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Published in:
10th IZA/SOLE Transatlantic Meeting of Labor Economists

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

TI 2010-093/3
Tinbergen Institute Discussion Paper

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Wages and commuting: quasi-natural experiments' evidence from firms that relocate

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08/09/2010

Abstract

We examine the causal effect of commuting distance on workers' wages in a quasi-natural experiments setting using information on all workers in Denmark. We account for endogeneity of distance by using changes in distance that are due to firms' relocations. For the range of commuting distances where income tax reductions associated with commuting do not apply, one kilometre increase in commuting distance induces a wage increase of about 0.42%, suggesting an hourly compensation of about half of the hourly net wage. Our findings are consistent with wage bargaining theory and suggest a bargaining power parameter of about 0.50. Due to the experimental setup we are able to exclude many competing explanations of the wage-distance relationship. *Keywords*: Commuting, wages, bargaining theory .*JEL codes*: J22, R41

1. Introduction

This paper examines the causal effect of commuting distance on wages from a wage bargaining perspective. One of the main issues we are concerned with is that distance may be endogenous with respect to wages. This is relevant because the literature emphasizes that it is not an easy task to find valid instruments for commuting distance, as it is related to labour and residence locations behaviour (Manning, 2003; Gubits, 2004). As emphasised by Manning (2003), but also in the literature study by Gibbons and Machin (2006), despite the large number of studies there is essentially no direct empirical evidence of the causal effect of commuting costs on wages. There are a number of reasons why the effect of the length of the commute on wages is of interest (for a review see Gibbons and Machin, 2006).

Evidence on equilibrium relationships between wages and commuting is informative about the frictions in the labour market that transport infrastructure may help to alleviate. In a competitive labour market without search frictions, firms do not determine wage levels based on the worker's commuting distance (as it is based on the worker's productivity level). If firms pay compensating wages for longer commutes, then firms must enjoy some monopsony power in the labour market which allows them to pay wages below marginal product. In a wage bargaining context with job search frictions, workers with long commuting distances are able to bargain for higher wages, because their opportunity costs of staying with the firm are less than those for other workers. To be more precise, a range of bargaining models imply that workers will get a fixed share of their commuting costs reimbursed through higher wages (e.g. Marimom and Zilibotti, 1999; Van Ommeren and Rietveld, 2005).[1] This share is determined by the degree of employer market power, which plays a major role in a wide range of bargaining models

[1] Wage compensation does not occur when workers with long commutes are fully compensated in the housing market through lower housing prices (see Zenou, 2009). We control for housing market compensation by keeping residential location constant.

(Pissarides, 2000). In a competitive labour market, employers have no market power, so the share is zero. In a market where employers have full market power, the share is one (and worker receive a wage which makes them indifferent between working and being unemployed), so workers receive full compensation. There is virtually no direct evidence on what an appropriate value of this share (equivalent to the bargaining power parameter) should be (see e.g. Shimer, 2005; Mortensen and Nagypal, 2007; and Gertler et al., 2008). It is one of the objectives of the current paper to determine the magnitude of this share for Denmark.[2] Evidence on a causal effect of the commuting distance on the wage implies that workers receive (a part) of their total commuting costs (inclusive time costs) reimbursed through higher wages.

The effect of the length of the commute on wages is also relevant in the context of income taxation. Income tax reductions for workers with a long commute can be found in many European countries (see Potter et al., 2006). In Denmark, workers with a one-way commute that exceeds 12.5 kilometres (about 50% of all workers) are entitled to a tax reduction. This tax reduction is based on a deduction that aims to compensate for monetary expenses associated with commuting per kilometre, i.e. fuel expenses, vehicle amortisation expenses, etc.[3] More precisely, in 2003 the workers were entitled to deduct 3.2 DKK per daily one-way kilometre for commutes between 12.5 and 50 kilometres and 1.6 DKK for longer commutes from taxable gross income.[4] On average, these reductions imply an increase in net wage of about 33% of the reduction, so

[2] Since the early 1980s, the Danish labour market has experienced a trend towards more decentralized bargaining regime based on flexible wage structures, inequality, and market-induced restraint (Iversen, 1996). Given the flexible wage structures in Denmark, individual unions and their employer counterparts determine the general wage level, while the workers bargain for additional bonuses at the level of firm, so the overall wage level is bargained at the individual level. In addition, the Danish labour market is relatively flexible, i.e. worker turnover is relatively high (Mortensen, 2001) and the high level of turnover applies to most categories of employees and is not caused by a minor share of (unskilled) workers being extremely mobile (Madsen, 2002).

[3] Employers seldomly reimburse commuting expenses explicitly (viz. through a fringe benefit), so we ignore this issue. Approximately 0.3% of workers have access to a company car. Including or excluding these workers does not affect estimation results.

[4] One DKK is approximately 0.13€. In 2005, per daily one-way kilometre the tax deductions were 3.36 DKK and 1.68 DKK respectively.

1.06 and 0.53 DKK per daily one-way kilometre respectively. This is substantial, as it implies an average net wage compensation of about 1.23% and 3.60% for commuting distances of respectively 12.5 and 50 one-way commuting kilometres (the average wage per working day was 1,114 DKK).

