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Do Commuting Subsidies Drive Workers to Better Firms?

Abstract

An unappreciated potential benefit of commuting subsidies is that they can expand the choice set of feasible job opportunities in a way that facilitates a better job match quality. Variations in wages and initial commuting distances, combined with major reforms of the commuting subsidy formula in Germany, generate 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 workers to switch to higher-paying jobs with longer commutes. 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-Codes: H200, H310, J200, J610, R230, R480.

Keywords: commuting, commuting subsidies, taxes, wage distribution, local labor markets, AKM, assortativity.

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1 Introduction

Individuals often spend an hour or more commuting each day. Despite the negative externalities due to added congestion and environmental impacts, many governments subsidize commuting at substantial fiscal cost. Both Germany and France allow individuals to deduct commuting costs from taxable income. Given the large negative externalities of commuting, policymakers must have alternative goals such as providing financial support for households with long commutes, which may be necessary for them to participate in the labor market in the first place. In addition, commuting subsidies 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 to move 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 relative 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. Our focus will be on the *positive* questions of how commuting subsidies affect commuting distances, matching of firms and workers, and labor market assortativity.

Despite the importance of commuting in daily life, empirical evidence on the effects of government subsidies on commuting and the consequences of such policies for employment is limited. There are several possible reasons for the lack of empirical evidence. First, many administrative datasets lack precise information on distances traveled to/from work. Both the place of residence and place of work may not be included in common administrative datasets, which means that researchers have to work with smaller survey datasets. Second, determining the effect of subsidies on workers ability to move to better paying firms requires administrative information on both the worker and the employer. Third, government policies that subsidize commuting often do not create clear natural experiments. In the US, for example, 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 set by German tax law and has changed several times over the last twenty years. Because the price is piecewise in distance and the after-tax-value of the deduction varies with 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 have the advantage of containing 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 the assortativity of workers and plants. In particular, it provides the wage decomposition of Abowd, Kramarz and Margolis (1999) or AKM, which decomposes the variation in wages into worker-specific and plant-specific components. This allows us to 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 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) in 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 place of work. Such an observation stands in contrast with the descriptive statistics for many countries other than the United States. Residential changes are much less common in many European countries than in the US, and as a result, people change the location of their jobs more frequently than they change their place of residence. 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 over 21% in the US, but 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 place of residence. But, because most urban models assume the place of work is fixed, standard models are less suitable 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 residential location and then, in response to government policies, reoptimize across job locations that differ in productivity. This polar case stands in contrast to the monocentric city model, and allows us to develop an intuition about the effect of commuting subsidies when we assume that job 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 his heterogeneous ability times the productivity level of the plant. 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 about the distribution of ability or if the commuting subsidy has a larger effect on the fraction of high-ability individuals with longer commutes than on 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 job relocations, combining our model with those already in the literature on residential relocation suggests that the predictions are likely to lie somewhere in-between. Finally, in the presence of labor market frictions, we show that commuting subsidies weaken the market power of firms, but more for firms closer to their employees.

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 exclude individuals who relocate residences. We use geocoded data on the location of residence and employer to calculate the shortest driving distances commuted to work. We exploit large changes in German tax law to identify the effect of commuting subsidies. In particular, we exploit exogenous changes in the commuting price specified in German tax law in 2004 (a reduction in commuting deduction parameter), 2007 (a drastic reduction), which was unexpectedly reversed in 2009. To obtain person-specific measures of these tax changes, we write a tax calculator that calculates the tax liabilities of each 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 provides 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 that are correlated with person-specific changes in the value of the commuting deduction and our outcome variables.

In our first step, we explain changes in commuting distance with changes in 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 average 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 our focus on an average effect, rather than on only low-income workers and because we focus on job changers. 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 distribution of plant effects 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 without the commuting deduction.

Although commuting subsidies induce workers to move 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 distribution of the person-specific component, more generous commuting subsidies have either no effect or a slightly negative effect on the plant component level. However, this effect of commuting subsidies on the plant component increases almost monotonically with 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 induces these workers to move to plants that pay a 0.49% higher wage premium. Since this effect is almost twice as large as the average effect and since the effects at the lower end of individual quality distribution are negligible, we conclude that commuting subsidies reinforce positive assortativity in the labor market. Thus, the subsidy was not effective at improving the plant-specific component of wages for low-income households relative to high-income households. 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. As a convenient short-hand, we sometimes refer to firms with better firm-specific components 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 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 the increasing wage dispersion in West Germany was due to rising assortativity. In particular, these 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 these increases. Although theoretically an increase in the generosity of commuting subsidies may increase or decrease heterogeneity in wages, our empirical analysis shows that commuting subsidies reinforce labor market inequalities in earnings.

One other published paper causally studies the effect of commuting subsidies on commuting distances and employment locations, which likely will become more footloose under work-from-home. 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 that the regression kink design yields a local average treatment effect and that 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 across the income distribution. Heuermann et al. (2017) also exploit changes in the commuting deduction formula in Germany, but focus mainly on a single

[1]Obviously, one can write down structural models for which the relationship between estimated worker and firm effects bears 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. Focusing on long-distance commuters, Elholm and Sigaard (2024) show that place-based subsidies increase commuting.

tax reform and study the incidence effects of a tax change on the wages of all workers, and thus not the effect on commuting distances or assortativity. Dauth and Haller (2020) regress changes in wages on changes in distance for job changers 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 on commuting more generally, but both papers focus on the role of tax rates overall.

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 matching process between workers and plants with important consequences for regional wage inequality. And there is a growing literature that decomposes the wage losses at the time of 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 that firm-effects explain a large share. Bertheau et al. (2023) find that employer-specific wage components explain between 35% and 60% of the earnings 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 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 as-

[3]The evidence on the US is mixed. On the one hand, the firm-specific component plays a smaller role in the US (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.

sortativity by allowing low-wage workers to increase their job set, commuting subsidies actually induce higher-wage workers to commute relatively longer, allowing them to match with higher-wage plants.

2 A Model of Endogenous Work Location

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 residence often and government subsidies for commuting are important. In the long run, household residence 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 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 US, 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, the mobility of households in Germany is relatively low, in particular when compared to other large countries (excep for Italy). Table 1 reports the fraction of households who moved to another dwelling in the last five years, relative to the total population and relative to the group of tenants renting at market prices. Renting in the market is the dominant form of housing arrangement in Germany. Considering also that mobility is typically much higher among young people, 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 labor economics literature suggests that individuals frequently change jobs—either in response to life cycle career dynamics, layoffs, or better jobs that are found—oftentimes in ways that do not require the worker to relocate residences. In our

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

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

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

sample, 86% of all workers who change jobs 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 in reality individuals likely reoptimize at both margins, studying this polar case allows us to highlight critical differences with the standard model, to develop a model applicable to countries where household locations change infrequently, and to gain insights for the large fraction of individuals that change jobs without changing residence.

