Do Commuting Subsidies Drive Workers to Better Firms?*

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Abstract

An unappreciated possible benefit of commuting subsidies is that they can expand the choice set of feasible jobs for workers in a way that facilitates better job match quality. Variation in wages and initial commuting distances, combined with major reforms to the commuting subsidy formula in Germany, generates worker-specific variation in commuting subsidy changes. We study the effect of changes in these subsidies on a worker's position in the wage distribution. Increases in the generosity of commuting subsidies induce longer commutes and workers to switch to higher-paying jobs. Although increases in commuting subsidies generally induce workers to switch to employers that pay higher wages, commuting subsidies also enhance positive assortativity in the labor market by better matching high-ability workers to higher-productivity plants. Greater assortativity induced by commuting subsidies corresponds to greater earnings inequality.

JEL classification: H20, H31, J20, J61, R23, R48

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1 Introduction

Individuals often spend an hour or more per day commuting. Despite the negative externalities of commuting resulting from added congestion and environmental impacts, many governments around the world subsidize commuting at substantial fiscal cost. For example, both Germany and France allow individuals to deduct commuting costs from taxable income. Given the large negative externalities from commuting, presumably policymakers utilize commuting subsidies to improve other outcomes in local labor markets. One possible reason for commuting subsidies is that they may improve the match quality of workers and employers. Commuting subsidies lower the cost of traveling to work, possibly expanding the choice set of workers in a way that facilitates a worker moving up in the wage distribution. In the presence of spatial mismatch, search frictions, restrictive zoning, or monopsony, expanding the choice set may improve welfare if reducing these frictions has sufficiently large benefits compared to the externality costs of commuting. Yet, the academic literature has limited evidence on how government policies can improve local labor market matching of firms and workers.

Despite the importance of commuting in day-to-day life, the empirical evidence on the effect of government taxes and subsidies on commuting and the consequences of such policies for employment is limited. Several possible reasons explain the lack of empirical evidence. First, many administrative datasets lack precise data on distances traveled to/from work. Calculating distance traveled requires information on both the residence and employment location. Both of these locational data may not be in common administrative datasets, meaning that researchers need to work with smaller survey datasets. Second, determining the effect on workers being able to move to higher paying firms requires administrative information to be able to determine if subsidies can help individuals find higher paying jobs than they would otherwise. Third, government policies that subsidize commuting often do not create clear natural experiments. For example, in the United States, most commuting subsidies occur via public transportation and the price changes are the same for all riders.

We overcome each of these limitations by studying tax deductions for commuting in Germany. The German setting has numerous advantages. First, given the prominent nature of commuting subsidies in the federal income tax code, tax changes affect many individuals differently. Individuals in Germany can deduct commuting expenses according to a formula: the number of days worked times the distance traveled times the "price" of commuting. The price of commuting is specified by German tax law and has changed several times over the last twenty years. Because the price is piecewise in distance and because the after-tax-value of the deduction varies depending on the marginal tax rate faced by the worker, combining major federal reforms with information on commuting distances and wages prior to a reform, generates *person-specific* variation in the value of commuting deductions. This provides us with ample exogenous variation to identify the effects. Second, the Integrated Employment Biographies (IEB) provided by the Institute for Employment Research (IAB) contains geocoded information on residence and employment, allowing us to calculate precise commuting distances before and after major tax reforms. These administrative data are remarkably rich and come with the advantage of having labor market information that would not be available in administrative tax return data. Finally, the IEB also contains information on plant and worker quality, allowing us to document the effect of commuting subsidies on assortativity of workers and plants. In particular, we calculated the wage decomposition of Abowd, Kramarz and Margolis (1999) or AKM, which decomposes the variation in wages into worker and plant-specific components. We can then test whether commuting subsidies reduce or reinforce positive assortativity in the labor market.

Theoretically, commuting subsidies could affect both the place of work and the place of residence. Despite this, few theoretical models allow for both places to respond to government policies, and most models allow only the residential location to respond. In standard spatial equilibrium models, such as the monocentric city model, households are assumed to commute to a fixed point (or points) at the city center and urban spatial structure adjusts in the long-run as a result of *residential* relocation only. As a result, all household moves must involve a change of residence only, but not a change of work. Such an observation stands in contrast with descriptive statistics for many countries other than the United States. Residential changes are much less common in many European countries than in the U.S., and as a result, people change the location of their jobs more frequently than they change residences. For example, Esipova, Pugliese and Ray (2013) summarize an international Gallup poll indicating that the percentage of individuals who moved from another city within the country during the last five years was above 21% in the U.S., but was less than 5% in Germany, and between 11 and 15% in the UK. Employment changes—holding constant residential location—are much more common. In our sample, 86% of all workers who change job locations do so without changing their residence. But, because most models assume the place of work is fixed, standard models are less applicable for studying many policy interventions.

Thus, we construct a theoretical model that shows the effect of commuting subsidies in a setting where workers have a fixed housing location and then reoptimize across job locations that differ in productivities in response to government policies. This polar case stands in contrast to the monocentric city model, shows several results, and allows us to build intuition on the effect of commuting subsidies when we think employment locations are the dominant relocation channel. In our model, individuals live at a fixed point and choose among two work locations that differ in productivity, incurring commuting costs that are proportional to distance plus an idiosyncratic component. Consistent with the wage formulation in Abowd, Kramarz and Margolis (1999), the wage paid to a worker is equal to their heterogeneous ability times the plant productivity level. Against this backdrop, we derive several results. First, larger commuting subsidies induce longer commutes; this effect is larger for higher-ability workers if the marginal tax rate on income is sufficiently flat in a local neighborhood of earnings and if the distribution of idiosyncratic commuting costs is non-decreasing. Second, under reasonable assumptions on the distribution of ability or if the commuting subsidy has a larger effect on the fraction of high-ability individuals with longer commutes than for low-ability individuals, an increase in commuting subsidies increases positive assortative matching—the average ability of more productive plants goes up. Although we consider a case with only employment relocations, combining our model with those already in the literature on residential relocation suggests that the predictions are likely somewhere in-between.

Then, using administrative data, we focus on a 50% random sample of the universe of German workers who change jobs between 2003 and 2015. As housing market data are not included, we excluded individuals who relocate residences. We use geocoded data on the location of the residence and employer to calculate the shortest driving distances commuted to work. We exploit large changes to German tax law to identify the effect of commuting subsidies. In particular, we exploit exogenous changes to the commuting price specified in German tax law in 2004 (a reduction in commuting tax deduction parameter), 2007 (a drastic reduction in tax deductibility parameter), which was unexpectedly reversed in 2009. To obtain person-specific measures of these tax changes, we write a tax calculator similar to NBER TAXSIM that calculates the tax liabilities of every worker in the administrative dataset. In particular, our calculator is useful to calculate how the commuting reforms affect person-specific commuting deductions due to differences in marginal tax rates and distances traveled. We then regress changes in commuting distances on changes in tax liabilities, using person-specific changes in the tax price of commuting resulting from tax reforms as an exogenous shock. The change in the tax price is calculated by holding constant distance and wages so that we rely on nonlinearities in the commuting formula and the marginal tax schedule to provide simulated exogenous variation. This yields a first-step estimate of how much distances change in response to subsidies. To then explore the effect of the reform on firm-specific quality, we regress changes in wages and changes in plant quality—as measured by the plant effect in Kline, Saggio and lvsten (2020)—on changes in person-specific commuting subsidies induced by the reform. The identifying assumption is that there are no time-varying unobservables correlated with person-specific changes to the value of the commuting deduction and our outcome variables.

In our first step, we explain commuting distance with the tax deduction for commuting. An increase in the generosity of the commuting deduction (also called an increase in the commuting subsidy) that lowers taxes paid by 100 Euros increases commuting by 2.5 kilometers or 12% of the mean commute. These estimates are 1.56 times larger than the only other paper found in the prior literature that causally investigates the effect of commuting subsidies on commuting distance (Paetzold 2019). This difference is likely due to the fact that we focus on an average effect rather than on only low-income workers and because we focus on job switchers. Turning to our second step, we then show that these increases in distance raise wages by 177 Euros per year or 0.46%. We show that absent the subsidy, under reasonable assumptions, the time costs of added commuting are at par with the increased wages. The commuting deduction, however, makes the added time costs clearly worthwhile given those increased wages. Finally, and most novel, after exploiting the estimation of the Abowd, Kramarz and Margolis (1999) person/plant effect in the wage decomposition, we show that the same more generous commuting subsidy saving 100 Euros of taxes induces workers to switch to plants that pay 0.28% higher wages overall (independent of worker quality). Comparing the percent change in the Abowd, Kramarz and Margolis (1999) plant effects with the percent change in total earnings due to the commuting subsidy suggests that the percent change in plant quality is 61% of the percent increase in earnings. In general, most people actually move very little through the plant effect distribution over time, so although small, this positive and significant effect implies the policy increased workers' choice set in a way that led them to find better paying firms than they would have absent the commuting deduction.

Although commuting subsidies induce workers to switch to jobs with higher firm-specific components of pay, the prior (average) effect masks whether the commuting subsidies reduce or reinforce homophily between workers and plants. To test this, we estimate the effect of commuting subsidies on the plant-specific component of pay by deciles of the worker-specific component of pay from our AKM decomposition. We find that for most lower deciles of the person-specific quality distribution, more generous commuting subsidies have either no effect or a slightly negative effect on the plant quality level. But, this effect of commuting subsidies on the plant component increases almost monotonically in deciles of person-specific quality. For individuals in the highest deciles of the worker-specific component of the wage distribution, a more generous commuting subsidy saving 100 Euros of taxes induce these workers to switch to plants that pay a 0.49% higher wage premium. Given this effect is almost double the average effect and because the effects at the lower end of individual quality are negligible, we conclude that commuting subsidies reinforce positive assortativity in the labor market. Thus, if the goal of the subsidies was to improve the plant-specific component of wages for low-income households rather than for high-income households, it is likely the subsidy was not effective at meeting this goal. It is important to note that AKM is a very good first-order approximation to the wage structure with respect to both the "firm-specific component of pay" and "worker-specific component of pay" but may not relate to underlying structural parameters such as firm-quality or worker-ability. Nonetheless, as a convenient short-hand throughout the paper, we sometimes refer to firms with better firm-specific components of wages as "higher quality" and workers with better worker-specific components of wages as "higher ability."[1]

The correlation between AKM worker and firm effects is inherently interesting even if it does not directly measure ability-productivity matching. Greater assortativity corresponds to greater earnings dispersion, all else equal. Card, Heining and Kline (2013) show that a large part of increasing wage dispersion in West Germany was due to rising assortativity. In particular, those authors show that the rise in assortative matching explains 34% of the rise in inequality for male workers. Thus, if commuting subsidies increase assortativity as we find, they also—all else equal—contribute to increased (within labor market) earnings inequality. The relatively recent rise of wage and income inequality in many countries around the world (Atkinson, Piketty and Saez 2011) has created public policy challenges for how to mitigate rises in inequality. Although theoretically an increase in the generosity of commuting subsidies may increase or decrease heterogeneity in wages, our empirical analysis that commuting subsidies reinforce labor market inequities in earnings.

One other paper causally studies the effect of commuting subsidies on commuting distances. Paetzold (2019) studies these subsidies in Austria.[2] However, his paper exploits a regression kink design using a kink in the tax code near 10,000 Euros of income. Given the regression kink design yields a local average treatment effect and given this kink is relatively low in the income distribution, generalizing the results from that setting is problematic, especially as commuting distances and private costs vary substantially over the income distribution. Heuermann et al. (2017) also exploit changes in the commuting deduction formula in Germany, but mainly focus on a single tax reform and study the incidence effects on wages of all workers of a change in taxes, and thus not the effect on commuting distances. Dauth and Haller (2020) regress changes in wages on changes

[1] These terms are mainly convenient, but obviously, one write down structural models for which the relationship between estimated worker and firm effects bear no relationship to underlying latent productivity or ability.

[2] Boehm (2013) studies the effect of commuting subsidies on the decision to change jobs or residence and whether subsidies increase or decrease commutes.

in distance for job switchers in Germany, but do not identify the role of commuting subsidies. Mulalic, Van Ommeren and Pilegaard (2014) investigate how wages respond to changes in commuting distance due to relocations by firms in the Danish context, but again do not investigate the effect of commuting subsidies. Finally, Wildasin (1985) and Agrawal and Hoyt (2019) study the effect of income taxes, more generally, on commuting, but both papers focus on the role of tax rates overall and not targeted deductions for commuting.

Our study also relates to theoretical work on optimal commuting subsidies. Borck and Wrede (2009) show in an agglomeration framework with intra- and intercity commuting that commuting subsidies can be efficiency enhancing by inducing households to find the jobs with the highest social value. Borck and Wrede (2005) and Borck and Wrede (2008) discuss the political economy and mode choice aspects of commuting subsidies. Our work is complementary to that literature.

