Claussen, Jörg; Streich, David

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Commuting costs and housing prices

Jörg Claussen* David J. Streich†

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Abstract

We study the effect of the introduction of the Deutschlandticket (DT), a large-scale German policy intervention that substantially decreased the costs of commuting by public transport, on housing prices. We use the introduction of the DT and cross-sectional variation in the reduction of commuting costs (by commuting distance) in a continuous-treatment difference-in-differences (DiD) setting. Our analyses are based on detailed data on commuting patterns on a municipality-pair level and extensive data on rental offerings from three large online platforms for our analyses. We document a small increase in relative rents in municipality pairs with higher cost savings from the DT. The effect is driven by smaller apartments and by municipality pairs with more feasible public transport commutes. Further heterogeneity results suggest that commuters use the cost savings to pay higher rents in more attractive housing locations, which aggravates existing housing market pressure in urban areas.

Keywords: commuting costs · public transport · subsidies · housing costs
JEL-Classification: H23 · H31 · R23

*University of Munich, Kaulbachstr. 45, 80539 Munich, Germany. E-Mail: j.claussen@lmu.de, ORCID-ID: 0000-0001-8432-8860.

†Catholic University Eichstaett-Ingolstadt, Auf der Schanz 49, 85049 Ingolstadt, Germany. E-Mail: david.streich@ku.de, ORCID-ID: 0000-0002-5222-6912

1 Introduction

When choosing a residential location, households trade off lower housing costs in remote locations and lower costs of commuting in more central locations. Commuting costs are determined by the opportunity costs of time spent in traffic as well as the financial costs of commuting arising from gasoline prices for car-based commutes (Molloy and Shan, 2013) or train fares for public transport commutes. Ceteris paribus, a decrease in financial commuting costs should therefore make remote housing locations relatively more attractive and could help ease the pressure in urban housing markets observed across the developed world. In this paper, we study the effects of the Deutschlandticket (DT), a large-scale policy intervention in Germany that substantially lowered the financial costs of commuting by public transport, on housing markets. The DT is a flat-rate public transport tariff that can be used in all regional and local public transport. It was introduced as a long-term subsidy for public transport use in May 2023. We use the introduction of the DT as an exogenous shock to commuting costs for public transport commutes, which is a widely used mode of commuting in Germany.[1] Since the financial costs of commuting by public transport are now flat, longer-distance commuters are particularly affected by the shock to commuting costs. We use these cross-sectional differences to identify the effect of the DT on housing prices in a continuous-treatment difference-in-differences (DiD) estimation.

We use two main datasets for our analyses. First, we use highly granular administrative data on the places of residence and work for the population of all German workers. Data are collected by the statistical offices of the 16 federal states and are published annually for all municipality pairs with at least ten commuters. We use the commuting data to form weights for our regression analyses (to ensure that more frequented commutes obtain higher weights than less frequented commutes) and account for the feasibility of a commuting route (by only investigating real estate prices in municipality pairs with existing commuters). Second, we collect a large dataset containing all real estate listings appearing on three large online platforms (Immoscout24, Immowelt, eBay Kleinanzeigen) between May 2022 and April 2024, which gives us one year worth of data before and after the DT introduction. We focus on the rental market as we expect changes in location choices to materialize here first. Importantly, for housing price effects to materialize, we do not expect households to move only based on the reduction in commuting costs. Instead, it is sufficient for those households that have already decided to move to take into account the reduction in commuting costs in their re-location decision (Molloy and Shan, 2013). We aggregate the listings data to the muni-pair-month level.

Our results can be summarized as follows. First, we document an increase in relative rental prices for municipality pairs that benefit more from the Deutschlandticket. The treatment

[1] In 2020, 14% of employed persons used public transport to commute (https://www.destatis.de/DE/Themen/Arbeit/Arbeitsmarkt/Erwerbstaetigkeit/im-Fokus-Pendler.html).

effect is precisely estimated, but economically small. Given that commuting cost savings are concentrated in few long-distance commuters and average out over large rental markets, this is not surprising. In addition, we find that the treatment effect takes half a year to materialize and peaks three quarters after the DT introduction. This suggests that our results may only capture the initial housing market effects of the DT. Second, we find that the treatment effect is driven by smaller apartments (whose tenants may be more mobile and price-sensitive) and municipality pairs that are more likely commutable by public transport (as measured by the subscription share to public transport tickets and female commuter shares). Third, in an attempt to disentangle different location choice motives, our results consistently point to higher treatment effects in municipalities that are more attractive to live in (as proxied by previous rent differences, regional classifications, population density, and per-capita business tax revenue). These results suggest that commuters use the commuting cost savings to pay higher rents in more attractive housing locations, which aggravates local housing market pressure rather than alleviate it.

We contribute to the empirical literature on the relationship between commuting costs and real estate markets. The two studies that are most closely related to ours are Molloy and Shan (2013), who find that an increase in gasoline prices in the US is associated with a small reduction in housing construction in locations with relatively commute times, and Baum-Snow (2010), who links urban highway construction to US housing decentralization. Our setting differs from these two studies as we exploit a clear-cut policy intervention designed to decrease the cost of public transport (rather than car-based commutes). In doing so, we also add to an existing literature on the effects of public transport subsidies. Gohl and Schrauth (2024), for instance, have found that a previous, temporary version of the DT has caused a shift from car-based to public-transport-based commuting, which was associated with a temporary reduction in air pollution in core urban areas. We add to their findings by showing that the DT affects housing prices by altering the residential location choices of commuters.