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, $f'(u) \geq 0$.*

A specific example further illustrates Result 1. 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 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 $1 - F(\tilde{u})$.

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. 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 most 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 firm locations must move in opposite directions as commuting subsidies change. As 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.*

It is tempting to believe that higher subsidies increase not only commuting and matching, but also inequality when measured by the variance of gross wages. The reason why this is not generally true is that the variance of wages is a highly nonlinear expression of the commuting subsidy. What can be shown is that in a highly simplified model with only one ability type inequality rises under an easy to interpret condition.

2.4 Commuting Subsidies and Labor Market Power

Commuting subsidies may play a positive role when there are labor market frictions, perhaps in the form of monopsony power. Workers facing low wage offers close to their residence may be able to overcome the market power of local firms if they commute sufficiently long distances. Commuting subsidies make such long commutes more attractive. To address this within our model, we make several assumptions, while maintaining the main setup of our model. We continue to assume two work locations with different distances. In contrast to the baseline model, however, at each location there is only one firm. Hence each firm has some market power in the labor market, while in the output market firms are in a perfectly competitive environment (exogenous output price p). On the worker side, we consider only one ability type and therefore drop the α index, while we keep the heterogeneity in individual commuting costs u, which is an important ingredient of allocating workers to locations.

A worker at location i earns gross wage w_i, which is a choice variable of the firm. One unit of labor produces one unit of output. Each worker supplies labor inelastically. A worker's net income can be written as $y_i = w_i - ud_i - T(m_i)$, where $m_i = w_i - cd_i$.

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

The worker who is indifferent between the two locations (for given wages) has commuting costs $\tilde{u} = \frac{w_2 - w_1 - T(m_2) + T(m_1)}{d_2 - d_1}$. This follows the same logic as in the main model. Workers with low u work at the more distant location 2, while those with high u work at location 1.

Each firm sets its wage, anticipating the allocation decision of workers just described, implying the existence of strategic wage setting. A firm's profit is $\pi_i = (p - w_i)n_i$, where $n_1 = 1 - F(\tilde{u})$ and $n_2 = F(\tilde{u})$ are the number of workers in each firm. Profit maximization leads to the first-order condition

$$(p - w_i)\frac{dn_i}{dw_i} = n_i. \tag{12}$$

The derivative $\frac{dn_i}{dw_i} = f(\tilde{u})\frac{1 - T_i'}{d_2 - d_1} > 0$ gives the responsiveness of workers to wage adjustments in one location. With this preparation, we can state the following.

Result 4. *Consider the model with two work locations, in which one firm in each location produces output with only labor. Each firm maximizes profits by choosing its wage rate. Workers differ only in their commuting cost u, which are assumed to be uniformly distributed. A rise in commuting subsidy c raises the number of workers in the more distant location and raises the wage at both firms if the marginal tax rate is constant locally, but the wage increase in the closer location is larger than in the more distant location. Hence, the commuting subsidy weakens the market power of the firm at the closer location.*

Proof. See Appendix A.1. □

Intuitively, the prior result involves conducting comparative statics in the context of a Nash game. As shown by Caputo (1996), a change in the commuting cost parameter has two effects: (1) a non-strategic effect that captures the response of firm 1 holding constant firm 2 at its Nash value and (2) a strategic effect that captures the response of firm 1 via the direct response of firm 2 due to the subsidy change.[7] In the context of our model, the direct effect of the policy change is that wages in firm 1 must rise to lower the price-wage margin. However, because the game is one of strategic complementarity, prices rise in 2 as well, but by less than the wage increase in 1. Thus, in the aggregate, the price-wage difference at firm 1 shrinks more than at firm 2.

Result 4 provides a basis for the beneficial effect of a commuting subsidy in a labor market with frictions. Of course, the result has been derived under simplifying

[7] Caputo (1996) thus writes, justifying some of the simplifications we have made, that "The use of simplifying or special cases is therefore a natural response by the users of game theory in their attempt to draw tight conclusions about the comparatives statics properties of the level of the decision variables using primal comparative statics methodology from a model which has fundamental but unconventional qualitative comparative statics properties."

assumptions. The result is silent on possible distributional effects when heterogeneity in ability were considered. In our empirical analysis we return to this aspect.

2.5 Bridge to Empirics

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 to firms. The formal results indicate that even in a simple model with fixed residences and two work locations, comparative statics often depends on assumptions about the distributions of idiosyncratic commuting costs and ability. As the distribution of idiosyncratic costs is typically not directly observable, it is an empirical question how changes in commuting costs 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 residential 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 to future research and turn now to our empirical analysis.

To bridge 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 implying that the effect of taxes on distance is opposite in sign to the direct effect of c on distance.

3 Institutional Background

Taxpayers can deduct work-related expenses ("Werbungskosten"). 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.[8] The general formula for commuting deductions is

$$C = n \times d \times c \tag{13}$$

where n is the number of commuting days per year, d is distance, and c 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

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

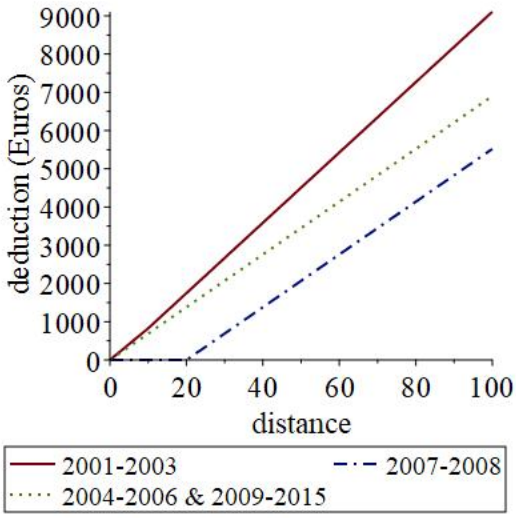
shortest distance one way unless it can be proven that a longer way is more economical. Finally, c is a parameter that has changed over time according to German law, which we will exploit for identification. The mode of transportation is irrelevant for the deduction, except trips by plane which are not deductible. There is an upper limit for C at 4,500 Euros for all modes other than transportation by car. Assuming transportation by car, the time variation in deductible commuting expenses is given by Table 2 and Figure 1.

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 commuting deduction has changed over time.

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 1,044 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) but only effective in 2009. This is our third reform. In the 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.[9] 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.[10]

The first two reforms were implemented as budget consolidations and are thus exogenous from the viewpoint of an individual taxpayer.[11] 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 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

[9] From 2011 onward the lump sum deductible S was increased from 920 to 1,000 Euros.