Despite the large theoretical and empirical debate around the relationship between wages and the length of the commute, it is maybe surprising that there is an absence of accurate empirical estimates of the *causal* effect of the length of the commute on wages (see e.g. Zax, 1991; Manning, 2003). Hence, there is a knowledge gap between the theoretical and empirical literature. We aim to fill this gap in the literature by estimating the *causal* effect of workers' commuting distance on wages. We estimate (reduced-form) panel data models using matched data from workers and firms for Denmark. We are interested in two types of effects of commuting distance on wages. So, we discuss (i) the effect of commuting distance on wages for the range in commuting distance where the income tax reduction is not applicable (where the effect refers to overall (time and monetary) costs associated with commuting), and (ii) the effect where income tax reduction is applicable (where the effect refers principally to time costs losses associated with commuting).

Our study deals with a range of statistical difficulties that have not been properly addressed in the literature by making use of exogenous changes in commuting distance due to firm relocations, which fits in the literature of quasi-natural experiments. Therefore, our study strongly contrasts with previous studies. Our estimates can be interpreted from a wage bargaining perspective, whereas interpretation of previous studies, mainly based on cross-section data, is not straightforward, because of alternative explanations (see e.g. Zax, 1991; White, 1977; Benito and Oswald, 1999; Manning, 2003; Simonsohn, 2006). In principle, in addition to the wage bargaining explanation, there are at least four other explanations for a *positive correlation* between the length of the commute and wages.

First, according to urban economic theory, workers with a higher income choose a different residence location and therefore a different commute (Wheaton, 1974). This explanation relates to reversed causation. Second, unobserved variables, such as skills, may affect both commuting distance and wages, causing spurious correlation between the length of the commute and wages (Manning, 2003). A common method of dealing with these two explanations is the use of an instrumental variable estimation procedure. The problem with this approach in the current setting is finding suitable instruments for the length of the commute as argued by Manning (2003). We use employer-induced changes in distances rather than an instrument variable approach.[5] Third, given a competitive labour market, employers located at locations far from residences compensate workers with appropriately higher wages, which implies a spatial wage gradient (e.g. Fujita et al., 1997). This idea is confirmed by empirical findings (Timothy and Wheaton, 2001). We deal with this alternative explanation by using (year-specific) firm fixed effects. Fourth, Manning (2003) points out that, in a monopsonistic labour market with search frictions and a distribution of wages, workers receive many job offers but only those above a reservation wage are accepted; otherwise it pays to wait for further offers. The reservation wage rises with the commuting cost associated with the job offer. So, on average, wages rise with commuting distance because workers only accept distant jobs that, at least partially, compensate for additional commuting costs. We control for this explanation by focusing on changes in wages of workers who remain with their employer.

The next section introduces the identification strategy to estimate the causal effect of

[5] Manning (2003) re-examines the results by Benito and Oswald (1999) and finds that the IV approach used by Benito and Oswald (1999) is sensitive to the choice of the instruments.

commutes on wages in a wage bargaining framework; Section 3 provides information on the data employed; Section 4 presents the empirical results; Section 5 concludes.

2. Identification strategy

Wage bargaining theory predicts a positive relationship between wages and commutes for workers, ceteris paribus. To guarantee the ceteris paribus condition, it is useful to focus on workers who stay with their employer and do not change residence. The hypothesis is then investigated using Danish register data on *all* workers that are matched to *all* firms *that relocate*. The worker's commuting distance, defined by the residence and the workplace location, is usually self chosen by the worker. However, quite regularly, the workplace location is changed due to a relocation by the worker's employer. The commuting distance change is then employer-induced and therefore exogenous with respect to individual wages. In our approach, we only use these exogenous changes. The idea to use workplace relocation as a source of exogenous change in commuting distance is also exploited in Zax (1991) and Zax and Kain (1996), who analyse the effects of a relocation of a single firm on job and residential moving behaviour.[6] The analysis of the relationship between wages and commuting distances based on exogenous changes in the distance due to firm relocation fits in the literature of quasi-natural experiments.

More formally, our approach entails estimating a worker's first-differences wage model with controls for worker- and firm-specific time-invariant factors. Let $W_{i,f,t}$ denote the worker $i's$ wage in year t of firm f. We assume the following specification of wages:

$$log(W_{i,f,t}) = \alpha_0 + \alpha_1 d_{i,f,t} + \alpha_2 X_{i,f,t} + \eta_{f,t} + \varepsilon_i + u_{i,f,t} \quad (1)$$

[6] See also Gutiérrez-i-Puigarnau and van Ommeren (2010), who estimate distance effects on labour supply, but in their study firm relocations are not observed (but derived from job and residential mobility data).