2 The Deutschlandticket

In response to the energy crisis triggered by the Russian invasion in Ukraine, the German government decided in 2022 to subsidize public transport to mitigate income shocks. It initially introduced the temporary 9-Euro-ticket (9ET), which was available from June to August 2022. The 9ET provided a flat-rate subscription to all regional public transportation at a price of 9€ per month. Due to the widespread use of the 9ET (it was sold over 52 million times, cf. Gohl and Schrauth, 2024), discussions over a long-term version of this public transport subsidy ensued. Eventually, the DT was introduced on May 1st, 2023. Like the 9ET, the DT is a flat-rate tariff valid for all local and regional public transport in Germany. The price was initially set at 49€ per month, but was increased to 58€ in January 2025. While it is only sold as a digital subscription-based ticket, subscription can be cancelled on a monthly basis (until the 10th of each month to the end of the month).

The cost savings for commuters from the DT are substantial: The price for a monthly public transport ticket in Berlin decreased by almost half (from 86€ to 49€, cf. Gohl and Schrauth, 2024). For longer commutes, the cost savings are even greater. For instance, the costs for the 80-km commute from Munich to Ingolstadt, which one of the authors of this study undertakes several times a week, has decreased by more than 200€ per month. The attractiveness of the DT is also visible in its high adoption. In the first month after introduction, approximately 9 million DTs have been sold.[2]

3 Data

To assess the impact of the DT on housing prices, we draw on two rich datasets. First, we use highly granular administrative data on the places of residence and work of the population of German workers. Data are collected by the statistical offices of the individual federal states and consolidated in the so-called *Pendleratlas* ("commuter atlas"). Data are compiled annually as of June 30 and are reported for each municipality pair with at least 10 commuters.[3] Commuter data are also provided by gender, in which case the minimum number of commuters by commuting route is 3. Data are generally reported on a municipality-pair basis. However, data for the federal states of Schleswig-Holstein, Rhineland-Palatinate, Mecklenburg-Vorpommern, and Thuringia are reported on slightly more aggregated municipality association levels. Typically, prohibitively small municipalities join larger, nearby municipalities to be mutually governed in a municipality association for efficiency.[4]

Figure 1 illustrates the distribution of commuting distances on a log scale. The majority of commuters live within 100 kilometers of their place of work; the average German worker commutes 21 kilometers (see Table A1 in the Appendix).[5] Commuting distances are larger among male commuters than female commuters (panel b) of Figure 1). This pattern is likely a consequence of women looking for jobs closer to home as they bear a larger share of care responsibilities. Finally, long-distance commutes exceeding 100 kilometers are substantially more common for residents of urban municipalities (see panel c) of Figure 1). On the one hand, this may reflect differences in the feasibility of long distance commutes between urban and

[2] https://www.mdr.de/nachrichten/deutschland/gesellschaft/deutschlandticket-bilanz-verkehrsunternehmen\-bahn-oepnv-100.html

[3] Municipality pairs with less than 10 commuters are omitted for data protection reasons.

[4] While the commuting data essentially covers the universe of German workers and provides detailed data on a municipality-pair basis, it cannot distinguish between actual commutes and "paper commutes" in which an employee's place of work is registered in a different municipality, but the employee does not actually commute. This has likely become more relevant as more companies have allowed employees to work from home during and after the Covid pandemic.

[5] Distance estimates are based on centroid-to-centroid differences (when the origin municipality is different from the destination municipality) or the estimated radius of a municipality (when the origin municipality is the destination municipality).

rural areas (for instance, the 500-kilometer commute from Munich to Berlin can be achieved in less than 4 hours by train). On the other hand, this may reflect the higher prevalence of working-from-home among predominantly urban service jobs.

Second, we use a large number of rental listings compiled through regular scrapes of the three largest online real estate platforms in Germany (Immoscout24, Immowelt, eBay Kleinanzeigen). All three platforms are repeatedly scraped in 5-minute intervals to ensure that we do not systematically omit listings in high-demand urban areas, in which listings are only online for mere hours. In total, we compile 2.4 million rental property listings between May 1, 2022 and April 30, 2024. Thus, we construct a 2-year sample of rental listings, with 1 year of data before and after the introduction of the DT in May 2023. For each listing, we use the day at which it was first observed on a platformas the relevant date. To account for adjustments in the rental price over time, we use the last observed rent for our analyses. This measure should account for market-based price adjustments and be closest to the eventual rent. However, in the rental market, adjustments and deviations of offer and rent prices rarely occur. We then aggregate the rental data to the municipality-month level using rents per square meter. The rents do not include utility costs.