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

[11] 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.[12] Each observation contains a unique worker and establishment identifier, socio-economic characteristics of the worker, information on the worker's place of residence and place of 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 moved 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). All wage results will be presented in 2015 Euros.

To investigate the commuting behavior of workers, municipal boundaries 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 then 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.[13]

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

$$\ln w_{it} = \alpha_i + \psi_{f(it)} + \beta x_{it} + u_{it} \tag{14}$$

worker fixed effects α_i which capture 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 x_{it}, which 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 plant fixed effect describes the systematic part of a worker's wage, which is common to

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

[13] 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.

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 identified 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.[14] 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 need to measure the effective tax change at various points of the income distribution. 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 proof of expenses, as explained in Section 3. Denote total itemized deductions be $R = C + D$. The simulator

[14] Bonhomme et al. (2023) notes "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."

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 $T(z)$.[15] Then taxable income is given by

$$z = m - \max(C + D, S) \tag{15}$$

where m is gross income and deductions explained in Section 3. Applying the German income tax schedule to taxable income then yields tax liability $T(z)$.[16]

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 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,[17] 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 is gross income.[18]

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

$$\triangle tax_{it} \equiv \triangle T_t(z_{it}) = \triangle T_t(m_{it}, C(d_{it}, p_{it}), S_t, D_{it}), \tag{16}$$

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

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

[16] We do not observe marital status and Germany uses income splitting. Thus, each partner is affected by a reform to the commuting expenses individually because deductibles are measured relative to the lump sum amount S individually, not jointly, e.g.,with two individuals indexed i, we have $T(z_1, z_2) = 2T\left(\left(\sum_i m_i - \sum_i \max(C_i + D_i, S)\right)/2\right)$. We also have some measurement error in the tax-price because if a person is married and his/her partner has very different income, then we make a large mistake if we assume mistakenly that the person is single.

[17] $T(z)$ 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.

[18] 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 (15). 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 (13), we can write $C_{it} = C(d_{it}, c_{it})$: the commuting deduction is a function of d_{it}, the distance to a job, and c_{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 (our preferred approach), ii) zero, so that the average deduction of itemizers and non-itemizers 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.[19] 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.

[19] 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

We focus on job changers. While commuting subsidies may also induce changes in residential locations, we do not know anything about the change in house prices. As house prices vary considerably across 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 that residential mobility is rare in Germany, as discussed in Section 2, this is not a critical assumption as the relative cost of changing residence is likely to be higher than changing jobs.

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

$$\triangle \ln d_{it} = \beta_1 \triangle \overline{tax^*_{it}} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_{it} \tag{17}$$

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, as 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. Since 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.[20] In all specifications, standard errors are clustered at the 257 commuting zones level.

In many specifications, 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 given in (16). The expression in (16) is not empirically relevant for two reasons. First,

[20] 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.

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 (16) depends on endogenous variables that are influenced by the reforms. 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:

$$\triangle\overline{tax}_{it}^{*} = \triangle\overline{T}(\overline{m_i}, c(\overline{d_i}, c_{it}), \overline{S}, \overline{D_i}). \tag{18}$$

where the "bar" notation denotes that we hold fixed those values at the *old* job/tax system. By holding constant wages and distances at the old job, (18) 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 effect that then changes commuting through changes in labor supply rather than through commuting incentives. At the same time, marginal tax rates have an effect on the after-tax price of commuting, but such an effect is likely to be second-order. Finally, because the effect of marginal tax rates on labor supply is likely to be first-order, we hold the tax function and the standard deduction constant in the year of the *old* job. Inspection of (18) shows that variation in this variable results from changes of the commuting formula via changes in the rate at which the government allows you to deduct commuting expenses, c_{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.[21]

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.

[21] 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 c_{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

$$\triangle y_{it} = \beta_2 \triangle \ln d_{it} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_{it} \tag{19}$$

where $\triangle y_{it} = \{\triangle \ln w_{it}, \triangle\psi_{f(it)}^{AKM}\}$ with $\triangle \ln w_{it}$ denoting the (log) change in wages and $\triangle\psi_{f(it)}^{AKM}$ is the change in the plant-fixed effect (in units of log wages) from an estimation of the AKM model in (14). 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, (17) is the first stage of this IV estimator. Recall that, 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. A subsequent section will address possible limitations of the instrument.

As a first analysis, 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, $\psi_{f(it)}^{AKM}$, as a measure of employer quality. Recall that the plant fixed effects are measured in log wage units but do not include 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 $\triangle\overline{tax_{it}^{*}}$, β_2 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 to the earnings regressions is that the change in taxes is economy wide, which may alter the wages that different firms offer via general equilibrium 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

$$\triangle\psi_{f(it)}^{AKM} = \gamma_1\alpha_i^{PE} + \gamma_2\alpha_i^{PE} \times \triangle \ln d_{it} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_i \tag{20}$$

where α_i^{PE} is the estimated person effect from the AKM model in (14) 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 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:

$$\triangle\psi_{f(it)}^{AKM} = \theta_1 1_q^{PE} + \theta_2 1_q^{PE} \times \triangle \ln d_{it} + X_i\theta + \zeta_t + \zeta_c + \varepsilon_{it} \tag{21}$$

where $\triangle\psi_{f(it)}^{AKM}$ is the change in the plant fixed effect after a worker changes jobs, 1^{PE} are indicators for the deciles, q, of α_i^{PE} 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. The coefficients θ_2 tell us how making the commuting subsidy more generous influences assortativity by decile.

6 Results

6.1 Descriptive Statistics

Before proceeding, 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 calendar 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* (365) day rather than per work

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 job changers.

day because we do not know the precise number of days worked. Moreover, the average changes in our instrument induced by the commuting reforms are 164.9, 325.3, and -317.6, in the 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, (17) and (19), where (17) is the first stage of the IV estimation of (19). We will first discuss the estimates of (17) before turning to the estimates of (19). In our setting, the first-stage is a policy-relevant parameter in its own-right, and for this reason we discuss it first. 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 very

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 (17) in Panel A and the estimates of (19) 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%.

low-income workers. Panel A of Table 4 shows the results of (17).

