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Abstract. We investigate the welfare implications of property taxation. We apply a sufficient statistics approach that accounts for the distributional effects of tax changes at the household level within a spatial equilibrium framework. We show that equity effects are driven by price adjustments in the housing and labor markets, while efficiency is determined by changes in public goods. Using microdata and exploiting 5,500 municipal property tax changes in Germany, where assessed housing values remain constant, we find that 83 percent of the tax burden is passed through to rental prices, with modest labor market effects. Simulations of the welfare effects of property taxes reveal that the price effects of property tax hikes are regressive. Despite the low efficiency costs of the tax, it becomes distributionally neutral only if public good preferences are very high.

Keywords: property taxation, welfare, tax incidence, local labor markets, rental housing
JEL Codes: H22, H41, H71, R13, R31, R38

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1 Introduction

Over the past centuries, real property—comprising land, buildings, and improvements—has constituted the largest share of wealth in both the U.S. and Europe, making the property tax a crucial tool for policymakers (Piketty and Zucman, 2014, Dray et al., 2023). Despite over a century of economic research, our understanding of the effects of property taxes is still in a "sad state" (Oates and Fischel, 2016, p. 415). This assessment seems particularly true regarding the welfare effects of property taxation. Theoretically, two competing views on the incidence of the property tax—the new view vs. the benefit view—offer very different answers to the question of who bears the burden of property taxes. Empirically, institutional settings and data availability make identification challenging: long and wide panels of local property tax rates and housing prices have been relatively scarce, and clean policy variation is hard to isolate with frequent, non-random re-assessments of property values.

In this paper, we aim to add to the understanding of the welfare effects of property taxes by combining a novel theoretical approach with reduced-form evidence based on 5,500 local property tax changes. Theoretically, we extend the canonical sufficient statistics framework to account for both efficiency and equity and apply it for the first time in a spatial equilibrium context. Household welfare only depends on price effects, pre-reform quantities, and the transmission of tax revenues into public goods. Empirically, we exploit the institutional setting in Germany, where municipalities adjust property tax rates but assessed values remain fixed. Based on local housing and labor market panel data, we estimate the relevant price and revenue responses using event study techniques. Finally, we combine the quasi-experimental estimates with a standard household survey to quantify the welfare effects derived from the theoretical framework and simulate the welfare effects of property taxes across the entire income distribution.

The paper consists of three parts. In the first theoretical part, we propose a sufficient statistics approach in a spatial equilibrium context to analyze the welfare effects of property taxation. We extend the conventional sufficient statistics framework, focusing on efficiency effects, by allowing for heterogeneous households and welfare weights. This generalization enables us to pin down both the equity and efficiency effects of property taxes. Starting from a generic utility function, where households enjoy consumption of housing, a composite good, and local public goods, we introduce heterogeneity by allowing households to be (a combination of) renters, landlords, and entrepreneurs. In contrast to canonical spatial equilibrium models, we do not impose any specific functional form or representative agent assumptions. Using standard envelope arguments, we show that household-level welfare effects of a tax change depend on a few empirical objects: (i) price responses on housing and labor markets, (ii) pre-reform behavior and thus expenditures and income streams, and (iii) the utility effect of changes in local public goods. We demonstrate the sufficient statistics properties of our framework by connecting it to other theoretical models studying the impact of property taxation—including partial equilibrium analyses, the capital tax and the benefit view, and the structural spatial equilibrium literature.

In the second part, we use the German institutional setting as a laboratory to estimate the relevant price and revenue responses that determine the welfare effects of the property tax. German municipalities autonomously adjust local property tax rates (*Grundsteuer B*) via municipality-specific scaling factors to a federal tax rate. More than ten percent of German municipalities change their local property tax rate each year, resulting in around 5,500 tax changes that we can exploit for identification. A key feature of our identification strategy is that local tax rates are the only channel through which municipalities can influence the tax burden. Assessed property values remain fixed over time; authorities at the state level assess new buildings based on historical prices. We demonstrate that property tax changes are not systematically driven by housing market shocks or local business cycles. Instead, municipalities increase taxes to consolidate their budget and improve fiscal sustainability. This type of tax variation is very similar to Romer and Romer (2010)'s narrative approach, which has been used to isolate plausibly exogenous tax variation (Guajardo et al., 2014, Alesina et al., 2015, Giroud and Rauh, 2019). We combine administrative data on the universe of municipalities and their local property tax rates with detailed microdata on rental prices from *ImmoScout24*, the leading German real-estate marketplace, between 2007 and 2015. We implement a series of event studies exploiting the within-municipality variation in tax rates over time to estimate reduced form effects of property taxes on rental prices, wages, business income, as well as municipal tax revenues as a proxy for local public goods.

We derive three main empirical results: First, total, tax-inclusive rents increase due to a property tax hike. Our point estimates imply a pass-through of 83% on rental prices. Second, property tax increases only marginally affect local wages and business incomes. Third, tax revenues respond almost one-to-one to a rise in tax rates. The ratio of the estimated revenue effect to the mechanical revenue effect is 0.96, which implies a low deadweight loss. Our event study design shows flat pre-trends in all relevant outcomes. Moreover, baseline estimates survive seven major identification tests: introducing fine regional-by-year fixed effects, inspecting pre-trends in municipal business cycles, testing selection on unobservables, instrumenting for tax rate changes using a rule in the municipal fiscal equalization scheme, varying the size of the effect window, focusing only on large tax changes and applying estimators that are robust to heterogeneous treatment effects.

In the third part of the paper, we combine the sufficient statistics framework with the reduced-form estimates to assess the welfare effects of property taxation. Our approach allows us to go beyond representative agent representations to simulate the relative burden of tax increases. Using microdata from the German Income and Expenditure Survey, we can simulate the predicted money-metric welfare effects of property tax changes at the household level. We find that the *distributional effects* of the property tax are regressive—i.e. when only considering price effects ("incidence"). Utility losses due to a one percentage point increase in the property tax are relatively larger for households at the bottom of the distribution and increase inequality in consumption. Households from the first decile have relative utility losses of around 1.7 percent, while households in the top decile lose around 0.7 percent. This pattern already emerges when relying solely on the partial-equilibrium textbook incidence model. Introducing general equilibrium effects and heterogeneity in pass-through does not qualitatively change the distributional impact. This set of results ignores that higher tax rates raise tax revenues, which can be redistributed to households. Our framework also allows us to quantify this channel and, thereby, to additionally account for the *efficiency effects* of the property tax and their impact on welfare. Assuming that higher property tax revenues directly translate into a higher level of local amenities, we show that the public good channel can offset the regressive distributional effect of the property tax if households value one additional euro of public spending as much as one euro of private consumption. However, in contrast to standard intuition, even in this extreme case of local public good preferences, the property tax rate is not progressive because of general equilibrium responses and heterogeneity in pass-through. As public good preferences decrease, the property tax becomes more regressive and eventually converges to the abovementioned incidence results.

Based on these results, we answer Oates and Fischel (2016)'s question "Are local property taxes regressive, progressive, or what?" as follows: (i) The property tax is *not* progressive, (ii) it is at most neutral as implied by the benefit view, and (iii) it turns regressive under reasonable assumptions on public good preferences and government efficiency.

Related Literature. Our paper contributes to various strands of the literature. Empirically, we provide reduced form evidence on the effects of property taxes on housing prices using administrative tax data from German municipalities and microdata on rental ads. We add to the classical empirical literature on the pass-through of the property tax on rents, which has predominantly focused on the United States and offered a wide range of estimates, ranging from 0–115 percent (Orr, 1968, 1970, 1972, Heinberg and Oates, 1970, Hyman and Pasour, 1973, Dusansky et al., 1981, Carroll and Yinger, 1994). Based on municipal panel data and rich policy variation due to 5,500 local tax changes, we estimate an average pass-through rate of 83%.[1]

To the best of our knowledge, this is the first paper to apply a sufficient statistics approach for welfare analysis in a spatial equilibrium context. Following the seminal contributions by Rosen (1979) and Roback (1982), spatial equilibrium models have become the "workhorse of the urban growth literature" (Glaeser, 2009, p. 25)—see, e.g., Moretti (2011), Kline and Moretti (2014), and Redding and Rossi-Hansberg (2017) for surveys and Ahlfeldt et al. (2015), Diamond (2016), Suárez Serrato and Zidar (2016), Monte et al. (2018), and Fajgelbaum and Gaubert (2020) for recent applications. These quantitative spatial models are very sophisticated and complex, the downside being that they often have to rely on specific and potentially strong assumptions to ensure analytical tractability (Proost and Thisse, 2019, Albouy and Stuart, 2020). We can relax most of these assumptions and arrive at similar welfare conclusions: Effects are governed by changes in housing and labor market prices and local amenities (Busso et al., 2013). For instance, our approach allows us to abstain from specific functional form assumptions on household utility, the firm side, and the housing market. Instead of considering a few

[1] While this paper provides novel evidence on the welfare effects of property taxation, there are a few recent papers studying the quantity effects of property taxes, which are relevant for the efficiency margin. Lyytikäinen (2009) shows that property tax increases reduce housing investments in Finland—a pattern confirmed by Lutz (2015) for the state of New Hampshire in the U.S. Baum-Snow and Marion (2009) show that higher tax credits for low-income housing yield an increase in affordable housing. Levy (2022) shows a similar pattern for France where location-specific buy-to-rent subsidies to investors have a positive effect on the local housing stock.

representative agents, welfare effects can then be simulated at the household level, accounting for various dimensions of heterogeneity—given suitable microdata and empirical estimates.

We also contribute to the literature using sufficient statistics by highlighting the *distributional effects* of tax changes. The existing sufficient statistics approaches in public finance have focused on the efficiency costs of taxation and used it as a measure for the aggregate effect on welfare (Chetty, 2009, Kleven, 2021). We add the distributional perspective to this literature by allowing for household heterogeneity and arbitrary welfare weights. This extension enables researchers to disaggregate welfare effects (e.g., along household characteristics) and disentangle the different channels that drive changes in social welfare. Given the affordability crisis in the housing market, knowing the distributional impacts of this widely-used housing policy is important, particularly in light of recent evidence that individuals' redistributive concerns tend to dominate efficiency arguments in the case of income and estate taxes (Stantcheva, 2021).

The proposed sufficient statistics framework goes beyond the analysis of property taxes. We introduce the model to suit our specific purpose. Still, the same approach could be used to analyze the household-level welfare effects of any policy change; it can also be applied to non-policy-related changes in the economic environment like structural change or trade shocks. Our representation of the framework concentrates on a set of markets relevant to the property tax literature, but many extensions are possible. Two key restrictions to our approach are whether researchers have suitable microdata and credible empirical estimates.

Our paper speaks to the long-standing theoretical debate on the welfare effects of property taxes, where the capital tax (or new) view has been contrasted with the benefit view. The capital tax view adopts a general equilibrium perspective in a closed economy and argues that the national average burden of the property tax is borne by capital owners, i.e., typically richer landlords (Mieszkowski, 1972, Mieszkowski and Zodrow, 1989). Our framework captures this idea by allowing landlords to invest in housing and returns to housing to respond to property taxes. We also account for the position of landlords relative to renters in the income distribution. We deviate from the assumption of a fixed capital stock in the economy and assume global capital markets and perfect mobility of capital such that higher property taxes may reduce the overall housing capital stock in the society. In contrast, the benefit view builds on a Tiebout (1956) model with perfect zoning and mobile individuals, who choose among municipalities offering different combinations of tax rates and local public goods (Hamilton, 1975, 1976). The tax is equivalent to a user fee for local public services. Our framework captures this channel as higher property taxes may increase tax revenues, translating into changes in local public goods, which are valued by households. Thereby, we also speak to the literature highlighting the role of (fiscal) amenities for individual well-being (Gyourko and Tracy, 1991, Bradbury et al., 2001, Bayer et al., 2007, Cellini et al., 2010, Ferreira, 2010, Boustan, 2013, Schönholzer and Zhang, 2017, Brülhart et al., 2024).

The remainder of this paper is organized as follows. In Section 2, we introduce the theoretical framework. Section 3 introduces the institutional setting of property taxation in Germany and describes the data used. We set up our empirical model in Section 4 and present reduced-form results in Section 5. Section 6 presents the welfare effects of the tax. Section 7 concludes.

2 Welfare Effects of Policy Changes

In this section, we propose a general sufficient statistics framework to quantify the welfare effects of policy changes. In Section 2.1, we introduce the framework and derive the welfare consequences of local property tax increases. In Section 2.2, we discuss the relation to other modeling approaches of property tax incidence, including quantitative structural spatial equilibrium models.

2.1 Sufficient Statistics for Household Welfare

The economy consists of a continuum of households $i \in \mathcal{I}$ who choose to live in one out of many small cities, $c \in \mathcal{C}$. Cities may differ in size, productivity, and local amenities A_c. These amenities include local public goods and services like safety, parks, and infrastructure. They may also capture exogenous, geographical attributes such as sunshine hours. Municipalities levy a property tax t_c on real estate and land and use the revenues to finance the endogenous part of A_c.

We assume that households derive utility from consuming housing h_i, a composite good x_i, and local amenities A_c. Households pay the tax-inclusive consumer price $q_c = p_c + t_c$ per square meter of housing h_i.[2] Their budget constraint is given by $x_i + q_c h_i = y_i$, where y_i is income and x_i the numéraire. Households may receive income from various activities. We focus on the three income streams typically covered in the spatial equilibrium literature: wages, profits, and rental income. Households may supply labor hours l_i and earn hourly wages w_c, which leads to the classical consumption-leisure trade-off. Similarly, households may use their time to exert entrepreneurial effort e_i and receive business income $\pi_c e_i$. Business incomes might derive from a local firm that is subject to the local property tax (Suárez Serrato and Zidar, 2016), and from developers who use land and capital to produce floor space (Ahlfeldt et al., 2015). Some households become landlords and rent out floor space s_i. Being a landlord generates rental income $p_c s_i$ but is costly as it requires time and financial investments. Finally, households may have fixed other income m_i. Hence, we define income as $y_i = w_c l_i + \pi_c e_i + p_c s_i + m_i$.

Households differ in preferences and characteristics, including endowments, occupations, and household composition. We summarize all this heterogeneity in the household-specific utility function $u_i(x_i, h_i, l_i, e_i, s_i, A_c)$, which is differentiable in all arguments with marginal utilities $u'_x, u'_h, u'_A > 0$ and $u'_l, u'_e, u'_s < 0$.[3]

Households maximize utility by choosing consumption goods and locations, and (potentially) supplying labor, entrepreneurial effort, and rental units. Assuming that the economy is in equilibrium (indicated by superscript stars), we derive the following result:

Proposition 1 (Household Welfare)**.** *The money-metric effect of a small increase in the local property*

[2] Property taxes could also be modeled as ad valorem taxes.

[3] For comparability and to investigate comparative statics, we recast our model economy in a fully specified canonical structural framework following Suárez Serrato and Zidar (2016) and Ahlfeldt et al. (2015) in Appendix A.

tax t_c on household i's utility is given by:

$$\Delta W_i := \frac{\mathrm{d}u_i/\mathrm{d}t_c}{\partial u_i/\partial x} = -h_i^*\frac{\mathrm{d}q_c^*}{\mathrm{d}t_c} + l_i^*\frac{\mathrm{d}w_c^*}{\mathrm{d}t_c} + e_i^*\frac{\mathrm{d}\pi_c^*}{\mathrm{d}t_c} + s_i^*\frac{\mathrm{d}p_c^*}{\mathrm{d}t_c} + \delta_i\frac{\mathrm{d}A_c^*}{\mathrm{d}t_c} \qquad \textit{with } \delta_i = \frac{\partial u_i/\partial A_c}{\partial u_i/\partial x}. \quad (1)$$

This proposition follows directly from the envelope theorem (see Appendix B for a formal derivation). The consequences of a small tax increase on household i's utility are summarized by a few empirical objects: (i) the pass-through of tax increases in (tax-inclusive) factor prices, (ii) households' pre-reform behavior and thus consumption and income streams, and (iii) the change in local amenities. The latter effect is weighted according to household i's relative preference for public vs. private goods and services. Following from the standard envelope argument, changes in household behavior—i.e., quantity responses—have no first-order consequences for utility.

Aggregation and Social Welfare. The household welfare effects ΔW_i can easily be aggregated into changes in social welfare $\Delta W := \sum_i g_i \Delta W_i$ by imposing a set of social marginal welfare weights g_i (Saez and Stantcheva, 2016).

Distribution and Efficiency. Proposition 1 captures both the equity and efficiency effects of a property tax increase. Most of the existing sufficient statistics literature focused on efficiency (Kleven, 2021). The standard approach estimates tax base effects to measure the deadweight loss and thus the potential for welfare improvements absent distributional concerns. Efficiency effects enter our framework via the transmission of tax revenues into amenities (as in the benefit view, see below): The larger the distortions caused by higher property taxes, the lower the additional tax revenue, and the lower the potential to expand amenities. Let B_c be the tax base and assume that tax revenues translate one-to-one into amenities, such that $A_c = t_c B_c$. Then, $\mathrm{d}A_c/\mathrm{d}t_c \cdot t_c/A_c = 1 + \mathrm{d}B_c/\mathrm{d}t_c \cdot t_c/B_c$. The latter term $\mathrm{d}B_c/\mathrm{d}t_c \cdot t_c/B_c$ is the tax base elasticity, which plays the key role in standard sufficient statistics welfare analyses (cf., e.g., Chetty, 2009, for a discussion of the elasticity of taxable income in the context of the personal income tax).

We extend this approach by additionally illustrating the distributional effects. Equity effects are governed by price responses ("incidence"), that determine which households bear what share of the tax burden. In the standard model, such price effects are at play as well but cancel out and do not affect aggregate welfare ΔW under certain assumptions.[4] We abstain from these assumptions and allow for heterogeneous households and arbitrary welfare weights instead. Thereby, our framework is additionally able to capture distributional effects between households as we aim to estimate ΔW_i along the income distribution using household microdata.

[4] Too see this in our set-up, consider a partial-equilibrium perspective of the housing market with social welfare changes $\Delta W = \sum_i g_i(-h_i^* \mathrm{d}q_c^*/\mathrm{d}t_c + s_i^* \mathrm{d}p_c^*/\mathrm{d}t_c + \delta_i \mathrm{d}A_c^*/\mathrm{d}t_c)$. Let us further impose that taxes fund public services one-to-one: $\mathrm{d}A_c^*/\mathrm{d}t_c = \sum_i (\mathrm{d}t_c h_i^*/\mathrm{d}t_c)/|\mathcal{I}| = (\sum_i h_i^* + t_c \mathrm{d}\sum_i h_i^*/\mathrm{d}t_c)/|\mathcal{I}|$, which distinguishes mechanical and behavioral revenue effects. Using $q_c^* = p_c^* + t_c$, we can rewrite $\Delta W = -\mathrm{d}(p_c^* + t_c)/\mathrm{d}t_c \sum_i g_i h_i^* + \mathrm{d}p_c^*/\mathrm{d}t_c \sum_i g_i s_i^* + (\sum_i h_i^* + t_c \mathrm{d}\sum_i h_i^*/\mathrm{d}t_c)\sum_i g_i \delta_i/|\mathcal{I}|)$. With market clearing ($\sum_i h_i^* = \sum_i s_i^*$), uniform social marginal welfare weights ($g_i = 1$), and $\delta_i = 1$, the formula simplifies to: $\Delta W = t_c \mathrm{d}\sum_i h_i^*/\mathrm{d}t_c$, which is the behavioral revenue loss as in the traditional Harberger style analysis.

Empirical Implementation. Proposition 1 characterizes the welfare implications of property tax increases in terms of estimable sufficient statistics, namely the reduced-form effects of property taxes on equilibrium rents, wages, profits, and amenities. Equation (1) describes these welfare effects in a generic form, where housing price, income, and public good responses to property tax changes are homogeneous at the city level. In practice, it will often be more realistic to allow for heterogeneity in price effects, e.g., by housing segments, worker types, or income groups. The theoretical framework naturally allows for such extensions.

Moreover, the welfare effects depend on how much household i spends on housing, how much it works, and in which occupation(s), as well as the relative preference for local public goods and services. Pre-reform equilibrium quantities $h_i^*, l_i^*, e_i^*, s_i^*$ (or corresponding income streams and expenses) are typically observable in household microdata. While surveys might produce evidence on individual public good preferences δ_i, in most cases, researchers impose some form of homogeneity within certain groups of individuals and estimate or calibrate the parameter accordingly (as in Suárez Serrato and Wingender, 2014, Fajgelbaum et al., 2018, and Brülhart et al., 2024).

In Section 5, we estimate the price effects of property tax changes, exploiting the institutional setting in Germany with numerous small tax reforms at the local level. We then connect theory and empirics in Section 6 to simulate the welfare effects of tax increases at the household level. We also illustrate the empirical relevance of different types of heterogeneity in our setting.

2.2 Relation to Property Tax Literature

In the following, we discuss how our approach relates to alternative modeling approaches for studying the welfare effects of property taxes.

Partial Equilibrium. The result in Proposition 1 nests the standard textbook model of tax incidence in a partial equilibrium setting. To see this, consider a world with only two price-taking households R and L, and abstract from public goods. Household R has fixed income and consumes housing h at price q including taxes, i.e., $u_R(-qh, h)$. Household L lives abroad and receives rental income ps from renting out real estate to R. Her utility thus reduces to $u_L(ps, s)$, which equals $u_L(ph, h)$ if markets clear. Higher taxes affect household welfare by $\Delta W_R = -h\mathrm{d}q/\mathrm{d}t$ and $\Delta W_L = h\mathrm{d}p/\mathrm{d}t$, respectively. The loss in household R's utility after introducing property taxes t increases in (i) the amount h of floor space rented and (ii) the pass-through of taxes on consumer price rents q. Similarly, landlord L's welfare loss depends on (i) the amount of floor space rented out ($s = h$) and (ii) the pass-through of taxes on net-of-tax rents, i.e., producer prices p. The pass-through on q and p determines whether R or L bear the larger share of the tax burden, corresponding to changes in consumer and producer surplus, respectively.

Capital Taxes and General Equilibrium. Proposition 1 also incorporates potential interactions with other sectors. A classic example highlighted in the capital tax view of property taxation is general-equilibrium effects on the capital market (Mieszkowski, 1972). With property taxes reducing the after-tax yield on capital in the housing market, capital owners are expected to shift investments to more profitable uses. This shift away from the housing sector reduces the demand for construction services and residential land—potentially hurting workers and owners of construction companies as well as landowners. Higher costs for commercial real estate also create an incentive for local firms to substitute for other production factors. Under certain conditions (e.g., a fixed capital supply in the economy), property taxes may also reduce the overall return on capital and, thus, capital incomes. Such general-equilibrium responses trigger additional welfare effects that need to be taken into account. We subsume these effects in the proposition above via their impact on wages ($\mathrm{d}w_c^*/\mathrm{d}t_c$) and profits ($\mathrm{d}\pi_c^*/\mathrm{d}t_c$).

Tiebout Sorting. Moreover, Proposition 1 incorporates a key mechanism of the benefit view of property taxation, where taxes act like user fees for local public services and households move to find their preferred mix of taxes and amenities (Tiebout, 1956, Hamilton, 1976). A standard partial-equilibrium analysis would neglect the fact that municipalities around the world use property taxes to finance local public goods. The welfare consequences of property tax reforms thus crucially depend on the use of tax revenues. This idea is reflected in the last term on the right-hand side of the equation in Proposition 1: if tax increases translate into higher levels of local public good provision ($\mathrm{d}A_c^*/\mathrm{d}t_c > 0$), households are compensated for higher costs-of-living (in proportion to their relative preferences for public goods, δ_i). If rent increases and public good expansions exactly offset each other, property taxes will have no impact on household welfare.

Quantitative Spatial Equilibrium. Combining general equilibrium analyses with a spatial perspective is the key feature of local labor market and quantitative spatial models (see, e.g., Epple and Sieg, 1999, Kline, 2010, Moretti, 2011, Redding and Rossi-Hansberg, 2017). Assuming that households, firms, and capital are mobile across space gives rise to further equilibrium responses and capitalization effects in local prices and incomes. A prime example of such a spatial equilibrium mechanism is labor mobility (Brueckner, 1981). If workers can avoid a city's rising property tax by moving to another place, local firms will have to pay a compensating differential for workers to stay in the city ($\mathrm{d}w_c^*/\mathrm{d}t_c > 0$). Hence, the capitalization of tax increases in local equilibrium prices and incomes depends on the degree of mobility of workers and firms. Moreover, firms typically pay property taxes as well, which will affect input factors, their prices as well as after-tax profits. Equation (1) reflects the welfare impact of these various mechanisms in the reduced-form effects on rents, wages, and profits.

Proposition 1 offers a shortcut to the often complex derivations of equilibrium conditions in structural spatial equilibrium models (cf. Appendix A for a structural representation of our framework). By applying a sufficient statistics approach, we abstract from specific functional form assumptions on, e.g., household utility or firm production. Moreover, we allow for an arbitrary level of heterogeneity in household characteristics, choices, and preferences, which have been assumed homogeneous in many previous applications. For example, households may combine different occupations and receive income from various sources, whereas workers, firm owners, and landlords used to be modeled as three distinct representative agents in canonical structural models. We also abstain from the usual requirement that firm owners and landlords are absent from the city. Equation (1) enables a direct mapping between theoretical predictions and reduced-form results using microdata and, e.g., estimating heterogeneity by household types or market segments. In contrast, quantitative spatial equilibrium models have to impose more structure in order to keep the model analytically tractable.

3 Institutions and Data

We rely on the institutional setting of local property taxation in Germany to identify the sufficient statistics needed to quantify the household level welfare effects. Section 3.1 describes the relevant features of property taxation in Germany. Section 3.2 gives an overview of the data used in our empirical analysis.

3.1 Property Taxation in Germany

The German property tax (*Grundsteuer B*) is a one-rate tax levied on the value of land and built structures. Residential and commercial properties are both subject to the same property tax rate. The tax rate is collected by the municipality, and local property tax revenues are one of the most important revenue sources for German municipalities, amounting to a total of 12 billion EUR for all municipalities in 2013. Importantly, municipalities can only adjust the local tax rate. All other legal regulations of the property tax, i.e., the definition of the tax base as well as assessment rules, are set at the federal level and have been unchanged during the period we study and also decades before.[5]

The property tax liability is calculated according to the following formula:

$$\textit{Tax Liability} = \textit{Assessed Value} \times \underbrace{\textit{Federal Tax Rate} \times \textit{Municipal Scaling Factor}}_{\text{Local Property Tax Rate}}. \tag{2}$$

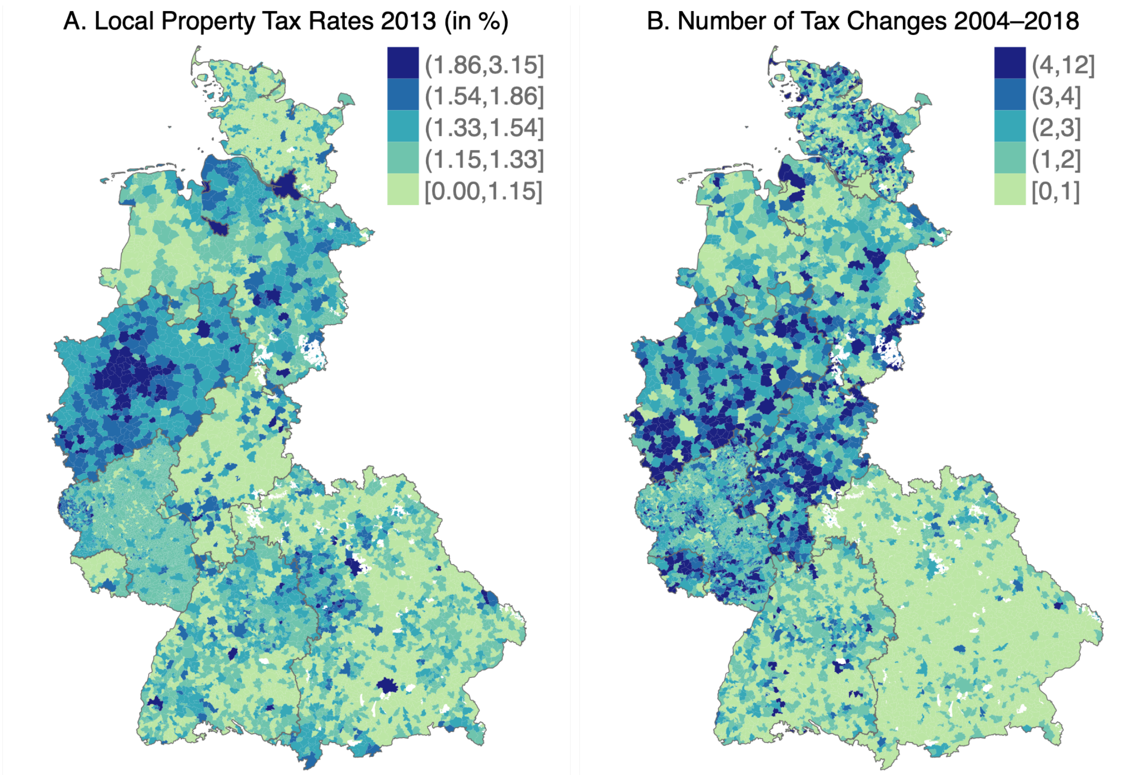
We discuss the different elements of the formula below.

Assessed Values. The property value (*Einheitswert*) is assessed by the state tax offices (not by the municipality) when the property is built and, importantly, remains fixed over time. The last general assessment of property values took place in 1964 in West Germany. In order to make the assessment comparable for new buildings, property valuation is based on prices as of 1964 using historical rents. There is no regular reassessment of properties to adjust the assessed value to current market values or inflation. Neither are assessed values updated when the property is sold. Reassessments only occur if the owner creates a new building or substantially improves an existing structure on her land.[6] As a consequence, assessed values differ from

[5] See Spahn (2004) for a more detailed discussion. All legal regulations can be found in the *Grundsteuergesetz*.

[6] The improvement has to concern the "hardware" of the property, such as adding a floor. Maintaining the roof or installing a new kitchen does not lead to a reassessment. Lock-in effects or assessment limits are thus not an issue in the German context other than in some U.S. states (see, e.g., Ferreira, 2010, Bradley, 2017).

Figure 1: Variation in Local Property Taxes



Notes: The left panel of this figure shows the local property tax rates in 2013 for all West German municipalities, assuming a federal tax rate of 0.35 percent. The right panel depicts the number of local property tax changes by municipality in the period 2004–2018. Municipalities are grouped into population-weighted quintiles and shaded according to the tax rate or the number of tax changes, respectively. Jurisdictional boundaries are as of December 31, 2015. Gray lines indicate federal state borders. White areas indicate unpopulated unincorporated areas (*gemeindefreie Gebiete*). See Appendix C for detailed information on all variables. *Maps:* © GeoBasis-DE / BKG 2019.

current market values. The average assessed value for West German homes was 39,136 EUR in 2013, roughly a fifth of the reported current market value (EVS, 2013). Assessment notices do not provide any detail on how specific parts of the building contribute to the assessed value. These practices make the assessment barely transparent for landlords and renters. There is also no deduction for mortgage payments or debt services in the German property tax.

Federal Tax Rates. The federal tax rate (*Grundsteuermesszahl*) is set at 0.35 percent for all property types in West Germany with only two exceptions. First, the federal tax rate for single-family homes is 0.26 percent up to the assessed value of 38,347 EUR; and 0.35 percent for every euro the assessed value exceeds this threshold. Second, the federal tax rate for two-family houses is 0.31 percent.

Municipal Scaling Factors. Municipal councils decide annually on the local scaling factor (*Realsteuerhebesatz*). The decision is usually made at the end of the preceding year, and most tax changes become effective in January.

Figure 1 demonstrates the substantial cross-sectional and time variation in local property tax rates induced by differences and changes in scaling factors. The left panel of the figure shows local tax rates for all West German municipalities in 2013, assuming an average federal tax rate of 0.35 percent. Depicted local property tax rates vary between 0.8 and 3 percent (bottom and top one percent). Annual mean and median tax rates increased steadily from around 0.9 in 1990 to 1.3 percent in 2018.

The right panel of Figure 1 demonstrates the number of municipal scaling factor changes from 2004 to 2018, i.e., the years we exploit for identification. Over this period, 84 percent of all municipalities have changed their local tax rate at least once. On average, municipalities changed the factor twice during this period, i.e., every seven years. Many municipalities experienced even more changes. One percent of municipalities changed their property tax multiplier more than seven times since 2004. Around 94 percent of all tax changes during this period are tax increases.

We show in Section 5.2 that reforms are not driven by local business cycles. Instead, and in line with Fuest et al. (2018) and Lichter et al. (2024), we demonstrate and discuss in Section 4.2 that municipalities increase property taxes to improve their fiscal position.

Statutory Incidence and Ancillary Costs. The statutory incidence of the property tax is on the property owner, i.e., the landlord. However, a salient legal regulations on operating costs (*Betriebskostenverordnung*) stipulates that property taxes for rental housing are part of the ancillary costs (*Nebenkosten*) that renters have to pay to their landlords on top of monthly net-of-tax rents. By this regulation, landlords are directed to include the tax payments also in the ancillary bill that renters receive each spring retroactively for the preceding year. Other typical ancillary costs are fees for garbage collection, water supply, or janitor and cleaning services.

Municipal Revenues and Local Public Goods. Property (and business) tax revenues are an important source of revenue for German municipalities because they are the only major instruments at the disposal of municipalities to raise tax revenues. In 2013, the average (median) annual revenues of municipalities were 2,691 (2,353) euro per capita. 28% of the revenues are coming from local business and property taxes that are directly controlled by the municipalities. Per capita property tax revenues average to 155 euro (21% of local taxes).[7]

Compared to the U.S., revenues raised at the state and local level are lower in Germany. Unlike in the U.S., important types of local public goods such as schooling, police, or high and freeways are financed at the level of the state or federal level. About 80% of the expenditures are spent on maintaining the usual administrative duties, that is, to pay municipal employees, maintain the existing buildings, co-finance public firms (waste, energy, and public transport), and cover housing costs of welfare recipients as mandated by federal law. About 15% of the expenditures are used for investment projects, such as rebuilding the city hall, replacing street lamps, or extending parks.

[7] Other important revenues come from federal level taxes. Municipalities receive a share of the personal income tax revenues and the value-added tax revenues, based on the number of taxpayers and other economic indicators.

3.2 Data and Descriptive Statistics

We combine housing market microdata with administrative data on the fiscal and economic situation of German municipalities, and administrative wage and employment data from social security registers. Based on these sources, we construct an annual panel data set for the universe of West German municipalities.[8] This section gives an overview of the data used for our empirical analysis and the estimation sample. Appendix C provides more details on the definition and the sources of all variables.

Housing Market Microdata. Our main data source is a microdata set with real-estate advertisements covering apartments offered for rent on the online platform *ImmoScout24*. This website is by far the largest real estate platform in Germany. The data includes real-estate advertisements since 2007, yielding on average more than three million ads per year. The data is provided by the research data center FDZ Ruhr at RWI (Boelmann and Schaffner, 2019).

The most important information we extract from this data set is rental prices. Our main variable is the total rent per square meter, i.e., the consumer price of housing, q_c. This variable includes property tax payments and all other ancillary costs (*Bruttowarmmiete*).[9] We also observe the net-of-tax rent (*Nettokaltmiete*), i.e., the producer price, p_c, which is also the contractually agreed and legally binding price. As common for data from internet platforms, prices are offered and not transaction prices. In the German rental market, there are few negotiations and offered rents are usually well in line with concluded rents (Mense et al., 2023).

Besides rents, the dataset contains a vast set of housing unit characteristics mentioned in the real-estate ads. We residualize both rent-per-square-meter measures in a standard hedonic regression accounting for the following characteristics: construction year, number of rooms, type of dwelling, housing unit quality, plot size quality of equipment and furnishings. The data also includes municipality identifiers for the location of the advertised object. This regional information allows ads to be linked to the corresponding municipalities, the respective property tax rates, and various other fiscal and economic indicators.

German Municipality Data. We compile a comprehensive municipality-year panel using data from various administrative sources. The Federal Statistical Office and the Statistical Offices of the Länder provide the largest part of this municipality-level data. The most important variable in the context of this study is the municipal property tax rate, which we observe since the 1990s. In addition, we extract economic and fiscal indicators, such as municipal population, tax revenues, or business profits. Besides data from the statistical offices, we compile data on the local number of individuals registered as unemployed as well as county-level GDP to proxy

[8] We exclude East Germany from our baseline sample since there has been a substantial amount of municipal mergers within East Germany from the mid-1990s until the late 2000s, which induces measurement error in the main regressors (Fuest et al., 2018). Moreover, the federal tax rate in East Germany is different from West Germany (cf. Section 3), which implies that the same change in the local scaling factor leads to different increases in the local property tax rate. Results are similar when including East Germany (see Section 5.2).

