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Do local fuel prices affect remote working behaviors and carbon emission savings?

Evidence from German panel data^{*}

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Abstract

Given the importance of the transport sector for greenhouse gas emissions, both behavioral change will be needed to mitigate climate change in addition to technological innovation. We focus on the case of remote working as a less carbon-intensive substitute to commuting and analyze whether employees react to price incentives and work more from home in times of higher local fuel prices. Applying an instrumental variables approach based on panel data from Germany, we find moderate fuel price effects on remote working frequency, which are restricted to occupations with high skill-level and regions with limited alternatives to car commuting. We use these results to predict changes in remote working frequency as a consequence to increasing carbon prices as discussed for climate policy. Results indicate that even with ambitious carbon pricing, individual remote working frequency will increase modestly, causing only limited reductions in German national aggregate fuel and carbon emissions.

Keywords: fuel price; elasticity; remote working; telework; commuting; longitudinal

JEL Codes: H23, Q41, Q48, Q54, Q58, R41

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1. Introduction

With the rise of remote working in recent years (Brynjolfsson et al. 2022; Tito 2025), its risks and potential benefits are discussed not only in relation to aspects such as productivity, travel time savings, and work-life balance (e.g., Bloom et al. 2015; Beckel et al. 2023; Kelly et al. 2022), but also to fuel and carbon emission savings. While scientific research in this regard is mixed (Tao et al. 2023; Hook et al. 2020; O'Brien and Yazdani Aliabadi 2020; Marz and Şen 2022), the argument that increasing remote working may help mitigate climate change is put forward also in the public (Büttner and Breitzkreuz 2020; Öko-Institut 2022; Crow and Millot 2020; Acerini et al. 2021).

It seems a convincing idea that the opportunity of remote working may boost the impact of increasing fuel prices via carbon pricing (through emission trading or carbon taxes) as higher fuel prices may encourage employees to work from home and avoid high commuting costs. However, while factors affecting remote working have received considerable scholarly attention (Ferreira et al. 2021; Tahlyan et al. 2024; Brynjolfsson et al. 2020) and fuel prices are mentioned as an impact factor for remote working behavior (e.g., Patino-Artaza et al. 2024; Peñafiel-Mera and Santos 2024), the relationship between fuel prices and remote working have not been empirically studied yet.

Thereby, an understanding of remote working is needed both for policy design regarding remote working conditions and for analyses and simulations of the impact of carbon pricing on fuel consumption and carbon emissions. The latter is particularly important as carbon price elasticities are not fully understood yet. This is true in particular concerning individuals and private households, although more than 60% of carbon emissions worldwide are related to household consumption, with the top three emitting activities transportation, housing, and food (Hertwich and Peters 2009; Ivanova et al. 2016). Empirical analyses point toward low price sensitivity in both everyday behaviors and investment decisions, including, for instance, electricity demand (Borenstein 2012), natural gas consumption (Davis and Kilian 2011; Xiang and Lawley 2019), and the choice of heating systems (Sahari 2019; Decker and Menrad 2015). Studies of transportation demand report modest price effects as well, e.g. limited demand responses to current prices (Knittel and Tanaka 2021; Kilian and Zhou 2024), ignorance of fuel economy information of passenger cars (Allcott and Knittel 2019), and low consideration of future fuel costs in vehicle purchases (Gillingham et al. 2021). Reasons for this may be that bounded rationality, such as loss aversion, framing, and satisficing (Gerarden et al. 2017; Allcott and Kessler 2019; Kahneman and Tversky 2012), as well as social influences, such as social contagion and social norms (Bollinger and Gillingham 2012; Kastner and Stern 2015; Welsch and Kühling 2009; Liebe et al. 2021; Kaiser et al. 2020; Vallet and Pressman 2020), play a larger role for individuals' behaviors, which may offset price effects.

In this study, we investigate how employees' remote working behaviors are influenced by local fuel prices in Germany. This is a relevant case as commuting accounted for 18% of passenger-kilometers and thus approximately 12% of total energy consumption of the transport sector in Germany in 2021 (Kraftfahrt-Bundesamt 2024). Remote working has long been of minor importance even in countries with adequate ICT infrastructure (Milasi et al. 2021; Brenke 2016; Sostero et al. 2023). It was only during the COVID-19 pandemic that working from home became popular (and for some periods of the pandemic even mandatory) as a means to reduce the spread of the virus, and even after the slow-down and the end of the pandemic, remote working remained rather common with 22.3% of employees in Germany working from home sometimes or regularly in 2022 (Schana 2023; for evidence from other countries: Frommelt, Milic, and Rochat 2023; Vyas 2022). As the technical and institutional conditions for remote work remained in place in most cases, many employees were free to return to their workplaces or continue working remotely. This may have opened up opportunities for individual optimization strategies to balance work and care demands but also to reduce commuting costs as fuel prices rose steeply during this period.

However, for a number of reasons we expect only modest price effects on remote working demand, which would be in line with the existing literature on limited energy price sensitivity cited above. First, fuel prices are only one factor influencing commuting cost, in addition to, for instance, parking fees, fixed costs of car ownership, and public transport costs. Rational actors will weigh all these factors as well as the potential benefits of commuting, such as subsidized lunches or better networking opportunities at the office. Second, a relevant part of occupations, in particular manual work, do not allow for remote working (Alipour et al. 2023). We address this by testing for differential effects for occupational groups. Third, fuel prices are only a relevant factor if employees commute longer distances by car and alternative transport means are not available; otherwise, employees may substitute car commuting by cheaper modes of transport instead of working remotely. Approximately 69% of employees in Germany commuted by car or motorbike and 48% of employees had a trip of more than 10km during the COVID phase (Statistisches Bundesamt 2022). While data limitations prevent restricting the sample directly to car commuters, we differentiate effects between urban agglomerations and rural regions to estimate the car commuter price elasticity, as in contrast to agglomerations with excellent public transport, in rural regions alternatives such as active travel and public transport are less available. Employees commute almost exclusively by car in such regions, which allows estimates with only a minimal attenuation bias due to non-car commuters. We determine an upper bound of roughly 10% for this bias based on a complementary data set including regionally differentiated estimates of car and non-car commutes in Germany. Finally, effects of fuel prices may unfold only in the long run (Brons et al. 2008; Sterner 2007; Donna 2021; Nguyen and Vo 2020; Kemel et al. 2011), and on the other hand, high commuting costs may trigger strategic decisions to reduce

the commuting distance, either by moving closer to the workplace or looking for a job closer to home as an alternative to working remotely. As this is not the focus of the present study, we exclude respondents who move within the observation period to avoid bias due to selective moves in order to obtain unbiased estimates of short term remote working choices conditional on commuting costs.

The analyses are based on data from a panel survey of a large nationwide randomly drawn sample of young and middle-aged individuals (Brüderl, Drobnič, et al. 2023; Bujard et al. 2025), which are combined with fuel prices (Super E5 and Diesel) of local gas stations using mean prices of the five gas stations closest to each survey participant's main residence in the month of the survey. We take advantage of the variation in fuel prices across locations and over time as survey data collection spans several months per panel wave. By applying fixed-effects instrumental variable (IV) estimators, we model the effect of fuel price changes on remote working net of time-constant interindividual differences due to, for instance, type of occupation, education, and preference for working remotely. We find that remote working frequency increases with rising local fuel prices, but the effect is modest with 1.298 additional monthly days working from home at a fuel price increase of 1 €/l. In particular, employees in urban regions do not react to fuel price changes, whereas employees in rural regions moderately do.

Putting this effect into context, we show that, given this association, a carbon price of 85 €/tCO₂ would lead to 0.2 additional remote working days per month on average and a more ambitious carbon price of 300 €/tCO₂ to 1.0 additional remote working days per month. This is only a moderate increase compared to the current population mean of 5.3 monthly remote working days, and in particular, the change is markedly smaller than the paradigm shift we observe during the COVID-19 pandemic with a rise in remote working frequency from 2.2 days per month in 2019 to 5.6 days in 2020. Thus, price effects appear less relevant in the domain of remote working while social norms and institutions largely shape remote working patterns.

We combine this result with estimates of both direct price effects and effects of remote working on fuel consumption and carbon emissions from the literature (Kilian and Zhou 2024; 2020; Levin, Lewis, and Wolak 2017; for Germany: Khanna, Dubernet, and Jochem 2025; Alberini, Horvath, and Vance 2022; Frondel and Vance 2018). This approach of using estimated elasticity coefficients is common in the literature (e.g., Gowrisankaran et al. 2016). Thus, we compare the direct effect of the carbon price increase on fuel consumption and carbon emissions, as previously investigated in the literature, with the additional effect caused by increased remote working, which to our knowledge has not yet been investigated. Our results show that the additional impact of price-induced increases in remote working on fuel consumption is about one tenth of the direct price effect on fuel consumption and, consequently, carbon emissions.

The study contributes to the literature by showing modest reactions to fuel price changes in terms of remote working frequency as well as fuel consumption and carbon emissions and identifying groups more likely to work from home due to high fuel prices. Although several authors mention fuel prices as an impact factor for remote working behavior (e.g., Patino-Artaza et al. 2024; Peñafiel-Mera and Santos 2024), empirical research on this topic is scarce. Some studies have been published, which find fuel price effects on aspects such as commuting behavior and mode choice (Belloc et al. 2023; Gillingham and Munk-Nielsen 2019; Ha et al. 2020), but to the best of our knowledge we are the first to investigate how monthly local fuel prices affect remote working frequency.

More on a general note, it is one of the first studies to demonstrate that local fuel prices data collected by the German Market Transparency Unit for Fuels can be fruitfully used in microlevel analyses as an explaining variable. Although these data have been available for more than a decade and used frequently for the analysis of competitive behavior (e.g., Haucap et al. 2017; Kihm et al. 2016; Fischer 2023; Neukirch and Wein 2019), its use in combination with micro-level survey data to analyze individual transport behavior is still limited (exceptions being, e.g., Hagedorn, Thomas et al. 2023; Findenegg and Wessel 2024).

The remainder of the paper is structured as follows. Section 2 describes the data and our empirical strategy. Section 3 presents remote working elasticity estimates, results of a simulation of additional remote working days conditional on varying levels of carbon prices, and finally the results of a simulation of the impact of carbon price increases on energy demand and carbon emissions both via the direct elasticity and via remote working. Section 4 concludes.