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%. 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 the 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

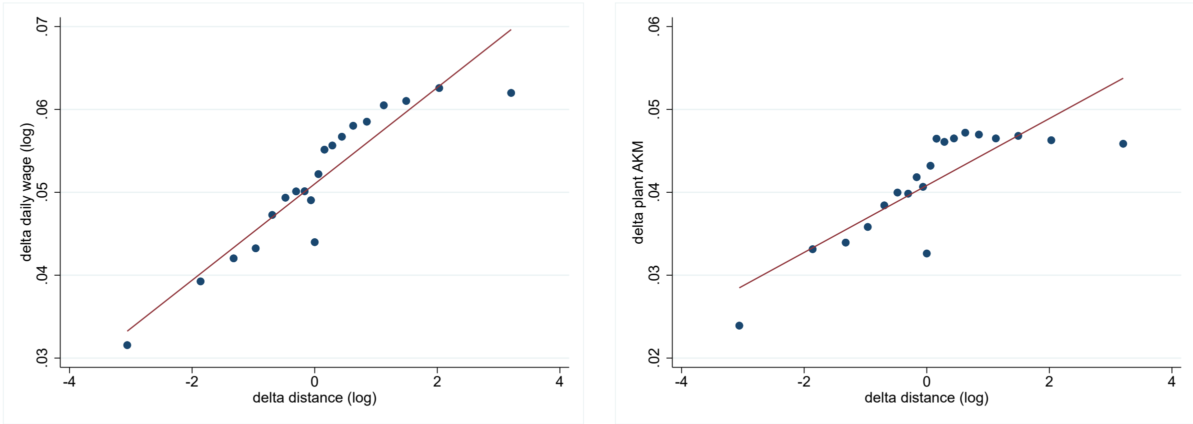
Euros. Thus, a one standard deviation change in taxes due to a change in the commuting deduction formula causes a change in distance to work by approximately 5.1 kilometers or 24% of the mean distance traveled in our sample. Another way to benchmark this effect is to compare it to the only other empirical 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 larger. 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. Furthermore, a key difference is that we focus on job changers and our effects do not include the null effects on non-marginal individuals who do not change jobs. Thus, our estimates are an average treatment effect for job changers at all levels of income. 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 of *switchers* and the effects in that sample will be larger than when including non-switchers.

As an alternative explanation, we take the variable $\triangle\overline{tax}^{*}_{it}$ and divide by the old commuting distance of the work and then reestimate our model with this transformed variable as the dependent variable. The advantage of this specification is that the coefficients can be thought of related to the "price" savings per kilometer of commuting. This alternative model yields a coefficient of -0.629 (se: -0.053) without covariates and -0.701 (se: 0.054) with the full set of covariates. Keeping in mind that the tax change is in hundreds of Euros, this model says that an increase in the taxed value of the commuting deduction by one Euro per kilometer lowers commuting distances by 0.7%. In order to think of this in the context of a "price" elasticity per kilometer of distance, we can divide by the mean percent change taxes per kilometer. At the old job, an individual had taxes of 8,164 Euro. Given a 230 day work year and a mean commute of 21 kilometers, this was 0.845 per kilometer of travel prior to the reform. For the mean tax change of 276 Euro, this changed by 0.029 Euro per kilometer, or a 3.38% percent change in the tax price of commuting per kilometer. Given our coefficient estimates, the elasticity of commuting distances with respect to the tax-price per kilometer is a reasonable 0.207.

Next, we study whether increases in commuting distance induce workers to move up the wage distribution. Before turning to the second stage, 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

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.

outliers.

Turning to (19), 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. Comparing across columns, 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 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.

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, we can use 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 lowers 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).[22] 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 (19) 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%.[23] In

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

[23]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

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 (17) where distance traveled is replaced by time traveled. The estimates of (19), 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%.

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,

the IV estimate in Panel B or C times the first stage coefficient in Panel A.

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 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 Robustness

In this section we address two potential concerns with the empirical design. First, the use of lagged distance (and income) to construct simulated tax rates may introduce a mechanical bias in the estimates. Second, we discuss issues of interpretation from using a sample of job switchers rather than all households. Finally, we address several assumptions of our tax calculator, sample selection, and the role of limited mobility bias.

6.3.1 Identification and Sample Selection

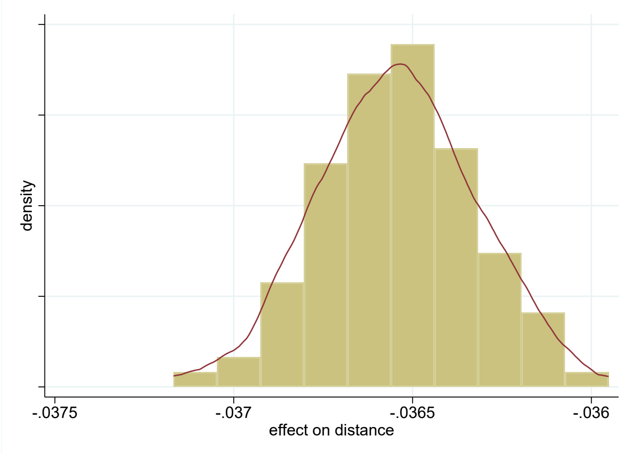
A well known limitation of simulated tax instruments, as used in the literature on the elasticity of taxable income (ETI), is that they rely on lagged characteristics that also enter into the dependent variable. In our setting, this is relevant because the initial commuting distance $d_{i,t-1}$ is used to construct the simulated tax rates and also appears in our outcome variable $\triangle \ln d_{it}$. Thus, by construction, when the commuting deduction falls, the instrument mechanically forces a negative correlation with the outcome variable even if no relationship truly exists (Peri and Sparber 2011). The opposite is true when the commuting deduction increases.[24] In the ETI literature, the solution is to use the method of Weber (2014), but this approach is not available to us because longer time lags are not available to us. To determine whether this is important in practice, we conduct placebo estimations by dropping all individuals who change jobs in the reform years. Then, focusing on the set of untreated individuals who change jobs in non-reform years, we randomly assign each of these individuals to a treated year. We then construct their simulated tax change in that treatment year. We then estimate (17) 100 times for each randomization (rerunning our tax calculator each time). We repeat this excercise using the plant AKM as an outcome. This will tell us the magnitude of the bias in our results.

Figure 3 shows the result. The distribution of coefficients for the change in distance regression, indicates that the placebo estimates range between -0.037 and -0.036.

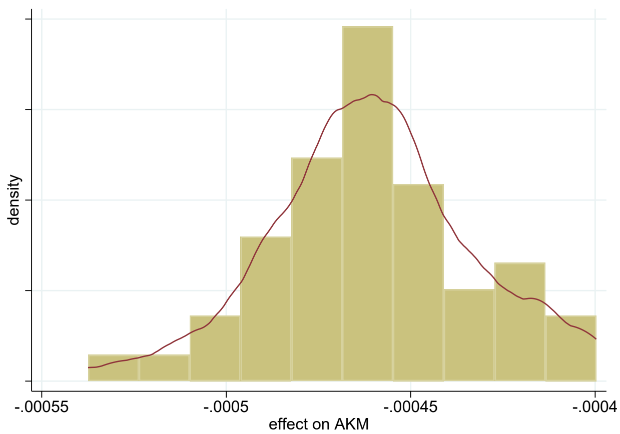
[24] Using lagged income to capture the progressivity of the tax schedule may also introduce some bias, albeit not mechanical like this.