Finally, we contribute to a literature in labor economics on assortativity in the labor market. A growing empirical literature in economics has studied whether there is assortativity in labor markets (Abowd, Kramarz and Margolis 1999; Abowd et al. 2003; Abowd et al. 2018; Schmutte 2014; Torres et al. 2018; de Melo 2018; Combes et al. 2012; Bartolucci, Devicienti and Monzón 2018). Dauth et al. (2022) show that larger cities allow for a more efficient match process between workers and plants, and this has important consequences for regional wage inequality. And there is a growing literature that decomposes wage losses at employment at a job displacement to see how much of those losses is due to the firm effects. Schmieder, von Wachter and Heining (2023) show that in Germany, many displaced workers move to lower-wage firms with 70% of wage losses explained by firm-specific effects and Fackler, Mueller and Stegmaier (2021) also find firm-effects explain a large share. Bertheau et al. (2023) find that employer-specific wage components explain between 35% and 60% of the earning response in countries such as Austria, Italy, and Spain.[3] Our approach has similarities to these papers, but uses an entirely different research design, reaching a similar quantitative magnitude (61%) of the share of the earnings response that is explained by the firm-specific component. But, the role of government policies in explaining assortativity in the labor market and the ability to induce individuals to move to higher paying firms remains understudied.[4] A key contribution of our paper is to document that government policies can reinforce assortativity. Although commuting subsidies might be designed to reduce assortativity by allowing lower-wage workers to increase their job set, commuting subsidies actually

[3]The evidence on the U.S. is mixed. On the one hand, the firm-specific component plays a smaller role in the U.S. (Lachowska, Mas and Woodbury 2020). But Woodcock (2008), finds that 60% of earnings growth is due to sorting into firms that pay higher average earnings.

[4]Bennedsen et al. (2022) study government policies and job matches during the COVID-19 crisis.

induce higher-wage workers to commute relatively longer, allowing them to match with higher wage plants.

2 A Model of Endogenous Work Location

In this section, we develop a simple model of endogenous work location choice when the residence of households is fixed. Standard spatial models, such as the monocentric city model (Brueckner 1987), traditionally assume that following an economic shock, households reoptimize by changing their residential location, but still commute to a fixed location or area of the city.[5] In our model, the location of employment can be optimized across places within a metropolitan area. While this is opposite to the standard monocentric city model, our setup captures well the typical situation in Germany where households do not change residency often and government subsidies for commuting play an important role. In the long run, household residency may be endogenous as well, but we ignore this here, as the short-run effects of changes in commuting subsidies do not typically lead to household relocation in Germany. We view our model as complementary to standard closed city metropolitan models.

In many countries around the world, residential mobility is substantially lower than in the United States. For example, using survey data, Gallup (2013) reports that the fraction of individuals who moved from another city or area within the country during the last five years was above 21% in the U.S., between 16 and 20% in France, less than 5% in Germany, and between 11 and 15% in the UK. A similar picture arises from the EU-SILC database on European countries, see Table 1. Within Europe, mobility of households in Germany is relatively low, in particular when compared to other large countries (with the exception of Italy). Table 1 reports the fraction of households who moved to another dwelling in the last five years, expressed relative to the overall population and relative to the group of tenants who rent at market price. Renting in the market is the dominant form of housing arrangement in Germany. Considering also that mobility is typically much higher when young, it is plausible to assume that residential changes of average workers in mid-career are relatively rare. The numbers in Table 1 are higher than the Gallup numbers because they include moves within the same area, while Gallup focuses only on moves across urban areas.

Moreover, the literature on labor economics suggests that individuals frequently change jobs–either in response to life cycle career dynamics, firings, or better jobs that are found–oftentimes in ways that do not require the worker to relocate residences. In

[5] Of course, "open city" variants of spatial equilibrium models, where individuals can change metropolitan areas, allow individuals to change both residential and employment locations. But many location changes are within metropolitan areas.

Table 1: Share of population having moved to other dwellings within the last five year period

Share in %	Overall	Tenants renting at market price
France	27.0	51.9
Germany	21.9	35.6
Italy	8.9	23.3
Spain	13.0	51.8
UK	30.8	77.1

Source: EU-SILC ad hoc modules, 2012, Housing conditions

our sample, 86% of all workers who change job locations do so without changing their residence. We make progress on this issue by focusing on a polar extreme variant of the standard monocentric city model. In our model, household locations are fixed and households reoptimize employment locations in response to shocks. While the reality is that individuals likely reoptimize on both margins, studying this polar case allows us to highlight critical differences with the standard model, to develop a model applicable for countries where household locations change infrequently, and to draw out insights for the large fraction of individuals that change jobs without changing residential locations.

2.1 The Model

As motivated above, we assume that the residence of all households is fixed at a given point in space, but there are two different work locations, $i = 1, 2$. Location 2 is further away at distance $d_2 > d_1 \geq 0$, but the firm at location 2 is more productive and thus pays a higher wage due to higher firm productivity $\psi_2 > \psi_1$. Households differ in their ability (education) $\alpha \in [\underline{\alpha}, \overline{\alpha}]$, which is continuously distributed with density $h(\alpha)$. A household's gross wage is the product of individual ability and firm productivity

$$w = \alpha\psi. \tag{1}$$

We assume that households supply one unit of labor inelastically. The wage is therefore equal to gross income. The functional form of this wage expression is selected to map our theoretical model to the standard Abowd, Kramarz and Margolis (1999) decomposition of (log) wages into additively separable worker-specific and firm-specific components.

The utility of a household depends on after-tax income, which is entirely used for consumption of a numéraire good y. A household's after-tax income takes into account commuting cost ukd to work location with distance d, where kd is the "typical" cost of commuting to distance d. We normalize the typical cost by setting the parameter $k = 1$. The typical cost might represent the cost of commuting with an average car.

Individual costs may differ due to a more or less fuel-efficient car, or by using a different transportation mode (e.g., public transportation). Hence there is an individual-specific idiosyncratic aspect of commuting costs, which is captured by $u \in [\underline{u}, \bar{u}]$ with $\underline{u} \geq 0$. The cost shock is drawn from a distribution with density $f(u)$ and cumulative density $F(u)$, and $f(u)$ is the same for all types α, that is, the covariance between u and α is zero, and an individual's draw is independent of job location.

For an individual working at location i, consumption y_i is equal to:

$$y_i = \alpha\psi_i - ud_i - T(\alpha\psi_i - cd_i). \tag{2}$$

Then, $T(m_i)$ is the tax bill when working at location with distance i and taxable income $m_i \equiv \alpha\psi_i - cd_i$ is equal to earnings net of deductible commuting expenses, where $0 \leq c < 1$ is the deductibility share of commuting cost for tax purposes. Parameter c is the key policy instrument in our model, and we look at the effect of changes in c further below. In line with most personal income tax systems, we assume that the marginal tax rate is non-decreasing in taxable income, i.e. $T'(m_2) \geq T'(m_1)$, if $m_2 > m_1$.

Each household optimizes the work location in order to maximize consumption. As in the standard monocentric city model, changing jobs is costless, and there is no job search; as a result any reoptimization of jobs is best thought of as a long-run equilibrium. A household trades off a higher wage against a longer commute. The government influences this decision through the progressivity of the income tax and the deductibility parameter c. An individual of a given ability type α and commuting shock u prefers job location 2 over job 1 if $y_2(\psi_2, d_2) > y_1(\psi_1, d_1)$. Given type α, the individual that is indifferent between jobs has idiosyncratic commuting cost shock

$$\tilde{u}(\alpha) \equiv \frac{\alpha(\psi_2 - \psi_1) + T(m_1) - T(m_2)}{d_2 - d_1}. \tag{3}$$

Individuals with $u \leq \tilde{u}(\alpha)$, that is with low commuting cost, choose job 2, while those above choose job 1 at a closer distance. The fraction of individuals of a given ability type α who choose the better paying job at d_2 is therefore $F(\tilde{u}(\alpha))$. The threshold $\tilde{u}(\alpha)$ depends on α, as can be seen by differentiating (3), to obtain

$$\frac{d\tilde{u}}{d\alpha} = \frac{\psi_2(1 - T_2') - \psi_1(1 - T_1')}{d_2 - d_1}, \tag{4}$$

where T_i' is an abbreviation for the marginal tax rate when working at location i. The derivative in (4) is positive if the marginal tax rate doesn't increase too much locally as a result of switching to the higher paying job. In that case, the fraction of long distance commuters is larger for higher-ability types than for lower ability types.

2.2 Comparative Statics: Commuting Subsidies

As our empirical model will exploit changes to the commuting deduction parameter, we proceed by analyzing the comparative statics with respect to c. A change in the commuting subsidy c has an unambiguously positive effect on the fraction of individuals commuting long distances for all levels of α:

$$\frac{dF(\tilde{u}(\alpha))}{dc} = f(\tilde{u})\frac{d\tilde{u}}{dc} = f(\tilde{u})\left[\frac{d_2T_2' - d_1T_1'}{d_2 - d_1}\right] > 0. \tag{5}$$

The effect is larger for higher α types under a certain condition:

$$\frac{d^2F(\tilde{u})}{dcd\alpha} = f'(\tilde{u})\frac{d\tilde{u}}{d\alpha}\frac{d\tilde{u}}{dc} + f(\tilde{u})\frac{d^2\tilde{u}}{dcd\alpha}, \tag{6}$$

which is positive when the distribution of the commuting cost is nondecreasing ($f' \geq 0$) and the tax system is not too progressive (see (4), as then $\frac{d\tilde{u}}{d\alpha} > 0$). The second term in (6) is positive given a progressive tax system because

$$\frac{d^2\tilde{u}}{dcd\alpha} = \frac{T_2''\psi_2 d_2 - T_1''\psi_1 d_1}{d_2 - d_1} > 0.$$

We summarize our findings so far.

Result 1. *(a) The fraction of long distance commuters is increasing in ability α if the marginal tax rate $T'(m)$ is not increasing too much locally, so that $\frac{1-T_1'}{1-T_2'} < \frac{\psi_2}{\psi_1}$ holds. (b) Larger commuting subsidies induce more long distance commuting, and the effect is larger for higher-ability types if statement (a) holds and if the distribution of commuting costs is nondecreasing, $f'(u) \geq 0$.*

While result 1 is derived under general conditions, it is useful to consider a specific example. Inspection of (5) shows that this increasing in ability for a uniform density $f(u)$ when the tax function $T(m)$ is strictly convex. Differentiating the numerator in (5) with respect to α gives $d_2T_2''(m_2)\psi_2 - d_1T_1''(m_1)\psi_1$, which is positive if $T_2'' > 0$ because $m_2 = \alpha\psi_2 - cd_2 > \alpha\psi_1 - cd_1 = m_1$.

While Result 1 is reassuring in terms of its comparative statics, one might wonder whether a comparable result holds in terms of wages rather than ability, because the latter may not be perfectly observed in practice. In a second step of our analysis, we therefore establish an analytical result, similar to Result 1(a), in terms of observable wages. To this end, we utilize a specific property of our two work location model: as a result of the commuting decision, for each ability type α there exist two different levels of wages: $w_2(\alpha) = \alpha\psi_2$ and $w_1(\alpha) = \alpha\psi_1$, with $w_2 > w_1$. More precisely, consider wage

$$w = \alpha^L \psi_2 = \alpha^H \psi_1, \tag{7}$$

that is a low [high] ability type $\alpha^L[\alpha^H]$ commuting to a high [low] productivity firm. The fraction of long distance commuters at wage w is therefore

$$\lambda(w) = \frac{h(\alpha^L)}{h(\alpha^L) + h(\alpha^H)}, \tag{8}$$

where $\alpha^L = w/\psi_2$ and $\alpha^H = w/\psi_1$ is obtained from (7). Condition (8) is thus an implicit function of the wage. Our interest lies in the effect of the wage on the share $\lambda(w)$. Differentiating (8) with respect to w and using (8) leads to $h'(\alpha^L)h(\alpha^H)\frac{1}{\psi_2} - h'(\alpha^H)h(\alpha^L)\frac{1}{\psi_1}$. The sign of this expression depends on the slope of the density of the type distribution α (not commuting cost u) relative to the firm productivity differential. More precisely, we obtain:

Result 2. *The share of long distance commuters is increasing in the wage w if the density $h(\alpha)$ is decreasing and*

$$\frac{h'(\alpha^L)}{h'(\alpha^H)} \frac{h(\alpha^H)}{h(\alpha^L)} < \frac{\psi_2}{\psi_1}. \tag{9}$$

Condition (9) *holds when $h''(\alpha) \leq 0$.*

To see that (9) holds under a concave density, note that it can be rewritten as $\frac{h'(\alpha^L)}{h'(\alpha^H)} < \frac{h(\alpha^L)}{h(\alpha^H)} \frac{\psi_2}{\psi_1}$. The right hand side is larger than 1 because both terms are greater than 1. The left hand side is less or equal to 1 if $h''(\alpha) \leq 0$.

We can replace our assumption of a decreasing density $h(\alpha)$ with the opposite and obtain the same qualitative result as in Result 2 by reversing the inequality sign in (9), that is, the share of long distance commuters is increasing in the wage if the density $h(\alpha)$ is increasing in α and condition (9) is reversed.

The advantage of Result 2 is that it speaks about the fraction of long distance commuters as function of the observable wage. A potential problem is that it relates, in turn, to properties of the ability distribution. Note, however, that condition (9) is not too demanding because it requires only qualitative properties on the slope and curvature of the density. Moreover, empirically we can rely on the person-specific and firm-specific decomposition of the AKM model.

2.3 Matching of Workers and Firms

In our empirical analysis below we look at the matching of workers and firms, and how this matching varies with the commuting subsidy. Do commuting subsidies allow for better assortative matching of worker ability types (α) and firm quality types (ψ)? This can be studied in our model by comparing the average ability at a given firm before and after a commuting deduction reform. For example, the average ability level of workers at firm 2, α_2, is given by

$$\alpha_2 \equiv \frac{\int_\alpha \alpha F(\tilde{u}(\alpha))h(\alpha)d\alpha}{\int_\alpha F(\tilde{u}(\alpha))h(\alpha)d\alpha}. \tag{10}$$

The numerator uses the number of individuals of a given ability level who work at firm 2 and then integrates their productivity over all ability types. The denominator normalizes by the total number of individuals working at firm 2. Note that $F(\tilde{u})$ is a function of α from (3), but to simplify notation, we drop that argument (of course, the functional dependence is kept). Similar to (10), we can define the average ability at firm 1, α_1, which looks like (10) with $F(\tilde{u})$ being replaced by $1 - F(\tilde{u})$, both in the numerator and denominator.