2. Methods

2.1 Data

Analyses are based on data from the German Family Panel (pairfam), Release 14.0 (Brüderl, Drobnič, et al. 2023) and FReDA Release 5.0.0 (Bujard et al. 2025), a nationwide randomly sampled panel study of initially more than 12,000 individuals covering the birth cohorts 1971-73, 1981-83, 1991-93, and, as of 2018, 2001-2003. We use data covering the period 2021-2024 (pairfam wave 14 and pairfam-FReDA waves 2B and 3B). Details of sample design and data collection are given in the panel documentation (Brüderl, Schmiedeberg, et al. 2023; Hank et al. 2024; Schneider et al. 2021).

The survey data are combined with local fuel prices collected by the Market Transparency Unit for Fuels. This public institution has institutionally provided real-time access to market price data since August 31, 2013. Companies operating public petrol stations or have the power to set their prices are obliged to report price changes for Super E5, Super E10 and Diesel at maximum five minutes after a

change to the Market Transparency Unit for Fuels. Price notations are gross including taxes as paid by the customer. Incoming price data are passed to consumers through consumer information service providers. The data used in this analysis are obtained from one such consumer information service provider (Tankerkönig 2025). To combine survey data with fuel data, the geographic coordinates generated from the addresses of respondents' main residences and all gas stations in Germany are used and each respondent's main residence is matched with the nearest five gas stations active in the interview month.

The analysis identifying survey participants' remote working responsiveness to price signals is restricted to individuals in paid work who have not moved between the panel waves in focus. The latter restriction is made to prevent bias due to systematic variation in relocations, e.g. if employees who wish to avoid commuting move to urban areas with on average higher fuel prices, or vice versa, those having better opportunities to work from home moving to more rural areas with lower housing prices, which may create spurious correlations and statistical artifacts. Employees with changing work locations such as truck drivers and those away on a job for installation / repairs are excluded as they were not asked in the survey if they partly worked from home. Observations with missing data in dependent or independent variables are excluded from the analysis. These are mainly cases with unclear types of occupations.

2.2 Analytic strategy and variables

The dependent variable giving the remote working frequency is constructed from a question that asks about the remote working frequency ("How often do you work from home?") with response categories daily, several times per week, once per week, 1-3 times per month, less often, and never. Based on this question, we calculate the monthly number of days worked from home assuming 20 workdays per month with possible values 0 (no remote working at all), 1, 2, 4, 12, and 20 (exclusively remotely).

For the calculation of fuel prices (in €/l), we calculate the mean fuel price in the month in which the interview took place. The monthly aggregation is motivated by drivers' low refueling frequency and adaption processes of remote working frequency due to menu costs. As diesel vehicles are rather common in Germany, we consider prices for Super E5 and Diesel (i.e., the two most common fuel types, E5 indicating gasoline with an ethanol share of 5%). We sampled the 10th and 20th day of each month and station in Germany and calculate mean values for each station-month price over the respective stations' daily prices. In this way, we generate monthly gas station price time series for each

gas station in Germany over the entire observation period.¹ To exclude outliers, we drop observations with prices lower than 0.5 €/l and greater than 2.5 €/l. These are mostly obvious entry errors such as negative prices or prices of an order higher than in the aforementioned price interval. Further, we dropped observations with missing data on the stations' geolocation and the year of observation. Altogether this amounts to approximately 2.0% missing month-station observations. As we calculate fuel prices by averaging the monthly price of the five nearest gas stations, missing values in the fuel price data is substituted by the nearest gas station for the calculation. As prices are relatively homogeneous within small regions, this will have only moderate effects on the subsequent analysis. Mean prices for both fuel types are combined in a single variable containing the mean price for both fuels.

To identify the causal effect of fuel prices on remote working frequency we apply an IV fixed-effects approach making use of the panel structure of our data and the link of the survey data with local fuel prices. This has several advantages over a naïve cross-sectional analysis relying on the assumption that fuel prices and socio-demographic data are exogenous and spatially independently distributed and are therefore orthogonal to the decision to work remotely. It can be argued that individuals are mostly price-takers in the very short-run (Gillingham 2014). This view is supported by the latest refinery and fuel wholesale trade sector investigation of the German Cartel Office (Bundeskartellamt 2025). Local deviations from general price trends, however, may arise due to local and more regional market structures and fuel transport infrastructure (Kihm et al. 2016; Ghazanfari 2022; Bergantino et al. 2023). Moreover, although we do not find significant differences in fuel prices between federal states and by settlement structure (Appendix, Table A12) systematic patterns may exist at the micro level. For instance, fuel prices may be higher in more prosperous cities or regions with high average income where at the same time remote working may be more frequent due to the higher share of white-collar jobs. Competition in densely populated areas with more competitors may as well drive prices down. While confounders such as education and type of occupation can be accounted for, further unobserved variables may bias estimations. Fixed-effects (FE) panel models with two or more observations per individual are less prone to such bias as they rely on the – plausible – assumption that local fuel price changes and changes in respondent characteristics over our observation period are spatially independently distributed. Moreover, FE models, which estimate within-person effects, are robust against potential time-constant confounding factors such as education. To prevent bias due to potentially time-varying confounders the models include type of occupation (blue collar vs. intermediate and white collar occupations), type of employment (full-time, part-time, and self-

¹ We have roughly 60,000-350,000 daily price observations. Price changes increased towards the end of the observation period due to erratic price setting (obfuscation to reduce price signal quality) and strategic interaction motives (implicitly coordinated pricing) – which are both legal activities.

employment) and family situation (including dummies for having a partner, cohabiting with a partner, and living with children in the household).

To address potential bias due to price endogeneity caused by the simultaneity in the supply and demand relationship of remote working, we apply an IV approach. Exclusively including fixed effects might otherwise lead to bias in the case of latent supply and demand shifters (e.g., Berry and Haile 2021), at least if no variables accounting for unobserved demand and supply shocks are included in the regression. Moreover, the elasticity of the supply function may induce bias unless unobserved demand shocks are relatively small and the supply curve is fairly horizontal, i.e. with near constant marginal costs (Levin et al. 2017). For the IV estimation we use world market oil prices as an instrument for local retail fuel prices (Brent crude oil price, traded at Rotterdam). By this, we are able to address the supply function shifts explicitly, while fixed effects thus control for (supposedly small) unobserved demand shifts. The choice of instrument is line with the literature (Hughes et al. 2008; Li et al. 2014; Marion and Muehlegger 2011; Borenstein et al. 1997; Hughes et al. 2008; Kilian and Zhou 2024). We adopt the identification strategy presented by Kilian and Zhou (2024) who use global fuel price shifts interacted with state-level input price pass-through as an instrument. With this specification, only exogenous variation is used to identify supply side shifts, while FE variables and the trend in the second stage IV equation will control solely for latent (remote working) demand shocks. With regard to external validity, this IV approach also contributes to the transferability of the results to other situations, as only exogenous shares of variation in retail fuel prices are used to estimate the remote working response. This minimises possible situational distortions, for example from omitted variable bias.

Weak instrument test results indicate the relevance of the Brent crude oil price as instrument (see Tables A2, A4, A6, A8, A10). The exclusion restrictions holds because the Brent price does affects remote working decisions only via the local fuel prices in the short term. Fuel prices are expected to be relevant only for employees who commute longer distances by car. We therefore expect a larger fuel price effect in regions outside urban agglomerations with longer commuting distances and less dense public transport networks as in these regions the proportion of car commuters is larger, and employees cannot easily substitute car commuting in times of high fuel prices. Accordingly, fuel price effects in such rural regions can be regarded as the upper bound of the fuel price elasticity on remote working. We implement an interaction model distinguishing urban agglomerations with more than 500,000 inhabitants from less urbanized regions, based on the bik classification (Arbeitsgruppe Regionale Standards 2019).

Second, we estimate an interaction model which yields differential effects according to type of occupation, differentiating between high-skilled and intermediate/low-skilled occupations, following the definition by the International Labour Office (2012) based on the International Standard

Classification of Occupations, ISCO-08. We assume that remote working is less likely in blue-collar occupations whereas it is expected to be particularly common in self-employment and white-collar occupations. These expectations are derived from research showing that more tasks are suited for remote working and control is less strict with higher skill level of occupation (Sarbu 2015; Kelly et al. 2022). In Germany, the remote working capacity varies between 21 and 91 percent across ISCO-08 1-digit groups (Alipour et al. 2023).

In addition, we run several robustness checks, presented in the Appendix (Tables A3-A8). First, we consider SuperE5 and Diesel fuel separately, and second, we calculate the mean price over the 10 instead of 5 nearest gas stations to account for outliers in the data. Results do not change substantially in any of these alternative specifications. Further, we apply the model to the period before the COVID-19 pandemic to test whether the same fuel price effects can be found for this period (Appendix, Tables A9/A10). As expected, all pre-pandemic models unambiguously yield null results, which may be interpreted as a test for the parallel trends assumption. All subsamples, also conditional on heterogeneous price changes over time, show the same remote working price responsiveness. Only after the COVID-19 pandemic, which made working from home possible, and mobility restrictions were eased significant remote working price elasticity are observed.

As an additional causality robustness check, we draw on a diff-in-diff IV panel identification strategy to obtain estimated for the remote working price elasticity. For this, we define quartile bins of price change intensity, which contain respondents subject to increasing treatment (i.e., price change intensity). We then estimate remote working price elasticity differences between the lowest and the highest price change quartile bins in order to obtain price reactions conditional on treatment intensity. This is done both in the full sample and a reduced sample dropping extreme cases of initially never and always remotely working respondents (Appendix, Table A11).

2.3 Simulation of the impact of carbon price increases on energy demand

We use these empirical results to estimate the role of remote working on effects of carbon price-induced fuel price increases on energy demand in transportation. For this, we draw on price elasticities reported in the literature and calculate the total price elasticity including, first, the direct effect on total fuel consumption keeping working schemes constant and, second, the indirect effect of increasing remote working to reduce fuel consumption.