Figure 3: Placebo Test

(a) Distance



(b) Plant AKM



Notes: This figure shows a placebo test where we randomly assign untreated individuals into treatment years and calculate their tax changes in those years. Panel (a) shows the effect of these simulated tax changes on distance, while Panel (b) shows the effect of these simulated tax changes on the plant AKM. Recall that our estimated coefficient corresponding to Panel (a) is -0.1192 and our estimated coefficient corresponding to Panel (b) is $0.0187 * (-0.1192) = -0.0022$.

The very tight band on this comes from randomizing untreated units to treated years and identifying the simple mechanical correlations, which should be common to all radomizations. Given our estimated coefficient in Table 4 is -0.1192, these results appear to be about 30% too large in absolute value. Turning to the results for plant AKMs, where time-lagged distance does not appear directly in the explanatory variable, but where the use of lagged income to calculate tax changes may be correlated with the change in the plant-component of wages, our placebo estimates yield a distribution between -0.0005 and -0.0004. As these placebo estimates are derived from a regression of changes in plant AKMs on changes in tax rates, our estimated reduced form is given by -0.0022. This suggests a bias of less than 25%. Critically, the entire distribution of the placebo estimates is well outside our actually estimated effects. Given the magnitude and significance of our estimated effects in Table 4, adjusting for this bias would still yield effects that are economically meaningful and statistically significant.[25]

Second, in order to obtain a large sample to conduct heterogeneity analysis and to eliminate confounding effects from residential relocations, 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. The assumption we have made is that the subsidies affect where to search, but not whether to change jobs. This assumption is necessarily a function of the data we have access to. However, comparing the number of job switchers in years of the reform with non-reform years, we find no meaningful differences in the means of the number of job switchers in reform/non-reform years other than standard trends over time.

Moreover, as discussed above, this selection is likely to be most important in our first-stage distance regressions rather than in regressions explaining the changes in plant-AKM. Intuitively, in our first-stage distance equations, there are some individuals who experience a change in commuting deduction without a change in their distance commuted (non-switchers). Thus, in this setting, our effects are treatment effects conditional on the job change. In the second-stage, however, we regress changes in the plant's AKM on changes in distance, appropriately instrumented. If we were to include non-switchers in this stage, both the dependent variable (changes in plant-AKM) and the independent

[25] To further explore this, we have also used a grouping estimator (Burns and Ziliak 2017). Unfortunately, the few covariates that we have (gender, occupation, and region, etc.) substantially compress distance and leave almost no variation across groups in the mean distances. Thus, the grouping estimator requires we use deciles of old distance plus other observables to group on. Doing this, however, yields results consistent with the placebo effects and main results in the paper.

variable of interest (changes in distance) would be zero, implying that it is likely that our results would be similar in this sample as these observations would simply influence other covariates.

6.3.2 Other Checks

Next, we verify that our estimates are not sensitive to the assumptions we have made. First, we check sensitivity to the assumed amount of other deductions, D, and we check sensitivity to the maximum commuting distance, which we assume to be 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 non-itemizers. In all cases, a 100 Euro change in taxes reduces commuting distances by between 9 and 11%. Second, Table A.2 shows the sensitivity to the maximum commuting distance we allow in the data. Since some workers may commute regularly, but work remotely and rarely travel long distances to the office, we assume that the maximum daily commute is 100 kilometers. Adjusting this threshold downward slightly lowers the coefficients , while adjusting the threshold upward slightly raises the coefficients.

Table A.3 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 services sector, and exclude workers in multi-plant industries where the distance variable may be measured with error. Finally, the last Column uses the sample 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 can lead to 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 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).[26] As can be seen, the coefficient in panel C related to the AKM model changes only negligibly. This is as expected, as concerns about limited mobility bias are likely to be a concern when correlating plant and worker effects.

[26] 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://tlamadon.github.io/pytwoway/index.html`.

7 Heterogeneity

In contrast to the previous literature, 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 4 shows that there is little heterogeneity in the effect of the subsidy on distance by individual characteristics: women and men respond equally, as do citizens and non-citizens. With respect to education, the largest effects on distance are found for low-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 high-skilled workers. The higher returns to commuting for high-skilled workers provide 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), Le Barbanchon, Rathelot and Roulet (2021), and Caldwell and Danieli (2023) who argue that the marginal costs of commuting for women are higher than for 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 jobs when they have a long commute. 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 whether 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.

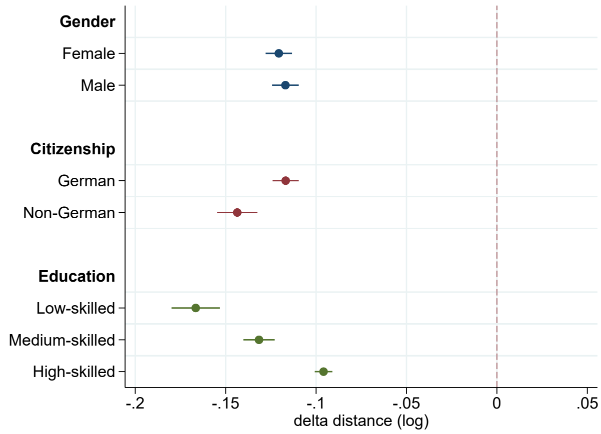
Finally, Figure A.2 shows heterogeneous effects by occupation, industry, and task. The largest effects on the wage and plant-quality measures are in industries classified as "construction", occupations classified as "personal services", and tasks classified as "complex". Note that an individual in a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

8 Assortative Matching

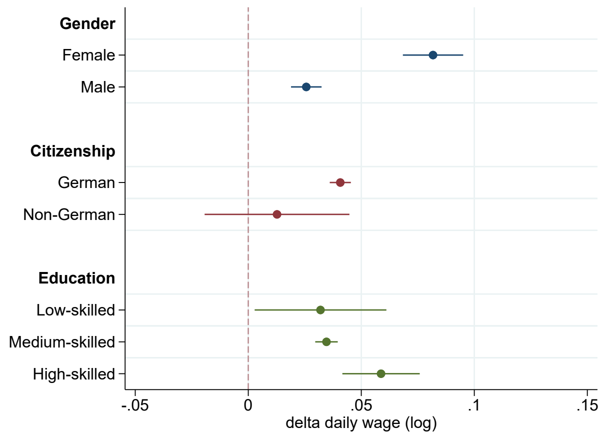
Related to the literature on the sorting of high-wage workers to high paying plants, does the commuting subsidy reinforce this phenomenon or does it act as a force to reduce