Differentiating (10), we can express the effect of a change in the commuting subsidy via parameter c on the average ability at firm 2 as follows:

$$\frac{d\alpha_2}{dc} = \frac{\int_\alpha (\alpha - \alpha_2)\frac{dF(\tilde{u})}{dc}h(\alpha)d\alpha}{\int_\alpha F(\tilde{u})h(\alpha)d\alpha}. \tag{11}$$

We are interested in the sign of (11), which depends on the sign of the numerator. If positive, higher commuting subsidies induce more assortative matching because $\psi_2 > \psi_1$. If negative, the commuting subsidies mitigate assortativity. This ambiguity justifies the need for our subsequent empirical analysis. Note that the derivative $dF(\tilde{u})/dc > 0$ is positive, but in general a function of α, see (6), which implies that there is no simple condition that makes $d\alpha_2/dc > 0$. However, we can provide conditions when $d\alpha_2/dc > 0$ is more likely to hold.

In particular, (11) makes it clear that there are three different possibilities. First, (11) is more likely to be positive if α_2 is small, that is, initially the average ability of workers in firm 2 is low, because then there are only few cases with negative entries in the numerator. However, such an explanation is unappealing from an empirical perspective because of the consensus in the empirical literature that assortative matching occurs in equilibrium. Thus, we rule out this condition as holding. Second, (11) is more likely positive if there are few individuals for whom $\alpha < \alpha_2$, but many for whom $\alpha > \alpha_2$. This condition implies that firm 2 likely hires many high-ability workers, but also must hire some very low-ability workers and this skewed distribution pulls down the mean.

At the same time, firm 1 follows the opposite practice. Such a pattern is consistent with the empirical evidence on positive assortativity, implying that commuting subsidies reinforce existing patterns. Finally, (11) is more likely positive if the value of the derivative $dF(\tilde{u})/dc > 0$ is larger for high-ability types (i.e. $\alpha > \alpha_2$) than for low-ability types (i.e. $\alpha < \alpha_2$). To shed light on this condition, we can draw on Result 1, which shows that $dF(\tilde{u})/dc$ is increasing in α if the marginal tax rate $T'(m)$ is not increasing too much locally and if the distribution of commuting costs is nondecreasing, $f'(u) \geq 0$. With a uniform density, this will hold if the tax function is strictly convex, e.g. progressive, as is the case for more tax systems.[6]

As the average ability in society is a convex combination of the average abilities in the two firms, α_1 and α_2, we conclude that the average ability in the two firm locations must move in opposite directions as commuting subsidies change. Since α_1 and α_2 are endogenous variables whose value depends on all parameters of the model, it is an empirical question whether commuting subsidies lead to more or less assortative matching.

Result 3. *A rise in commuting subsidies increases assortative matching, that is, the average ability of workers at the more [less] productive firm goes up [down] if (a) the distribution of individual ability is such that there are many individuals with a productivity greater than the average productivity in firm 2 or (b) the commuting subsidy has a larger effect on the fraction of high-ability individuals commuting longer distances than for low-ability individuals.*

Our analysis provides insights into the effects of higher commuting subsidies on commuting distance, the fraction of commuters with high-ability/wage, and the matching of workers with firms. The formal results indicate that even in a simple model with fixed residencies and two work locations, comparative statics often depend on assumptions concerning the distributions of idiosyncratic commuting costs and ability. As the distribution of idiosyncratic costs is typically not directly observable, it is an empirical question of how changes in commuting cost affect commuting and matching. We expect this also to be true in a more general model, in which for example households may differ in their exogenous residence location and choose from more than two work locations. While an extension of the theoretical model in this direction is of interest in itself we leave it for future research and now turn to our empirical analysis.

To bridge our theory to empirics, note that the comparative statics we derive above are with respect to the cost parameter c. Our empirical model will study the effect of taxes on commuting distances. Given a tax function $T(m, c)$,taxes will fall if c increases

[6]From Result 1(a) the tax system must be convex, but not too convex.

implying that the effect of taxes on distance are opposite signed to the direct effect of c on distance.

3 Institutional Background

In Germany, taxpayers can deduct work related expenses ("Werbungskosten") before the income tax schedule applies. There is a lump sum deductible S for all taxpayers who do not itemize. Individuals who itemize may claim expenses for commuting C and other purposes D, so that total itemized deductions are $R = C + D$. The claimed amount is thus the larger of R and S.

Our interest lies in reforms to the determination of C.[7] The general formula for commuting deductions is

$$C = n \times d \times p \tag{12}$$

where n is the number of commuting days per year, d is distance, and p is price/cost per kilometer. One can deduct all days actually commuted; however, the German tax authority typically accepts 230 days (5-day working week), and 280 days (6-day working week). These numbers of days are a common practice for taxpayers to use because claiming more than those threshold days requires proof of plausibility. Distance is the shortest distance one way unless it can be proven that a longer way is more economical. Finally, p is a parameter that has changed over time according to German law, which we will exploit for identification. The mode of transportation is irrelevant for the deduction, except trips by plane which are not deductible. There is an upper limit for C at 4500 Euros for all modes other than transportation by car. Assuming transportation by car, the time variation in total deductible commuting expenses is given by Table 2 and Figure 1.

In our period of analysis, there have been three quantitatively important changes to the tax deductibility of commuting expenses. The first, moderate one in 2004 reduced the "price" per kilometer of commuting between one-sixth and one-fourth (from 36 and 40 cents, respectively, to 30 cents per kilometer) and also reduced the lump sum deductible S from 1044 Euro to 920 Euro. The second change occurred in 2007: commuting of the first 20 kilometers became not deductible at all, while distances above 20 were deductible at the same price as before. There was no simultaneous change in the lump sum deductible.

The reform of 2007 was ruled unconstitutional in late 2008 and the Federal Supreme Court reinstated the parameters for tax deductibility for commuting from 2006 (BVerfG, Urteil vom 09.12.2008, 2 BvL 1/07) effective in 2009. This is our third reform. In the

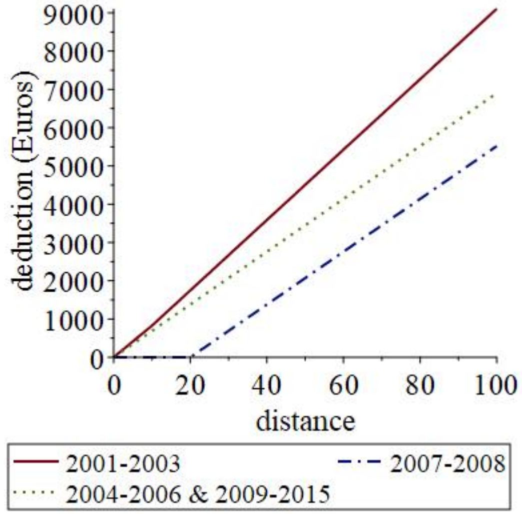
[7] The legal basis for commuting expenses can be found in §9 Einkommensteuergesetz (EStG).

Table 2: Commuting Deduction Reforms

	$d \leq 10$	$10 < d \leq 20$	$d > 20$
2001-2003	$0.36nd$	$3.6n + 0.4(d-10)n$	$3.6n + 0.4(d-10)n$
2004-2006	$0.3nd$	$0.3nd$	$0.3nd$
2007-2008	0	0	$0.3n(d-20)$
2009-2015	$0.3nd$	$0.3nd$	$0.3nd$

Notes: This table shows the commuting deduction formula.

Figure 1: Visual Representation of the Commuting Formula



Notes: This figure shows how the value of the commuting deduction has changed over time.

view of the court, the 2007 law violated the principle of horizontal equity by not allowing short commuters to deduct anything, while longer commutes could deduct commutes above 20 kilometers. The actual commuting decisions in 2007 and 2008 were based on the law as originally intended for those years before the court intervened.[8] The Court reform of 2009 was unique in its implementation, and perhaps salience, while also occurring in a period coming out of the Great Recession.[9]

The first two reforms were implemented as measures of budget consolidation and are thus exogenous from the viewpoint of an individual taxpayer.[10] In the early to mid 2000s Germany was stuck in a situation of low economic growth, high structural unemployment, and excessive public deficits leading in some years even to an overshooting of the 3 percent deficit ceiling of the Maastricht treaty. In 2007, the change in commuting subsidies went hand in hand with other revenue-raising measures: for example, the federal government increased the VAT by 3 percentage points and introduced a tax on the rich with a top marginal income tax rate of 45% for incomes (singles) above 250.000 Euros to reduce the deficit.

The commuting tax deduction is a significant tax expenditure: In 2011, total gross wages in Germany were 931 billion Euros. Individuals who itemized in their income tax declaration had work related deductions equal to about 36 billion Euros, of which 58.5% (about 21 billion Euros) are attributed to commuting (Statistisches Bundesamt, 2015). Taking an average marginal tax rate of 25% for illustrative purposes, the government saves about 5 billion Euros if it were to cut the commuting tax deductibility completely (assuming no lump sum deductible).

4 Data

4.1 Data on Earnings and Location

To study the effect of commuting subsidies, we need detailed information on job duration, earnings, place of residence, and information on workers' previous and current employers. To identify workers who change jobs, we combine two administrative data sets: The Integrated Employment Biographies (IEB) and the IEB GEO provided by the Institute for Employment Research (IAB).

The IEB contains longitudinal information on plants and workers' job duration (on a daily basis), separations, hirings, and daily wages (deflated by the consumer price

[8]From 2011 onward the lump sum deductible S was increased from 920 to 1000 Euros.

[9]Excluding it from our empirical analysis increases the magnitude of our effects in absolute value.

[10]Deutscher Bundestag, Entwurf eines Steueränderungsgesetzes 2007, Drucksache 16/1859, June 19, 2006; Bundesministerium der Finanzen: Entwurf des Bundeshaushalts 2007 und des Finanzplans des Bundes 2006-2010, Monatsbericht, August 2006, p. 63-75.

index). The IEB comprises the universe of unemployed job seekers and wage and salary employees registered with the German social security system, which covers approximately 80% of all people employed in Germany. Because the information is used to calculate social security contributions, the data set is highly reliable and especially useful for analyses taking earnings and labor market transitions into account.[11] Each observation contains a unique worker and establishment identifier, socio-economic characteristics of the worker, information on the worker's place of residence and work at the municipality level.

While the information on job durations and gross daily wages is highly reliable, the IEB has no detailed information on the number of hours worked. Furthermore, wages are top-coded at the social security contribution ceiling. To address the first issue, we restrict our analysis to workers who switched from a full-time job to a full-time job. Second, we impute wages above the social security contribution ceiling, using the procedure suggested by Card, Heining and Kline (2013) and implemented by Dauth and Eppelsheimer (2020). Daily wages are expressed in 2015 Euros using the CPI.

To investigate the commuting behavior of workers, administrative boundaries like municipalities are not suitable as their geographic size varies considerably. For this reason, the IEB has been geo-coded. The IEB GEO provides the exact geographic location of worker's residence and workplace for the period 1999–2017 (see Ostermann et al., 2022). We use these geocodes to calculate the commuting distance in kilometers using the route on public roads conditional on the shortest commuting time between the worker's residence and workplace.[12]

To capture heterogeneity by worker and plants, we rely on the employer and worker wage effects of a wage decomposition first introduced by Abowd, Kramarz and Margolis (1999), henceforth AKM, which provides a suitable approximation of the German wage structure (Card, Heining and Kline, 2013). The AKM decomposition splits up individual workers' wages into four components

$$\ln w_{it} = \alpha_i + \psi_{f(it)} + \beta x_{it} + u_{it} \tag{13}$$

worker fixed effects α_i which captures both time-invariant observable and unobservable characteristics of worker i, plant fixed effects $\psi_{f(it)}$, where f denotes the plant at which worker i is employed in year t. Time-varying observable worker characteristics are denoted by βx_{it}, where x_{it} includes year dummies and a third-order polynomial of worker's age interacted with education. Finally, u_{it} is an idiosyncratic log wage component. Note that worker and plant fixed effects are identified by workers moving across plants. The

[11] We use the IEB-version IEB_v_15_00. For details on the IEB, see Jacobebbinghaus and Seth (2007)

[12] We use the IEB_geo_v_02 version of the geocoded dataset, the Open Source Routing Machine (OSRM) provided by Huber and Rust (2016), and an offline version of OpenStreetMap for 2014.

plant fixed effect describes the systematic part of a worker's wage, which is common to all workers of the plant regardless of individual characteristics and thus represents the wage premium enjoyed by every worker employed at plant f. Whereas the worker fixed effect describes worker's time-invariant human capital rewarded equally across plants.

AKM effects are calculated for the IEB based on full-time workers aged 18–60. Following the methodology by Card, Heining and Kline (2013), we estimate these regressions over rolling 5-year windows. To address concerns regarding limited mobility bias resulting from the large number of firm-specific effects that are identifies from workers moving across firms, in a robustness check we follow Bonhomme et al. (2023) and calculate AKM effects using the leave-one-out connected set.[13] This set contains the largest set of plants that are connected by at least one mover and remain connected after any mover is removed from the sample.

We draw a 50 percent random sample of all workers in Germany aged 18 to 60 who separated from a job and took up a new job within 31 days during the observation period 2002-2015. We retain workers switching to a different plant identifier. To correctly identify transitions to a new employer we drop all transitions due to spin-offs or mergers using a procedure proposed by Hethey-Maier and Schmieder (2013). The exact geocode also allows us to exclude job transitions due to a plant's ID change. We restrict the sample to workers with at least six months of tenure at the old job and exclude workers who switched jobs twice within one year. We only keep workers with unambiguous addresses and thus high-quality geocodes. Household location is endogenous and housing prices are not available. We, therefore, concentrate on workers changing employers but did not change residence within 6 months after the job change, which is roughly 86% of all workers changing jobs. Finally, we are interested in daily commuters which is the reason why we drop all workers who commuted more than 100 km to their old or new jobs. Our final estimation sample consists of 2,409,738 transitions.