The total price elasticity $\varepsilon_{tot} = F(\varepsilon_{dir}, \varepsilon_{ind})$ is given as a function of the direct and the indirect elasticity with

$$\varepsilon_{dir} = \frac{\partial Q_{fuel}}{\partial P_{fuel}} \frac{P_{fuel}}{Q_{fuel}}$$

and

$$\varepsilon_{ind} = \frac{\partial Q_{remote\ work}}{\partial P_{fuel}} \frac{P_{fuel}}{Q_{remote\ work}} * \frac{\partial Q_{fuel}}{\partial Q_{remote\ work}} \frac{Q_{remote\ work}}{Q_{fuel}}.$$

ε_{dir} is the elasticity of fuel consumption in reaction to fuel price increases, including both reduced fuel consumption and higher efficiency. Recent estimates from a German sample reveal an elasticity of -.309 (Alberini et al. 2022), which is within the typical range of elasticities found (see literature review in the Appendix). In a robustness check a higher fuel price - quantity elasticity of -.529 (Khanna et al. 2025) is used (Appendix Table A15).

ε_{ind} is the product of the price elasticity of remote working ($\varepsilon_{remote,PR} = \frac{\partial Q_{remote\ work}}{\partial P_{fuel}} \frac{P_{fuel}}{Q_{remote\ work}}$) and the elasticity of fuel consumption conditional on additional remote working ($\varepsilon_{remote,RF} = \frac{\partial Q_{fuel}}{\partial Q_{remote\ work}} \frac{Q_{remote\ work}}{Q_{fuel}}$). For the latter, we use estimates reported in the literature (Macias et al. 2025; Faber et al. 2024; Hook et al. 2020). As mobility patterns related to remote working may have changed with the spread of remote working in the pandemic we present two scenarios based on the mean value of the results reported in the review of (Hook et al. 2020), which is -.128, and a higher value (-.200) drawn from the more recent literature (Macias et al. 2025; Faber et al. 2024). Note that in an extreme scenario with an elasticity of zero, implying that employees would reinvest all the saved commuting time in non-work mobility (Hook et al. 2020), no additional fuel savings would result from remote working.

For the price elasticity of remote working we use our estimates from the first step of our analysis in section 3.1 and calculate the elasticity at a carbon price of 177 €/tCO₂, as in the intermediate scenario in section 3.2. With a 8.9% fuel price increase (based on the 10-year mean fuel price (Statistisches Bundesamt 2024)) in this scenario and a price-induced 24.2% increase in remote working we get an elasticity of .369. For robustness checks we use the highest carbon price scenario with 300 €/tCO₂ and the extreme values within the 95%-CI of the coefficient, .491 and 2.166, with the respective elasticities of .136 and .601 (Appendix Tables A14 and A15).

Fuel savings arise due to direct and indirect effects:

$$\Delta Q_{fuel,total} = \Delta Q_{fuel,dir} + \Delta Q_{fuel,ind} * (1 - \Delta Q_{fuel,dir})$$

Note that the direct effect enters the equation twice as it reduces the indirect effect: The additional reduction of mileage and emissions via increased remote working (indirect effect) diminishes as fuel economy increases (direct effect). The naïve indirect effect is thus reduced by the factor $(1 - \Delta Q_{fuel,dir})$.

Accordingly, we may integrate the indirect effect to define a corrected total price elasticity of fuel consumption. The total elasticity thus results as the direct elasticity augmented by the factor of the ratio of the total effect quantity change to the direct effect quantity change.

$$\varepsilon_{total} = \frac{\Delta Q_{fuel,total}}{\Delta Q_{fuel,dir}} \varepsilon_{dir}$$

3. Results

3.1 Effects of prices on remote working

Table 1 presents some descriptive statistics of the analysis sample (for a description of the pairfam sample, see (Brüderl, Schmiedeberg, et al. 2023)).

Table 1: Summary statistics

	T1 (2021/10 – 2022/03)		T2 (2022/10 – 2023/01)		T3 (2023/10 – 2024/01)	
Fuel price (€/l)	1.65	(0.05)	2.02	(0.08)	1.83	(0.04)
% working remotely	57.1		64.9		64.1	
Remote working frequency (days/month)	5.39	(7.12)	5.99	(7.11)	5.92	(7.05)
Type of employment						
Full-time	68.1		66.2		65.8	
Part-time	24.4		28.4		28.7	
Self-employment	7.5		5.4		5.5	
Type of occupation						
Blue-collar	12.5		12.4		12.0	
Intermediate	20.7		20.2		20.1	
White-collar	66.8		67.4		68.0	
Level of education						
Low	2.4		2.2		2.2	
Intermediate	41.8		41.7		41.3	
High	55.8		56.1		56.4	
Birth cohort						
1971-73	34.6		34.6		34.6	
1981-83	41.4		41.4		41.4	
1991-93	23.1		23.1		23.1	
2001-03	0.9		0.9		0.9	
Women	51.5		51.5		51.5	
Settlement structure						
Urban agglomerations	36.8		36.8		36.8	
Regions outside agglomerations	63.2		63.2		63.2	
<i>N_{respondents}</i>	1,232		1,232		1,232	
<i>N_{observations}</i>	3,696		3,696		3,696	

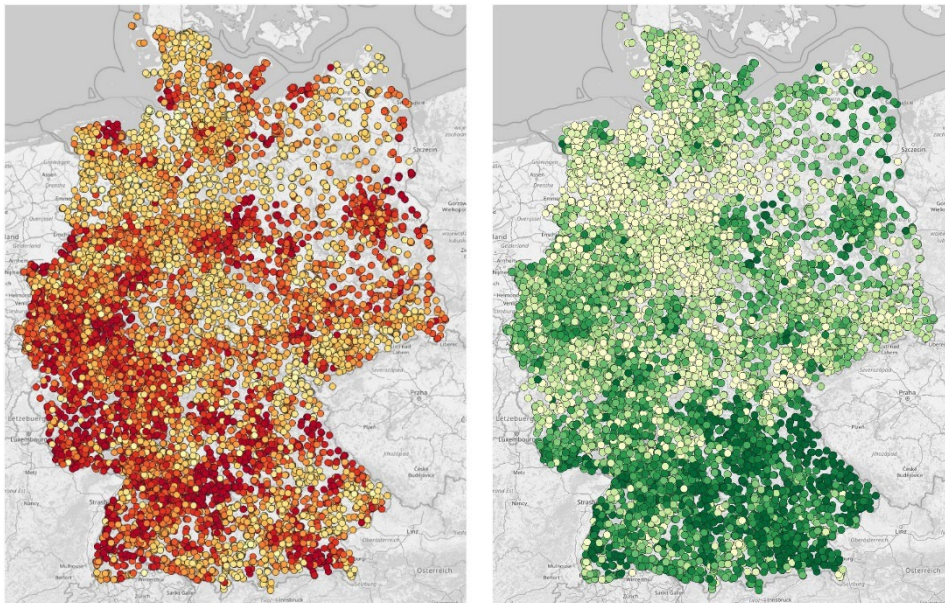
Notes: Means and standard deviations for metric variables, percentages for binary variables.

Although socio-demographic control variables are not required in the fixed-effects panel model, we summarize them for information about the sample. Fuel prices have increased in the sample considerably from 1.65 €/l to 2.02 €/l between the first and the second time point and then diminished

again in the last year. In contrast, remote working behavior has changed only moderately with an increase of 11 % between the first and second time point, and virtually no change between the second and the third time point. As expected, employment variables are largely stable with only minimal variation in employment, occupation, and level of education. The demographic variables and settlement structure are identical over the two time points by design.

Figure 1 illustrates the regional distribution of fuel prices development between the panel waves in focus (11/2021 vs 11/2022, and 11/2022 vs 11/2023, respectively). Despite some regional patterns in price changes variation within the regions is considerable. A regression of fuel price changes on federal states and settlement type did not reveal a significant association (see Appendix, Table A12). We can thus assume that the fuel price effect is not confounded with regional characteristics.

Figure 1: Changes in fuel prices (mean of Super E5 and Diesel) between 11/2021 and 11/2022, and between 11/2022 and 11/2023, respectively



Notes: price changes are categorized by 10% percentiles (darker color indicate larger price changes). For data confidentiality reasons, the map includes locations of gas stations rather than respondents.

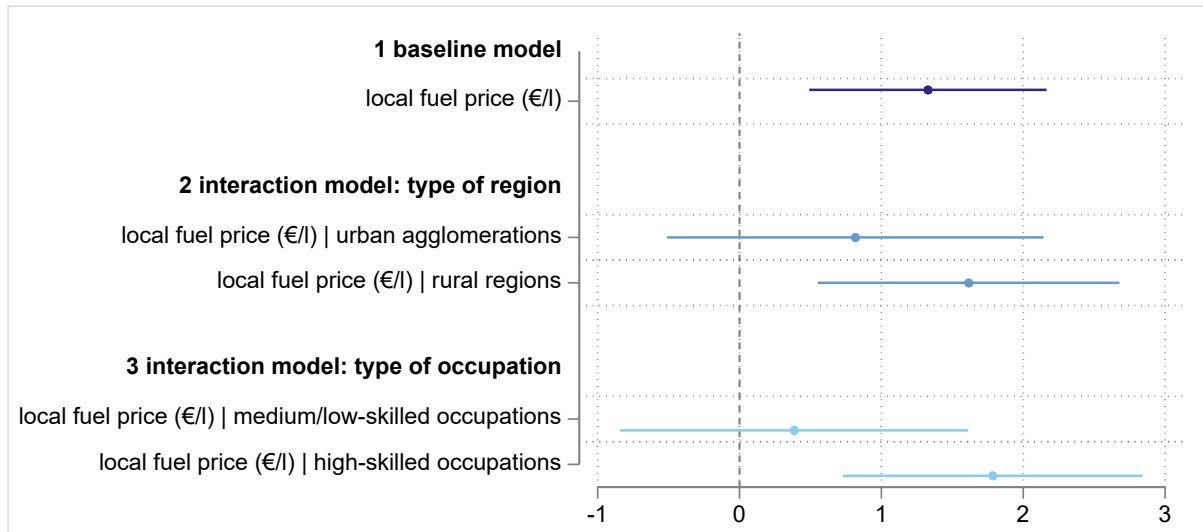
The estimation results (Figure 2) show that employees' remote work frequency increases with rising fuel prices. A unit increase in local fuel prices, i.e. 1 €/l, is associated with 1.298 additional remote working days per month. Note that this coefficient averages effects of the entire sample, including employees who do not respond to fuel prices at all because they, for instance, work entirely from home, do not have the option to work from home, or do not commute by car.