where $d_{i,f,t}$ is the worker $i's$ commuting distance in period t employed by firm f. The matrix $X_{i,f,t}$ includes exogenous time-varying controls for workers' and firms' characteristics, ε_i is a worker fixed effect, and $u_{i,f,t}$ is the overall error. We emphasise that in (1) we have included year-specific firm fixed effects $\eta_{f,t}$, which control for all year-specific differences between firms (e.g., firms' size, firms' location, firms' sales, etc.). We estimate all models in terms of worker first-differences, that is, variables are formulated as changes from one time period to another, implying that:

$$log(W_{i,f,t}) - log(W_{i,f,t-1}) = \alpha_1(d_{i,f,t} - d_{i,f,t-1}) + \alpha_2(X_{i,f,t} - X_{i,f,t-1}) + \varphi_{f,t} + v_{i,f,t} \quad (2)$$

where $v_{i,f,t} = u_{i,f,t} - u_{i,f,t-1}$ and $\varphi_{f,t} = \eta_{f,t} - \eta_{f,t-1}$. Thus, we use within-workers' variation in commuting distance to explain within-worker's variation in wages and further control for year-specific changes in firm characteristics.[7] Consistent estimation of α_1 requires that the change in commuting distance, $d_{i,f,t} - d_{i,f,t-1}$, is exogenous and therefore not related to $v_{i,f,t}$.

In order to guarantee that the change in commuting distance is exogenous, we make two data selections. First, we select firms that changed location, so the change in commuting distance is the result of an employer-induced workplace relocation. This selection may create a selection bias as the set of firms that relocate may not be random. This bias is likely minimal however because we include (year-specific) firm fixed effects. Second, to control for *voluntary* worker changes in distance, we select workers (of firms that relocate) who did not change employer or residence (so we keep residence location constant). In this way, changes in distances are due to (usually unexpected) exogenous shocks in commuting distance.[8] Selecting a sample of workers

[7] As we essentially have two periods in our data, this specification implies that we include only one $\varphi_{f,t}$ per firm.

[8] The shock is usually unexpected, because firms do not announce long in advance that they consider relocating. This phenomenon may have several explanations. For example, a long announcement period may increase uncertainty, which may immediately increase worker job quitting behaviour, absenteeism, etc., which firms prefer to avoid.

who do not change employer and do who not change residence may create a selection bias. We will explicitly address the potential bias of this selection by comparing results of different samples and by estimating Heckman selection models.

We are mainly interested in the effect of changes in commuting distance on changes in wages, so we have experimented with functional form for commuting distance, and employed different samples and selection procedures. Our estimate imply that including observations of voluntary worker changes in distance through residential moves may bias estimation results, but including these changes through job moves does not bias the results. In the current paper, we discuss the results of a specification using commuting distance, and its square, and we explicitly allow for the nonlinear effect of income tax reduction associated with commuting. In addition, we also discuss the results which allow for the possibility that an increase in commuting distance induces a different wage effect than a decrease.

3. Empirical analyses

3.1. The data

The data used in the empirical analysis are derived from annual register data from Statistics Denmark for the years 2003–2005. Our period of observation is thus three years. For each year on 31 December, we have information on worker's residence location and the workers' establishment workplace location, annual *net* wages, and a range of explanatory variables (e.g. number of children).[9] Commuting distances have been calculated using information on exact residence and workplace addresses using the shortest route. For convenience, we will refer to establishments as firms.

[9] Wage data are derived from workers' pay slips which are observed by Danish Tax Authorities.

3.2. Selection of sample and descriptive statistics

We observe the full population of 321,337 firms[10] and 2,710,462 workers. We select firms that changed address between January 2004 and December 2004 (11,314 firms; 64,643 workers). Records with missing information (4,209 firms; 5,857 workers); workers with more than 1 job (3,122 firms; 15,576 workers) and part-time workers (1,948 firms; 23,485 workers) were excluded. Furthermore, we excluded 337 observations referring to address changes that did not imply a change in commuting distance.[11] Moreover, observations for which commuting distance is greater than 100 km (179 firms; 878 workers), change in commuting distance is greater than 50 kilometers (19 firms; 434 workers), and the absolute change in log(wage) is greater than 0.5 (167 firms; 1,474 workers) were excluded as they were assumed to be outliers. Our econometric approach is based on a sample of (maximally) 1,333 firms and 8,601 workers. The full sample selection process can be found in Appendix A (Table A1).

Our focus is on a sample of workers who stayed with their firm and did not change residence from January 2003 to December 2005 (1,144 firms; 6,165 workers). We use wage data for the years 2003 and 2005, because within these years the commuting distance is constant (which is not the case for 2004). So, in the analysis, we focus on annual changes between 2003 and 2005. The data also contains information on worker's job function, so we are able to control for promotions.[12]

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[10] The statistical unit of firms is an administrative unit used by the tax authorities' register of enterprises liable to VAT. These units are identified by their so-called SE number. In most cases, the SE number unit is identical to the legal unit, i.e. the enterprise, but an enterprise might choose to split its registration up into several SE numbers (a divided registration). We assume that each SE number is a separate firm.

[11] One reason may be a change in street name, or building number, but it may also occur given a move within the same building (e.g. from one floor to another).