4.2 Tax Calculator

In order to study the effect of commuting tax breaks on commuting distances and on job match quality, we also need to measure the effect tax change at various points of the income distribution. To do this, we write a tax simulator similar to NBER TAXSIM (Feenberg and Coutts 1993) for the German tax code. Our tax simulator accounts for deductible expenses, including commuting expenses (C) and other deductible expenses (D), in addition to the standard deduction (S) that is available for every worker without

[13] Bonhomme et al. (2023) note "If firms are weakly connected to one another because of limited mobility of workers across firms, FE estimates of the contribution of firm effects to wage inequality are biased upwards while FE estimates of the contribution of the sorting of workers to firms are biased downwards."

proof of expenses, as explained in Section 3. Denote total itemized deductions be $R = C + D$. The simulator also accounts for the basic allowance of tax-exempt income and marginal tax rates. The German tax system does not feature tax brackets – instead marginal tax rates are a continuous function of taxable income (z) such that the marginal tax rate is given by $T'(z)$ and tax liabilities are given by $T(z)$.[14] Then taxable income is given by

$$z = m - \max(C + D, S) \tag{14}$$

where m is gross income and C is explained in Section 3. Applying the German income tax schedule to taxable income then yields tax liability $T(z)$.

In our simulator, statutory reforms can influence the tax burden of an individual through commuting deductions, standard deduction, and marginal tax rate changes.

Our empirical model and identification strategy will rely on reforms to the commuting deduction. However, the tax schedule has changed over time, generally showing a decline in total taxes paid for a given level of income. While changes in the marginal tax rate influence the value of the commuting deduction conditional on itemizing, they also affect other behaviors such as labor supply, and for this reason, as we discuss subsequently we will rely on a simulated measure of the changes in the value of the commuting deduction, holding constant its tax-price.

We identify changes to all of these parameters from the German tax law. We then code all of these provisions of German tax law for all years from 2002-2015. After writing our tax simulator, which takes the set $\{m, C, D\}$ as inputs at the individual level,[15] we are able to simulate tax liabilities for individuals. Obviously, our tax simulator misses some elements of the tax code – as do all tax calculators, including TAXSIM – but for our purposes, we capture the key commuting elements of the tax code. To implement our simulator, we assume that the (annualized) labor income observed in the IAB data is gross income.[16]

Using our tax calculator, when an individual i changes jobs in year t, the change in taxes is given by

$$\triangle tax_{it} = \triangle T_t(z_{it}) = \triangle T_t(m_{it}, c(d_{it}, p_{it}), S_t, D_{it}) \tag{15}$$

which depends on parameters of the tax systems and endogenous variables, such as income

[14] To determine the level of taxes, the German income tax system is given by piece-wise quadratic formulas that transforms taxable income into a parameter (y) that then yields income tax liability.

[15] $T(z)$ and S are parameters of the tax law and require no assumptions at the individual level to calculate taxes. Note that C is also a function of individual commuting distance d and the legally specified price of commuting.

[16] This could miss other sources of capital income, which may result in us underestimating marginal tax rates.

and distance. Summarizing notation, T_t is the tax function for Germany. This function depends on taxable income, z_{it}, which is defined by (14). Notice, gross income m changes as an individual moves from one job to the next, the standard deduction changes over time but in the same manner for all individuals, and other deductions D_{it} may change from year to year if the individual changes deductions over time. As these deductions are unobserved to us, we place assumptions on D_{it} as discussed in the next paragraph. Finally, using (12), we can write $C_{it} = c(d_{it}, p_{it})$: the commuting deduction is a function of d_{it}, the distance to a job, and p_{it} is a tax parameter that changes over time (possibly differently for individuals depending on the commuting distance in Table 2). The number of days worked, which we assume is constant at full-time work, is suppressed from the commuting deduction function for simplicity.

In our data, we do not observe whether individuals itemize and the amount of other deductibles D, and thus cannot exactly predict how tax parameter changes affect the after-tax cost of commuting. We, therefore, assume various values of D for taxpayers, that cover a range of plausible values. Our approach is bench-marked by grouped data (by income range) in 2011 on the number of itemizers, the average amount of deductibles by itemizers (with and without commuting expenses), and the average commuting expenses, see Table 8 in Statistisches Bundesamt (2015). We consider three possible values for the average deductible of a non-itemizer: i) the same value D as the average value of a commuter who itemizes in that income range, ii) zero, so that the average deduction of itemizers and non-itermizers is much smaller than in case i), and iii) the lump sum deductible S, which leads to higher average values of D than in i) for medium income levels, but lower ones for the lowest and high incomes.[17] Based on these values we compute the corresponding value of the average value of D from itemizers and non-itemizers by income range. Finally, to calculate commuting deductions, we use the formula in Table 2 where we assume 230 days—the number of days suggested by most tax software—and we use the value of distance calculated in the IAB data for the value of d.

5 Empirical Methodology

To study the effect of commuting deductions on labor market outcomes, we show that more generous commuting subsidies increase the distances that workers commute. Then, we proceed to show how those distance changes influence wages and plant quality.

[17] High-income earners have large commuting expenses, which dominate the assumed high other deductible value of non-itemizers.

5.1 First Step: Effect of Subsidies on Distance

As our main goal is to study the effect of commuting subsidies, we focus on job switchers. While commuting subsidies may also induce changes in residential locations, we do not know anything about the change in housing prices. As house prices vary considerably between regions they might offset the effect of tax liabilities, to identify a clean effect of the real value of the commuting deduction, we do not include any residential changes. Furthermore, given residential mobility is infrequent in Germany, as discussed in Section 2, this is not a critical assumption, as the relative cost of changing residences is likely larger than jobs.

To study the effect of commuting deductions on commuting distance for the sample of job changers, we estimate:

$$\triangle \ln d_{it} = \beta_1 \triangle \overline{tax^*_{it}} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_{it} \tag{16}$$

where $\ln d_{it}$ is the (log) distance to work for person i for a job in year t and $\overline{tax^*_{it}}$ are taxes as defined below. We let $\triangle$ denote the difference operator, which shows the year-over-year change in a variable: in our setting, because we focus on job changers, this is the new job value minus the old job value. In this way, we can think of the difference operator as indicating a change from one job to the next, removing an individual-specific effect in the levels equation. Given we only observe workers when they change jobs, aggregate shocks are accounted for by ζ_t. In our preferred specification, we control for a vector of individual characteristics X_i in the *base year* (prior to the job change). Although time-invariant, the inclusion of base-year effects is common in the literature on the elasticity of taxable income (Saez, Slemrod and Giertz 2012). In addition, we include base-year commuting-zone fixed effects, ζ_c, to account for shocks common to all job changers in a given local labor market.[18] In all specifications, standard errors are clustered at the 257 commuting zone level.

In our preferred specification, we control for sex, age, age square, education, task complexity of the old job, whether the worker lives in East Germany, and whether the worker has foreign citizenship. We distinguish three education levels: low-skilled, medium-skilled, and high-skilled workers. Low-skilled workers are workers with no vocational degree, medium-skilled workers possess a vocational degree, and high-skilled workers have an academic degree. With respect to job complexity, we distinguish jobs requiring simple tasks, expert tasks, specialist tasks, and complex tasks.

Critically, this equation uses a simulated tax rate rather than the actual tax change

[18] To assign job switchers to local labor markets we use an updated classification by Kosfeld and Werner (2012) based on commuting links. This classification groups the 401 counties in Germany into 257 local labor market areas with an average radius of 21 kilometers.

given in (15). The expression in (15) is not empirically relevant for two reasons. First, our interest is in understanding the effect of the *commuting deduction* and not changes in *all* taxes in the tax function. Second, the tax function in (15) depends on endogenous variables. To deal with these issues and to isolate pure changes in the commuting deduction formula, we construct a *simulated* measure of the average tax rate that only exploits variation in the tax code due to commuting-specific reforms:

$$\triangle \overline{tax^*_{it}} = \triangle \overline{T}(\overline{m_i}, c(\overline{d_i}, p_{it}), \overline{S}, \overline{D_i}). \tag{17}$$

where the "bar" notation denotes that we hold fixed those values at the *old* job level. By holding constant wages and distances at the old job, (17) tells us the change in incentives that a worker has simply as a result of changes in the commuting formula. In addition, to isolate changes in commuting subsidies and not changes in taxes more generally, we hold constant marginal tax rates and the standard deduction. For example, higher marginal tax rates may create an income effect that then changes commuting. At the same time, marginal tax rates could have an effect on the after-tax price of commuting, but such an effect is likely to be second-order. Ultimately, because the effect of marginal tax rates on labor supply are likely first-order, we hold the tax function and standard deduction constant in the year of the *old* job. Inspection of (17) shows that variation in this variable results from changes to the commuting formula via changes in the rate that the government allows you to deduct commuting expenses, p_{it}. However, this parameter then interacts with person-specific distances, incomes, and other deductibles to determine the simulated value of the tax change. This implies that person-specific variation comes from both initial distances and incomes, with incomes influencing the value of the commuting deduction due to the progressivity of the marginal tax rate schedule.[19]

The key variable $\triangle \overline{tax^*_{it}}$ is the tax change (in hundreds of Euros). We enter the tax variables in Euros so that we can estimate the percent change in distance per 100 Euro value of tax change. Thus, a *one hundred* Euro increase in taxes changes distance to work by $\beta_1 \times 100$ percent. Estimation in levels of the tax variable rather than log changes is preferred given the inclusion of zeros and negative values in $\overline{tax^*_{it}}$. Critically, note that when the commuting deduction becomes more generous, the overall taxes paid go down, implying that the expected sign of the coefficient is negative.

[19] As noted above, while we do not have person-specific other deductions (D), we do allow this variable to vary based on income deciles justifying the i subscript. But we also consider a value of D common to all taxpayers and the results are similar, so most of the variation comes from how $\overline{m_i}$ and $\overline{d_i}$ interact with time changes in p_{it}.

5.2 Second Step: Effect of Subsidies on Job Quality and Assortative Matching

In the second step, we study whether these induced changes in distance result in better wages and, more generally, with a match of a worker to a "better" quality plant, where better quality is simply given by the firm-specific component of pay. To do this, we estimate

$$\triangle y_{it} = \beta_2 \triangle \ln d_{it} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_{it} \tag{18}$$

where $\triangle y_{it} = \{\triangle \ln w_{it}, \triangle\psi^{AKM}_{f(it)}\}$ with $\triangle \ln w_{it}$ denoting the (log) change in wages and $\triangle\psi^{AKM}_{f(it)}$ is the change in the plant-fixed effect (in units of log wages) from an estimation of the AKM model in (13). In all specifications, because we are interested in the effect of changes in distance induced from changes in commuting subsidies, we instrument for $\triangle \ln d_{it}$ with $\triangle\overline{tax^*_{it}}$. This then tells us how a change in distance, induced only by variation in the commuting deduction, influences whether workers move to "better" jobs. In other words, (16) is the first stage of this IV estimator. Recall, given the discussion above, the tax change is based solely on simulated tax changes due to policy changes to the commuting formula. For this reason, following the literature on simulated tax instruments, the instrument satisfies the exclusion restriction.

As a first test, we analyze if commuting subsidies induce workers to sort into high-paying jobs. Although this provides an initial test of the role of subsidies on earnings, this provides only an initial test because wages reflect both time-varying individual-specific and fixed plant-specific components of wages. To more formally analyze whether the worker moves to a better employer, we use the AKM plant fixed effects, $\psi^{AKM}_{f(it)}$, as a measure of employer quality. Recall that the plant fixed effects are measured in log wage units but have removed out any individual-specific component to the wage or individual characteristics, and so are interpreted as the plant-specific effect on wages. Thus, after instrumenting $\triangle \ln d_{it}$ with $\triangle\overline{tax^*_{it}}$, then β tells us the percent change in the plant effect due to a one percent increase in distance induced by a change in the commuting subsidy reforms. Another reason to prefer the plant AKM regressions over the earnings regressions is that the change in taxes are economy wide, which may alter the wages that different firms offer via general equilibirum effects on the labor market. The use of the plant AKM mitigates any such concern, as the plant AKM's are estimated over the entire sample.

Similar to the predictions of Becker's marriage model, the labor and urban literature have highlighted the role of positive assortative matching between employers and employees, whereby high-ability workers match to high-quality plants. A growing empirical literature in economics has studied whether there is assortativity in the labor market (Abowd, Kramarz and Margolis 1999; Abowd et al. 2003; Abowd et al. 2018; Torres et al. 2018; de Melo 2018; Combes et al. 2012; Bartolucci, Devicienti and Monzón 2018). Recently, Dauth et al. (2022) show that larger cities allow for a more efficient match process between workers and plants, and this has important consequences for regional wage inequality. We might test whether assortativity is influenced by the commuting subsidy. In our context, can public policies reinforce assortativity? In particular, we wish to determine if the commuting subsidy helps reinforce the positive assortativity in the labor market. As motivation, a simple model of plant assortativity may take the form

$$\triangle\psi^{AKM}_{f(it)} = \gamma_1\alpha^{PE}_i + \gamma_2\alpha^{PE}_i \times \triangle \ln d_{it} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_i \tag{19}$$

where α^{PE}_i is the estimated person effect from the AKM model in (13) and $\triangle \ln d_{it}$ is instrumented by simulated-tax changes from the commuting deduction. Then, in the absence of any subsidy, γ_1 measures the correlation between the person effect and the the change in the plant effect. The coefficient γ_2 measures how the commuting subsidy affects that correlation via distance changes. But, we prefer to estimate this relationship more nonparametrically:

$$\triangle\psi^{AKM}_{f(it)} = \theta_1 1^{PE}_q + \theta_2 1^{PE}_q \times \triangle \ln d_{it} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_{it} \tag{20}$$

where $\triangle\psi^{AKM}_{f(it)}$ is the change in the plant fixed effect after a worker changes jobs, 1^{PE} are indicators for the deciles q of α^{PE}_i, of (time-invariant) person-fixed effects, and $\triangle \ln d_{it}$ is the change in (log) distance. Again, to isolate the effect of the subsidy on changes in distance, we instrument for it with $\triangle\overline{tax}^*_{it}$. Then, the pattern of θ_1 tells us how the pattern of plant quality varies across the distribution of person quality in the absence of the subsidy reforms. Tthe coefficients θ_2 tell us how making the commuting subsidy more generous influences that assortativity for each decile.