When differentiating between urban agglomerations and more rural regions, we find that the fuel price effect is limited to employees living outside urban agglomerations. Among employees living outside agglomerations a unit increase in fuel prices is associated with 1.577 additional remote

working days, whereas no significant fuel price effect is found in urban agglomerations. This is in line with our hypothesis that car commuting, and hence fuel prices, play a more dominant role in rural areas with poor public transport and larger commuting distances. The estimate for regions outside urban agglomerations can be regarded as an estimate of the fuel price elasticity of remote working, as in these regions with long commuting distances fuel price increases will lead to relevant increases in commuting costs and limited availability of transport alternatives makes remote working an attractive substitute to commuting. This allows us to make a meaningful estimate of elasticity. Still, some employees will commute by bike or public transport also in these regions, which may cause an attenuation bias, i.e. a downward bias of our regression result. To estimate an upper bound for the attenuation bias we draw on descriptive statistics of the distribution of transport modes for commuting in these regions, based on data from the German Mobility Panel (KIT 2023), assuming no price response among employees using non-car transportation for commuting. A maximum attenuation bias of 13.3% arises in terms of the number of trips to work (given by the share of active travel and public transport trips on all commuting trips), and 7.3% in terms of travel distance (see Appendix, Table A13).

When differentiating between occupations with low and high skill-level, we find a higher fuel price effect among high-skilled employees than among employees with lower skill-levels. Employees in high-skilled occupations increase their remote working frequency by 1.746 days per month at a unit increase in local fuel prices whereas no significant increase is found among intermediate/low-skilled employees. The interaction effect is only marginally significant, which may be due to the rough classification of occupations according to skill-level rather than remote working potential of occupations. For instance, intermediate/low-skilled occupations include also telemarketers who may easily work from home whereas some high-skill occupations such as elementary school teachers typically require direct face-to-face contact with their pupils and therefore have less remote working potential.

Figure 2: Effects on remote working frequency (FE IV Coefficients & 95% CI)

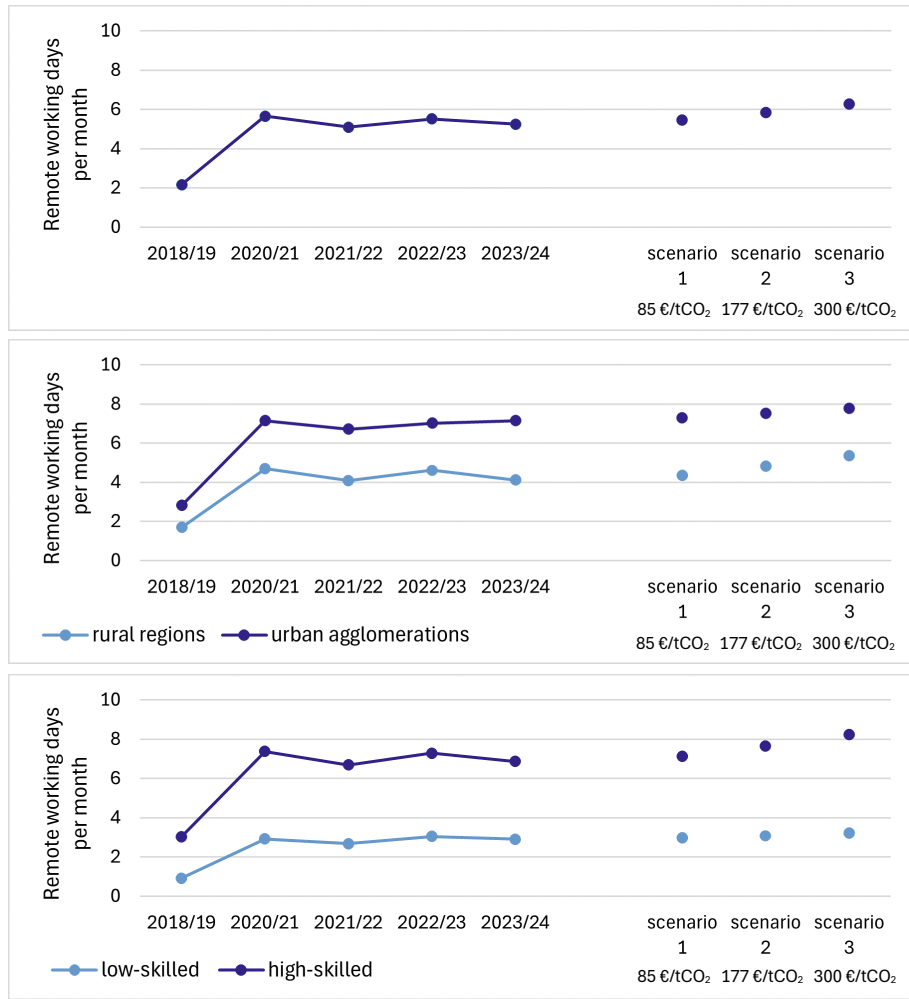


Notes: The figure shows coefficients and 95% confidence intervals from fixed-effects IV models. Effect sizes can be interpreted as shifts in days worked from home per month. Remote working frequency increases with rising fuel prices (Model 1: $\beta=1.329$, $R^2=.011$; Model 2: $\beta_{low-skilled}=0.386$, $\beta_{high-skilled}=1.785$, $R^2=.011$; Model 3: $\beta_{agglomerations}=0.816$, $\beta_{rural}=1.615$, $R^2=.011$). $N_{observations}=3696$; $N_{respondents}=1232$. All models include type of employment (full-time, part-time, self-employment), and family situation (partnership, cohabitation, children in the household). For full results, see Tables A1/A2 in the Appendix.

3.2 Effects of future carbon price increases on remote working

While these effects are significant, they are moderate in size. This is illustrated by the predictions presented in Figure 3. For this, we assume fuel prices that would result from increasing carbon prices as they are forecasted for near-term “fit-for-55” climate policy scenarios considering the latest EU climate policy changes (Pietzcker et al. 2021; Kalkuhl et al. 2023; Rickels et al. 2023), in particular the introduction of carbon price for transportation and heating sectors (“EU Emission Trading Scheme II”). Depending on assumptions on concrete policy design and technological development transport sector carbon prices in Germany in 2030 may range from 100 to 405 €/tCO₂ (Pietzcker et al. 2021; Pahle et al. 2025). We therefore define three carbon price scenarios: scenario 1 draws on current 2030 EEX future prices of 85 €/tCO₂ (average EEX EUA Futures price from Dec 15, 2024, to Jan 15, 2025 and the highest notation until 31st of October 2025); scenario 2 uses on the average global socially optimal carbon price according to a current meta study of 177 €/tCO₂ (Tol 2023), and represents current estimates of likely future transport sector carbon prices (Pahle et al. 2025); scenario 3 assumes a carbon price of 300 €/tCO₂ which would result from more ambitious transport sector-specific targets as discussed in the mentioned literature.

Figure 3: Remote working frequency - prediction of scenarios



Notes: Means of remote working days per month in the full sample and in subsamples and predicted means with fuel prices based on 2023/24 prices and carbon prices as assumed in the three scenarios.

The latter scenario follows the sector-specific targets set out in the current EU climate policy. Even the highest assumed carbon prices (scenario 3) would result in just one additional remote working day per month on average, i.e. from currently 5.2 to 6.3 days per month (Figure 3a). Compared to the steep shift in remote working during the COVID-19 pandemic, included in Figure 3 for comparison reasons, this rise is rather small. Scenarios 1 and 2 with lower assumed carbon prices do not result in substantial increases in remote working frequency.

Differences between subgroups are displayed in Figures 3b and 3c. For regions outside urban agglomerations, the maximum assumed increase in carbon prices (scenario 3) would result in 1.2 additional remote working days whereas in urban regions with excellent public transport carbon prices would not have any impact on remote working (Figure 3b). Similarly, among employees in high-skilled occupations high carbon prices as in scenario 3 we get 1.4 additional remote working days whereas in lower-skilled occupations the increase is only 0.3 days (Figure 3c). Taken together, however, even in

subgroups most affected by higher fuel prices, carbon pricing would increase remote working frequency only moderately as we do not find groups with increases of more than 1.4 additional monthly remote working days.

3.3 Direct and indirect effects of carbon price increases on fuel consumption and carbon emissions

The modest dimension of this effect becomes clear when we set it in context with direct price effects on fuel consumption, using the intermediate of the aforementioned carbon pricing scenarios, which is within the most realistic range according to the literature (Pahle et al. 2025).

Aggregate Effects

Table 2 shows the reduction in emissions via the direct and indirect effects in order to illustrate the potential of additional fuel savings conditional on employees' responsiveness to fuel prices in remote working decisions. For illustration, we present also national-level figures on fuel consumption and emission savings, taking into account that the indirect effect applies only to the 50.18% share of employed car commuters in Germany (Statistisches Bundesamt 2025). The baseline national-level fuel consumption and carbon emission statistics, are drawn from official statistics (Statistisches Bundesamt 2024; Umweltbundesamt 2025).

In the base scenario, an individual total fuel quantity reduction of 8.53% arises, of which 12.41%, or 1.06 percentage points, are caused by remote working. Hence, the indirect effect via remote working is an order of magnitude smaller than the overall effect. Accordingly, the total elasticity is $-.353$ and thus substantially more elastic as compared to the direct elasticity of $-.309$. In the higher remote work – fuel quantity elasticity scenario ($\varepsilon_{remote,RF} = -.200$), which corresponds to more recent estimates from the literature from the post-COVID period, remote working contributes more to the fuel consumption reduction (22.08% of the total reduction). If this is combined with the high scenario for the fuel price – remote work quantity elasticity ($\varepsilon_{PR,remote} = -.601$), the total fuel consumption decreases by 10.16%, of which 35.99% are caused by remote working. The total elasticity decreases to $-.420$, i.e. fuel consumption becomes considerably more elastic.

