel costs? One possibility is to use the approximation to the utility function in (9) which, when compared with (1) can be seen to show that workers who work shorter hours have a larger implicit cost of commuting.

Table 3 presents some evidence on whether there is evidence that part-time workers have higher ‘returns’ to commuting. It reports the results from the estimation of earnings equations where the commute variable is included plus the commute divided by hours (plus hours as an extra control). The LFS contains information on the number of days per week

⁹ For example, to explain the within-household results one might think that some two-person households consist of a main earner who works in the CBD and a second earner who works locally. Households with better-paid workers might then prefer to locate further from the CBD.

¹⁰ Adam Smith would appear to have been the first person to have estimated wage gradients: “the wages of labour in a great town and its neighbourhood are frequently ... twenty or five-and-twenty per cent higher than at a few miles distance. Eighteen pence a day may be reckoned the common price of labour in London and its neighbourhood. At a few miles distance, it falls to fourteen and fifteen pence. Tenpence may be reckoned its price in Edinburgh and its neighbourhood. At a few miles distance, it falls to eight pence” (Smith, 1986, p. 177). If one thinks of a ‘few miles’ as being 3-5 and of the speed of walking (the predominant means of getting to work in those days) as being 3 miles per hour, Smith’s estimates are broadly comparable with ours.

worked so the hours variable used is basic usual hours divided by days per week worked as this is what the theory would suggest is important. In the BHPS, there is no information on number of days worked so weekly hours are divided by 5.

For each data set, three specifications are reported: a cross-sectional regression with all the controls included in Table 2, and first-differenced equations for all workers and for job movers only. In all cases the variable interacting commute with hours has a significant positive coefficient suggesting that those who work fewer hours have a higher apparent 'return' to commuting. This is particularly true in the fixed effect regressions which suggests the results cannot easily be explained by a failure to adequately control for labour quality. There is evidence for the 'implicit' compensating wage differential predicted by the theory of worker search in 'thin' labour markets¹².

One might be concerned with the inclusion of a potentially endogenous variable like hours in these regressions. Most part-time workers in Britain are women and the main reason they are working part-time is because they have responsibilities for young children. So we might expect that women with young children have particularly high costs of commuting and the search model then predicts a high apparent return for them. The last two rows of Table 3 investigate this: it is indeed the case that women with dependent children have higher 'returns' to commuting than the aggregate returns presented in Table 2.

An alternative way of testing the hypothesis that the positive relationship between wages and commuting represents the explicit compensating differentials of wage gradients is to see whether there is full compensation for longer commutes. The theory of 'wage

¹¹ Note that the level of travel costs in the labour force as a whole will influence the 'return' to commuting in the market but that individual travel costs will not have any effect.

¹² It is perhaps worth a footnote to remark that it is often very hard to find evidence of explicit compensating wage differentials when there is vertical differentiation in the non-wage characteristics of jobs. But, the results here suggest that implicit compensating differentials for horizontally differentiated job characteristics that are the outcome of workers systematically selecting jobs may be easier to find in the data.

gradients' predicts there should be full compensation, the 'thin' markets hypothesis that it will be less than full (as shown in Proposition 1). This is the subject of the next section.

3. The Impact of Wages and Commute on Separations Rates

This section investigates the relationship between separation rates, wages and commuting time. If those with longer commutes are fully compensated there is no reason to think that separation rates should be higher for these jobs. On the other hand, if there is, on average, less than full compensation, we would expect to see higher separation rates for those with long commutes.

In the model of the first section the separation rate is a function of utility received in the job i.e. can be written as $s(w - at)$ so that, if the higher wages received by those with longer commutes exactly compensate them for the extra travel time, the ratio of the absolute value of the coefficient on the commute to the coefficient on the wage in a separations equation should be equal to the coefficient on the commute in the wage equations estimated above.

On the other hand, if there is less than full compensation (as suggested by Proposition 1 above) then we would expect to find a more powerful disutility associated with commute in the separations equation than from the wage equation. The idea of using separation rates to estimate the disutility of non-wage job characteristics was proposed by Gronberg and Reed (1994), analysed in a search model by Hwang, Mortensen and Reed (1998) and has been applied to the specific case of the disutility associated with commuting by van Ommeren, van den Berg and Gorter (1999). van Ommeren, van den Berg and Gorter (1999) also have a useful discussion of when the Gronberg-Reed methodology may fail: if job search intensity is

endogenous and job search costs both time and money, then because those with long commutes and higher wages have different amounts of time and money than those with short commutes, there may be independent effects of commuting time and wages in the separations equation.

Table 4 presents some estimates of separation elasticities from the LFS and BHPS. In the LFS, we observe individuals in employment in a given quarter and then a quarter later. We can identify whether they have left the initial job and are subsequently either out of work or in another job. However, there is no information on economic activity at any point in time other than the two observations e.g. if an individual is in a new job, we do not know whether there was an intervening period of non-employment or whether there was a direct job-to-job move. For the BHPS we observe employment at one interview and then (approximately) a year later. We can identify whether the individual is still in the original job and, furthermore, whether there has been any spell of non-employment between the two interviews.