[12] Variable 'change in workers function' is computed from labour market administrative register's variable RASDISCO, which is a 4-digit function code, including more than thousand different function descriptions. For some industries, particular for government sector, consulting etc., it is common practice that workers change

Table 1. *Summary statistics*

Variable	Mean	Std. Dev.	Minimum	Maximum
Change in commuting distance (km)	-0.4537	14.3492	-49.9630	49.8160
Abs change in commuting distance (km)	9.2884	10.9461	0.0010	49.9630
log(wage2005)–log(wage2003)	0.0526	0.1841	-0.4994	0.4979
Change in workers function	0.4819	0.4997	0.0000	1.0000
Workers with commuting distance between 12.5 and 50 km in 2005 (share)	0.4381	0.4962	0.0000	1.0000
Workers with commuting distance > 50 km in 2005 (share)	0.0616	0.2405	0.0000	1.0000

Notes: Number of observations: 6,165.

Table 1 shows summary statistics of variables of interest. They show, as one may expect given random sampling, that the average change in commuting distance is close to zero. The average absolute change is 9.29 km, which is substantial compared to the average level of distance (17.50 km). So, we have a sufficient number of large exogenous changes in commuting distance. The share of workers entitled to a tax reduction (those with one way commute that exceeds 12.5 kilometres) is approximately 50%.

We have also calculated the correlation between changes in commuting distance and changes in wages, which appears to be 0.08. This is in line with a range of other studies (see e.g. Manning, 2003) although these studies include the change in distance and not only changes induced by firm relocations. The positive correlation suggests that variation in the commuting distance is important for determining variation in wages.

4. Empirical results

The econometric results of several specifications of first-differences models based on (2) are shown in Table 2. In these specifications, we initially do not correct for any sample selection effect. The first two columns show the results for a linear and a quadratic specification of commuting distance and where we also allow the distance effect to depend on whether the one-way commuting distance is between 12.5 and 50 kilometres or exceeds 50 kilometres, i.e.

function every 2nd or 4th year. This explains the high percentage of workers that change function from 2003 to 2005.

whether workers are entitled to an income tax reduction associated with commuting. The effect of commuting distance appears to be statistically significant and positive (within the relevant range) in all specifications. We also find evidence that the marginal effect is not linear, in line with the fact that income tax reduction apply to longer distances only and that the time cost of commuting is concave function of distance. Concavity makes sense. Speed of travel is strongly increasing in distance, implying that marginal costs of distance are smaller for longer distance. The quadratic specification [2] implies a marginal effect of 0.0049 for a minimal commuting distance. The marginal effect is only slightly lower at let's say 10 km, but substantially lower at the average commuting distance, where income tax reductions apply (see last two columns of Table 3). The marginal effect of commuting distance just above 12.5 where income tax reductions apply is 0.00190 (s.e. is 0.00041). It is positive up to 50 kilometres which applies to the large majority of observations (94%). For very long distances, the marginal time losses due to an increase in distance are too small to identify plausibly due to a high speed as well as income tax reductions. We do not reject the hypothesis that the marginal effect is zero at commuting distance just above 50 km suggesting that income tax reductions fully compensate for commuting time costs.

Both specifications imply that, for the commuting distance range where the income tax reduction does not apply, an increase in commuting distance by 1 kilometre induces on average a wage increase of 0.42%.[13] This is an economically significant effect. For example, if the commuting distance to a firm increases by 10 km, which is about the average change of a firm that relocates, wages increase by approximately 4.2%. This corresponds to 46.78 DKK per working day, or 2.34 DKK per additional kilometre travelled per day worked. Given a

[13] The effects are not different when we estimate the same models on sample including only workers with commuting distance below 12.5 kilometres for which income tax reductions are not applicable (see Appendix B).

commuting speed of 35 km/h (this speed applies to distances of about 10 km), the compensation is about 81.86 DKK per hour, or 49.43% of the net hourly wage (which is 165.59 DKK on average). This estimate is likely an underestimate because it assumes that workers travel each day to their workplace, which is not the case due to business travel, teleworking and absenteeism.[14] Assuming that workers commute 90% of their workdays, the compensation will be closer to 54% of the hourly wage. Transport economists typically find that the value of time for commuters is about 50% of the wage (Small and Verhoef, 2007). This result seems to hold for Denmark.[15] Monetary costs are typically of the same magnitude (Van Ommeren and Fosgerau, 2009). This result implies that workers bargain for about half a commuting costs. Our implicit estimate of the bargaining parameter is consistent with those reported in a number of papers in the labour market literature. Mortensen and Nagypal (2007) propose in their survey paper a value of 0.5 for this parameter.[16]

The marginal effect of commuting distance at the average commuting distance (17.5 km) is 0.0017. This corresponds to 1.9 DKK per working day, or 0.94 DKK per kilometre travelled per day worked. Given a commuting speed of 35 km/h, the compensation is now about 33.13 DKK per hour, or 22.01% of the net hourly wage, again about half of the commuting costs related to time losses.