The bottom part of Table 2 shows macroeconomic effects, including reductions in household carbon emissions due to reduced fuel consumption and total nationwide carbon emissions. As the indirect effects concern only employees commuting by car, the percentage of the total reduction is somewhat lower at the macro than the individual level. Overall, however, the effect of introducing a carbon price of 177 €/tCO₂ on remote working and mobility is substantial and may reduce national carbon emissions by 1.24% in the base scenario, with the isolated direct effect being 1.15%. While this is a relevant order of magnitude for achieving the German government's medium-term 2030 climate targets, the indirect

effect via remote working only adds .08 percentage points or 6.64% of the total savings due to altered mobility behavior. With regard to the extreme scenario of high fuel price-remote work quantity elasticity (-.601) and remote work-fuel quantity elasticity (-.200), the reductions in household fuel consumption and corresponding carbon emissions amount to 8.82% and national carbon emissions decrease by 1.36%. Of this, 15.30% are attributable to remote working.

Table 2: Direct and indirect effects of a 177 €/tCO₂ price on fuel consumption and carbon emissions

Direct fuel price-quantity elasticity (ε_{dir})		-0.309	
Direct quantity reduction ($\Delta Q_{fuel,dir}$)		7.47%	
Fuel price - remote working elasticity ($\varepsilon_{PF,remote}$)	-0.136	-0.369 (base case)	-0.601
Individual effects			
Indirect quantity reduction via remote working ($\Delta Q_{fuel,ind}$)			
$\varepsilon_{remote,RF}$ high (-.200)	.61%	1.65%	2.69%
$\varepsilon_{remote,RF}$ base (-.128)	.39%	1.06%	1.72%
Total fuel quantity reduction ($\Delta Q_{fuel,total}$)			
$\varepsilon_{remote,RF}$ high (-.200)	8.08%	9.12%	10.16%
$\varepsilon_{remote,RF}$ base (-.128)	7.86%	8.53%	9.19%
Percentage of indirect effect on total effect			
$\varepsilon_{remote,RF}$ high (-.200)	8.17%	22.08%	35.99%
$\varepsilon_{remote,RF}$ base (-.128)	5.24%	14.17%	23.09%
Total fuel price - quantity elasticity (ε_{total})			
$\varepsilon_{remote,RF}$ high (-.200)	-0.334	-0.377	-0.420
$\varepsilon_{remote,RF}$ base (-.128)	-0.325	-0.353	-0.380
National-level effects			
Household carbon emission reduction			
$\varepsilon_{remote,RF}$ high (-.200)	7.78%	8.30%	8.82%
$\varepsilon_{remote,RF}$ base (-.128)	7.67%	8.00%	8.33%
Total carbon emission reduction			
$\varepsilon_{remote,RF}$ high (-.200)	1.20%	1.28%	1.36%
$\varepsilon_{remote,RF}$ base (-.128)	1.18%	1.24%	1.29%

Notes: National-level figures for 2024: household fuel consumption at 363,368 GWh, household carbon emissions at 100.2 MtCO₂, total national carbon emissions at 649.0 MtCO₂. German national household carbon emissions and reductions in carbon emissions are calculated from energy consumption data assuming a fuel carbon intensity of 2.51 kgCO₂/liter.

In both robustness check scenarios with a carbon price of 300 €/tCO₂ and with a greater fuel price-quantity elasticity of -.529, the direct effect exceeds the indirect effect via the remote working channel even more. This leads to a lower on-top effect via remote working (slightly more than half as high as

in the base case), but the national-level effects on fuel consumption and carbon emissions are significantly greater and (almost) double (see Tables A14 and A15).

Type of Occupation and Type of Region Effects

The distributional effects of a carbon tax of 177 €/tCO₂ follow analogously and are shown in Table 3. The first column contains the aggregate base effect without differentiating according to type of occupation and type of region. It should be noted that we contrast either occupational or regional effects, but not both dimensions simultaneously. We derive carbon emissions per subgroup from total German carbon emissions using the German mobility panel (MOP) via the ratios of subgroups' shares in population accounting for the subgroups' kilometers driven. In order to calculate reactions to the carbon price increase we apply direct and indirect elasticities to the subgroups' total carbon emissions correcting the indirect elasticity for the share of commuters in Germany (.5018).

The results show that white collar workers and those in rural areas have higher total fuel price-quantity elasticities and thereby reduce their total fuel consumption more than in the base case. Blue collar workers and urban dwellers reduce their fuel consumption to a lower degree. The indirect effect via remote working is particularly low among blue collar workers and similarly low for inhabitants of urban areas whereas white collar workers and inhabitants of rural areas have a modestly higher inclination to use remote working in reaction to potential carbon price increases vis-à-vis the undifferentiated benchmark case.

In a last step we calculate tax revenues in the scenarios, presented in the bottom panel of Table 3. With a 5.9-fold increase in the carbon price from €30/tCO₂ to €177/tCO₂, tax revenues rise significantly by a factor of 5.4, which is slightly less than proportional due to the consumption reduction caused by the carbon price increase. The distribution of tax revenues among the various subgroups is heterogeneous already in the current (initial) situation. Due to their higher CO₂ emissions the aggregate tax burden is higher among white collar workers and urban dwellers than among blue collar workers and the rural population. In the €177/tCO₂ carbon price scenario, emission reductions are higher and, accordingly, relative tax revenue increases for white collar workers and rural residents are relatively lower than for blue-collar workers and the urban population. The greater effect by far, however, stems from the initial carbon consumption shares and corresponding tax revenue levels. The bottom of Table 3 reveals that a carbon price increase to 177 €/tCO₂ leaves the ratios of tax revenue across subgroups more or less unchanged.

Table 3: Direct and indirect effects of a 177 €/tCO₂ price on fuel consumption and carbon emissions (incl. type of occupation and type of region effects)

Direct fuel price-quantity elasticity (ε_{dir})					-0.309
Direct quantity reduction ($\Delta Q_{fuel,dir}$)					7.47%
	Total (base case)	Blue collar	White collar	Rural area	Urban area
Fuel price - remote working elasticity ($\varepsilon_{PF,remote}$)	-0.369	-0.107	-0.495	-0.448	-0.227
Individual effects					
Indirect quantity reduction via remote working ($\Delta Q_{fuel,ind}$)					
$\varepsilon_{remote,RF}$ high (-.200)	1.65%	0.48%	2.22%	2.01%	1.01%
$\varepsilon_{remote,RF}$ base (-.128)	1.06%	0.31%	1.42%	1.29%	0.65%
Total fuel quantity reduction ($\Delta Q_{fuel,total}$)					
$\varepsilon_{remote,RF}$ high (-.200)	9.12%	7.95%	9.69%	9.47%	8.48%
$\varepsilon_{remote,RF}$ base (-.128)	8.53%	7.78%	8.89%	8.76%	8.12%
Percentage of indirect effect on total effect					
$\varepsilon_{remote,RF}$ high (-.200)	22.08%	6.41%	29.66%	26.85%	13.57%
$\varepsilon_{remote,RF}$ base (-.128)	14.17%	4.11%	19.03%	17.22%	8.71%
Total fuel price - quantity elasticity (ε_{total})					
$\varepsilon_{remote,RF}$ high (-.200)	-0.377	-0.329	-0.401	-0.392	-0.351
$\varepsilon_{remote,RF}$ base (-.128)	-0.353	-0.322	-0.368	-0.362	-0.336
National-level effects: intergroup differences					
Household carbon emissions: absolute (MtCO ₂)	100.23	33.87	66.35	34.53	65.70
Household subsample shares: blue vs. white and rural vs. urban	100.0%	41.8%	58.2%	32.4%	67.7%
Household carbon emission reduction: absolute (MtCO ₂)					
$\varepsilon_{remote,RF}$ high (-.200)	8.32	2.61	5.69	2.93	5.24
$\varepsilon_{remote,RF}$ base (-.128)	8.02	2.58	5.43	2.80	5.12
Household carbon emission reduction: relative					
$\varepsilon_{remote,RF}$ high (-.200)	8.30%	7.71%	8.58%	8.48%	7.98%
$\varepsilon_{remote,RF}$ base (-.128)	8.00%	7.62%	8.18%	8.11%	7.80%
Household carbon emissions tax redistribution effects					
absolute CO2 tax revenue at 30€/tCO2 (bln €)	3.01	1.02	1.99	1.04	1.97
relative CO2 tax revenue at 30€/tCO2 (bln €)	-	33.8%	66.2%	34.5%	65.5%
$\varepsilon_{remote,RF}$ high (-.200): absolute tax revenue at 177€/tCO2 (bln €)	16.27	5.53	10.74	5.59	10.70
$\varepsilon_{remote,RF}$ high (-.200): relative tax revenue at 177€/tCO2	-	34.0%	66.0%	34.3%	65.7%
$\varepsilon_{remote,RF}$ base (-.128): absolute tax revenue at 177€/tCO2 (bln €)	16.32	5.54	10.78	5.62	10.72
$\varepsilon_{remote,RF}$ base (-.128): relative tax revenue at 177€/tCO2	-	33.9%	66.1%	34.4%	65.6%

Notes: National-level figures for 2024: household fuel consumption at 363,368 GWh, total national carbon emissions at 649.0 MtCO₂. German national household carbon emissions and reductions in carbon emissions are calculated from energy consumption data assuming a fuel carbon intensity of 2.51 kgCO₂/liter.

4. Discussion

In this contribution we investigated employees' remote working frequencies in reaction to fuel price changes. Using data from a German panel study linked to monthly prices of local gas stations near to the survey respondents' main residences, we show that remote working frequency increases with rising fuel prices but only to a moderate degree. Reasons for this may be habitation effects and the complexity of the remote working decision, but also constraints given by the nature of people's occupations or set by their employers.

These results add to the large body of literature that find only moderate price elasticities in fuel demand (Knittel and Tanaka 2021; Wang and Chen 2014; Brons et al. 2008; Goetzke and Vance 2021; Levin et al. 2017; Coglianese et al. 2017). Moreover, it is in line with the modest price effects found in other domains of energy consumption such as electricity demand (Borenstein 2012), natural gas consumption (Davis and Kilian 2011; Xiang and Lawley 2019), and the choice of heating systems (Sahari 2019; Decker and Menrad 2015).

These results have direct policy implications, demonstrating the limited short-term impact of price incentives to opt out of mobility. This insufficient demand response to prices may be the reason why environmental policy has largely relied on bans and technological standards to limit consumer choice to environmentally friendly products (European Parliament 2023; U.S. Department of Transportation 2023).