We organize our data in a municipality-dyad panel (origin municipality i, destination municipality j, month t), which allows us to exploit dyad-level variation in commuting intensity and cost savings (as a function of distance) to explain differences in relative housing price changes. Table 1 reports summary statistics for the main variables of interest on a dyad level (panel A) and on a municipality level (panel B). The statistics suggest that the DT represents a substantial shock to commuting costs. Using distance-based prices for public transport subscriptions to estimate commuting costs prior to the DT, annual cost savings from the DT are 400€ for the average municipality pair. Panel B of the table further suggests that there is substantial variation in average rental prices per square meters in the sample.

4 Results

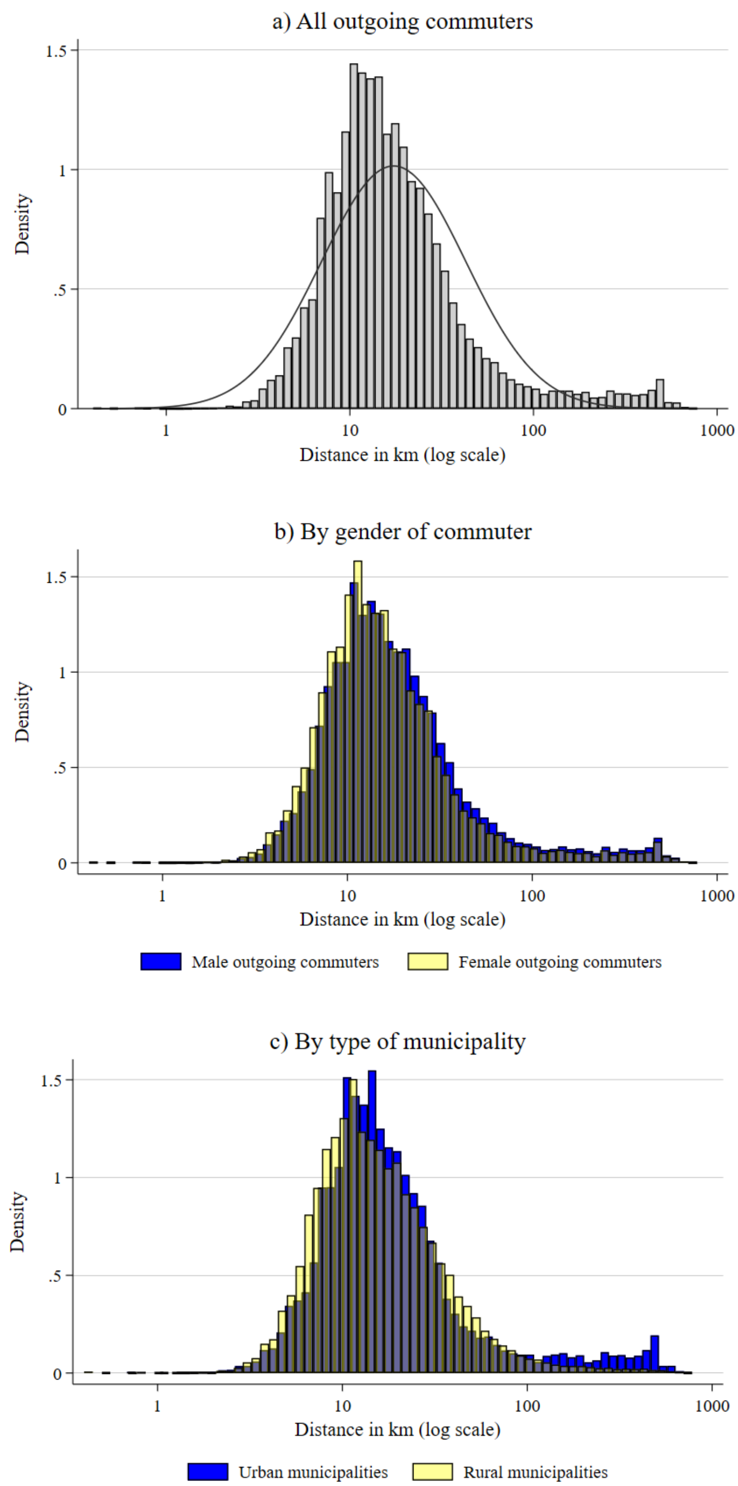
4.1 Baseline results

We use the following baseline regression model to assess the impact of the DT introduction on housing prices:

$$\Delta_{ij,t}\text{Rent} = \alpha_{ij} + \alpha_t + \beta \times \text{Post}_t \times T_{ij} + \epsilon_{ij,t} \quad (1)$$

$\Delta_{ij,t}$Rent is the difference in monthly net rent per square meter between the origin municipality i and destination municipality j. α_{ij} captures time-invariant variation on the dyad level (e.g., structural differences in housing demand). α_t captures time-varying macro characteristics (e.g., energy prices or interest rates). $Post_t$ is an indicator variable taking on the value one after the implementation of the DT (May 2023). T_{ij} is our measure of cross-sectional treatment intensity based on the dyad-level cost savings from the DT. Both variables ($Post_t$

Figure 1: Distribution of commuting distances



Note: The figure displays histograms of commuting distances for all commuters (panel a), by gender of the commuter (panel b), and by the type of the origin municipality (panel c). Commuting distances are estimated as the kilometer distance between the centroids of the origin and destination municipalities. Municipality types follow the definition of the *Regionalstatistische Raumtypologie* (RegioStaR) provided by the Federal Ministry for Digital and Transport (BMDV, 2021).