[9] We drop properties with unrealistic prices per square meter (bottom and top 0.5 percent) and ads that have been online for over half a year.

and control for fluctuations in the local business cycle. We further use social security data provided by the Institute for Employment Research (IAB) on municipal-level average wages.

Estimation Sample. We combine housing market and municipality data to build an estimation sample with municipality-year observations spanning the period from 2008 to 2015. In the main estimation sample, we can exploit rental data for around 4,000 municipalities, which cover more than 90 percent of the West German population. The sample period is narrower than the original data coverage since we include leads and lags of property tax rate changes as the main explanatory variable (see Section 4.1). In the baseline specification, we use tax data from 2004 until 2018.

Appendix Table C.2 provides descriptive statistics of our baseline sample listing all outcome variables, main regressors, and control variables used in the empirical analysis.

4 Empirical Strategy

4.1 Empirical Model

As derived from the theoretical framework, we are interested in the effects of property taxes on the following outcome variables: total (tax-inclusive) and net-of-tax rents as well as wages, business profits, and tax revenues. We make use of an event study design similar to Suárez Serrato and Zidar (2016) to investigate the effects of property tax changes with $\bar{j}$ lags and $\underline{j}$ leads of the treatment variable. Using the distributed-lag representation in a first-differences setting, our empirical model is given by:

$$\Delta \ln Y_{c,t} = \sum_{j=-\underline{j}+1}^{\bar{j}} \gamma_j \Delta PropertyTaxRate_{c,t-j} + \psi \Delta \boldsymbol{X}_{c,t} + \theta_{r(c),t} + \varepsilon_{c,t}, \tag{3}$$

where we regress the first difference of outcome variable Y (in logs) in municipality c, metropolitan statistical area (MSA) $r(c)$, and year t on leads and lags of year-to-year changes in the local property tax rate, $\Delta PropertyTaxRate_{c,t}$. Our main outcome variable is the hedonically corrected total rent per square meter in municipality c and year t. In addition, we assess the effect of property taxes on other housing or local labor market variables as suggested by our theoretical framework. Municipal control variables, which are included depending on the specification (see below), are denoted by $\boldsymbol{X}_{c,t}$. In the baseline specification, we include the local business tax rate—the other tax instrument at the disposal of German municipalities. The error term is denoted by $\varepsilon_{c,t}$. In our baseline specification, the regression is weighted by municipal population—we find very similar results when using alternative measures such as the number of ads.

This specification is equivalent to using a standard event study where treatment indicators for tax changes are scaled with the size of the tax change and treatment indicators at the endpoints of the effect window ($j = -\underline{j}, \bar{j}$) are binned (Schmidheiny and Siegloch, 2023). First-differencing wipes out time-invariant municipal confounders. The model further includes

74 sets of MSA-by-year fixed effects $\theta_{r(c),t}$, controlling flexibly for annual shocks at the level of metropolitan statistical areas (*Raumordnungsregionen*).

Since Equation (3) is specified as a distributed-lag model, we need to cumulate the resulting estimates $\widehat{\gamma}_j$ of year-to-year effects over j to make them interpretable in a canonical event study logic. We thus sum the distributed-lag estimates to recover the treatment effect estimates $\widehat{\beta}_j$ relative to the pre-treatment period. Normalizing effects to one period prior to the property tax reform, i.e., setting $\widehat{\beta}_{-1} = 0$, treatment effect estimates $\widehat{\beta}_j$ can be uniquely recovered:

$$\widehat{\beta}_j = \begin{cases} -\sum_{k=j+1}^{-1} \widehat{\gamma}_k & \text{if } -\underline{j} \leq j \leq -2 \\ 0 & \text{if } j = -1 \\ \sum_{k=0}^{j} \widehat{\gamma}_k & \text{if } 0 \leq j \leq \overline{j}. \end{cases} \tag{4}$$

The event-study nature of the empirical setup enables us to investigate dynamic treatment effects of property taxes on the respective outcomes and thereby account for lagged responses and potential delays in housing market adjustment. Our baseline specification includes four leads and lags, i.e., $\underline{j} = 4$ and $\overline{j} = 4$, respectively. The choice of the event window is determined by data availability over time. Our baseline specification is a compromise between the length of the event window and statistical power. We experimented with other event window definitions, finding very similar results (see Section 5.2).

Inference is based on cluster-robust standard errors accounting for arbitrary correlation of unobserved components within municipalities over time.

4.2 Identification

Our identifying variation is induced by around 5,500 property tax changes. In order to identify the causal effect of property taxes on outcome Y, we need parallel trends between municipalities with and without a property tax change in the absence of tax changes. Following common practice, we assess the plausibility of our identifying assumption by testing for pre-treatment differences in trends.

While our empirical findings presented below show flat pre-trends throughout, it is important to understand why municipalities change tax rates. When investigating the role of municipal confounders (see the second test in Section 5.2), we show that municipalities raise taxes and cut expenditures to reduce the reliance on debt and improve fiscal sustainability. This type of tax variation is very similar to Romer and Romer (2010)'s narrative approach, which has been used to isolate plausibly exogenous tax variation (Guajardo et al., 2014, Alesina et al., 2015, Giroud and Rauh, 2019).

A remaining concern for identification is confounding shocks that coincide with tax changes and, hence, do not show in the pre-trends. While MSA-by-year fixed effects absorb any shock at the level of the metropolitan statistical area, estimates could still be biased if shocks occurred at finer geographical levels. We conduct seven major identification tests to assess whether our research design is able to identify the causal effect of property taxes.

First, we assess the role of regional confounders and replace the MSA-by-year fixed effects with fine-grained region-by-year dummies and analyze if and how pre- and post-treatment estimates respond. We thereby move the model closer to a border design: in the extreme case, we include commuting zone-by-year fixed effects and only compare municipalities within the 204 CZs (instead of the 74 MSAs). Second, we assess the role of municipal confounders (which cannot be assessed by the former test). We directly test for pre-trends when using potential confounders such as local unemployment, GDP per capita, and population as outcomes. Moreover, we include (the lags of) these variables as controls in our baseline model. Third, we assess the role of other unobservable municipal confounders by calculating bounds on our estimates following Oster (2019). Fourth, we purify the variation in municipal property taxes by applying an instrumental variables strategy, exploiting a feature of the German fiscal equalization schemes at the level of the federal states (see Appendix D for details). Fifth, we vary the size of our effect window, which directly affects which municipality-year observations are used in the treatment and control group (Schmidheiny and Siegloch, 2023). Sixth, we test whether our results are robust to using dummy variable specifications, which only focus on larger tax changes (Akcigit et al., 2022). Seventh, we assess whether our estimates are biased by heterogeneous treatment effects by applying the estimators of Sun and Abraham (2021) as well as de Chaisemartin and D'Haultfœuille (2020, 2024).

5 Reduced-Form Effects of Property Tax Changes

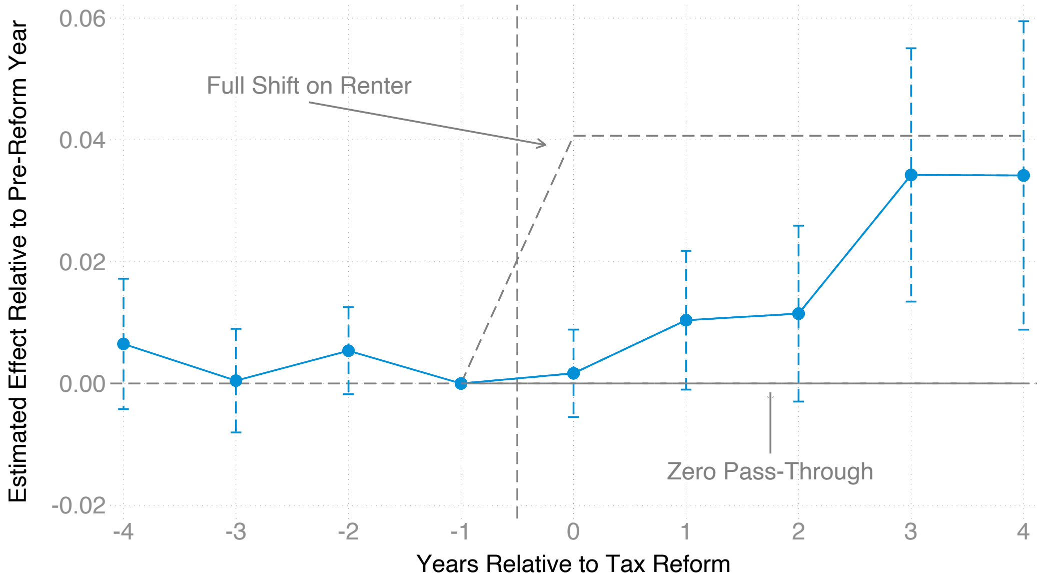
This section presents the reduced-form effects of property tax changes using the outlined empirical approach. In Section 5.1 we present the baseline results for the effect of property taxes on rental prices. We test the identification in Section 5.2.

5.1 Property Taxes and Rental Prices

Figure 2 shows the baseline result for the effect of property taxes on the total rent including property taxes, i.e., the consumer price of housing. While pre-trends are reasonably flat and statistically indistinguishable from zero, the figure shows that tax-inclusive rents increase following a hike in the property tax. A one percentage point increase in the local property tax rate (which corresponds roughly to a 70 percent increase in the tax rate) leads to a 3.4 percent increase in total rents after three years. The endpoints of the event study also reflect the long-run average effects (Schmidheiny and Siegloch, 2023), as estimates remain stable when extending the number of lags (see below). We can relate this number to the average tax-to-rent ratio of 4.1% as reported in the German Income and Expenditure Survey (EVS, 2013). Our estimate thus translates into an 83% pass-through of property taxes on renters, as indicated by the gray dashed lines.

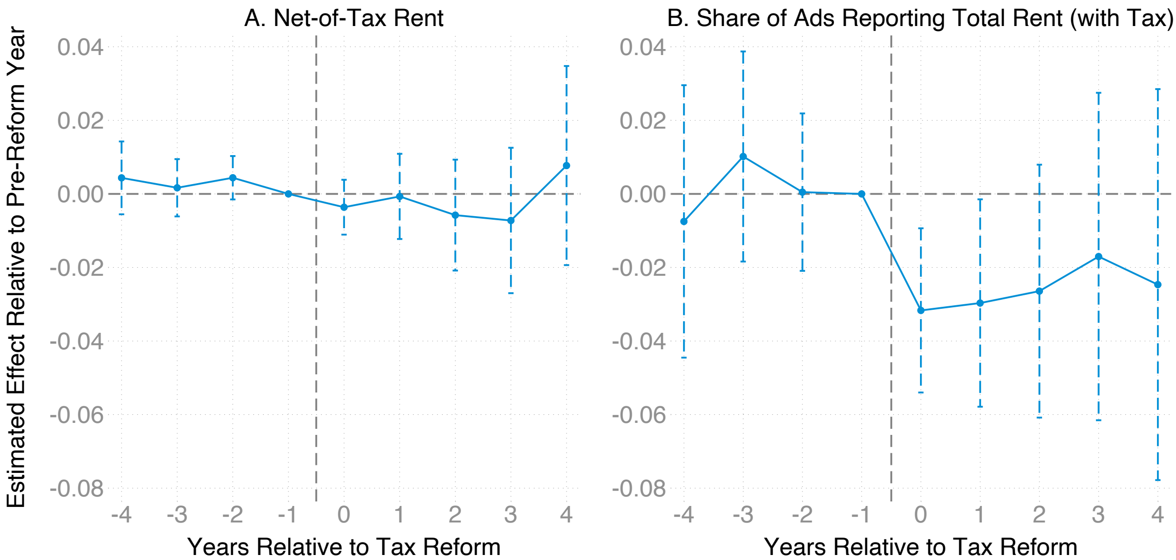
Our results imply that in the long run, the lion's share of the property tax is passed through to consumer prices. In the short run—i.e., up to two years after the policy change—around one-third of the property tax due appears to be passed through. A likely explanation for this sluggish adjustment is rooted in the institutional setting of the German property tax and the fact that we draw on apartment advertisement data. As discussed in Section 3.1, landlords are

Figure 2: Effect of Property Taxes on Total Rent



Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year. The underlying econometric model is described in equations (3) and (4). The specification also accounts for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. Dashed gray lines indicate the implied estimates for either zero or full shifting of taxes from landlords to tenants based on the corresponding average tax-to-rent ratio reported in the German Income and Expenditure Survey (EVS, 2013). See Appendix C for detailed information on all variables.

Figure 3: Pass-Through of Property Taxes: Mechanisms



Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on log net-of-tax rents (Panel A) and the share of ads that reported the total, tax-inclusive rent (Panel B), both relative to the pre-reform year. The underlying econometric model is described in equations (3) and (4). The specification also accounts for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

allowed and even supposed to bill the full property tax payments to tenants via the ancillary costs. This implies that even if property taxes changed just after signing the contract, landlords are entitled to charge tenants higher tax payments without changing the rental contract. Put differently, landlords might (either strategically or unconsciously) choose to not update the advance payments for the ancillary costs in their online ads after a tax increase because they will still receive the full tax amount at the end of the year.

One way to test for this mechanism is to check the effect on net-of-tax rents (*Nettokaltmiete*), which have to be stated in the rental contract and are the legally binding price. Panel A of Figure 3 shows that net-of-tax rents, i.e., producer prices, are largely unaffected by property tax changes. This corresponds to the close-to-full-shifting long-run results conveyed by Figure 2. Importantly, we do not see a significant decline in the producer price in the short run, which implies that landlords immediately pass through the major share of property taxes on renters.[10]

Given the zero effect on the legally binding net-of-tax rent, the sluggish adjustment in tax-inclusive total rents may be explained by (i) a lack of salience or attention to the tax on the side of the landlord (Chetty, 2009), or (ii) an active and potentially strategic decision of landlords. Whereas net-of-tax rents need to be included when posting rental ads online, landlords can choose whether to specify the total rent including ancillary costs in addition. Panel C of Figure 3 shows the effect of property tax increases on the share of ads that report both the net and the total rent, i.e., both net-of-tax producer prices and consumer prices including taxes. The graph shows that the share of ads containing information on such ancillary costs drops immediately after a property tax increase by around three percentage points (or around 6%). This pattern suggests that landlords try to reduce the salience of higher total rents due to increasing property taxes given that they can charge higher taxes retroactively.

Against this backdrop, we thus expect close to full-shifting already in the short run. In the German context, the institutional setting helps ensure that the effective statutory incidence determines large parts of the economic incidence.

5.2 Identification and Sensitivity Checks

While the estimated pre-trends are reassuringly flat in our baseline specification, we further test whether the treatment effects in Figure 2 depict the causal effect of property tax changes. As discussed in Section 4.2, we run seven major tests. We present the results of these tests in Figure 4. To improve readability, we summarize pre-treatment effects (leads of up to four years prior to a tax change) and long-run effects (four years after a policy change) by calculating the average over the respective estimates. All corresponding event study graphs are presented in Appendix E.

[10] For sitting renters with *existing* contracts, the legal setting implies that property taxes will be passed through completely as landlords are entitled to charge higher taxes retroactively. Since net-of-tax rents, i.e., producer prices, for newly negotiated contracts are largely unchanged, we do not expect any compensating reduction in existing contracts, either. Unfortunately, there exists no municipal panel data on rents in existing contracts in Germany.

(1) Regional Confounders. The first identification check concerns the geographic definition of the control group and the influence of regional shocks. In the baseline specification, we include MSA-by-year fixed effects, which implies that we identify price effects only within the 74 German metropolitan areas. In other words, any confounding shock occurring at the level of the MSA or higher is accounted for. To test the sensitivity of our findings with regard to systematic confounding regional shocks, we estimate a series of specifications including either broader or finer region-by-year-fixed effects. The stability of the post- and pre-treatment estimates across specifications is an indication of the ability of regional shocks to overturn our results. Appendix Figure E.1 and the summary measures reported in Figure 4 show the results. As soon as we include state-by-year fixed effects, pre-trends are flat, and post-treatment patterns very similar to our baseline specification emerge. The more finely we control for regional shocks, the more precise and larger estimates become. This pattern implies that, if anything, confounding local shocks lead to a downward bias in estimated price effects.

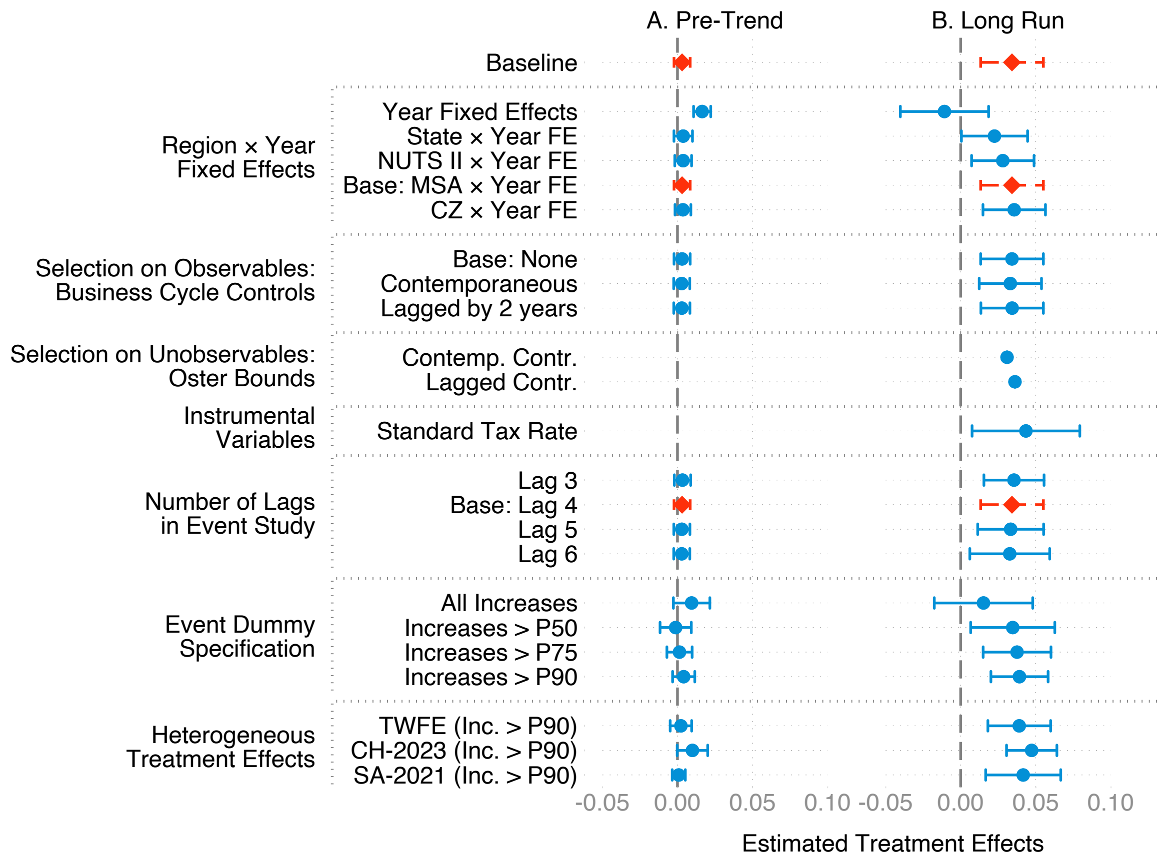
(2) Municipal Confounders. A remaining threat to identification arises from time-varying confounders at the municipal level. Clearly, we cannot account for them using region-by-year fixed effects as our identifying variation is at the municipal level. As an alternative, we add the most likely confounding variables—relating to local business cycles—as controls in the regression. More specifically, we control for unemployment, population, and GDP. We estimate two alternative specifications: first, we include these variables using contemporaneous values. Second, due to the obvious bad-control problem, we estimate a specification controlling for these variables lagged by two years. Figure 4 shows that the results are almost unchanged (see Appendix Figure E.2 for detailed event study results).

To further alleviate endogeneity concerns with regard to local business cycles, we also put these variables at the left-hand side of our event study model in Equation (3) and test for potential pre-trends in these measures. In line with Fuest et al. (2018) and Lichter et al. (2024), we find no economically relevant evidence that local business cycles are driving local tax rate changes after conditioning on MSA-by-year fixed effects (see Appendix Figure E.3).

While it is reassuring that pre-trends are reasonably flat and local business cycles do not drive our estimates, it is important to understand why municipalities change tax rates. Appendix Figure E.4 shows that municipalities increase local taxes to improve fiscal sustainability (as in Fuest et al., 2018, Lichter et al., 2024). While tax revenues increase, expenditures—especially debt services—are reduced. Moreover, the reliance on loans is decreasing. As revenue and expenditure pre-trends are flat, the decision to increase tax rates does not seem to be driven by labor or housing market considerations.

(3) Selection on Unobservables. In the previous check, we tested for observable municipal confounders driving our estimates. While variables picking up local business cycles are prime suspects when it comes to potential confounders, systematic unobserved municipal confounders might still compromise identification. To investigate the relevance of this potential source of endogeneity, we follow Oster (2019) and calculate bounds for our estimates when

Figure 4: Probing Identification



Notes: This figure presents the results for seven of out the eight identification checks outlined in Section 4.2. Estimates depict the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year. The baseline result corresponding to Figure 2 is shown in red, results from alternative specifications are depicted in blue. Panel A presents summary estimates of pre-treatment trends, i.e., the average coefficient in the four years prior to a tax reform. Panel B shows the medium-run effect measured as the average estimate of the third and fourth lag in the property tax rate. All regressions also account for leads and lags in the local business tax rate. Observations are weighted by average population levels over the sample period. Horizontal bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

allowing for unobserved confounders. These bounds approximate the pass-through that could potentially result assuming that the inclusion of unobserved confounders would move our estimates in the same direction as accounting for observable control variables (see previous paragraph). Using standard parameters for the calibration ($\delta = 1$ and $R^2_{max} = 1.3 \cdot R^2_{controlled}$), we find that the resulting bounds are close to our baseline estimate and thus unlikely to overturn our results. Bounded coefficients are reported in Figure 4 (see Appendix Table E.1 for more details on this check).

(4) Instrumental Variables. The fourth threat to identification originates from the fact that tax reforms are never truly exogenous. To tackle this classic endogeneity concern, we pursue an instrumental variable strategy exploiting an institutional feature of German federalism. In Appendix D, we develop the instrumental variables strategy in detail by explaining the fiscal equalization scheme, deriving the induced incentives in a theoretical model, and setting up the empirical model based on these incentives. In a nutshell, each state has a fiscal equalization scheme that redistributes among municipalities within the state based on municipalities' fiscal capacities and needs. In order to determine the capacity of a municipality, the actual property tax base is multiplied by a common state-wide standard tax rate that varies over time. In general, increases in the state-wide tax rate incentivize municipalities to raise their own local tax rates. This incentive to increase the own property tax rate is particularly strong for municipalities whose actual tax rates are relatively low compared to the new standard rate. We exploit this feature and the variation in the standard rate to construct an instrument for local property tax changes. We show a strong first-stage relationship and a significant reduced-form effect (see Appendix Figures D.1 and D.2). The implied long-run two-stage least squared estimates reported in Figure 4 amount to 0.04.

(5) Lag Length. We experiment with the number of lags included in the event-study specification, contrasting the baseline specification, which accounts for four lags with alternative models relying on three to six lags. Schmidheiny and Siegloch (2023) show that the choice of the lag length in combination with the binning of endpoints directly affects the assignment of municipality-years to treatment or control group. Figure 4 and Appendix Figure E.5 show that the choice of the lag length does not affect the estimates and, importantly, that the full effect on rents has materialized after three to four years, which justifies our baseline specification.

(6) (Large) Tax Increases. Our baseline model uses an event study specification with a continuous treatment variable. In other words, we scale a dummy variable indicating a tax increase with the size of the tax change. As an additional test, we also estimate a model where tax increases are coded as binary event dummies. Following common practice (see, e.g., Akcigit et al., 2022), we also estimate specifications where we look at large tax increases (50th, 75th, and 90th percentile of the tax increase distribution). Figure 4 and Appendix Figure E.6 show that the various event dummy specifications yield similar results. The only exception is the specification that uses all increases, and hence also encompasses very small property tax changes. Note that we rescale the estimates to make them comparable. All specifications show the response to a one-percentage-point increase in the property tax rate.

(7) Heterogeneous Treatment Effects. Our baseline two-way fixed effects (TWFE) model may deliver biased estimates in case of heterogeneous treatment effects. Based on the results of test (6) above, we apply the estimators of Sun and Abraham (2021) and de Chaisemartin and D'Haultfœuille (2020, 2024) to our sample of large tax increases. Results depicted in Figure 4 and Appendix Figure E.7 show that estimates are similar across specifications.

Further Robustness Checks. Additionally, we show that our baseline estimates survive the following five robustness checks. First, we vary the way how we control for changes in the local business tax rate. Instead of using all lags, we run three alternative specifications: (i) excluding the business tax rate completely from the set of regressors, (ii) controlling for the log business tax rate only, and (iii) accounting for the full set of leads and lags in the business tax rate. Second, we rerun the baseline regression but estimate the model using municipality fixed effects instead of the first differences specification. Third, we present results for different cut-off values regarding the minimum number of rental ads per municipality-year cell. We compare our baseline threshold of one ad to four alternative limits: (i) five ads, (ii) 15 ads, (iii) 25 ads, or (iv) 50 ads. Fourth, we vary the weights employed in the regression (baseline: average population levels over the sample period) and test two alternative weighting procedures: (i) using annual population levels, and (ii) weighting by the number of rental ads in a municipality per year. Fifth, we extend the estimation sample and include municipalities in East Germany (baseline: West Germany only). Sixth, we assess how sensitive our results are with respect to the hedonic correction of rents we conduct before running our baseline model. A summary of these additional tests is presented in Appendix Figure E.8. Full event-study results for the various tests are shown in Appendix Figures E.9 to E.14.

6 Welfare Simulations

In this section, we feed the reduced-form evidence into our theoretical framework to simulate the welfare effects of property taxation. We start by explaining how we implement the simulation in Section 6.1. In Section 6.2, we provide a detailed analysis of the welfare consequences of the property tax, focusing on how changes in market prices affect households along the income distribution. In Section 6.3, we complement this distributional perspective by showing how tax revenues and, as a consequence, changes in public good provision affect household welfare.

6.1 Data and Implementation

Data. We base our simulation on the 2013 wave of the German Income and Expenditure Survey (EVS, 2013), a representative cross-sectional household study conducted every five years by the German Federal Statistical Office. In line with the empirical analysis in Section 5, we focus on respondents from West Germany, yielding a sample of $|\mathcal{I}| = 32{,}458$ households. The survey includes information on the household context, incomes from various sources, and basic housing characteristics, in particular the tenancy status and size of the main residence. In addition, the Federal Statistical Office reports rental payments for renters and imputed rents as well as property tax payments in case of owner-occupied housing.

Empirical Implementation. We simulate the welfare effects of a hypothetical one percentage point increase in the local property tax rate based on Equation (1) derived in Section 2. The formula depends on (i) pre-reform quantities of the housing and labor market, (ii) housing/labor market price responses to marginal changes in the tax, and (iii) the effect of property tax changes on public goods. We discuss the three types of ingredients in turn.

All relevant pre-reform quantities or corresponding income streams are directly observable in the EVS microdata: We observe floor space of renters (h_i^*) and rental income of landlords

($p_c^* s_i^*$), workers' earnings ($w_c^* l_i^*$), and business profits ($\pi_c^* e_i^*$).[11]

In terms of price responses, we use reduced-form estimates based on our quasi-experimental research design developed in Section 4. The price effects given by Equation (4) measure semi-elasticities, hence the percent change of a given price $q_c^*, w_c^*, \pi_c^*, p_c^*$ in response to a one percentage point increase in the local property tax t_c. We use the long-run price changes, which emerge after three to four years, and denote long-run semi-elasticities as $\widehat{\beta}$.[12] Hence, we operationalize the housing channel ($-h_i^* \mathrm{d}q_c^*/\mathrm{d}t_c$, the first term in of Equation (1)) as $-q_c^* h_i^* \widehat{\beta}^q$. The first two variables, q_c^* and h_i^*, are observed in the EVS, the last one is the baseline estimate for total rents. Regarding incomes, we empirically implement the earnings channel ($l_i^* \mathrm{d}w_c^*/\mathrm{d}t_c$, the second term in Equation (1)) as $w_c^* l_i^* \widehat{\beta}^w$, i.e., observed pre-reform earnings $w_c^* l_i^*$ times the estimated semi-elasticity on wages $\widehat{\beta}^w$. This rewriting allows us to use income streams rather than requiring labor market quantities. We simulate changes in business profits and landlord income—the third and fourth terms in Equation (1)—accordingly as $\pi_c^* e_i^* \widehat{\beta}^\pi$ and $p_c^* s_i^* \widehat{\beta}^p$ using the estimated semi-elasticities on business profits and net-of-tax rents.

The long-run semi-elasticity of total rents, $\widehat{\beta}^q$, implied by our baseline reduced-form results depicted in Figure 2, is equal to 0.034 (see Column (1) of Table 1). For homeowners, we simulate the additional payments based on imputed rents.[13] For changes in landlord income, we use the long-run estimate on net-of-tax rents $\widehat{\beta}^p = 0.001$ (see Column (2) of Table 1 and Figure 3).

So far, we have only estimated the effects on housing prices. In order to obtain the long-run effects of property tax changes on wages and business profits, $\widehat{\beta}^w$ and $\widehat{\beta}^\pi$, we apply the same empirical model as before. Table 1 shows the corresponding long-run estimates in Columns (9) and (13). Full event-study estimates are depicted in Appendix Figure E.15. Overall, average wages and business incomes are hardly affected by property tax changes, long-run effects are close to and statistically indistinguishable from zero. We observe average profits at the municipal level only for two states in West Germany such that the estimates are based on fewer observations and are less precise.

Finally, Equation (1) incorporates the welfare impact of property tax changes via the public good channel. This channel depends on two elements: The change in public good provision $\mathrm{d}A_c^*/\mathrm{d}t_c$, and households' marginal valuation of public goods and services vs. private consumption, δ_i. Measuring the level of public goods and their tax-induced change is less straightforward than measuring prices and their reactions and, hence, needs some additional assumptions. Our baseline measure of changes in local public goods is the additional property tax revenues of the municipality. This measure is independent of the use of tax revenues, assuming that municipal governments spend the tax money optimally to serve their constituents. We find that tax revenues increase by around 66% after a one percentage point increase in the property tax (see Column (14) of Table 1 and Figure 6 below).

The long-run change in local public goods is scaled by households' marginal preference for

[11] Note that Equation (1) also referred to pre-reform quantities s_i^*, l_i^*, e_i^*, which we do not observe in the EVS. However, the survey contains information on income streams from these activities, which is sufficient as we can rewrite the respective expressions using the estimated semi-elasticities rather than absolute price responses.

[12] Formally, we calculate long-run semi-elasticities as $\widehat{\beta} = \exp(0.5\widehat{\beta}_3 + 0.5\widehat{\beta}_4) - 1$ for each price $q_c^*, w_c^*, \pi_c^*, p_c^*$.

[13] Imputed rents are calculated by the Federal Statistical Office and directly reported in the EVS data.

Table 1: Summary Estimates of Price Effects for Simulation

Panel A – Effects on Total and Net Rents

	All Rental Ads		By Apartment Size			By Construction Year		
	Total Rent	Net Rent	Below 60m²	Between 60–80m²	Above 80m²	Before 1949	Between '49–'90	After 1990
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Long-Run Effect	0.034***	0.001	-0.000	0.033**	0.050***	0.041	0.017	0.003
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.032)	(0.015)	(0.022)
Muni.×Year Obs.	23,303	23,236	23,303	23,303	23,303	23,303	23,303	23,303

Panel B – Effects on Wages, Profits, and Public Goods

	Wage Earnings					Public Goods	
	Average Wage	P25 Wage	P50 Wage	P75 Wage	Business Profits	Prop Tax Reven.	Munic. Expenses
	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Long-Run Effect	-0.007	-0.056	-0.021	0.013	-0.035	0.508***	-0.067*
	(0.011)	(0.047)	(0.018)	(0.010)	(0.132)	(0.026)	(0.037)
Muni.×Year Obs.	37,781	38,782	38,782	38,782	8,347	41,190	41,286

Notes: This table depicts long-run price effects for various outcomes (in logs) in response to a one percentage point increase in the property tax rate relative to the pre-reform year. The underlying econometric model is described in equations (3) and (4). The specification also accounts for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Full event-study estimates are depicted in Appendix Figure E.15. Standard errors in parentheses are robust to clustering at the municipality level (* $p < .1$, ** $p < .05$, *** $p < .01$.) See Appendix C for detailed information on all variables.

publicly provided goods relative to their marginal utility from consumption. In the baseline, we assume δ_i to be homogeneous and calibrate it to $\delta_i = 1$, which implies that households are indifferent between one additional euro spent by the local government and one that goes into their own pocket. Using tax revenues as a measure of public goods and assuming $\delta_i = 1$ also yields the case of a lump-sum rebate of tax revenues, which is typically a benchmark in optimal tax analyses. We also calibrate the parameter to $\delta_i = 0$, which effectively shuts down the public goods channel. Moreover, we assume an intermediate value $\delta_i = 0.5$ to test the robustness of our results and incorporate differential degrees of rivalness, i.e., whether A_c is a pure public or a publicly provided private good (Brülhart et al., 2024).

Heterogeneity in Price Effects. So far, we treated housing and labor effort as homogeneous goods with a uniform price per city. This assumption might mask important heterogeneities as rents may vary depending on apartment characteristics like size, construction year, or location. Moreover, richer and poorer households also differ in their housing consumption. For instance, the microdata reveals that poorer households inhabit smaller units (also per capita) and richer households reside more often in newly built homes (see Appendix Figure E.16). We thus complement the estimates on average rents by investigating heterogeneous price effects for various housing segments. Results are summarized in Columns (3)–(8) of Table 1. We find that the pass-through is higher for larger and older units. For the simulation, we also cross both dimensions of apartment heterogeneity and estimate price effects for the resulting nine cells.[14] Moreover, we incorporate heterogeneous effects along the wage distribution as lower-tail wages are more negatively affected whereas there is some suggestive evidence for small positive compensating differentials in the upper tail (see Columns (10)–(12) of Table 1). Full event-study results for these heterogeneous effects are depicted in Appendix Figure E.15.

Aggregation. We perform all simulations at the household level and calculate the money-metric utility change ΔW_i from Equation (1) in euros per year for each household in the survey. We then scale this absolute measure by households' reported consumption expenses and depict relative utility losses. In most of the analyses, we group households $i \in \mathcal{I}$ in percentiles of the consumption expenditure distribution and present average relative utility changes for these hundred groups. When aggregating, we account for household sampling weights and use the OECD-modified equivalence scale to adjust for differences in household size.

Inference. We calculate empirical confidence bounds for our welfare predictions by running 1,000 bootstrap replications of the simulation procedure. In each of these runs, we randomly (i) sample with replacement from the survey data, and (ii) draw from the distributions of reduced-form estimates. It turns out that most of the variance in our predictions is due to imprecise estimates of business incomes and—to a lesser extent—wages.