We model the instantaneous separation rate, s , as:

$$s = e^{b \cdot x} \tag{10}$$

where x is a vector of relevant characteristics (that will include the log wage and the commute). The probability, $p(x)$, of remaining in the initial job in a period of time t is then given by:

$$p(x) = e^{s(x)t} = e^{b \cdot x + \ln(t)} \tag{11}$$

We will model a binary variable that takes the value one if the individual stays in the job and zero otherwise. Given (11), the appropriate likelihood function is the complementary log-log model. We estimate separations models for all separations (i.e. those to other jobs and non-

employment) and only for those to other jobs (on the grounds that these are more likely to be voluntary on the part of workers and are more likely to reveal the preferences of workers).

Table 4 presents the estimates. If both log wages and commute are included in the separations equation, then we find the expected effect: separations are declining in the wage and increasing in the commute. If hours of work are interacted with the commute, one finds that the ‘cost of commuting’ is larger for those who work short hours. The implied value of ‘ α ’, the cost of commuting is much larger than that derived from the wage equations which is consistent with less than full compensation. It is, perhaps, rather too large to be plausible given that one might expect the coefficient to be $(1/H)$ where H is daily hours). One possible source of the problem is that measurement error (or transitory variation) in the wage will tend to reduce the coefficient on the wage in the separations equation but not the ‘coefficient’ in the wage equation as it is the dependent variable there.

One way of dealing with this is to estimate a separations equation in which the wage is dropped and only the commute is included. If there is full compensation, there is no reason why those with a longer commute should have higher separations rates but, if there is less than full compensation, there is. These models are also estimated in Table 3. Those with longer commutes do have significantly higher separations rates and those who work short hours have a larger effect of commuting time on separations.

The evidence in this section is consistent with our model of a ‘thin’ labour market in which there is less than full compensation for longer commutes. The next section presents evidence on ‘wasteful’ commuting.

4. Wasteful Commuting

In the theoretical model of the first section, there is no reason why anyone should have to work in any other location than where they live because of the assumption that the distribution of homes and jobs is identical. But, because of the thinness of labour markets, there is some commuting in equilibrium. In this model all commuting is ‘wasteful’.

As soon as the location of jobs differs from that of homes, some commuting is inevitable. But, one can still ask whether the amount of commuting is excessive. There is already a literature on this ‘wasteful commuting’ that is familiar to urban economists but less familiar to labour economists. This research was started by Hamilton with Roell (1982) who argued that 90% of urban commuting is wasteful. They drew the conclusion that there was something seriously wrong with urban economic models, though they did not identify what. However, their computations of the extent of ‘wasteful commuting’ were based on a stylised model of a city in which there are smooth uniform employment and population gradients.

Later papers in this literature have used the actual distribution of jobs and homes to compute the actual amount of commuting and the minimum amount that would occur if, given the distribution of residences, workers were assigned job locations to minimize commute¹³. So, if there are L locations and the actual number of workers who live in location i and work in location j is given by N_{ij} and the distance between the two locations is given by d_{ij} , then the actual total commuting, TC , is given by:

$$TC = \sum_{i=1}^L \sum_{j=1}^L d_{ij} N_{ij} \quad (12)$$

¹³ Or, as is sometimes done, one can interpret the ‘efficient’ outcome as keeping job locations fixed and re-arranging places of residence. Though, as this involves breaking up and re-arranging marriages and separating children from their parents, this is a less appealing interpretation.

and the minimum total commute is found by choosing the number of people who should live in i and work in j , N_{ij}^* to solve the linear-programming problem (what is known as a ‘transport’ problem):

$$\begin{aligned}
 & \min \sum_{i=1}^L \sum_{j=1}^L d_{ij} N_{ij}^* \\
 & \text{s.t.} \quad \sum_{i=1}^L N_{ij}^* = \sum_{i=1}^L N_{ij} \quad \forall j \\
 & \quad \quad \sum_{j=1}^L N_{ij}^* = \sum_{j=1}^L N_{ij} \quad \forall i
 \end{aligned} \tag{13}$$

The two constraints say that, for every location the number of people assigned to work there must be equal to the actual number who work there and that the number of people who live there is equal to the actual number.

This kind of problem was first solved by White (1988) who concluded that wasteful commuting was only about 10% of actual commuting in a sample of US cities. Her conclusion was that ‘wasteful’ commuting was empirically unimportant. Her conclusions were criticised by Hamilton (1989) who argued that her results were largely the result of using large zones. Subsequent studies (e.g. Small and Song, 1992; Merriman et al, 1995) have confirmed this conclusion.

Here we present some results on ‘wasteful’ commuting in Greater London using data from the 1991 Census. For a 10% sub-sample information is tabulated on the number of people who live in a particular ‘ward’ and work in every other one. Greater London is divided into 782 wards with an average area of 2 square kilometres. The sample is restricted to those who both live and work in wards in the Greater London area because it is important to ensure that the number of residents is equal to the number of jobs¹⁴.

¹⁴ For Greater London, inward commuting is obviously very important and, not surprisingly leads to a reduction in the measure of wasteful commuting (Frost, Linneker and Spence, 1998).