Our empirical results are consistent with those reported in a number of papers in the urban economics literature that examine the relationship between wages and commutes (but which ignore endogeneity issues as emphasized by Manning (2003)). For example, Madden (1985) investigates how wages vary with distance from the central business district (CBD). She

[14] Absenteeism rates are about 3% and the sum of business travel and teleworking occur likely at similar rate.
[15] Fosgerau et al. (2007) estimated value of time of 76 DKK per hour for Danish commuters for year 2005.
[16] Shimer (2005) proposes a value of 0.4 as a value for the worker's bargaining power parameter (based on the interpretation of this parameter as unemployment insurance), while Hall (2008) suggests 0.7 if one permits a broader interpretation of this variable. Cahuc et al. (2006) estimated the bargaining power of workers between 0 and 0.33.

regresses change in commuting distance on the change in wages for workers who changed job, changed residence, or both. For workers who changed job, she reports a positive relationship between wage and commuting distance changes.

Table 2. *First-difference wage model with firm fixed-effects*

	[1]	[2]	[3]	[4]	[5]
	all observations		abs. change in commuting distance>500m		
Change in commuting distance	0.00423*** (0.00066)	0.00494*** (0.00074)	0.00433*** (0.00070)	0.00502*** (0.00078)	
Change in commuting distance squared / 100		-0.00194** (0.00091)		-0.00189** (0.00095)	
Change in commuting distance (increase)					0.00443*** (0.00076)
Change in commuting distance (decrease)					0.00425*** (0.00074)
Change in commuting distance * $D_{12.5}$	-0.00263*** (0.00058)	-0.00256*** (0.00058)	-0.00264*** (0.00061)	-0.00258*** (0.00061)	-0.00265*** (0.00061)
Change in commuting distance * D_{50}	-0.00374*** (0.00064)	-0.00315*** (0.00070)	-0.00377*** (0.00068)	-0.00320*** (0.00073)	-0.00379*** (0.00068)
Change in worker's function	0.01912*** (0.00527)	0.01914*** (0.00526)	0.02418*** (0.00605)	0.02423*** (0.00605)	0.02425*** (0.00606)
Firm fixed effects (1,144)	Yes	Yes	Yes	Yes	yes
R-squared	0.3600	0.3606	0.3690	0.3696	0.3690
No. of observations	6165	6165	5085	5085	5085

Notes: Dependent variable is change in logarithm of wage; $D_{12.5}$ is dummy variable indicating if the worker one-way commuting distance is between 12.5 and 50 km; D_{50} is dummy variable indicating if the worker one-way commuting distance exceeds 50 km; *** indicates that estimates are significantly different from zero at the 0.01 level; standard errors are in parentheses.

The results are almost identical if one excludes observations referring to changes in commuting distance smaller than 500 meters (see the last three columns in Table 2).[17] We have also estimated models that distinguish between different effects of increases and decreases in commuting distance (see the last column in Table 2). A F-test (F=0.1403; p-value=0.7080) does not reject the null hypothesis that these effects are identical. As nominal wage decreases are extremely uncommon for workers who stay with the same firm, this indicates that workers with reduced distances receive smaller nominal wage increases than other workers in the same firm.

We have estimated the same models on other, less-selective, samples of data. So we have included data on (i) workers who change employer, (ii) workers who change residence, and (iii) workers who change both employer and residence. The effects of commuting distance, reported

[17] These changes in distances are usually economically of no importance, but are relatively common in our data (18% of observations).

in Table 3, are very similar to the results reported in Table 2, except for a sample that includes residence change, most likely because distance changes of residential movers are compensated on the housing market (in line with theory, see Zenou, 2009).[18]

Table 3. *First-difference wage model. Effect of distance.*

Sample	N	Change in commuting distance	Change in commuting distance squared/100	Change in commuting distance * $D_{12.5}$	Wage effect at commuting distance of 10km	Wage effect at average commuting distance (17.5km)
Sample used for Table 2	6,165	0.00490*** (0.00070)	-0.00194** (0.00091)	-0.00256*** (0.00058)	0.00455*** (0.00074)	0.00170*** (0.00041)
Sample including employer change	7,248	0.00431*** (0.00067)	-0.00222** (0.00082)	-0.00197*** (0.00052)	0.00387*** (0.00067)	0.00156*** (0.00037)
Sample including residence change	7,338	0.00109*** (0.00026)	0.00056 (0.00070)	-0.00024 (0.00032)	0.00120*** (0.00026)	0.00105*** (0.00030)
Sample including employer and residence change	8,601	0.00110*** (0.00024)	0.00029 (0.00064)	-0.00018 (0.00030)	0.00116*** (0.00024)	0.00102*** (0.00027)
Heckman selection model (selection regarding residence change)	8,601	0.00477*** (0.00067)	-0.00221** (0.00081)	-0.00239*** (0.00052)	0.00433*** (0.00067)	0.00161*** (0.00037)
Heckman selection model (selection regarding employer change)	8,601	0.00535*** (0.00074)	-0.00194** (0.00091)	-0.00294*** (0.00058)	0.00496*** (0.00073)	0.00173*** (0.00041)
Heckman selection model (selection regarding residence and employer changes)	8,601	0.00480*** (0.00068)	-0.00197** (0.00082)	-0.00247*** (0.00053)	0.00441*** (0.00067)	0.00164*** (0.00037)

Notes: *** indicates that estimates are significantly different from zero at the 0.01 level; standard errors are in parentheses.