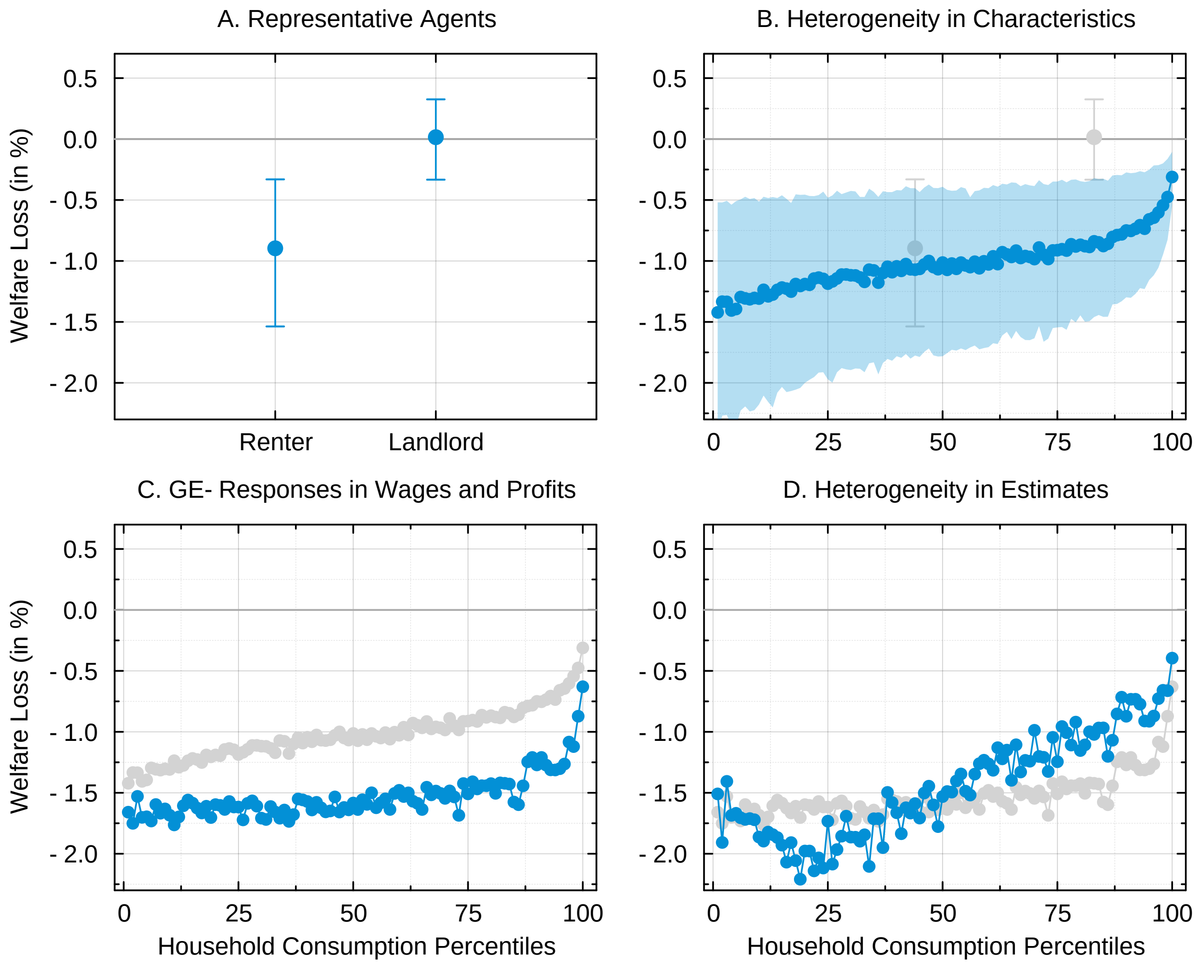
6.2 Distributional Effects

In the following two sections, we present the welfare consequences of a one percentage point increase in the property tax rate as described in Section 6.1. In Section 6.2, we present the distributional effects driven by the price effects as depicted in Equation (1), i.e., incidence. Section 6.3 highlights the role of efficiency aspects by incorporating public goods in the simulation. Results are summarized in Figure 5.[15]

Benchmark: Representative Agents. We start the exposition with a classical benchmark from the literature, namely a partial-equilibrium model with two representative agents. We identify (i) renters, defined as households who rent their main residence and have no rental income, and (ii) landlords, i.e., owners with positive rental income. To keep the benchmark as simple as possible, we discard general equilibrium responses in wages and profits as well as heterogeneity among groups or in estimates. In line with structural approaches, we further assume landlords to live abroad (Suárez Serrato and Zidar, 2016). Renter welfare is thus only governed by changes in rental expenses, and landlord welfare only by changes in rental income. Panel A of Figure 5 depicts the resulting relative utility changes. For the representative renter household, our estimates imply a 202 euro loss in money-metric welfare, which translates into

[14] We tested for other heterogeneities in rent effects, but did not find statistically significant differences.
[15] Corresponding absolute, i.e., unscaled, money-metric welfare changes can be found in Appendix Figure E.17.

Figure 5: Property Tax Increases and Household Welfare



Notes: This figure illustrates the relative welfare consequences of a one percentage point increase in the local property tax over the household consumption distribution (in percent). We calculate relative welfare losses as money-metric utility changes in euro per year divided by annual household consumption. Absolute welfare changes are depicted in Appendix Figure E.17. Starting from a stylized benchmark case presented in Panel A, we introduce more heterogeneity in our welfare simulations step-by-step as we move to Panel-D: Panel A reports welfare in a partial-equilibrium model with two representative agents (landlords and renters). Panel B additionally accounts for differences in the numbers of these two agents, their different positions in the consumption distribution, and their housing expenditures; Panel C additionally introduces general equilibrium effects on the labor market (via wage and business income effects); Panel D additionally allows for heterogeneity in price effects of rents and wages. The gray coefficients/dots indicate the estimates from the previous panel to improve comparability. We simulate these changes for each household in the German Income and Expenditure Survey (EVS, 2013); Section 6.1 provides more details on the empirical implementation. The curves are based on average changes within percentiles of the consumption distribution across households using sampling weights and the OECD-modified equivalence scale. Shaded blue areas and vertical bars correspond to empirical 95% confidence bounds using 1,000 bootstrap replications. See Appendix C for detailed information on all variables.

a utility loss of 0.8 percent relative to consumption expenses. For landlords, we find hardly any utility change that follows directly from the estimate on net-of-tax rents, which is close to zero.

Heterogeneity in Characteristics. This stylized benchmark case simplifies the world in two key dimensions. First, the estimates for the representative agents are not informative about the size of either group and its position in the income distribution. In our sample, we have 13,122 renter and only 4,195 landlord households; the representative renter is close to the median of the consumption distribution, whereas the representative landlord belongs to the top quintile. Second, it masks heterogeneity in real-world characteristics: The microdata includes 15,141 *additional* households who cannot be classified easily as renters or landlords as they neither rent their main residence nor receive any rental income. Furthermore, twelve percent of landlords rent their homes, and many landlords are, in fact, not absent but live in the same city and are thus affected by tax reforms themselves.

We address these complications with our sufficient statistics approach by exploiting the full heterogeneity in observable household characteristics and allowing households to differ in housing tenure, expenditures, and rental income. Panel B of Figure 5 shows the results.[16]

As expected when ignoring tax revenues, we find that all households across the distribution experience a significant welfare loss. The proposed framework enables us to investigate the underlying distributional effects in detail. We find a regressive pattern with households in the bottom decile losing 1.3 percent of their consumption, whereas households from the top decile lose around 0.6 percent due to the tax increase. Our results show that property taxes are regressive and increase inequality in consumption. The underlying driver is households' expenditure share on housing, which decreases from above 40 to below 10 percent along the distribution (see descriptives in Appendix Figure E.16). The benchmark in Panel A hides heterogeneity in welfare losses across renter households and understates landlords' welfare losses since many landlords invest locally and are thus affected by taxes themselves. Hence, keeping the assumption of absent landlords would yield a more regressive pattern along the consumption distribution.

General Equilibrium Responses. We continue by switching from partial to general equilibrium and incorporating responses in wages and business profits using the estimates depicted in Table 1. Both price effects are statistically indistinguishable from zero with small negative point estimates. We take these estimates at face value and simulate changes in wage earnings and business income for each household on top of the two partial equilibrium channels (i.e., housing expenses and rental income). Results are depicted in Panel C of Figure 5. Given the negative estimates on wages and profits, welfare losses increase throughout the distribution, with somewhat larger losses for upper percentiles where business profits play a more prominent role. As the regressive pattern remains, but standard errors increase strongly,[17] we do not present confidence in the main text. As shown in Appendix Figure E.18, we can still reject that welfare losses are zero for large parts of the distribution. This result is unsurprising as we find negative externalities in the labor market, which should aggravate the negative welfare effects depicted in Panel B. A more interesting test regarding general equilibrium effects is whether the property tax remains regressive compared to a partial-equilibrium perspective. While the slope becomes flatter, we can still reject that utility losses at the bottom of the consumption distribution are identical to the ones at the top. Formally, we estimate the linear fit across the percentiles of the consumption distribution in each of the 1,000 bootstrap replications. Only 13 of the replications yield a negative slope, indicating a progressive welfare impact; the

[16] Each circle in the figure represents average relative welfare losses among households from percentile p.

[17] Labor market price effects are small but quite noisy—particularly the business income estimates due to data limitations (see Section 6.1).

remaining 987 replications indicate a positive slope, implying a regressive welfare impact of property taxes.

Heterogeneity in Estimates. As discussed in Section 2, there are two sources of heterogeneity driving the household-level welfare effects. One is heterogeneity in characteristics, which we exploited when moving from representative agents to the microdata (cf. panels A and B). Housing consumption varies along the distribution (e.g., housing expenditure shares decrease, and richer households live in larger units). The second source is heterogeneity in price effects, which we introduce by allowing the pass-through and wage capitalization to differ across segments (see Table 1). We map these estimates according to the characteristics of households' main residence and their position in the wage distribution. Accounting for heterogeneous price effects yields a hockey stick pattern shown in Panel D of Figure 5. While households at the very bottom of the consumption distribution lose less than households around the first quintile, the figure still shows an overall regressive effect of property taxes along the consumption distribution. We confirm this by testing again for the best linear fit during each bootstrap replication. Out of the 1,000 resulting gradients, only 26 replications indicate a negative slope and thus a progressive impact of the tax. 974 replications are best approximated with a positive slope, implying that the distributional welfare impact of the property tax is regressive.

To wrap up, the distributional effects of property taxes are regressive along the consumption distribution. This picture already emerges in a partial-equilibrium perspective with homogenous price effects and observable heterogeneity in household characteristics. It also prevails when allowing for general equilibrium responses and heterogeneity in estimated price effects.

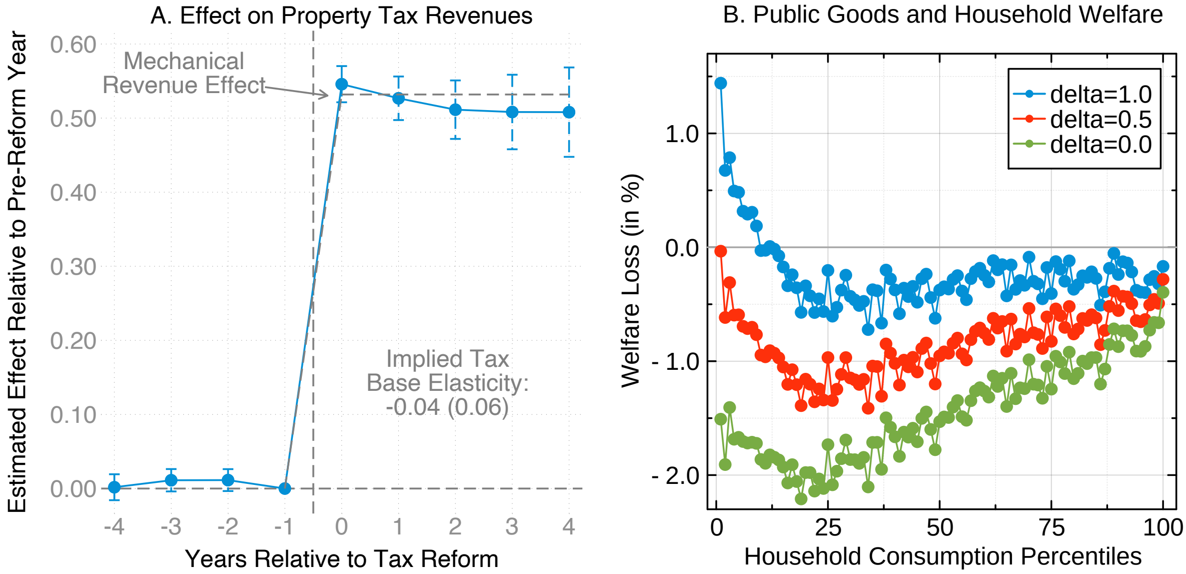
6.3 Efficiency Effects: Tax Revenues and Public Goods

So far, we have simulated the distributional effects of property taxes, i.e., welfare implications arising from price effects. We have ignored the last part of Equation (1), which states that higher taxes may lead to additional revenues that should eventually benefit taxpayers—a mechanism ignored in distributional analyses that focus solely on incidence.

In order to assess how higher tax revenues affect household welfare via public goods, we have to take three steps. The first question is how much tax revenues are raised by increasing the tax rate. Hence, it asks for the efficiency of the tax. The answer to this question depends on the mechanical vs. behavioral revenue effects in response to tax increases. We estimate the tax revenue response to a one percentage point increase in the tax rate using our reduced-form setting. Panel A of Figure 6 shows that the efficiency losses are low: The long-run ratio of the estimated to the mechanical revenue effect is 0.96, which translates into a tax base elasticity of 0.04 (standard error 0.06).

The second step is to quantify the share of tax revenues that is transformed into public goods. Abstracting from government inefficiencies and rent-seeking behavior (Diamond, 2017), it seems reasonable to assume that local governments use tax revenues in a way that optimally serves the constituents. In other words, we assume full transmission of additional tax revenues

Figure 6: Effect of Property Taxes on Tax Revenues



Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on property tax revenues (in logs) relative to the pre-reform year (Panel A). The underlying econometric model is described in equations (3) and (4). The specification also accounts for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. The dashed gray line indicate the implied estimate for tax revenues without any behavioral responses, i.e. the mechanical effect on tax revenues. Panel B illustrates the relative welfare consequences of a one percentage point increase in the local property tax rate along the household consumption distribution for different marginal valuations of public goods and services vs. private consumption ($\delta_i = [1, 0.5, 0]$). We calculate relative welfare losses as money-metric utility changes in euro per year divided by annual household consumption. We simulate these changes for each household in the German Income and Expenditure Survey (EVS, 2013); Section 6.1 provides more details on the empirical implementation. The curves are based on average changes within percentiles of the consumption distribution across households using sampling weights and the OECD-modified equivalence scale. See Appendix C for detailed information on all variables.

into public goods A_c, which provides an upper bound for the role of public goods in this respect.

The third step is to understand households' marginal preferences for public goods and services vs. private consumption, captured by δ_i in Equation (1). Panel B of Figure 6 illustrates two polar cases and an in-between scenario: First, the case with $\delta_i = 0$, which is just the distributional analysis from Panel D in Figure 5. The second polar case is $\delta_i = 1$. Hence, households are indifferent between consumption of one additional unit of the private vs. the public good, implying publicly provided private goods rather than pure public goods. Third, we simulate household welfare for the intermediate case of $\delta_i = 0.5$.

Adding public goods to the equation leads to a mechanical increase in welfare throughout the distribution. More interestingly, it diminishes or even abolishes the regressive pattern from Section 6.2, depending on the preferences for local public goods. In the extreme case of $\delta = 1$, we observe welfare effects that are close to zero for most of the consumption distribution. Given that the deadweight loss of the property tax is small, almost all tax revenues are redistributed, and individuals value the redistributed tax euro as much as the initially taxed euro. The bottom 10% of the distribution experience positive welfare effects as they tend to live in smaller apartments that face a lower pass-through rate (see Table 1) but enjoy public goods worth the average tax bill. Estimated linear fits during each bootstrap replication reveal regressive distributional welfare effects (positive slope) in half of the replications. In the other half, the slope turns negative, implying a progressive impact. Hence, we cannot rule out that the scenario assuming $\delta = 1$ is distributionally neutral.

The role of the general equilibrium effects is interesting in this context. Because of the modeled spillovers on the labor market, the property tax base elasticity is not sufficient to capture the full efficiency cost of the property tax as property taxes (may) generate fiscal externalities in the personal income tax, social security contributions, and profit taxes for firms (Chetty, 2009). In our simulation, we account for these tax-base externalities and assume that the additional changes in tax revenues affect the local public good.[18] Given the small magnitudes in general equilibrium effects, the spillovers on other government revenues are of secondary importance.

Even in the extreme case with local public good preferences $\delta = 1$, the property tax rate is not progressive. As public good preferences decrease, the welfare effects of the property tax become more regressive and eventually, for $\delta = 0$, converge to the simulation results presented in Panel D of Figure 5, which ignore the public good channel.

7 Conclusion

"Are local property taxes regressive, progressive, or what?" This paper tries to answer this long-standing question in public finance, which has been raised by Oates and Fischel (2016).

Our answer relies on a framework that, for the first time, applies a sufficient statistics approach in a spatial equilibrium context to study the effect of property taxes on housing and labor markets. We extend the canonical sufficient statistics formulation to account for distributional effects across households that are heterogeneous in various dimensions. We estimate price responses in the housing and labor market as well as changes in tax revenues, exploiting property tax changes induced by 5,500 local tax reforms happening in West Germany between 2004 and 2018. We use the quasi-experimental estimates to simulate the welfare effects of property tax changes across the household distribution.

We answer Oates and Fischel (2016) with a triad: (i) The property tax is not progressive. (ii) The property tax can be approximately welfare neutral if public goods are provided efficiently by governments and individuals value a marginal increase of the local public good as much as a one-euro increase in their private income. (iii) The property tax is, hence, regressive in most settings.

[18] Note that this simplifying assumption is not exactly accurate as labor and profit taxes mostly accrue to the federal government.

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A Structural Representation of the Spatial Equilibrium Model

In this appendix, we provide a detailed description of the structural representation of the spatial equilibrium framework introduced in Section 2 of the paper. It includes all derivations and intermediate steps needed to solve the model and analyze the equilibrium properties. We introduce local property taxation into a Rosen-Roback-type general equilibrium model of local labor markets (Suárez Serrato and Zidar, 2016). The model consists of four groups of agents: workers, firms producing tradable goods, construction companies producing floor space and landowners. Workers and firms are mobile and locate in one out of C cities, indexed by c.

First, we outline the model in Appendix A.1. Second, we solve for the spatial equilibrium quantities and prices (Appendix A.2). In Appendix A.3, we derive welfare effects of tax changes and show how marginal welfare effects relate to the key elasticities of the model in this context. Finally, we study the comparative statics of the model to show how changes in the property tax rate affect the equilibrium outcomes, i.e., population size, floor space, land use, rents, wages, and land prices (see Appendix A.4).

A.1 Agents and Markets

A.1.1 Workers

The economy consists of a continuum of households $i \in \mathcal{I}$ who choose to live in one out of many small cities, $c \in \mathcal{C}$. We assume that labor is homogeneous and each worker provides inelastically one unit of labor, earns a wage w_c, and pays rent q_c for residential floor space.[19] Each city c has amenity A_c that is exogenously given, which may be determined by exogenous geographical factors and endogenous (fiscal) amenities, which are financed by local government via taxation. Local governments levy a property tax t_c, such that total rents q_c are defined as $q_c = p_c(1 + t_c)$, where p_c is the net-of-tax rent, i.e. the producer price of rental housing. Workers maximize utility over floor space h_i, a composite good bundle x_i of non-housing goods and locations c. The price of the composite good bundle is μ, which is later normalized to one. Workers are mobile across municipalities, but mobility is imperfect due to individual location preferences, such that local labor supply is not necessarily infinitely elastic. [20] We assume that households have preferences for public goods measured by $g \in (0, 1)$. Note that the relative public good preference δ given in Equation (1) is equal to $\delta = g/(1 - g)$.

The household's maximization problem in a given municipality c is given by:

$$\max_{h_i, x_i} U_{ic} = A_c^g \left(h_i^\alpha x_i^{1-\alpha} \right)^{1-g} e_{ic} \qquad \text{s.t. } q_c h_i + \mu x_i = w_c \tag{A.1}$$

with the bundle x_i of non-housing goods Z and the normalized aggregate price index ρ defined

[19] We assume that there is only one homogeneous housing good and do not differentiate between owner-occupied and rental housing in this structural model (Poterba, 1984).

[20] In the Appendix, we model the property tax as ad valorem tax. It could also be an excise tax as in Section 2.

as in Melitz (2003):

$$x_i = \left(\int\limits_{z\in Z} x_{iz}^{\rho}\, \mathrm{d}z \right)^{\frac{1}{\rho}} \qquad\qquad \mu = \left(\int\limits_{z\in Z} \mu_{iz}^{-\frac{\rho}{1-\rho}}\, \mathrm{d}z \right)^{-\frac{1-\rho}{\rho}} = 1 \tag{A.2}$$

and $h_i, x_{iz}, A_c, q_c, w_c, t_c, \mu_{iz}, e_{ic} > 0$ and $\alpha, \rho \in (0,1)$. The parameter ρ relates to the elasticity of substitution between any two composite goods, which is given by $\frac{1}{1-\rho}$ (Dixit and Stiglitz, 1977). The Lagrangian reads:

$$\begin{aligned} \max_{h_i, x_i} \mathcal{L} = g \ln A_c + \alpha(1-g) \ln h_i + (1-\alpha)(1-g) \ln x_i + \ln e_{ic} \\ + \lambda \left(w_c - q_c h_i - x_i \right) \end{aligned} \tag{A.3}$$

and first-order conditions of the household problem are given by:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial h_i} &= \frac{\alpha(1-g)}{h_i} - \lambda q_c \overset{!}{=} 0 \\ \frac{\partial \mathcal{L}}{\partial x_i} &= \frac{(1-\alpha)(1-g)}{x_i} - \lambda \overset{!}{=} 0 \\ \frac{\partial \mathcal{L}}{\partial \lambda} &= w_c - q_c h_i - x_i \overset{!}{=} 0 \end{aligned}$$

Now we can solve by substitution. The optimal floor space consumption is then given by:

$$\begin{aligned} \frac{\alpha(1-g)}{h_i} &= \lambda q_c \\ &= \frac{(1-\alpha)(1-g)}{x_i} q_c \\ h_i &= \frac{\alpha}{1-\alpha} \frac{x_i}{q_c} \\ &= \frac{\alpha}{1-\alpha} \frac{w_c - q_c h_i}{q_c} \\ &= \frac{\alpha}{1-\alpha} \left(\frac{w_c}{q_c)} - h_i \right) \\ h_i^* &= \alpha \frac{w_c}{q_c} \end{aligned} \tag{A.4}$$

and we can solve for the optimal consumption level of the composite good bundle:

$$\begin{aligned} x_i &= w_c - q_c h_i \\ &= w_c - q_c \alpha \frac{w_c}{q_c} \\ x_i^* &= (1-\alpha) w_c \end{aligned} \tag{A.5}$$

where α is the share of the household's budget spent on housing. Household i's demand of good variety z is then given by $x_{iz}^* = (1-\alpha) w_c \mu_{iz}^{-\frac{1}{1-\rho}}$. Using the optimal consumption quantities, log indirect utility is defined as:

$$
\begin{aligned}
V_{ic}^H &= \ln U(h_i^*, x_i^*, A_c, e_{ic}) \\
&= \alpha(1-g)\ln h_i^* + (1-\alpha)(1-g)\ln x_i^* + g\ln A_c + \ln e_{ic} \\
&= \alpha(1-g)\ln\left(\alpha\frac{w_c}{q_c}\right) + (1-\alpha)(1-g)\ln\left([1-\alpha]w_c\right) + g\ln A_c + \ln e_{ic} \\
&= \underbrace{(1-g)\left(\alpha\ln\alpha + [1-\alpha]\ln[1-\alpha]\right)}_{=a_0} + g\ln A_c + \ln e_{ic} \\
&\quad + (1-g)(\alpha\ln w_c - \alpha\ln p_c - \alpha\ln[1+t_c] + (1-\alpha)\ln w_c) \\
V_{ic}^H &= a_0 + \underbrace{(1-g)(\ln w_c - \alpha\ln p_c - \alpha\ln[1+t_c]) + g\ln A_c}_{=V_c^H} + \ln e_{ic}. \qquad \text{(A.6)}
\end{aligned}
$$

We defined a constant term $a_0 = (1-g)(\alpha\ln\alpha + [1-\alpha]\ln[1-\alpha])$ that is the same for all workers in the economy to simplify the notation. The individual (indirect) utility is a combination of this constant a_0, a common term V_c^H identical to all workers in the municipality, and the idiosyncratic location preferences e_{ic}. As in Kline and Moretti (2014), we assume that the logarithm of e_{ic} is independent and identically extreme value type I distributed with scale parameter $\sigma^H > 0$. The corresponding cumulative distribution function is $F(z) = \exp\left(-\exp[-z/\sigma^H]\right)$. Due to these city preferences, workers are not fully mobile between cities and real wages w_c/q_c do not fully compensate for different amenity levels A_c across municipalities (other than in Brueckner, 1981). The greater σ^H, the stronger workers' preference for given locations and the lower workers' mobility. There is a city-worker match that creates a positive rent for the worker and decreases mobility. A worker i will prefer municipality a over municipality b if and only if:

$$
\begin{aligned}
V_{ia}^H &\geq V_{ib}^H \\
V_a^H + \ln e_{ia} &\geq V_b^H + \ln e_{ib} \\
V_a^H - V_b^H &\geq \ln e_{ib} - \ln e_{ia}.
\end{aligned}
$$

Given the distribution of $\ln e_{ic}$, it follows that the difference in preferences between two municipalities follows a logistic distribution with scale parameter σ^H, i.e., $\ln e_{ib} - \ln e_{ia} \sim logistic(0, \sigma^H)$. The probability that worker i locates in municipality c when choosing between C cities is then:

$$
N_c = \Pr\left(V_{ic}^H \geq V_{ij}^H, \forall j \neq c\right) = \frac{\exp\left(V_c^H/\sigma^H\right)}{\sum_{k=1}^C \exp\left(V_k^H/\sigma^H\right)}.
$$

This expression is equivalent to the share of workers locating in municipality c given that we normalize the total number of workers N to one. Note that the term a_0 cancels out as it is constant across municipalities. Taking logs we arrive at the (log) labor supply curve in municipality c:

$$\ln N_c^S = \frac{V_c^H}{\sigma^H} \underbrace{- \ln\left(C\pi^H\right)}_{=a_1}$$

$$\ln N_c^S = \underbrace{\frac{1-g}{\sigma^H}}_{=\epsilon^{\text{NS}}} \ln w_c \underbrace{-\frac{\alpha(1-g)}{\sigma^H}}_{=1+\epsilon^{\text{HD}}} \ln p_c \underbrace{-\frac{\alpha(1-g)}{\sigma^H}}_{=1+\epsilon^{\text{HD}}} \ln \tau_c + \frac{g}{\sigma^H} \ln A_c + a_1 \tag{A.7}$$

where we define all terms constant across municipalities as $a_1 = -\ln\left(C\pi^H\right)$ with $\pi^H = \frac{1}{C}\sum_{k=1}^{C} \exp\left(V_k^H/\sigma^H\right)$ being the average utility across all municipalities and we rewrite the property tax rate as $\tau_c = 1 + t_c$. Note that C is given, and for large C, a change in V_c^H does not affect the average utility π^H. The labor supply elasticity is given by:

$$\frac{\partial \ln N_c^S}{\partial \ln w_c} = \frac{1-g}{\sigma^H} = \epsilon^{\text{NS}} > 0. \tag{A.8}$$

Floor Space Demand. Demand for residential housing in city c is determined by the number of workers in city c and their individual housing demand as indicated by equation (A.4):

$$H_c = N_c h_i^* = N_c \alpha \frac{w_c}{q_c}$$

$$\ln H_c = \ln N_c + \ln \alpha + \ln w_c - \ln p_c - \ln \tau_c. \tag{A.9}$$

It follows that the intensive margin housing demand elasticity conditional on location choice is equal to -1. In addition, there is an extensive margin with people leaving the city in response to higher costs of living. The aggregate residential housing demand elasticity is given by:

$$\frac{\partial \ln H_c}{\partial \ln p_c} = \frac{\partial \ln N_c}{\partial \ln p_c} - 1 = -\frac{\alpha(1-g) + \sigma^H}{\sigma^H} = \epsilon^{\text{HD}} < 0.$$

A.1.2 Firms

Firms $j = 1, ..., J$ are monopolistically competitive and produce tradable consumption goods. Each firm produces a different variety Y_{jc} using labor N_{jc} and commercial floor space M_{jc}. Firms have different productivity across places due to exogenous local production amenities measured by B_c, and idiosyncratic productivity shifters ω_{jc}. Firm j's profits in city c are then given by:

$$y_{jc}^F = \mu_{jc} Y_{jc} - w_c N_{jc} - q_c^M \kappa M_{jc} \tag{A.10}$$

$$Y_{jc} = B_c \omega_{jc} N_{jc}^{\beta} M_{jc}^{1-\beta}$$

with $Y_{jc}, N_{jc}, M_{jc}, \mu_{jc}, y_c^W, r_c^M > 0$. w_c and p_c^M denote the factor prices of labor and commercial floor space, respectively. The scale parameter $\kappa > 0$ allows property taxes on commercial rents to differ from residential property taxes. Following Melitz (2003), we substitute the final good price μ_{jc} by the inverse of product j's aggregate demand function:

$$Y_{jc} = Q \left(\frac{\mu_{jc}}{\mu} \right)^{-\frac{1}{1-\rho}}$$

with price index $\mu = 1$ as normalized above, and $Q > 0$ as total product demand in the economy. The parameter ρ relates to the elasticity of substitution between any two varieties. We define the exponent $-\frac{1}{1-\rho}$ as the constant product demand elasticity $\epsilon^{\text{PD}} < -1$. We can rewrite firm j's profits as:

$$y^F_{jc} = \underbrace{Q^{1-\rho} Y_{jc}^{-(1-\rho)}}_{=\mu_{jc}} Y_{jc} - w_c N_{jc} - p^M_c (1+t_c) \kappa M_{jc}.$$

Using the production function for Y_{jc} we can rewrite this expression as:

$$y^F_{jc} = Q^{1-\rho} \underbrace{\left(B_c \omega_{jc} N^{\beta}_{jc} M^{1-\beta}_{jc} \right)^{\rho}}_{=Y_{jc}} - w_c N_{jc} - p^M_c (1+t_c) \kappa M_{jc} \tag{A.11}$$

with $B_c, \omega_{jc} > 0$ and $\beta \in (0,1)$.

Profit-maximizing behavior leads to the following first-order conditions for labor and floor space:

$$\begin{aligned} \frac{\partial y^F_{jc}}{\partial N_{jc}} &= \rho \beta Q^{1-\rho} B^{\rho}_c \omega^{\rho}_{jc} N^{\rho\beta-1}_{jc} M^{\rho(1-\beta)}_{jc} - w_c \stackrel{!}{=} 0 \\ \frac{\partial y^F_{jc}}{\partial M_{jc}} &= \rho(1-\beta) Q^{1-\rho} B^{\rho}_c \omega^{\rho}_{jc} N^{\rho\beta}_{jc} M^{\rho(1-\beta)-1}_{jc} - p^M_c (1+t_c)\kappa \stackrel{!}{=} 0. \end{aligned}$$

Again, we shorten the notation by using $\tau_c = (1+t_c)$. Taking logs of the second condition we can derive the floor space demand of firms conditional on labor input, factor prices, and local productivity:

$$\begin{aligned} \ln \left(p^M_c \tau_c \kappa \right) &= \ln \rho + \ln(1-\beta) + (1-\rho) \ln Q + \rho \ln B_c + \rho \ln \omega_{jc} + \rho\beta \ln N_{jc} \\ &\quad - (1 - \rho[1-\beta]) \ln M_{jc} \\ \ln M_{jc} &= \Big(\ln \rho + \ln[1-\beta] + [1-\rho] \ln Q + \rho \ln B_c + \rho \ln \omega_{jc} + \rho\beta \ln N_{jc} \\ &\quad - \ln p^M_c - \ln[\tau_c \kappa] \Big) \Big/ \Big(1 - \rho[1-\beta] \Big). \end{aligned} \tag{A.12}$$

We can derive log labor demand from the first first-order condition using the conditional factor demand for commercial floor space from equation (A.12):

$$\begin{aligned} \ln y^W_c &= \ln \rho + \ln \beta + (1-\rho) \ln Q + \rho \ln B_c + \rho \ln \omega_{jc} - (1-\rho\beta) \ln N_{jc} + \rho(1-\beta) \ln M_{jc} \\ \ln N_c &= \Big(\ln \rho + \ln \beta + [1-\rho] \ln Q + \rho \ln B_c + \rho \ln \omega_{jc} + \rho(1-\beta) \ln M_{jc} - \ln w_c \Big) \Big/ \Big(1 - \rho\beta \Big) \end{aligned}$$

$$
\begin{aligned}
&= \Big(\ln\rho + \ln\beta + [1-\rho]\ln Q + \rho \ln B_c + \rho \ln \omega_{jc} \\
&\quad + \rho[1-\beta]\Big[\ln\rho + \ln\{1-\beta\} + \{1-\rho\}\ln Q + \rho\ln B_c + \rho\ln\omega_{jc} + \rho\beta\ln N_{jc} \\
&\qquad - \ln p_c^M - \ln\{\tau_c\kappa\}\Big] \Big/ \Big[1-\rho\{1-\beta\}\Big] - \ln w_c \Big) \Big/ \Big(1-\rho\beta\Big) \\
\ln N_{jc}^* &= \Big(\ln\rho + [1-\rho+\rho\beta]\ln\beta + \rho[1-\beta]\ln[1-\beta] + [1-\rho]\ln Q + \rho\ln B_c \\
&\quad - [1-\rho+\rho\beta]\ln w_c - \rho[1-\beta]\ln p_c^M - \rho[1-\beta]\ln[\tau_c\kappa] + \rho\ln\omega_{jc}\Big) \Big/ \Big(1-\rho\Big) \quad \text{(A.13)}
\end{aligned}
$$

Using equation (A.12) from above and firm j's labor demand in city c we can also solve for the commercial floor space demand of firm j:

$$
\begin{aligned}
\ln M_{jc}^* = \Big(&\ln\rho + \rho\beta\ln\beta + [1-\rho\beta]\ln[1-\beta] + [1-\rho]\ln Q + \rho\ln B_c - \rho\beta\ln w_c \\
&- [1-\rho\beta]\ln p_c^M - [1-\rho\beta]\ln[\tau_c\kappa] + \rho\ln\omega_{jc}\Big) \Big/ \Big(1-\rho\Big) \qquad \text{(A.14)}
\end{aligned}
$$

Equations (A.13) and (A.14) define the factor input demand conditional on local productivity and factor prices. We can now substitute the factor demand in the firm profit equation (A.11) and rewrite profits as a function of factor prices:

$$
\begin{aligned}
y_{jc}^F &= Q^{1-\rho} \underbrace{\Big(B_c \omega_{jc} N_{jc}^{\beta} M_{jc}^{1-\beta}\Big)^{\rho}}_{=Y_{jc}} - w_c N_{jc} - p_c^M \tau_c \kappa M_{jc} \\
y_{jc}^F(N_{jc}^*, M_{jc}^*) &= B_c^{\frac{\rho}{1-\rho}} \omega_{jc}^{\frac{\rho}{1-\rho}} w_c^{-\frac{\rho\beta}{1-\rho}} p_c^{M^{-\frac{\rho(1-\beta)}{1-\rho}}} (\tau_c\kappa)^{-\frac{\rho(1-\beta)}{1-\rho}} Q \rho^{\frac{\rho}{1-\rho}} \beta^{\frac{\rho\beta}{1-\rho}} (1-\beta)^{\frac{\rho(1-\beta)}{1-\rho}} (1-\rho)
\end{aligned}
$$

The term $1-\rho > 0$ at the end of the expression indicates that profits are a markup over costs. As defined before, this term is equivalent to the inverse of the absolute product demand elasticity, i.e., $1-\rho = -1/\epsilon^{\text{PD}}$. The more elastic product demand ($\epsilon^{\text{PD}} \downarrow$), the lower the markup and the lower firms' profits in the tradable good sector. Following Suárez Serrato and Zidar (2016) we define the value of firm j in city c in terms of factor costs and local productivity:

$$
\begin{aligned}
V_{jc}^F &= \frac{1-\rho}{\rho} \ln y_{jc}^F(N_{jc}^*, M_{jc}^*) \\
V_{jc}^F &= b_0 + \underbrace{\ln B_c - \beta\ln w_c - (1-\beta)\ln p_c^M - (1-\beta)\ln(\tau_c\kappa)}_{=V_c^F} + \ln\omega_{jc} \qquad \text{(A.15)}
\end{aligned}
$$

with constant $b_0 = \frac{1-\rho}{\rho}\ln Q + \ln\rho + \beta\ln\beta + (1-\beta)\ln(1-\beta) + \frac{1-\rho}{\rho}\ln(1-\rho)$. We assume that idiosyncratic productivity shifters $\ln\omega_{jc}$ are i.i.d. and follow an extreme value type I distribution with scale parameter σ^F. As before in the context of household location choice, we normalize the total number of firms to $F = 1$. Using the log-profit equation and the distributional assumption on $\ln\omega_{jc}$ we denote the share of firms locating in city c by:

$$
F_c = \Pr\Big(V_{jc}^F \geq V_{jk}^F, \forall k \neq c\Big) = \frac{\exp\left(V_c^F/\sigma^F\right)}{\sum_{g=1}^{C} \exp\Big(V_g^F/\sigma^F\Big)}. \qquad \text{(A.16)}
$$

The number of firms in city c from equation (A.16) (extensive margin) and the firm-specific labor demand from equation (A.13) (intensive margin) define the aggregate log labor demand in city c:

$$\begin{aligned}
\ln N_c^D &= \ln F_c + \mathrm{E}_{\omega_{jc}}\left[\ln N_{jc}^*\right] \\
&= \frac{1}{\sigma^F}\ln B_c - \frac{\beta}{\sigma^F}\ln w_c - \frac{1-\beta}{\sigma^F}\ln p_c^M - \frac{1-\beta}{\sigma^F}\ln(\tau_c\kappa) - \ln\left(C\pi^F\right) \\
&\quad + \frac{\rho}{1-\rho}\ln B_c - \frac{1-\rho+\rho\beta}{1-\rho}\ln w_c - \frac{\rho(1-\beta)}{1-\rho}\ln p_c^M - \frac{\rho(1-\beta)}{1-\rho}\ln(\tau_c\kappa) \\
&\quad + \frac{1}{1-\rho}\ln\rho + \frac{1-\rho+\rho\beta}{1-\rho}\ln\beta + \frac{\rho(1-\beta)}{1-\rho}\ln(1-\beta) + \ln Q + \frac{\rho}{1-\rho}\mathrm{E}_{\omega_{jc}}\left[\ln\omega_{jc}\right] \\
\ln N_c^D &= \underbrace{\left(\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right)}_{=\epsilon^{\mathrm{B}}}\ln B_c \underbrace{-\left(1+\beta\left[\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right]\right)}_{=\epsilon^{\mathrm{ND}}}\ln w_c \underbrace{-(1-\beta)\left(\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right)}_{=1+\epsilon^{\mathrm{MD}}}\ln p_c^M \\
&\quad \underbrace{-(1-\beta)\left(\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right)}_{=1+\epsilon^{\mathrm{MD}}}\ln(\tau_c\kappa) + b_1
\end{aligned} \tag{A.17}$$

as a function of local productivity B_c, wages w_c, and the total factor price costs of commercial floor space $p_c^M\tau_c\kappa$ with constant term $b_1 = \Big(\ln\rho + [1-\rho+\rho\beta]\ln\beta + \rho[1-\beta]\ln[1-\beta] + \rho\mathrm{E}_{\omega_{jc}}\left[\ln\omega_{jc}\right]\Big)\Big/\Big(1-\rho\Big) + \ln Q - \ln C - \ln\pi^F$, where we define the average firm value across locations defined as $\pi^F = \frac{1}{C}\sum_{k=1}^{C}\exp\left(V_k^F/\sigma^F\right)$. The labor demand elasticity is defined as:

$$\frac{\ln N_c^D}{\ln w_c} = \underbrace{-\frac{\beta}{\sigma^F}}_{\text{Ext. margin}} \underbrace{-1-\frac{\beta\rho}{1-\rho}}_{\text{Int. margin}} = \epsilon^{\mathrm{ND}} < 0. \tag{A.18}$$

Labor demand increases in local productivity B_c (i.e., $\epsilon^{\mathrm{B}} > 0$) and decreases in the (tax-inclusive) factor price of commercial floor space defined by $p_c^M\tau_c\kappa$ (i.e., $1+\epsilon^{\mathrm{MD}} < 0$).