Figure 4: Heterogeneity by Individual Characteristics

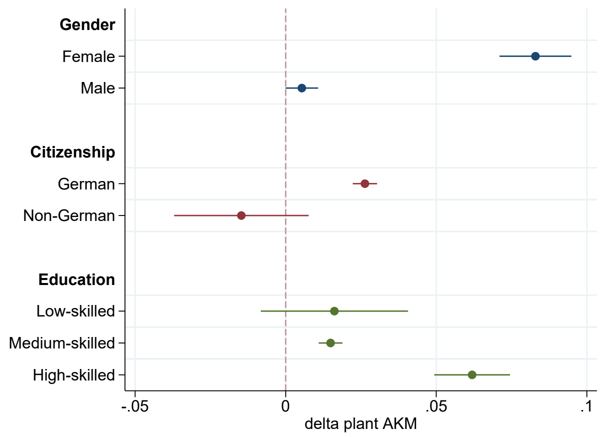
(a) Distance



(b) Earnings

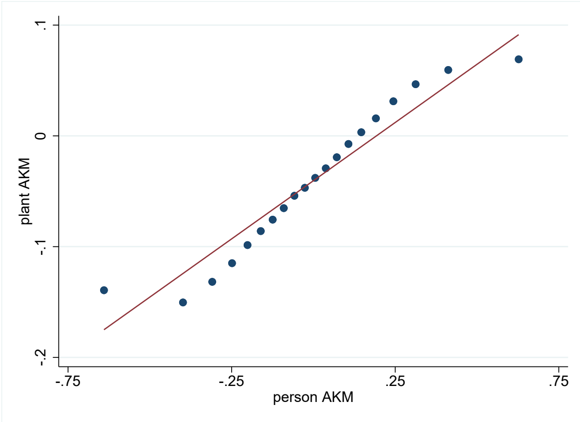


(c) Plant AKM



Notes: This figure shows heterogeneous effects by gender, citizenship, education, and skill level. Panel (a) presents the results of (17) when the tax variable is interacted with individual characteristics. Panel (b) presents the results of (19) 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 5: 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.

positive assortative matching? To do this, we next interact the subsidy with indicators for deciles of the income distribution as in (21). Before proceeding, Figure 5 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 (20), 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 of 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. In contrast to Figure 5, the coefficient γ_1 is negative. This is because, 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 becomes 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 the taxable income literature. Critical to our analysis, however, is the sign of γ_2 which is positive. This implies that the ability to move to a better-paying employer is increasing in the worker-specific component of wages as those workers increase their commute as a result of an increase in the generosity of the commuting subsidy.

Next, in our preferred approach, we show the effect of the subsidy on assortativity using the nonparametric approach of (21). In our main analysis we use deciles of the AKM person-specific effect, but we also present results estimating the AKM effects using the leave-one-out connected set to address limited mobility bias. 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 6 presents the results: Panel (a) indicates the heterogeneous

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 (20), 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%.

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 wage that a worker moves to. In other words, commuting subsidies induce high-ability individuals to move up the firm (wage) quality distribution more 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 6 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 second decile with those in the top decile. As indicated by the summary statistics in Table A.4, 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 increases 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.[27]

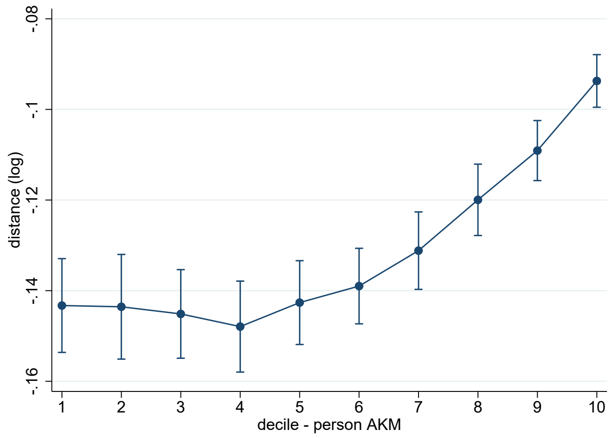
As discussed, limited mobility bias is a concern in the AKM model, especially when correlating plant and individual effects. Figure A.4 shows the same figures as in the main text using the leave-one-out data set discussed previously. The results are robust and Panel (c) again features a strong positive 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 in the qualitative result of the paper.

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 necessarily translate into job 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

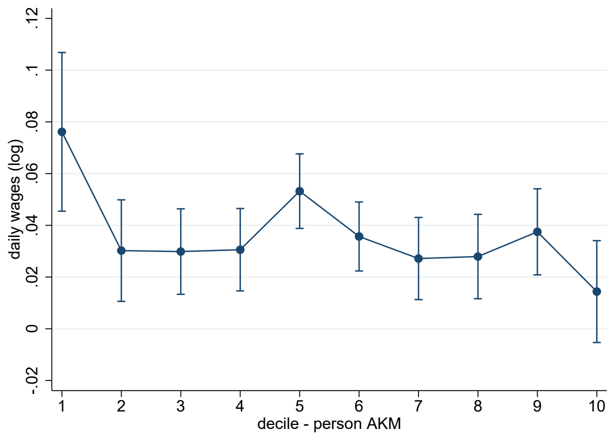
[27] In the second stage, the mean plant AKM in the second decile and the top decile are -0.123 and 0.064, respectively.

Figure 6: Assortativity by Deciles of Person Fixed Effects

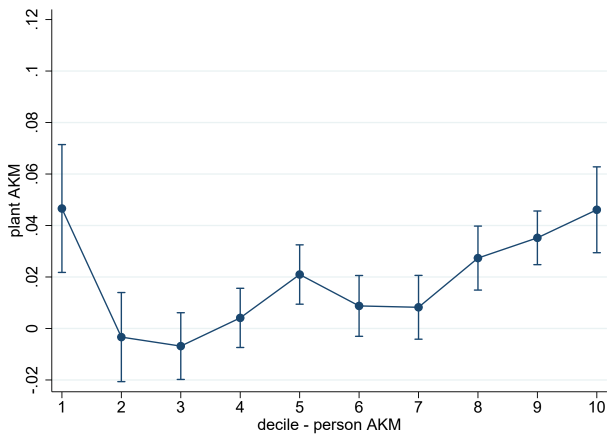
(a) Distance



(b) Earnings



(c) Plant AKM



Notes: This Figure presents the estimates of (21), 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 the regressivity of higher-income tax payers receiving larger tax benefits.

9 Conclusion

Commuting subsidies are often regarded as "bad" policies because they encourage wasteful commuting that increases congestion and generates environmental externalities. We show theoretically that commuting subsidies may have a potential redeeming feature: they expand the potential choice set of workers facilitating the matching of workers to better paying plants. From a policy perspective, this channel is especially important for low-wage workers who are likely to face substantial search costs or spatial mismatch. But whether those commuting subsidies—often implemented via tax law—actually incentivize low-wage workers more than high-wage 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 firms. This process reinforces assortativity in the labor market. In turn, the increase in assortativity contributes to increased (within labor market) earnings inequality.