Applied to carbon prices to reduce carbon emissions and mitigate climate change, we show that even the highest price assumed will lead to only one additional remote working day per month. Together with the mixed findings in the literature regarding emission savings due to remote working (Tao et al. 2023; Simon and O'Brien 2023; Santos and Azhari 2022; Hook et al. 2020; O'Brien and Yazdani Aliabadi 2020; Marz and Şen 2022), we conclude that carbon prices only have a modest impact on fuel and carbon emission savings via remote working.

Moreover, we should keep in mind that remote working capacities are higher in high-skilled than in low-skilled occupations. Thus, workers in low-skilled occupations, who are less able to work from home, will be less able to evade the higher fuel prices. As at the same time wages in these occupations are markedly lower than in high-skilled occupations, climate policies based on fuel prices may not only be of limited effectiveness but at the same time increase inequality by burdening in particular lower-income groups. However, we show that the distribution of tax burden remains largely unchanged by carbon price increases, with the lion's share of additional tax revenue remaining with white collar workers and urban inhabitants.

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Do local fuel prices affect remote working behaviors and carbon emission savings? Evidence from German panel data

Appendix

Table A1: FE IV regression of remote working frequency on local fuel prices – reduced form (second stage)

	(1)		(2)		(3)	
	b	s. e.	b	s. e.	b	s. e.
Local fuel price (€/l)	1.329***	(0.427)				
Local fuel price (€/l) × urban			0.816	(0.677)		
Local fuel price (€/l) × rural			1.615***	(0.542)		
Local fuel price (€/l) × med/low-skilled					0.386	(0.626)
Local fuel price (€/l) × high-skilled					1.785***	(0.539)
Type of employment						
Part-time	0.325	(0.441)	0.313	(0.443)	0.316	(0.441)
Self-employed	1.850	(1.146)	1.822	(1.152)	1.906*	(1.144)
Medium/low-skilled occupations	-0.271	(1.029)	-0.256	(1.035)	2.237	(1.795)
Having a partnership	-0.293	(0.530)	-0.292	(0.530)	-0.290	(0.530)
Cohabiting with a partner	0.118	(0.633)	0.123	(0.633)	0.104	(0.633)
Children in the household	0.019	(0.625)	0.006	(0.624)	0.022	(0.624)
Time trend	0.013*	(0.007)	0.013*	(0.007)	0.014*	(0.007)
<i>N</i> _{observations}	3,696		3,696		3,696	
<i>N</i> _{respondents}	1,232		1,232		1,232	
<i>R</i> ²	.010		.011		.011	

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

The table displays the full results of the models presented in the coefficient plot in Figure 2.

Table A2: FE IV regression of remote working frequency on local fuel prices – first stage

	(1)		(2)				(3)			
	b	s. e.	Urban b	s. e.	Rural b	s. e.	M/low-skilled b	s. e.	High-skilled b	s. e.
Brent price (€/l)	3.610***	(0.043)								
Brent price * gas station distance	0.047	(0.029)								
Brent price (€/l) × urban			3.502***	(0.070)	0.098***	(0.013)				
Brent price (€/l) × rural			0.026**	(0.011)	3.580***	(0.049)				
Brent price * gas station distance × urban			0.073	(0.088)	-0.001	(0.009)				
Brent price * gas station distance × rural			0.001	(0.001)	0.046	(0.032)				
Brent price (€/l) × medium/low-skilled							3.545***	(0.046)	0.075***	(0.024)
Brent price (€/l) × high-skilled							0.031	(0.020)	3.575***	(0.040)
Brent price * gas station distance × m/l-skilled							0.033	(0.026)	0.010	(0.017)
Brent price * gas station distance × high-skilled							0.011	(0.019)	0.037*	(0.022)
Type of employment										
Part-time	0.017**	(0.008)	0.009*	(0.005)	0.008	(0.006)	0.004	(0.004)	0.012*	(0.007)
Self-employed	0.017	(0.013)	0.003	(0.009)	0.014*	(0.009)	0.015*	(0.008)	0.003	(0.011)
Medium/low-skilled occupations	0.017*	(0.010)	0.009*	(0.005)	0.008	(0.009)	0.071***	(0.020)	-0.058***	(0.015)
Having a partnership	0.005	(0.008)	0.009**	(0.004)	-0.004	(0.006)	0.001	(0.004)	0.004	(0.007)
Cohabiting with a partner	-0.021**	(0.009)	-0.005	(0.003)	-0.016*	(0.009)	-0.010*	(0.005)	-0.011	(0.008)
Children in the household	0.003	(0.008)	-0.001	(0.004)	0.004	(0.007)	0.005	(0.005)	-0.002	(0.006)
Time trend	-0.001***	(0.000)	-0.000***	(0.000)	-0.001***	(0.000)	-0.000***	(0.000)	-0.001***	(0.000)
<i>N</i> _{observations}	3,696		3,696				3,696			
<i>N</i> _{respondents}	1,232		1,232				1,232			
Cragg-Donald Wald F-statistic	10,096.05		5,040.69				5,026.81			
Stock & Yogo weak ID Test (critical value 10%)	19.93		16.87				16.87			
Hansen J statistic (& p-value)	0.103	(0.748)	1.675	(0.433)			1.475	(0.478)		

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A3: FE IV regression of remote working frequency on local Super E5 prices – reduced form (second stage)

	(1)		(2)		(3)	
	b	s. e.	b	s. e.	b	s. e.
Local Super E5 price (€/l)	2.204***	(0.708)				
Local Super E5 price (€/l) × urban			1.383	(1.107)		
Local Super E5 price (€/l) × rural			2.655***	(0.888)		
Local Super E5 price (€/l) × m/low-skilled					0.690	(1.017)
Local Super E5 price (€/l) × high-skilled					2.940***	(0.887)
Type of employment						
Part-time	0.330	(0.441)	0.316	(0.443)	0.323	(0.441)
Self-employed	1.850	(1.146)	1.819	(1.152)	1.906*	(1.144)
Medium/low-skilled occupations	-0.261	(1.028)	-0.250	(1.034)	3.838	(2.601)
Having a partnership	-0.286	(0.530)	-0.289	(0.530)	-0.288	(0.530)
Cohabiting with a partner	0.109	(0.635)	0.116	(0.635)	0.096	(0.634)
Children in the household	0.017	(0.625)	0.005	(0.624)	0.016	(0.625)
Time trend	0.012*	(0.007)	0.012*	(0.007)	0.012*	(0.007)
<i>N</i> _{observations}	3,696		3,696		3,696	
<i>N</i> _{respondents}	1,232		1,232		1,232	
<i>R</i> ²	.010		.011		.011	

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A4: FE IV regression of remote working frequency on local Super E5 prices – first stage

	(1)		(2)				(3)			
	b	s. e.	Urban b	s. e.	Rural b	s. e.	M/low-skilled b	s. e.	High-skilled b	s. e.
Brent price (€/l)	2.142***	(0.023)								
Brent price * gas station distance	0.058***	(0.016)								
Brent price (€/l) × urban			2.090***	(0.036)	0.015**	(0.007)				
Brent price (€/l) × rural			-0.001	(0.006)	2.155***	(0.027)				
Brent price * gas station distance × urban			0.110**	(0.046)	-0.004	(0.003)				
Brent price * gas station distance × rural			0.000	(0.000)	0.050***	(0.017)				
Brent price (€/l) × medium/low-skilled							2.175***	(0.025)	-0.025*	(0.014)
Brent price (€/l) × high-skilled							-0.006	(0.011)	2.144***	(0.021)
Brent price * gas station distance × m/l-skilled							0.028**	(0.014)	0.026***	(0.010)
Brent price * gas station distance × high-skilled							0.010	(0.010)	0.050***	(0.011)
Type of employment										
Part-time	0.008*	(0.004)	0.004	(0.003)	0.004	(0.003)	0.003	(0.002)	0.005	(0.004)
Self-employed	0.010	(0.007)	-0.000	(0.005)	0.010**	(0.005)	0.009**	(0.005)	0.001	(0.006)
Medium/low-skilled occupations	0.006	(0.007)	0.001	(0.003)	0.004	(0.006)	0.750***	(0.012)	-0.746***	(0.009)
Having a partnership	0.000	(0.004)	0.001	(0.003)	-0.001	(0.004)	-0.003	(0.002)	0.003	(0.004)
Cohabiting with a partner	-0.009*	(0.005)	-0.000	(0.002)	-0.009*	(0.004)	-0.004	(0.003)	-0.005	(0.004)
Children in the household	0.003	(0.005)	0.000	(0.003)	0.003	(0.004)	0.002	(0.003)	0.001	(0.004)
Time trend	-0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)	-0.000	(0.000)
<i>N</i> _{observations}	3,696		3,696				3,696			
<i>N</i> _{respondents}	1,232		1,232				1,232			
Cragg-Donald Wald F-statistic	10,477.96		5,219.75				5229.97			
Stock & Yogo weak ID Test (critical value 10%)	19.93		16.87				16.87			
Hansen J statistic (& p-value)	0.128	(0.721)	1.729	(0.421)			1.504	(0.471)		

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A5: FE IV regression of remote working frequency on local Diesel prices – reduced form (second stage)

	(1)		(2)		(3)	
	b	s. e.	b	s. e.	b	s. e.
Local Diesel price (€/l)	0.950***	(0.305)				
Local Diesel price (€/l) × urban			0.580	(0.489)		
Local Diesel price (€/l) × rural			1.159***	(0.390)		
Local Diesel price (€/l) × m/low-skilled					0.263	(0.451)
Local Diesel price (€/l) × high-skilled					1.283***	(0.387)
Type of employment						
Part-time	0.324	(0.441)	0.311	(0.442)	0.312	(0.440)
Self-employed	1.856	(1.147)	1.830	(1.152)	1.908*	(1.144)
Medium/low-skilled occupations	-0.274	(1.030)	-0.258	(1.036)	1.524	(1.474)
Having a partnership	-0.297	(0.530)	-0.295	(0.530)	-0.290	(0.530)
Cohabiting with a partner	0.119	(0.633)	0.122	(0.633)	0.104	(0.632)
Children in the household	0.014	(0.625)	0.001	(0.624)	0.018	(0.624)
Time trend	0.014**	(0.007)	0.014**	(0.007)	0.014**	(0.007)
$N_{observations}$	3,696		3,696		3,696	
$N_{respondents}$	1,232		1,232		1,232	
R^2	.010		.011		.011	

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A6: FE IV regression of remote working frequency on local Diesel prices – first stage