Floor Space Demand. Analogous to labor demand, we can also derive firms' demand for commercial floor space using the intensive margin commercial floor space demand from equation (A.14) and the location choice of firms from equation (A.16):

$$\begin{aligned}
\ln M_c^D &= \ln F_c + \mathrm{E}_{\omega_{jc}}\left[\ln M_{jc}^*\right] \\
&= \frac{1}{\sigma^F}\ln B_c - \frac{\beta}{\sigma^F}\ln w_c - \frac{1-\beta}{\sigma^F}\ln p_c^M - \frac{1-\beta}{\sigma^F}\ln(\tau_c\kappa) - \ln\left(C\pi^F\right) \\
&\quad + \frac{\rho}{1-\rho}\ln B_c - \frac{\rho\beta}{1-\rho}\ln w_c - \frac{1-\rho\beta}{1-\rho}\ln p_c^M - \frac{1-\rho\beta}{1-\rho}\ln(\tau_c\kappa) \\
&\quad + \frac{1}{1-\rho}\ln\rho + \frac{\rho\beta}{1-\rho}\ln\beta + \frac{1-\rho\beta}{1-\rho}\ln(1-\beta) + \ln Q + \frac{\rho}{1-\rho}\mathrm{E}_{\omega_{jc}}\left[\ln\omega_{jc}\right] \\
\ln M_c^D &= \underbrace{\left(\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right)}_{=\epsilon^{\mathrm{B}}}\ln B_c \underbrace{-\beta\left(\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right)}_{=1+\epsilon^{\mathrm{ND}}}\ln w_c \underbrace{-\left(1+[1-\beta]\left[\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right]\right)}_{=\epsilon^{\mathrm{MD}}}\ln p_c^M
\end{aligned}$$

$$\underbrace{-\left(1+[1-\beta]\left[\frac{1}{\sigma^F}+\frac{\rho}{1-\rho}\right]\right)}_{=\epsilon^{\mathrm{MD}}}\ln(\tau_c\kappa)+b_2 \tag{A.19}$$

with constant $b_2 = \Big(\ln\rho + \rho\beta\ln\beta + [1-\rho\beta]\ln[1-\beta] + \rho\mathrm{E}_{\omega_{jc}}\left[\ln\omega_{jc}\right]\Big)\Big/\Big(1-\rho\Big) + \ln Q - \ln C - \ln\pi^F$. The commercial floor space demand elasticity is defined as:

$$\frac{\partial \ln M_c^D}{\partial \ln p_c^M} = -\frac{1-\beta}{\sigma^F} - 1 - \frac{\rho(1-\beta)}{1-\rho} = \epsilon^{\mathrm{MD}} < 0.$$

A.1.3 Construction Sector

We assume that a competitive, local construction sector provides both residential and commercial floor space. For positive supply on the two markets, there must be a no-arbitrage condition between both construction types. Following Ahlfeldt et al. (2015), we assume that the residential share ν of total floor space is determined by the prices of residential housing, p_c, and commercial floor space, p_c^M:

$$\begin{aligned} &\nu = 1, && \text{for } p_c^M < \phi p_c \\ &\nu \in (0,1), && \text{for } p_c^M = \phi p_c \\ &\nu = 0, && \text{for } p_c^M > \phi p_c \end{aligned} \tag{A.20}$$

with $\phi \geq 1$ denoting additional regulatory costs of commercial land use compared to residential housing.[21] In equilibrium, the no-arbitrage condition fixes the ratio between residential and commercial floor space prices, and every municipality has a positive supply of residential housing H_c and commercial floor space M_c. We can rewrite the two types of floor space in terms of total floor space, S_c, available in city c:

$$H_c = \nu S_c \qquad\qquad M_c = (1-\nu)S_c. \tag{A.21}$$

We follow the standard approach in urban economics and assume that the housing construction sector relies on a Cobb-Douglas technology with constant returns to scale using land ready for construction, L_c, and capital, K_c, to produce total floor space (see, e.g., Thorsnes, 1997, Epple et al., 2010, Combes et al., 2021). Assuming constant returns to scale, and thereby, zero profits in the construction sector is standard. Note that it is not necessary to make this assumption in our sufficient statistics framework. Construction firms may have positive business incomes, which directly affect utility, see Equation (1). Total floor space is given by:

$$S_c = H_c + M_c = L_c^{\gamma} K_c^{1-\gamma} \tag{A.22}$$

with γ being the output elasticity of land. In contrast to the capital tax literature, we assume global capital markets with unlimited supply at an exogenous rate s (Oates and Fischel, 2016).

[21] We abstract from heterogeneity in the residential land use share, ν, and the regulatory markup, ϕ, for simplicity. This assumption does not influence our results qualitatively.

Consequently, the price for capital s is given and constant across municipalities. Profits in the construction industry are given by:

$$\Pi_c^C = p_c^M \underbrace{L_c^\gamma K_c^{1-\gamma}}_{=S_c} - l_c L_c - s K_c \tag{A.23}$$

with inputs and factor prices $L_c, K_c, l_c, s > 0$ and the output elasticity of land defined as $\gamma \in (0, 1)$. Profit-maximizing behavior yields the following first-order conditions:

$$\begin{aligned} \frac{\partial \Pi_c^C}{\partial L_c} &= \gamma p_c^M \frac{S_c}{L_c} - l_c \stackrel{!}{=} 0 \\ \frac{\partial \Pi_c^C}{\partial K_c} &= (1-\gamma) p_c^M \frac{S_c}{K_c} - s \stackrel{!}{=} 0. \end{aligned}$$

Treating the supply of capital K_c as infinitely elastic and the price of capital s as exogenous, we can solve for land prices l_c as a function of the floor space price p_c^M. Taking logs of the second first-order condition we can derive the capital demand of the construction industry conditional on factor prices and land input:

$$\begin{aligned} \ln s &= \ln(1-\gamma) + \ln p_c^M + \ln S_c - \ln K_c \\ \ln s &= \ln(1-\gamma) + \ln p_c^M + \gamma \ln L_c + (1-\gamma) \ln K_c - \ln K_c \\ \ln K_c &= \frac{1}{\gamma} \ln(1-\gamma) + \frac{1}{\gamma} \ln p_c^M + \ln L_c - \frac{1}{\gamma} \ln s. \end{aligned}$$

Using the capital demand and the first-order condition with respect to land, we can solve for the price ratio of land to floor space in city c:

$$\begin{aligned} \ln l_c &= \ln \gamma + \ln p_c^M + \ln S_c - \ln L_c \\ &= \ln \gamma + \ln p_c^M + \gamma \ln L_c + (1-\gamma) \ln K_c - \ln L_c \\ &= \ln \gamma + \ln p_c^M - (1-\gamma) \ln L_c + \frac{1-\gamma}{\gamma} \Big(\ln(1-\gamma) + \ln p_c^M + \gamma \ln L_c - \ln s \Big) \\ &= \underbrace{\ln \gamma + \frac{1-\gamma}{\gamma} \ln(1-\gamma)}_{=c_0} - \frac{1-\gamma}{\gamma} \ln s - \frac{1}{\gamma} \ln p_c^M \\ \ln l_c &= c_0 - \frac{1-\gamma}{\gamma} \ln s + \frac{1}{\gamma} \ln p_c^M \end{aligned} \tag{A.24}$$

where we shorten the notation by introducing the term c_0 that is constant across municipalities. Land prices increase in the floor space rent p_c^M (and equivalently in residential rents p_c).

A.1.4 Land Supply

While the total land area in each municipality is fixed and inelastic, the share of land ready for residential or commercial construction may be elastic. We model the supply of land ready for construction in city c according to the following log supply function:

$$\ln L_c = \theta \ln l_c \tag{A.25}$$

with land supply elasticity $\epsilon^{\text{LS}} = \theta > 0$. The preparation of new areas includes, e.g., clearing and leveling the site and building road access and connections to the electrical grid.

A.1.5 Local Governments

Local governments use a share $\psi \in (0,1)$ of the property tax revenues to finance the local public good A_c. All remaining revenues $1-\psi$ are assumed to be wasted and/or captured by politicians as rents (Diamond, 2017). The government budget is defined as:

$$g_c = \psi \underbrace{\left(H_c p_c t_c + M_c p_c^M \left[\{1+t_c\}\kappa - 1\right]\right)}_{\text{Total tax revenue}}$$

$$\ln g_c = \ln \psi + \ln \left(H_c p_c t_c + M_c p_c^M \left[\{1+t_c\}\kappa - 1\right]\right), \tag{A.26}$$

where total tax revenue is the sum of residential property tax payments, $H_c p_c t_c$, and property taxes on rented commercial floor space, $M_c p_c^M$. Increases in city c's property tax rate t_c yield higher tax revenues and, thereby, a mechanical increase in local spending on the public good.

A.2 Equilibrium

The spatial equilibrium is determined by equalizing supply and demand on the markets for labor, residential housing, commercial floor space, and land in each city as well as the government budget constraint. Hence, we can summarize the equilibrium conditions using the following twelve equations:

$$\begin{aligned}
\ln N_c &= \frac{1-g}{\sigma^H}\ln w_c - \frac{\alpha(1-g)}{\sigma^H}\ln p_c - \frac{\alpha(1-g)}{\sigma^H}\ln \tau_c + \frac{g}{\sigma^H}\ln A_c + a_1 \\
\ln N_c &= \left(\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right)\ln B_c - \left(1 + \beta\left[\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right]\right)\ln w_c - (1-\beta)\left(\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right)\ln p_c^M \\
&\quad - (1-\beta)\left(\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right)\ln(\tau_c\kappa) + b_1 \\
\ln H_c &= \ln N_c + \ln \alpha + \ln w_c - \ln p_c - \ln \tau_c \\
\ln H_c &= \ln \nu + \ln S_c \\
\ln M_c &= \left(\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right)\ln B_c - \beta\left(\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right)\ln w_c - \left(1 + [1-\beta]\left[\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right]\right)\ln p_c^M \\
&\quad - \left(1 + [1-\beta]\left[\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right]\right)\ln(\tau_c\kappa) + b_2 \\
\ln M_c &= \ln(1-\nu) + \ln S_c \\
\ln S_c &= (1-\gamma)\ln K_c + \gamma \ln L_c \\
\ln K_c &= \ln L_c + \frac{1}{\gamma}\ln p_c^M + \frac{1}{\gamma}\ln(1-\gamma) - \frac{1}{\gamma}\ln s
\end{aligned}$$

$$\ln L_c = \theta \ln l_c$$
$$\ln l_c = c_0 - \frac{1-\gamma}{\gamma} \ln s + \frac{1}{\gamma} \ln p_c^M$$
$$\ln p_c^M = \ln \phi + \ln p_c$$
$$\ln A_c = \ln \psi + \ln \left(H_c p_c t_c + M_c p_c^M [\{1 + t_c\}\kappa - 1] \right)$$

where we again use $\tau_c = 1 + t_c$ to simplify the notation in the following. We further simplify the equations using the key elasticities we defined above (see also Table A.1 for an overview):

$$\ln N_c = \epsilon^{\text{NS}} \ln w_c + (1 + \epsilon^{\text{HD}}) \ln p_c + (1 + \epsilon^{\text{HD}}) \ln \tau_c + g\epsilon^{\text{A}} \ln A_c + a_1 \tag{A.27a}$$
$$\ln N_c = \epsilon^{\text{B}} \ln B_c + \epsilon^{\text{ND}} \ln w_c + (1 + \epsilon^{\text{MD}}) \ln p_c^M + (1 + \epsilon^{\text{MD}}) \ln(\tau_c \kappa) + b_1 \tag{A.27b}$$
$$\ln H_c = \ln N_c + \ln \alpha + \ln w_c - \ln p_c - \ln \tau_c \tag{A.27c}$$
$$\ln H_c = \ln \nu + \ln S_c \tag{A.27d}$$
$$\ln M_c = \epsilon^{\text{B}} \ln B_c + (1 + \epsilon^{\text{ND}}) \ln w_c + \epsilon^{\text{MD}} \ln p_c^M + \epsilon^{\text{MD}} \ln(\tau_c \kappa) + b_2 \tag{A.27e}$$
$$\ln M_c = \ln(1 - \nu) + \ln S_c \tag{A.27f}$$
$$\ln S_c = (1 - \gamma) \ln K_c + \gamma \ln L_c \tag{A.27g}$$
$$\ln K_c = \ln L_c + \frac{1}{\gamma} \ln p_c^M + \frac{1}{\gamma} \ln(1 - \gamma) - \frac{1}{\gamma} \ln s \tag{A.27h}$$
$$\ln L_c = \theta \ln l_c \tag{A.27i}$$
$$\ln l_c = c_0 - \frac{1-\gamma}{\gamma} \ln s + \frac{1}{\gamma} \ln p_c^M \tag{A.27j}$$
$$\ln r_c^M = \ln \phi + \ln p_c \tag{A.27k}$$
$$\ln A_c = \ln \psi + \ln \left(H_c p_c t_c + M_c p_c^M [\{1 + t_c\}\kappa - 1] \right) \tag{A.27l}$$

We can solve this system of equations for the equilibrium quantities in terms of population, residential housing, commercial floor space, use of capital, developed land, equilibrium prices for labor, residential housing, commercial floor space, and land as well as public good provision in equilibrium.

The derivation proceeds in four steps: First, we derive effective housing demand as a function of exogenous parameters and endogenous public goods (Appendix A.2.1). Second, we similarly solve for effective housing supply (Appendix A.2.2). Combining both we, third, derive equilibrium prices and quantities conditional on local public good provision (Appendix A.2.3). In Appendix A.2.4 we also solve for public good provision in equilibrium. Appendix A.2.5 provides a summary of the equilibrium prices and quantities.

A.2.1 Step 1 – Effective Housing Demand

To solve the model, we first derive the effective residential housing demand function, taking into account the extensive margin of people moving across locations. By combining

Table A.1: Key Elasticities of the Spatial Equilibrium Model

Key Elasticity	Definition
Panel A – Labor Market	
Labor Supply w.r.t.	
Wages	$\epsilon^{\text{NS}} = \frac{\partial \ln N_c}{\partial \ln w_c} = \frac{1-g}{\sigma^H}$
Amenities/Local Public Goods	$g\epsilon^{\text{A}} = \frac{\partial \ln N_c}{\partial \ln A_c} = \frac{g}{\sigma^H}$
Labor Demand w.r.t.	
Wages	$\epsilon^{\text{ND}} = \frac{\partial \ln N_c}{\partial \ln w_c} = -\left(1 + \beta\left[\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right]\right)$
Productive Amenities	$\epsilon^{\text{B}} = \frac{\partial \ln N_c}{\partial \ln B_c} = \frac{1}{\sigma^F} + \frac{\rho}{1-\rho}$
Panel B – Construction Sector and Land Market	
Residential Housing Demand w.r.t. Rents	$\epsilon^{\text{HD}} = \frac{\partial \ln H_c}{\partial \ln p_c} = -\frac{\alpha(1-g)+\sigma^H}{\sigma^H}$
Commercial Floor Space Demand w.r.t. Rents	$\epsilon^{\text{MD}} = \frac{\partial \ln M_c}{\partial \ln p_c^M} = -\left(1 + [1-\beta]\left[\frac{1}{\sigma^F} + \frac{\rho}{1-\rho}\right]\right)$
Panel C – Land Market	
Land Supply w.r.t. Land Prices	$\frac{\partial \ln L_c}{\partial \ln l_c} = \theta$

Notes: This table summarizes the key supply and demand elasticities of the structural spatial equilibrium model.

equations (A.27a) and (A.27c), we get the following expression:

$$\ln H_c^D = a_1 + \ln \alpha + g\epsilon^{\text{A}} \ln A_c + \epsilon^{\text{HD}} \ln p_c + \epsilon^{\text{HD}} \ln \tau_c + \left(1 + \epsilon^{\text{NS}}\right) \ln w_c.$$

By clearing the labor market, i.e., equating expressions (A.27a) and (A.27b), we can derive wages as a function of amenities, public goods, and floor space prices:

$$\begin{aligned} \ln w_c = \Big(& b_1 - a_1 - g\epsilon^{\text{A}} \ln A_c + \epsilon^{\text{B}} \ln B_c - \left[1 + \epsilon^{\text{HD}}\right] \ln \tau_c + \left[1 + \epsilon^{\text{MD}}\right] \ln\left[\tau_c \kappa\right] \\ & - \left[1 + \epsilon^{\text{HD}}\right] \ln p_c + \left[1 + \epsilon^{\text{MD}}\right] \ln p_c^M \Big) \Big/ \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right). \end{aligned} \tag{A.28}$$

As the partial derivative of log wages with respect to residential housing costs is positive ($-\left[1 + \epsilon^{\text{HD}}\right] / \left[\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right] > 0$), wages (partly) compensate for higher rents and/or higher residential property taxes *ceteris paribus*. Using this intermediate wage equation, we can rewrite residential housing demand as a function of housing costs, exogenous amenities, and local public goods:

$$\begin{aligned} \ln H_c^D = \Big(& \left[1 + \epsilon^{\text{NS}}\right] b_1 - \left[1 + \epsilon^{\text{ND}}\right] a_1 - \epsilon^{\text{A}} \left[1 + \epsilon^{\text{ND}}\right] g \ln A_c + \epsilon^{\text{B}} \left[1 + \epsilon^{\text{NS}}\right] \ln B_c \\ & - \left[1 + \epsilon^{\text{NS}} + \epsilon^{\text{HD}} \left\{1 + \epsilon^{\text{ND}}\right\}\right] \ln p_c - \left[1 + \epsilon^{\text{NS}} + \epsilon^{\text{HD}} \left\{1 + \epsilon^{\text{ND}}\right\}\right] \ln \tau_c \\ & + \left[1 + \epsilon^{\text{MD}}\right] \left[1 + \epsilon^{\text{NS}}\right] \ln p_c^M + \left[1 + \epsilon^{\text{MD}}\right] \left[1 + \epsilon^{\text{NS}}\right] \ln[\tau_c \kappa] \Big) \Big/ \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right) + \ln \alpha \end{aligned}$$

and use the no-arbitrage condition in equation (A.27k) to rewrite residential housing demand in terms of residential rents:

$$\ln H_c^D = \Big(\left[1 + \epsilon^{\text{NS}}\right] b_1 - \left[1 + \epsilon^{\text{ND}}\right] a_1 + \left[1 + \epsilon^{\text{MD}}\right] \left[1 + \epsilon^{\text{NS}}\right] \ln \phi + \epsilon^{\text{B}} \left[1 + \epsilon^{\text{NS}}\right] \ln B_c$$

$$- \epsilon^{\mathrm{A}} \left[1+\epsilon^{\mathrm{ND}}\right] g \ln A_c - \left[\epsilon^{\mathrm{HD}} \left\{1+\epsilon^{\mathrm{ND}}\right\} - \epsilon^{\mathrm{MD}} \left\{1+\epsilon^{\mathrm{NS}}\right\}\right] \ln p_c$$
$$- \left[1+\epsilon^{\mathrm{NS}} + \epsilon^{\mathrm{HD}} \left\{1+\epsilon^{\mathrm{ND}}\right\}\right] \ln \tau_c$$
$$+ \left[1+\epsilon^{\mathrm{MD}}\right] \left[1+\epsilon^{\mathrm{NS}}\right] \ln[\tau_c \kappa]\Big) \Big/ \Big(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\Big) + \ln \alpha.$$

Residential housing demand is now a function of exogenous parameters and two endogenous measures, residential rents p_c, and public good levels A_c.

Definition A.1 (Effective Housing Demand). *The effective residential housing demand elasticity $\tilde{\epsilon}^{\mathrm{HD}}$ captures the response of residential housing demand to changes in residential rents holding public good levels constant but taking into account equilibrium effects on the labor market and the commercial floor space market. We define the effective residential housing demand elasticity as:*

$$\tilde{\epsilon}^{\mathrm{HD}} = - \frac{\epsilon^{\mathrm{HD}}[1+\epsilon^{\mathrm{ND}}] - \epsilon^{\mathrm{MD}}[1+\epsilon^{\mathrm{NS}}]}{\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}} < 0.$$

Given that $\epsilon^{\mathrm{HD}} < 0$, $\epsilon^{\mathrm{MD}} < 0$, $\epsilon^{\mathrm{ND}} < 0$, and $\epsilon^{\mathrm{NS}} > 0$, it follows that $\epsilon^{\mathrm{HD}} < 0$.

We can rewrite residential housing demand accordingly using this definition:

$$\ln H_c^D = \Big(\left[1+\epsilon^{\mathrm{NS}}\right] b_1 - \left[1+\epsilon^{\mathrm{ND}}\right] a_1 + \left[1+\epsilon^{\mathrm{MD}}\right] \left[1+\epsilon^{\mathrm{NS}}\right] \ln \phi + \epsilon^{\mathrm{B}} \left[1+\epsilon^{\mathrm{NS}}\right] \ln B_c$$
$$- \epsilon^{\mathrm{A}} \left[1+\epsilon^{\mathrm{ND}}\right] g \ln A_c + \left[1+\epsilon^{\mathrm{MD}}\right] \left[1+\epsilon^{\mathrm{NS}}\right] \ln \kappa\Big) \Big/ \Big(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\Big)$$
$$+ \ln \alpha + \tilde{\epsilon}^{\mathrm{HD}} \ln p_c + \tilde{\epsilon}^{\mathrm{HD}} \ln \tau_c. \tag{A.29}$$

A.2.2 Step 2 – Effective Housing Supply

To clear the residential housing market, demand needs to equal floor space supply, which we can rewrite as a function of capital costs and residential rents by combining equation (A.27d) and equations (A.27g)–(A.27k):

$$\begin{aligned}
\ln H_c^S &= \ln S_c + \ln \nu \\
&= \underbrace{(1-\gamma) \ln K_c + \gamma \ln L_c}_{=\ln S_c} + \ln \nu \\
&= \underbrace{(1-\gamma) \ln L_c + \frac{1-\gamma}{\gamma} \ln p_c^M + \frac{1-\gamma}{\gamma} \ln(1-\gamma) - \frac{1-\gamma}{\gamma} \ln s}_{=(1-\gamma)\ln K_c} + \gamma \ln L_c + \ln \nu \\
&= \underbrace{\theta \ln l_c}_{=\ln L_c} + \frac{1-\gamma}{\gamma} \ln p_c^M + \frac{1-\gamma}{\gamma} \ln(1-\gamma) - \frac{1-\gamma}{\gamma} \ln s + \ln \nu \\
&= \underbrace{\frac{\theta}{\gamma} \ln p_c^M - \frac{\theta(1-\gamma)}{\gamma} \ln s + \theta c_0}_{=\theta \ln l_c} + \frac{1-\gamma}{\gamma} \ln p_c^M + \frac{1-\gamma}{\gamma} \ln(1-\gamma) - \frac{1-\gamma}{\gamma} \ln s + \ln \nu \\
&= \frac{1-\gamma+\theta}{\gamma} \ln p_c^M - \frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \theta c_0 + \ln \nu
\end{aligned}$$

$$\ln H_c^S = \frac{1-\gamma+\theta}{\gamma} \underbrace{(\ln p_c + \ln \phi)}_{=\ln p_c^M} - \frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \theta c_0 + \ln \nu.$$

Using these intermediate steps, we can also derive the effective housing supply elasticity.

Definition A.2 (Effective Housing Supply)**.** *The effective residential housing supply elasticity $\tilde{\epsilon}^{\text{HS}}$ captures the response of residential housing supply to changes in residential rents taking into account both the factor substitution in the construction industry and the elasticity of land supply. We define the effective residential housing supply elasticity as:*

$$\tilde{\epsilon}^{\text{HS}} = \frac{1-\gamma+\theta}{\gamma} > 0.$$

Given that $\gamma \in (0,1)$ and $\theta > 0$ it follows that $\tilde{\epsilon}^{\text{HS}} > 0$.

By rewriting the residential housing supply, we get:

$$\ln H_c^S = \tilde{\epsilon}^{\text{HS}} \ln p_c + \tilde{\epsilon}^{\text{HS}} \ln \phi - \frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \theta c_0 + \ln \nu. \tag{A.30}$$

A.2.3 Step 3 – Equilibrium Conditional on Public Good Provision

Net-of-tax Rents. Using equations (A.29) and (A.30) we can clear the residential housing market and solve for equilibrium net-of-tax rents for residential floor space in city c as a function of equilibrium public good provision A_c^* and exogenous parameters:

$$\begin{aligned}
\ln p_c^* = & \Bigg(\left[\ln \alpha - \ln \nu - \theta c_0 - \frac{1-\gamma}{\gamma} \ln\{1-\gamma\} + \frac{\{1+\theta\}\{1-\gamma\}}{\gamma} \ln s \right] \left[\epsilon^{\text{NS}} - \epsilon^{\text{ND}} \right] \\
& + \left[1 + \epsilon^{\text{NS}} \right] b_1 - \left[1 + \epsilon^{\text{ND}} \right] a_1 + \left[\left\{ 1 + \epsilon^{\text{MD}} \right\} \left\{ 1 + \epsilon^{\text{NS}} \right\} - \tilde{\epsilon}^{\text{HS}} \left\{ \epsilon^{\text{NS}} - \epsilon^{\text{ND}} \right\} \right] \ln \phi \\
& - \epsilon^{\text{A}} \left[1 + \epsilon^{\text{ND}} \right] g \ln A_c^* + \epsilon^{\text{B}} \left[1 + \epsilon^{\text{NS}} \right] \ln B_c + \tilde{\epsilon}^{\text{HD}} \left[\epsilon^{\text{NS}} - \epsilon^{\text{ND}} \right] \ln \tau_c \\
& + \left[1 + \epsilon^{\text{MD}} \right] \left[1 + \epsilon^{\text{NS}} \right] \ln \kappa \Bigg) \Bigg/ \Bigg(\left[\tilde{\epsilon}^{\text{HS}} - \tilde{\epsilon}^{\text{HD}} \right] \left[\epsilon^{\text{NS}} - \epsilon^{\text{ND}} \right] \Bigg) \\
\ln p_c^* = & \frac{\tilde{\epsilon}^{\text{HD}}}{d_0} \ln \tau_c - \frac{g \epsilon^{\text{A}} \left(1 + \epsilon^{\text{ND}} \right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}} \right)} \ln A_c^* \\
& + \frac{\epsilon^{\text{B}} \left(1 + \epsilon^{\text{NS}} \right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}} \right)} \ln B_c + \frac{\left(1 + \epsilon^{\text{MD}} \right) \left(1 + \epsilon^{\text{NS}} \right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}} \right)} \ln \kappa + \frac{d_{rH}}{d_0}
\end{aligned} \tag{A.31}$$

with

$$d_0 = \tilde{\epsilon}^{\text{HS}} - \tilde{\epsilon}^{\text{HD}} > 0 \tag{A.32}$$

$$\begin{aligned}
d_{rH} = & \ln \alpha - \ln \nu - \theta c_0 - \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1+\epsilon^{\text{NS}}}{\epsilon^{\text{NS}} - \epsilon^{\text{ND}}} b_1 \\
& - \frac{1+\epsilon^{\text{ND}}}{\epsilon^{\text{NS}} - \epsilon^{\text{ND}}} a_1 + \left(\frac{\left[1 + \epsilon^{\text{MD}} \right] \left[1 + \epsilon^{\text{NS}} \right]}{\epsilon^{\text{NS}} - \epsilon^{\text{ND}}} - \tilde{\epsilon}^{\text{HS}} \right) \ln \phi.
\end{aligned}$$

Using the no-arbitrage condition in equation (A.27k) we can solve for the equilibrium net-of-tax price of commercial floor space, again as a function of equilibrium local public goods:

$$\begin{aligned}\ln p_c^{M*} = & \frac{\tilde{\epsilon}^{\text{HD}}}{d_0}\ln\tau_c - \frac{g\epsilon^{\text{A}}\left(1+\epsilon^{\text{ND}}\right)}{d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln A_c^* \\ & + \frac{\epsilon^{\text{B}}\left(1+\epsilon^{\text{NS}}\right)}{d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln B_c + \frac{\left(1+\epsilon^{\text{MD}}\right)\left(1+\epsilon^{\text{NS}}\right)}{d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln\kappa + \frac{d_{r^M}}{d_0}\end{aligned} \tag{A.33}$$

with

$$\begin{aligned}d_{r^M} = & \ln\alpha - \ln\nu - \theta c_0 - \frac{1-\gamma}{\gamma}\ln(1-\gamma) + \frac{(1+\theta)(1-\gamma)}{\gamma}\ln s + \frac{1+\epsilon^{\text{NS}}}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}b_1 \\ & - \frac{1+\epsilon^{\text{ND}}}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}a_1 + \left(\frac{\left[1+\epsilon^{\text{NS}}\right]\left[1+\epsilon^{\text{MD}}\right]}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}} - \tilde{\epsilon}^{\text{HD}}\right)\ln\phi.\end{aligned}$$

Wages. Having solved for the price of residential and commercial floor space, we can derive equilibrium wages in city c by exploiting the intermediate wage equation (A.28):

$$\begin{aligned}\ln w_c^* = & -\frac{\tilde{\epsilon}^{\text{HS}}\left(\epsilon^{\text{HD}}-\epsilon^{\text{MD}}\right)}{d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln\tau_c - \frac{g\epsilon^{\text{A}}\left(\tilde{\epsilon}^{\text{HS}}-\epsilon^{\text{MD}}\right)}{d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln A_c^* \\ & + \frac{\epsilon^{\text{B}}\left(\tilde{\epsilon}^{\text{HS}}-\epsilon^{\text{HD}}\right)}{d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln B_c + \frac{\left(1+\epsilon^{\text{MD}}\right)\left(\tilde{\epsilon}^{\text{HS}}-\epsilon^{\text{HD}}\right)}{d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln\kappa + \frac{d_w}{d_0}\end{aligned} \tag{A.34}$$

with

$$\begin{aligned}d_w = & \left(\theta c_0 - \ln\alpha + \frac{1-\gamma}{\gamma}\ln[1-\gamma] + \ln\nu - \frac{[1-\gamma][1+\theta]}{\gamma}\ln s\right)\frac{\epsilon^{\text{HD}}-\epsilon^{\text{MD}}}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}} \\ & + \frac{\tilde{\epsilon}^{\text{HS}}\left(1+\epsilon^{\text{HD}}\right)-\epsilon^{\text{HD}}\left(1+\epsilon^{\text{MD}}\right)}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}\ln\phi - \frac{\tilde{\epsilon}^{\text{HS}}-\epsilon^{\text{MD}}}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}a_1 + \frac{\tilde{\epsilon}^{\text{HS}}-\epsilon^{\text{HD}}}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}b_1.\end{aligned}$$

Land Prices. The construction problem yields the relation between commercial floor space prices and land prices in equation (A.27j). Solving for land prices yields:

$$\begin{aligned}\ln l_c^* = & \frac{\tilde{\epsilon}^{\text{HD}}}{\gamma d_0}\ln\tau_c - \frac{g\epsilon^{\text{A}}\left(1+\epsilon^{\text{ND}}\right)}{\gamma d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln A_c^* \\ & + \frac{\epsilon^{\text{B}}\left(1+\epsilon^{\text{NS}}\right)}{\gamma d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln B_c + \frac{\left(1+\epsilon^{\text{MD}}\right)\left(1+\epsilon^{\text{NS}}\right)}{\gamma d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln\kappa + \frac{d_l}{\gamma d_0}\end{aligned} \tag{A.35}$$

with

$$\begin{aligned}d_l = & \ln\alpha - \ln\nu - \frac{1-\gamma}{\gamma}\ln(1-\gamma) - \frac{1+\epsilon^{\text{ND}}}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}a_1 + \frac{1+\epsilon^{\text{NS}}}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}b_1 + (\gamma d_0 - \theta)\,c_0 \\ & + \frac{(1-\gamma)(1+\theta-\gamma d_0)}{\gamma}\ln s + \frac{1+\epsilon^{\text{NS}}+\epsilon^{\text{HD}}\left(1+\epsilon^{\text{ND}}\right)}{\epsilon^{\text{NS}}-\epsilon^{\text{ND}}}\ln\phi.\end{aligned}$$

Developed Land. Using equilibrium land prices and the land supply function allows us to solve for equilibrium land use in city c:

$$\ln L_c^* = \frac{\tilde{\epsilon}^{\text{HD}}\theta}{\gamma d_0}\ln\tau_c - \frac{g\theta\epsilon^{\text{A}}\left(1+\epsilon^{\text{ND}}\right)}{\gamma d_0\left(\epsilon^{\text{NS}}-\epsilon^{\text{ND}}\right)}\ln A_c^*$$

$$+\frac{\theta\epsilon^{\mathrm{B}}\left(1+\epsilon^{\mathrm{NS}}\right)}{\gamma d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln B_c+\frac{\theta\left(1+\epsilon^{\mathrm{MD}}\right)\left(1+\epsilon^{\mathrm{NS}}\right)}{\gamma d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln\kappa+\frac{\theta d_l}{\gamma d_0}. \tag{A.36}$$

Capital Stock. Equilibrium land use and equilibrium floor space prices also determine the equilibrium capital stock in equation (A.27h):

$$\begin{aligned}\ln K_c^*=&\frac{\tilde{\epsilon}^{\mathrm{HD}}(1+\theta)}{\gamma d_0}\ln\tau_c-\frac{g\epsilon^{\mathrm{A}}(1+\theta)\left(1+\epsilon^{\mathrm{ND}}\right)}{\gamma d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln A_c^*\\&+\frac{\epsilon^{\mathrm{B}}(1+\theta)\left(1+\epsilon^{\mathrm{NS}}\right)}{\gamma d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln B_c+\frac{(1+\theta)\left(1+\epsilon^{\mathrm{MD}}\right)\left(1+\epsilon^{\mathrm{NS}}\right)}{\gamma d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln\kappa+\frac{d_K}{\gamma d_0}\end{aligned} \tag{A.37}$$

with

$$\begin{aligned}d_K=&(1+\theta)\left([\ln\alpha-\ln\nu]\left[\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right]-\left[1+\epsilon^{\mathrm{ND}}\right]a_1+\left[1+\epsilon^{\mathrm{NS}}\right]b_1\right)\\&-\theta\left(1+\theta\gamma d_0\right)c_0-\frac{(1-\gamma)(1+\theta)-\gamma d_0}{\gamma}\ln(1-\gamma)\\&+\frac{(1-\gamma)(1+\theta)^2-\gamma(1+\theta[1-\gamma])d_0}{\gamma}\ln s\\&+\frac{(1+\theta)\left(1+\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{HD}}\left[1+\epsilon^{\mathrm{ND}}\right]\right)}{\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}}\ln\phi.\end{aligned}$$