An alternative, and usually better, way to examine selection sample issues is to estimate Heckman selection models. The inclusion of instruments in the first step of the models is based on the presence of search frictions in labour and housing markets. Given these frictions, the spatial configuration of jobs and residence affects job and residential mobility (Manning, 2003). It seems however reasonable to assume that the spatial configuration of jobs and residences does not directly affect annual changes in wages, so we use this configuration as an instrument. For single-wage earners, the spatial configuration is captured by the commuting distance. For two-earner households, it is captured by three variables: the commuting distances of both wage earners as well as the distance between the workplaces of the wage earners.[19] In Table 3, we

[18] The full results of the estimates are provided in Appendix C (Table C1- C3).

[19] Deding et al. (2009) hypothesize that residential mobility depends positively on the commuting distances of both spouses, but negatively on the distance between workplaces. Further, workers' job mobility depends positively on the worker's commuting distance, negatively on the spouse's commuting distance, and positively on the distance between workplaces. Using data for Denmark, Deding et al. (2009) show that these hypotheses hold, and that the effects of spatial configuration are rather large.

report the results of Heckman selection models using the spatial configuration of jobs and residence as instrument. Accounting for sample selectivity in this way does not change our main result.[20] We have also estimated Heckman selection models applying another set of instruments. We control for number of children up to 12 years old, but use the presence of children in the age between 12 and 18 as an instrument. Children in this age group likely have no direct effect on changes of wages, but strongly affect residential, but also job, mobility. The results obtained from Heckman selection models applying these instruments are almost identical to the results presented above (see Appendix D).

5. Conclusion

This paper analyses the *causal* effect of commuting distance on wages using matched register data for firms and workers for Denmark. We deal with the endogeneity of commuting distance by means of an innovative approach using changes in commuting distance that are due to firm relocations and therefore exogenous. We take into account that above 12.5 kilometres income tax reductions apply. We show that, for the commuting distance range where the income tax reductions associated with commuting do not apply, commuting distance increases imply an overall hourly wage compensation of about 49% on average. The effect of commuting distance at the average commuting distance, where income tax reduction is applicable, is much lower, i.e. about 22%. The effect becomes zero at commuting distance of 50 kilometres. The estimated positive effect of change in commuting distance on wages is consistent with wage bargaining, and due to the quasi-natural experimental setup, excludes other competing explanations. Our results imply wage bargaining parameter of about 0.5 for both the range in commuting distance where the income tax reduction associated with commuting is not applicable and for commuting

[20] The full results of the Heckman selection models are provided in Appendix D.

distances where income tax reduction is applicable. The results appear robust with specification and accounting for selection effects.

Our findings have a number of implications. First it demonstrates that wage bargaining with respect to commuting is an important characteristic of the (Danish) labour market, in line with range of theoretical models (Marimom and Zilibotti, 1999). So it is able to demonstrate that employer have some labour market power and pay below workers productivity (Pissarides, 2000). Second, evidence of a wage-commute relationship puts a price on commuting distance and points to the economic benefits from transport infrastructure improvements.

Appendix A

Table A1. *Sample selection procedure*

		Workers	Firms
1	Address changes, total	64,643	11,314
2	Workers with more than 1 job, part-time workers and missing information	44,918	9,279
2.1	*Missing information regarding number of jobs*	*1,713*	*638*
2.2	*Missing information regarding part-time / full –time job*	*3,404*	*3,178*
2.3	*Missing information regarding worker's wage*	*740*	*393*
2.4	*More than 1 job (in the last year)*	*15,576*	*3,122*
2.5	*Workers without full-time job (that last at least 1 year, continuously)*	*23,485*	*1,948*
3=1-2	Address changes	19,725	2,035
4	Change in commuting distance = 0	8,338	337
5=3-4		*11,387*	*1,698*
6	Commuting distance > 100 km	878	179
7=5-6		*10,509*	*1,519*
8	Change in log(wage)>0.5	1,474	167
9=7-8		*9,035*	*1,302*
10	Change in commuting distance > 50 km	434	19
11=9-10	**Full sample**	***8,601***	***1,333***
12	Change in residence	1,263	192
13	Employer change	1,353	130
14=11-12	***Sample 1 (exclude change in residence)***	***7,338***	***1,267***
15=11-13	***Sample 2 (exclude employer change)***	***7,248***	***1,201***
16	**Sample 3 (exclude residence and employer changes)**	**6,165**	**1,144**

Appendix B

Table B1. *First-difference wage model with firm fixed-effects (commuting distance < 12.5 km)*

	[1]	[2]	[3]
	all observations	abs. change in commuting distance>500m	
Change in commuting distance	0.00504***	0.00507***	
	(0.00108)	(0.00507)	
Change in commuting distance (increase)			0.00407
			(0.00261)
Change in commuting distance (decrease)			0.00585***
			(0.00220)
Change in worker's function	0.03034***	0.03944***	0.03870***
	(0.00907)	(0.01228)	(0.01241)
Firm fixed effects (1,144)	Yes	Yes	yes
R-squared	0.4622	0.4932	0.4933
No. of observations	2097	1598	1598

Notes: as for Table 2.