Everyone is assumed to live and work at the geographical midpoint of each ward and commuting is measured in terms of distance between midpoints as no other information is available. The first column of Table 5 shows that the average one-way commute is slightly over 8km for men and 6km for women. When one solves the linear programming problem one finds that the minimum commute is only 55% of this level suggesting a substantial amount of wasteful commuting. Note that this will be an under-estimate of the actual minimum commute because we are forced to work with a 10% sub-sample. One way of visualizing this for those familiar with the London underground is to note that in the rush hour, the platforms of stations within the 14km long Circle line are equally busy in both directions implying that, for every person going in one direction, there is another going in the opposite direction.

There are a number of potential problems with arguing that these estimates support the view that labour markets are thin. First, it may be that distance is a poor measure of commuting time: for example, it is much faster to travel 15km down a tube line than to attempt to drive 5km where there is no tube line. But, one feature of the solution to the transport problem is that as many people as possible should work where they live however the distances between points are measured¹⁵. The actual numbers who do are much smaller than the maximum theoretically possible: for example, column 3 of Table 5 shows that rather small numbers of people (5% of men and 10% of women) live and work in the same ward but column 4 shows that the maximum theoretically possible is 10 times this for men and 6 times this level for women. These measures are also indicative of a large amount of 'wasteful' commuting.

¹⁵ This assumes the 'triangle' inequality is satisfied i.e. that the distance between A and B is less than the sum of the distance between A and C and C and B. This is reasonable as one can always travel from A to B via C. It also assumes that there is zero distance for all travel within an area: this is not strictly speaking true of our wards.

A more serious problem is that the computation of wasteful commuting assumes that all workers are freely substitutable within jobs: it ignores segmentation in the labour market. So, when we observe someone living in A and working in B and someone else living in B and working in A, this is classed as ‘wasteful’ commuting although A might be a brain surgeon and B might be a cleaner in which case it does not make much sense to think that they could swap jobs¹⁶.

With the UK census data, one can do something about this as the data analysed is broken down by a number of characteristics, most usefully age and occupation. Unfortunately, only univariate tables are provided so one is forced to analyze age and occupation separately. The results are also reported in Table 5. As the minimum commute must rise as one is imposing more restrictions on the minimization problem but average commute is unaffected by this decomposition, it must be the case that the extent of wasteful commuting falls. But the most striking feature is how little it falls. If the male labour market is treated as a single aggregate, disaggregating by occupation results in a rise in the minimized commute by an average of only 30 metres. Other disaggregations have a somewhat larger effect but a large amount of ‘wasteful’ commuting still remains. The same is true when one looks at the maximum number of people who could live and work in the same area: this must fall as one imposes more constraints but remains very substantially above the actual.

There is a simple reason why segmenting the labour market does not make very much difference. In the example of the brain surgeon and the cleaner given above, wasteful commuting disappears when one disaggregates because there is a negative correlation between the areas of work across occupations, a negative correlation between areas of residence across occupation and a positive correlation between the area of work of one

¹⁶ Although the fact that the ‘fraudulent’ doctors sometimes exposed are generally reported to have done as good a job as the regular doctors might suggest this is not a well-chosen example.

occupation and the area of residence of the other. But, the actual data does not look anything like this: Table 6 presents some correlations for men and Table 7 for women. In the first panel of Table 6, the correlations in the number of residents in different broadly-defined occupations across wards are presented. This shows that there is, for most occupational groups, a positive correlation in the areas where they live, the exception being that there is a negative correlation in the areas of residence for managerial/professional workers and semi/un-skilled manual workers. For most other occupational groups this correlation is quite high. The second panel examines the correlation in the areas where people of different occupations work: these correlations are all positive and higher than the correlations in area of residence. This is because jobs in London are more concentrated than homes. Finally, Panel C looks at the correlation between the numbers of people in a particular occupation living in an area and the number of people of another occupation working in that area. These correlations are all low. So, there is a high correlation in the areas where people of different occupations live and work that can explain why disaggregation makes little difference to measures of 'wasteful' commuting.

However, the labour market segments used in the analysis so far are still large and one would like to know what happens if one disaggregates further. I do not have the necessary data to do this but I would conjecture that 'wasteful' commuting is a real phenomenon that cannot be made to disappear by segmenting the labour market in a plausible way¹⁷. There are two reasons I would give for making this conjecture.

First, equilibrium wage dispersion seems to be a real phenomenon. Anybody who has ever investigated it has found that there is substantial pay variation among workers doing a tightly defined job in a tightly defined area: the 'law of one wage' does not apply perfectly.

¹⁷ Of course there is a trivial way to make 'wasteful' commuting 'disappear'. Simply assume that the market is so segmented that the labour sold by each individual is unique. But, then markets will be 'thin' in the classical sense of there not being large numbers in the market.

And, the same frictions that support the existence of equilibrium wage dispersion are also likely to lead to a certain amount of ‘wasteful’ commuting.

The second argument for believing that ‘wasteful’ commuting is a real phenomenon comes from an analogous phenomenon in another part of economics. In trade between countries, one generally observes large trade flows in both directions within industries, the phenomenon of intra-industry trade or ‘cross-hauling’. If moving goods is costly, this should not happen in a perfectly competitive market. The phenomenon of ‘wasteful’ commuting is nothing but ‘cross-hauling’ of workers.

Some commentators argue against the existence of intra-industry trade just as we have suggested some might argue against ‘wasteful’ commuting: that the market is competitive but that the industries used in most analyses are too broadly defined and there is no intra-industry trade in identical products. However, empirical studies have found that defining industries more tightly does not make intra-industry trade go away: it seems to be a real phenomenon.