6 Results

6.1 Descriptive Statistics

Before proceeding to our results, it is useful to provide some descriptive statistics concerning our sample. Table 3 shows the demographic statistics, changes in distances, and changes in taxes for our sample. As can be seen, the mean distance to a prior job is 21.1 kilometers, earning the worker a wage of 105 Euros per day. The average change in distance is approximately one kilometer, corresponding to a change in daily wages of 4 Euros per day. When calculating daily wages, these are per calendar day rather than per work day because we do not know the precise number of days worked. Moreover, the

Table 3: Summary Statistics

	Mean	SD
Male	0.705	0.456
Foreign	0.071	0.256
Age (years)	37.573	9.758
Low-skilled	0.040	0.197
Medium-skilled	0.751	0.432
High-skilled	0.208	0.406
East Germany (residence)	0.175	0.380
Delta distance	0.970	23.959
Drive distance to new job	22.044	20.177
Drive distance to old job	21.074	19.837
Delta commuting time	0.798	19.323
Commuting time to new job	20.896	16.263
Commuting time to old job	20.099	16.081
Delta wage (in Euro)	3.935	26.051
Daily wage (new job real imputed in Euro)	108.916	52.232
Daily wage (old job real imputed in Euro)	104.981	54.166
Delta AKM (log)	0.041	0.191
AKM plant fixed effect new job	0.000	0.196
AKM plant fixed effect old job	-0.042	0.211
AKM person fixed effect	-0.005	0.289
Change in Subsidy in 100 Euro (abs. values reform periods)	2.761	2.064
Observations	2,409,738	

Notes: This table provides descriptive statistics for the sample of movers used in our analysis.

average changes in our instrument induced by the commuting reforms are 164.9, 325.3, and -317.6, in years 2004, 2007, and 2009, with a mean change of 276 Euros in absolute value. Finally, Figure A.1 shows that over time, there is a downward trend in commuting distance: later in the sample, more workers have short commutes and fewer workers have long commutes. The median commute until 2009 was 14.9 km and increased to 15.1 km afterward.

6.2 Effect of Subsidies on Distance and Job Quality

Recall, our empirical model is fully characterized by the two equations, (16) and (18), where (16) is the first stage of the IV estimation of (18). We will first discuss the estimates of (16) before turning to the estimates of (18). In our setting, the first-stage is a policy-relevant parameter in its own-right, and for this reason we discuss it initially. The magnitudes are interesting in their own right because the empirical evidence on the effect of commuting subsidies is limited, and the prior literature generally only applies to

Table 4: Baseline Results: Effect of Commuting on Distance

	(1)	(2)	(3)	(4)	(5)
		PANEL A: EFFECT ON DISTANCE			
$\triangle \overline{tax^*_{it}}$ (hundreds)		-0.1174***	-0.1174***	-0.1177***	-0.1192***
		(0.0038)	(0.0037)	(0.0037)	(0.0038)
		PANEL B: EFFECT ON WAGES			
$\triangle \ln d_{it}$	0.0062***	0.0452***	0.0448***	0.0392***	0.0333***
	(0.0003)	(0.0027)	(0.0027)	(0.0024)	(0.0023)
F-stat		970.130	990.682	1017.040	994.129
		PANEL C: EFFECT ON PLANT AKM			
$\triangle \ln d_{it}$	0.0044***	0.0316***	0.0307***	0.0241***	0.0187***
	(0.0004)	(0.0021)	(0.0021)	(0.0019)	(0.0018)
F-stat		970.130	990.682	1017.040	994.129
Observations	2,409,738	2,409,738	2,409,738	2,409,738	2,409,738
OLS or IV (Panel B/C)	OLS	IV	IV	IV	IV
Year FE	Y	Y	Y	Y	Y
LMR FE	N	N	Y	Y	Y
Worker controls	N	N	N	Y	Y
Person FE	N	N	N	N	Y

Notes: This table shows the estimates of (16) in Panel A and the estimates of (18) when the dependent variable is daily wages (Panel B) and when the dependent variable is the plant AKM (Panel C). Panel A presents the first-stage, while Column (1) shows the OLS regression of the second stage and all other columns show the IV estimates. Each column successively adds controls to the model. Standard errors are clustered at the commuting zone level. *** 99%, ** 95%, * 90%.

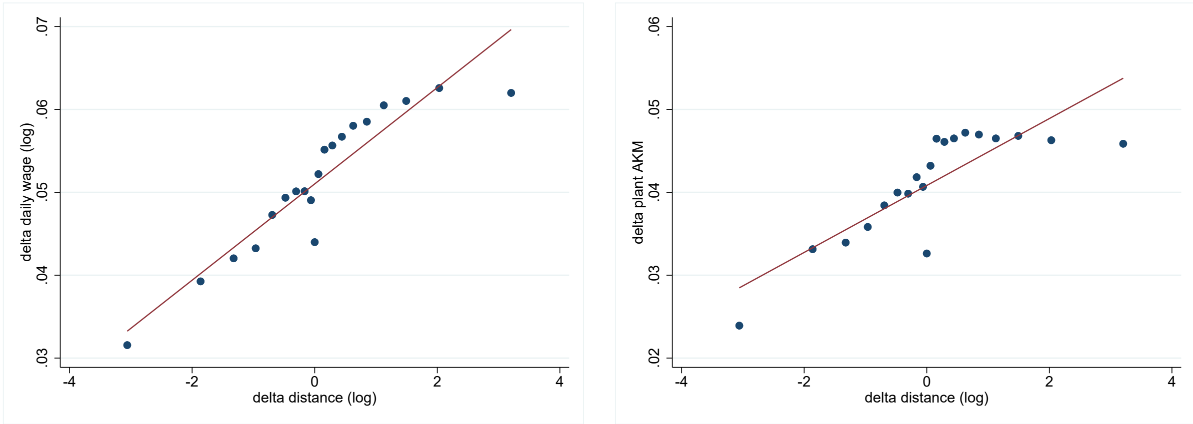
very low-income workers. Panel A of Table 4 shows the results of (16).

First, note the implied nature of the bias between column 1 and column 2 in Table 4: the Column (1) OLS estimates are biased down relative to Column (2) IV estimates. This suggests that workers tend to move to lower paying jobs when travel distance is increasing and vice-versa. This bias is consistent with a search-based framework where a many job moves involve increases or decreases in overall utility (Lavetti and Schmutte 2020). From this perspective, reassuringly, the IV is picking up the part of job mobility associated with the changing disutility from commuting.

To interpret the magnitudes, recall that the outcome variable, d_{it}, is in logs but that the tax variable, $\overline{tax^*_{it}}$, is in hundreds of Euros. Then, because distance is in logs, multiplying by 100 gives the percent change due to a 100 Euro *increase* in taxes, which results from a *decrease* in the commuting deduction. In Column (4), containing a full set of controls, a 100 Euro increase in taxes paid decreases commuting distance by 12%.

Figure 2: Binscatter of Effect of Distance on Firm Quality

(a) Earnings (b) Plant AKM



Notes: Figure 2 (a) shows the change in log wages with respect to the change in distance for our sample of job switchers. Figure 2 (b) shows the change in the plant AKM, which is in units of log wages, with respect to the change in distance. These figures show the raw data before residualizing on any fixed effects or controls.

With respect to the sign of this effect, recall that an increase in commuting deductions lowers tax payments. Thus, the negative relationship between taxes and distance implies a positive relationship between the size of the commuting deduction and distance traveled.

With respect to the magnitude, at the mean commute, this represents a change of 2.5 kilometers. To put the magnitude in perspective, Table 3 indicates that, conditional on experiencing a tax change, a one standard deviation change in the instrument is 206 Euros. Thus, a one standard deviation change in taxes due to a change in the commuting deduction formula causes a change in distance to work by approximately 5.1 kilometers or 24% of the mean distance traveled in our sample. Another way to benchmark this effect is to compare it to the only other empirical estimate in the literature: Paetzold (2019) estimates that when the after-tax cash value of the commuter deduction in Austria increases by 1 Euro, commuting increases by approximately 16 meters. Our estimates imply a 1 Euro change in taxes causes commuting distances to change by 25 meters. Thus, our results are 1.56 times large. The likely explanation for this difference is that Paetzold (2019) uses a regression kink design that estimates a local average treatment effect in the neighborhood of the first Austrian tax bracket, which occurs only at 11,000 Euro. Our estimates are an average treatment effect on the treated for those experiencing a change as a result of the commuting reform, which include many higher-income individuals. Furthermore, a key difference is that we focus on job switchers and our effects do not include the null effects on non-marginal individuals who do not change jobs. Given the reforms affect different income levels and because our sample includes both high-income and low-income workers, our results are representative of the entire population.

Next, we study whether increases in commuting induce workers to move up the wage distribution. Before turning to the second stage regressions, Figure 2 visualizes the underlying relationships in our data, by showing the correlation between our measures of the change in job quality (earnings and the plant AKM) and the change in log-distance. As the figure indicates, there is a strong positive relationship between changes in quality and changes in distance. Moreover, the figure indicates that our result is not driven by outliers.

Turning to (18), as a first attempt at studying the effect of commuting subsidies on job quality, we use wages as a metric of job quality. Regressing the change in wages on the (log) change in distance, and instrumenting for it with the simulated tax value of the commuting deduction change, we estimate the effect of changes in distance—induced by the commuting reform—on (log) wages. Panel B of Table 4 shows the results. Focusing on Column (4), a 1 percent increase in distance increases the real wage by 0.04%. With respect to the sign, recall that making the commuting deduction more *generous* lowers taxes and increases the distance traveled to work. Thus, these results suggest that the commuting deduction also allows workers to switch to higher-wage jobs that are further away. In terms of the magnitude, using the means from Table 3, where the wage is expressed as a daily wage per 365 days in the year. Thus, annual wages increase by approximately 15 Euros. Multiplying by the percent change from our first stage, note that a 100 Euro change in taxes from a more generous commuting deduction raises wages by 180 Euros. As expected, the induced wage increase is larger than the magnitude of the commuting subsidy necessary to induce a 1% change in distance.

Another way to benchmark the magnitude is to convert commuting distance into travel costs. To do this, we can use data on driving times to reestimate our model, combined with estimates of the value of time from the literature. Because our distance data is based on optimized time paths of driving on a road network, we know the distance in kilometers and minutes. Rather than using distance in kilometers, we can use distance in minutes in all of our regressions.

Reestimating the first stage in minutes rather than in kilometers (Table 5), a change in the commuting deduction that lowers taxes by 100 Euros raises commute times by 10%. The second stage in the table shows that a 1% increase in driving time raises wages by 0.05%, so that same tax change raises wages by 0.46%. At the means in Table 3, a change in the generosity of the commuting deduction that lower taxes by 100 Euros would raise daily (there and back) commutes by 3.92 minutes, which implies an additional 15 hours of commuting per year. The literature finds that individuals value commuting time at approximately 50% of the gross wage (Small, Verhoef and Lindsey

2007).[20] Assuming a 7.5 hour work day and 230 days of work per year implies a mean hourly wage of 22.21 Euro. Thus, the added commuting predicted by our empirical model has a time cost of 167 Euros per year. Given these driving times are calculated under ideal rather than congested times of day, the true costs may be higher. Table 5 indicates that a 1% increase in commuting time raises wages by 0.05%. Thus, the 10% change in times induced by the subsidy raised wages by 0.46% or approximately 177 Euros per year. Note that, at the mean, the added cost of commuting (167 Euro) induced by the subsidy is approximately equal to the pure wage increase (177 Euro). This combined with the fact that commuting costs are likely an underestimate because they are under ideal conditions suggests that for many individuals this increase in distance does not make sense absent a tax incentive. However, the commuting subsidy saves the individual an additional 100 Euros of taxes resulting in an after-tax wage increase of 277 Euro; the added after-tax cost of commuting from a longer commute is clearly smaller than the gain in after-tax wages. Critically, note that at lower wages, the commuting deduction will make the increase in wages larger than the added time cost of commuting, consistent with our subsequent heterogeneous results showing larger responses for low-income workers.

Next, we turn to the estimation of (18) when the dependent variable is the change in the plant-specific AKM effect following a job change. Panel C of Table 4 indicates that a 1% change in distance increases the plant-quality AKM measure by 0.03%.[21] In other words, a more generous commuting deduction that saves 100 Euros of taxes raises the plant AKM by 0.28%. In terms of interpreting magnitudes, recall that the plant fixed effects are measured in log wage units. However, in general, most people actually move very little through the plant effect distribution over time. Thus, although small, simply finding a positive and statistically significant effect due to a subsidy change of several hundred Euros, implies the policy increased workers' choice set in some way that led them to find different paying jobs than they would have otherwise. For this reason, we interpret the effects as an economically important and significant effect of commuting subsidies on workers ability to move to better paying firms. These results show that, on average, commuting subsidies drive workers to better-paying employers. They do not, yet, imply anything about assortativity, an issue we will return to after performing some heterogeneity exercises.