Table 1: Summary statistics

	N	Mean	Median	SD	Min	Max
Panel A: Dyads						
Commuters ('000)	611,743	0.2	0.0	4.9	0.0	1,681.6
Female commuters ('000)	569,698	0.1	0.0	2.5	0.0	818.9
Male commuters ('000)	574,316	0.1	0.0	2.5	0.0	862.7
Distance (km)	611,743	54.7	22.1	94.6	0.4	787.4
Estimated commuting costs (k€ p.a.)	611,743	1.5	1.2	0.9	0.5	3.9
Estimated cost savings (k€ p.a.)	611,743	0.4	0.1	0.6	0.0	3.4
Panel B: Municipalities / municipality associations						
Outgoing commuters ('000)	6,654	3.6	1.8	7.8	0.0	226.7
Incoming commuters ('000)	6,651	3.6	0.9	15.9	0.0	507.8
Local commuters ('000)	6,654	2.9	0.6	26.0	0.0	1,596.9
Female commuter share (outgoing)	6,650	0.5	0.5	0.0	0.3	0.9
Population ('000)	6,654	12.5	4.5	63.6	0.1	3,664.1
Area (sq km)	6,654	53.0	34.7	58.1	1.4	891.1
Population density ('000)	6,654	0.2	0.1	0.3	0.0	4.8
No. destination munis	6,654	29.2	22.0	36.0	0.0	1,077.0
1(Urban)	6,654	0.3	0.0	0.5	0.0	1.0
Unemployment rate	6,647	0.0	0.0	0.0	0.0	0.4
Business tax / employee (k€)	6,651	0.4	0.3	0.5	0.0	19.1
Subscription share season ticket	6,654	0.2	0.2	0.0	0.1	0.5
Average no. listings (per month)	5,954	14.0	3.5	54.9	1.0	801.0
Average days on market	5,954	56.1	51.1	34.4	0.0	587.0
Average rent per sqm (€)	5,954	9.5	9.1	2.5	2.1	30.0

Note: The table reports summary statistics on a dyad (panel A) and municipality level (panel B). Panel A contains data on a municipality-pair level for years 2021 through 2023. Commuting distances are estimated as the kilometer distance between the centroids of the origin and destination municipalities. Commuting costs and cost savings are estimated using distance-based public transport subscription prices in 2021 (i.e., before the introduction of the DT). Urban municipalities are classified according to the RegioSTAR7 (R7) classification. Business tax / employee is computed as a municipality's business tax (*Gewerbesteuer*) base, divided by its population.

and T_{ij}) are individually absorbed by the time and dyad fixed effects, respectively. The main coefficient of interest is β, which measures the additional change in relative rents in dyads with higher cost savings from the DT. Importantly, we apply analytical weights using the directed dyad-level commuting intensity (number of commuters between muni i and muni j). This ensures that more commonly commuted dyads receive higher weights in the regressions. Standard errors are clustered on the dyad level.

Table 2 reports the treatment coefficient β for two specifications. Column 1 reports the regression coefficient for a continuous-treatment DiD specification using the dyad-level cost savings estimate Savings_{ij} as a measure of cross-sectional treatment intensity. Column 2 reports the coefficient for a regression using a dummy variable indicating cost savings in the top quintile (in which savings exceed 450€ annually). The intuition is that cost savings must be sufficiently large to affect residential location choices. Both coefficients are positive and statistically significant at the 1% level. The results suggest that relative rents increase in municipality pairs with higher potential cost savings from the DT. The economic impact is small: An increase in annual cost savings by €1,000 (which is equivalent to a shift from the median to more than the 90th percentile) is associated with an increase in relative annual rents by less than 30€ (assuming an area of 50 square meters). The coefficient from the binary treatment intensity specification suggests that the effect is largely driven by municipality pairs in the top quintile of cost savings.

Table 2: Baseline treatment effect

	(1) $\Delta_{ij,t}\text{Rent}$	(2) $\Delta_{ij,t}\text{Rent}$
$1(\text{Post}_t = 1) \times \text{Savings}_{ij}$	0.043^{**}	
	(0.015)	
$1(\text{Post}_t = 1) \times 1(\text{Savings}_{ij} > Q_{0.8})$		0.051^{**}
		(0.018)
Constant	-0.982^{***}	-0.980^{***}
	(0.001)	(0.001)
Obs.	3,494,331	3,494,331
Adj. R2	0.694	0.694
Month FE	✓	✓
Dyad FE	✓	✓

Note: The table reports the treatment coefficients β of weighted least squares regressions specified in equation 1. Observations are weighted according to the number of commuters between municipalities i and j. Specification (1) uses a continuous treatment intensity measure (annual cost savings per commuter from DT), specification (2) uses a binary variable indicating that cost savings per commuter are in the top quintile. Standard errors (clustered at the dyad level) are reported in parentheses ($^{*}p < 0.05,^{**} p < 0.01,^{**} p < 0.001$).