The conclusion drawn by many trade economists is that intra-industry trade is indicative of imperfect competition in the product market, perhaps because of product differentiation. Imperfect competition is now a standard approach in trade theory and labour economists, faced with the existence of ‘wasteful’ commuting, should adopt a similar approach to thinking about labour markets and conclude that frictions and/or job differentiation are important and that these make labour markets, to some degree, ‘thin’.

This section has argued that the phenomenon of ‘wasteful’ commuting or cross-hauling of labour is a real feature of labour markets and that this is evidence that, from the perspective of workers, there is some ‘thinness’ in labour markets that is going to give their employers some market power over them.

5. Conclusion

This paper has argued that for employers to have non-negligible monopsony power over their workers, labour markets have to be ‘thin’, that workers have a limited range of employment opportunities at every moment. This notion of ‘thinness’ is more subtle than that used in classical models of monopsony but has much the same effect. The paper has also argued that evidence from the commuting patterns of workers does suggest that labour markets are, indeed, ‘thin’ in the dimension of geographical location and that awareness of this can help to explain some aspects of commuting that we observe. The positive correlation between wages and commute are explained, at least in part, as the outcome of a process of job search by workers who seek to both maximize wages and minimize commutes but in which the infrequent rate at which they get job opportunities makes this difficult. And, the evidence that those with longer commutes have, on average, higher separation rates is consistent with this view that more distant jobs will, on average be less appealing. Finally, the paper has argued that ‘wasteful’ commuting is a real phenomenon and one that can best be explained by the existence of sizeable frictions in the labour market. All this adds up to a picture of that labour market in which, consistent with Manning (2003), employers have non-negligible market power over their workers.

Table 1
The Distribution of Daily Commute Times

Daily Commute (Hours)	LFS (%)	BHPS (%)
0<=commute<=0.25	15.9	17.9
0.25<commute<=0.5	33.6	34.3
0.5<commute<=1.0	31.7	30.1
1.0<commute<=1.5	10.1	9.6
1.5<commute<=2.0	6.0	5.7
2.0<commute	2.7	2.4
mean	0.75	0.72

Table 2
The Coefficient on Commute Time in an Earnings Function

	LFS	BHPS	Sample	Other Controls	Estimation Method
1	0.282 (0.003)	0.266 (0.005)	All	Year	Cross-Section
2	0.254 (0.003)	0.242 (0.006)	All	Year, region	Cross-Section
3	0.184 (0.003)	0.184 (0.005)	All	Year, region, employer	Cross-Section
4	0.069 (0.003)	0.087 (0.004)	All	Year, region, employer, personal	Cross-Section
5	0.037 (0.008)	0.028 (0.005)	All	Year, employer, personal	First Differences
6	0.056 (0.018)	0.058 (0.011)	Job Movers	Year, employer, personal	First Differences
7	0.071 (0.005)	0.052 (0.009)	All	Year, employer, personal	Household Fixed Effects

Notes.

1. The dependent variable is the log of the hourly wage. The LFS sample is from 1994-2001 inclusive, the BHPS sample from 1991-2000 inclusive. The size of the LFS sample is 80136 for the cross-section samples, 16347 for the first-differenced sample and 1983 for the first-differenced job-movers. The size of the BHPS sample is 26207 for the cross-section samples, 16560 for the first-differenced sample and 2745 for the first-differenced job-movers.
2. Travel to work time is measured as the two-way daily commuting time in hours.
3. The employer controls used are employer size dummies (six in the LFS, nine in the BHPS), dummies for public sector and trade union recognition, and 77 industry dummies (77 in the LFS, 10 in the BHPS). The personal controls used are dummies for gender, black, asian, marital status, and the presence of children in the household, a quartic in experience and job tenure, 4 education dummies and occupation dummies (60 in the LFS, 9 in the BHPS). Marital status, kids and the tenure and experience variables are all interacted with gender.

Table 3
The Impact of Hours on the Wage-Commute Trade-Off

Data Set	Coefficient on commute time (standard error)	Coefficient on commute time divided by hours (standard error)	Sample	Other Controls	Estimation Method
LFS	0.06 (0.005)	0.08 (0.030)	All	Year, region, employer, personal	Cross-Section
LFS	0.01 (0.011)	0.213 (0.055)	All	Year, employer, personal	First Differences
LFS	-0.013 (0.037)	0.496 (0.226)	Job Movers	Year, employer, personal	First Differences
BHPS	0.08 (0.006)	0.063 (0.027)	All	Year, region, employer, personal	Cross-Section
BHPS	-0.01 (0.008)	0.289 (0.040)	All	Year, employer, personal	First Differences
BHPS	0.026 (0.017)	0.236 (0.082)	Job Movers, Home Stayers	Year, employer, personal	First Differences
LFS	0.098 (0.009)		Women with Young Children	Year, regional, employer, personal	Cross-Section
BHPS	0.138 (0.014)		Women with Young Children	Year, regional, employer, personal	Cross-Section

Notes.