Our paper is not meant to be a *normative* evaluation of commuting subsidies, but rather the *positive* effects of subsidies on employer-employee matching. However, our results have some normative implications. Abstracting from externalities, 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 workers 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, this government policy works to reinforce homophily by benefiting high-ability workers relatively more in terms of labor market wage improvements.

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10 Appendices (for online publication only)

A.1 Theory Appendix: Proof of Result 4

Proof. We start from the first-order condition for profit maximization. Without loss of generality, focus on firm 1. Assuming that u is uniformly distributed, $f = \frac{1}{\bar{u}-\underline{u}}$ is a constant and $F(\tilde{u}) = \frac{\tilde{u}-\underline{u}}{\bar{u}-\underline{u}}$ (recall that there is only one type of worker ability and hence integrating over all u gives 1). This assumption implies that $\frac{dn_1}{dw_1} = f\frac{1-T_1^{'}}{d_2-d_1} > 0$. Inserting this in the first order condition, making use of the indifferent type type $\tilde{u}$, gives

$$(p - w_1)(1 - T_1^{'}) = (d_2 - d_1)\bar{u} - w_2 + w_1 + T(m_2) - T(m_1). \tag{A.1}$$

This condition can be differentiated to obtain the slope of the reaction curve, which will be used in the proof below. We get after simplifying and using $dm_1/dw_1 = 1$:

$$\frac{dw_1}{dw_2} = \frac{1 - T_2^{'}}{2(1 - T_1^{'}) + (p - w_1)T_1^{''}} \tag{A.2}$$

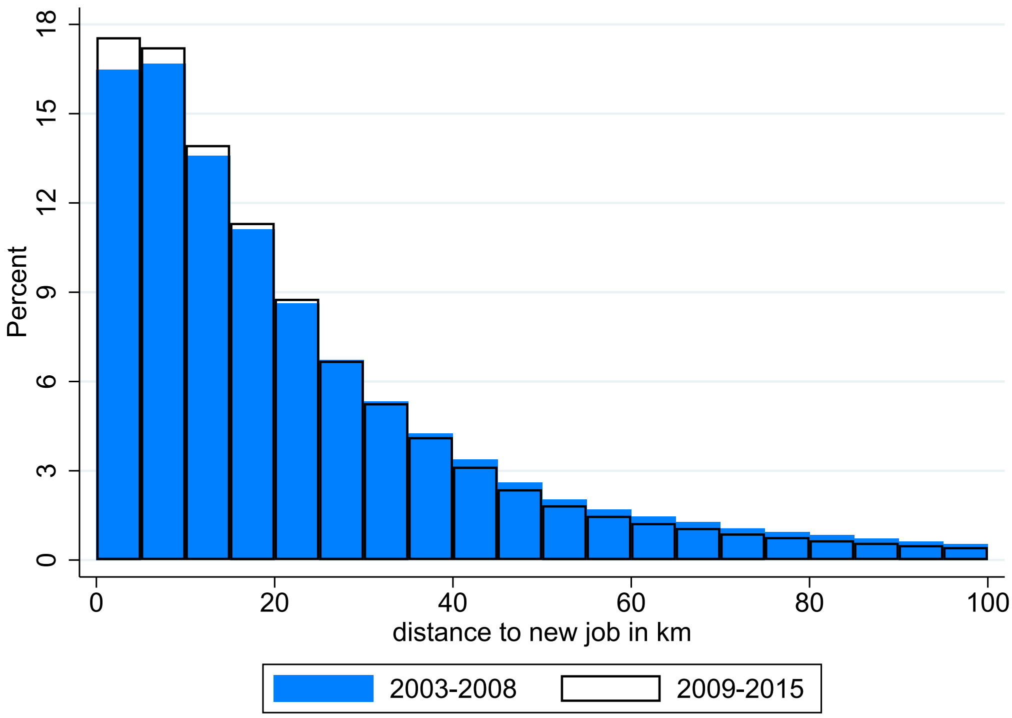
This expression lies between 0 and 1, as $T_2^{'} \geq T_1^{'}$ due to $m_2 > m_1$ when $d_2 > d_1$, the marginal tax rate is 1 at most, and (12) implies that the price exceeds the wage, and convexity of the tax schedule implies a non-negative second derivative of the tax function $T(m)$. A similar condition holds for firm 2's reaction function that implies $dw_2/dw_1 < 1$. As both reaction functions are positive sloping, the game is supermodular and an equilibrium will exist by Topkis' Theorem.

We now consider a change in c. Usually, this would require us to conduct comparative statics on the two first order conditions describing the Nash equilibrium. In a special case, we can simplify the analysis and focus only one firm's condition, namely, when the left hand side of (12) is independent of c and the other firm's wage. This is the case if we assume that the marginal tax rate is locally constant because then the derivative $\frac{dn_1}{dw_1} = f\frac{1-T_1^{'}}{d_2-d_1}$ is independent of c. The left hand side is also independent of w_2 under the assumptions made. For the right hand side, it is true that a rise in c leads to an increase in $\tilde{u}$, and thus a fall of $n_1 = 1 - F(\tilde{u})$. To stay on the first order condition, the wage w_1 has to rise to lower the price-wage margin. Because wages are strategic complements according to (A.2), and the slopes of the reaction functions are less than 1, the wage at firm 2 rises as well, but less so. Hence the price-wage difference at firm 1 shrinks more than at firm 2.

A.2 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: 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 services 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%.

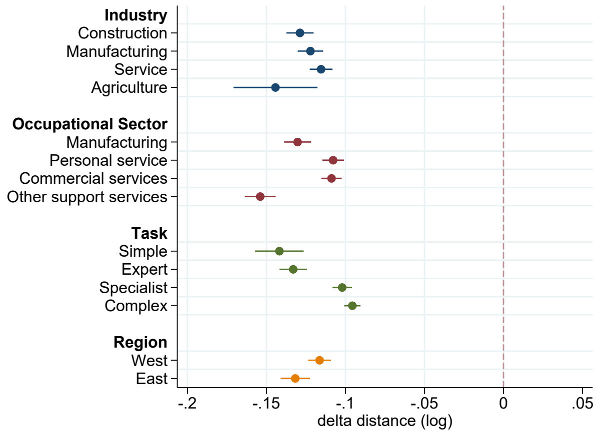
Table A.4: Means of Dependent Variables by Deciles of Person AKM

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

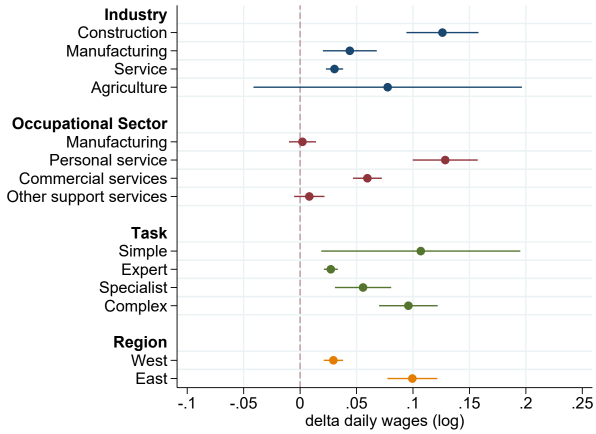
Notes: This table provides the means of each dependent variable by deciles of the plant AKM, which correspond to the deciles used in our analysis.