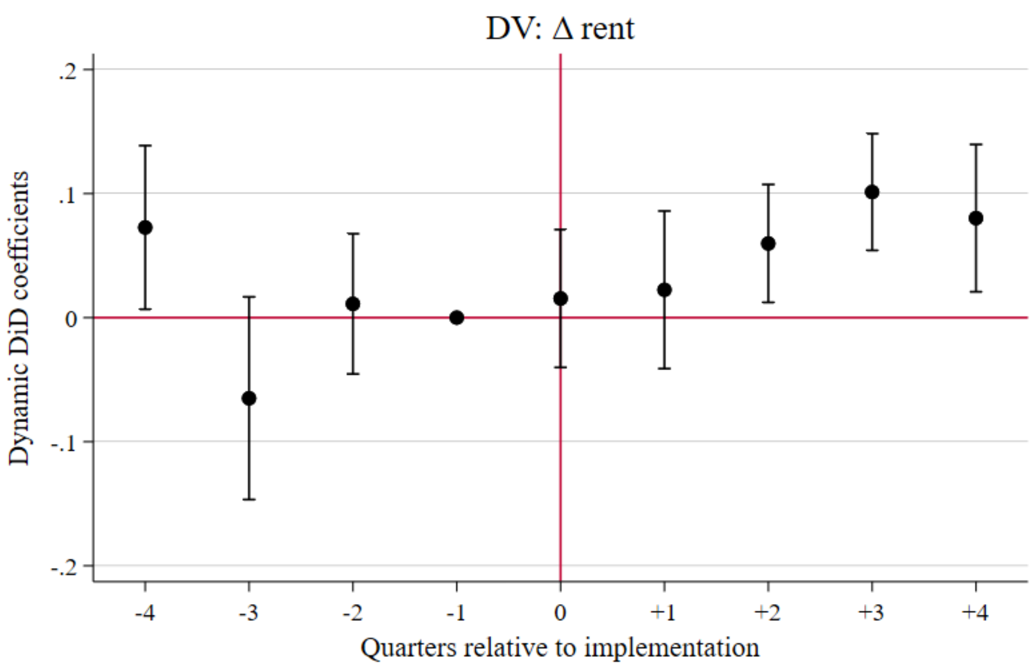
To assess the timing of the main treatment effect and ensure that the parallel trend assumption holds, Figure 2 plots the coefficients from a dynamic DiD specification of the following form:

$$\Delta_{ij,t}\text{Rent} = \alpha_{ij} + \alpha_t + \sum_q \beta_q \times 1(t = q) \times T_{ij} + \epsilon_{ij,t} \tag{2}$$

where q denote calendar quarters and T_{ij} is the binary treatment intensity measure.[6]

The coefficients suggest that — prior to the introduction of the DT and after accounting for dyad and time fixed effects — there is no systematic difference in relative rents between municipality dyads with high and low cost savings *before* the DT introduction. While relative rents are significantly higher in Q2 of 2022 ($t = -4$) relative to the reference quarter (Q1 of 2023, $t = -1$), this does not seem to be a general trend in the pre-period. After the introduction of the DT, it takes almost half a year for the treatment effect to materialize. Specifically, the treatment coefficient turns significantly positive in quarter $t + 2$. This result is in line with expectations as the effect of the commuting cost shock is likely driven by the location decisions of those households that are already looking to move rather than households deciding to move because of the lower commuting costs (cf. Molloy and Shan, 2013). In quarters $t+3$ and $t+4$, the treatment effect is substantially larger than the pooled treatment coefficient reported in Table 2 (0.10 and 0.08, respectively).

Figure 2: Baseline treatment effect: Dynamic DiD



Note: The figure depicts the point estimates and 95% confidence intervals of dynamic DiD coefficients obtained from weighted least squares regressions as specified in equation 2. Quarters are defined as calendar quarters. Quarter $t = -4$ refers to Q2 of 2022 (May and June). Quarter $t = +4$ refers to Q2 of 2024 (May and June). The implementation date of the DT (May 2023) is contained in Q2 of 2023 ($t = 0$).

[6] $q = -4$ refers to the second quarter of 2022 containing May and June 2022.

4.2 Heterogeneity results

To ensure that the treatment effect we document in the previous section indeed reflect residential location choices in response to the shock in commuting costs, we investigate several dimensions of treatment heterogeneity in this section. Specifically, we look at differences in treatment effects by proxies for the mobility and price sensitivity of tenants (object size/number of bedrooms), the feasibility of a commute by public transport (e.g., dyad-level subscriber share to public transport season tickets), as well as two opposing motives for residential location choices.

4.2.1 Object size

Table 3 reports the DiD coefficients separately for objects with less than 3 bedrooms and objects with at least 3 bedrooms. In line with the baseline results, all coefficients are positive. However, while the coefficients for smaller objects are highly statistically significant ($p < 0.001$, respectively), they are barely significant for larger objects ($p < 0.05$ for the continuous specification and $p < 0.1$ for the binary specification). The results suggest that the aggregate treatment effect reported in Table 2 is mainly driven by smaller objects. Specifically, the treatment effect for smaller apartments is between two and three times as large as the aggregate effect and the effect for larger apartments.

One interpretation of this pattern is that tenants of smaller objects (single or couple households) are arguably more geographically mobile than tenants of larger objects (who are more likely families). Thus, turnover is higher for this sub-segment, causing rents to adjust faster to changes in location preferences. Another interpretation is that tenants of smaller objects are more price-sensitive and thus react more to changes in commuting costs.