1. As for Table 2.
2. In the final two rows, the sample is women with a youngest child aged under 5.

Table 4
The Impact of Wages and Commute on Separations Rates

		Coefficient on Log Wage (standard error)	Coefficient on commute (standard error)	Coefficient on commute divided by hours (standard error)	Number of Observations
All leavers	LFS	-0.342 (0.054)	0.173 (0.045)		28575
All leavers	LFS	-0.34 (0.054)	0.015 (0.086)	0.978 (0.458)	27949
All leavers	LFS		0.161 (0.045)		28702
All leavers	LFS		-0.006 (0.085)	0.952 (0.455)	27949
Job Movers	LFS	-0.245 (0.08)	0.143 (0.061)		27795
Job Movers	LFS	-0.249 (0.08)	-0.035 (0.128)	1.066 (0.746)	27181
Job Movers	LFS		0.121 (0.061)		27911
Job Movers	LFS		-0.055 (0.127)	1.064 (0.741)	27181
All leavers	BHPS	-0.298 (0.044)	0.161 (0.03)		21893
All leavers	BHPS	-0.314 (0.044)	0.13 (0.039)	0.244 (0.15)	21893
All leavers	BHPS		0.129 (0.028)		24248
All leavers	BHPS		0.109 (0.037)	0.226 (0.135)	23986
Job Movers	BHPS	-0.21 (0.053)	0.124 (0.037)		20438
Job Movers	BHPS	-0.212 (0.053)	0.062 (0.049)	0.417 (0.214)	20438
Job Movers	BHPS		0.107 (0.035)		22595
Job Movers	BHPS		0.059 (0.047)	0.381 (0.194)	22364

Notes.

1. The reported coefficients are from the estimated complementary log-log model of (11) where the dependent variable is a binary variable taking the value one if the individual stayed in the job.
2. The other controls included are as for Table 2.

Table 5
Actual and Minimum Commutes in Greater London, 1991

	Commuting Distance (km)		Numbers Living and Working in Same Ward		Extra Constraints	Number of Observations
	Actual Average	Minimized Average	Actual	Maximized		
Men	8.09	4.26	6577	63622	None	115615
Men	8.09	4.30	6577	61263	Age (7 categories)	115615
Men	8.09	4.26	6577	55132	Occupation (23 categories)	115615
Women	6.12	3.42	10541	64412	None	108693
Women	6.12	3.45	10541	61650	Age (7 categories)	108693
Women	6.12	3.57	10541	55366	Occupation (23 categories)	108693

Notes.

1. The minimized average commute is found by solving the transport problem in (13).
2. The extra constraints are that the constraints in (13) must be satisfied for each age or occupation category.

Table 6**Correlations between Areas of Residence and Work in London: Men****A. Places of Residence**

	Managerial and Professional	Clerical and Secretarial	Skilled Manual	Personal Services and Sales	Semi- and Unskilled Manual
Managerial and Professional	1.00				
Clerical and Secretarial	0.42	1.00			
Skilled Manual	0.14	0.66	1.00		
Personal Services and Sales	0.53	0.65	0.54	1.00	
Semi- and Unskilled Manual	-0.05	0.58	0.74	0.48	1.00

B. Places of Work

	Managerial and Professional	Clerical and Secretarial	Skilled Manual	Personal Services and Sales	Semi- and Unskilled Manual
Managerial and Professional	1.00				
Clerical and Secretarial	0.95	1.00			
Skilled Manual	0.71	0.73	1.00		
Personal Services and Sales	0.91	0.91	0.64	1.00	
Semi- and Unskilled Manual	0.65	0.69	0.83	0.65	1.00

C. Places of Work (Rows) and Residence (Columns)

	Managerial and Professional	Clerical and Secretarial	Skilled Manual	Personal Services and Sales	Semi- and Unskilled Manual
Managerial and Professional	-0.07	-0.09	-0.07	-0.02	-0.10
Clerical and Secretarial	-0.14	-0.12	0.04	-0.07	-0.01
Skilled Manual	-0.20	-0.17	0.04	-0.14	0.00
Personal Services and Sales	-0.03	-0.03	0.10	0.05	0.04
Semi- and Unskilled Manual	-0.13	-0.10	0.12	-0.07	0.10

Notes.

These show the correlations between places of work/residence for different occupations.

Table 7

Correlations between Areas of Residence and Work in London: Women

A. Places of Residence

	Managerial and Professional	Clerical and Secretarial	Skilled Manual	Personal Services and Sales	Semi - and Unskilled Manual
Managerial and Professional	1.00				
Clerical and Secretarial	0.47	1.00			
Skilled Manual	0.09	0.26	1.00		
Personal Services and Sales	0.37	0.78	0.31	1.00	
Semi - and Unskilled Manual	-0.02	0.36	0.36	0.49	1.00

B. Places of Work

	Managerial and Professional	Clerical and Secretarial	Skilled Manual	Personal Services and Sales	Semi - and Unskilled Manual
Managerial and Professional	1.00				
Clerical and Secretarial	0.95	1.00			
Skilled Manual	0.58	0.54	1.00		
Personal Services and Sales	0.77	0.79	0.54	1.00	
Semi - and Unskilled Manual	0.76	0.77	0.54	0.73	1.00

C. Places of Work (Rows) and Residence (Columns)

	Managerial and Professional	Clerical and Secretarial	Skilled Manual	Personal Services and Sales	Semi - and Unskilled Manual
Managerial and Professional	0.05	0.00	-0.01	0.12	0.03
Clerical and Secretarial	-0.12	-0.11	-0.07	0.04	0.03
Skilled Manual	-0.09	-0.10	0.19	-0.03	0.03
Personal Services and Sales	-0.11	-0.11	-0.02	0.06	0.06
Semi - and Unskilled Manual	-0.09	-0.01	0.14	0.04	0.22

Notes.
As for Table 5.