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

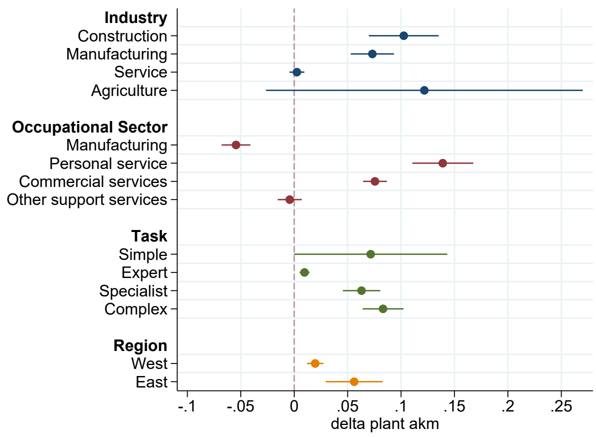
(a) Distance



(b) Earnings



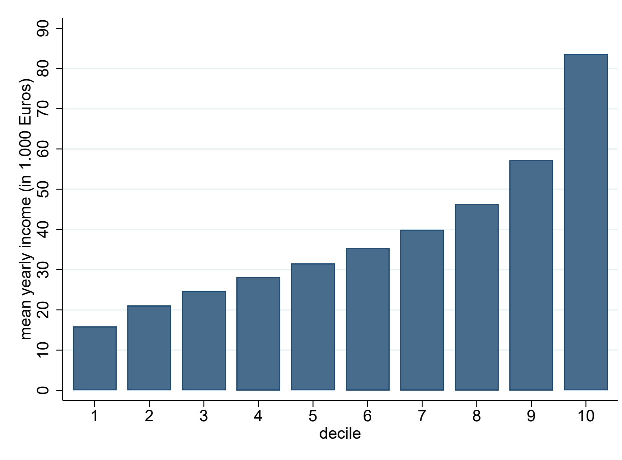
(c) Plant AKM



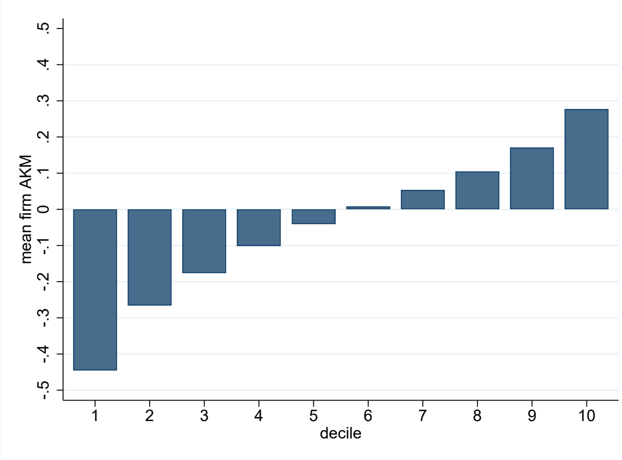
Notes: This figure shows heterogeneous effects by industry, occupation, and task. Panel (a) presents the results of (17) when the tax variable is interacted with individual characteristics. Panel (b) presents the results of (19) when the dependent variable is the change in earnings, while Panel (c) presents 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



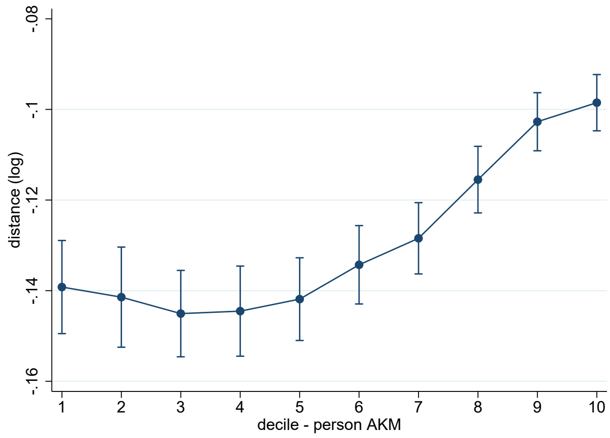
(b) Plant AKM Deciles



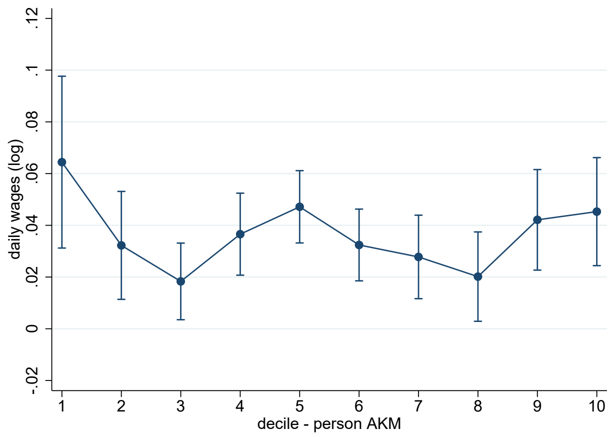
Notes: Panel (a) shows the mean income by deciles of the income distribution in our sample. Panel (b) shows the mean plant AKM by deciles of the plant AKM distribution in our sample.

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

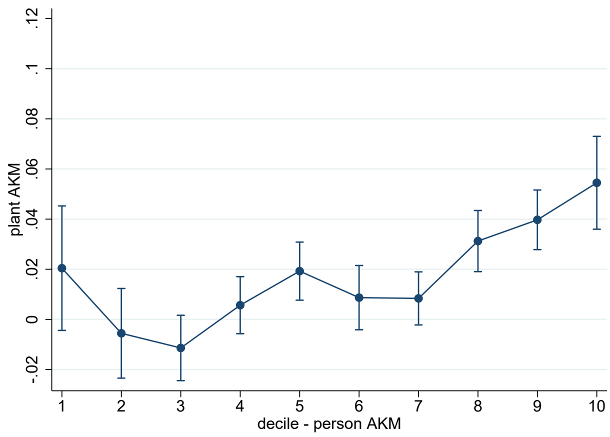
(a) Distance



(b) Earnings



(c) Plant AKM



Notes: This Figure presents the estimates of (21), 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.