	(1)		(2)				(3)			
	b	s. e.	Urban b	s. e.	Rural b	s. e.	M/low-skilled b	s. e.	High-skilled b	s. e.
Brent price (€/l)	5.075***	(0.067)								
Brent price * gas station distance	0.041	(0.043)								
Brent price (€/l) × urban			4.916***	(0.115)	0.180***	(0.021)				
Brent price (€/l) × rural			0.055***	(0.017)	5.004***	(0.076)				
Brent price * gas station distance × urban			0.023	(0.143)	0.004	(0.015)				
Brent price * gas station distance × rural			0.001	(0.003)	0.046	(0.047)				
Brent price (€/l) × medium/low-skilled							4.931***	(0.073)	0.165***	(0.037)
Brent price (€/l) × high-skilled							0.066**	(0.030)	5.000***	(0.064)
Brent price * gas station distance × m/l-skilled							0.030	(0.038)	0.001	(0.025)
Brent price * gas station distance × high-skilled							0.017	(0.028)	0.027	(0.034)
Type of employment										
Part-time	0.025**	(0.012)	0.013*	(0.008)	0.012	(0.009)	0.005	(0.006)	0.020*	(0.010)
Self-employed	0.018	(0.019)	0.006	(0.014)	0.012	(0.013)	0.015*	(0.009)	0.003	(0.017)
Medium/low-skilled occupations	0.026*	(0.014)	0.016*	(0.008)	0.011	(0.013)	-0.610***	(0.030)	0.628***	(0.023)
Having a partnership	0.012	(0.012)	0.017**	(0.007)	-0.005	(0.009)	0.007	(0.006)	0.005	(0.010)
Cohabiting with a partner	-0.030**	(0.013)	-0.010*	(0.005)	-0.020	(0.013)	-0.015*	(0.008)	-0.016	(0.011)
Children in the household	0.010	(0.011)	0.001	(0.006)	0.009	(0.010)	0.009	(0.008)	0.001	(0.009)
Time trend	-0.002***	(0.000)	-0.001***	(0.000)	-0.002***	(0.000)	-0.001***	(0.000)	-0.001***	(0.000)
<i>N</i> _{observations}	3,696		3,696				3,696			
<i>N</i> _{respondents}	1,232		1,232				1,232			
Cragg-Donald Wald F-statistic	8,619.77		4,269.62				4,296.92			
Stock & Yogo weak ID Test (critical value 10%)	19.93		16.87				16.87			
Hansen J statistic (& p-value)	0.095	(0.757)	1.653	(0.438)			1.460	(0.482)		

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A7: FE regression of remote working frequency on local fuel prices (10 nearest gas stations)

	(1)		(2)		(3)	
	b	s. e.	b	s. e.	b	s. e.
Local fuel price (€/l)	1.328***	(0.427)				
Local fuel price (€/l) × urban			0.818	(0.678)		
Local fuel price (€/l) × rural			1.614***	(0.542)		
Local fuel price (€/l) × m/low-skilled					0.383	(0.625)
Local fuel price (€/l) × high-skilled					1.786***	(0.539)
Type of employment						
Part-time	0.325	(0.441)	0.313	(0.443)	0.316	(0.441)
Self-employed	1.855	(1.146)	1.827	(1.152)	1.908*	(1.144)
Medium/low-skilled occupations	-0.270	(1.029)	-0.255	(1.035)	2.245	(1.793)
Having a partnership	-0.294	(0.530)	-0.293	(0.530)	-0.289	(0.530)
Cohabiting with a partner	0.116	(0.633)	0.120	(0.633)	0.102	(0.633)
Children in the household	0.015	(0.625)	0.002	(0.624)	0.017	(0.624)
Time trend	0.013*	(0.007)	0.013*	(0.007)	0.014*	(0.007)
<i>N</i> _{observations}	3,696		3,696		3,696	
<i>N</i> _{respondents}	1,232		1,232		1,232	
<i>R</i> ²	.011		.011		.011	

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A8: FE IV regression of remote working frequency on local fuel prices (10 nearest gas stations) – first stage

	(1)		(2)				(3)			
	b	s. e.	Urban b	s. e.	Rural b	s. e.	M/low-skilled b	s. e.	High-skilled b	s. e.
Brent price (€/l)	3.608***	(0.042)								
Brent price * gas station distance	0.049*	(0.028)								
Brent price (€/l) × urban			3.503***	(0.070)	0.097***	(0.013)				
Brent price (€/l) × rural			0.027**	(0.011)	3.580***	(0.048)				
Brent price * gas station distance × urban			0.066	(0.088)	0.000	(0.009)				
Brent price * gas station distance × rural			0.001	(0.001)	0.048	(0.031)				
Brent price (€/l) × medium/low-skilled							3.553***	(0.045)	0.070***	(0.023)
Brent price (€/l) × high-skilled							0.030	(0.019)	3.572***	(0.039)
Brent price * gas station distance × m/l-skilled							0.029	(0.025)	0.014	(0.016)
Brent price * gas station distance × high-skilled							0.014	(0.018)	0.038*	(0.021)
Type of employment										
Part-time	0.016**	(0.008)	0.008	(0.005)	0.008	(0.006)	0.004	(0.004)	0.013*	(0.007)
Self-employed	0.014	(0.012)	0.003	(0.009)	0.011	(0.008)	0.012*	(0.006)	0.002	(0.011)
Medium/low-skilled occupations	0.016*	(0.009)	0.008*	(0.005)	0.008	(0.009)	0.070***	(0.019)	-0.059***	(0.014)
Having a partnership	0.006	(0.007)	0.009**	(0.004)	-0.003	(0.006)	0.002	(0.004)	0.004	(0.006)
Cohabiting with a partner	-0.019**	(0.009)	-0.005	(0.003)	-0.015*	(0.008)	-0.009*	(0.005)	-0.010	(0.007)
Children in the household	0.006	(0.008)	0.000	(0.004)	0.006	(0.007)	0.005	(0.005)	0.001	(0.006)
Time trend	-0.001***	(0.000)	-0.000***	(0.000)	-0.001***	(0.000)	-0.000***	(0.000)	-0.001***	(0.000)
<i>N</i> _{observations}	3,696		3,696				3,696			
<i>N</i> _{respondents}	1,232		1,232				1,232			
Cragg-Donald Wald F-statistic	10,373.46		5169.29				5,170.37			
Stock & Yogo weak ID Test (critical value 10%)	19.93		16.87				16.87			
Hansen J statistic (& p-value)	0.105	(0.746)	1.675	(0.433)			1.473	(0.479)		

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A9: FE IV regression of remote working frequency on local fuel prices – observation period 2019/2020

	(1)		(2)		(3)	
	b	s. e.	b	s. e.	b	s. e.
Local fuel price (€/l)	4.682	(4.056)				
Local fuel price (€/l) × urban			4.469	(4.394)		
Local fuel price (€/l) × rural			3.245	(3.649)		
Local fuel price (€/l) × m/low-skilled					1.259	(2.872)
Local fuel price (€/l) × high-skilled					6.530	(5.455)
Type of employment						
Part-time	-1.011	(1.522)	-0.993	(1.528)	-1.009	(1.521)
Self-employed	1.947	(2.461)	1.996	(2.471)	2.041	(2.526)
Medium/low-skilled occupations	0.770	(1.106)	0.770	(1.135)	7.591	(6.926)
Having a partnership	0.253	(0.645)	0.283	(0.645)	0.256	(0.647)
Cohabiting with a partner	-0.565	(0.513)	-0.580	(0.522)	-0.510	(0.536)
Children in the household	-0.604	(0.560)	-0.746	(0.585)	-0.540	(0.554)
Time trend	0.054**	(0.023)	0.049**	(0.023)	0.055**	(0.023)
$N_{\text{observations}}$	1,432		1,432		1,432	
$N_{\text{respondents}}$	716		716		716	
R^2	.011		.0168		.0023	

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A10: FE IV regression of remote working frequency on local fuel prices (observation period 2019/2020) – first stage

	(1)		(2)				(3)			
			Urban		Rural		M/low-skilled		High-skilled	
	b	s. e.	b	s. e.	b	s. e.	b	s. e.	b	s. e.
Brent price (€/l)	0.428***	(0.068)								
Brent price * gas station distance	0.005	(0.057)								
Brent price (€/l) × urban			0.580	(0.400)	-0.352	(0.436)				
Brent price (€/l) × rural			-0.855***	(0.323)	1.397***	(0.373)				
Brent price * gas station distance × urban			1.072**	(0.431)	-0.857*	(0.447)				
Brent price * gas station distance × rural			0.327*	(0.175)	-0.389*	(0.205)				
Brent price (€/l) × medium/low-skilled							0.664***	(0.104)	-0.065	(0.060)
Brent price (€/l) × high-skilled							-0.045**	(0.022)	0.401***	(0.073)
Brent price * gas station distance × m/l-skilled							-0.100	(0.071)	-0.023	(0.046)
Brent price * gas station distance × high-skilled							-0.002	(0.017)	0.065	(0.060)
Type of employment										
Part-time	0.014	(0.016)	-0.011	(0.011)	0.025	(0.017)	0.003	(0.008)	0.012	(0.016)
Self-employed	0.023	(0.015)	0.014	(0.035)	0.004	(0.041)	0.020	(0.017)	0.002	(0.021)
Medium/low-skilled occupations	-0.020	(0.032)	0.014	(0.022)	-0.040	(0.034)	1.094***	(0.019)	-1.139***	(0.022)
Having a partnership	0.032**	(0.015)	0.018	(0.018)	0.014	(0.024)	0.013	(0.010)	0.018	(0.013)
Cohabiting with a partner	-0.027	(0.018)	-0.016	(0.037)	-0.014	(0.043)	-0.001	(0.010)	-0.026*	(0.016)
Children in the household	-0.014	(0.023)	0.049	(0.039)	-0.062	(0.044)	0.001	(0.007)	-0.015	(0.023)
Time trend	-0.005***	(0.000)	-0.002***	(0.000)	-0.003***	(0.000)	-0.002***	(0.000)	-0.003***	(0.000)
<i>N</i> _{observations}	1,432		1,432				1,432			
<i>N</i> _{respondents}	716		716				716			
Cragg-Donald Wald F-statistic	37.85		20.27				18.59			
Stock & Yogo weak ID Test (critical value 10%)	19.93		16.87				16.87			
Hansen J statistic (& p-value)	1.187	(0.276)	4.506	(0.105)			1.443	(0.486)		

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; reference categories: high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household.