Is the induced increase in plant quality economically large? In general, individuals do not move much over the plant quality distribution, so this effect may be economically

[20] Other studies find smaller and larger estimates (Brownstone and Small 2005; Le Barbanchon, Rathelot and Roulet 2021; Small, Winston and Yan 2005).

[21] Of course, one might be interested in knowing the direct effect of the subsidy on wages or the plant AKM rather than the IV estimate. In this case, the reduced form coefficient would simply be equal to the IV estimate in Panel B or C times the first stage coefficient in Panel A.

Table 5: Baseline Results: Effect of Commuting on Time

	(1)	(2)	(3)	(4)	(5)
			PANEL A: EFFECT ON TIME		
$\triangle \overline{tax}^{*}_{it}$ (hundreds)		-0.0974***	-0.0974***	-0.0976***	-0.0989***
		(0.0031)	(0.0031)	(0.0030)	(0.0031)
			PANEL B: EFFECT ON WAGES		
$\triangle \ln time_{it}$	0.0073***	0.0545***	0.0540***	0.0473***	0.0401***
	(0.0003)	(0.0032)	(0.0032)	(0.0029)	(0.0028)
F-stat		987.086	1005.410	1033.710	1010.770
			PANEL C: EFFECT ON PLANT AKM		
$\triangle \ln time_{it}$	0.0051***	0.0380***	0.0370***	0.0291***	0.0226***
	(0.0004)	(0.0025)	(0.0025)	(0.0023)	(0.0022)
F-stat		987.086	1005.410	1033.710	1010.770
Observations	2,409,738	2,409,738	2,409,738	2,409,738	2,409,738
OLS or IV	OLS	IV	IV	IV	IV
Year FE	Y	Y	Y	Y	Y
LMR FE	N	N	Y	Y	Y
Worker controls	N	N	N	Y	Y
Person FE	N	N	N	N	Y

Notes: Panel A in this table shows the estimates of (16) where distance traveled is replaced by time traveled. The estimates of (18), also replace distance with time, and Panel B presents the results when the dependent variable is daily wages while Panel C presents the results when the dependent variable is the plant AKM (Panel C). Panel A presents the first-stage, while Column (1) shows the OLS regression of the second stage and all other columns show the IV estimates. Each column successively adds controls to the model. Standard errors are clustered at the commuting zone level. *** 99%, ** 95%, * 90%.

meaningful. To interpret the economic magnitude, it is useful to compare the coefficients in Panel C with those in Panel B. The ratio then determines the relative percent increases in earnings with the percent increases in plant quality. We find that the percent change in plant quality is 61% (0.0291/0.0473) of the percent increase in earnings.

6.3 Heterogeneity

In contrast to the prior literature (Paetzold 2019), we are able to estimate the effect of commuting subsidies over a broad range of the population. Thus, one might wonder how the responses vary by individual characteristics. To do this, we interact the variables of interest with indicators for various worker characteristics.

Figure 3 shows that there is not much heterogeneity in the effect of the subsidy on distance by individual characteristics: women and men are equally responsive, as are citizens and noncitizens. With respect to education and skill levels, the largest effects on distance are lower education and skilled workers. But, when turning to the effect on wages or plant AKM, the pattern reverses. Generally, a one percent increase in distance has a larger effect on earnings and the overall quality of the employer for women and higher-education and higher-skilled workers. The higher returns to commuting for higher-skilled workers provides some initial evidence that the commuting subsidy may reinforce assortative matching.

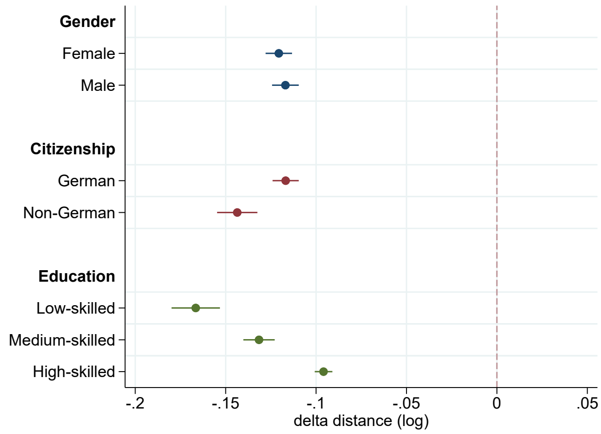
One explanation for women having higher returns to distance is given by Manning (2003) who argues that the marginal costs of commuting for women with household responsibilities are higher and Le Barbanchon, Rathelot and Roulet (2021) and Caldwell and Danieli (2023) who conclude that women face a larger cost of distance than men. Consequently, search theory would predict higher returns to commuting. In addition, the result is consistent with Mulalic, van Ommeren and Borghorst (2022) who show that women with children are more likely to leave their job when they have a long commute and these women are less likely to be compensated for commuting than males. Search frictions are also likely the cause for lower returns of non-citizens as the employer's monopsony power is larger for this group (Hirsch and Jahn 2015).

We have also tested if there are any differences across geographic locations, such as urban or rural areas. Indeed, there are statistically significant differences between East and West Germany, suggesting that some of the effects in the East may be due to the commuting subsidy allowing workers to commute to the West for better jobs.

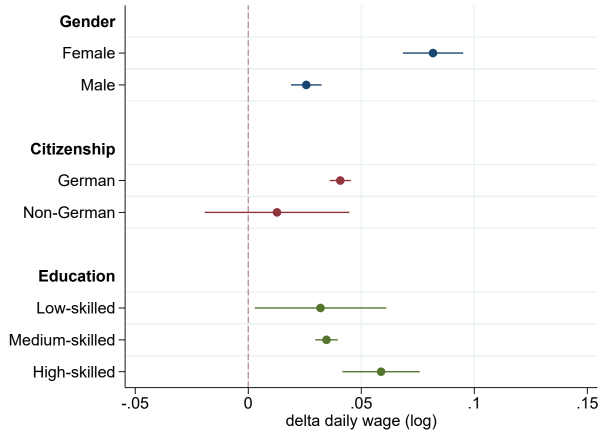
Finally, Figure A.2 shows heterogeneous effects by occupation, industry, and task. The largest effects on the wage and plant-quality measures are in industries classified as "construction", occupations classified as "personal services", and tasks classified as "complex". Note that an individual in a service industry need not have an occupation

Figure 3: Heterogeneity by Individual Characteristics

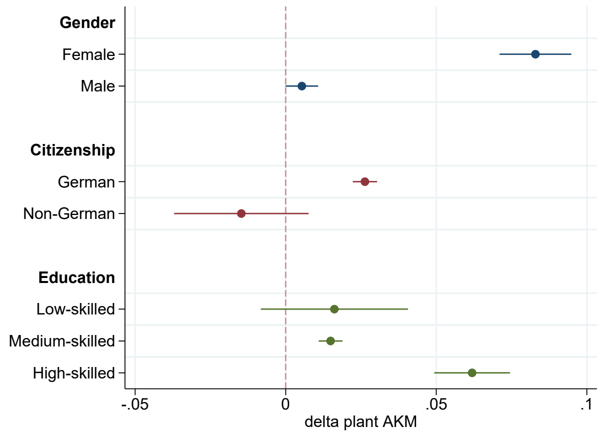
(a) Distance



(b) Earnings

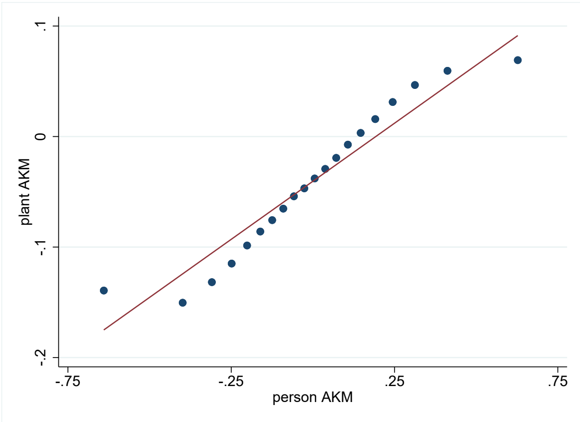


(c) Plant AKM



Notes: This figure shows heterogeneous effects by gender, citizenship, education, and skill level. Panel (a) presents the results of (16) when the tax variable is interacted with individual characteristics. Panel (b) presents the results of (18) when the dependent variable is the change in earnings, while Panel (c) presents the results when the dependent variable is the change in the plant AKM. Standard errors are clustered at the commuting zone level, and 95% confidence intervals are given by the lines.

Figure 4: Positive Relationship Between Person and Plant AKM



Notes: This figure shows the raw correlation between plant AKM of the initial job and person-AKM in our sample of job switchers.

that is classified as services; occupation classifications are based on the job performed, which may not be related to the overall industry of the employer.

6.4 Assortative Matching

Related to the recent literature on sorting of high-wage workers to high-wage paying plants, does the commuting subsidy reinforce this phenomenon or does it act as a force to reduce positive assortative matching. To do this, we next interact the subsidy with indicators for deciles of the income distribution as in (20). Before proceeding, Figure 4 shows that plant effects are positively correlated with individual effects for our sample of job changers. The question is whether the commuting subsidy flattens or increases this slope.

We first estimate (19), where we allow the correlation of the person effect and the change in the plant effect for job changers, to be influenced by commuting changes induced by the reform to the commuting deduction. Table 6 presents the results where γ_1 denotes the correlation for job changes not induced by the subsidy to change and where γ_2 denotes the influence of the subsidy's effect on that correlation via changes in commuting. Unlike Figure 4, the coefficient γ_1 is negative. The reason is that, unlike the figure which uses the level of the plant AKM in the old job, the regression equation uses the change in the plant AKM from the old to the new job. Intuitively, as the change in distance to work become very small, the ability to find another high-quality plant with the same commuting costs declines substantially as the ability of the worker increases. The intuition is similar to standard mean reversion in the elasticity of taxable income literature. But, critical to our analysis is the sign of γ_2 which is positive. This says that the ability to move to a better paying employer is increasing in the worker-specific

Table 6: Assortativity Induced by the Commuting Deduction

	(1)	(2)	(3)	(4)
γ_1	-0.0564***	-0.0610***	-0.0612***	-0.0623***
	(0.0013)	(0.0019)	(0.0019)	(0.0016)
γ_2	0.0008	0.0590***	0.0563***	0.0534***
	(0.0007)	(0.0106)	(0.0104)	(0.0103)
F-stat		392.308	392.370	388.692
Observations	2,409,738	2,409,738	2,409,738	2,409,738
OLS or IV	OLS	IV	IV	IV
Year FE	Y	Y	Y	Y
LMR FE	N	N	Y	Y
Worker controls	N	N	N	Y

Notes: This Table presents the estimates of (19), where γ_1 denotes the relationship between the change in plant AKM and the level of the person-AKM and γ_2 denotes how that relationship is influenced by the subsidy as a result of changes in commuting distances. Column (1) shows the OLS regression of the second stage and all other columns show the IV estimates. Each column successively adds controls to the model. Standard errors are clustered at the commuting zone level. *** 99%, ** 95%, * 90%.

component of wages as those workers increase their distance to work as a result of an increase in the generosity of the commuting subsidy.

Next, we show the effect of the subsidy on assortativity using the nonparametric approach of (20). In our main analysis, we utilize deciles of the AKM person-specific effect, but we also present results estimating the AKM effects using the leave-one-out connected set. The first Panel of Figure A.3a shows the mean income in each decile while the second graph shows the mean of the plant AKM by decile. Figure 5 presents the results: Panel (a) indicates the heterogeneous effect of the subsidy on distance; Panel (b) shows the effects of distance changes induced by the subsidy on earnings; and Panel (c) shows the effect on the plant AKM by deciles of person-effects.

With respect to distances in Panel (a), the lowest person-specific AKM deciles have the largest changes in distance in absolute value per Euro change in the subsidy. A one Euro chance in the subsidy is a larger percentage change in income for these groups. Moreover, low-income households are likely to face the largest frictions in the labor market and more generous commuting subsidies can help these. Panel (b) indicates that a one percent change in distance induced by the commuting deduction has similar—albeit slightly increasing over the middle deciles—effects on wages over the entire distribution. Daily wages capture individual, plant, and idiosyncratic components.

Turning to Panel (c), except for the lowest decile which is noisy, we notice a generally monotonic positive relationship over the person-specific deciles. This positive relationship indicates that a one-percent increase in distance induced by the commuting subsidy has a larger positive effect on the plant-specific of the wage that a worker moves to. In other words, commuting subsidies induce high-ability individuals to move up the firm (wage) quality distribution moreseo than lower-ability individuals, which reinforces positive assortative matching. Critically, the effects are negative in the lower deciles and positive in the upper deciles, both of which make the slope of Figure 5 steeper. To highlight the statistical meaningfulness of this effect, note that the estimates in the top two deciles are statistically different from those in the second and third deciles from the bottom of the person-specific wage distribution. Interestingly, for individuals at the very top of the person-specific wage distribution, their percent movement up in the plant-specific wage distribution is larger than the percent increase in their earnings.