Floor Space. Land use and the capital stock in equilibrium also determine total floor space production. Using the production function of the construction sector we can solve for the equilibrium floor space quantity in city c:

$$\begin{aligned}\ln S_c^*=&\frac{\tilde{\epsilon}^{\mathrm{HS}}\tilde{\epsilon}^{\mathrm{HD}}}{d_0}\ln\tau_c-\frac{\tilde{\epsilon}^{\mathrm{HS}}g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln A_c^*\\&+\frac{\tilde{\epsilon}^{\mathrm{HS}}\epsilon^{\mathrm{B}}\left(1+\epsilon^{\mathrm{NS}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln B_c+\frac{\tilde{\epsilon}^{\mathrm{HS}}\left(1+\epsilon^{\mathrm{MD}}\right)\left(1+\epsilon^{\mathrm{NS}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln\kappa+\frac{d_S}{\gamma d_0}\end{aligned} \tag{A.38}$$

with

$$\begin{aligned}d_S=&\frac{1-\gamma+\theta}{\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}}\Big([\ln\alpha-\ln\nu]\left[\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right]-\left[1+\epsilon^{\mathrm{ND}}\right]a_1+\left[1+\epsilon^{\mathrm{NS}}\right]b_1\\&\qquad+\left[1+\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{HD}}\left\{1+\epsilon^{\mathrm{ND}}\right\}\right]\ln\phi\Big)\\&+(1-\gamma+\theta-\gamma d_0)\left(\frac{[1-\gamma][1+\theta]}{\gamma}\ln s-\theta c_0-\frac{1-\gamma}{\gamma}\ln[1-\gamma]\right).\end{aligned}$$

Using the residential share ν of total floor space we can solve for residential housing in equilibrium:

$$\begin{aligned}\ln H_c^*=&\frac{\tilde{\epsilon}^{\mathrm{HS}}\tilde{\epsilon}^{\mathrm{HD}}}{d_0}\ln\tau_c-\frac{\tilde{\epsilon}^{\mathrm{HS}}g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln A_c^*\\&+\frac{\tilde{\epsilon}^{\mathrm{HS}}\epsilon^{\mathrm{B}}\left(1+\epsilon^{\mathrm{NS}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln B_c+\frac{\tilde{\epsilon}^{\mathrm{HS}}\left(1+\epsilon^{\mathrm{MD}}\right)\left(1+\epsilon^{\mathrm{NS}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln\kappa+\frac{d_H}{\gamma d_0}\end{aligned} \tag{A.39}$$

with

$$d_H=d_S+\gamma d_0\ln\nu.$$

Similarly, we can solve for equilibrium commercial floor space production:

$$\ln M_c^* = \frac{\tilde{\epsilon}^{\mathrm{HS}}\tilde{\epsilon}^{\mathrm{HD}}}{d_0}\ln\tau_c - \frac{\tilde{\epsilon}^{\mathrm{HS}}g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln A_c^* + \frac{\tilde{\epsilon}^{\mathrm{HS}}\epsilon^{\mathrm{B}}\left(1+\epsilon^{\mathrm{NS}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln B_c + \frac{\tilde{\epsilon}^{\mathrm{HS}}\left(1+\epsilon^{\mathrm{MD}}\right)\left(1+\epsilon^{\mathrm{NS}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}\ln\kappa + \frac{d_M}{\gamma d_0} \tag{A.40}$$

with

$$d_M = d_S + \gamma d_0 \ln(1-\nu).$$

Population. By exploiting the labor supply to city c as a function of rents and wages, we can also solve for equilibrium population:

$$\begin{aligned}\ln N_c^* = &-\frac{\tilde{\epsilon}^{\mathrm{HS}}\left(\epsilon^{\mathrm{ND}}\left[1+\epsilon^{\mathrm{HD}}\right]-\epsilon^{\mathrm{NS}}\left[1+\epsilon^{\mathrm{MD}}\right]\right)}{d_0\left(\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{ND}}\right)}\ln\tau_c - \frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{MD}}+\epsilon^{\mathrm{ND}}\left[1+\tilde{\epsilon}^{\mathrm{HS}}\right]\right)}{d_0\left(\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{ND}}\right)}\ln A_c^* \\ &+ \frac{\epsilon^{\mathrm{B}}\left(1+\epsilon^{\mathrm{HD}}+\epsilon^{\mathrm{NS}}\left[1+\tilde{\epsilon}^{\mathrm{HS}}\right]\right)}{d_0\left(\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{ND}}\right)}\ln B_c \\ &+ \frac{\left(1+\epsilon^{\mathrm{MD}}\right)\left(1+\epsilon^{\mathrm{HD}}+\epsilon^{\mathrm{NS}}\left[1+\tilde{\epsilon}^{\mathrm{HS}}\right]\right)}{d_0\left(\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{ND}}\right)}\ln\kappa + \frac{d_N}{d_0}\end{aligned} \tag{A.41}$$

with

$$\begin{aligned}d_N = &-\frac{1+\epsilon^{\mathrm{MD}}+\epsilon^{\mathrm{ND}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}}a_1 + \frac{1+\epsilon^{\mathrm{HD}}+\epsilon^{\mathrm{NS}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}}b_1 \\ &+ \left(\ln\nu - \ln\alpha + \theta c_0 + \frac{1-\gamma}{\gamma}\ln[1-\gamma] - \frac{[1-\gamma][1+\theta]}{\gamma}\ln s\right) \\ &\qquad\times\left(\frac{\epsilon^{\mathrm{ND}}\left[1+\epsilon^{\mathrm{HD}}\right]-\epsilon^{\mathrm{NS}}\left[1+\epsilon^{\mathrm{MD}}\right]}{\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}}\right) \\ &+ \frac{\tilde{\epsilon}^{\mathrm{HS}}\epsilon^{\mathrm{ND}}\left(1+\epsilon^{\mathrm{HD}}\right)+\left(1+\epsilon^{\mathrm{MD}}\right)\left(1+\epsilon^{\mathrm{HD}}+\epsilon^{\mathrm{NS}}\right)}{\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}}\ln\phi.\end{aligned}$$

A.2.4 Step 4 – Equilibrium Public Good Provision

So far, we solved the equilibrium conditional on equilibrium public good levels A_c^* to differentiate between the direct effects of taxes on equilibrium outcomes and the indirect effects operating through increases in local public goods financed via property taxes.

We can now also derive equilibrium public good provision A_c^* as a function of exogenous parameters. To simplify exposition and keep the model analytically tractable, we assume that rents for residential housing equal the prices for commercial floor space ($\phi = 1$), which implies that both types of land use are subject to the same regulations (Ahlfeldt et al., 2015). Moreover, we assume that residential and commercial floor space is taxed at the same rate, i.e., $\kappa = 1$.

Using the no-arbitrage condition from equation (A.27k), the supply functions for residential and commercial floor space from equations (A.27d) and (A.27f), effective housing supply from equation (A.30), and equilibrium rents for residential housing in equation (A.43), we can solve for equilibrium public good provision:

$$
\begin{aligned}
\ln A_c &= \ln \psi + \ln\left(H_c p_c t_c + M_c p_c^M \underbrace{\left[\{1+t_c\}^{\overbrace{\kappa}^{=1}} - 1 \right]}_{=t_c} \right) \\
&= \ln \psi + \ln\left(H_c p_c t_c + M_c \underbrace{\overbrace{\phi}^{=1} r_c}_{=p_c^M} t_c \right) \\
&= \ln \psi + \ln\left(\nu S_c p_c t_c + (1-\nu) S_c p_c t_c\right) \\
&= \ln \psi + \ln S_c + \ln p_c + \ln t_c \\
&= \ln \psi + \underbrace{\ln H_c - \ln \nu}_{=\ln S_c} + \ln p_c + \ln t_c \\
&= \underbrace{\tilde{\epsilon}^{\mathrm{HS}} \ln p_c + \tilde{\epsilon}^{\mathrm{HS}} \ln \phi - \frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \theta c_0 + \ln \nu}_{=\ln H_c} \\
&\quad + \ln \psi - \ln \nu + \ln p_c + \ln t_c \\
&= \left(1 + \tilde{\epsilon}^{\mathrm{HS}}\right) \ln p_c + \ln t_c + \underbrace{\tilde{\epsilon}^{\mathrm{HS}} \ln \phi}_{=0} - \frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \theta c_0 + \ln \psi \\
&= \left(1 + \tilde{\epsilon}^{\mathrm{HS}}\right) \left(\frac{\tilde{\epsilon}^{\mathrm{HD}}}{d_0} \ln \tau_c - \frac{g \epsilon^{\mathrm{A}} \left[1 + \epsilon^{\mathrm{ND}}\right]}{d_0 \left[\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right]} \ln A_c \right. \\
&\qquad \left. + \frac{\epsilon^{\mathrm{B}} \left[1 + \epsilon^{\mathrm{NS}}\right]}{d_0 \left[\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right]} \ln B_c + \underbrace{\frac{\left[1 + \epsilon^{\mathrm{MD}}\right] \left[1 + \epsilon^{\mathrm{NS}}\right]}{d_0 \left[\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right]} \ln \kappa}_{=0} + \frac{d_{rH}}{d_0} \right) \\
&\quad + \ln t_c - \frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \theta c_0 + \ln \psi \\
\ln A_c^* &= \left(\frac{\tilde{\epsilon}^{\mathrm{HD}} \left[1 + \tilde{\epsilon}^{\mathrm{HS}}\right]}{d_0} \ln \tau_c + \ln t_c + \frac{d_{rH} \left[1 + \tilde{\epsilon}^{\mathrm{HS}}\right]}{d_0} + d_G \right. \\
&\quad \left. + \frac{\epsilon^{\mathrm{B}} \left[1 + \tilde{\epsilon}^{\mathrm{HS}}\right] \left[1 + \epsilon^{\mathrm{NS}}\right]}{d_0 \left[\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right]} \ln B_c \right) \Bigg/ \left(\frac{g \epsilon^{\mathrm{A}} \left[1 + \epsilon^{\mathrm{ND}}\right] \left[1 + \tilde{\epsilon}^{\mathrm{HS}}\right]}{d_0 \left[\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right]} + 1 \right)
\end{aligned}
\tag{A.42}
$$

with

$$
d_G = -\frac{(1+\theta)(1-\gamma)}{\gamma} \ln s + \frac{1-\gamma}{\gamma} \ln(1-\gamma) + \theta c_0 + \ln \psi.
$$

A.2.5 Summary

Hence, we arrive at the following spatial equilibrium prices and quantities for city c (conditional on equilibrium public good levels A_c^* and assuming equal tax rates and equal prices for residential and commercial floor space, i.e., $\kappa = \phi = 1$):

$$
\begin{aligned}
\ln p_c^* &= \frac{\tilde{\epsilon}^{\text{HD}}}{d_0} \ln \tau_c - \frac{g\epsilon^{\text{A}} \left(1+\epsilon^{\text{ND}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_{r^H}}{d_0} \\
\ln p_c^{M*} &= \frac{\tilde{\epsilon}^{\text{HD}}}{d_0} \ln \tau_c - \frac{g\epsilon^{\text{A}} \left(1+\epsilon^{\text{ND}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_{r^M}}{d_0} \\
\ln l_c^* &= \frac{\tilde{\epsilon}^{\text{HD}}}{\gamma d_0} \ln \tau_c - \frac{g\epsilon^{\text{A}} \left(1+\epsilon^{\text{ND}}\right)}{\gamma d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{\gamma d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_l}{\gamma d_0} \\
\ln w_c^* &= -\frac{\tilde{\epsilon}^{\text{HS}} \left(\epsilon^{\text{HD}} - \epsilon^{\text{MD}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln \tau_c - \frac{g\epsilon^{\text{A}} \left(\tilde{\epsilon}^{\text{HS}} - \epsilon^{\text{MD}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\epsilon^{\text{B}} \left(\tilde{\epsilon}^{\text{HS}} - \epsilon^{\text{HD}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_w}{d_0} \\
\ln S_c^* &= \frac{\tilde{\epsilon}^{\text{HS}}\tilde{\epsilon}^{\text{HD}}}{d_0} \ln \tau_c - \frac{\tilde{\epsilon}^{\text{HS}} g\epsilon^{\text{A}}(1+\epsilon^{\text{ND}})}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\tilde{\epsilon}^{\text{HS}}\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_S}{\gamma d_0} \\
\ln H_c^* &= \frac{\tilde{\epsilon}^{\text{HS}}\tilde{\epsilon}^{\text{HD}}}{d_0} \ln \tau_c - \frac{\tilde{\epsilon}^{\text{HS}} g\epsilon^{\text{A}}(1+\epsilon^{\text{ND}})}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\tilde{\epsilon}^{\text{HS}}\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_H}{\gamma d_0} \\
\ln M_c^* &= \frac{\tilde{\epsilon}^{\text{HS}}\tilde{\epsilon}^{\text{HD}}}{d_0} \ln \tau_c - \frac{\tilde{\epsilon}^{\text{HS}} g\epsilon^{\text{A}}(1+\epsilon^{\text{ND}})}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\tilde{\epsilon}^{\text{HS}}\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_M}{\gamma d_0} \\
\ln L_c^* &= \frac{\tilde{\epsilon}^{\text{HD}}\theta}{\gamma d_0} \ln \tau_c - \frac{g\theta\epsilon^{\text{A}} \left(1+\epsilon^{\text{ND}}\right)}{\gamma d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\theta\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{\gamma d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{\theta d_l}{\gamma d_0} \\
\ln N_c^* &= -\frac{\tilde{\epsilon}^{\text{HS}} \left(\epsilon^{\text{ND}}\left[1+\epsilon^{\text{HD}}\right] - \epsilon^{\text{NS}}\left[1+\epsilon^{\text{MD}}\right]\right)}{d_0 \left(\epsilon^{\text{NS}} + \epsilon^{\text{ND}}\right)} \ln \tau_c - \frac{g\epsilon^{\text{A}} \left(1+\epsilon^{\text{MD}} + \epsilon^{\text{ND}}\left[1+\tilde{\epsilon}^{\text{HS}}\right]\right)}{d_0 \left(\epsilon^{\text{NS}} + \epsilon^{\text{ND}}\right)} \ln A_c^* \\
&\quad + \frac{\epsilon^{\text{B}} \left(1+\epsilon^{\text{HD}} + \epsilon^{\text{NS}}\left[1+\tilde{\epsilon}^{\text{HS}}\right]\right)}{d_0 \left(\epsilon^{\text{NS}} + \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_N}{d_0} \\
\ln K_c^* &= \frac{\tilde{\epsilon}^{\text{HD}}(1+\theta)}{\gamma d_0} \ln \tau_c - \frac{g\epsilon^{\text{A}}(1+\theta)\left(1+\epsilon^{\text{ND}}\right)}{\gamma d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* + \frac{\epsilon^{\text{B}}(1+\theta)\left(1+\epsilon^{\text{NS}}\right)}{\gamma d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_K}{\gamma d_0} \\
\ln A_c^* &= \left(\frac{\tilde{\epsilon}^{\text{HD}}\left[1+\tilde{\epsilon}^{\text{HS}}\right]}{d_0} \ln \tau_c + \ln t_c + \frac{d_{r^H}\left[1+\tilde{\epsilon}^{\text{HS}}\right]}{d_0} + d_G \right. \\
&\quad \left. + \frac{\epsilon^{\text{B}}\left[1+\tilde{\epsilon}^{\text{HS}}\right]\left[1+\epsilon^{\text{NS}}\right]}{d_0\left[\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right]} \ln B_c \right) \Bigg/ \left(\frac{g\epsilon^{\text{A}}\left[1+\epsilon^{\text{ND}}\right]\left[1+\tilde{\epsilon}^{\text{HS}}\right]}{d_0\left[\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right]} + 1 \right)
\end{aligned}
$$

with d_0, d_{r^H}, d_{r^M}, d_l, d_w, d_S, d_H, d_M, d_N, and d_G being constant terms.

Total Rents. Based on these derivations, we can also solve for the total rent in city c, which is one of the key parameters in the sufficient statistics approach in Section 2:

$$
\begin{aligned}
\ln q_c^* = \ln p_c^* \tau_c = \frac{\tilde{\epsilon}^{\text{HS}}}{d_0} \ln \tau_c &- \frac{g\epsilon^{\text{A}} \left(1+\epsilon^{\text{ND}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln A_c^* \\
&+ \frac{\epsilon^{\text{B}} \left(1+\epsilon^{\text{NS}}\right)}{d_0 \left(\epsilon^{\text{NS}} - \epsilon^{\text{ND}}\right)} \ln B_c + \frac{d_{r^H}}{d_0}
\end{aligned} \tag{A.43}
$$

Real Wages. Combining the previous results, we can also derive the real wage in city c, i.e., local wages adjusted for local costs of living—a measure that has been frequently used in the previous literature (see, e.g., Kline and Moretti, 2014). Using the equilibrium wage w_c^* and the equilibrium total rent for residential housing, q_c^*, we derive the real wage as (again conditional on equilibrium public good levels and assuming $\kappa = \phi = 1$):

$$\ln \frac{w_c^*}{q_c^*} = -\frac{\tilde{\epsilon}^{\mathrm{HS}} \left(\epsilon^{\mathrm{HD}} - \epsilon^{\mathrm{MD}} + \epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)}{d_0 \left(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)} \ln \tau_c - \frac{g\epsilon^{\mathrm{A}} \left(\tilde{\epsilon}^{\mathrm{HS}} - \epsilon^{\mathrm{MD}} - \epsilon^{\mathrm{ND}} - 1\right)}{d_0 \left(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)} \ln A_c^*$$
$$+ \frac{\epsilon^{\mathrm{B}} \left(\tilde{\epsilon}^{\mathrm{HS}} - \epsilon^{\mathrm{HD}} - \epsilon^{\mathrm{NS}} - 1\right)}{d_0 \left(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)} \ln B_c$$
$$+ \frac{d_w - d_{r^H}}{d_0}. \tag{A.44}$$

A.3 Welfare Analysis

Following the standard approach in the spatial equilibrium literature, we assume a utilitarian welfare function that aggregates the utility of all agents—workers, firm owners, construction company owners, and landlords—in the economy:

$$W = W^H + W^F + \underbrace{W^C}_{=0} + W^L.$$

We measure worker welfare, W^H, by workers' utility and the welfare of firm owners, W^F, by the firm values defined above. The welfare of construction firm owners, W^C, and landlords' welfare, W^L, are measured by their profits. Following standard practice, the construction sector is assumed to operate under perfect competition and makes zero profits; thus, the welfare of construction firms is zero. We assume that the economy is large and a change in city c's property tax rate does not affect the utility of workers, firms, or landlords in other locations.

Worker Welfare. Following the setup in Kline and Moretti (2014), we define workers' aggregate welfare as the inclusive value of equation (A.6). Welfare is then given by (with the number of workers still being normalized to one):

$$W^H = \sigma^H \ln \left(\sum_{c=1}^{C} \exp \left[\frac{V_c^H}{\sigma^H} \right] \right).$$

We are interested in the change in welfare if city c increases its property tax rate by a small amount:

$$\begin{aligned}
\frac{\mathrm{d}W^H}{\mathrm{d}\ln \tau_c} &= \frac{\sigma^H}{\sum_{k=1}^{C} \exp\left(V_k^H/\sigma^H\right)} \sum_{k=1}^{C} \frac{\mathrm{d}\exp\left(V_k^H/\sigma^H\right)}{\mathrm{d}\ln \tau_c} \\
&= \frac{\sigma^H}{\sum_{k=1}^{C} \exp\left(V_k^H/\sigma^H\right)} \sum_{k=1}^{C} \exp\left(\frac{V_k^H}{\sigma^H}\right) \frac{1}{\sigma^H} \frac{\mathrm{d}V_k^H}{\mathrm{d}\ln \tau_c} \\
&= \sum_{k=1}^{C} \frac{\exp\left(V_k^H/\sigma^H\right)}{\sum_{m=1}^{C} \exp\left(V_m^H/\sigma^H\right)} \frac{\mathrm{d}V_k^H}{\mathrm{d}\ln \tau_c} \\
&= \sum_{k=1}^{C} N_k \frac{\mathrm{d}V_k^H}{\mathrm{d}\ln \tau_c}
\end{aligned}$$

$$\frac{\mathrm{d}W^H}{\mathrm{d}\ln\tau_c} = N_c \frac{\mathrm{d}V_c^H}{\mathrm{d}\ln\tau_c} = -N_c\left([1-g]\left[\alpha\frac{\mathrm{d}\ln q_c^*}{\mathrm{d}\ln\tau_c} - \frac{\mathrm{d}\ln w_c^*}{\mathrm{d}\ln\tau_c}\right] - g\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c}\right).$$

To first order, an increase in city c's property tax affects workers' welfare via the pass-through of property taxes on tax-inclusive total rents $q_c^* = \tau_c p_c^* = (1+t_c)p_c^*$, its effect on wages w_c^*, and the transmission into local public goods A_c^*. Following the envelope conditions, behavioral responses will have no first-order impact on household utility. The sign and the magnitude of the welfare consequences for residents in city c depend (i) on the extent to which wages and net-of-tax rents compensate for the utility loss due to higher tax payments, and (ii) on the responsiveness of equilibrium public good spending to changes in the tax rate. The lower the preferences for public goods, g (relative to the preferences for private goods, $1-g$,) the more important the former effect. The higher public good preferences, the more important the latter effect.

Welfare of Firm Owners. We derive firm values accordingly and again use the inclusive value from equation (A.15) to measure the welfare of firm owners (Suárez Serrato and Zidar, 2016):

$$W^F = \sigma^F \ln\left(\sum_{c=1}^{C}\exp\left[\frac{V_c^F}{\sigma^F}\right]\right).$$

Looking at the change in firm owners' welfare in response to marginal increases in city c's tax rate yields the following result:

$$\frac{\mathrm{d}W^F}{\mathrm{d}\ln\tau_c} = F_c \frac{\mathrm{d}V_c^F}{\mathrm{d}\ln\tau_c} = -F_c\left([1-\beta] + [1-\beta]\frac{\mathrm{d}\ln p_c^{M*}}{\mathrm{d}\ln\tau_c} + \beta\frac{\mathrm{d}\ln w_c^*}{\mathrm{d}\ln\tau_c}\right).$$

A change in the property tax rate thus operates via (i) the impact on local wages w_c^*, and (ii) the impact on the total price of commercial floor space $\kappa(1+t_c)p_c^{M*} = \kappa\tau_c p_c^{M*}$. Thus, the change in firm owners' welfare depends on the share of the tax burden that can be passed on to landlords in terms of lower net-of-tax prices for commercial floor space and the share that can be shifted to workers via lower wages. Both effects are weighted according to their importance in the production function governed by the Cobb-Douglas parameter β.

Welfare of Construction Company Owners. The welfare of firm owners in the construction industry is given by their profits based on equation (A.23):

$$W^C = \sum_{c=1}^{C}\Pi_c^C = \sum_{c=1}^{C}\left(p_c^{M*}S_c^* - sK_c^* - l_c^*L_c^*\right) = 0.$$

Property tax increases yield lower sales in the construction industry because workers and firms demand less floor space S_c^* and every unit is sold at a lower price p_c^{M*}. Construction firms react by decreasing their demand for land, L_c^*, and capital, K_c^*, and thus the price of land, l_c^*, will decrease as well. With some algebra, one can show that W^C evaluates to zero in equilibrium and construction firms still make zero profits irrespective of the tax as long as we assume price-taking behavior and constant returns to scale (see, e.g., Thorsnes, 1997, Epple et al., 2010, Combes et al., 2021).

Welfare of Landowners. Since construction companies operate in a perfectly competitive market, landlord welfare will be determined by the impact on landowners. We denote landowners' profits by producer surplus as in Kline and Moretti (2014), i.e., the area between land prices and the inverse land supply function defined in equation (A.25). We normalize this number with the size of the nationwide land market denoted by Λ:

$$W^L = \frac{1}{\Lambda}\sum_{c=1}^{C}\int_0^{L_c^*}\left(l_c^* - u^{\frac{1}{\theta}}\right)\,\mathrm{d}u = \frac{1}{\Lambda}\sum_{c=1}^{C}\left(l_c^* L_c^* - \frac{L_c^{*\,1+\frac{1}{\theta}}}{1+\frac{1}{\theta}}\right) = \frac{1}{\Lambda}\sum_{c=1}^{C}\left(l_c^* L_c^* - \frac{\theta L_c^* \overbrace{L_c^{*\,\frac{1}{\theta}}}^{=l_c^*}}{1+\theta}\right)$$

$$W^L = \frac{1}{\Lambda}\sum_{c=1}^{C}\frac{l_c^* L_c^*}{1+\theta}.$$

Tax increases in city c reduce the welfare of landowners according to the following expression:

$$\begin{aligned}
\frac{\mathrm{d}W^L}{\mathrm{d}\ln\tau_c} &= \frac{1}{(1+\theta)\Lambda}\left(l_c^*\frac{\mathrm{d}L_c^*}{\mathrm{d}\ln\tau_c} + L_c^*\frac{\mathrm{d}l_c^*}{\mathrm{d}\ln\tau_c}\right) \\
&= \frac{1}{(1+\theta)\Lambda}\left(l_c^*\frac{\mathrm{d}\exp\left[\ln L_c^*\right]}{\mathrm{d}\ln\tau_c} + L_c^*\frac{\mathrm{d}\exp\left[\ln l_c^*\right]}{\mathrm{d}\ln\tau_c}\right) \\
&= \frac{1}{(1+\theta)\Lambda}\left(l_c^*\frac{\mathrm{d}\exp\left[\ln L_c^*\right]}{\mathrm{d}\ln L_c^*}\frac{\mathrm{d}\ln L_c^*}{\mathrm{d}\ln\tau_c} + L_c^*\frac{\mathrm{d}\exp\left[\ln l_c^*\right]}{\mathrm{d}\ln l_c^*}\frac{\mathrm{d}\ln l_c^*}{\mathrm{d}\ln\tau_c}\right) \\
&= \frac{1}{(1+\theta)\Lambda}\left(l_c^* L_c^*\frac{\mathrm{d}\ln L_c^*}{\mathrm{d}\ln\tau_c} + L_c^* l_c^*\frac{\mathrm{d}\ln l_c^*}{\mathrm{d}\ln\tau_c}\right) \\
&= \frac{l_c^* L_c^*}{(1+\theta)\Lambda}\left(\frac{\mathrm{d}\ln L_c^*}{\mathrm{d}\ln\tau_c} + \frac{\mathrm{d}\ln l_c^*}{\mathrm{d}\ln\tau_c}\right) \\
\frac{\mathrm{d}W^L}{\mathrm{d}\ln\tau_c} &= \frac{l_c^* L_c^*}{\gamma\Lambda}\frac{\mathrm{d}\ln r_c}{\mathrm{d}\ln\tau_c} = \frac{l_c^* L_c^*}{\Lambda}\frac{\mathrm{d}\ln l_c^*}{\mathrm{d}\ln\tau_c} = \Lambda_c\frac{\mathrm{d}\ln l_c^*}{\mathrm{d}\ln\tau_c},
\end{aligned}$$

where Λ_c denotes the share of local land sales $l_c^* L_c^*$ relative to the nationwide land market Λ. The stronger the impact of property taxes on land prices and the more severe the reduction in land demand due to higher taxes, the bigger the welfare loss for landowners. As their welfare is decreasing in the land supply elasticity (see denominator), landlords will only bear part of the tax burden as long as the supply of land ready for construction is not perfectly elastic. Otherwise, landlords make zero profits and won't bear any tax burden.

Summary. After deriving the welfare impact of property tax increases for all four groups of agents, we summarize the welfare consequences in the following Proposition A.1:

Proposition A.1 (Welfare Effects in the Structural Model). *Let W^H, W^F, W^C, and W^L denote the welfare of workers, firm owners, constructors, and landowners in the spatial equilibrium, respectively. The welfare changes of a marginal increase in city c's property tax rate t_c are determined by:*

(i) the elasticities of equilibrium rents, land prices, and wages with respect to the property tax rate,

(ii) the responsiveness of the local public good provision in equilibrium with respect to the tax,

(iii) three exogenous model parameters, namely the housing share in consumption, α, the labor share in the tradable good production, β, and the preferences for local public goods, g.

This result is based on the four welfare predictions (each evaluated for a single household):

$$\frac{\mathrm{d}W^H}{\mathrm{d}\ln\tau_c} = -\left([1-g]\left[\alpha\frac{\mathrm{d}\ln q_c^*}{\mathrm{d}\ln\tau_c} - \frac{\mathrm{d}\ln w_c^*}{\mathrm{d}\ln\tau_c}\right] - g\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c}\right) \tag{A.45}$$

$$\frac{\mathrm{d}W^F}{\mathrm{d}\ln\tau_c} = -\left([1-\beta] + [1-\beta]\frac{\mathrm{d}\ln p_c^{M*}}{\mathrm{d}\ln\tau_c} + \beta\frac{\mathrm{d}\ln w_c^*}{\mathrm{d}\ln\tau_c}\right) \tag{A.46}$$

$$\frac{\mathrm{d}W^C}{\mathrm{d}\ln\tau_c} = 0 \tag{A.47}$$

$$\frac{\mathrm{d}W^L}{\mathrm{d}\ln\tau_c} = \frac{\mathrm{d}\ln l_c^*}{\mathrm{d}\ln\tau_c}. \tag{A.48}$$

The analysis shows that workers' marginal welfare loss from tax hikes decreases in the preference for the local public good, g. Hence, the stronger the preferences for public goods and the stronger the transmission of taxes into public good spending, the smaller the welfare loss as workers are compensated for rising costs of living. Proposition A.1 implies that the rent, land price, wage, and public good elasticities with respect to the property tax are sufficient to infer the welfare effects of the tax in a local labor market model (given the housing share in consumption, the labor share in production, and the preferences for public goods). In the following, we discuss the comparative statics behind these elasticities.

A.4 Comparative Statics

Using the equilibrium outcomes derived in Appendix A.2 we can take a closer look at the comparative statics in the model. In Appendix A.4.1, we first analyze the effects of tax increases on the key determinants for welfare effects laid out in Appendix A.3. In a second step, we derive comparative statics of other equilibrium prices in Appendix A.4.2. Finally, in Appendix A.4.3 we discuss comparative statics for equilibrium quantities.

A.4.1 Key Determinants for Welfare Effects

As stated in Proposition A.1 on the welfare effects in our structural equilibrium model, we are particularly interested in four elasticities: the elasticity of total rents with respect to property tax changes, the elasticity of local wages with respect to property tax changes, the elasticity of land prices with respect to property tax changes, and the elasticity of local public good provision with respect to property tax changes. In the following, we discuss the comparative statics for each of these four elasticities.

Local Public Goods. We start by studying the impact of property tax increases on local public goods, which is given by the following formula:

$$\frac{\mathrm{d}\ln A_c^*\left(t_c, p_c^*\left[\tau_c, A_c^*\left\{\tau_c\right\}\right]\right)}{\ln \tau_c} = \underbrace{\frac{\partial \ln A_c^*}{\partial \ln t_c}}_{>0} \underbrace{\frac{\partial \ln t_c}{\partial \ln \tau_c}}_{>0} + \underbrace{\frac{\partial \ln A_c^*}{\partial \ln p_c^*}}_{>0} \left(\underbrace{\frac{\partial \ln p_c^*}{\partial \ln \tau_c}}_{<0} + \underbrace{\frac{\partial \ln p_c^*}{\partial \ln A_c^*}}_{<0} \frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln \tau_c} \right)$$

$$\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln \tau_c} = \frac{\left(1+t_c\right)/t_c}{\frac{g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})(1+\tilde{\epsilon}^{\mathrm{HS}})}{(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}})(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}})}+1} + \frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)/\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)}{\frac{g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})(1+\tilde{\epsilon}^{\mathrm{HS}})}{(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}})(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}})}+1}. \qquad \text{(A.49)}$$

This effect on equilibrium public good provision in city c can thus be decomposed in (i) a positive mechanical effect through higher revenues from taxing the existing housing stock at current prices, and (ii) a countervailing behavioral effect on the tax base reflecting that higher taxes decrease prices and quantities traded on both floor space markets.

Just as in the standard Laffer curve argument, the higher the property tax rate t_c, the more important the second, behavioral channel distorting the tax base relative to the mechanical revenue effect. The total effect of tax increases on public-good spending will be positive as long as the tax rate is sufficiently small:

$$\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln \tau_c} > 0 \quad \Leftrightarrow \quad t_c < -\frac{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}{\tilde{\epsilon}^{\mathrm{HS}}\left(1+\tilde{\epsilon}^{\mathrm{HD}}\right)}.$$

In the following, we turn to the elasticities of total rents, wages, and land prices with respect to property tax increases and use this intermediate result to disentangle the different driving forces underlying the model.

Total Rents. The effect of property tax increases on equilibrium tax-inclusive total rents for residential and commercial floor space in city c is given by the following formula:

$$\begin{aligned}
\frac{\mathrm{d}\ln q_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln \tau_c} &= \frac{\mathrm{d}\ln \tau_c p_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln \tau_c} = \frac{\mathrm{d}\ln \tau_c p_c^{M*}\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln \tau_c} \\
&= \frac{\partial \ln q_c^*}{\partial \ln \tau_c} + \frac{\partial \ln q_c^*}{\partial \ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln \tau_c} \\
&= \underbrace{\frac{\tilde{\epsilon}^{\mathrm{HS}}}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}}_{>0} \underbrace{-\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)}{\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}}_{>0} \underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}+\frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})(1+\tilde{\epsilon}^{\mathrm{HS}})}{(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}})(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}})}+1}}_{\lesseqgtr 0}. \qquad \text{(A.50)}
\end{aligned}$$

The impact of tax increases on consumer prices (total rents) ($\mathrm{d}\ln q_c^*/\mathrm{d}\ln \tau_c$) can be decomposed into two effects: (i) a direct effect reflecting the pass-through of tax increases in consumer price rents that depends on the relative elasticities of (effective) housing supply and housing demand as in the standard textbook incidence model, and (ii) an indirect effect operating through the transmission of tax revenue into local public goods and the capitalization of public good provision in local prices. Figure A.1 illustrates these two effects. Panel A shows the partial, direct effect reflecting the standard tax incidence mechanism. The more mobile households are and the more elastic housing demand is, the lower (higher) will be the direct pass-through of tax increases in consumer (producer) price rents. Panel B depicts the indirect effect and shows how the analysis changes when higher taxes lead to additional local public good provision, which is capitalized in rents and increases the local cost of living. The indirect effect countervails the decrease in housing demand triggered by the tax increase—thereby raising consumer price rents even further and alleviating the reduction in producer price rents. This latter effect will be positive as long as public good spending increases in the tax rate.

Wages. Third, the effect of property tax increases on equilibrium wages is given by:

$$\begin{aligned}\frac{\mathrm{d}\ln w_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln \tau_c} &= \frac{\partial \ln w_c^*}{\partial \ln \tau_c} + \frac{\partial \ln w_c^*}{\partial \ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln \tau_c} \\ &= \underbrace{-\frac{\tilde{\epsilon}^{\mathrm{HS}}\left(\epsilon^{\mathrm{HD}}-\epsilon^{\mathrm{MD}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}}_{\lesseqgtr 0} \underbrace{-\frac{g\epsilon^{\mathrm{A}}\left(\tilde{\epsilon}^{\mathrm{HS}}-\epsilon^{\mathrm{MD}}\right)}{d_0\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}}_{<0} \underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}+\frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}+1}}_{\lesseqgtr 0}.\end{aligned} \tag{A.51}$$

The total effect of property tax increases on equilibrium wages in city c can be decomposed into (i) a direct effect that potentially compensates for higher costs of living and (ii) an indirect effect operating through higher local public good provision. Both effects may potentially be smaller or larger than zero, the sign being theoretically undetermined in both cases.

Tax increases trigger two opposing effects for profit-maximizing firms in the city. On the one hand, higher property tax payments raise the factor price of commercial floor space and firms thus try to re-optimize by using less floor space relative to labor. On the other hand, property taxes make it more costly for workers to live in city c and residents demand higher wages to compensate for increased costs of living. Without compensating wage increases, inframarginal workers will move to other places. The sign and the magnitude of the two direct effects of tax increases on wages are determined by the relative strength of the residential and the commercial floor space demand elasticity, ϵ^{HD} and ϵ^{MD}, respectively.