Appendix C

Table C1. *First-difference wage model with firm fixed-effects. Sample includes employer and residence changes*

	[1]	[2]	[3]	[4]	[5]
	all observations		excl.|change in commuting distance|<500m		
Change in commuting distance	0.00111***	0.00110***	0.00115***	0.00114***	
	(0.00024)	(0.00024)	(0.00025)	(0.00025)	
Change in commuting distance squared / 100		0.00029		0.00032	
		(0.00064)		(0.00067)	
Change in commuting distance (increase)					0.00135***
					(0.00030)
Change in commuting distance (decrease)					0.00081**
					(0.00033)
Change in commuting distance * $D_{12.5}$	-0.00009	-0.00018	-0.00008	-0.00018	-0.00002
	(0.00022)	(0.00030)	(0.00023)	(0.00031)	(0.00023)
Change in commuting distance * D_{50}	-0.00080***	-0.00097**	-0.00082***	-0.00101**	-0.00077***
	(0.00024)	(0.00046)	(0.00025)	(0.00048)	(0.00025)
Change in worker's function	0.02748***	0.02748***	0.03005***	0.03005***	0.02926***
	(0.00388)	(0.00388)	(0.00445)	(0.00445)	(0.00449)
Firm fixed effects (1,333)	yes	Yes	Yes	yes	Yes
R-squared	0.2836	0.2836	0.2871	0.2871	0.2872
No. observations	8601	8601	7234	7234	7234

Notes: as for Table 2.

Table C2. *First-difference wage model with firm fixed-effects. Sample included employer changes*

	[1]	[2]	[3]	[4]	[5]
	all observations		excl.|change in commuting distance|<500m		
Change in commuting distance	0.00347***	0.00431***	0.00355***	0.00437***	
	(0.00060)	(0.00067)	(0.00062)	(0.00070)	
Change in commuting distance squared / 100		-0. 00222**		-0. 00216**	
		(0.00082)		(00085)	
Change in commuting distance (increase)					0.00386***
					(0.00067)
Change in commuting distance (decrease)					0.00331***
					(0.00065)
Change in commuting distance * $D_{12.5}$	-0.00203***	-0.00197***	-0.00205***	-0.00200***	-0.00207***
	(0.00052)	(0.00052)	(0.00054)	(0.00054)	(0.00054)
Change in commuting distance * D_{50}	-0.00298***	-0.00235***	-0.00302***	-0.00241***	-0.00306***
	(0.00057)	(0.00061)	(0.00060)	(0.00064)	(0.00060)
Change in worker's function	0.02563***	0.02573***	0.02789***	0.02804***	0.02708***
	(0.00418)	(0.00417)	(0.00490)	(0.00490)	(0.00494)
Firm fixed effects (1,201)	Yes	Yes	yes	Yes	Yes
R-squared	0.3033	0.3041	0.3131	0.3140	0.3133
No. observations	7248	7248	6153	6153	6153

Notes: as for Table 2.

Table C3. *First-difference wage model with firm fixed-effects. Sample includes residence changes*

	[1]	[2]	[3]	[4]	[5]
	all observations		excl.|change in commuting distance|<500m		
Change in commuting distance	0.00111***	0.00109***	0.00117***	0.00115***	
	(0.00026)	(0.00026)	(0.00028)	(0.00028)	
Change in commuting distance squared / 100		0.00056		0.00057	
		(0.00070)		(0.00073)	
Change in commuting distance (increase)					0.00134***
					(0.00035)
Change in commuting distance (decrease)					0.00096**
					(0.00038)
Change in commuting distance * $D_{12.5}$	-0.00007	-0.00024	-0.00007	-0.00024	-0.00004
	(0.00024)	(0.00032)	(0.00025)	(0.00034)	(0.00025)
Change in commuting distance * D_{50}	-0.00078***	-0.00112**	-0.00081***	-0.00116**	-0.00079***
	(0.00027)	(0.00050)	(0.00028)	(0.00053)	(0.00028)
Change in worker's function	0.02223***	0.02221***	0.02847***	0.02844***	0.02842***
	(0.00465)	(0.00465)	(0.00524)	(0.00524)	(0.00524)
Firm fixed effects (1,267)	Yes	Yes	yes	yes	Yes
R-squared	0.3190	0.3191	0.3219	0.3220	0.3220
No. observations	7338	7338	6221	6221	6221

Notes: as for Table 2.