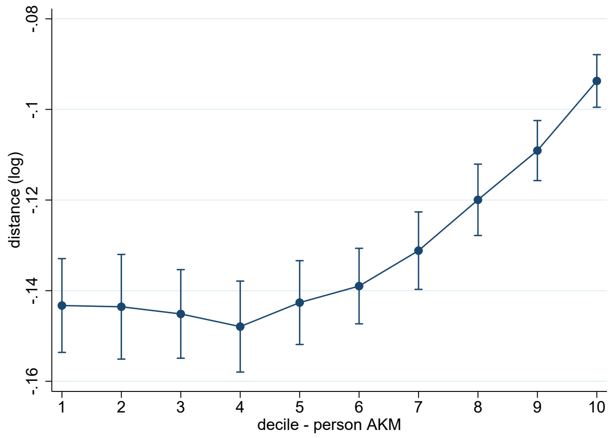
Although Panel (c) shows an increasing slope over the person AKM distribution, some of this might be undercut by the fact that the first-stage responses differ. However, this is not the case because the average commuting distance and average plant AKM increase dramatically by person AKM deciles and the second-stage coefficients are oppositely signed at the bottom of the distribution. To highlight this, we compare the effects in the 2nd decile with those in the top decile. As indicated by the summary statistics in Table A.3, the mean distances in these two deciles are 19.89 and 25.07 kilometers so that a 100 Euro decrease in taxes paid due to a more generous commuting deduction increase commuting distance by 2.85 kilometers for lower ability workers and 2.35 kilometers for higher-ability workers. A more generous commuting deduction that saves 100 Euros of taxes *lowers* the plant AKM by only 0.02% for individuals in the second decile but *raises* the plant AKM by 0.49% for individuals in the top decile. Thus the difference in the mean plant AKM of the deciles of the ability distribution widens.[22]

Taken together, we conclude that the commuting deduction enhances assortativity in the labor market. Commuting subsidies increase commuting for all workers, but slightly more for workers with a lower person-specific wage component. These longer commutes increase daily wages for all deciles of the person-specific distribution. But perhaps more importantly, these longer commutes do not translate into job wage improvements. Even though low-income households likely face the most frictions in the labor market, the commuting deduction does not help them overcome these frictions with respect to the wage quality of the plants employing them. Although their distances increase more and this helps to raise their earnings, the wage quality of the plants they are induced to move to remain unchanged. Instead, more generous commuting deductions allow higher-ability households to better match to better paying plants, enhancing inequities in the labor market. Moreover, because marginal tax rates are higher for high-income

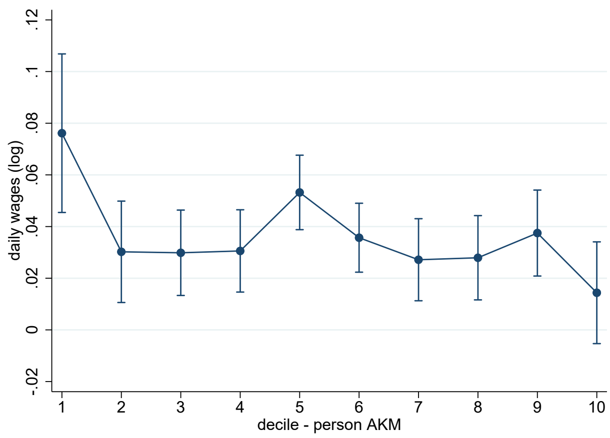
[22]In the second stage, the mean plant AKM in the 2nd decile and the top decile are -0.123 and 0.064, respectively.

Figure 5: Assortativity by Deciles of Person Fixed Effects

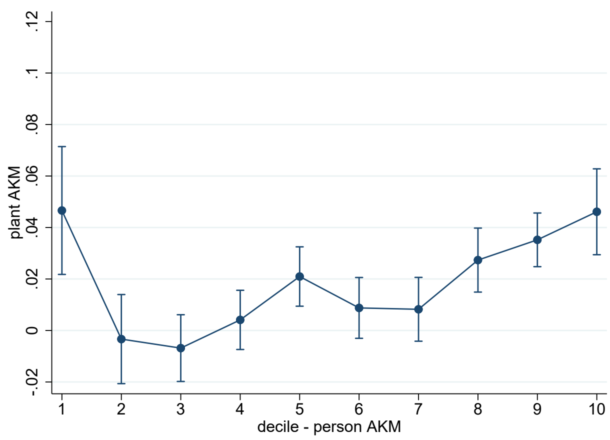
(a) Distance



(b) Earnings



(c) Plant AKM



Notes: This Figure presents the estimates of (20), Panel (a) plots the effect of the tax variable by deciles of the person-AKM effect. Panel (b) plots the effect of changes in distance induced by the commuting subsidy on changes in log wages, while Panel (c) shows the effect on changes in the plant AKM. Panels (b) and (c) instrument for distance changes with our simulated tax rates. Decile 10 is the top decile. Standard errors are clustered at the commuting zone level, and 95% confidence intervals are depicted in the figure.

workers, commuting reforms likely provide more Euros of tax savings for high-income individuals. Thus, our estimated effects which compare the same amount of tax savings (100 Euros) to all groups are amplified by the distribution of actual tax breaks over the income distribution. The increases in assortivity as a result of the commuting subsidies increase earnings inequality above and beyond any direct changes in regressivity from higher-income tax payers receiving larger tax benefits.

6.5 Robustness

Finally, we verify that our estimates are not sensitive to the assumptions we have made. In particular, we verify sensitivity to the assumed amount of other deductions, D, and we verify sensitivity to the maximal commuting distance that we assume amounts to a regular commute. Table A.1 shows that changing the assumed amount of other deductions by 25% or 50% does not change our point estimates much, nor does calculating D from nonintemizers. In all cases, a 100 Euro change in taxes decreases commuting distances by 9 to 11%. Second, Table A.2 show the sensitivity to the maximal commuting distance we allow in the data. As some workers may not make regular commutes, instead working remotely and traveling a long distance to the office infrequently, we assume the maximum daily commute is 100 kilometers. Adjusting this threshold downward lowers the coefficients slightly, while adjusting the threshold upward raises the coefficients slightly.

Table A.4 presents various other robustness checks. The first two robustness checks restrict the sample to individuals with wages below the social security contribution threshold, exclude workers employed in the temporary help service sector, and workers in multi-plant industries which may have the distance variable measured with error. Finally, in the last Column uses the sample we estimated the AKM effects with the leave-one-out connected set to address the possibility of limited mobility bias in the AKM effects. As discussed previously, limited mobility bias may result in an upward bias of the contribution of firm effects and a downward bias in the estimated covariance of worker and plant effects (Abowd et al. 2003; Kline, Saggio and lvsten 2020; Bonhomme et al. 2023). To address this issue we report results using the heteroskedastic fixed-effects method (FE-HE), which restricts attention to the the leave-one-out connected set of firms (those that remain connected after any given mover is removed from the sample) following Bonhomme et al. (2023).[23] As can be seen, the coefficient in panel C related to the AKM model changes only negligibly.

[23]Bonhomme et al. (2023) note that "The heteroskedastic fixed-effects method for bias-correction of Kline, Saggio and lvsten (2020) recovers estimates of the variance components on the leave-one-out connected set." To implement this, we use the code available from `https://github.com/tlamadon/pytwoway`.

Figure A.4 shows the same figures as in the main text using the leave-one-out data set. The results are robust and Panel (c) again features a strong positive slope. This provides additional evidence of assortative matching of workers to plants being strengthened by the commuting subsidy. This suggests also that limited mobility bias is not a major concern.

Finally, recall that our paper conditions on the sample of job-switchers, potentially raising issues related to the extensive margin: did the policy induce people to switch jobs? If so, then one might worry about whether the sample selection is correlated with tax changes. Given the magnitude of the estimated effects, it seems plausible that this is not a strong enough incentive to induce people to change jobs, even if it affects where they search conditional on thinking about changing jobs. Unfortunately, we do not currently have a 50% sample of all workers but we only have access to a 50% sample of job switchers. However, running a series of linear probability models on the 2% sample of the German population, we find no significant labor market effects on the extensive margin.

7 Conclusion

Commuting subsidies are often regarded as "bad" policies because they encourage wasteful commuting that increases congestion and generates environmental externalities. We show that commuting subsidies may have a potential redeeming feature: they expand the potential choice set of workers facilitating matches of workers with better plants. From a policy perspective, this channel is especially important for low-wage workers that are likely to face substantial search costs or confront spatial mismatch. But whether those commuting subsidies—often implemented via tax law—actually incentivize low-income workers more so than high-income workers remains an empirical question.

We derive, theoretically, conditions under which commuting deductions will result in assortative matching in the labor market. Using major German tax reforms and administrative data, we document that more generous commuting deductions increase commuting distance. A one-hundred Euro change in the commuting subsidy induces larger changes in distance for lower-ability groups because the amount is a larger percentage of income. Commuting subsidies allow low-ability and high-ability workers to increase their daily wages. However, for high-ability workers, a one percent change in distance induced by the commuting subsidy has a larger positive effect on the firm quality (productivity) that they can move to compared to lower-ability workers. Combining this with the fact that higher-wage workers have higher marginal tax rates, and thus receive larger commuting deductions, implies the total effect of commuting deductions is tilted toward higher-income earners. In other words, commuting subsidies allow for high-ability individuals to better match with higher paying forms. This process reinforces assortativity in the labor market. In turn, the increase assortativity contributes to increased (within labor market) earnings inequality.

Our paper is not meant to be a normative evaluation of commuting subsidies. In particular, we do not consider the negative environmental externalities of commuting. Abstracting from those issues, commuting subsidies may improve welfare if they can facilitate better paying job by expanding the set of job opportunities for workers. From a social welfare perspective, such an improvement is likely to be welfare-improving if it benefits low-income workers more than high-income workers. While we find the average effect of the subsidies allows workers to move to higher paying plants, because the subsidy increases homophily by disproportionately improving the ability to move up the wage distribution of already high-income workers, it is likely that the overall welfare effects of the mechanism are not large or possibly even negative. More generally, the welfare implications hinge upon whether the commuting subsidies address a market failure such as monopsony in labor markets or search frictions.

The process by which individuals sort into plants depends on numerous factors. Our paper highlights that government policies can be an important determinant in the matching process of people and plants. In particular, in the case of commuting subsidies, government policy can improve the match quality of both low-ability and high-ability workers. Despite benefiting all worker types, government policy can work to reinforce homophily by benefiting high-ability workers relatively more in terms of labor market wage improvements.

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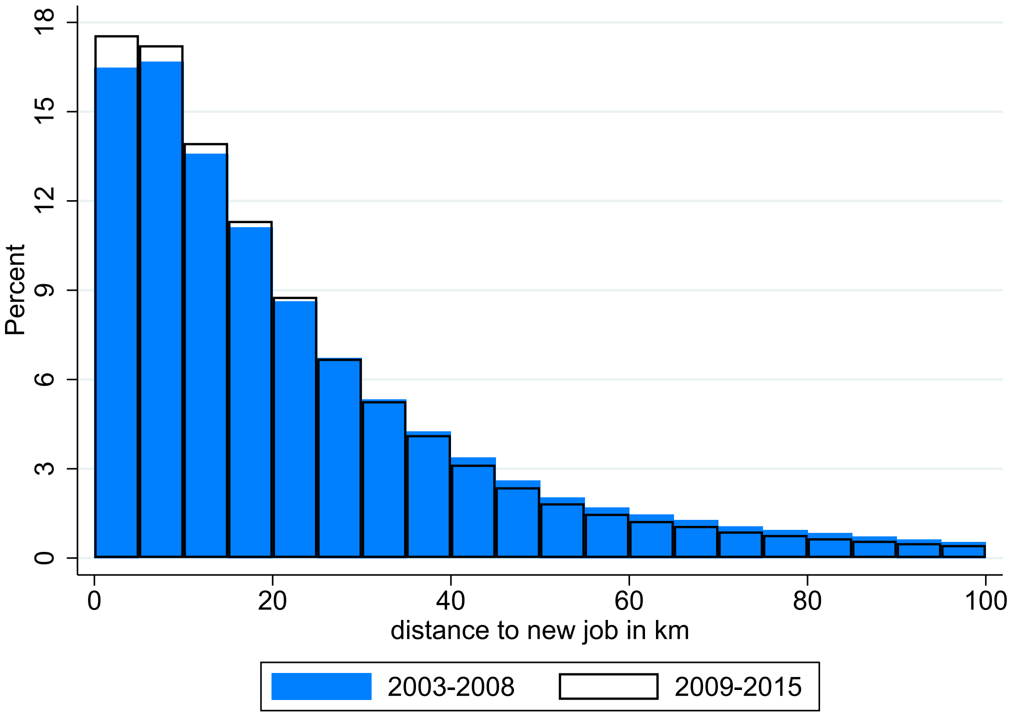
A Appendices (for online publication only)

Data Appendix

In this section, we present various robustness checks described in the text.

Figure A.1: Commuting Distances over Time



Notes: This figures shows how distance to work has changed over time.