Table A11: Difference-in-difference regression of remote working frequency changes on local fuel price changes

	(1)		(2)	
	b	s. e.	b	s. e.
Price change group				
intermediate (2nd & 3rd quartile)	0.726	(0.447)	0.191	(0.765)
high (4th quartile)	1.197**	(0.546)	0.722	(0.951)
Type of employment				
Part-time	-0.941***	(0.354)	-1.004*	(0.546)
Self-employed	-0.603	(0.888)	0.515	(1.589)
Medium/low-skilled occupations	-0.124	(0.255)	-1.090*	(0.658)
Having a partnership	0.065	(0.680)	2.031*	(1.184)
Cohabiting with a partner	0.261	(0.616)	-0.163	(1.117)
Children in the household	0.015	(0.348)	-0.749	(0.694)
Year	-0.426**	(0.203)	-1.099***	(0.349)
$N_{\text{observations}}$	836		318	
$N_{\text{respondents}}$	418		159	
R^2	.012		.041	

Notes: * $p < .1$; ** $p < .05$; *** $p < .01$; robust standard errors in parentheses; model (1): full sample; model (2): restricted sample without employees working always or never from home; reference categories: lowest fuel price change quartile; high-skilled occupations, full-time employment, no partner, no cohabitation, no child in the household; survey year 2021.

Table A12: Fixed-effects regression of local fuel prices on regional characteristics

	b	s. e.
Settlement structure (ref.: 20,000 – 50,000 inhabitants) × month		
> 500,000 inhabitants × month	-0.000	(0.000)
100,000 – 500,000 inhabitants × month	-0.000	(0.000)
50,000 – 100,000 inhabitants × month	-0.000	(0.000)
5,000 – 20,000 inhabitants × month	0.000	(0.000)
< 5,000 inhabitants × month	0.000	(0.001)
Federal states (ref.: Rhineland-Palatinate) × month		
Schleswig-Holstein × month	0.000	(0.001)
Hamburg × month	0.000	(0.001)
Niedersachsen (Lower Saxony) × month	-0.000	(0.000)
Bremen × month	0.000	(0.001)
Nordrhein-Westfalen (North Rhine-Westfalia) × month	-0.000	(0.000)
Hessen (Hesse) × month	-0.000	(0.001)
Baden-Württemberg × month	-0.000	(0.000)
Bayern (Bavaria) × month	0.001	(0.001)
Saarland × month	-0.000	(0.001)
Berlin × month	-0.000	(0.001)
Brandenburg × month	0.001**	(0.001)
Mecklenburg-Vorpommern × month	0.000	(0.001)
Sachsen (Saxony) × month	0.000	(0.001)
Sachsen-Anhalt (Saxony-Anhalt) × month	0.001	(0.001)
Thüringen (Thuringia) × month	0.001*	(0.001)
Month	0.007***	(0.001)
Intercept	1.733***	(0.001)
R^2	.180	
N	3,804	

Note: * $p < .10$, ** $p < .05$, *** $p < .01$.

Table A13: Number and distance of trips to work by transport mode in counties with poor public transport

	Active travel	Public transport	Car	Total
Number of trips	25	27	341	393
Distance travelled (km)	96.3	558.8	8,331	8,986.1
Average distance per trip (km)	3,9	20,7	24,4	22,9
Share on total trips	6,4%	6,9%	86,8%	100%
Share on distance travelled	1,1%	6,2%	92,7%	100%

Notes: Active travel includes walking, bike, and e-bike; car commute includes also motorbikes.

Source: German Mobility Panel.

Table A14: Direct and indirect effects of a 300 €/tCO₂ price

Direct fuel price-quantity elasticity (ε_{dir})	-0.309		
Direct quantity reduction ($\Delta Q_{fuel,dir}$)	13.72%		
Fuel price-remote working elasticity ($\varepsilon_{PF,remote}$)	-0.136	-0.369 (base case)	-0.601
Individual effects			
Indirect quantity reduction via remote working ($\Delta Q_{fuel,ind}$)			
max (-0.200)	1.05%	2.82%	4.60%
med (-0.128)	0.67%	1.81%	2.95%
Total fuel quantity reduction ($\Delta Q_{fuel,total}$)			
max (-0.200)	14.76%	16.45%	18.32%
med (-0.128)	14.39%	15.53%	16.67%
Percentage of indirect effect on total effect			
max (-0.200)	7.62%	20.59%	33.56%
med (-0.128)	4.89%	13.21%	21.53%
Total fuel price-quantity elasticity (ε_{total})			
max (-0.200)	-0.333	-0.373	-0.413
med (-0.128)	-0.324	-0.350	-0.376
National-level effects			
Household fuel consumption and carbon emission reduction			
max (-0.200)	14.24%	15.14%	16.03%
med (-0.128)	14.06%	14.63%	15.20%
German national carbon emissions reduction			
max (-0.200)	2.20%	2.34%	2.48%
med (-0.128)	2.17%	2.26%	2.35%

Notes: National-level figures for 2024: household fuel consumption at 363,368 GWh, household carbon emissions at 100.2 MtCO₂, total national carbon emissions at 649.0 MtCO₂. German national household carbon emissions and reductions in carbon emissions are calculated from energy consumption data assuming a fuel carbon intensity of 2.51 kgCO₂/liter. The calculation of the overall national effects takes into account that the indirect remote working effect is relevant only for the 50.18% of employed car commuters (Statistisches Bundesamt 2025). In this extreme scenario of a 300 €/tCO₂ price on fuel consumption, total quantity reductions and emission savings are greater than in the 177 €/tCO₂ case presented in Table 2. The direct effect exceeds the indirect effect even more than in the base case in Table 2 by reducing the contribution of remote working to the overall volume reduction. The change in the total fuel price elasticity caused by the remote working channel is also relatively lower than in the base case. The isolated direct effect of introducing a carbon price of 300 €/tCO₂ on mobility only may reduce national carbon emissions by 2.12%. Sources: Fuel energy consumption of German households (Statistisches Bundesamt 2024); National German carbon emissions (Umweltbundesamt 2025).

Table A15: Effects of a direct price-fuel quantity elasticity of -.529

Direct fuel price-quantity elasticity (ε_{dir})	-0.529		
Direct quantity reduction ($\Delta Q_{fuel,dir}$)	12.79%		
Fuel price - remote working elasticity ($\varepsilon_{PF,remote}$)	-0.136	-0.369 (base case)	-0.601
Individual effects			
Indirect quantity reduction via remote working ($\Delta Q_{fuel,ind}$)			
max (-0.200)	0.58%	1.55%	2.53%
med (-0.128)	0.37%	1.00%	1.63%
Total fuel quantity reduction ($\Delta Q_{fuel,total}$)			
max (-0.200)	13.36%	14.34%	15.32%
med (-0.128)	13.16%	13.78%	14.41%
Percentage of indirect effect on total effect			
max (-0.200)	4.50%	12.16%	19.81%
med (-0.128)	2.89%	7.80%	12.71%
Total fuel price-quantity elasticity (ε_{total})			
max (-0.200)	-0.553	-0.593	-0.634
med (-0.128)	-0.544	-0.570	-0.596
National-level effects			
Household fuel consumption and carbon emission reduction			
max (-0.200)	13.08%	13.57%	14.06%
med (-0.128)	12.97%	13.29%	13.60%
German national carbon emissions reduction			
max (-0.200)	2.02%	2.10%	2.17%
med (-0.128)	2.00%	2.05%	2.10%

Notes: National-level figures for 2024: household fuel consumption at 363,368 GWh, household carbon emissions at 100.2 MtCO₂, total national carbon emissions at 649.0 MtCO₂. German national household carbon emissions and reductions in carbon emissions are calculated from energy consumption data assuming a fuel carbon intensity of 2.51 kgCO₂/liter. The calculation of the overall national effects takes into account that the indirect remote working effect is relevant only for the 50.18% of employed car commuters (Statistisches Bundesamt 2025). In this extreme scenario of a direct fuel price-quantity elasticity of 0.529 on fuel consumption, quantity reductions in sum are greater than in the -.309 elasticity case presented in Table 2. The direct effect exceeds the indirect effect even more than in the base case in Table 2 by reducing the contribution of remote working to the overall volume reduction. The change in the total fuel price elasticity caused by the remote working channel is also relatively lower than in the base case. The isolated direct effect of introducing a carbon price of 177 €/tCO₂ at a high direct fuel price-quantity elasticity (ε_{dir}) of -.529 on mobility only is substantial and may reduce national carbon emissions by 1.97%. Sources: Fuel energy consumption of German households (Statistisches Bundesamt 2024); National German carbon emissions (Umweltbundesamt 2025).

Table A16: Direct and indirect elasticities for calibration of the policy simulation

Study	Elasticity (point estimate + [95% CI])
<i>Direct fuel price - quantity elasticity (ε_{dir})</i>	
Khanna, Dubernet, and Jochem 2025 (Germany)	-.53 [-.68, -.38]
Kilian and Zhou 2024	-.28 [-.32, -.24], -.37 [-.54, -.20]
Alberini, Horvath, and Vance 2022 (Germany)	-.31 [-.62, .00]
Marz and Şen 2022	-.45
Frondel and Vance 2018 (Germany)	-.39 [-.56, -.22]
Coglianesi et al. 2017	-.37 [-.84, .10]
Levin, Lewis, and Wolak 2017	-.30 [-.36, -.23] to -.38 [-.44, -.32]
<i>Elasticity of fuel consumption through additional remote working ($\varepsilon_{remote,RF}$)</i>	
Hook et al. 2020	maximum (-.20), medium (-.13), minimum (.00)
Faber et al. 2024	
Macias, Ravalet, and Rérat 2025	-.11 (2018/19), -.13 (2019/20), -.25 (2020/21)
	-.18

Notes: Hook et al. (2020) is a review article presenting systematic evidence on point estimates; the table therefore borrows information on point estimates only whereas CIs are not reported. The cases minimum, medium, and maximum summarize the evidence on point estimates reported. Faber et al. (2024) and Macias et al. (2025) similarly reported statistical significance levels, but no CIs or standard errors.

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