Appendix D

Table D1. *Heckman selection models.* E*stimates of logarithm of changes in wage with changes in commuting distance*, firm fixed-*effects.*

		[1]	[2]	[3]	[4]	[5]	[6]
Logarithm of changes in wage	Change in commuting distance	0.00477***	0.00535***	0.00480***	0.00479***	0.00531***	0.00480***
		(0.00067)	(0.00074)	(0.00068)	(0.00067)	(0.00074)	(0.00068)
	Change in commuting distance	-0.00221**	-0.00194**	-0.00197**	-0.00214**	-0.00192**	-0.00194**
	squared / 100	(0.00081)	(0.00091)	(0.00082)	(0.00081)	(0.00091)	(0.00082)
	Change in commuting distance	-0.00239***	-0.00294***	-0.00247***	-0.00238***	-0.00291***	-0.00246***
	* $D_{12.5}$	(0.00052)	(0.00058)	(0.00053)	(0.00052)	(0.00058)	(0.00053)
	Change in commuting distance	-0.00288***	-0.00354***	-0.00304***	-0.00287***	-0.00351***	-0.00304***
	* D_{50}	(0.00063)	(0.00069)	(0.00064)	(0.00063)	(0.00069)	(0.00064)
	Change in worker's function	0.01819***	0.01566***	0.01840***	0.01841***	0.01482***	0.01837***
		(0.00471)	(0.00513)	(0.00478)	(0.00472)	(0.00514)	(0.00478)
	Dummy indicating 1 child				0.01871***	0.01370**	0.01713**
					(0.00622)	(0.00656)	(0.00637)
	Dummy indicating 2 children				0.01457**	0.00811	0.01271**
					(0.00628)	(0.00609)	(0.00634)
	Dummy indicating 3 or more				0.01909*	0.01715*	0.01712*
	children				(0.01004)	(0.01058)	(0.01007)
Dependent variable is dummy variable that defines the selection	*Change in commuting distance*	-0.01481***	-0.01265**	-0.01184***	-0.01228***	-0.01291***	-0.01085***
		(0.00179)	(0.00503)	(0.00163)	(0.00176)	(0.00501)	(0.00160)
	Change in commuting distance	-0.00678	0.03425	-0.00226	-0.08096	0.00244	-0.00211**
	squared / 100	(0.00515)	(0.00629)	(0.00445)	(0.05338)	(0.06126)	(0.00449)
	Change in commuting distance	0.00649**	0.00974**	0.00674***	0.00809***	0.00956**	0.00708***
	* $D_{12.5}$	(0.00235)	(0.00387)	(0.00203)	(0.00239)	(0.00387)	(0.00204)
	Change in commuting distance	0.00825**	0.01076**	0.00773***	0.01043**	0.01060**	0.00830***
	* D_{50}	(0.00373)	(0.00459)	(0.00317)	(0.00385)	(0.00456)	(0.00319)
	Change in worker's function	-0.10028**	-0.06952**	-0.05628**	-0.11304***	-0.06816**	-0.05311*
		(0.03578)	(0.03290)	(0.02867)	(0.03609)	(0.03278)	(0.02871)
	Commuting distance	**-0.00704*** **	**0.00237** **	**-0.00284*** **			
	(inst.)	**(0.00115)**	**(0.00098)**	**(0.00096)**			
	Commuting distance for	**0.00006**	**0.00095**	**0.00117**			
	spouse (inst.)	**(0.00102)**	**(0.00089)**	**(0.00082)**			
	Distance between workplaces	**0.00432*** **	**-0.00277*** **	**0.00002**			
	(inst.)	**(0.00093)**	**(0.00053)**	**(0.00058)**			
	Dummy indicating 1 child				0.26229***	0.05324	0.19066***
					(0.05211)	(0.04509)	(0.04101)
	Dummy indicating 2 children				0.47242***	0.02905	0.27109***
					(0.05468)	(0.04296)	(0.04086)
	Dummy indicating 3 or more				0.44445***	0.01332	0.22748***
	children				(0.10289)	(0.07383)	(0.07219)
	Dummy indicating presence of				**0.20456*** **	**-0.11123*** **	**0.04354**
	***children 12-18 years old* (inst.)**				**(0.05206)**	**(0.03151)**	**(0.03554)**
	Intercept	1.13476***	0.86710***	0.60122***	0.88097***	0.87916***	0.45019***
		(0.03458)	(0.02972)	(0.02774)	(0.02889)	(0.02761)	(0.02364)
	Sigma	0.15506***	0.18177***	0.15525***	0.15378***	0.18249***	0.15441***
		(0.00183)	(0.00244)	(0.00210)	(0.00159)	(0.00241)	(0.00179)
	Rho	0.23939***	-0.83025***	0.16996	0.13022	-0.83784***	0.10310
		(0.08353)	(0.01636)	(0.11363)	(0.10630)	(0.01529)	(0.13848)
	Log Likelihood	-355	-882	-2481	-283	-887	-2441
	No. Observations	8601	8601	8601	8601	8601	8601

Notes: (1) Columns [1] and [4] account for selection regarding residence change; columns [2] and [5] account for selection regarding employer change, columns [3] and [6] account for selection regarding both changes.

(2) Max.likelihood method is used to estimate the model. The coefficient associated with inverse Mills ratios is defined as σ multiplied with ρ.

(3) ***,**,* indicate that estimates are significantly different from zero at the 0.01, at the 0.05 and the 0.10 level, respectively.

(4) Standard errors are in parentheses.

(5) All explanatory variables in the selection equation are in 2003, so prior to the (possible) move.

(6) Instruments are indicated with bold type.

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