Table A.1: Robustness to Other Deductions Size

	(1) Base	(2) $D+25\%$	(3) $D-25\%$	(4) $D+50\%$	(5) $D-50\%$	(6) D(no-item)	(7) D(920)	(8) D(2008)
				Panel A: Effect on Distance				
$\triangle \overline{tax^*_{it}}$ (hundreds)	-0.1177***	-0.1197***	-0.1061***	-0.1195***	-0.0999***	-0.1013***	-0.1200***	-0.1120***
	(0.0037)	(0.0038)	(0.0034)	(0.0038)	(0.0032)	(0.0033)	(0.0038)	(0.0035)
				Panel B: Effect on Wages				
$\triangle \ln d_{it}$	0.0392***	0.0390***	0.0373***	0.0396***	0.0337***	0.0391***	0.0386***	0.0391***
	(0.0024)	(0.0024)	(0.0025)	(0.0024)	(0.0025)	(0.0026)	(0.0024)	(0.0025)
F-stat	1017.040	1015.410	970.473	1013.660	966.267	942.113	1020.380	1003.820
				Panel C: Effect on Plant AKM				
$\triangle \ln d_{it}$	0.0241***	0.0236***	0.0237***	0.0239***	0.0212***	0.0253***	0.0234***	0.0247***
	(0.0019)	(0.0019)	(0.0021)	(0.0019)	(0.0021)	(0.0022)	(0.0019)	(0.0020)
F-stat	1017.040	1015.410	970.473	1013.660	966.267	942.113	1020.380	1003.820
Observations	2,409,738	2,409,738	2,409,738	2,409,738	2,409,738	2,409,738	2,409,738	2,409,738
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
LMR FE	Y	Y	Y	Y	Y	Y	Y	Y
Worker controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: This table shows whether the results of Column (4) in Table 4 are robust to different assumptions on other deductible expenses, D. Column (1) reproduces the specification in the main text, Column (2) adds 25% to D to calculate taxes, Column (3) subtracts 25%, Column (4) adds 50%, Column (5) subtracts 50%, Column (6) assumes there are no other itemized deductions, Column (7) assumes the maximum amount of other itemized deductions, and Column (8) uses data from another year to calculate the deductions. Standard errors are clustered at the commuting zone level. *** 99%, ** 95%, * 90%.

Table A.2: Robustness to Other Distance Thresholds

	(1) 100km	(2) 75km	(3) 125km	(4) 200km
	Panel A: Effect on Distance			
$\triangle \overline{tax}_{it}^{*}$ (hundreds)	-0.1177***	-0.1123***	-0.1210***	-0.1186***
	(0.0037)	(0.0039)	(0.0035)	(0.0024)
	Panel B: Effect on Wages			
$\triangle \ln d_{it}$	0.0392***	0.0421***	0.0372***	0.0333***
	(0.0024)	(0.0028)	(0.0021)	(0.0016)
F-stat	1017.040	839.366	1201.960	2546.870
	Panel C: Effect on Plant AKM			
$\triangle \ln d_{it}$	0.0241***	0.0269***	0.0224***	0.0185***
	(0.0019)	(0.0021)	(0.0017)	(0.0013)
F-stat	1017.040	839.366	1201.960	2546.870
Observations	2,409,738	2,272,907	2,495,752	2,659,192
Year FE	Y	Y	Y	Y
LMR FE	Y	Y	Y	Y
Worker controls	Y	Y	Y	Y

Notes: This table shows whether the results of Column (4) in Table 4 are robust to different assumptions on the maximum distance traveled in our sample. Column (1) reproduces the specification in the main text, Column (2) restricts the same to individuals commuting no more than 75 km, Column (3) restricts to less than 125 km, and Column (4) restricts to less than 200 km. Standard errors are clustered at the commuting zone level. *** 99%, ** 95%, * 90%.

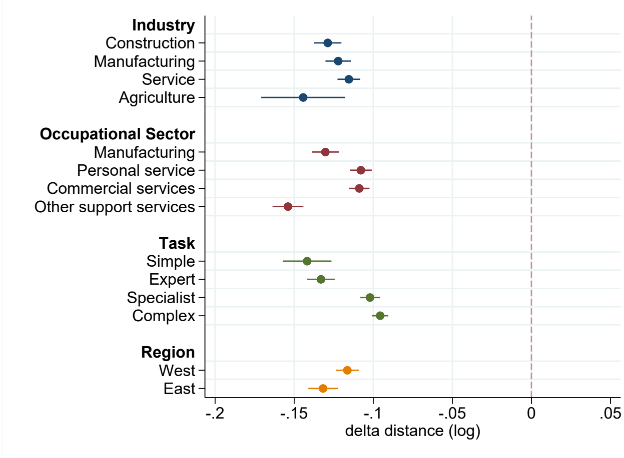
Table A.3: Means of Dependent Variables by Deciles of Person AKM

Decile	Distance	Earnings	Plant AKM
1	19.250	4.113	-0.145
2	19.887	4.241	-0.123
3	19.958	4.321	-0.092
4	20.005	4.384	-0.070
5	20.174	4.447	-0.050
6	20.440	4.513	-0.034
7	21.014	4.598	-0.013
8	21.852	4.716	0.010
9	23.087	4.899	0.039
10	25.070	5.153	0.064

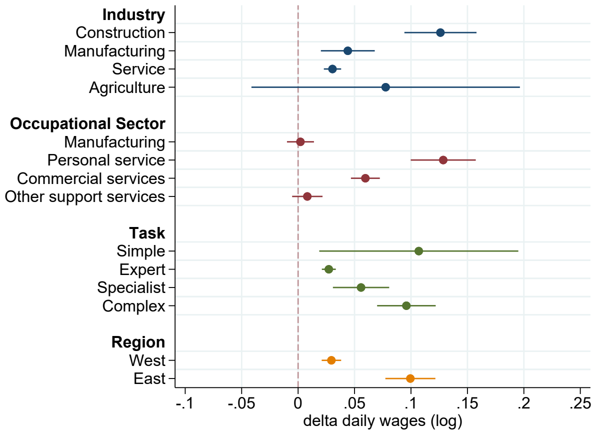
Notes: This table provides the means of each dependent variable by deciles of the plant AKM, which correspond to the deciles used in our analysis.

Figure A.2: Heterogeneity by Industry, Occupation, Task, and Region

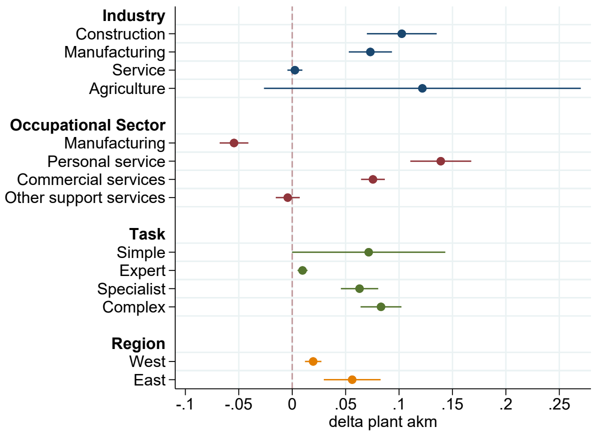
(a) Distance



(b) Earnings



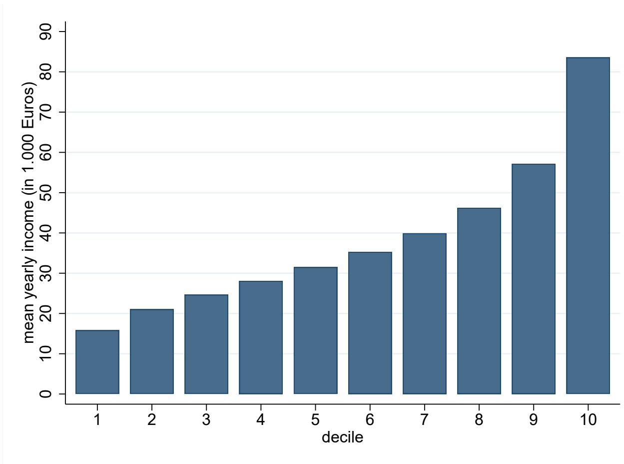
(c) Plant AKM



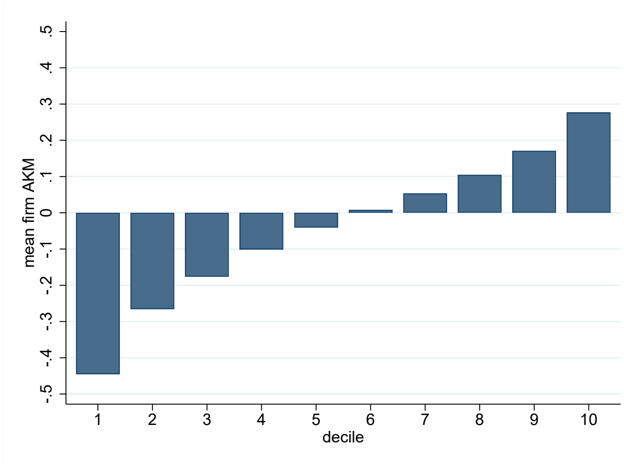
Notes: This figure shows heterogeneous effects by industry, occupation, and task. Panel (a) presents the results of (16) when the tax variable is interacted with individual characteristics. Panel (b) presents the results of (18) when the dependent variable is the change in earnings, while Panel (c) presents the results when the dependent variable is the change in the plant AKM. Standard errors are clustered at the commuting zone level, and 95% confidence intervals are given by the lines.

Figure A.3: Income and Plant AKM Distribution

(a) Income Deciles



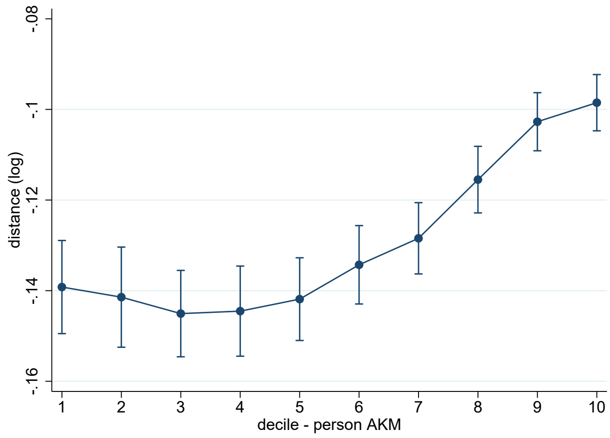
(b) Plant AKM Deciles



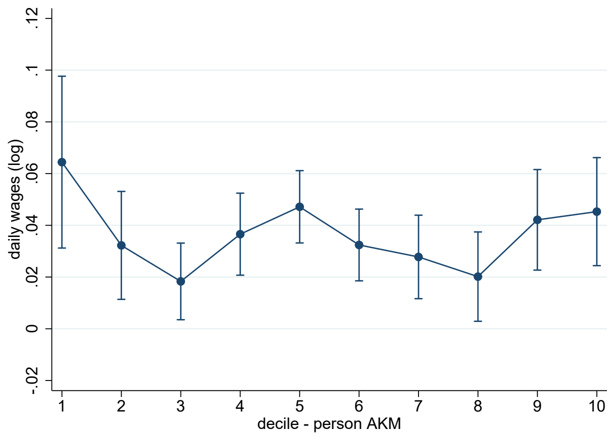
Notes: Panel (a) shows the mean income by deciles of the income distribution in our sample. Panel (b) shows the mean plant AKM by deciles of the plant AKM distribution in our sample.

Figure A.4: Assortativity by Deciles of Person Fixed Effects - Leave-One-Out-Data

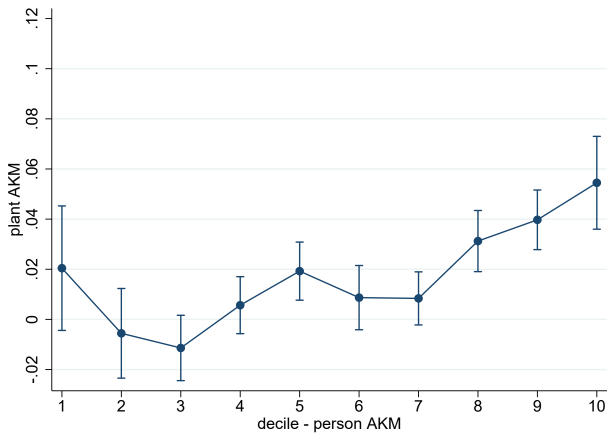
(a) Distance



(b) Earnings



(c) Plant AKM



Notes: This Figure presents the estimates of (20), Panel (a) plots the effect of the tax variable by deciles of the wages. Panel (b) plots the effect of changes in distance induced by the commuting subsidy on changes in log wages, while Panel (c) shows the effect on changes in the plant AKM. The only difference from the figure in the text is that this figure uses the leave-one-out data. Panels (b) and (c) instrument for distance changes with our simulated tax rates. Decile 10 is the top decile. Standard errors are clustered at the commuting zone level, and 95% confidence intervals are depicted in the figure.

Table A.4: Robustness Checks

	(1) Baseline	(2) No imputed wages	(3) No temp sector and multi plant industries	(4) Leave one out connected set
		Panel A: Effect on Distance		
$\triangle\overline{tax}^*_{it}$ (hundreds)	-0.1177***	-0.1327***	-0.1119***	-0.1176***
	(0.0037)	(0.0042)	(0.0039)	(0.0038)
		Panel B: Effect on Wages		
$\triangle \ln d_{it}$	0.0392***	0.0395***	0.0338***	0.0378***
	(0.0024)	(0.0024)	(0.0026)	(0.0025)
F-stat	1017.040	1018.610	842.039	980.813
		Panel C: Effect on Plant AKM		
$\triangle \ln d_{it}$	0.0241***	0.0235***	0.0158***	0.0228***
	(0.0019)	(0.0019)	(0.0019)	(0.0019)
F-stat	1017.040	1018.610	842.039	980.813
Observations	2,409,738	2,152,673	1,490,142	2,286,650
Year FE	Y	Y	Y	Y
LMR FE	Y	Y	Y	Y
Worker controls	Y	Y	Y	Y

Notes: This table shows whether the results are robust to different samples. Column (1) reproduces the specification in the main text, Column (2) restricts the sample to individuals with wages below the social security contribution threshold, Column (3) excludes workers employed in the temporary help service sector and in multi plant industries as distance might be measured with error, and Column (4) uses the sample for which we estimated the AKM effects with the leave one out connected set. Standard errors are clustered at the commuting zone level. *** 99%, ** 95%, * 90%.