Appendix

Proof of Proposition 1:

First, consider the distribution of utility across employed workers. Suppose a fraction $G(v)$ workers are employed in firms offering utility v or less. Then, equating inflows and outflows, we must have:

$$[\mathbf{d} + \mathbf{q}S(v)](1-u)G(v) = \mathbf{q} [S(b) - S(v)]u \quad (14)$$

which, using (6), can be re-arranged to give:

$$G(v) = \frac{\mathbf{d} [S(b) - S(v)]}{S(b) [\mathbf{d} + \mathbf{q}S(v)]} \quad (15)$$

Now consider how we can work out the distribution of wages conditional on commute. It is more convenient to first consider the distribution of utility across workers conditional on commute, t . Define $n(v, t)$ to be the number of workers with utility equal to v with a commute of t . These workers leave employment at a rate $[\mathbf{d} + \mathbf{q}S(v)]$. There are $[u + (1-u)G(v)]$ workers who might be interested in a job that pays utility v and they receive offers at a rate $\mathbf{I} f(v + \mathbf{a}t)$. Hence, equating inflows and outflows, we must have:

$$[\mathbf{d} + \mathbf{q}S(v)]n(v, t) = \mathbf{I} f(v + \mathbf{a}t)[u + (1-u)G(v)] \quad (16)$$

Then, using (6) and (15) we have, after some re-arrangement:

$$n(v, t) = \frac{\mathbf{d} \mathbf{I} f(v + \mathbf{a}t)}{[\mathbf{d} + \mathbf{q}S(v)]^2} = \mathbf{f}(v) f(v + \mathbf{a}t) \quad (17)$$

where:

$$\mathbf{f}(v) \equiv \frac{d\mathbf{l}}{[\mathbf{d} + \mathbf{q}S(v)]^2} \quad (18)$$

The distribution function of worker utility, v , conditional on t , denoted by $G(v|t)$, will then be given by:

$$G(v|t) = \frac{\int_b^v n(x, t) dx}{\int_b^\infty n(x, t) dx} \quad (19)$$

Now consider the distribution of wages, conditional on the commute. Denote the distribution function for wages conditional on t as $G_w(w|t)$. The relationship between $G_w(w|t)$ and $G(v|t)$ is given by:

$$G_w(w|t) = G(w - \mathbf{a}t|t) \quad (20)$$

Hence the impact of t on $\ln G_w(w|t)$ is given by:

$$\frac{\partial \ln G_w(w|t)}{\partial t} = -\mathbf{a} \frac{\partial \ln G(w - \mathbf{a}t|t)}{\partial v} + \frac{\partial \ln G(w - \mathbf{a}t|t)}{\partial t} \quad (21)$$

Now, changing the variable of integration in (19) from x to $z = x + \mathbf{a}t$ we can write $\ln G(v|t)$ as:

$$\ln G(v|t) = \ln \left(\int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z - \mathbf{a}t) f(z) dz \right) - \ln \left(\int_{b+\mathbf{a}t}^\infty \mathbf{f}(z - \mathbf{a}t) f(z) dz \right) \quad (22)$$

Differentiating (22) with respect to v we have that:

$$\frac{\partial \ln G(v|t)}{\partial v} = \frac{\mathbf{f}(v) f(v + \mathbf{a}t)}{\int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z - \mathbf{a}t) f(z) dz} \quad (23)$$

and, differentiating (22) with respect to t we have that:

$$\begin{aligned} \frac{\partial \ln G(v|t)}{\partial t} = & \mathbf{a} \frac{\mathbf{f}(v)f(v+\mathbf{a}t) - \mathbf{f}(b)f(b+\mathbf{a}t) - \int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}'(z-\mathbf{a}t)f(z) dz}{\int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z-\mathbf{a}t)f(z) dz} \\ & + \mathbf{a} \frac{\mathbf{f}(b)f(b+\mathbf{a}t) + \int_{b+\mathbf{a}t}^{\infty} \mathbf{f}'(z-\mathbf{a}t)f(z) dz}{\int_{b+\mathbf{a}t}^{\infty} \mathbf{f}(z-\mathbf{a}t)f(z) dz} \end{aligned} \quad (24)$$

Combining (23) and (24) in (21) and re-arranging leads to:

$$\begin{aligned} \frac{\partial \ln G_w(v|t)}{\partial t} = & \mathbf{a} \mathbf{f}(b)f(b+\mathbf{a}t) \left[\frac{1}{\int_{b+\mathbf{a}t}^{\infty} \mathbf{f}(z-\mathbf{a}t)f(z) dz} - \frac{1}{\int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z-\mathbf{a}t)f(z) dz} \right] \\ & + \mathbf{a} \left[\frac{\int_{b+\mathbf{a}t}^{\infty} \frac{\partial \ln \mathbf{f}(z-\mathbf{a}t)}{\partial v} \mathbf{f}(z-\mathbf{a}t)f(z) dz}{\int_{b+\mathbf{a}t}^{\infty} \mathbf{f}(z-\mathbf{a}t)f(z) dz} - \frac{\int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \frac{\partial \ln \mathbf{f}(z-\mathbf{a}t)}{\partial v} \mathbf{f}(z-\mathbf{a}t)f(z) dz}{\int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z-\mathbf{a}t)f(z) dz} \right] \end{aligned} \quad (25)$$

The term on the right-hand side on the first line of (25) is always negative so this always works to make the distribution of the wage increasing in t (in the sense of first-order stochastic dominance). This effect comes from the fact that an increase in t raises the lowest wage acceptable to any worker.

So, let us concentrate on being able to sign the term on the second line of (25). This term can be written as:

$$\left[\frac{\int_{v+\mathbf{a}t}^{\infty} \frac{\partial \ln \mathbf{f}(z-\mathbf{a}t)}{\partial v} \mathbf{f}(z-\mathbf{a}t)f(z) dz \cdot \int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z-\mathbf{a}t)f(z) dz}{\int_{b+\mathbf{a}t}^{\infty} \mathbf{f}(z-\mathbf{a}t)f(z) dz \cdot \int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z-\mathbf{a}t)f(z) dz} - \frac{\int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \frac{\partial \ln \mathbf{f}(z-\mathbf{a}t)}{\partial v} \mathbf{f}(z-\mathbf{a}t)f(z) dz \cdot \int_{v+\mathbf{a}t}^{\infty} \mathbf{f}(z-\mathbf{a}t)f(z) dz}{\int_{b+\mathbf{a}t}^{\infty} \mathbf{f}(z-\mathbf{a}t)f(z) dz \cdot \int_{b+\mathbf{a}t}^{v+\mathbf{a}t} \mathbf{f}(z-\mathbf{a}t)f(z) dz} \right] \quad (26)$$

Now, if $\frac{\partial \ln \mathbf{f}(v)}{\partial v}$ is decreasing in v (so that $\ln \mathbf{f}(v)$ is concave, then we have that:

$$\frac{\partial \ln \mathbf{f}(z)}{\partial v} \leq \frac{\partial \ln \mathbf{f}(v + \mathbf{a}t)}{\partial v} \quad \text{for } z \geq v + \mathbf{a}t \quad (27)$$

and:

$$\frac{\partial \ln \mathbf{f}(z)}{\partial v} \geq \frac{\partial \ln \mathbf{f}(v + \mathbf{a}t)}{\partial v} \quad \text{for } z \leq v + \mathbf{a}t \quad (28)$$

Using (27) and (28) the term in (26) must be negative and, hence, the concavity of $\ln \mathbf{f}(v)$ in v is a sufficient condition for the distribution of wages to be increasing in t .

We now only need to provide a condition for when $\ln \mathbf{f}(v)$ is concave in v . From (18) we have that:

$$\ln \mathbf{f}(v) = \ln(\mathbf{d}l) - 2\ln(\mathbf{d} + \mathbf{q}S(v)) \quad (29)$$

from which we can, by differentiating twice, derive:

$$\frac{\partial^2 \ln \mathbf{f}(v)}{\partial v^2} = \frac{2\mathbf{q}}{(\mathbf{d} + \mathbf{q}S(v))^2} \left[\mathbf{q}(S'(v))^2 - (\mathbf{d} + \mathbf{q}S(v))S''(v) \right] \quad (30)$$

As $H''(v) > 0$ a sufficient condition for this to be negative is that:

$$(S'(v))^2 - S(v).S''(v) < 0 \quad (31)$$

Now, from (5) we have that:

$$S(v).S''(v) = f(v) \int_v [1 - F(x)] dx = f(v) \int_v \frac{[1 - F(x)]}{f(x)} f(x) dx \quad (32)$$

Now if $[1-F(x)]$ is log-concave then $([1-F(x)]/f(x))$ is increasing in x so that (32) implies that:

$$S(v).S''(v) = f(v) \int_v \frac{[1-F(x)]}{f(x)} f(x) dx > f(v) \frac{[1-F(v)]}{f(v)} \int_v f(x) dx = [1-F(v)]^2 = [S'(v)]^2 \quad (33)$$

where the last equality follows from differentiation of (5). This proves (31) which is a sufficient condition for $\ln f(v)$ to be concave in v which is a sufficient condition for wages to be increasing in t . This proves part (a) of the Proposition.

Now consider part (b). By differentiating (19) we have that:

$$\begin{aligned} \frac{1}{a} \frac{\partial \ln G(v|t)}{\partial t} &= \frac{\int_b^v f(x) f'(x+at) dx}{\int_b^v f(x) f(x+at) dx} - \frac{\int_b^\infty f(x) f'(x+at) dx}{\int_b^\infty f(x) f(x+at) dx} \\ &= \frac{\int_b^v \frac{\partial \ln f(x+at)}{\partial w} f(x) f(x+at) dx}{\int_b^v f(x) f(x+at) dx} - \frac{\int_b^\infty \frac{\partial \ln f(x+at)}{\partial w} f(x) f(x+at) dx}{\int_b^\infty f(x) f(x+at) dx} \end{aligned} \quad (34)$$

Now, (34) can be re-arranged to give:

$$\begin{aligned} \frac{1}{a} \frac{\partial \ln G(v|t)}{\partial t} \cdot \int_b^v f(x) f(x+at) dx \cdot \int_b^\infty f(x) f(x+at) dx &= \int_b^v \frac{\partial \ln f(x+at)}{\partial w} f(x) f(x+at) dx \cdot \int_b^\infty f(x) f(x+at) dx \\ &\quad - \int_b^\infty \frac{\partial \ln f(x+at)}{\partial w} f(x) f(x+at) dx \cdot \int_b^v f(x) f(x+at) dx > 0 \end{aligned} \quad (35)$$

where the final inequality follows if $\ln(f(w))$ is concave in w .