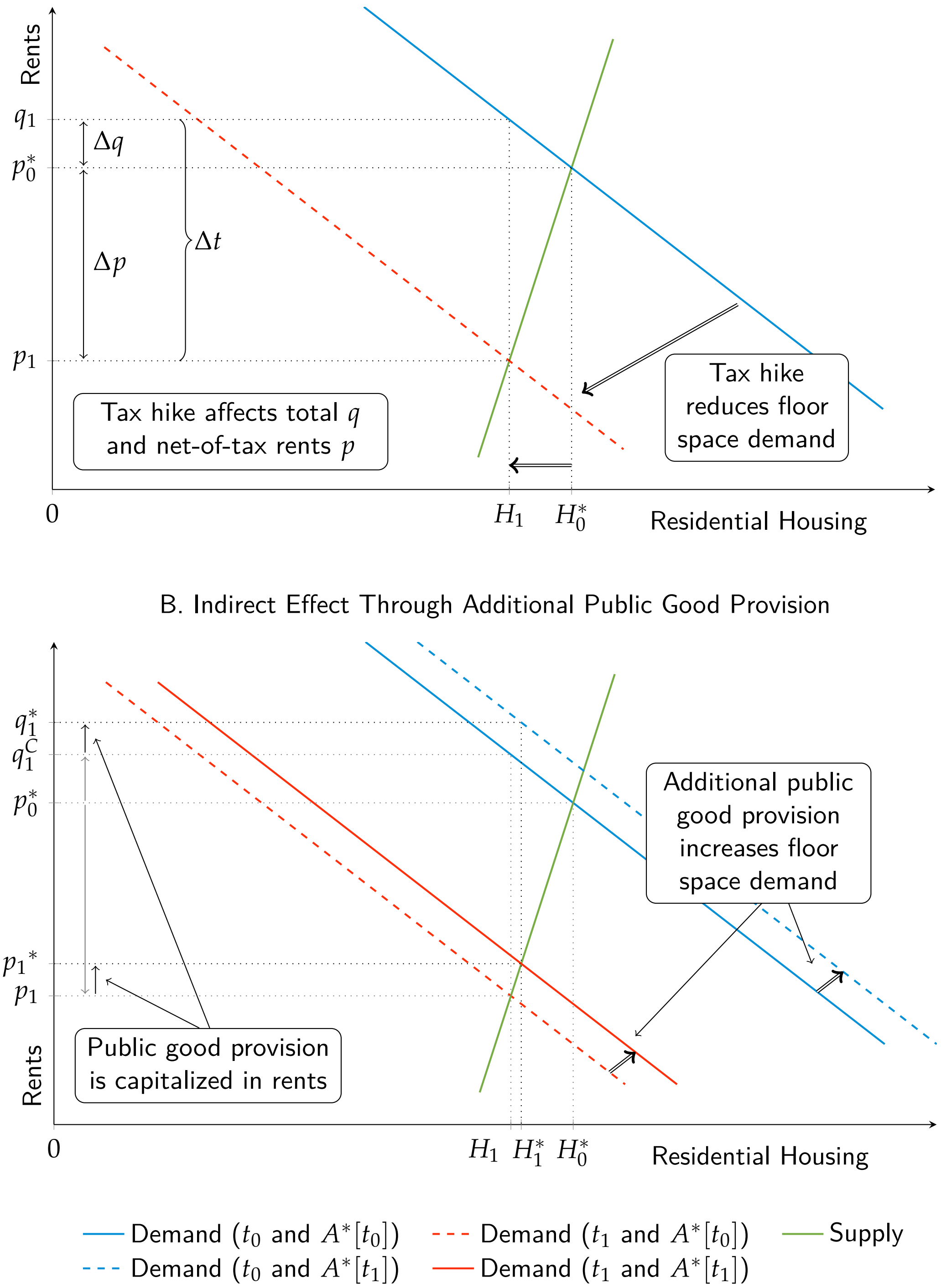
The indirect effect again operates through the capitalization of public goods into wages and depends on the extent to which tax increases yield additional public good spending at the local level. As long as higher taxes raise the level of public good provision, the indirect channel will lead to lower wages, since workers are compensated via additional amenities.

Figure A.2 illustrates both the direct and the indirect effect for the impact of tax increases on wage earnings ($\mathrm{d}\ln w_c^*/\mathrm{d}\ln \tau_c$). Tax increases lead to rising consumer price rents, which reduces the attractiveness of the city for workers; their labor supply to the city decreases (see Panel A). Taxes also increase the factor price of commercial floor space and reduce firms' floor space demand, which lowers the marginal product of labor and thus decreases labor demand. Panel A illustrates the case where workers are more responsive and wages increase in response to the tax. The indirect effect through additional public good spending operates in the opposite direction and makes the city more attractive for both workers and firms (see Panel B).

Figure A.1: Comparative Statics of Tax Increases on the Housing Market

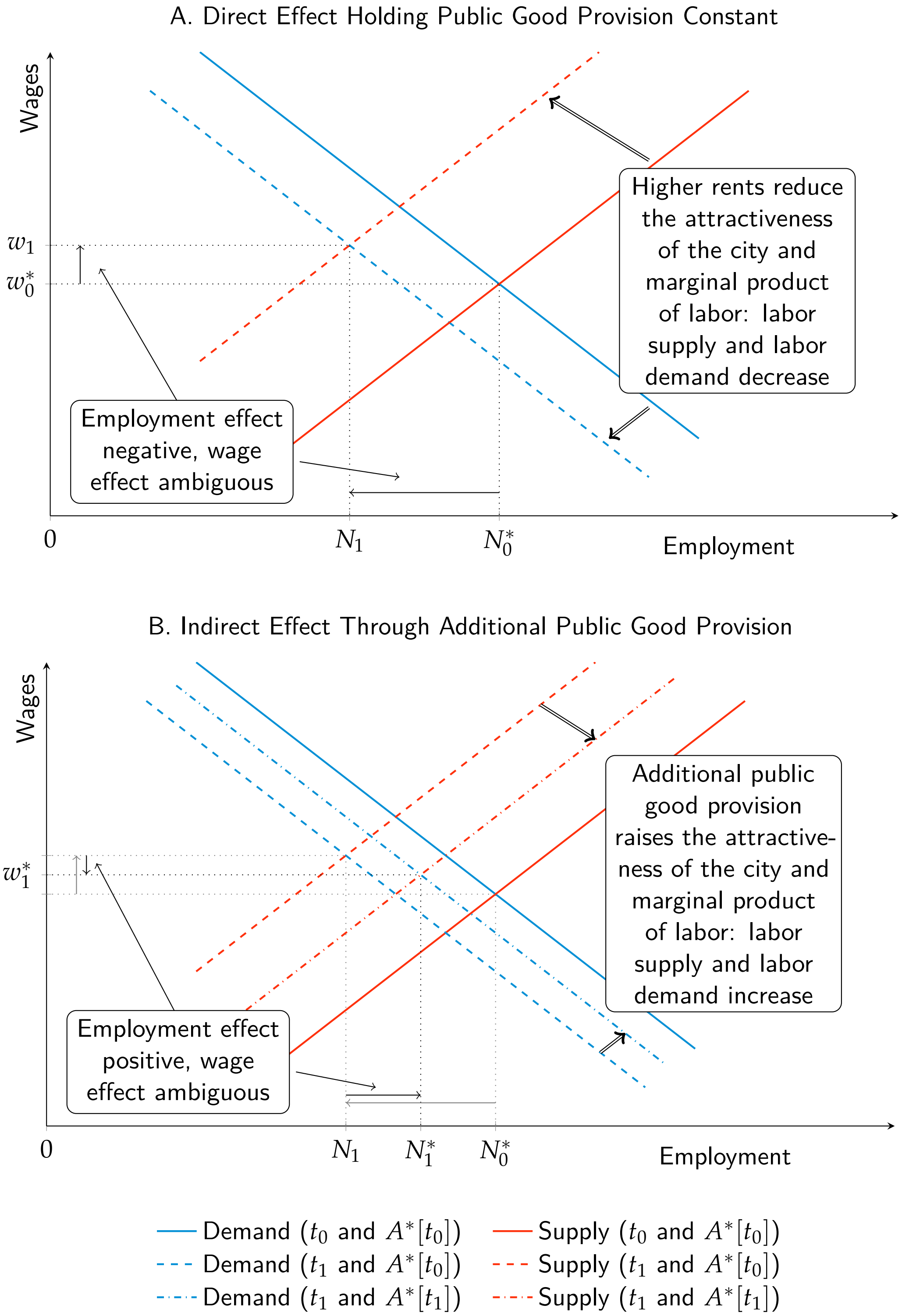
A. Direct Effect Holding Public Good Provision Constant

B. Indirect Effect Through Additional Public Good Provision



Notes: This figure illustrates the comparative statics of property tax increases on equilibrium tax-inclusive total and net-of-tax rents, q and p, respectively. Panel A shows the partial, direct effect conditional on local public good provision A_c. Panel B shows the additional indirect effect coming through changes in public goods. Subscripts 0 and 1 refer to the situation before and after the tax change, respectively.

Figure A.2: Comparative Statics of Tax Increases on the Labor Market



Notes: This figure illustrates the comparative statics of property tax increases on equilibrium wages y^W. Panel A shows the direct effect conditional on local public good provision A_c. Panel B shows the additional indirect effect coming through changes in public goods. Subscripts 0 and 1 refer to the situation before and after the tax change, respectively.

Land Prices. Finally, we derive the effect of property tax increases on equilibrium land prices:

$$\begin{aligned}\frac{\mathrm{d}\ln l_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} &= \frac{\partial\ln l_c^*}{\partial\ln\tau_c} + \frac{\partial\ln l_c^*}{\partial\ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c} \\ &= \underbrace{\frac{\tilde{\epsilon}^{\mathrm{HD}}}{\gamma\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)}}_{<0} \underbrace{-\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)}{\gamma\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}}_{>0} \underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}+\frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}+1}}_{\lesseqgtr 0}.\end{aligned} \tag{A.52}$$

The total effect of property tax increases on equilibrium land prices in city c ($\mathrm{d}\ln l_c^*/\mathrm{d}\ln\tau_c$) can again be decomposed in (i) a direct, negative effect that reflects lower construction activity and reduced land use in the construction sector due to the tax increase, and (ii) an indirect effect operating through higher local public good provision, where the sign is again theoretically undetermined. This indirect effect depends on the impact of public goods on land prices (second term in the last equation) and the degree to which tax increases raise the public good provision (last term in the equation). This latter effect will be positive as long as public good spending increases in the tax rate.

The reasoning behind the negative direct effect is that less land is needed for construction if population levels, floor space demand, and the housing stock decrease. As a result, land prices decrease as well to balance supply and demand, and to reach a new equilibrium on the market for land ready for development. This direct effect is again potentially diminished by an indirect effect operating through increases in local public goods, which would make city c more attractive due to increased non-pecuniary amenities in the city.

A.4.2 Additional Results for Equilibrium Prices

In the following, we derive how other equilibrium prices in the structural model respond to changes in property taxes. In particular, we study the impact on net-of-tax rents and real wages, i.e., wages relative to tax-inclusive local housing costs, which has been a key parameter in previous studies. We derive the following theoretical predictions:

Net-of-tax Rents. The total effect of property tax increases on equilibrium net-of-tax rents for residential and commercial floor space in city c can be decomposed in (i) a direct, negative effect that compensates for higher costs of living due to the tax increase, and (ii) an indirect effect operating through higher local public good provision with an ambiguous sign:

$$\begin{aligned}\frac{\mathrm{d}\ln p_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} &= \frac{\mathrm{d}\ln p_c^{M*}\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} \\ &= \frac{\partial\ln p_c^*}{\partial\ln\tau_c} + \frac{\partial\ln p_c^*}{\partial\ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c}\end{aligned}$$

$$= \underbrace{\frac{\tilde{\epsilon}^{\mathrm{HD}}}{\tilde{\epsilon}^{\mathrm{HS}} - \tilde{\epsilon}^{\mathrm{HD}}}}_{<0} - \underbrace{\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)}{\left(\tilde{\epsilon}^{\mathrm{HS}} - \tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)}}_{>0} \underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}} + \frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})(1+\tilde{\epsilon}^{\mathrm{HS}})}{(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}})(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}})} + 1}}_{\lesseqgtr 0}, \tag{A.53}$$

where the first fraction reflects the direct, negative effect, the second fraction reflects the capitalization of public goods into rents, and the third fraction denotes the translation of property taxes into public good spending. The indirect effect depends on the capitalization of public goods in rental prices and the degree to which tax increases raise the public good provision. It will be positive as long as public good spending increases in the tax rate.

The statutory incidence of property taxes in our model is on the user of the housing services. Workers and firms thus have to finance the additional burden of higher property taxes. However, we assume that both groups of agents are at least somewhat mobile across jurisdictions and housing demand is thus at least somewhat elastic. As a result, renters are able to shift part of the additional tax burden onto landlords, leading to a decrease in net-of-tax rents for residential and commercial floor space when holding public good levels constant, i.e., a direct, negative effect. As in the case of the direct effect on tax-inclusive total rents, the first term again resembles very closely the standard textbook result on tax incidence: The direct effect on renters and landlords is solely determined by the supply and demand elasticities of the housing market.

At the same time, tax increases impact the provision of local public goods in equilibrium. Higher property taxes will increase tax revenues for given prices and quantities on the housing market, and, thus, increase the spending on public goods. Capitalization of public goods would thus reduce the downward pressure on net-of-tax rents. However, there is a countervailing effect of property taxes on housing prices and quantities, which potentially lowers tax revenues and, thereby, public good spending. As discussed above, the combined effect is theoretically undetermined, as is thus the indirect effect of property taxes on housing costs.

Real Wages. The total effect of property tax increases on equilibrium real wages in city c, i.e., the wage adjusted for local costs of living, can also be decomposed in (i) a direct, negative effect that reflects higher costs of living due to the tax increase even after accounting for potentially compensating rent decreases, and (ii) an indirect effect operating through higher local public good provision:

$$\begin{aligned}\frac{\mathrm{d}w_c^*/q_c^*}{\mathrm{d}\ln\tau_c} &= \frac{\partial \ln w_c^*}{\partial \ln \tau_c} + \frac{\partial \ln w_c^*}{\partial \ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c} \\ &= \underbrace{-\frac{\tilde{\epsilon}^{\mathrm{HS}}\left(\epsilon^{\mathrm{HD}} - \epsilon^{\mathrm{MD}} + \epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)}{d_0\left(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)}}_{<0} \underbrace{-\frac{g\epsilon^{\mathrm{A}}\left(\tilde{\epsilon}^{\mathrm{HS}} - \epsilon^{\mathrm{MD}} - \epsilon^{\mathrm{ND}} - 1\right)}{d_0\left(\epsilon^{\mathrm{NS}} - \epsilon^{\mathrm{ND}}\right)}}_{<0} \underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}} + \frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})(1+\tilde{\epsilon}^{\mathrm{HS}})}{(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}})(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}})} + 1}}_{\lesseqgtr 0},\end{aligned} \tag{A.54}$$

where the first fraction reflects the direct effect, the second fraction reflects the capitalization of public goods into wages and rents, and the third fraction denotes the translation of property taxes into public good spending. The indirect effect depends on the capitalization of public goods in wages and rents, and the degree to which tax increases raise the public good provision.

As seen before, net-of-tax rents for residential housing may decrease in reaction to higher taxes thereby partly compensating for tax increases. The additional property tax burden would thus be shared between renters and landlords. Similarly, firms may compensate for higher costs of living in the municipality by paying higher wages. However, even taking together lower net-of-tax rents and potentially higher wages does not fully balance the additional property tax burden. Real incomes in the jurisdiction thus decrease in response to tax increases (direct effect).

For real wages, the indirect effect operating through higher public good provision does not alleviate the direct effect but yields additional downward pressure on real wages as long as the effect of property taxes on public good spending is positive. This mirrors the fact that workers' compensation for higher costs of living may also come through increases in local public goods instead of higher real wages.

A.4.3 Results for Equilibrium Quantities

In the following, we derive how equilibrium quantities in the structural model respond to changes in property taxes. We derive the following theoretical predictions:

Population. The total effect of property tax increases on equilibrium population levels in city c can be decomposed into (i) a direct, negative effect that is due to lower real wages, and (ii) an indirect effect operating through higher local public good provision:

$$\begin{aligned}\frac{\mathrm{d}\ln N_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} &= \frac{\partial \ln N_c^*}{\partial \ln \tau_c} + \frac{\partial \ln N_c^*}{\partial \ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c} \\ &= \underbrace{-\frac{\tilde{\epsilon}^{\mathrm{HS}}\left(\epsilon^{\mathrm{ND}}\left[1+\epsilon^{\mathrm{HD}}\right]-\epsilon^{\mathrm{NS}}\left[1+\epsilon^{\mathrm{MD}}\right]\right)}{d_0\left(\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{ND}}\right)}}_{<0} \\ &\quad \underbrace{-\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{MD}}+\epsilon^{\mathrm{ND}}\left[1+\tilde{\epsilon}^{\mathrm{HS}}\right]\right)}{d_0\left(\epsilon^{\mathrm{NS}}+\epsilon^{\mathrm{ND}}\right)}}_{>0} \underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}+\frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}+1}}_{\lesseqqgtr 0},\end{aligned} \tag{A.55}$$

where the first fraction reflects the direct, negative effect, the second fraction reflects workers' valuation of public goods when choosing their location, and the third fraction denotes the translation of property taxes into public good spending. The indirect effect depends on workers' (positive) valuation of public goods when choosing locations and the degree to which tax increases raise the public good provision. This indirect effect will be positive as long as public good spending increases in the tax rate.

When property taxes in city c increase, it becomes more expensive to live there—even after considering compensating effects through lower net-of-tax rents and potentially higher wages. With constant local public goods and lower real incomes after the tax reform, the city becomes less attractive to live in (direct effect). As we assume that workers are at least somewhat mobile across jurisdictions, inframarginal workers will leave the municipality after the tax increase. The indirect effect through increases in local public goods works in the opposite direction and thus reduces the outflow of workers as long as public good levels increase in the tax rate.

Housing Stock The total effect of property tax increases on the residential, commercial, and total housing stock in equilibrium in city c can be decomposed in (i) a direct, negative effect that reflects lower rents and lower demand due to the tax increase, and (ii) an indirect effect operating through higher local public good provision:

$$\begin{aligned}\frac{\mathrm{d}\ln H_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} = \frac{\mathrm{d}\ln M_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} &= \frac{\mathrm{d}\ln S_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} \\ &= \frac{\partial\ln H_c^*}{\partial\ln\tau_c} + \frac{\partial\ln H_c^*}{\partial\ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c} \\ &= \underbrace{\frac{\tilde{\epsilon}^{\mathrm{HS}}\tilde{\epsilon}^{\mathrm{HD}}}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}}_{<0} - \underbrace{\frac{\tilde{\epsilon}^{\mathrm{HS}} g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)}{\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}}_{>0} \underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}} + \frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}+1}}_{\lesseqgtr 0},\end{aligned} \tag{A.56}$$

where the first fraction reflects the direct, negative effect, the second fraction reflects the impact of public goods on the housing stock, and the third fraction denotes the translation of property taxes into public good spending. The indirect effect depends on the impact of public goods on the local housing stock (positive) and the degree to which tax increases raise the public good provision, which can be positive or negative. It will be positive as long as public good spending increases in the tax rate.

With constant public goods and lower real wages, the jurisdiction becomes less attractive to live in. Population levels decline in response to property tax increases. If fewer people are willing to locate in city c, the demand for residential housing declines. A similar mechanism is at work for firms' location choice and their demand for commercial floor space. Eventually, both the residential housing stock and the amount of commercial floor space will be lower compared to the pre-reform equilibrium. This direct effect is in line with the prediction of the new view on the property tax. When accounting for endogenous local public goods, this prediction becomes less clear-cut due to the indirect effect. As long as public good spending increases in the tax rate, the public good provision alleviates the negative effect on the housing stock as higher public good levels increase the demand for city c despite the loss in real wages.

Land Use. The total effect of property tax increases on the equilibrium quantity of land used for residential or commercial construction activity in city c can also be decomposed in (i) a direct, negative effect that reflects lower activity in the construction sector due to the tax increase, and (ii) an indirect effect operating through higher local public good provision:

$$\begin{aligned}\frac{\mathrm{d}\ln L_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} &= \frac{\partial\ln L_c^*}{\partial\ln\tau_c} + \frac{\partial\ln L_c^*}{\partial\ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c} \\ &= \underbrace{\frac{\tilde{\epsilon}^{\mathrm{HD}}\theta}{\gamma\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)}}_{<0} - \underbrace{\frac{\theta g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)}{\gamma\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}}_{>0}\underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}+\frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})(1+\tilde{\epsilon}^{\mathrm{HS}})}{(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}})(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}})}+1}}_{\lesseqgtr 0},\end{aligned} \tag{A.57}$$

where the first fraction reflects the direct, negative effect, the second fraction reflects the impact of public goods on land use, and the third fraction denotes the transmission of property taxes into public good spending. The indirect effect depends on the impact of public goods on land use and the degree to which tax increases raise the public good provision. It will be positive as long as public good spending increases in the tax rate.

With decreasing housing demand and lower levels of floor space provision after an increase in the property tax, the demand of the construction sector for land ready for building decreases as well. This mechanism is reflected in the direct effect. As before, the indirect effect works in the opposite direction and mitigates the direct effect as long as public good spending increases in the tax rate.

Capital Stock. Finally, the total effect of property tax increases on the equilibrium capital stock in city c can again be decomposed in (i) a direct, negative effect that reflects lower construction activity due to the tax increase, and (ii) an indirect effect operating through higher local public good provision:

$$\begin{aligned}\frac{\mathrm{d}\ln K_c^*\left(\tau_c, A_c^*\left[\tau_c\right]\right)}{\mathrm{d}\ln\tau_c} &= \frac{\partial\ln K_c^*}{\partial\ln\tau_c} + \frac{\partial\ln K_c^*}{\partial\ln A_c^*}\frac{\mathrm{d}\ln A_c^*}{\mathrm{d}\ln\tau_c} \\ &= \underbrace{\frac{\tilde{\epsilon}^{\mathrm{HD}}(1+\theta)}{\gamma\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)}}_{<0} - \underbrace{\frac{g\epsilon^{\mathrm{A}}\left(1+\epsilon^{\mathrm{ND}}\right)(1+\theta)}{\gamma\left(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}\right)\left(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}}\right)}}_{>0}\underbrace{\frac{\frac{\tilde{\epsilon}^{\mathrm{HD}}\left(1+\tilde{\epsilon}^{\mathrm{HS}}\right)}{\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}}}+\frac{1+t_c}{t_c}}{\frac{g\epsilon^{\mathrm{A}}(1+\epsilon^{\mathrm{ND}})(1+\tilde{\epsilon}^{\mathrm{HS}})}{(\tilde{\epsilon}^{\mathrm{HS}}-\tilde{\epsilon}^{\mathrm{HD}})(\epsilon^{\mathrm{NS}}-\epsilon^{\mathrm{ND}})}+1}}_{\lesseqgtr 0},\end{aligned} \tag{A.58}$$

where the first fraction reflects the direct, negative effect, the second fraction reflects the impact of public goods on the equilibrium capital stock, and the third fraction denotes the translation of property taxes into public good spending, where the sign of the latter term is again theoretically undetermined. The indirect effect depends on the impact of public goods on the capital stock and the degree to which tax increases raise the public good provision. It will be positive as long as public good spending increases in the tax rate.

Lower population levels, lower housing demand, and a smaller housing stock reduce the need for additional construction. Analogous to the demand for developed land, the capital demand of the construction sector declines, too. Again, this is in line with the capital tax view and reflects the direct effect for given levels of the public good. The indirect effect operates through the impact of public goods on the capital stock and will alleviate the direct negative effect as long as tax increases yield additional tax revenues that are spent on increases in local public good provision.

B Proof of Proposition 1 (Household Welfare)

Proof. We start the derivation assuming that households maximized utility, all markets cleared, and the economy is in equilibrium. We rewrite the utility function $u_i(x_i^*, h_i^*, l_i^*, e_i^*, s_i^*, A_c^*)$ by substituting the budget constraint $x_i^* + q_c^* h_i^* = w_c^* l_i^* + \pi_c^* e_i^* + p_c^* s_i^* + m_i^*$ for x_i^* such that we get $u_i(-q_c^* h_i^* + w_c^* l_i^* + \pi_c^* e_i^* + p_c^* s_i^* + m_i^*, h_i^*, l_i^*, e_i^*, s_i^*, A_c^*)$.

We are interested in the utility consequences of a small increase in the local property tax t_c:

$$\frac{\mathrm{d}u_i}{\mathrm{d}t_c} = \frac{\partial u_i}{\partial x}\left(-\frac{\mathrm{d}q_c^* h_i^*}{\mathrm{d}t_c} + \frac{\mathrm{d}w_c^* l_i^*}{\mathrm{d}t_c} + \frac{\mathrm{d}\pi_c^* e_i^*}{\mathrm{d}t_c} + \frac{\mathrm{d}p_c^* s_i^*}{\mathrm{d}t_c} + \frac{\mathrm{d}m_i^*}{\mathrm{d}t_c}\right) + \frac{\partial u_i}{\partial h}\frac{\mathrm{d}h_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial l}\frac{\mathrm{d}l_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial e}\frac{\mathrm{d}e_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial s}\frac{\mathrm{d}s_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial A}\frac{\mathrm{d}A_c^*}{\mathrm{d}t_c}. \tag{B.1}$$

Applying the product rule to the terms in parentheses yields:

$$\frac{\mathrm{d}u_i}{\mathrm{d}t_c} = \frac{\partial u_i}{\partial x}\left(-h_i^*\frac{\mathrm{d}q_c^*}{\mathrm{d}t_c} - q_c^*\frac{\mathrm{d}h_i^*}{\mathrm{d}t_c} + l_i^*\frac{\mathrm{d}w_c^*}{\mathrm{d}t_c} + w_c^*\frac{\mathrm{d}l_i^*}{\mathrm{d}t_c} + e_i^*\frac{\mathrm{d}\pi_c^*}{\mathrm{d}t_c} + \pi_c^*\frac{\mathrm{d}e_i^*}{\mathrm{d}t_c} + s_i^*\frac{\mathrm{d}p_c^*}{\mathrm{d}t_c} + p_c^*\frac{\mathrm{d}s_i^*}{\mathrm{d}t_c} + \frac{\mathrm{d}m_i^*}{\mathrm{d}t_c}\right) + \frac{\partial u_i}{\partial h}\frac{\mathrm{d}h_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial l}\frac{\mathrm{d}l_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial e}\frac{\mathrm{d}e_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial s}\frac{\mathrm{d}s_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial A}\frac{\mathrm{d}A_c^*}{\mathrm{d}t_c}. \tag{B.2}$$

Since households optimized and the economy is in equilibrium, we can now exploit the first-order conditions ($u_h' = u_x' q_c$, $u_l' = -u_x' w_c$, $u_e' = -u_x' \pi_c$, and $u_s' = -u_x' p_c$) to rewrite the marginal utilities from housing and the supply of labor, entrepreneurial effort, and rental units:

$$\frac{\mathrm{d}u_i}{\mathrm{d}t_c} = \frac{\partial u_i}{\partial x}\left(-h_i^*\frac{\mathrm{d}q_c^*}{\mathrm{d}t_c} - q_c^*\frac{\mathrm{d}h_i^*}{\mathrm{d}t_c} + l_i^*\frac{\mathrm{d}w_c^*}{\mathrm{d}t_c} + w_c^*\frac{\mathrm{d}l_i^*}{\mathrm{d}t_c} + e_i^*\frac{\mathrm{d}\pi_c^*}{\mathrm{d}t_c} + \pi_c^*\frac{\mathrm{d}e_i^*}{\mathrm{d}t_c} + s_i^*\frac{\mathrm{d}p_c^*}{\mathrm{d}t_c} + p_c^*\frac{\mathrm{d}s_i^*}{\mathrm{d}t_c} + \frac{\mathrm{d}m_i^*}{\mathrm{d}t_c}\right) + q_c^*\frac{\partial u_i}{\partial x}\frac{\mathrm{d}h_i^*}{\mathrm{d}t_c} - w_c^*\frac{\partial u_i}{\partial x}\frac{\mathrm{d}l_i^*}{\mathrm{d}t_c} - \pi_c^*\frac{\partial u_i}{\partial x}\frac{\mathrm{d}e_i^*}{\mathrm{d}t_c} - p_c^*\frac{\partial u_i}{\partial x}\frac{\mathrm{d}s_i^*}{\mathrm{d}t_c} + \frac{\partial u_i}{\partial A}\frac{\mathrm{d}A_c^*}{\mathrm{d}t_c}. \tag{B.3}$$

The previous step allows the simplification of the whole expression as all individual quantity responses drop out and thus have no first-order welfare implications. This result is known as the envelope theorem. We arrive at:

$$\frac{\mathrm{d}u_i}{\mathrm{d}t_c} = \frac{\partial u_i}{\partial x}\left(-h_i^*\frac{\mathrm{d}q_c^*}{\mathrm{d}t_c} + l_i^*\frac{\mathrm{d}w_c^*}{\mathrm{d}t_c} + e_i^*\frac{\mathrm{d}\pi_c^*}{\mathrm{d}t_c} + s_i^*\frac{\mathrm{d}p_c^*}{\mathrm{d}t_c} + \frac{\mathrm{d}m_i^*}{\mathrm{d}t_c}\right) + \frac{\partial u_i}{\partial A}\frac{\mathrm{d}A_c^*}{\mathrm{d}t_c}. \tag{B.4}$$

Dividing by household's marginal utility from consumption $\partial u_i/\partial x$ and keeping other incomes m_i fixed, we arrive at:

$$\frac{\mathrm{d}u_i/\mathrm{d}t_c}{\partial u_i/\partial x} = -h_i^*\frac{\mathrm{d}q_c^*}{\mathrm{d}t_c} + l_i^*\frac{\mathrm{d}w_c^*}{\mathrm{d}t_c} + e_i^*\frac{\mathrm{d}\pi_c^*}{\mathrm{d}t_c} + s_i^*\frac{\mathrm{d}p_c^*}{\mathrm{d}t_c} + \delta_i\frac{\mathrm{d}A_c^*}{\mathrm{d}t_c}, \qquad \text{with } \delta_i = \frac{\partial u_i/\partial A_c}{\partial u_i/\partial x}, \tag{B.5}$$

which is the money-metric utility change ΔW_i defined in Equation (1). □

C Data Appendix

Appendix Table C.1 contains information on all variables and the respective data sources. Appendix Table C.2 depicts descriptive statistics.

Table C.1: Definition of Variables and Data Sources

Variable	Years	Source
Business Tax Rates	2001–2018	Annual reports on the business tax scaling factors of German municipalities are published by the Statistical Offices (publication *Hebesätze der Realsteuern*). We calculate the local business tax rate as the product of local business tax scaling factors and a federal tax rate of 5% (before 2008) and 3.5% (since 2008).
Business Profits	2010–2018	Annual statistics on the tax base of the local business tax in a municipality are provided by the Statistical Offices of the Länder Bavaria and North Rhine-Westphalia. The statistics are not available at the municipal level for the remaining states.
Debts/Loans	2008–2015	Annual statistics on the debt of German municipalities provided by the Federal Statistical Office and the Statistical Offices of the Länder (publication *Jährliche Schulden der Kernhaushalte der Gemeinden/Gemeindeverbände 2010*, DOI for the year 2010: 10.7807/immo:red:wm:suf:v3 DOI: We use information on the total debt as well as on private market loans and public loans
Expenditures	2009–2015	Data on municipal expenditures are provided by the Federal Statistical Office and the Statistical Offices of the Länder (*Koordinierung länderübergreifende Datenanfrage*). Total expenditures are based on annual financial statements of German municipalities (*Jahresrechnungsstatistik*) using accrual accounting (*Doppelte Buchführung, Doppik*).
Housing Data	2008–2015	We calculate hedonically corrected municipality-year averages in per square meter tax-inclusive total rents (consumer price) as well as net-of-tax rents (producer price) [in German: *Bruttowarmmiete* and *Kaltmiete*, respectively] based on the dataset RWI-GEO-RED v3 provided by the research data center FDZ Ruhr. We also calculate the share of advertisements that report the tax-inclusive total rent. The dataset includes all real-estate advertisements published on the platform *ImmoScout24* (Boelmann and Schaffner, 2019). We combine four scientific use files which are differentiated by ad types: houses offered for rent (DOI: 10.7807/immo:red:hm:suf:v3, apartments offered for rent (DOI: 10.7807/immo:red:wm:suf:v3), houses offered for sale (DOI: 10.7807/immo:red:hk:suf:v3), and apartments offered for sale (DOI: 10.7807/immo:red:wk:suf:v3). We drop properties with unrealistic prices per square meter (net-of-tax rents below three or above 20 EUR per square meter, roughly corresponding to the bottom and top 0.5 percent). We further exclude rental ads that are posted for more than six months.
Local GDP	2008–2015 (counties)	Data on the gross domestic product per capita in German counties is provided by the Working Group Regional Accounts (*Volkswirtschaftliche Gesamtrechnung der Länder, Revision 2014*).
Population	2008–2015	Annual data on municipal population are provided by the Federal Statistical Office and the Statistical Offices of the Länder (*Gemeindeverzeichnis*). We adjust population levels before 2011 using the Census shock to smoothen breaks in municipal time series due to different reporting methods.

continued

Table C.1 continued

Variable	Years	Source
Property Tax Rates	2001–2018	Annual reports on the property tax scaling factors of German municipalities are published by the Statistical Offices (publication *Hebesätze der Realsteuern*). We calculate the local property tax rate as the product of local property tax scaling factors and an average federal tax rate of 0.32%.
Revenues	2008–2015	Data on municipal revenues are provided by the Federal Statistical Office and the Statistical Offices of the Länder in the online database *Regionalstatistik*. Property tax revenues come from the publication *Realsteuervergleich*. Total Revenues are based on quarterly financial statements of German municipalities (*Vierteljährliche Kassenergebnisse*) using accrual accounting (*Doppelte Buchführung, Doppik*).
Standard Tax Rates	2001–2018 (states)	We collect state-level standard scaling factors (known as *Fiktive Hebesätze*, *Nivellierungshebesätze*, or *Durchschnittshebesätze*) for the local property tax from state laws on fiscal equalization schemes and publications of the Statistical Offices of the Länder. We calculate standard tax rates by multiplying these state-wide scaling factors with the average federal tax rate of 0.32%.
Unemployment	2008–2015	Annual statistics on the number of unemployed individuals in each German municipality are provided in the publication *Arbeitsmarkt in Zahlen – Arbeitsmarktstatistik / Arbeitslose nach Gemeinden* by the Federal Employment Agency (*Bundesagentur für Arbeit*).
Wages	2008–2015	The Institute for Employment Research (IAB) provided us with annual data on municipality-level average daily wages of all employees subject to social security.

Notes: This table summarizes the definition of variables used in our empirical analysis and provides details on the data sources. See Table C.2 for descriptive statistics.

Table C.2: Descriptive Statistics

Variable	Mean	SD	P10	P25	P50	P75	P90
Panel A – Housing Prices							
Total Rent (in €/m²)	9.15	2.11	7.00	7.63	8.59	10.23	12.04
Net-of-tax Rent (in €/m²)	6.91	1.89	4.99	5.52	6.40	7.93	9.49
Share Ads: Reporting Total Rent	0.63	0.21	0.35	0.49	0.64	0.78	0.89
Panel B – Fiscal Variables							
Local Property Tax Rate (in %)	1.75	0.70	1.09	1.26	1.54	2.03	2.84
Standard Tax Rate (in %)	1.35	0.71	0.65	0.88	1.18	1.45	2.64
Local Business Tax Rate (in %)	13.90	1.89	11.50	12.25	14.00	15.40	16.45
Total Revenues per Capita (in €)	2,331.99	1,266.25	1,347.30	1,628.70	2,108.84	2,836.30	3,584.78
Property Taxes Revenues per Capita (in €)	152.78	53.76	87.69	110.25	146.21	188.64	230.75
Total Expenditures per Capita (in €)	2,336.79	1,128.55	1,350.59	1,641.06	2,124.31	2,860.74	3,599.06
Total Debt per Capita (in €)	1,408.13	1,449.64	99.47	391.38	938.20	1,963.78	3,321.43
Private Market Loans per Capita (in €)	888.21	702.32	99.58	346.62	749.39	1,315.43	1,832.38
Public Loans per Capita (in €)	517.06	1,062.46	0.01	0.04	0.32	475.67	1,831.84
Panel C – Economic Indicators							
Average Daily Wages (in €)	73.56	16.76	53.56	62.13	72.06	84.07	94.45
Business Profits per Capita (in €)	142.80	181.86	56.90	79.72	111.65	162.51	271.03
Local Population Levels (in 1000s)	341.79	772.60	4.98	12.67	39.86	235.08	1,007.12
Local GDP per Capita (in €)	36,136.70	15,737.16	22,222.50	26,114.01	32,064.52	39,952.66	58,793.45
Local Unemployment Rate (in %)	8.57	4.74	4.00	5.40	7.80	10.80	14.00

Notes: This table provides descriptive statistics for the baseline estimation sample. All variables are weighted by average population levels over the sample period. See Table C.1 for detailed information on all variables.