Table 3: Treatment effect, by object size

	<3 bedrooms		3+ bedrooms	
	(1)	(2)	(3)	(4)
	Δ_{ij}Rent	Δ_{ij}Rent	Δ_{ij}Rent	Δ_{ij}Rent
$1(\text{Post} = 1) \times \text{Savings}_{ij}$	0.118***		0.052*	
	(0.019)		(0.020)	
$1(\text{Post} = 1) \times 1(\text{Savings}_{ij} > Q_{0.8})$		0.156***		0.040
		(0.023)		(0.021)
Constant	-1.370***	-1.367***	-0.862***	-0.859***
	(0.002)	(0.001)	(0.002)	(0.001)
Obs.	3,456,591	3,456,591	3,480,296	3,480,296
Adj. R2	0.496	0.496	0.516	0.516
Month FE	✓	✓	✓	✓
Dyad FE	✓	✓	✓	✓

Note: The table reports the treatment coefficients β of weighted least squares regressions specified in equation 1. Observations are weighted according to the number of commuters between municipalities i and j. Specifications (1) and (3) use a continuous treatment intensity measure (annual cost savings per commuter from DT), specifications (2) and (4) use a binary variable indicating that cost savings per commuter are in the top quintile. Standard errors (clustered at the dyad level) are reported in parentheses ($^{*}p < 0.05,^{**} p < 0.01,^{**} p < 0.001$).

4.2.2 Feasibility of public transport commute

The decrease in commuting costs should only affect relative housing prices when a commute is actually feasible by public transport. To investigate treatment effects separately by dyad-level proxies for feasibility, we adjust the baseline regression by splitting up the treatment coefficient β:

$$\Delta_{ij,t}\text{Rent} = \alpha_{ij} + \alpha_t + \sum_h I_h \times \beta_h \times \text{Post}_t \times T_{ij} + \epsilon_{ij,t} \tag{3}$$

where I_h are mutually exclusive and collectively exhaustive indicator variables for the various sub-samples considered.

We use two proxies for the feasibility of a dyad-level commute by public transport. First, we obtain representative survey data on the subscription to public transport season tickets (VDV, 2024). The survey was commissioned by the Association of German Transport Companies (VDV). Forsa, one of the leading polling companies in Germany, collected more than 80,000 survey responses starting in May 2023. The data are published on a region-type level (the so-called RegioStaR 7 classification). We compute the average subscription share on a muni-dyad level as a measure of commute feasibility. The intuition is that feasibility is higher for commutes with higher public transport subscriptions in the origin and destination municipalities.

Second, we use the share of female commuters as a proxy for commute feasibility. Fuchs et al. (2024) show that women display lower propensity to commute and lower commute distances than men. This pattern is replicated in the commuting data we use in this paper (see Figure 1). At the same time, survey data from the European Union suggests that women are much more likely to name public transport as their main mode of transport than men (20% vs. 14%, cf. Eurostat, 2020).

Table 4 reports the resulting treatment coefficients. Column 1 reports the baseline treatment effect for the binary specification. In column 2, the treatment effect is split up into municipality pairs with above-median and below-median subscriber shares. The coefficient for the above-median pairs is identical to the main treatment effect, while the coefficient for the below-median pairs is not distinguishable from zero. The coefficients suggest that the main treatment effect is driven by municipality pairs with higher public transport subscription shares in both origin and destination municipality. In column 3, the treatment effect is split up into municipality pairs with above-median female commuter shares and below-median female commuter shares. The coefficient is significantly positive and substantially larger than the baseline coefficient for the above-median municipality pairs and not distinguishable from zero for municipality with below-median female commuter shares.

Both results suggest that the treatment effect is driven by municipality pairs that are relatively more feasible to commute by public transport, which increases the confidence in our baseline results.

Table 4: Treatment effect, by feasibility of commute

	(1) $\Delta_{ij,t}$Rent	(2) $\Delta_{ij,t}$Rent	(3) $\Delta_{ij,t}$Rent
$1(\text{Post} = 1) \times 1(\text{Savings}_{ij} > Q_{0.8})$	0.051^{**}		
	(0.018)		
$1(\text{Post} = 1) \times 1(\text{Savings}_{ij} > Q_{0.8}) \times$ ...			
... $\times 1(\text{Subscribers}_{ij} > Q_{0.5})$		0.051^{**}	
		(0.018)	
... $\times 1(\text{Subscribers}_{ij} < Q_{0.5})$		0.000	
		(0.050)	
... $\times 1(\text{FemaleShare}_{ij} > Q_{0.5})$			0.090^{**}
			(0.035)
... $\times 1(\text{FemaleShare}_{ij} < Q_{0.5})$			0.028
			(0.019)
Constant	-0.980^{***}	-0.980^{***}	-0.984^{***}
	(0.001)	(0.001)	(0.001)
Obs.	3,494,331	3,494,331	3,247,843
Adj. R2	0.694	0.694	0.693
Month FE	✓	✓	✓
Dyad FE	✓	✓	✓

Note: The table reports the treatment coefficients β of weighted least squares regressions specified in equation 3. Observations are weighted according to the number of commuters between municipalities i and j. Standard errors (clustered at the dyad level) are reported in parentheses ($^{*}p < 0.05$,** $p < 0.01$,** $p < 0.001$).