Proposition 2:

If the mean of the wage offer distribution is increased then the average commute rises if $\ln[1-F(w)]$ is concave in w .

Proof

First, note that, if we write the wage distribution as $F(w - \mathbf{m})$ then, from (5), one can write $S(v - \mathbf{m})$ as well. Hence the density of workers in employment of quality μ with utility v and commute t can, using (17), be written as:

$$n(v-\mathbf{m},t) = \frac{dI f(v-\mathbf{m}+\mathbf{a}t)}{[d+\mathbf{q}S(v-\mathbf{m})]^2} = \mathbf{f}(v-\mathbf{m}) f(v-\mathbf{m}+\mathbf{a}t) \quad (36)$$

Now, the distribution function of travel time conditional on μ can be written as:

$$G_t(t;\mathbf{m}) = \frac{\int_b^\infty \int_0^t n(v-\mathbf{m},s) ds dv}{\int_b^\infty \int_0^\infty n(v-\mathbf{m},s) ds dv} = \frac{\int_b^\infty \mathbf{f}(v-\mathbf{m}) \int_0^t f(v-\mathbf{m}+\mathbf{a}s) ds dv}{\int_b^\infty \mathbf{f}(v-\mathbf{m}) \int_0^\infty f(v-\mathbf{m}+\mathbf{a}s) ds dv} \quad (37)$$

Changing the variable of integration in the second integral in numerator and denominator to $(v-\mu+\alpha s)$ means that we can write (37) as:

$$G_t(t;\mathbf{m}) = \frac{\int_b^\infty \mathbf{f}(v-\mathbf{m}) [F(v-\mathbf{m}+\mathbf{a}t) - F((v-\mathbf{m}))] dv}{\int_b^\infty \mathbf{f}(v-\mathbf{m}) [1 - F((v-\mathbf{m}))] dv} \quad (38)$$

Changing the variable of integration to $(v-\mu)$, one can write this as:

$$1 - G_t(t;\mathbf{m}) = \frac{\int_{b-\mathbf{m}}^\infty \mathbf{f}(v) [1 - F(v+\mathbf{a}t)] dv}{\int_{b-\mathbf{m}}^\infty \mathbf{f}(v) [1 - F(v)] dv} \quad (39)$$

Taking logs and differentiating we have that:

$$\frac{\partial \ln [1 - G_t(t;\mathbf{m})]}{\partial \mathbf{m}} = \frac{\mathbf{f}(b-\mathbf{m}) [1 - F(b-\mathbf{m}+\mathbf{a}t)]}{\int_{b-\mathbf{m}}^\infty \mathbf{f}(v) [1 - F(v+\mathbf{a}t)] dv} - \frac{\mathbf{f}(b-\mathbf{m}) [1 - F(b-\mathbf{m})]}{\int_{b-\mathbf{m}}^\infty \mathbf{f}(v) [1 - F(v)] dv} \quad (40)$$

Now, if $\ln[1-F(w)]$ is concave in w it must be the case that:

$$\frac{1 - F(w+\mathbf{a}t)}{1 - F(w)}$$

is decreasing in w . Hence, if $v \geq (b-\mu)$ it must be the case that:

$$\frac{1-F(v+\mathbf{a}t)}{1-F(v)} \leq \frac{1-F(b-\mathbf{m}+\mathbf{a}t)}{1-F(b-\mathbf{m})}$$

which implies that:

$$[1-F(v+\mathbf{a}t)] \leq \frac{1-F(b-\mathbf{m}+\mathbf{a}t)}{1-F(b-\mathbf{m})} \cdot [1-F(v)] \quad (41)$$

Using (41) in (40) we have that:

$$\frac{\partial \ln[1-G_t(t; \mathbf{m})]}{\partial \mathbf{m}} > \frac{\mathbf{f}(b-\mathbf{m})[1-F(b-\mathbf{m}+\mathbf{a}t)]}{\int_{b-\mathbf{m}}^{\infty} \mathbf{f}(v) \frac{1-F(b-\mathbf{m}+\mathbf{a}t)}{1-F(b-\mathbf{m})} \cdot [1-F(v)] dv} - \frac{\mathbf{f}(b-\mathbf{m})[1-F(b-\mathbf{m})]}{\int_{b-\mathbf{m}}^{\infty} \mathbf{f}(v)[1-F(v)] dv} = 0 \quad (42)$$

which shows that $[1-G_t(t; \mathbf{m})]$ is increasing in μ and hence an increase in μ increases the distribution of t in the sense of first-order stochastic dominance.

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