D Instrumental Variables Strategy

In the baseline empirical model, we exploit the substantial variation in property tax rates within municipalities over time to identify treatment effects. The underlying identifying assumption is that tax changes are not driven by factors that could have a direct effect on our outcomes of interest. To test this exogeneity assumption, we apply an instrumental variables strategy and purify the variation in local tax rates. We exploit a specific feature of the German system of fiscal federalism. Each state has its own fiscal equalization scheme through which resources are redistributed across municipalities within states (see, e.g., Buettner, 2006). In each state, municipalities receive transfers depending on their fiscal needs relative to their fiscal capacity. Fiscal need refers to the mandatory public services a municipality has to deliver and are largely determined by municipal population size. Fiscal capacity measures a municipality's ability to raise tax revenues. To assess this capacity, the property tax base of a municipality is multiplied by a standard tax rate instead of the actual one (and similarly for the local business tax).[22] This standard tax rate is common for all municipalities within a state and is supposed to reflect the average local tax rate in this state. As municipal tax rates increase over time (cf. Section 3.1), standard tax rates typically increase during our sample period as well—in some states annually and formula-based, in others in an unsystematic and discretionary rhythm.[23]

D.1 A Model of the German Fiscal Equalization Scheme

In this appendix, we formally model the incentives that arise in the municipal equalization schemes at the state level in Germany once a federal state increases its standard tax rate. The following discussion builds on the model of Egger et al. (2010). Municipalities raise revenues R from property taxes and receive transfers T via the state-level equalization scheme. Transfers are determined by the difference between fiscal needs N and fiscal capacity C:

$$T = \alpha(N - C), \tag{D.1}$$

where α is the exogenous share of the net fiscal need—i.e., the difference between fiscal need and fiscal capacity—that is to be covered by equalization transfers. Fiscal needs are a function of the population size of the municipality. To illustrate the immediate mechanics behind the equalization scheme, we abstract from population changes and assume that fiscal needs are exogenously given. Fiscal capacity is a function of the municipality's local tax base, denoted by B, and the state-level standard tax rate s. In line with the state laws on fiscal equalization, we model fiscal capacity as $C = sB$. The tax base $B(t)$ itself is a function of the tax rate t and we assume that the tax base is decreasing and concave in the tax rate, i.e., $B'_t < 0, B''_t < 0$.

We assume that the municipality chooses its tax rate in order to maximize revenues from

[22] The standard tax rate is composed of the federal tax rate and a state-level standard scaling factor (see equation (2)). State-specific standard tax rates are known as *Fiktive Hebesätze*, *Nivellierungshebesätze*, or *Durchschnittshebesätze*.

[23] We exclude the states of Baden-Württemberg and Saarland from this part of the analysis as the former did not change its standard tax rate in past decades and the latter implemented a large-scale municipal fiscal consolidation program at the same time, making it impossible to isolate the effects of standard tax rate changes.

taxes and transfers received via the equalization scheme:

$$\max_t R = \max_t tB(t) + T = \max_t tB + \alpha(N - sB). \tag{D.2}$$

The first-order condition for the revenue-maximizing tax rate is given by:

$$\begin{aligned} \frac{\mathrm{d}R}{\mathrm{d}t} &= B + tB_t' - \alpha s B_t' = 0 \\ B &= -B_t'(t - \alpha s), \end{aligned} \tag{D.3}$$

The municipality faces the typical Laffer curve trade-off when setting the tax rate. While a higher tax rate mechanically leads to more revenues, it also creates distortions thereby diminishing the tax base and thus tax revenues. The latter negative effect on the tax base is mitigated to some extent by equalization transfers, which compensate for a lower tax base independent of the chosen tax rate. The case with $\alpha = 0$ describes a world without equalization schemes. Rewriting the first-order condition, we characterize the optimal tax rate t^* as:

$$t^* = \frac{B}{-B_t'} + \alpha s. \tag{D.4}$$

Based on this setup, we can derive the first of the two theoretical predictions regarding the effect of increases in the state-level standard tax rate on local tax rates.

Proposition D.1 (Effects of Standard Tax Rate Increases I)**.** *If the state government increases the state-level standard tax rate s, this creates an incentive for municipalities to raise their local tax rate t.*

Proof. To derive this prediction, we start out with the characterization from equation (D.4) and take the total derivative with respect to the standard tax rate s:

$$\begin{aligned} \frac{\mathrm{d}t}{\mathrm{d}s} &= -\frac{B_t' B_t' \frac{\mathrm{d}t}{\mathrm{d}s} - BB_t'' \frac{\mathrm{d}t}{\mathrm{d}s}}{B_t'^2} + \alpha \\ B_t'^2 \frac{\mathrm{d}t}{\mathrm{d}s} &= -B_t' B_t' \frac{\mathrm{d}t}{\mathrm{d}s} + BB_t'' \frac{\mathrm{d}t}{\mathrm{d}s} + \alpha B_t'^2 \\ 2B_t'^2 \frac{\mathrm{d}t}{\mathrm{d}s} - BB_t'' \frac{\mathrm{d}t}{\mathrm{d}s} &= \alpha B_t'^2 \\ \frac{\mathrm{d}t}{\mathrm{d}s} &= \frac{\alpha B_t'^2}{2B_t'^2 - BB_t''} > 0. \end{aligned} \tag{D.5}$$

Since the tax base B is a decreasing and concave function in the local tax rate t, the derivate will be positive. $\square$

The previous literature has also confirmed this prediction empirically exploiting quasi-experimental equalization scheme reforms in the states Lower Saxony (Egger et al., 2010) and North Rhine-Westphalia (Baskaran, 2014, Rauch and Hummel, 2016). The prediction in Proposition D.1 could thus be used to construct an instrumental variables strategy exploiting only variation from state-level reforms. However, our identification approach introduced in Section 4 exploits only within-state variation in local tax rates and housing market trends. We account for geographically fine region-by-year fixed effects at the sub-state level throughout our analysis and also show that it is important to take out different trends within federal states (see the discussion in Section 5.2). This makes it impossible to use an instrument that relies only on variation at the level of the federal states.

Nevertheless, we can exploit the institutional setting of fiscal equalization schemes and exploit municipality-level variation in the incentives to adjust property tax rates as a response to state-level standard tax rate changes. This yields our second theoretical prediction on the effects of increases in state-level standard tax rates.

Proposition D.2 (Effects of Standard Tax Rate Increases II)**.** *The incentive to raise the municipal tax rate t following from an increase in the state-level standard tax rate s is larger the lower the local tax rate t compared to the standard tax rate s as long as the tax base $B(t)$ is sufficiently concave in t.*

Proof. To prove this prediction, we start with the result from equation (D.5) and take the total derivative with respect to the local tax rate t:

$$\begin{aligned}\frac{\mathrm{d}^2 t}{\mathrm{d}s\mathrm{d}t} &= \frac{\left(2B_t'^2 - BB_t''\right)\alpha 2B_t'B_t'' - \alpha B_t'^2\left(4B_t'B_t'' - BB_t''' - B_t'B_t''\right)}{\left(2B_t'^2 - BB_t''\right)^2} \\ &= \alpha\frac{2B_t'B_t''\left(2B_t'^2 - BB_t''\right) - B_t'^2\left(3B_t'B_t'' - BB_t'''\right)}{\left(2B_t'^2 - BB_t''\right)^2}. \end{aligned} \tag{D.6}$$

Using the first-order condition $B = -B_t'(t-\alpha s)$, we can rewrite this expression as:

$$\begin{aligned}\frac{\mathrm{d}^2 t}{\mathrm{d}s\mathrm{d}t} &= \alpha\frac{2B_t'B_t''\left[2B_t'^2 + B_t'(t-\alpha s)B_t''\right] - B_t'^2\left[3B_t'B_t'' + B_t'(t-\alpha s)B_t'''\right]}{\left(2B_t'^2 - BB_t''\right)^2} \\ &= \alpha B_t'^2\frac{2B_t''\left[2B_t' + (t-\alpha s)B_t''\right] - \left[3B_t'B_t'' + B_t'(t-\alpha s)B_t'''\right]}{\left(2B_t'^2 - BB_t''\right)^2} \\ &= \alpha B_t'^2\frac{4B_t'B_t'' + 2(t-\alpha s)B_t''^2 - 3B_t'B_t'' - (t-\alpha s)B_t'B_t'''}{\left(2B_t'^2 - BB_t''\right)^2} \\ &= \alpha B_t'^2\frac{B_t'B_t'' + (t-\alpha s)\left[2B_t''^2 - B_t'B_t'''\right]}{\left(2B_t'^2 - BB_t''\right)^2} \\ \frac{\mathrm{d}^2 t}{\mathrm{d}s\mathrm{d}t} &= \underbrace{\alpha B_t'^2}_{>0}\cdot\underbrace{\left[B_t'B_t'' + (t-\alpha s)\left(2B_t''^2 - B_t'B_t'''\right)\right]}_{\lesseqgtr 0}\Big/\underbrace{\left(2B_t'^2 - BB_t''\right)^2}_{>0}. \end{aligned} \tag{D.7}$$

The second derivative will thus be negative as long as the following condition holds:

$$\begin{aligned} B_t'B_t'' + (t-\alpha s)\left(2B_t''^2 - B_t'B_t'''\right) &< 0 \\ B_t'B_t'' &< -(t-\alpha s)\left(2B_t''^2 - B_t'B_t'''\right) \\ \frac{B_t'B_t''}{t-\alpha s} &< B_t'B_t''' - 2B_t''^2 \\ 2B_t''^2 - \frac{B_t'^2B_t''}{B} &< B_t'B_t''' \end{aligned}$$

$$
\begin{aligned}
B_t'' \left(2B_t'' - \frac{B_t'^2}{B} \right) &< B_t' B_t''' \\
B_t'' \left(\frac{2B_t''}{B_t'} - \frac{B_t'}{B} \right) &> B_t''' \\
B_t'' \left(\frac{2B_t''}{B_t'} + \frac{1}{t - \alpha s} \right) &> B_t'''. \qquad \text{(D.8)}
\end{aligned}
$$

The latter inequality holds as long as the tax base $B(t)$ is sufficiently concave in t. It follows that $\mathrm{d}^2 t/\mathrm{d}s\mathrm{d}t < 0$ in this case and the incentive to raise the local tax rate thus increases the smaller the local tax rate t relative to the standard tax rate s. □

Example. In the remainder of this section, we illustrate that the general condition in equation (D.8) is likely to be fulfilled in practice. To this end, let us assume a more specific tax base function $B(t) = \Lambda - \gamma t^k$, where Λ is the total tax base absent any property tax, i.e., for $t = 0$. The tax base is a decreasing and concave function in the tax rate of the order k.

Using this functional form for the tax base, verify that $\mathrm{d}^2 t/\mathrm{d}s\mathrm{d}t < 0$ if $\alpha k/(1+k) > t/s$:

$$
\begin{aligned}
-k(k-1)\gamma t^{k-2} \left(\frac{-2k(k-1)\gamma t^{k-2}}{-k\gamma t^{k-2}} + \frac{1}{t - \alpha s} \right) &> -k(k-1)(k-2)\gamma t^{k-3} \\
-t \left(\frac{2(k-1)}{t} + \frac{1}{t - \alpha s} \right) &> -(k-2) \\
-2(k-1) - \frac{t}{t - \alpha s} &> -k + 2 \\
-\frac{t}{t - \alpha s} &> k \\
-t &> kt - k\alpha s \\
k\alpha s &> (1+k)t \\
\frac{\alpha k}{1+k} &> \frac{t}{s}. \qquad \text{(D.9)}
\end{aligned}
$$

Equation D.9 shows a relationship between the degree of concavity (the higher k, the more concave the tax base in t), the relative difference between the municipalities tax rate t and the standard tax rate s, and the share of net fiscal need that is compensated, α. For given tax rates, the inequality will hold for more concave tax base function. For the local property tax, with a quite inelastic tax base, it seems likely that the function is somewhat concave, with k substantially higher than in the linear or the quadratic case.[24] For given concavity, the inequality will hold for lower municipal tax rates relative to standard tax rates. In other words, municipalities with a relatively lower property tax rate t will have a stronger incentive to increase t after an increase in the standard tax rate s.

[24] In the German context, we can fix $\alpha = 0.9$ (Baskaran, 2014). For $k = 4$ ($k = 5$), the inequality becomes $0.72 > t/s$ ($0.75 > t/s$). Hence municipalities whose tax rate t is around 25% below the standard tax rate have a stronger incentive to increase their tax rate the lower t compared to s.

D.2 Empirical Implementation

Section D.1 has shown that the fiscal equalization mechanism creates two incentives for local policymakers. First, once states raise their standard tax rates, they incentivize subordinate municipalities to increase local tax rates as well (see Egger et al., 2010, Baskaran, 2014, Rauch and Hummel, 2016, who study these incentive effects in the context of the German fiscal equalization schemes). Second, since fiscal equalization transfers are calculated based on relative differences within the state, increases in the state-wide standard tax rates create an additional incentive depending on the relative differences between standard and actual tax rates. The higher the new standard tax rate relative to a municipalities' actual one, the stronger the incentive for subsequent local tax increases.

We exploit these two incentives to construct our instrument as follows:

$$IV_{m,t} = StandardTaxRateIncrease_{s,t} \cdot \frac{StandardTaxRate_{s,t} - PropertyTaxRate_{m,t-1}}{PropertyTaxRate_{m,t-1}} \tag{D.10}$$

The instrument interacts a dummy variable indicating an increase in state s's standard tax rate in year t with a measure capturing the relative difference between the new standard tax rate and the old local tax rate in municipality m in year $t-1$. Although the instrument still relies on a municipality-specific component, we argue that the implied shock is exogenous from the standpoint of local policymakers for three reasons. First, municipalities are small compared to the size and number of municipalities per state. On average, there are around 1,000 municipalities per state, and no single municipality is dominating within states. Second, the instrument exploits only the relative difference between standard and local property tax rates, i.e., cross-sectional variation across municipalities rather than changes at the local level. Third, we fix local property tax rates in the year before the increase in the standard tax rate, which further alleviates the potential for endogenous responses at the local level.

Given the dynamics of our baseline estimates (cf. Figure 2), we are interested in the long-run effects of property taxes on rents and thus need combine the instrumental variables strategy with our event study approach. To do so, we estimate first-stage and reduced-form in a dynamic event study framework. We then retrieve the long-run effects as the event study estimates of four or more periods after a tax change. In a last step, we use the long-run first-stage and reduced-form estimates to calculate the second-stage IV estimate.

Using the instrument derived in (D.10), we estimate the following dynamic first-stage model using a distributed-lag representation:

$$\Delta PropertyTaxRate_{m,t} = \sum_{j=-\underline{j}+1}^{\bar{j}} \eta_j IV_{m,t-j} + \delta \Delta \mathbf{X}_{m,j} + \zeta_{r,t} + \epsilon_{m,t}. \tag{D.11}$$

Following our empirical event study methodology, we estimate the following reduced-form relationship to capture the effect of the instrument on rents:

$$\Delta \ln rents_{m,t} = \sum_{j=-\underline{j}+1}^{\bar{j}} \phi_j \Delta IV_{m,t-j} + \lambda \Delta \mathbf{X}_{m,t} + \xi_{r,t} + v_{m,t}, . \tag{D.12}$$

As in the baseline, we sum estimates $\widehat{\eta}_j$ and $\widehat{\phi}_j$ over years j to recover the cumulative treatment effects relative to the pre-reform period (cf. equation (4)).

In the last step, we calculate the long-run second-stage estimate by dividing the long-run reduced-form estimates by the long-run first-stage estimates. Confidence intervals for these second-stage estimates are based on the empirical distribution of estimated coefficients using 1,000 bootstrap replications.

D.3 Empirical results

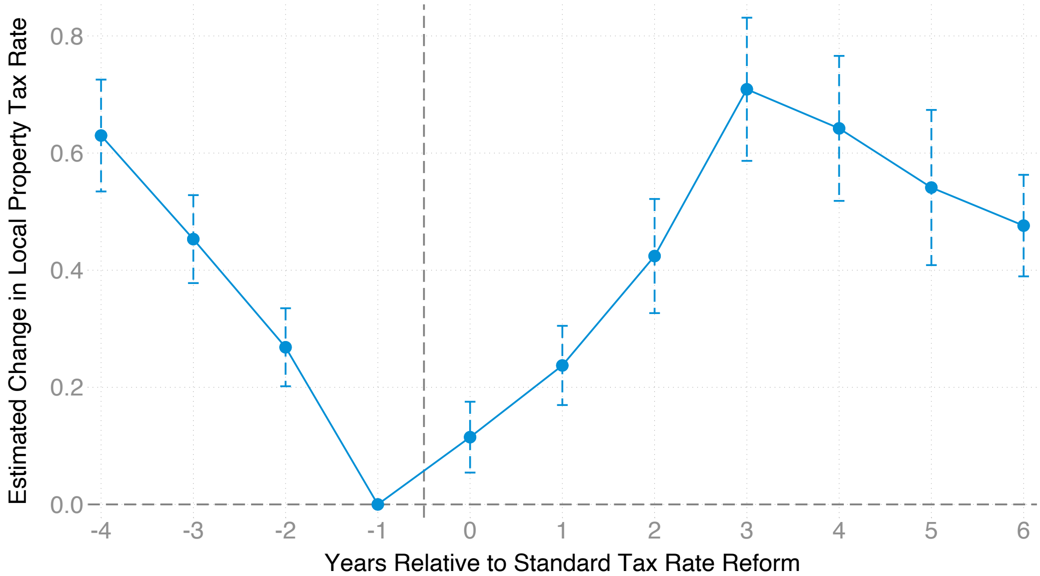
Figure D.1 shows the resulting first-stage relationship confirming the theoretical predictions. After an increase in the state-wide standard tax rate, municipalities respond by increasing their own property tax rates within the next three years and leveling off thereafter. Effects are stronger for municipalities with larger relative differences between the new standard tax rate and their old municipal tax rate. The long-run estimate is equal to 0.55, which implies that local property tax rates increase by half around half a point for each one percentage point increase in the relative difference to the standard tax rate. The figure also shows that local property tax rates decline in the instrument prior to standard tax rate increases – note that this pre-trend emerges by construction.[25]

Figure D.2 shows the reduce-form results. When regressing total rents on the standard tax rate, we detect a pattern that is roughly in line with the pattern of the baseline results. After the reform, it takes three to four years until a positive effect on total rents materializes. We estimate a long-run effect of 0.024. The delayed response to a *standard rate* change can be explained by the lagged first-stage response shown in Figure D.1.

While these dynamics are interesting and can be used to check the plausibility of the IV strategy, we are mainly interested in the long-run effects. Dividing the long-run reduced-form estimates (four or more years after a standard rate increase) by the long-run first-stage estimates, we back out a second-stage estimate of 0.043, which is of similar magnitude compared to the baseline estimate.

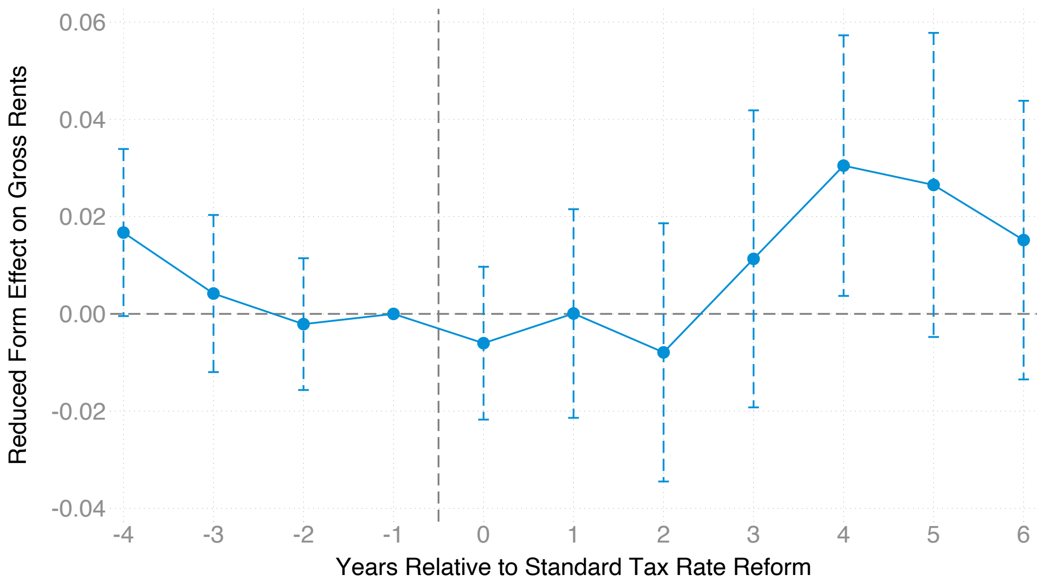
[25] Consider two municipalities A and B in the same state experiencing an increase in the state-wide standard tax rate in some year t. Four years before this reform, A and B had the same property tax rate, $PropertyTaxRate^A_{t-4} = PropertyTaxRate^B_{t-4}$. Municipality B raised its tax rate subsequently, such that in the pre-reform year, municipality A had a lower property tax rate, i.e., $PropertyTaxRate^A_{t-1} < PropertyTaxRate^B_{t-1}$. It follows that $IV_{A,t} > IV_{B,t}$ and we should see a declining pre-trend relative to the pre-reform year $t-1$.

Figure D.1: First Stage: Effect of Standard Tax Rate Changes on Property Taxes



Notes: This figure shows the estimated treatment effects of state-level reforms in the standard tax rate on local property tax rates using alternative specifications to account for regional confounders. Formally, we regress year-to-year changes in municipalities' property tax rates on leads and lags of the instrumental variable from equation (D.10), absorbing MSA-by-year fixed effects (cf. first-stage regression model in equation (D.11)). Municipalities in the state of Saarland are excluded from the estimation sample. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure D.2: Reduced Form: Effect of Standard Tax Rate Changes on Total Rents

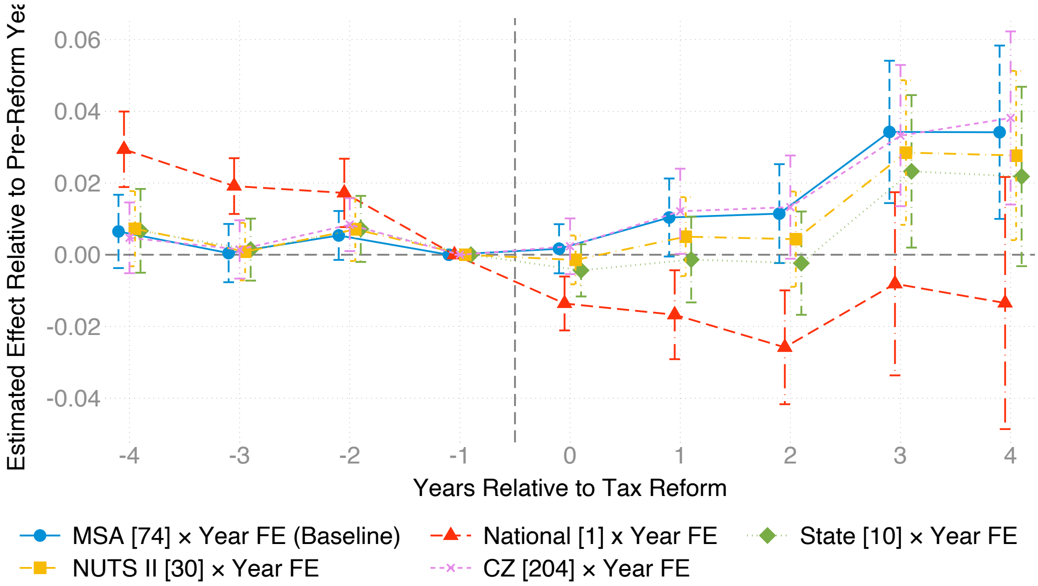


Notes: This figure illustrates the estimated reduced-form effect of the standard tax rate IV defined in equation (D.10) on total rents (in logs) relative to the year before a standard tax rate increase. The underlying econometric model is analogous to equations (3) and (4). The specification also accounts for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Municipalities in the state of Saarland are excluded from the estimation sample. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

E Additional Results

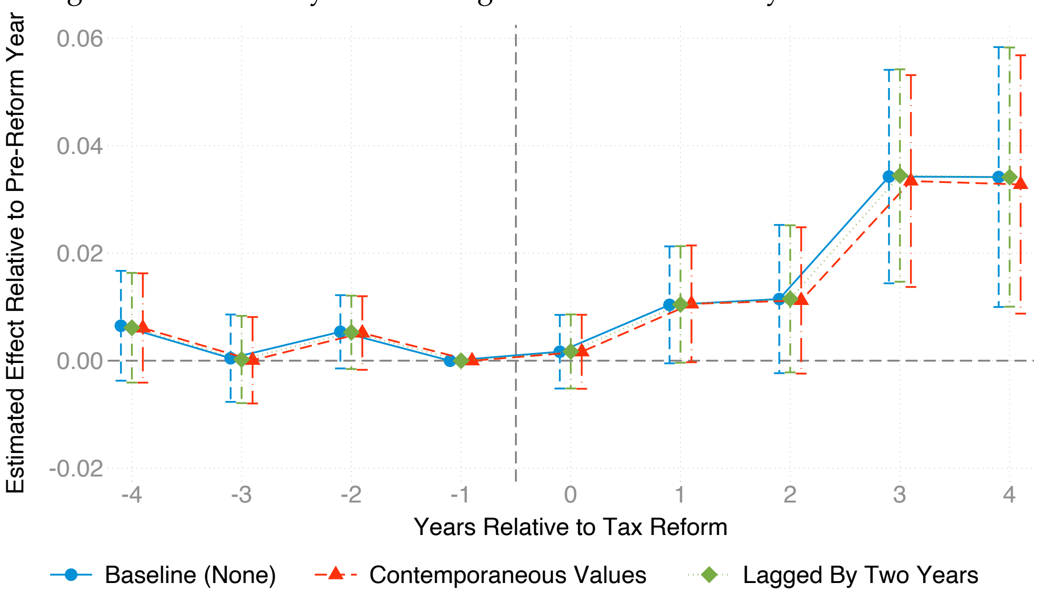
E.1 Additional Figures

Figure E.1: Sensitivity: Importance of Regional Confounders



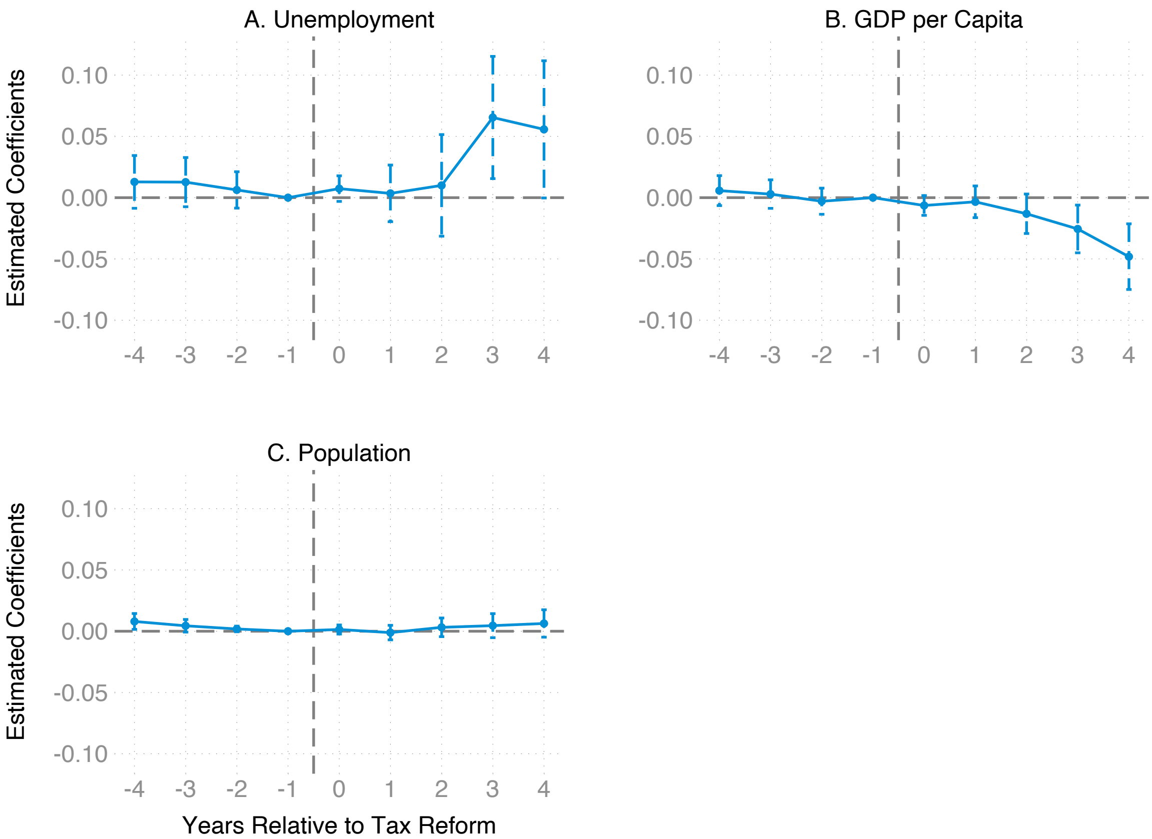
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year using various alternative regional time trend specifications. The underlying econometric model is described in equations (3) and (4). The specification also accounts for leads and lags in the local business tax rate and year fixed effects at various regional levels (see legend). Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.2: Sensitivity: Accounting for Local Business Cycle Confounders



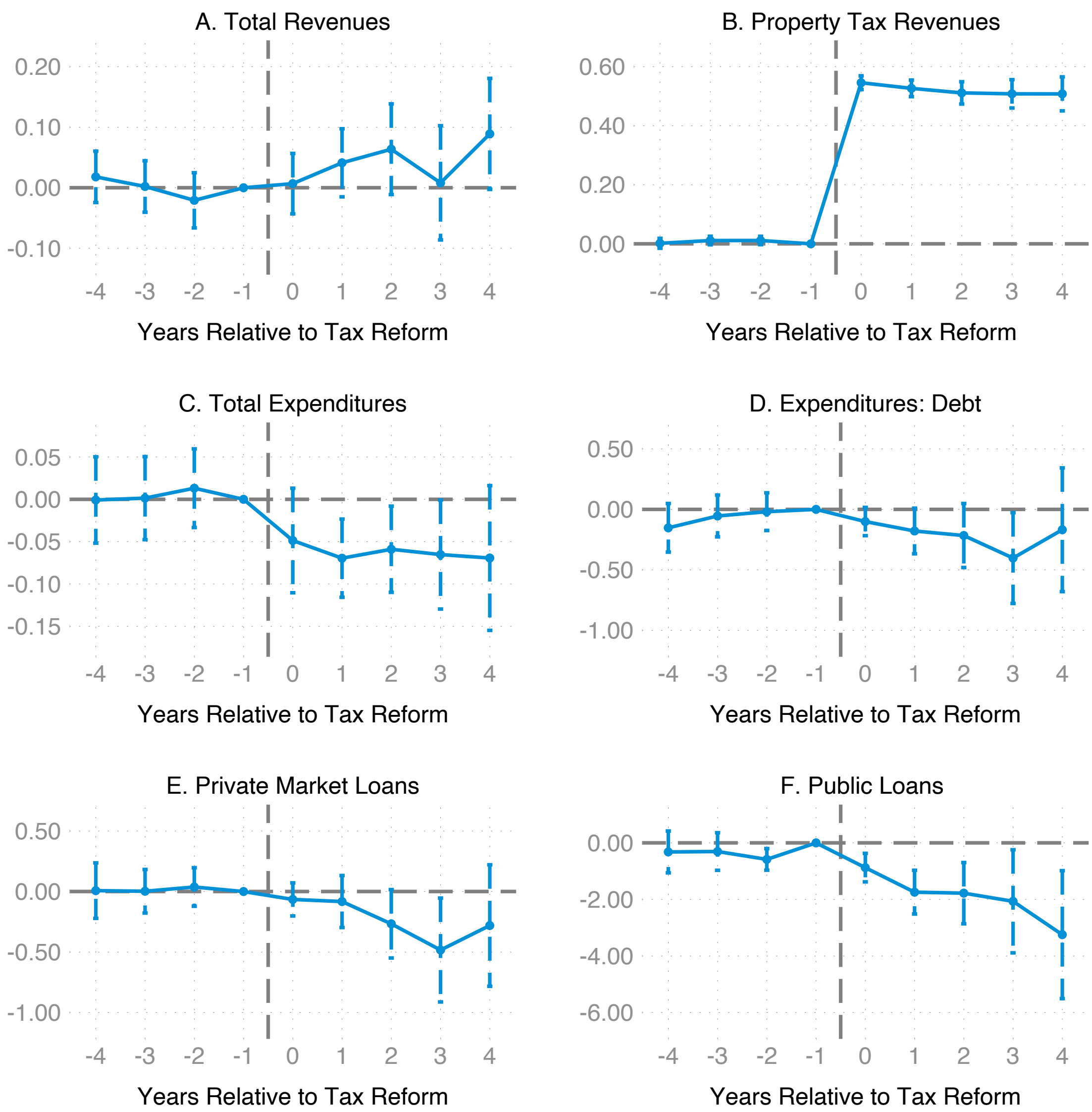
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year using different sets of control variables for local business cycles. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.3: Effect of Property Taxes on Local Business Cycle Outcomes



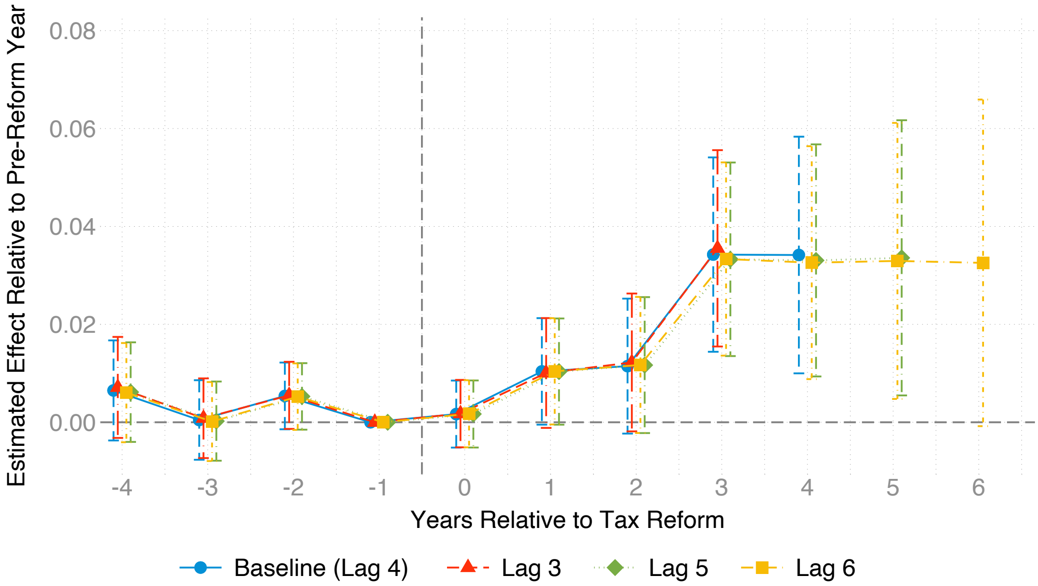
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on local business cycle measures relative to the pre-reform year. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.4: Effect of Property Taxes on Municipal Finances



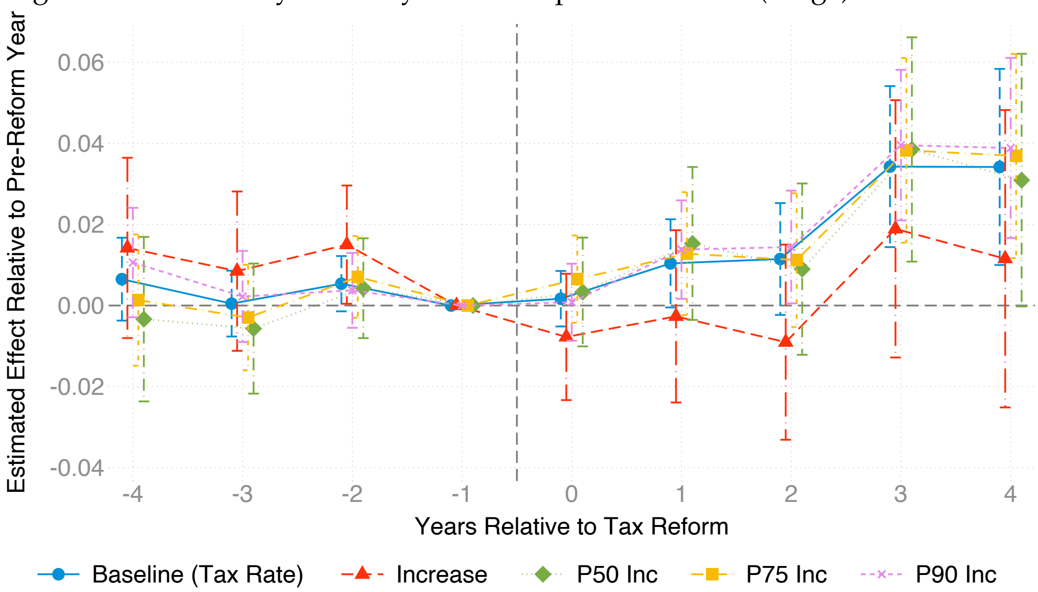
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on municipal revenues and expenditures relative to the pre-reform year. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.5: Sensitivity: Number of Lags