4.2.3 Location choice motives

We consider two motives for location choices with opposing implications for housing prices. On the one hand, the decrease in commuting costs makes living in more remote, cheaper places further away from work more attractive. This substitution effect may be driven by actual re-location choices (e.g., moving from an expensive city to a cheaper town and commuting to work) as well as omitted re-location choices (e.g., not moving out from one's parents to live closer to the place of work in the city). On the other hand, the decrease in commuting costs allows commuters to spend more on rent. This income effect may be driven by actual re-location choices (i.e., moving to more expensive locations), as well as omitted re-location choices (i.e., remaining in the expensive city even after taking a job in the countryside).

To assess which of these two motives dominates, we assess four heterogeneity dimensions. First, we distinguish by the pre-intervention price level difference between municipalities i and j. If the substitution effect (income effect) dominates, the treatment effect should be more (less) pronounced among municipality pairs where the origin destination is less expensive than the destination municipality.

Second, we classify municipalities into urban and rural municipalities based on their regional classification. Importantly, urban municipalities include large cities such as Berlin or Hamburg, as well as smaller towns and suburbs within the urban regions of large cities. If the substitution effect (income effect) dominates, the treatment effect should be more (less) pronounced when the origin municipality is rural (urban).

Third, as an alternative measure of regional classification, we use the average population density across origin and destination municipality as a heterogeneity dimension.

Finally, as a proxy for the quality of public services provided by a municipality, we use the business tax base of a municipality per inhabitant. The intuition is that municipalities with higher per-capita tax revenues are more attractive (and thus, more expensive).

Table 5 reports the coefficients of the various specifications. The coefficients reported in column 2 suggest that the changes in relative rents are more consistent with an income effect from the reduced commuting costs than with a substitution effect. Specifically, the treatment effect is significantly positive ($p < 0.001$) and substantially larger than the baseline effect when the origin municipality i is more expensive than the destination municipality j. When i is cheaper than j, the treatment effect is significantly negative ($p < 0.001$). The coefficients in column 3 are consistent with this notion as the treatment effect is positive among municipality pairs with an urban residence municipality (i) and negative among municipality pairs with a rural residence municipality (i). More specifically, the treatment is primarily driven by urban-to-rural commutes, for which relative prices increased significantly and by a substantially larger amount than in the baseline (see column 4).

The results are replicated when using population density as a proxy for housing market tightness (column 5) or the difference in per-capita business taxes as a proxy for the quality of public services (column 6).

All of the results reported above suggest that the income effect from the DT dominates the substitution effect. As a consequence, already expensive and densely populated urban municipalities experienced higher relative price pressure due to the DT, which further aggravates the existing divergence in housing costs.

5 Conclusion

Our results suggest that the DT, which substantially reduced public transport commuting costs, has led to an increase in the divergence in housing prices. Municipality pairs with higher estimated cost savings from the DT experienced significant increases in relative housing costs. The heterogeneity in the treatment effect hints at commuters using their savings to live in more expensive urban areas. Given the substantial cost-of-living crisis in large cities across the developed world, our results uncover an important unintended consequence of public transport subsidies. Instead of alleviating cost pressure in tight housing markets by making commutes more attractive, the substantial DT subsidy we study in this paper seems to have aggravated this problem.

Table 5: Treatment effect, by location choice motives

	(1) $\Delta_{ij,t}$Rent	(2) $\Delta_{ij,t}$Rent	(3) $\Delta_{ij,t}$Rent	(4) $\Delta_{ij,t}$Rent	(5) $\Delta_{ij,t}$Rent	(6) $\Delta_{ij,t}$Rent
$1(\text{Post} = 1) \times 1(\text{Savings}_{ij} > Q_{0.8})$	0.051^{**}					
	(0.018)					
$1(\text{Post} = 1) \times 1(\text{Savings}_{ij} > Q_{0.8}) \times$ ...						
... $\times 1(\Delta_{ij,t-1}\text{Rent} > 0)$		0.261^{***}				
		(0.027)				
... $\times 1(\Delta_{ij,t-1}\text{Rent} < 0)$		-0.132^{***}				
		(0.022)				
... $\times 1(\text{Urban}_i)$			0.067^{***}			
			(0.019)			
... $\times 1(\text{Rural}_i)$			-0.093^{**}			
			(0.030)			
... $\times 1(\text{Urban}_i) \times 1(\text{Urban}_j)$				0.036		
				(0.022)		
... $\times 1(\text{Urban}_i) \times 1(\text{Rural}_j)$				0.256^{***}		
				(0.022)		
... $\times 1(\text{Rural}_i) \times 1(\text{Urban}_j)$				-0.109^{***}		
				(0.033)		
... $\times 1(\text{Rural}_i) \times 1(\text{Rural}_j)$				0.066		
				(0.050)		
... $\times 1(\text{Density}_{ij} > Q_{0.5})$					0.052^{**}	
					(0.018)	
... $\times 1(\text{Density}_{ij} < Q_{0.5})$					-0.044	
					(0.035)	
... $\times 1(\Delta_{ij}\text{Business tax p.c.} > 0)$						0.265^{***}
						(0.025)
... $\times 1(\Delta_{ij}\text{Business tax p.c.} < 0)$						-0.175^{***}
						(0.022)
Constant	-0.980^{***}	-0.980^{***}	-0.980^{***}	-0.980^{***}	-0.980^{***}	-0.980^{***}
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Obs.	3,494,331	3,494,331	3,494,331	3,494,331	3,494,331	3,494,331
Adj. R2	0.694	0.694	0.694	0.694	0.694	0.694
Month FE	✓	✓	✓	✓	✓	✓
Dyad FE	✓	✓	✓	✓	✓	✓