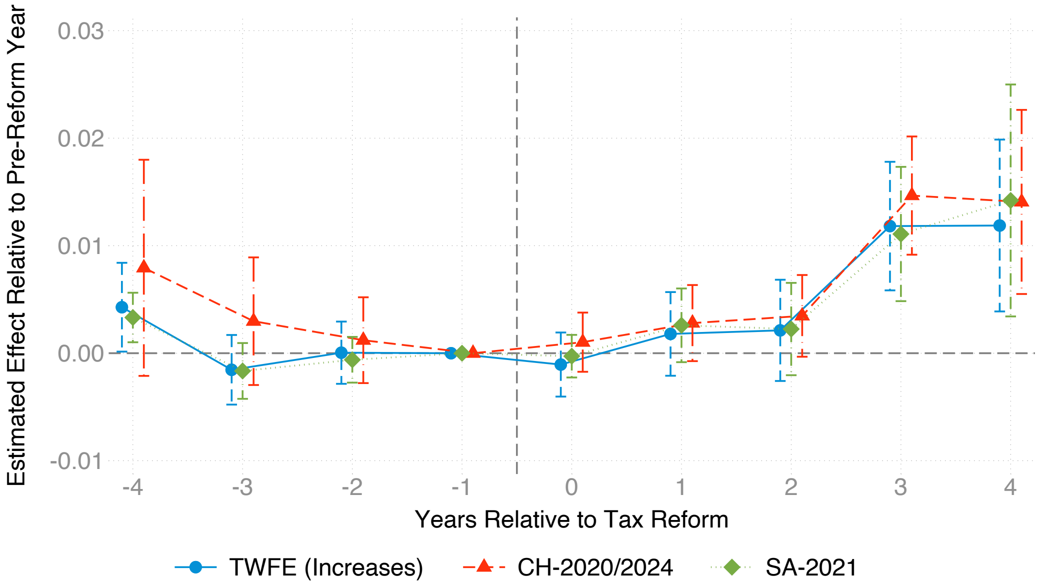
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year using alternative specifications regarding the lag length. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.6: Sensitivity: Dummy Variable Specification for (Large) Tax Increases



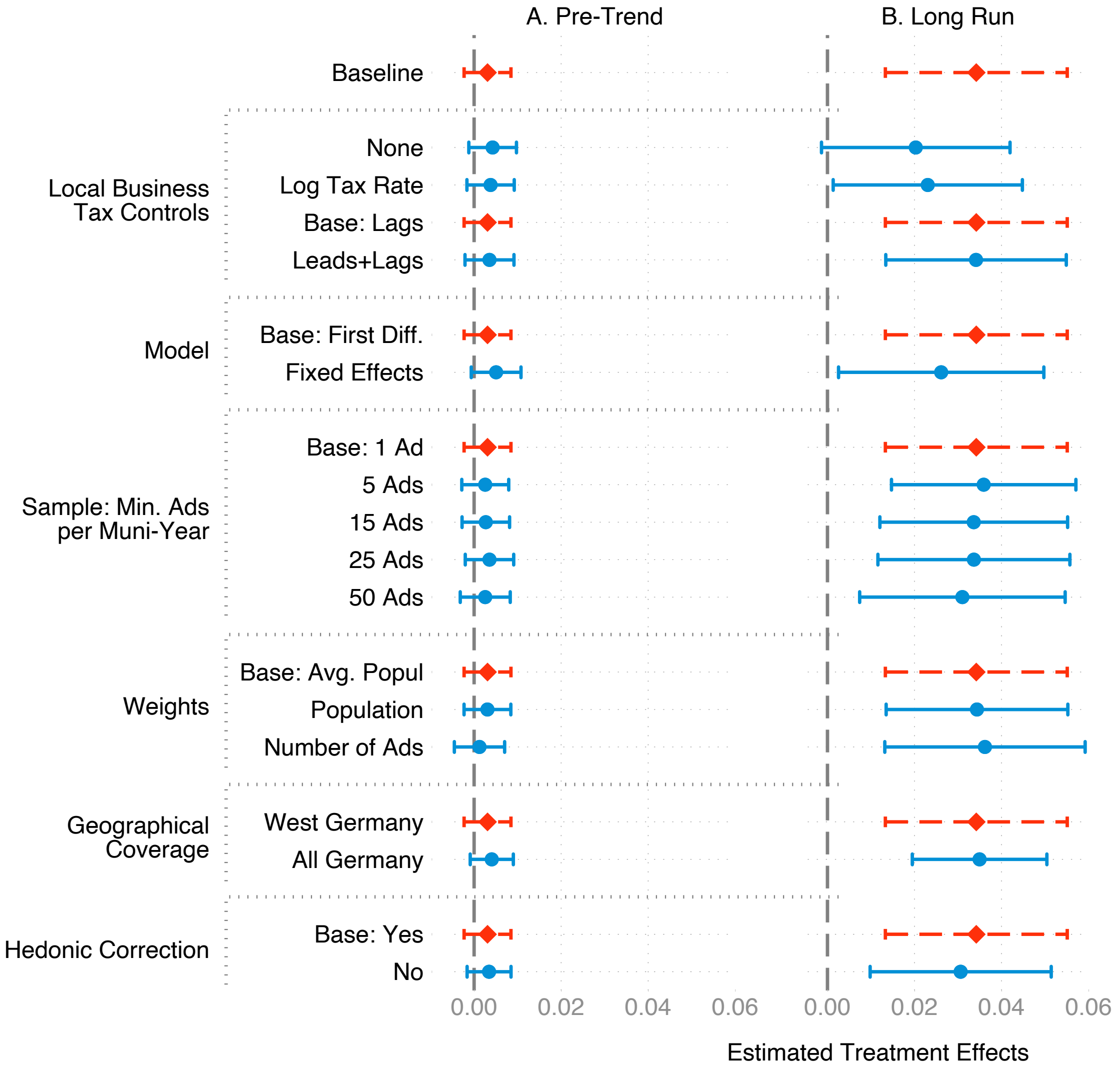
Notes: This figure illustrates the estimated treatment effect of property tax changes on total rents (in logs) relative to the pre-reform year using alternative definitions of event study variables. The baseline specification scales any change in property tax rates with the size of the tax change. The other specifications, described in the legend, use simply event indicators for any tax increase or larger tax increases (greater or equal to the P50, P75 or P90 of the tax increase distribution). The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.7: Sensitivity: Heterogeneous Treatment Effects



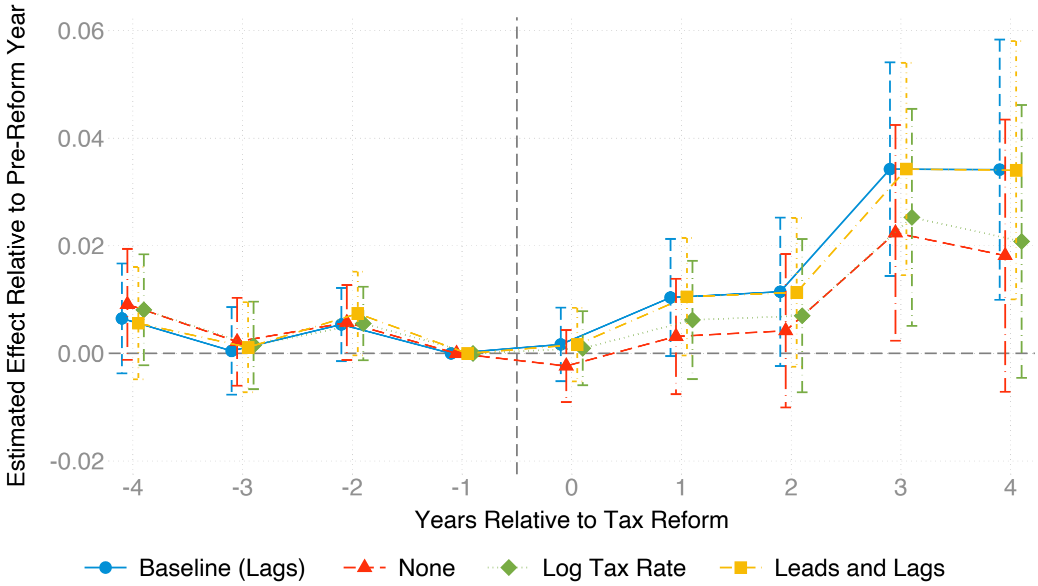
Notes: This figure illustrates the estimated treatment effect of large property tax increases on total rents (in logs) relative to the pre-reform year using alternative definitions of event study variables. Large property tax changes are defined as being above the median of the property tax distribution. The sample is restricted to municipalities with either no or one large change. The underlying econometric model is similar to equation (3) with the exception that we use a dichotomous treatment variable indicating a tax change instead of a continuous one. The baseline two-way fixed effects (TWFE) model is contrasted with models that account for heterogeneous treatment effects as indicated in the legend: CD2020 stands for de Chaisemartin and D'Haultfœuille (2020), SA2021 for Sun and Abraham (2021); and BJS 2022 for Borusyak et al., 2023. All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.8: Further Robustness Checks



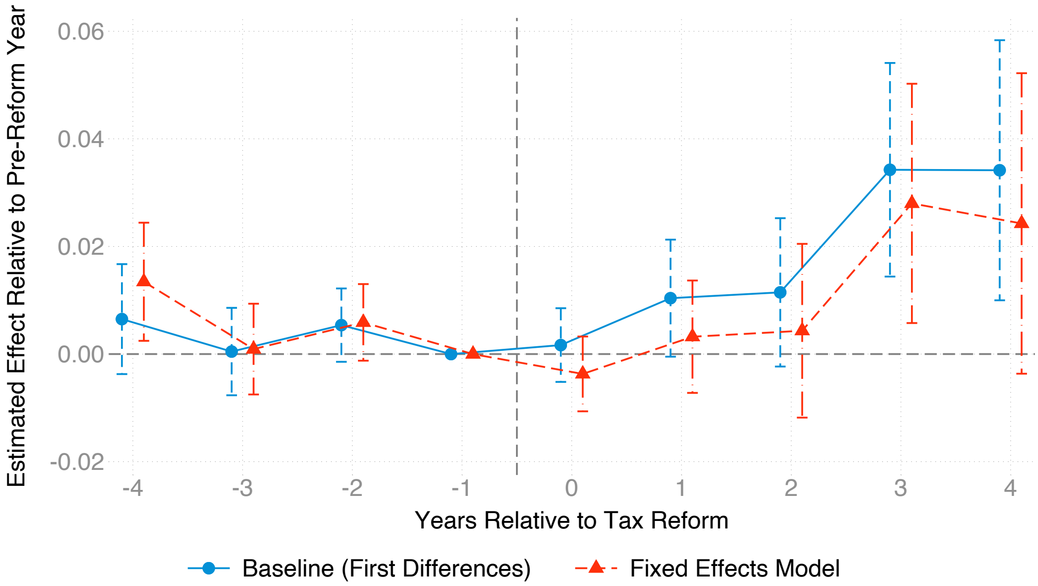
Notes: This figure presents the results from various sensitivity analyses. Estimates depict the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year. The baseline result corresponding to Figure 2 is shown in red, results from alternative specifications are depicted in blue. Panel A presents summary estimates of pre-treatment trends, i.e., the average coefficient in the four years prior to a tax reform. Panel B shows the medium-run effect measured as the average estimate of the third and fourth lag (and potentially later lags) in the property tax rate. Horizontal bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.9: Robustness: Controlling for Local Business Taxes



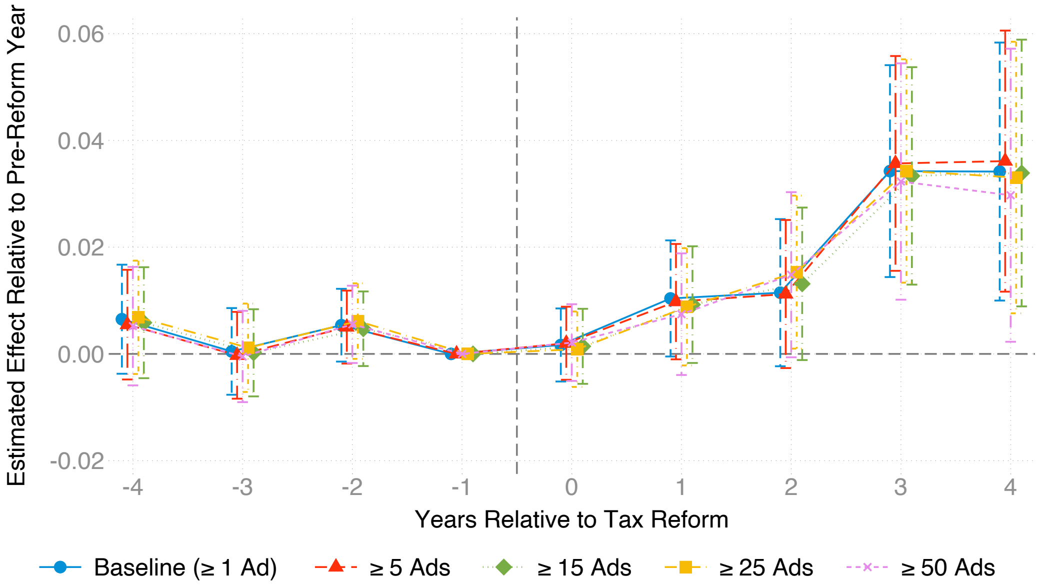
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year using alternative control sets for changes in local business tax rates. The underlying econometric model is described in equations (3) and (4). All specifications also account for MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.10: Robustness: First-Differences vs. Fixed Effects



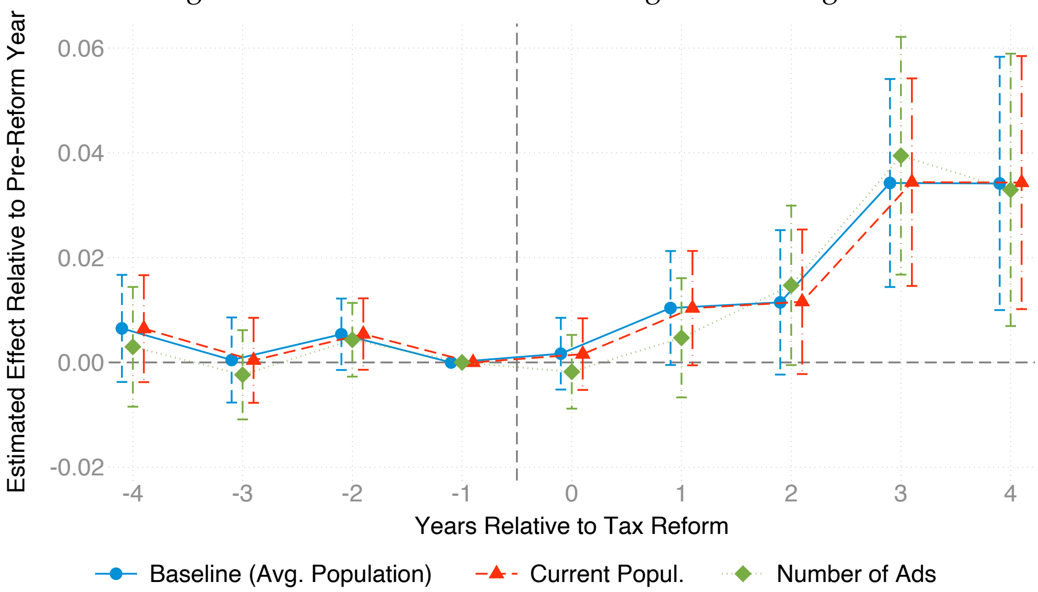
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year comparing first differences results and estimates from a model with municipality fixed effects. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.11: Robustness: Sample Restrictions in terms of Number of Ads



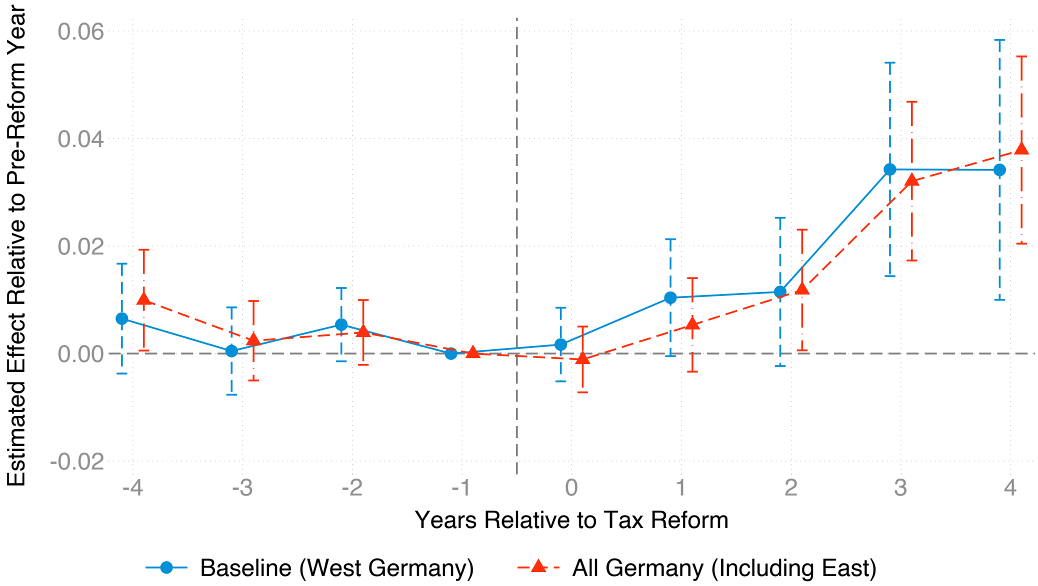
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year using different requirements regarding the minimum number of ads per municipality-year observation. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.12: Robustness: Different Regressions Weights



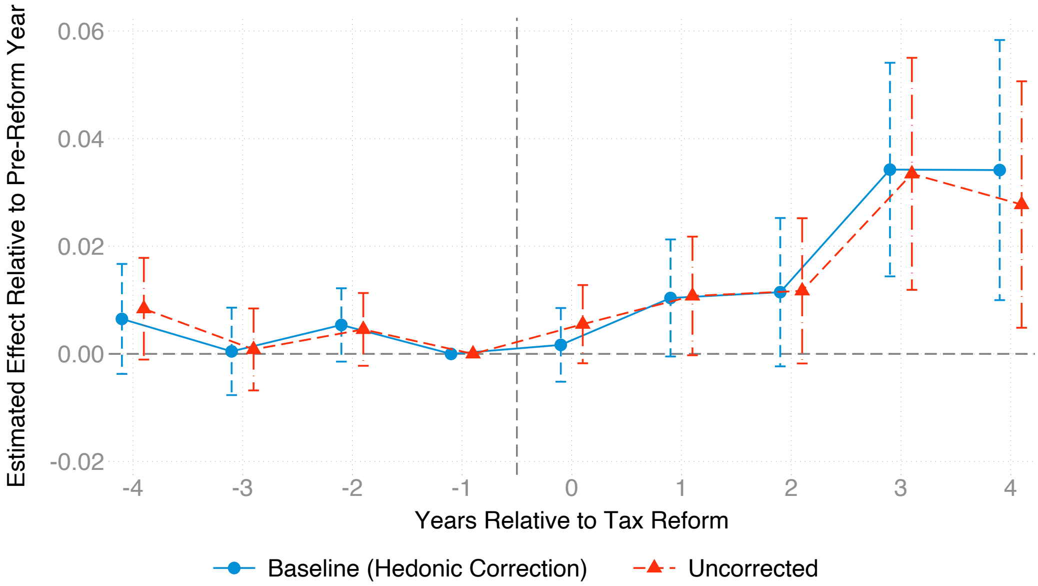
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year using different weighting procedures. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.13: Robustness: Geographical Coverage



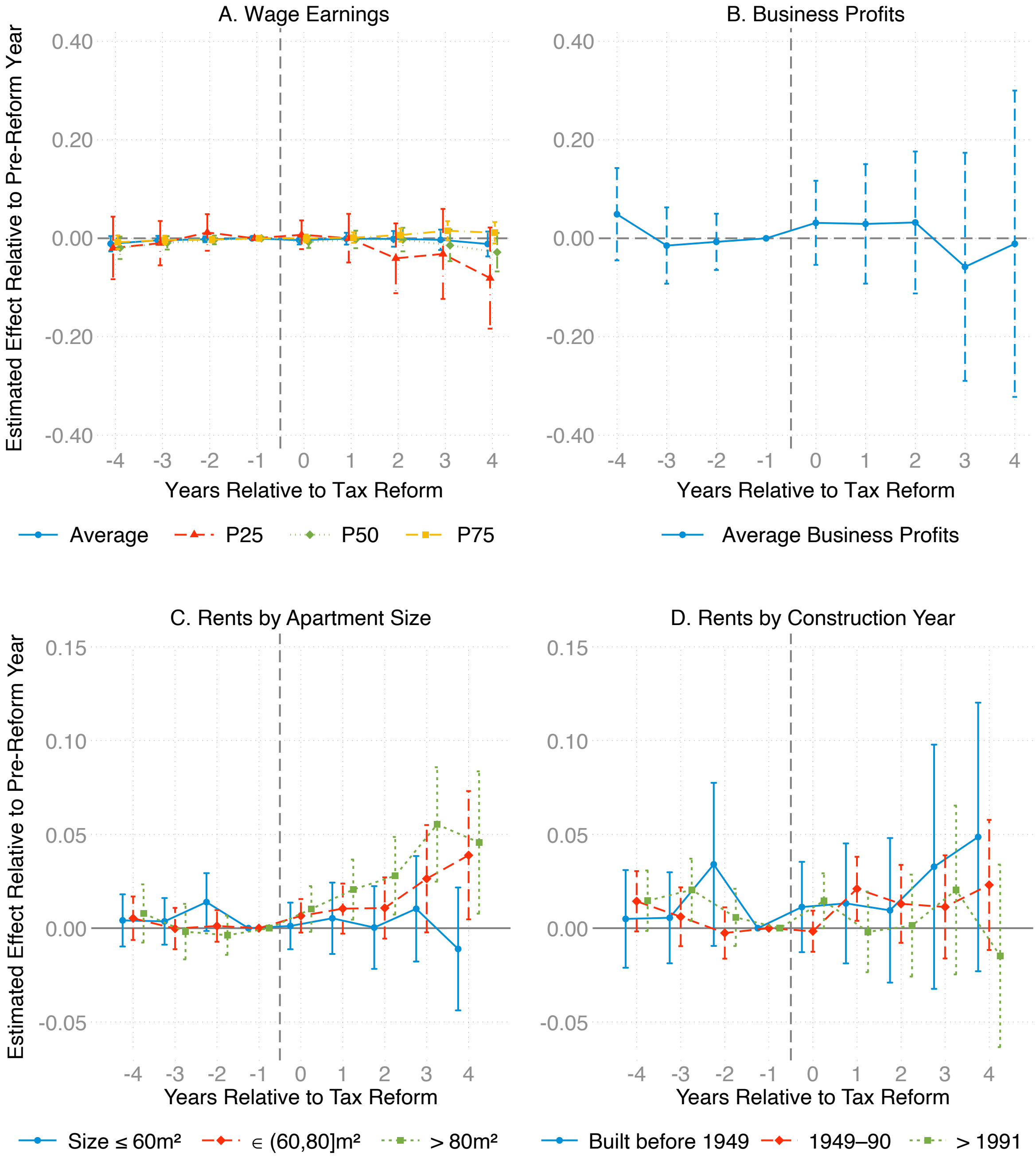
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year for West Germany only and all Germany including the East. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.14: Robustness: Hedonic Correction of Rent



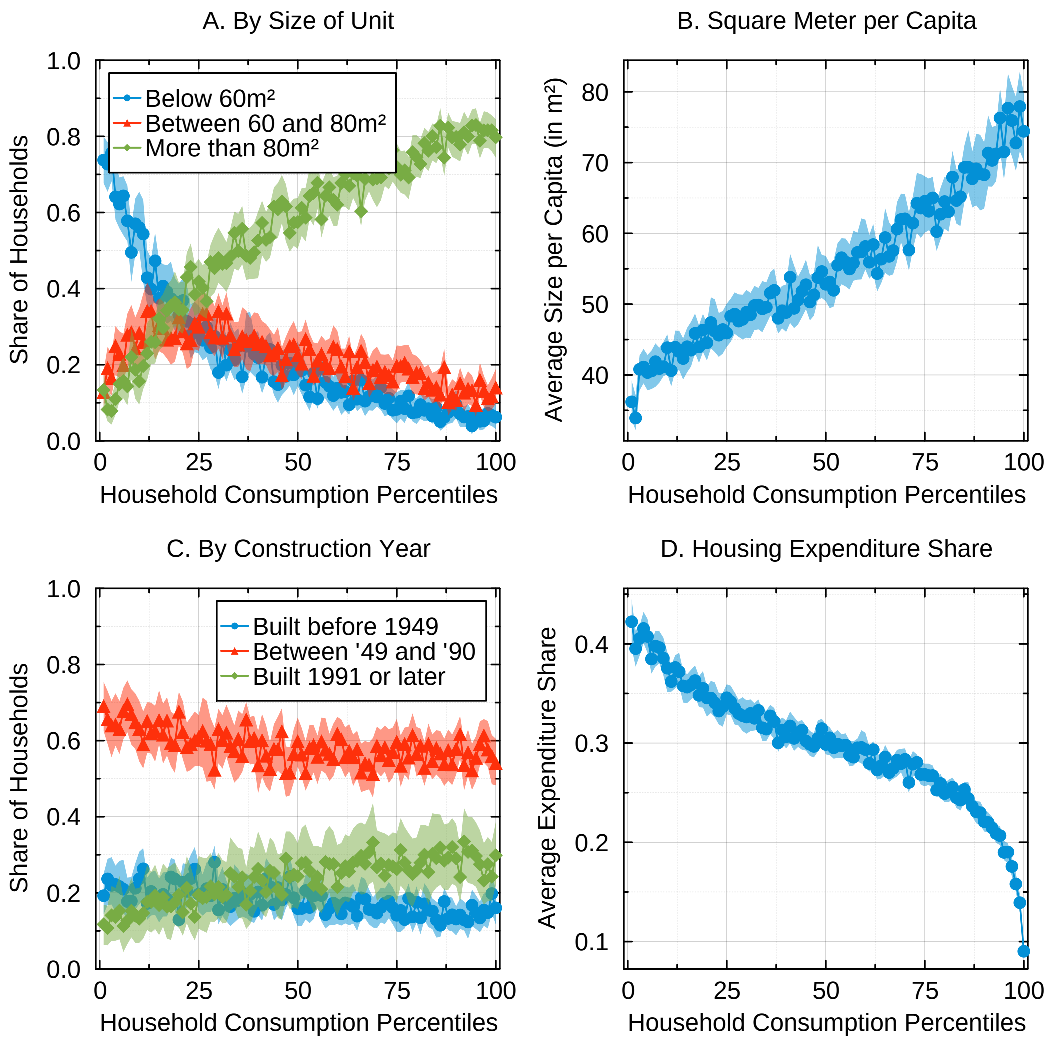
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.15: Price Effects for Simulation



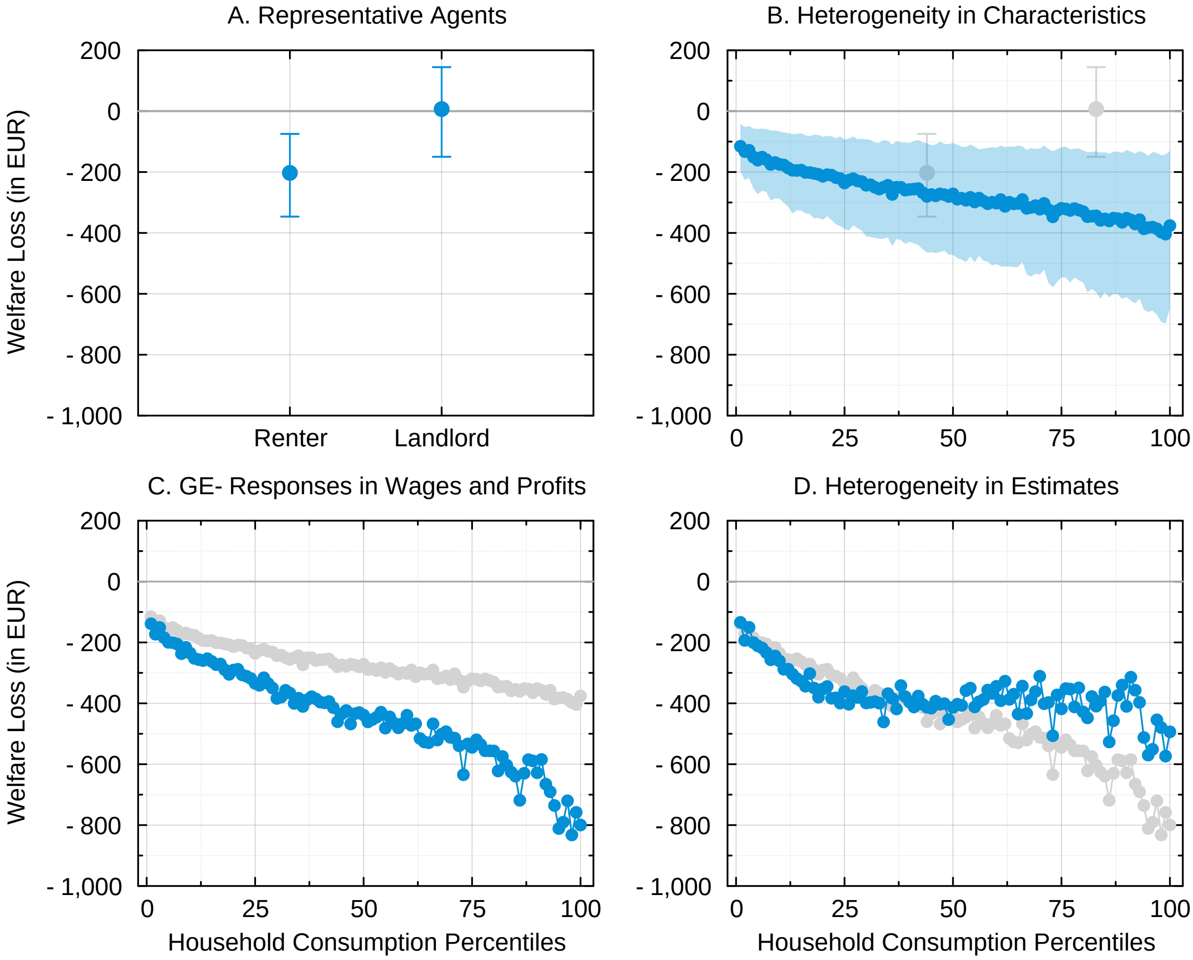
Notes: This figure illustrates the estimated treatment effect of a one percentage point increase in the property tax rate for the outcomes depicted in Table 1. The underlying econometric model is described in equations (3) and (4). All specifications also account for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Vertical bars indicate 95% confidence intervals. Standard errors are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.

Figure E.16: Descriptives on Housing Consumption in the EVS (2013)



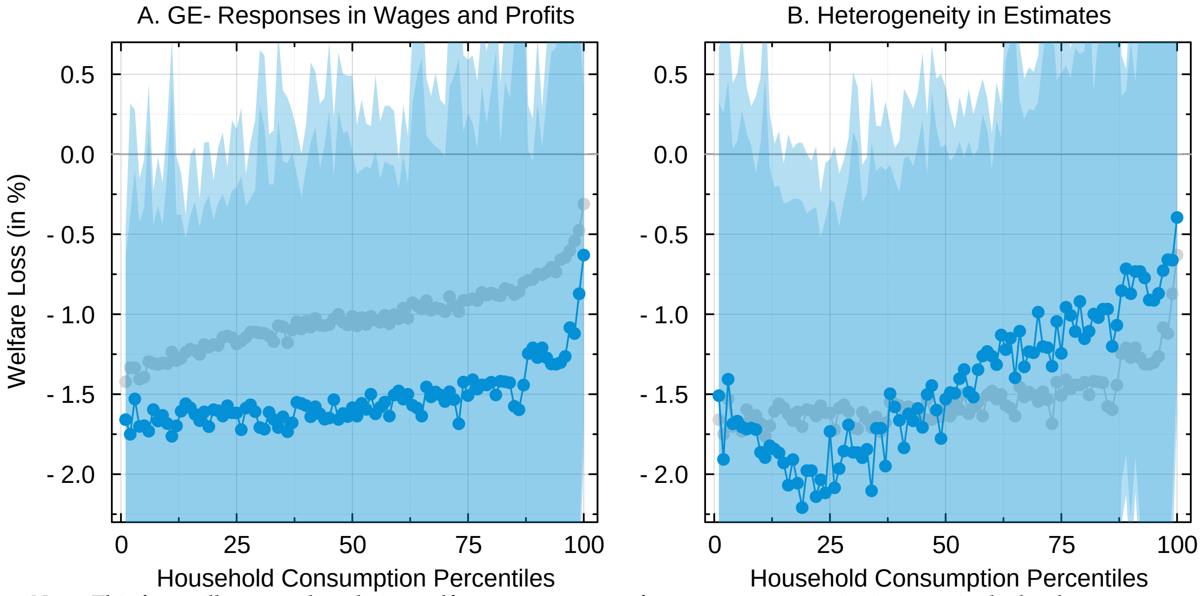
Notes: This figure provides descriptives statistics on households' average housing consumption along the distribution of consumption expenditures. We restricted the survey sample to households from West Germany. Panel A focuses on floor space consumption. Panel B depicts the average area per capita along the consumption distribution. Panel C illustrates buildings' average construction years. Panel D depicts the households' housing expenditure share. Shaded areas represent empirical 95% confidence bounds using 1,000 bootstrap samples. *Source:* Own calculations based on EVS (2013).

Figure E.17: Simulation Results – Absolute Money-Metric Utility Changes



Notes: This figure illustrates average absolute money-metric utility changes for each percentile along the consumption distribution (in euro per year). Starting from a stylized benchmark case presented in Panel A, we introduce more heterogeneity in our welfare simulations step-by-step as we move to Panel-D: Panel A reports welfare in a partial-equilibrium model with two representative agents (landlords and renters). Panel B additionally accounts for differences in the numbers of these two agents, their different positions in the consumption distribution, and their housing expenditures; Panel C additionally introduces general equilibrium effects on the labor market (via wage and business income effects); Panel D additionally allows for heterogeneity in price effects of rents and wages. The gray coefficients/dots indicate the estimates from the previous panel to improve comparability. We simulate these changes for each household in the German Income and Expenditure Survey (EVS, 2013); Section 6.1 provides more details on the empirical implementation. The curves are based on average changes within percentiles of the consumption distribution across households using sampling weights and the OECD-modified equivalence scale. Shaded blue areas and vertical bars correspond to empirical 95% confidence bounds using 1,000 bootstrap replications. See Appendix C for detailed information on all variables.

Figure E.18: Welfare Simulation – Additional Inference Tests



Notes: This figure illustrates the relative welfare consequences of a one percentage point increase in the local property tax over the household consumption distribution (in percent). We calculate relative welfare losses as money-metric utility changes in euro per year divided by annual household consumption. Absolute welfare changes are depicted in Appendix Figure E.17. This graph complements Panels C and D of Figure 5 by depicting empirical 90 and 95% confidence bounds using 1,000 bootstrap replications (darker and lighter blue shaded areas). See the original figure notes for details on the simulation.

E.2 Additional Tables

Table E.1: Bounded Estimates Following Oster (2019)

	(1) Uncontrolled Estimate	(2) Controlled Estimate	(3) Bounded Estimate
Panel A – Using Contemporaneous Controls			
Medium-Run Effect	0.034***	0.033***	0.031
	(0.011)	(0.011)	
Number of Observations	23,303	23,295	
Adjusted R-squared	0.003	0.004	
Panel B – Using Lagged Control Variables			
Medium-Run Effect	0.034***	0.034***	0.036
	(0.011)	(0.011)	
Number of Observations	23,303	23,294	
Adjusted R-squared	0.003	0.003	

Notes: This table illustrates the bounded estimates for the treatment effect of a one percentage point increase in the property tax rate on total rents (in logs) relative to the pre-reform year. Bounds have been obtained using the approximation in Oster (2019) and calibrating $\delta = 1$ and $R^2_{max} = 1.3 \cdot R^2_{controlled}$. Panel A presents bounds using contemporaneous business cycle control variables (population, unemployment, county-level GDP) for the controlled model. Panel B relies on the same control variables lagged by two years. The underlying econometric model is described in equations (3) and (4). The specification also accounts for leads and lags in the local business tax rate and MSA-by-year fixed effects. Observations are weighted by average population levels over the sample period. Standard errors (in parentheses) are robust to clustering at the municipality level. See Appendix C for detailed information on all variables.