Note: The table reports the treatment coefficients β of weighted least squares regressions specified in equation 3. Observations are weighted according to the number of commuters between municipalities i and j. Standard errors (clustered at the dyad level) are reported in parentheses ($^{*}p < 0.05,^{**} p < 0.01,^{**} p < 0.001$).

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Appendix

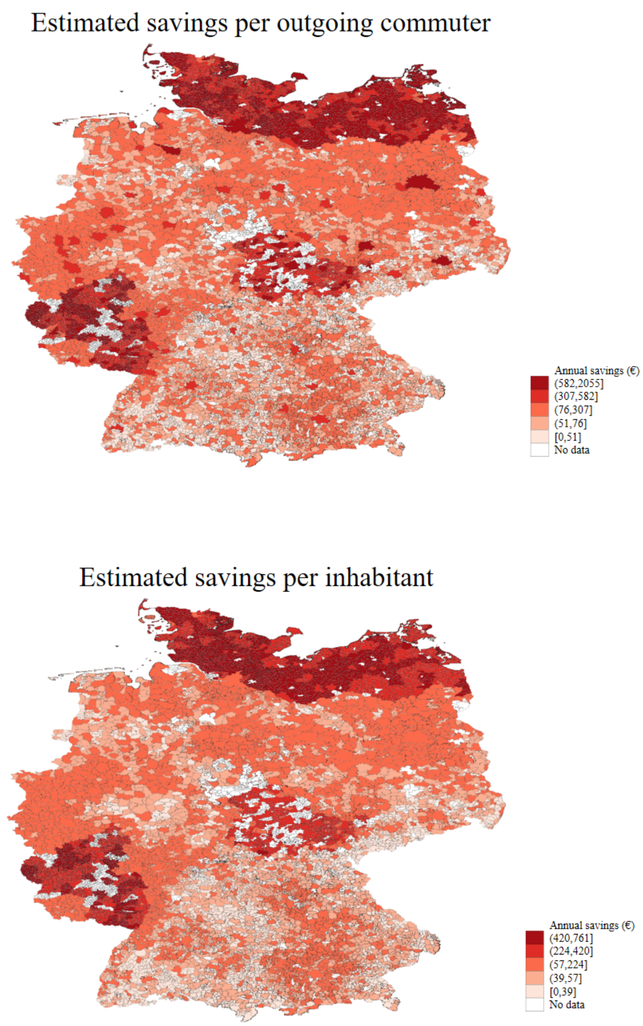
A1: Supplementary tables and figures

Table A1: Commuting distances (km)

	N	Mean	SD	p5	p25	p50	p75	p95
Total labor force	41,331,685	20.6	51.1	3.4	6.0	9.7	16.8	51.4
Panel A: By gender								
Male commuters	21,458,244	22.0	53.9	3.4	6.2	9.9	16.8	56.7
Female commuters	19,710,921	18.4	46.4	3.3	5.8	9.1	16.1	42.8
Panel B: By type of outgoing community (RegioStaR 7)								
Urban: metropolises (R7 = 71)	7,783,406	33.2	81.1	8.1	9.7	15.2	16.8	153.5
Urban: regiopolises (R7 = 72)	6,034,085	22.7	56.9	5.0	6.2	7.8	13.3	74.4
Urban: medium-sized cities (R7 = 73)	10,485,652	16.9	40.9	2.7	4.9	9.1	16.5	37.6
Urban: small towns (R7 = 74)	2,500,570	16.6	28.2	3.1	6.3	11.4	18.9	37.9
Rural: central cities (R7 = 75)	2,506,140	19.3	48.1	4.0	4.8	6.7	13.8	62.9
Rural: medium-sized cities (R7 = 76)	5,855,105	15.8	32.6	3.0	5.0	7.6	15.8	45.6
Rural: small-town areas (R7 = 77)	6,166,727	15.7	25.8	3.0	5.8	9.7	17.1	43.5
Panel C: By type of commute								
Local commuters	19,723,754	7.5	4.0	2.7	4.7	6.4	9.1	16.8
Outgoing commuters	21,607,931	32.6	68.5	5.5	9.8	14.9	25.2	107.6

Note: Municipality types follow the definition of the *Regionalstatistische Raumtypologie* (RegioStaR) provided by the Federal Ministry for Digital and Transport (BMDV, 2021). For local commuters, we compute the radius from the municipality's area in square kilometers a, assuming a circular shape ($r = \sqrt{a/\pi}$).

Figure A1: Regional distribution of cost savings



Note: