Property Taxation, Housing, and Local Labor Markets: Evidence from German Municipalities*

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Work in progress.
Preliminary and incomplete – do not cite without permission.
This version: May 12, 2017

Abstract. This paper analyzes the incidence of property taxation. We suggest a novel theoretical perspective by introducing property taxation into a Rosen-Roback type local labor market model. We find that the tax incidence depends on the housing supply elasticity, location preferences and the mobility of workers. The model incorporates standard mechanism present in models of the capital tax and the benefit view. We exploit the advantageous institutional setting of property taxation in Germany to provide clean reduced form estimates of the tax incidence, exploiting variation induced by more than 10,000 tax reforms in a panel of more than 20 years. Relying on mostly non-parametric event study designs, we confirm our theoretical predictions and that housing prices are negatively affected if housing supply is sufficiently elastic. Moreover, housing stock and population decline if tax rates increase. Our estimates imply that the property tax burden is fully borne by renters in the medium-run, while house owners are able to shift parts of the burden onto house seller.

Keywords: property taxation, tax incidence, local labor markets, rental housing

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1 Introduction

What is the incidence of the property tax? The answer to this question is relevant to policy-makers around the world. Property taxes affect both government and individual budgets and may thus have important efficiency and distributional implications. Economists have engaged in investigating the effects of the tax for over a century; a broad strand in the literature has emerged since then. However, there is still no consensus on the question of who bears the burden of the tax. This “sad state” of “our understanding of the incidence of local property taxes” (Oates and Fischel, 2016, p. 415) has two main reasons.

First, competing theoretical models with quite different perspectives on local property taxation exist. On the one hand, the capital tax view adopts a general equilibrium perspective and argues that the national average burden of the property tax is eventually borne by capital owners, i.e., landlords (Mieszkowski, 1972). Only local deviations from the national average are passed on to renters. On the other hand, 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 financed through property taxes (Hamilton, 1975). In the benefit view, the tax is equivalent to a neutral fee for local public services, whereas the tax is progressive, falling mainly on richer landlords in the capital tax view.

Second, from an empirical point of view, identification of the incidence of property taxation is challenging for various reasons. First of all, there is generally a lack of high-quality data on property taxes, public services and residential dwellings with a sufficiently large number of observations. Oftentimes only cross-sectional data is available, where tax rates and public services vary simultaneously. Another complication arises as municipalities may not only differ in their property tax rates, but also their assessment practice of property values, which makes statutory tax rates a rather coarse approximation of the effective municipal tax burden (Palmon and Smith, 1998). Last, most papers adopt a partial equilibrium perspective and only look at quantity or price effects – one exception being a recent paper by Lutz (2015) who looks at both capitalization and capital investment.

In this paper, we readdress the question of who bears the burden of the property tax. Theoretically, we make a novel contribution by introducing property taxation into a Rosen-Roback type local labor market model (Moretti, 2011). In this spatial equilibrium model, individuals are mobile and respond to changes in house prices, wages and local amenities. At the same time, people have location-specific preferences, which limit their regional mobility. Our model incorporates both capital tax and benefit view elements. The model predicts that property taxes are fully shifted onto house buyers/renters if housing supply is sufficiently elastic, which is in line with the stylized textbook model of tax incidence. Moreover, the property tax incidence on house prices is determined by the strength of locational preferences, the share of housing expenditures in overall consumption and the elasticity of labor demand. The incidence also depends on the assumption made on the use of the tax revenue. As suggested by the benefit view literature, the effects of property taxes on rents are mitigated if
renters are perfectly mobile and tax revenues are used to finance local consumption amenities.\(^1\)

In addition to the incidence of the property tax on house prices, our model predicts that municipal population is expected to decrease in the medium run as cities become less attractive if property taxes increase. In a similar vein, the number of housing units is predicted to decrease. Last, wages are expected to increase following a tax increase, partly compensating the local labor force for rising costs of living.

In the second part of the paper, we test the theoretical predictions using rich administrative panel data from German municipalities. Specifically, we make use of the quasi-experimental setting of property taxation in Germany (Grundsteuer). Municipalities can independently and annually adjust the local property tax rate via a municipality-specific scaling factor (Hebesatz).\(^2\)

Each year, more than 10 percent of the municipality change the local property tax, resulting in more than 10,000 tax reforms we can exploit for identification. Importantly, and unlike to other settings, municipalities cannot influence the assessment of property values, which is conducted by the federal states. Moreover, all other legal rules determining the total tax burden, such as liability criteria, are set at the federal level and cannot be influenced by municipalities, either. Hence, municipalities can only adjust the tax rates, which is important for the identification of causal effects. We gathered administrative data on the universe of 8,481 West German municipalities over more than twenty years.\(^3\) As house price data is much harder to obtain, we rely on a smaller sample with house price and net rent indices for different construction types and qualities for 547 municipalities, providing us with more than 44,000 house or apartment type-municipality-year observations. This subsample covers roughly 40 percent of the German population, namely all cities with a population of 100,000 or more and a third of all municipalities with between 20,000 and 100,000 inhabitants.

In order to empirically assess the effect of property taxes on house prices, the housing stock, population and wages, we implement a non-parametric event study design and exploit the within-municipality variation in tax rates over time with more than ninety percent of all municipalities changing their local tax rates within the observation period. Accounting for municipal fixed effects, the event study design enables us to assess the evolution of the property tax impact on the outcomes of interest in the short and medium run (up to five periods after the tax reform). In addition, we can test the exogeneity of tax reforms by investigating pre-trends. In the absence of a pre-trend, the identifying assumption is that there is no systematic regional factor driving both municipal property tax reforms and outcome variables. We explicitly test this assumption by flexibly controlling for shocks at the commuting zone level; estimates are robust.

Our results verify the theoretical priors. We show that real net rents decrease in the short run (implying that the tax burden is on the landlord), but revert back to pre-reform levels after four to five years, when housing supply had sufficient time to adjust. This suggests that in the medium run, renters bear the full burden of the property tax – in line with the statutory

\(^1\) We empirically show that the latter condition is not supported in the German context, which is not surprising given the institutional set-up.

\(^2\) See (\?) for similar policy variation in the context of German business taxes.

\(^3\) We exclude East German municipalities for various reasons, see the discussion in Section 4.1 for details.
incidence of the tax. In contrast, net house prices decline persistently after a tax increase. As predicted by the model, both municipal population and the number of housing units respond negatively to higher local property taxes which reflects the fact that higher costs of living make a city less pleasant to live in. However, we do not find significantly positive effects on local wages, potentially compensating for increasing costs of living. Possible explanations for this results are elastic labor demand and strong location-specific preferences, which make individuals less mobile. We also show that rents, population levels and wages do not differ prior to a tax change, which suggests that reverse causality is not an issue.

We add to the literature by investigating the effects of property taxes in a local labor market framework, which has become the “workhorse of the urban growth literature” (Glaeser, 2009, p. 25). Empirically, we provide clean, non-parametric evidence on the effects of the property tax on population, house prices and wages using high-quality administrative data from the universe of West German municipalities. Using Germany as a case study is particularly relevant in this context, as it has one of the highest renter rates and one of the largest private rental markets in the Western world (in relation to the housing stock). We hence add to the existing empirical literature on the incidence of the property tax on housing rents, which has predominantly focused on the US. As mentioned above, previous studies offer a wide range of estimates of the incidence. Earlier studies, e.g., by Orr (1968, 1970, 1972), Heinberg and Oates (1970), Hyman and Pasour (1973), Dusansky et al. (1981) and Carroll and Yinger (1994) found largely differing tax shifting onto renters, ranging from 0-115%.

We find that property tax increases lead to decreasing house prices, which is evidence of capitalization into house values. This finding is in line with the studies by Palmon and Smith (1998), who investigated 50 subdivisions located in the suburbs of Houston, Texas, and de Bartolomé and Rosenthal (1999), looking at 566 homes in 265 neighborhoods in the US. Our findings of a negative effect of property taxes on municipal population levels are in line with evidence provided by Ferreira (2010) and Shan (2010), who show that property taxes affect mobility rates of the elderly. Last, our study offers evidence that property tax increases reduce housing investment, a mechanism that Lyytikäinen (2009) shows for the case of Finnish municipalities. In a similar vein, a recent contribution by Lutz (2015) investigates 158 municipalities in the Boston area in New Hampshire and finds that property taxes reduce building permits and capital investment in rural areas, but not in the suburban ring: in urban areas property taxes are capitalized into land prices instead.

The remainder of this paper is organized as follows. In Section 2 we set up our theoretical model. Section 3 presents the institutional framework of property taxation in Germany. Section 4 provides information on the used data and shows some descriptive statistics. We set up our empirical model in Section 5. In Section 6, we present our results. Section 7 concludes.

2 Theoretical model

In this section, we introduce local property taxes into a Rosen-Roback type general equilibrium model of local labor markets as recently put forward by, e.g., Moretti (2011), Kline and Moretti
We are in a world with \( N \) workers that locate in one of the \( C \) cities. The model consists of three groups of agents, namely workers (Section 2.1), firms (Section 2.2) and house owners (Section 2.3). In Section 2.4, we solve for the equilibrium. In Section 2.5 we show how changes in the property tax rate affect the equilibrium outcomes, i.e., population size, rents and wages. All derivations are shown in Appendix A.

2.1 Household problem

We assume that labor is homogeneous and each worker provides one unit of labor. Each worker in city \( c \) earns a wage \( w_c \) and pays for housing \( r_c \). We assume that there is only one homogeneous housing good and do not differentiate between owner-occupied and rental housing in our model (Poterba, 1984). Each municipality has a specific unproductive consumption amenity \( A_c \). Workers maximize utility over housing \( h \), a composite non-housing good \( x \) and location \( c \). Moreover, labor is mobile across municipal borders, but not perfectly due to individual location preferences, so that local labor supply is not necessarily infinitely elastic. In addition to the net house price, there is a property tax in each city, denoted by \( t_c \), with the statutory incidence on the user of the housing service. Without loss of generality, we normalize the total number of workers to one \((N = 1)\) and the price of the composite good \( x \) to one.

The maximization problem of household \( i \) in a given municipality \( c \) is:

\[
\max_{h_i, x_i} U_{ic} = A_c h_i^\gamma x_i^{1-\gamma} e_{ic} \quad \text{s.t.} \quad r_c (1 + t_c) h_i + x_i = w_c
\]

with \( h_i, x_i, e_{ic}, A_c, r_c, w_c, t_c > 0 \) and \( \gamma \in (0, 1) \). The term \( e_{ic} \) denotes an idiosyncratic preference of person \( i \) for location \( c \). The solution to the household problem is given by:

\[
\begin{align*}
    h_i^* &= \frac{w_c}{r_c (1 + t_c)} \\
    x_i^* &= (1 - \gamma) w_c
\end{align*}
\]

where \( \gamma \) is share of the household’s budget spent for housing. Using the optimal consumption quantities, log indirect log utility is defined as:

\[
V_{ic} = \ln U(h_i^*, x_i^*, A_c, e_{ic}) = c_0 + \ln w_c - \gamma \ln r_c - \gamma \ln (1 + t_c) + \ln A_c + \ln e_{ic}
\]

with \( c_0 = \gamma \ln \gamma + (1 - \gamma) \ln (1 - \gamma) \). Hence utility can be decomposed into city-specific systematic part \( V_c \) and worker’s idiosyncratic preferences for a location \( e_{ic} \). As in Kline and Moretti (2014b), we assume that \( \ln e_{ic} \) is independent and identically extreme value type I distributed with scale parameter \( \sigma > 0 \). The corresponding cumulative distribution function is \( F(z) = \exp (- \exp [-z/\sigma]) \). Due to these city preferences, workers are not fully mobile between cities and real wages \( \frac{w_c}{r_c (1 + t_c)} \) do not fully compensate for different amenity levels \( A_c \) across municipalities. The greater \( \sigma \), 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.

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

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

Note that 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. Taking logs we arrive at the (log) labor supply in municipality $c$:

$$
\ln N_c = \frac{\ln w_c}{\sigma} - \gamma \frac{\ln r_c}{\sigma} - \gamma \frac{\ln (1 + t_c)}{\sigma} + \frac{\ln A_c}{\sigma} - \bar{U}
$$

with $\bar{U} = \ln C + \ln \pi - \frac{c_0}{\sigma}$ and $\pi = \frac{1}{C} \sum_{k=1}^{C} \exp \left( V_k / \sigma \right)$ being the average utility across all municipalities. Note that $C$ is given and for large $C$, a change in $V_c$ does not affect the average utility $\pi$.

### 2.2 Firm problem

The representative firm in each city produces one output good $Y_c$ using labor and capital ($N_c, K_c > 0$). Following Kline and Moretti (2014a), we assume that firms produce with a Cobb-Douglas technology ($\alpha, \beta > 0$ and $\alpha + \beta < 1$), which implies that there is a third location specific production factor. The production function is defined as:

$$
Y_c = N_c^\alpha K_c^\beta
$$

Capital markets are global, yielding a fixed interest rate of $\rho \in (0, 1)$. We normalize the price of the output good to one. Firms’ profits in $c$ are then given by:

$$
\Pi_c = N_c^\alpha K_c^\beta - w_c N_c - \rho K_c
$$

Using the first-order conditions and the profit equation, we can derive log labor demand as:

$$
\ln N_c = a_0 - \frac{\beta}{1 - \alpha - \beta} \ln \rho - \frac{1 - \beta}{1 - \alpha - \beta} \ln w_c
$$

with $a_0 = \frac{1 - \beta}{1 - \alpha - \beta} \ln \alpha + \frac{\beta}{1 - \alpha - \beta} \ln \beta$. Note that the labor demand curve is downward sloping with a constant labor demand elasticity $\frac{1}{\eta} = \frac{\partial \ln N_c}{\partial \ln w_c} = -\frac{1 - \beta}{1 - \alpha - \beta}$, with $\frac{1}{\eta} \leq -1$, given that $\alpha + \beta < 1$.\footnote{To keep the notation and the model as tractable as possible, we do not model this third factor explicitly. Moreover, it would be possible to account directly for a location specific amenity as done by Suárez Serrato and Zidar (2016). Such extensions are certainly interesting in other institutional settings but not important in our context.}

\footnote{For completion, inverse capital demand in city $c$ is given by $\ln \rho = \ln \beta + \frac{\alpha}{1 - \alpha} \ln \alpha - \frac{\alpha}{1 - \alpha} \ln w_c - \frac{1 - \alpha - \beta}{1 - \alpha} \ln K_c$.}
2.3 Housing market

Aggregate housing demand in city \( c \) is determined by the number of workers in city \( c \) and their individual housing demand as indicated by equation (1). Multiplying the number of workers in city \( c \) with the housing budget share and taking logs we arrive at the following log housing demand function:

\[
\ln H^d_c = \ln N_c + \ln \gamma + \ln w_c - \ln r_c - \ln(1 + t_c) \tag{5}
\]

Housing demand increases in local population, wages and the expenditure share spent for housing. It decreases with higher net housing costs and higher taxes. Let housing supply in city \( c \) be described by the following simple log supply function:

\[
\ln H^s_c = \theta \ln r_c \tag{6}
\]

Housing supply is increasing in the house price \( r_c \); the higher the elasticity of housing supply \( \theta > 0 \), the stronger this effect. The housing supply elasticity is exogenously determined by geography and land regulations.

2.4 Spatial equilibrium

The spatial equilibrium is determined by equalizing supply and demand on the labor and the housing market in each city, and hence given by equations (3), (4), (5), and (6). Solving the equation system (see Appendix A.4 for details) and denoting \( \tau_c = 1 + t_c \), we arrive at the following spatial equilibrium outcomes for city \( c \):

\[
\begin{align*}
\ln N^*_c &= c_N + \frac{1 + \theta}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\gamma \theta}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln \tau_c \\
\ln H^*_c &= c_H + \frac{1}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\eta \gamma \theta}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln \tau_c \\
\ln w^*_c &= c_w + \frac{1}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\gamma - \eta(1 - \gamma) + \sigma}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln \tau_c \\
\ln r^*_c &= c_r + \frac{1}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\gamma - \eta(1 - \gamma) + \sigma}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln \tau_c
\end{align*}
\]

with \( c_N, c_H, c_w, c_r \) being constant terms. It follows that log real wages are given by:

\[
\ln \left( \frac{w^*_c}{r^*_c \tau_c} \right) = (c_w - c_r) - \frac{1 - \eta \theta}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\sigma \theta - \eta \theta(1 - \gamma)}{\gamma(1 + \eta)(1 + \theta)(\sigma - \eta)} \ln \tau_c.
\]

Real wages decrease in the level of local amenities as workers must be compensated to live and work in cities with low levels of amenities. Real wages are also decreasing in local property tax rates as higher property taxes make it more expensive to live in a given city *ceteris paribus*.

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6 In the model workers and landowners are two distinct agents, which is convenient to analyze the welfare effects of changing housing parameters. Note that while this assumption is commonly made in the literature, it seems even plausible considering Germany’s large rental housing market.
The denominator of the fractions is always positive, given that \( \eta \in (-1, 0) \), \( \gamma \in (0, 1) \) and \( \sigma, \theta > 0 \). Note that its size is solely determined by the respective price elasticities of supply and demand on the housing and the labor market. See Appendix A.5 for details.

2.5 Comparative statics

We can now analyze how an increase in the local property tax affects the equilibrium outcomes.\(^7\) We derive the four following theoretical predictions:

**Prediction 1:** An increase in property tax in a municipality, decreases the population.

\[
\frac{\partial \ln N^*_c}{\partial \ln \tau_c} = -\frac{\gamma \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} < 0.
\]  

(7)

When property taxes in city \( c \) increase, it will be more expensive to live there. The city becomes less attractive and workers leave the municipality *ceteris paribus*:

**Prediction 2:** An increase in property tax in a municipality, decreases the housing stock.

\[
\frac{\partial \ln H^*_c}{\partial \ln \tau_c} = -\frac{(\gamma - \eta(1 - \gamma) + \sigma)\theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} < 0.
\]  

(8)

Predictions 2 follows from prediction 1, if the municipal population decline, the number of houses decreases as well.

**Prediction 3:** An increase in property tax in a municipality, increases the wage.

\[
\frac{\partial \ln w^*_c}{\partial \ln \tau_c} = -\frac{\eta \gamma \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} > 0.
\]  

(9)

In terms of price effects, workers who stay or move to city \( c \), must be compensated for higher costs of living following the tax reform and see a wage increase.

**Prediction 4:** An increase in property tax in a municipality, decreases net rents.

\[
\frac{\partial \ln r^*_c}{\partial \ln \tau_c} = -\frac{\gamma - \eta(1 - \gamma) + \sigma}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} < 0.
\]  

(10)

As people leave and housing demand decreases, net rents will be lower in the new equilibrium:

\(^7\) Verify that besides the incidence of the property tax rate, the model produces standard results when doing comparative statistics on amenities. Population and house prices are increasing in local consumption amenities \( A_c \), while wages work as a compensating differential and decrease in the consumption amenity.
**Prediction 5:** An increase in property tax in a municipality, decreases the real (i.e. adjusted for local costs of housing) wage.

\[
\frac{\partial \ln \left( \frac{w^*_c}{r^*_c} \right)}{\partial \ln \tau_c} = - \frac{\sigma \theta - \eta (1 - \gamma)}{\gamma (1 + \eta) + (1 + \theta) (\sigma - \eta)} < 0.
\]  

(11)

While wages are increasing and net rents are decreasing, the marginal effect of real wages is negative as real wages are defined in terms of the gross rent which increases more strongly than the wage \( w \).

The marginal effect given in equation (10) informs about the incidence of the property tax on net house prices. In Appendix A, we formally show that the negative effect of a tax increase on net house prices is larger, if the consumption share on housing, \( \gamma \), is increasing, labor demand is becoming more elastic (i.e., \( \eta \) is increasing), labor demand increases (i.e., \( \sigma \) is decreasing) and housing supply is becoming less elastic (i.e., \( \theta \) is decreasing). With respect to the housing supply, our model nests the standard textbook incidence model: If local housing supply is perfectly elastic, equation (10) implies that net house prices do not change in response to tax increases. As a consequence, tax-inclusive gross house prices increase with the tax. If housing supply is instead perfectly inelastic (\( \theta \rightarrow 0 \)), net rents decrease one-to-one to a marginal increase in \( \ln \tau_c \) and gross house prices are unaffected. In a general case with somewhat but not perfectly elastic housing supply, the tax burden is shared between renters and landlords or house buyers and sellers.

Equation (9) shows that wages increase if property taxes rise, which implies that firms also bear a part of the property tax burden as long as housing supply is somewhat elastic and labor demand somewhat inelastic. Population is responding negatively to tax increases if housing supply is somewhat elastic. In the special case of perfectly elastic labor demand and perfect worker mobility, the population response is solely determined by the housing supply elasticity:

\[
\lim_{\eta, \sigma \to 0} \frac{\partial \ln N^*_c}{\partial \ln \tau_c} = -\theta.
\]  

2.6 Spending of property tax revenues

So far we have made the implicit assumption that local amenities are exogenous, hence, for instance, purely determined by geographical location or weather conditions. In this section, we consider the case of property taxes being used to increase spending on local public goods. We assume that amenities are a composite, \( A_c = \bar{A}_c \cdot G_c \), where \( \bar{A}_c \) are exogenously given amenities (\( \frac{\partial \ln \bar{A}_c}{\partial \ln \tau_c} = 0 \)), and \( G_c \) is an endogenously provided local public good that is funded by local property tax revenues \( H_c r_c t_c \). We denote the share of tax revenues spent for the local public good \( \psi \in (0, 1] \) so that \( 1 - \psi \) of tax revenues are used to finance an external revenue requirement. The local public good is thus supplied according to the following equation:

\[
G_c = \psi H_c r_c t_c.
\]  

(12)

Moreover, we assume that workers have preferences for private goods, local public goods,
and exogenous amenities and augment the utility function accordingly:

$$U'_c = \tilde{A}_c \gamma A_c^{x+1-\gamma} \left( h_{ic} x_{ic}^{1-\gamma} \right)^{1-\delta} e_{ic}$$

where the exponent $\delta \in [0,1]$ measures the taste for the local public good.\(^8\) After solving the model, taking into account the new utility function and the public good supply, we can derive new equilibrium quantities and prices (all details and derivations can be found in Appendix A.7).

$$\ln N'_c = g_N + \frac{1 + \theta}{d_G} \ln A_c + \frac{\delta (1 + \theta)}{d_G} (\ln \psi + \ln t_c) - \gamma \theta (1 - \delta) + \delta (1 + \theta) \frac{\ln \tau_c}{d_G}$$

$$\ln H'_c = g_H + \frac{\theta (1 + \eta)}{d_G} \ln A_c + \frac{\delta \theta (1 + \eta)}{d_G} (\ln \psi + \ln t_c) - \theta \gamma (1 - \delta)(1 + \eta) - \eta (1 - \delta) + \sigma \frac{\ln \tau_c}{d_G}$$

$$\ln t'_c = g_r + \frac{\eta (1 + \theta)}{d_G} \ln A_c + \frac{\delta \eta (1 + \theta)}{d_G} (\ln \psi + \ln t_c) - \theta \gamma (1 - \delta)(1 + \eta) - \eta (1 - \delta) + \sigma \frac{\ln \tau_c}{d_G}$$

$$\ln w'_c = g_w + \frac{\eta (1 + \theta)}{d_G} \ln A_c + \frac{\delta \eta (1 + \theta)}{d_G} (\ln \psi + \ln t_c) - \eta \gamma \theta (1 - \delta) + \delta (1 + \theta) \frac{\ln \tau_c}{d_G}$$

with $d_G$ being defined as $d_G = \gamma (1 - \delta)(1 + \eta) + (1 + \theta)(\sigma - \eta - \delta)$. Note that $d_G > 0$ for reasonable assumptions on the preferences for public good ($\delta$), the labor demand elasticity ($\eta$) and the worker mobility ($\sigma$). The terms $g_N, g_H, g_r,$ and $g_w$ are constants (defined in the Appendix).

As done in Section 2.5, we can analytically derive the elasticities of the equilibrium outcomes with respect the tax rate $\tau_c$.\(^9\) It follows that

Looking at the population effect, we derive.

$$\frac{\partial \ln N'_c}{\partial \ln \tau_c} = - \frac{\gamma \theta (1 - \delta) + \delta (1 + \theta)}{d_G} + \frac{\delta (1 + \theta) 1 + t_c}{d_G}$$

For $\delta = 0$, we get the results shown in equation 7. For $\delta > 0$, we can rearrange, the equation as

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\(^8\) This model is a generalization of the theory outlined above and nests the basic model if individuals have no interest in public goods ($\delta \to 0$) and tax revenues are fully spent for an external revenue requirement ($\psi \to 0$).

\(^9\) Note that $\frac{\partial \ln t_c}{\partial \ln \tau_c} = \frac{\partial \ln t_c}{\partial \ln (1 + t_c)} = \frac{1 + t_c}{t_c}.$
follows.

\[
\frac{\partial \ln N_c'}{\partial \ln \tau_c} = - \frac{\gamma \theta (1 - \delta)}{\gamma (1 - \delta)(1 + \eta) + (1 + \theta)(\sigma - \eta - \delta)} + \frac{\delta (1 + \theta) 1}{d_G} \frac{1}{t_c}
\]

The negative term can be directly compared to the term in equation (7): the numerator is smaller by \(\delta \gamma \theta\), the denominator by \(\delta(1 + \theta + \gamma(1 + \eta))\). Thus, the denominator decreases more strongly than the numerator, which makes the negative effect smaller. The second term is unambiguously positive, which makes the negative population effect of a tax increase less severe. Note that the overall effect is still strictly smaller zero.

\[
\frac{\partial \ln N_c'}{\partial \ln \tau_c} = - \frac{\gamma \theta (1 - \delta) t_c + \delta (1 + \theta) t_c}{t_c[\gamma (1 - \delta)(1 + \eta) + (1 + \theta)(\sigma - \eta - \delta)]} \\
= - \frac{\delta + \gamma \theta t_c + \delta \theta (1 - t_c \gamma)}{t_c[\gamma (1 - \delta)(1 + \eta) + (1 + \theta)(\sigma - \eta - \delta)]} < 0
\]

The less severe population effect is perfectly intuitive. If the taxes are partly used to finance the local public good. The attractiveness of the municipality does not decrease as strongly compared to the case where the tax money would not be spent on the locality.

The new marginal effect on the housing stock is given by

\[
\frac{\partial \ln H_c'}{\partial \ln \tau_c} = - \theta \frac{\gamma (1 - \delta)(1 + \eta) - \eta(1 - \delta) + \sigma}{d_G} + \frac{\delta \theta (1 + \eta) 1 + t_c}{d_G} t_c
\]

We can arrange the expression as follows:

\[
\frac{\partial \ln H_c'}{\partial \ln \tau_c} = - \frac{(\gamma - \eta)(1 - \gamma) + \sigma - \delta(\gamma(1 + \eta) - \eta))\theta}{d_G} + \frac{\delta \theta (1 + \eta) 1 + t_c}{d_G} t_c
\]

Compared to equation (8), the numerator decreases by \(\delta(\gamma(1 + \eta) - \eta)\). As above the denominator decreases by \(\delta(1 + \theta + \gamma(1 + \eta))\). Again the denominator decreases more strongly, which will makes the negative effect on housing smaller. In addition, the second term is positive, which further decreases the negative effect on housing.

In line with these results, the marginal effects on the two prices are also dampened when part of the tax revenues are spent on the local public good. The positive effect of property tax increase on wages is not as strong as given in equation (9). Likewise, rents decrease less strongly compared to equation (10).

### 3 Institutional background

Property taxes are one of the oldest forms of taxation that is still used today. In Germany, the first universal property tax was implemented in Prussia in 1861. The current property tax regulations are based on a law from 1936. Besides local business taxes and municipal shares on federal income and sales taxes, the property tax is one of the three most important income
sources for the German municipalities. Around 14 percent of their tax revenues are collected by property taxes, which amounted to 11.6 billion EUR in 2012.

In the following we provide a short overview on the current institutional setting of property taxation in Germany (see Spahn, 2004, for more details). All legal regulations of the German property tax, i.e., the definition of the tax base, federal tax rates as well as legal norms regarding the property assessment are set at the federal level and have rarely been changed over the last decades. Besides the federal legal framework, the 11,442 German municipalities decide yearly on local scaling factors, which work as a multiplier to the federal rate. The property tax law distinguishes between taxes on agricultural land (Grundsteuer A) and taxes on other land and improvements (Grundsteuer B). We focus solely on the latter one in this paper as only this type of the tax is relevant for real estate property and the residential housing market.

The property tax due is calculated by multiplying the assessed value (Einheitswert) with the local property tax rate. The local property tax rate consists of two components. First, a federal tax rate according to the type of the land or building (Grundsteuermesszahl), and second a local scaling factor (Hebesatz), which is set annually by the municipality:

\[
\text{Tax Liability} = \text{Assessed Value}_{state} \times \text{Tax Rate}_{federal} \times \text{Scaling Factors}_{municipal} \quad (14)
\]

Property owners are liable for the tax payment irrespective of whether the house is owner-occupied, for rent or vacant. Only few exceptions from the tax exist for public sector property and the property of religious communities or charitable organizations, but even these exemptions do not apply if the property is for rent.

**Assessed values.** The house value is assessed by the tax offices of the federal state (not by the municipality!) when the property is built and, importantly, remains fixed over time. There is no regular reassessment of properties to adjust the rateable value to the market value of the property or to inflation rates. Reassessments only occur if the owner creates a new building or substantially improves an existing structure on her land.\(^{10}\) In order to make property values comparable across buildings with different construction years, the assessment refers to market values as of 1964 for land and buildings in West Germany. So even new buildings are assessed as if they were built several decades ago. As a consequence, assessed values differ substantially from current market values. This practice makes the assessment highly complicated and barely transparent for house owners, landowners and renters.

For our empirical analysis, it is important to note that the municipalities cannot influence the tax rates for two reasons. First, simply because they do not have the authority as this is a task conducted by the federal states. Second, even if municipalities had the power to influence the state, the institutional set-up is such that there are hardly any reassessments of the property.

\(^{10}\)While the property is reassessed when being sold, it will get assigned the same value if there has not been a substantial improvement of the property. The improvement has to concern the “hardware” of the property, such as adding a floor to the building. Installing a new kitchen does not yield for a reassessment.
Federal tax rates. The taxable value is calculated by multiplying the rateable value with federal tax rates. For West German houses, the federal property tax rate differs across building types ranging from 0.26 to 0.35 (see Table 1). For example, consider a one-family house in West Germany. The first 38,347 EUR are taxed at 0.26 percent while every euro above that threshold is taxed with the standard rate of 0.35 percent. The property tax is thus progressive for one-family houses and otherwise flat.\footnote{In East Germany, similar thresholds exist, but tax rates are higher on average, in order to account for the differences in the reference year for the assessment of rateable values in both parts of the country. In addition, tax rates in the former German Democratic Republic differ also depending on the year of construction and the size of the municipality in 1933.} There is no deduction for mortgage payments or debt services. The average property tax rate in our sample is 0.32%.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Tax Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-family houses</td>
<td></td>
</tr>
<tr>
<td>First 38,347 EUR</td>
<td>0.26</td>
</tr>
<tr>
<td>Additional value</td>
<td>0.35</td>
</tr>
<tr>
<td>Two-or more-family houses</td>
<td>0.31</td>
</tr>
<tr>
<td>Other/Unimproved land</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Table 1: Federal Tax Rates (in %) in West Germany

Municipal scaling factors. While the assessment of property values is done on the state level and federal tax rates are set at the federal level, the municipal councils decide yearly on the local scaling factor, which works as a multiplier to the federal tax rates. The decision is usually made in the last months of the preceding year, and most tax changes become effective on January 1st.

For a given housing stock and thus a fixed federal rate, local property tax rates only vary due to changes in local scaling factors. Figure 1 demonstrates the substantial cross-sectional and time variation in tax rates induced by changes in scaling factors. The left panel of the figure shows the local property tax rate of all West German municipalities in 2013, assuming a federal tax rate of 0.32%. The right panel demonstrates the number of changes of municipal scaling factors in the period 1992-2013. With scaling factors ranging from 2.30 to 5.35 (p1 and p99), local property tax rates vary between 0.74% and 1.71%. Annual mean and median scaling factors increased steadily from around 2.70 in 1992 to 3.40 in 2013. Hence the average effective local property tax rate in 2013 was $0.32\% \times 3.4 = 1.09\%$.

Over the period from 1992 to 2013, more than ninety percent of all municipalities changed their scaling factor at least once, while less than nine percent of municipalities still have the same multiplier as in the beginning of the 1990s. On average, municipalities changed the factor...
Figure 1: Variation in local property tax rates in West Germany

(a) Local property tax rates in 2013
(b) Number of scaling factor changes 1992-2013

Source: Statistical offices of the Laender. Maps: © GeoBasis-DE / BKG 2015. Notes: The left panel of the figure shows the local property tax rates in 2013 for all West German municipalities, assuming a federal tax rate of 0.32 percent. The right panel depicts number of changes of the municipal scaling factor by municipality in the period 1992-2013. Thin white lines indicate municipal borders, thick white lines indicate federal state borders.
three times 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 eight times since 1992, the first year of our data.

**Statutory incidence.** The property tax has to be paid by the owner of the property. However, for rental housing, property taxes are part of the ancillary costs that renters have to pay on top of net rents according to the legal regulations on operating costs (*Betriebskostenverordnung*).\(^{12}\) Landlords have the right to pass the full amount of the tax onto renters and it is a common practice to do so.\(^{13}\) Hence, *de facto*, the statutory incidence of the property tax for rental housing is on the renter. As a consequence, for both owner-occupied and rental housing, it is always the user of the housing service who has to pay the property tax.

## 4 Data and descriptive statistics

This sections gives an overview on the data used for our empirical analysis. It also provides descriptive statistics on the tax setting of local municipalities and the local housing markets in Germany. We combine rich administrative data on the fiscal, budgetary and economic situation of German municipalities (Section 4.1) with detailed housing market data including land costs, house prices and rents (Section 4.2) and administrative wage and employment records from the Federal Employment Agency (see Fuest et al., 2015, for details).

### 4.1 Municipalities

Administrative data on German municipalities are provided by the Statistical Offices of the German federal states. We collected data from the Statistical Offices for all German municipalities, including information on the economic, fiscal and budgetary situation, population indicators, the housing stock and construction activity. The data also includes local property tax multipliers, our main explanatory variable. In addition we collect district level unemployment rates from the Federal Employment Agency and district level GDP data from the Working Group Regional Accounts. The Federal Institute for Research on Building, Urban Affairs and Spatial Development (*BBSR*) provides us with definitions of commuting zones that are defined by actual commuting flows (*Arbeitsmarktregeionen*). Using these sources we construct a panel for all 8,481 West German municipalities from 1992 to 2013.

We decided to exclude East German municipalities for two reasons. First, and foremost, there were substantial mergers of East German municipalities after reunification, which complicates any longitudinal study. In fact, about 60 percent of the municipalities experienced at least one merger since 1990. Given that our data are based on the boundaries of 2010, the property tax

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\(^{12}\) On average, the local property tax due corresponds to four percent of net rents according to the federal German tenant association.

\(^{13}\) In a building with multiple housing units, the total tax bill of a specific property is usually split according to the number of square meters for each apartment.
rate of municipalities that saw a merger before 2010 is unobservable prior to the merger.\textsuperscript{14} Second, the East German housing market seems not representative given the tremendous population loss after reunification. In fact, from 1990 to 2009 East German municipalities lost 15 percent of their population on average. As a consequence, housing markets in many East Germany regions are subject to substantial excess supply.

4.2 Rental housing

We combine this panel with residential real estate house price and rent indices provided by the German real estate association IVD (\textit{Immobilienverband Deutschland}). This dataset delivers eight distinct price indices for standardized apartments with 70 square meter and three bedrooms. These indices differ by construction year and apartment quality and thus allow us to study heterogeneous effects of property taxes. It is important to note, that this data only includes net house prices and net rents (\textit{Nettokaltmiete}) and does not contain information on ancillary costs. Thus, we do not observe the gross price including the property tax, but only rents net of taxes. In the upper part of Figure B.1, we show exemplarily the price indicator for medium quality apartments built after 1948. There is a similar trend over time and by city size as in the lower part depicting the evolution of tax multipliers, although the rent increases are smaller in magnitude. Note that this graph shows nominal prices and thus does not account for rising price levels.

Unfortunately our housing market data covers only 547 municipalities and not all municipalities are covered over the full observation period. Figure B shows the number of covered municipalities and the population in these cities over the observation period. The left panel shows the absolute number while the right panel shows the percentage of all municipalities and the total German population, respectively. The remaining (unbalanced) panel consists of roughly 300 municipalities in every year, starting with 162 cities in 1992 and up to 375 cities in 2009. Although the sample represents less than five percent of all German municipalities, it includes a large share of bigger German cities. As can be seen in Figure 3(b), our sample covers roughly 38-44 percent of the German population or between 28 and 36 million people. Separated by city size, our sample includes more or less the universe of municipalities with 100,000 or more inhabitants (\textit{Großstädte}), roughly a third of all municipalities with population between 20,000 and 100,000 and rather few below (see Figure 4(a) for details). Figure 4(b) shows in addition the number of municipalities in our sample differentiated by their city size in 2010. Small and middle towns still make up the biggest share of our sample (roughly 75 percent of the covered municipalities have less than 100,000 inhabitants in that year), although we cover only a rather small proportion of all German municipalities with that size.

\textsuperscript{14} A possible solution would be to use a (weighted) average of the municipalities which merged, but this would introduce considerable measurement error in the form of artificial tax changes. Moreover, tax rates of newly merged municipalities might have changed because of the merger, which should also affect the housing market.
5 Empirical model

We make use of an event study design to investigate the effects of property tax changes. As shown in Section 3, we are faced with a situation where most municipalities change their tax rates more than once and where reforms have different sizes. For this reason, we follow the estimation setup outlined in Fuest et al. (2015). As identified by our theoretical model, we are interested in the effects of tax changes on the following outcome variables: net rents, net house prices, number of houses, number of apartments, wages and population. Denoting an outcome in municipality $m$ in year $t$ as $y_{m,t}$, our regression model reads as follows:

$$\ln y_{m,t} = \sum_{i=-4}^{5} \beta_j D_{m,t}^j + \mu_m + \zeta_{m,t} + \epsilon_{m,t},$$  \hspace{1cm} (15)

We regress our logged outcome variables on a set of dummy variables, $D_{m,t}^j$, indicating a tax event happening $j$ periods away. The event study is running from four years prior to an event ($j = -4$) to five years after the event ($j = 5$). Tax events are either tax increase, which make up more than 90% of the tax increases or big tax hikes, which are defined as a tax increase equal or larger than the 75th percentile of the tax increase distribution.\(^{15}\) The end points of the event study are adjusted to account for the fact that we cannot have a balanced panel in event time due to staggered tax reforms across municipalities ($\Omega$).\(^{16}\) The specification makes the set of $4 + 5 + 1$ regressors perfectly collinear, so one variable has to be dropped. We normalize coefficients with respect to the pre-reform year ($j = -1$).

To control for time-invariant factors, we include municipality fixed effects $\mu_m$.\(^{17}\) Hence, identification in the event study design is within municipality. Vector $\zeta_{m,t}$ controls for local shocks by including state-year fixed effects and linear district trends. The unobservable random term is denoted by $\epsilon_{m,t}$. We allow for clustering of standard errors on the municipal level to account for correlation in unobservable components over time and between the different building and construction types.\(^{18}\)

The $\beta_j$ coefficients, $j = -4, ..., 5$ show the response of municipalities from four years before until five years after a tax change. The pre-treatment coefficients, $\beta_j, \forall j < 0$, serve as a direct test of reverse causality. In order to obtain an unbiased estimate, we need pre-trends to be flat and insignificant. Given flat pre-trends, the identifying assumption of the model is that there is no other factor that simultaneously affects tax changes and outcome variables. While municipal fixed effects control for any time-invariant confounder, our estimator will be biased if local shocks affect both municipal fiscal policies and housing as well as labor markets.

We test the identifying assumption in several ways. First, we test the robustness of our estimates with respect to the inclusion of a very rich set of time-varying control variables. In

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15 As a robustness check, we restrict the analysis to municipalities with only one tax rate to rule out that our results are driven by the multiplicity of tax reforms in municipalities.

16 Hence, the coefficient $\beta_{-4}$ captures all tax changes occurring 4 or more years before the reform. Likewise, $\beta_5$ measures the effect of all tax changes that happened 5 or more years after a reform.

17 Our data contains several indices for each municipality differing by construction type and building quality. We include all indices and account for type-quality-specific municipality fixed effects in the rent regressions.

18 The results are not sensitive to whether we cluster on the municipal or the level of commuting regions.
our baseline, we include state-year fixed effects and linear district trends. As a robustness check, we estimate the model using simple year fixed effects (not capturing regional shocks) and check whether results are different. Moreover, we can estimate an even richer specification, in which we include commuting zone $\times$ year fixed effects. Effects are robust to the inclusion of finer regional controls and tend to become larger, which suggests that confounding variable would bias estimates towards zero. Second, we directly control for business cycle variables at the local level, by including municipal unemployment rates and district GDP per capita. Again, estimates are hardly affected. Last, we directly test whether tax reforms are driven by the local business cycle by using municipal unemployment and district GDP per capita as outcome variables in equation (15). We do not find any evidence that changes in the local business cycle triggered property tax changes as pre-trends are remarkably flat. This is in line with findings reported in Fuest et al. (2015), who document that changes in the local business tax are not driven by local shocks to GDP or unemployment, either.

6 Results

The following section presents our preliminary results. We will complement the event study estimates with the related results from a difference-in-difference model to quantify the magnitudes of the effects and relate these back to the theoretical elasticities. This will be done in the upcoming weeks.

In this section, we present the empirical results obtained by estimating equation (15). We first demonstrate housing market (Section 6.1) and then labor market outcomes (Section 6.2).

6.1 Housing market effects

First we analyze the effect of property tax changes on the net rent index in a municipality. The results of the corresponding event study regression can be seen in Panel A of Figure 2. Our estimates show that pre-reform trends are flat, which suggests there are no reverse causality issues and that tax increases are not just a reaction to increasing or decreasing rents in the years before. This is well in line with anecdotal evidence from city treasurers, who see the property tax as an instrument to raise revenue, not as a redistributive policy measure. The tax setting for the next year takes place in the last months of the preceding year (thus between $t = -1$ and $t = 0$) and we see an immediate reaction to tax increases. After one year, real net rents are 0.09 percent lower for a one percent increase in the tax and this effect is statistically different from zero. However, after two years, the negative effect on rents is going back. After five years real net rents are at the pre-reform level, which implies that the incidence is fully on the renter in the medium-run. A likely explanation of this adjustment paths lies in the supply of rental apartments which becomes more elastic over time.

Next, we look at the effects on net house prices, which are plotted in Panel B of Figure 2. Here, we see a significant and persistent decline in house prices following the tax change. After five years, house prices are 0.14 percent lower for a one percent tax increase. Translated to monetary terms, the effect implies that for a one euro increase in the property tax bill, the
house price is reduced by 4.50 euro. Hence, part of the tax burden is shifted onto the seller of the house.

While we detect significant price effects, theory also predicts the number of housing units to decline. As shown in Figure 3, both the number of residential houses and apartments declines following a tax increase. However, the magnitude of the changes is rather small.
6.2 Labor market effects

According to our theoretical model, an increase in the municipal property tax should negatively affect the number of residents in the city and have a positive impact on wages. In fact, Figure 4, shows the expected pattern. With a flat pre-trend, population levels slowly start to decline after the reform. Five years after the reform, population levels are 0.019 percent lower for a one percent increase in the tax. Property tax increases thus lead to rising costs of living compared to other municipalities, which makes these cities less attractive to live in. As a consequence of rising local prices, municipal wages are predicted to increase as a compensating differential. Panel B of Figure 4 shows slight, yet insignificant increase in wages when looking at large tax increases. Equation (9) suggests that the small wage effect could be due to a low worker mobility and/or elastic labor demand.
7 Conclusion

Despite the long and comprehensive literature on the incidence of property taxes, little is known on the actual incidence, thus, which share of a one euro increase in property taxes is the users of housing services. The theoretical literature mainly discussed the nature of the tax—thus, whether it is a capital tax or a beneficial tax. Previous empirical studies found a wide range of estimates from no shifting at all to over-shifting of 115 percent. However, these studies faced serious problems in terms of small sample sizes and endogeneity concerns due to the cross-sectional nature of their data.

We suggest a new theoretical angle to study the effect of property taxes by introducing property taxes into a local labor market in the spirit of Moretti, 2011. Our models nests elements of both the capital and the benefit view of property taxation, depending on the assumption on the parameters. We show that a rise in local property taxes should leave to a decrease in housing prices, a decrease in the housing and apartment stock as well as population decrease if property taxes increase. We find no evidence of wages increasing following a tax increase.

The results for the net prices of housing (rents and house price) inform about the incidence of the property tax. While we detect a short-run decrease of net rents following a tax increase, net rents are unaffected three years after the tax reform. This implies that in the medium-
run the burden of the property tax is fully borne by the renter. In contrast, housing price show a negative response, which is still visible after five years. Hence, part of the property tax burden is shifted on the sellers of houses (which are either the previous owner or the construction company for newly built houses). A likely driver of these differential effects is the housing-type specific supply elasticities. It is likely that the supply (relative to the demand) of rental apartment in bigger cities is more elastic than the supply of residential owner-occupied housing.
References


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A Appendix: Theoretical model

In this appendix, we provide the derivations of the theoretical main results presented in Section 2 of the paper.

A.1 Workers

We depart from the household’s maximization problem in a given municipality $c$ that is given by:

$$\max_{h_i, x_i} U_{ic} = A_c h_i^\gamma x_i^{1-\gamma} e_{ic} \quad \text{s.t.} \quad r_c (1 + t_c) h_i + x_i = w_c$$

with $h_i, x_i, A_c, r_c, w_c, t_c, e_{ic} > 0$ and $\gamma \in (0, 1)$. The Lagrangian reads:

$$\max_{h_i, x_i} L = A_c h_i^\gamma x_i^{1-\gamma} e_{ic} + \lambda (w_c - r_c [1 + t_c] h_i - x_i)$$

First-order conditions are given by:

$$\frac{\partial L}{\partial h_i} = A_c \gamma h_i^{\gamma - 1} x_i^{1-\gamma} - \lambda r_c (1 + t_c) = 0$$
$$\frac{\partial L}{\partial x_i} = A_c (1 - \gamma) h_i^{\gamma - 1} x_i^{1-\gamma} - \lambda = 0$$
$$\frac{\partial L}{\partial \lambda} = w_c - r_c (1 + t_c) h_i - x_i = 0$$

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

$$A_c \gamma h_i^{\gamma - 1} x_i^{1-\gamma} = \lambda r_c (1 + t_c)$$
$$A_c \gamma h_i^{\gamma - 1} x_i^{1-\gamma} = A_c (1 - \gamma) h_i^{\gamma - 1} x_i^{1-\gamma} r_c (1 + t_c)$$

$$h_i = \frac{\gamma}{1 - \gamma} \frac{x_i}{r_c (1 + t_c)}$$
$$h_i = \frac{\gamma w_c}{1 - \gamma} \left( r_c (1 + t_c) - h_i \right)$$
$$h_i^* = \frac{\gamma w_c}{r_c (1 + t_c)} \quad (A.1)$$

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

$$x_i = w_c - r_c (1 + t_c) h_i$$
$$x_i = w_c - r_c (1 + t_c) \gamma \frac{w_c}{r_c (1 + t_c)}$$
$$x_i^* = (1 - \gamma) w_c \quad (A.2)$$
where $\gamma$ is the share of the household’s budget spent for housing. Using the optimal consumption quantities, log indirect utility is defined as:

$$V_{ic} = \ln U(h^*_i, x^*_i, A_c, e_{ic}) = \gamma \ln h^*_i + (1 - \gamma) \ln x^*_i + \ln A_c + \ln e_{ic}$$

$$= \gamma \ln \left(\frac{w_c}{r_c(1 + t_c)}\right) + (1 - \gamma) \ln \left(\frac{(1 - \gamma)w_c}{\gamma r_c} + A_c + \ln e_{ic}\right)$$

$$= \gamma \ln \gamma + (1 - \gamma) \ln (1 - \gamma) + \gamma \ln w_c - \gamma \ln r_c - \gamma \ln (1 + t_c)$$

$$+ (1 - \gamma) \ln w_c + \ln A_c + \ln e_{ic}$$

$$V_{ic} = c_0 + \ln w_c - \ln r_c - \gamma \ln (1 + t_c) + \ln A_c + \ln e_{ic}.$$

Note that we defined a constant term $c_0$ that is the same for all workers in the economy to simplify the notation. The individual (indirect) utility is a combination of a common term identical to all workers in the municipality $V_c$ and the idiosyncratic location preferences $e_{ic}$. As in Kline and Moretti (2014b), we assume that $\ln e_{ic}$ is independent and identically extreme value type I distributed with scale parameter $\sigma > 0$. The corresponding cumulative distribution function is $F(z) = \exp(-\exp[-z/\sigma])$. Due to these city preferences, workers are not fully mobile between cities and real wages $w_c = \frac{w}{r(1 + t_c)}$ do not fully compensate for different amenity levels $A_c$ across municipalities. The greater $\sigma$, 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:

$$V_{ia} \geq V_{ib}$$

$$V_a + \ln e_{ia} \geq V_b + \ln e_{ib}$$

$$V_a - V_b \geq \ln e_{ib} - \ln e_{ia}.$$

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

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

Note that 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. Taking logs we arrive at the (log) labor supply curve in municipality $c$:

$$\ln N_c = \frac{V_c}{\sigma} - \ln (C\pi)$$
with \( \pi = \frac{1}{C} \sum_{k=1}^{C} \exp \left( \frac{V_k}{\sigma} \right) \) being the average utility across all municipalities. Note that \( C \) is given and for large \( C \), a change in \( V_c \) does not affect the average utility \( \pi \). We can rewrite this as:

\[
\ln N_c = \ln \frac{w_c}{\sigma} - \gamma \ln r_c - \frac{\ln(1 + t_c)}{\sigma} + \frac{\ln A_c}{\sigma} - \hat{U}
\]

(A.3)

where we collect all addends constant across municipalities as \( \hat{U} = \ln C + \ln \pi - \frac{c_0}{\sigma} \). The labor supply elasticity is given by \( \epsilon_{LS} = \frac{1}{\sigma} \).

A.2 Firms

The representative firm in city \( c \) maximizes profits:

\[
\Pi_c = N_c^\alpha K_c^\beta - w_c N_c - \rho K_c
\]

which leads to the following first-order conditions for capital and labor:

\[
\frac{\partial \Pi_c}{\partial N_c} = \beta Y_c - \rho \gamma = 0
\]

\[
\frac{\partial \Pi_c}{\partial K_c} = \alpha Y_c - w_c \gamma = 0
\]

Taking logs and using the two first-order conditions, we can further simplify to:

\[
\ln \beta + \ln Y_c - \ln K_c = \ln \rho
\]

\[
\ln \beta + \alpha \ln N_c + \beta \ln K_c - \ln K_c = \ln \rho
\]

\[
\ln K_c = \frac{\ln \beta + \alpha \ln N_c - \ln \rho}{1 - \beta}
\]

and:

\[
\ln \alpha + \ln Y_c - \ln N_c = \ln w_c
\]

\[
\ln \alpha + \alpha \ln N_c + \beta \ln K_c - \ln N_c = \ln w_c
\]

\[
\ln N_c = \frac{\ln \alpha + \beta \ln K_c - \ln w_c}{1 - \alpha}
\]

Substituting \( \ln K_c \) into \( \ln N_c \), we derive the optimal factor demand in terms of \( \ln N_c \):

\[
\ln N_c = \frac{\ln \alpha + \beta \ln \frac{\ln \beta + \alpha \ln N_c - \ln \rho}{1 - \beta} - \ln w_c}{1 - \alpha}
\]

\[
\left(1 - \alpha - \frac{\alpha \beta}{1 - \beta}\right) \ln N_c = \ln \alpha + \frac{\beta}{1 - \beta} \ln \beta + \frac{\alpha \beta}{1 - \beta} \ln N_c - \frac{\beta}{1 - \beta} \ln \rho - \ln w_c
\]

\[
\frac{1 - \alpha - \beta}{1 - \beta} \ln N_c = \ln \alpha + \frac{\beta}{1 - \beta} \ln \beta - \frac{\beta}{1 - \beta} \ln \rho - \ln w_c
\]
\[
\ln N_c = \frac{1 - \beta}{1 - \alpha - \beta} \ln \alpha + \frac{\beta}{1 - \alpha - \beta} \ln \beta - \frac{1 - \beta}{1 - \alpha - \beta} \ln w_c - \frac{\beta}{1 - \alpha - \beta} \ln \rho
\]

\[
\ln N_c = a_0 - \frac{\beta}{1 - \alpha - \beta} \ln \rho - \frac{1 - \beta}{1 - \alpha - \beta} \ln w_c
\]

where we shorten notation by introducing the term \(a_0\) that is constant across municipalities. We assume that capital markets are global and the interest rate \(\rho\) is exogenous. Moreover, we introduce \(\eta = \frac{1 - \alpha - \beta}{1 - \beta}\) as inverse labor demand elasticity (\(\epsilon_{LD} = \frac{1}{\eta}\)) and can thus further simplify the equation by writing inverse labor demand in the following way:

\[
\ln w_c = b_0 - \eta \ln N_c
\]

with \(b_0 = \ln \alpha + \frac{\beta}{1 - \beta} \ln \beta - \frac{\beta}{1 - \beta} \ln \rho\) as constant term across municipalities. For completeness, we can also solve for inverse capital demand in city \(c\) now:

\[
\ln \rho = \ln \beta + \frac{\alpha}{1 - \alpha} \ln \alpha - \frac{\alpha}{1 - \alpha} \ln w_c - \frac{1 - \alpha - \beta}{1 - \alpha} \ln K_c
\]

### A.3 Housing market

Aggregate housing demand in city \(c\) is determined by the number of workers in city \(c\) and their individual housing demand as indicated by equation (A.1):

\[
H_{d}^c = N_c h_i^* = N_c \gamma \frac{w_c}{r_c (1 + t_c)}
\]

\[
\ln H_{d}^c = \ln N_c + \ln \gamma + \ln w_c - \ln r_c - \ln (1 + t_c).
\]

It follows that the individual housing demand elasticity conditional on location choice is equal to \(\epsilon_{HD_{ind}} = -1\). However, there is also an extensive margin as people will leave the city if it becomes too expensive. The aggregate housing demand elasticity is thus given by:

\[
\epsilon_{HD} = \frac{\partial \ln H_{d}^c}{\partial \ln r_c} = \epsilon_{r_c} + \epsilon_{ind} = \frac{\partial \ln N_c}{\partial \ln r_c} - \frac{\partial \ln r_c}{\partial \ln r_c} = \frac{\gamma + \sigma}{\sigma}
\]

Let housing supply in city \(c\) be described by the following simple log supply function:

\[
\ln H_{s}^c = \theta \ln r_c
\]

with housing supply elasticity \(\epsilon_{HS} = \theta > 0\).

### A.4 Equilibrium

The spatial equilibrium is determined by equalizing supply and demand on the labor and the housing market in each city. Hence, we can summarize equilibrium conditions (A.3)–(A.6) as
follows:

\[
\ln N_c = \frac{\ln w_c}{\sigma} - \gamma \frac{\ln r_c}{\sigma} - \gamma \frac{\ln \tau_c}{\sigma} + \frac{\ln A_c}{\sigma} - \tilde{U} \tag{A.7}
\]

\[
\ln w_c = b_0 + \eta \ln N_c \tag{A.8}
\]

\[
\ln H_c = \ln N_c + \ln \gamma + \ln w_c - \ln r_c - \ln \tau_c \tag{A.9}
\]

\[
\ln H_c = \theta \ln r_c \tag{A.10}
\]

where we denote the gross price as \( \tau_c = 1 + t_c \) to simplify the notation in the following.

Now we solve for the equilibrium. Equalizing equations (A.9) and (A.10), thus housing demand and supply, and substituting in equation (A.8) for log wages \( \ln w_c \), we can write:

\[
\theta \ln r_c = \ln N_c + \ln \gamma + \ln w_c - \ln r_c - \ln \tau_c
\]

\[
(1 + \theta) \ln r_c = \ln N_c + \ln \gamma + \ln w_c - \ln \tau_c
\]

\[
\ln r_c = \frac{\ln N_c + \ln \gamma + \ln w_c - \ln \tau_c}{1 + \theta}
\]

\[
\ln r_c = \frac{(1 + \eta) \ln N_c + \ln \gamma + b_0 - \ln \tau_c}{1 + \theta} \tag{A.11}
\]

Similarly we solve the labor market equilibrium for \( \ln r_c \) by substituting log wages (A.8) in equation (A.7):

\[
\ln N_c = \frac{b_0 + \eta \ln N_c}{\sigma} - \gamma \frac{\ln r_c}{\sigma} - \gamma \frac{\ln \tau_c}{\sigma} + \frac{\ln A_c}{\sigma} - \tilde{U}
\]

\[
\gamma \ln r_c = b_0 + (\eta - \sigma) \ln N_c + \ln A_c - \gamma \ln \tau_c - \sigma \tilde{U}
\]

\[
\ln r_c = \frac{b_0 + (\eta - \sigma) \ln N_c + \ln A_c - \gamma \ln \tau_c - \sigma \tilde{U}}{\gamma} \tag{A.12}
\]

By setting equal the intermediate equations (A.11) and (A.12), we can solve for equilibrium population in city \( c \):

\[
\frac{(1 + \eta) \ln N_c + \ln \gamma + b_0 - \ln \tau_c}{1 + \theta} = \frac{b_0 + (\eta - \sigma) \ln N_c + \ln A_c - \gamma \ln \tau_c - \sigma \tilde{U}}{\gamma}
\]

\[
(\gamma [1 + \eta] + [1 + \theta] [\sigma - \eta]) \ln N_c = (1 - \gamma + \theta) b_0 - \gamma \ln \gamma - (1 + \theta) \sigma \tilde{U} - \gamma \theta \ln \tau_c + (1 + \theta) \ln A_c
\]

Equilibrium log population is then given by:

\[
\ln N_c^* = \frac{d_N}{d_0} + \frac{1 + \theta}{d_0} \ln A_c - \frac{\gamma \theta}{d_0} \ln \tau_c \tag{A.13}
\]

where we define \( d_N \) and \( d_0 \) as:

\[
d_N = (1 - \gamma + \theta) b_0 - \gamma \ln \gamma - (1 + \theta) \sigma \tilde{U}
\]

\[
d_0 = \gamma (1 + \eta) + (1 + \theta) (\sigma - \eta).
\]

29
Note that \( d_0 > 0 \) as \( \eta \) in \((-1, 0)\), \( \gamma \in (0,1) \) and \( \theta > 0 \).

To derive equilibrium wages, we substitute the population (A.13) back in equation (A.8):

\[
\ln w_c = b_0 + \eta \ln N_c \\
= b_0 + \frac{\eta}{d_0} \left( d_N + \{ 1 + \theta \} \ln A_c - \gamma \theta \ln \tau_c \right) \\
= \frac{d_w}{d_0} + \frac{\eta}{d_0} \left( \{ 1 + \theta \} \ln A_c - \gamma \theta \ln \tau_c \right) \\
\ln w_c^* = \frac{d_w}{d_0} + \frac{\eta(1 + \theta)}{d_0} \ln A_c - \frac{\eta \gamma \theta}{d_0} \ln \tau_c 
\] (A.14)

with \( d_w = (\gamma + \sigma + \sigma \theta)b_0 - \eta \gamma \ln \gamma - \eta(1 + \theta)\sigma \tilde{U} \).

Next, we derive the equilibrium house price level by substituting equation (A.13) into (A.11):

\[
\ln r_c = \frac{(1 + \eta) \ln N_c + \ln \gamma + b_0 - \ln \tau_c}{1 + \theta} \\
= \frac{1}{1 + \theta} \left( \frac{1 + \eta}{d_0} \left[ d_N + \{ 1 + \theta \} \ln A_c - \gamma \theta \ln \tau_c \right] + \ln \gamma + b_0 - \ln \tau_c \right) \\
= \frac{d_c}{d_0} + \frac{1 + \eta}{d_0} \ln A_c - \frac{\gamma \theta (1 + \eta) + d_0}{d_0(1 + \theta)} \ln \tau_c \\
\ln r_c^* = \frac{d_c}{d_0} + \frac{1 + \eta}{d_0} \ln A_c - \frac{\gamma - \eta(1 - \gamma) + \sigma}{1 + \theta} \ln \tau_c 
\] (A.15)

where \( d_c \) is defined as:

\[
d_c = \frac{(1 + \eta)d_N + (\ln \gamma + b_0)d_0}{1 + \theta} \\
= b_0(1 + s)\left( 1 + \theta \right) + \left( \eta \left[ \gamma - \theta - 1 \right] + \sigma \left[ 1 + \theta \right] - \gamma \eta \right) \ln \gamma - (1 + \theta)(1 + \eta)\sigma \tilde{U} \\
d_c = (\sigma - \eta) \ln \gamma - (1 + \eta)\sigma \tilde{U} + (1 + \sigma)b_0.
\]

Last, housing is determined by substituting the equilibrium house price into equation (A.10):

\[
\ln H_c = \theta \ln r_c \\
\ln H_c^* = \frac{d_c \theta}{d_0} + \frac{(1 + \eta) \theta}{d_0} \ln A_c - \frac{(\gamma - \eta[1 - \gamma] + \sigma) \theta}{d_0} \ln \tau_c 
\] (A.16)

Hence, we arrive at the following spatial equilibrium outcomes for city \( c \):

\[
\ln N_c^* = c_N + \frac{1 + \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\gamma \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln \tau_c 
\] (A.17)

\[
\ln H_c^* = c_H + \frac{(1 + \eta) \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln A_c - \frac{(\gamma - \eta[1 - \gamma] + \sigma) \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln \tau_c 
\] (A.18)

\[
\ln w_c^* = c_w + \frac{\eta(1 + \theta)}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\eta \gamma \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln \tau_c 
\] (A.19)

\[
\ln r_c^* = c_r + \frac{1 + \eta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\gamma - \eta[1 - \gamma] + \sigma}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln \tau_c 
\] (A.20)
with \( c_N = d_N/d_0, c_H = d_r/d_0, c_w = d_w/d_0, c_r = d_r/d_0 \) being constant terms. Form here, we can also derive the log real wage:

\[
\ln \left( \frac{w^*_c}{r^*_c \tau_c} \right) = \ln w^*_c - \ln r^*_c - \ln \tau_c^*
\]

\[
= (c_w - c_r) - \frac{1 - \eta \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln A_c
\]

\[
+ \frac{-\eta \gamma \theta + \gamma - \eta(1 - \gamma) + \sigma - \gamma + \eta(1 - \gamma + \theta) - \sigma(1 + \theta)}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln \tau_c
\]

\[
\ln \left( \frac{w^*_c}{r^*_c \tau_c} \right) = (c_w - c_r) - \frac{1 - \eta \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln A_c - \frac{\sigma \theta - \eta \theta(1 - \gamma)}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \ln \tau_c.
\]

### A.5 Demand and Supply Elasticities

Given the assumptions on the model parameters, i.e., \( \eta \in (-1, 0), \gamma \in (0, 1) \) and \( \sigma, \theta > 0 \), the denominator of the fractions is always positive. We argued before that its size is solely determined by the respective price elasticities of supply and demand on the housing and the labor market, which are given by:

\[
\begin{align*}
\epsilon^{LS} &= \frac{\partial \ln N^S}{\partial \ln w} = \frac{1}{\sigma} \quad &\epsilon^{HD} &= \frac{\partial \ln H^D}{\partial \ln r} = -\frac{\gamma + \sigma}{\sigma} \\
\epsilon^{LD} &= \frac{1}{\partial \ln w} \frac{\partial \ln N^D}{\partial \ln w} = \frac{1}{\eta} \quad &\epsilon^{HS} &= \frac{\partial \ln H^S}{\partial \ln r} = \theta.
\end{align*}
\]

We can now rewrite the denominator in terms of these elasticities:

\[
\gamma(1 + \eta) + (\sigma - \eta)(1 + \theta) = \gamma \sqrt[1+\epsilon^{HD}]{\frac{1+\chi^{LS}_{\epsilon^{LD}}}{\sigma}} \left( 1+\gamma \right) \left( \sigma - \eta \right) \left( 1+\gamma \right) = -\left( 1+\epsilon^{HD} \right) \frac{\epsilon^{LD}+1}{\epsilon^{LS} \epsilon^{LD}} + \left( 1+\epsilon^{HS} \right) \frac{\epsilon^{LD}-\epsilon^{LS}}{\epsilon^{LS} \epsilon^{LD}}.
\]

### A.6 Comparative statics

In the following, we derive how equilibrium outcomes respond to changes in taxes:

\[
\begin{align*}
\frac{\partial \ln N^*_c}{\partial \ln \tau_c} &= -\frac{\gamma \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \leq 0 \\
\frac{\partial \ln H^*_c}{\partial \ln \tau_c} &= -\frac{(\gamma - \eta(1 - \gamma) + \sigma) \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \leq 0 \\
\frac{\partial \ln w^*_c}{\partial \ln \tau_c} &= -\frac{\eta \gamma \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \geq 0 \\
\frac{\partial \ln r^*_c}{\partial \ln \tau_c} &= -\frac{\gamma - \eta(1 - \gamma) + \sigma}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \leq 0
\end{align*}
\]

The elasticities can be inferred from the equilibrium conditions in equations (A.3)-(A.6). Note that we refer to aggregate housing demand, which takes into account both the intensive and the extensive margin, i.e., that rent increases may not only affect individual consumption conditional on location, but also the location choice itself.
\[
\frac{\partial \ln \frac{w^c_r}{r^c}}{\partial \ln \tau_c} = -\frac{\sigma \theta - \eta (1 - \gamma)}{\gamma (1 + \eta) + (1 + \theta)(\sigma - \eta)} \leq 0.
\]

The expression \(\frac{\partial \ln r^*_c}{\partial \ln \tau_c} = -\frac{\gamma - \eta(1 - \gamma) + \sigma}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)}\) informs about the incidence of the property tax on net house prices, which depends on the housing expenditure share \(\gamma\), the inverse labor demand elasticity \(\eta\), the housing supply elasticity \(\theta\) and the worker mobility \(\sigma\). Taking a closer look at these determinants, we derive:

\[
\frac{\partial^2 \ln r^*_c}{\partial \ln \tau_c \partial \gamma} = \frac{-[\gamma - \eta(1 - \gamma + \theta) + \sigma(1 + \theta)](1 + \eta) + (\gamma - \eta(1 - \gamma) + \sigma)[1 + \eta]}{[\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)]^2} \leq 0
\]

\[
\frac{\partial^2 \ln r^*_c}{\partial \ln \tau_c \partial \eta} = \frac{\theta(\sigma - \eta)(1 + \eta)}{[\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)]^2} \leq 0
\]

\[
\frac{\partial^2 \ln r^*_c}{\partial \ln \tau_c \partial \theta} = \frac{0 + (\gamma - \eta(1 - \gamma) + \sigma)[-\eta + \sigma]}{[\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)]^2} \leq 0
\]

\[
\frac{\partial^2 \ln r^*_c}{\partial \ln \tau_c \partial \sigma} = \frac{(\gamma - \eta(1 - \gamma + \theta) + \sigma(1 + \theta)) + (\gamma - \eta(1 - \gamma) + \sigma)[1 + \theta]}{[\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)]^2} \geq 0
\]

\[
\frac{\partial^2 \ln r^*_c}{\partial \ln \tau_c \partial \sigma} = \frac{\gamma \theta(1 + \eta)}{[\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)]^2} \geq 0.
\]

Likewise, for an exogenous change in amenities, we get:

\[
\frac{\partial \ln N^*_c}{\partial \ln A_c} = \frac{1 + \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} > 0
\]

\[
\frac{\partial \ln H^*_c}{\partial \ln A_c} = \frac{(1 + \theta)\theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \geq 0
\]

\[
\frac{\partial \ln A_c}{\partial \ln A_c} = \frac{\eta(1 + \theta)}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \leq 0
\]

\[
\frac{\partial \ln w^*_c}{\partial \ln A_c} = \frac{1 + \eta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \geq 0
\]

\[
\frac{\partial \ln \frac{w^*_c}{r^*_c}}{\partial \ln \tau_c} = -\frac{1 - \eta \theta}{\gamma(1 + \eta) + (1 + \theta)(\sigma - \eta)} \leq 0.
\]

**A.7 Model with endogenous amenities**

In this section, we extend the basic model presented so far to analyze the case with endogenous amenities. As before we assume that workers receive utility from local amenities as well the consumption of housing and a private good. While we treated local amenities as exogenous so far, we now assume that amenities \(A_c\) are a composite of an exogenous part \(\bar{A}_c\) and a local public good \(G_c\). Moreover, we assume that individuals have preferences over public and private
goods, which we denote by \( \delta \in (0, 1) \):

\[
U'_i = \tilde{A}_c \gamma^\delta \left( h_i x_i^{1-\gamma} \right)^{1-\delta} \epsilon_{i,c}
\]

Individuals maximize utility subject to the budget constraint \((r_c(1 + t_c)h + x = w)\) just as before. The log indirect utility function is now given by:

\[
V'_{i,c} = c_1 + (1 - \delta) \ln w_c - \gamma(1 - \delta) \ln r_c - \gamma(1 - \delta) \ln (1 + t_c) + \ln \tilde{A}_c + \delta \ln G_c + \ln \epsilon_{i,c}
\]

with \( c_1 = \gamma(1 - \delta) \ln \gamma + (1 - \gamma)(1 - \delta) \ln (1 - \gamma) \). Given the distributional assumption that \( \epsilon_{i,c} \) is i.i.d. extreme value type I distributed with scale parameter \( \sigma \), we can derive the log labor supply to city \( c \) analogously to equations (A.3)–(A.24) from above:

\[
\ln N_c = \frac{(1 - \delta)}{\sigma} \ln w_c - \frac{\gamma(1 - \delta)}{\sigma} \ln r_c - \frac{\gamma(1 - \delta)}{\sigma} \ln (1 + t_c) + \frac{1}{\sigma} \ln \tilde{A}_c + \frac{\delta}{\sigma} \ln G_c - \bar{U} \quad (A.21)
\]

where we again denote the log of the product of the number of cities and the average utility across places as \( \bar{U} = \ln (C \pi) \). It follows that (log) housing demand in city \( c \) is now given by:

\[
H^d_i = N_i h^* = N_i \gamma \frac{w_c}{r_c(1 + t_c)}
\]

\[
\ln H^d_i = \ln N_c + \ln r_c = \ln H^d_c = \ln \gamma + \ln w_c - \ln r_c - \ln (1 + t_c) \quad (A.22)
\]

The firm side as well as housing supply are unaffected by our modifications to the model, thus inverse log labor demand and log housing supply are still given by:

\[
\ln w_c = b_0 + \eta \ln N_c \quad (A.23)
\]

\[
\ln H^s_i = \theta \ln r_c \quad (A.24)
\]

where we keep the notation from above, i.e., \( b_0 = \ln \alpha + \frac{\beta}{1 - \beta} \ln \beta - \frac{\beta}{1 - \beta} \ln \rho \) and \( \frac{1}{\eta} = \frac{1 - \beta}{1 - \alpha - \beta} \).

Equations (A.21)–(A.24) were sufficient to characterize the equilibrium in the basic model. As we introduced the endogenous public good \( G_c \), we need an additional equation to describe the use of tax revenues. We assume that local governments use a share \( \psi \in (0, 1) \) of their tax revenues to finance the local public good supply \( G_c \):

\[
G_c = \psi H_c r_c t_c
\]

\[
\ln G_c = \ln \psi + \ln H_c + \ln r_c + \ln t_c. \quad (A.25)
\]

The remaining share \( 1 - \psi \) of their tax revenues is used for an exogenous revenue requirement. These five equations (A.21)–(A.25) define the spatial equilibrium in the extended model with endogenous amenities.

We solve the model in the same way as before and get the following equilibrium quantities
\(N^*, H^*, G^*\) and prices \(r^*, w^*\) for the extended model.

\[
\ln N_c' = g_N + \frac{1+\theta}{d_G} \ln \bar{A}_c + \frac{\delta(1+\theta)}{d_G} (\ln \psi + \ln t_c) - \frac{\gamma(1-\delta)(1+\theta) + \delta(1+\theta)}{d_G} \ln(1+t_c) \quad (A.26)
\]

\[
\ln H_c' = g_H + \frac{\theta(1+\eta)}{d_G} \ln \bar{A}_c + \frac{\delta\theta(1+\eta)}{d_G} (\ln \psi + \ln t_c)
- \theta \frac{\gamma(1-\delta)(1+\eta) - \eta(1-\delta) + \sigma}{d_G} \ln(1+t_c) \quad (A.27)
\]

\[
\ln r_c' = g_r + \frac{1+\eta}{d_G} \ln \bar{A}_c + \frac{\delta(1+\eta)}{d_G} (\ln \psi + \ln t_c)
- \eta \frac{\gamma(1-\delta)(1+\eta) - \eta(1-\delta) + \sigma}{d_G} \ln(1+t_c) \quad (A.28)
\]

\[
\ln w_c' = g_w + \frac{\eta(1+\theta)}{d_G} \ln \bar{A}_c + \frac{\delta\eta(1+\theta)}{d_G} (\ln \psi + \ln t_c)
- \frac{\gamma(1-\delta)(1+\eta) - \eta(1-\delta) + \sigma}{d_G} \ln(1+t_c) \quad (A.29)
\]

\[
\ln G_c' = g_G + \frac{(1+\eta)(1+\theta)}{d_G} \ln \bar{A}_c + \frac{\gamma(1-\delta)(1+\eta) + (1+\theta)(\sigma - \eta[1-\delta])}{d_G} (\ln \psi + \ln t_c)
- \frac{(1+\theta)(\sigma + \gamma(1-\delta)(1+\eta) - \eta(1-\delta))}{d_G} \ln(1+t_c) \quad (A.30)
\]

with constant terms \(g_N, g_H, g_r, g_w, g_G\) defined as:

\[
\begin{align*}
g_N &= \frac{(1+\theta) - \gamma(1-\delta)}{d_G} b_0 - \frac{1+\theta}{d_G} \sigma \bar{U} - \frac{\gamma(1-\delta) - \delta(1+\theta)}{d_G} \ln \gamma \\
g_H &= \frac{1+\sigma - \delta}{d_G} b_0 - \frac{1+\eta}{d_G} \sigma \bar{U} + \frac{\sigma - \eta(1-\delta)}{d_G} \theta \ln \gamma \\
g_r &= \frac{1+\sigma - \delta}{d_G} b_0 - \frac{1+\eta}{d_G} \sigma \bar{U} + \frac{\sigma - \eta(1-\delta)}{d_G} \ln \gamma \\
g_w &= \frac{(\sigma - \delta)(1+\theta) + \gamma(1-\delta)}{d_G} b_0 - \frac{1+\theta}{d_G} \eta \sigma \bar{U} - \frac{\gamma(1-\delta) - \delta(1+\theta)}{d_G} \eta \ln \gamma \\
g_G &= \frac{(1+\sigma - \delta)(1+\theta)}{d_G} b_0 - \frac{(1+\eta)(1+\theta)}{d_G} \sigma \bar{U} + \frac{\sigma(1+\theta) - \eta(1-\delta)(1+\theta)}{d_G} \ln \gamma
\end{align*}
\]

and a common denominator \(d_G\) denoted by the following expression:

\[
d_G = \gamma(1-\delta)(1+\eta) + (1+\theta)(\sigma - \eta - \delta).
\]

which is positive \((d_G > 0)\) as long as the preferences for the public good are sufficiently low:

\[
\delta < \frac{\gamma(1+\eta) + (1+\theta)(\sigma - \eta)}{\gamma(1+\eta) + (1+\theta)}.
\]

This is most likely the case as \(\delta, \gamma \in (0,1), \eta \in (-1,0)\) and \(\sigma, \theta > 0\). Consider, for instance, the US with housing share \(\gamma = 0.3\), location preferences \(\sigma = 0.829\) and housing supply elasticity \(\theta = 0.513\) (Suárez Serrato and Zidar, 2016, p. 2614, Table 6, Panel A, Column 1). The denominator \(d_G\) will be positive for all \(\eta\) as long as public good preferences \(\delta\) are below 0.857.
The extended model nests the basic model outlined above. If individual preferences for the public good are zero ($\delta \to 0$) and all tax revenues are used to finance the external revenue requirement instead of local public goods ($\psi \to 0$), the equilibrium quantities and prices of the extended model converge to the equilibrium of the basic model (see equations (A.17)–(A.20)).

We can now study the effect of tax changes when local public goods are endogenous. Thus we take the derivative with respect to the tax rate $t_c$:

$$\frac{\partial \ln N^*}{\partial t_c} = -\frac{\gamma \theta (1 - \delta)}{(1 + t_c) d_G} + \frac{\delta (1 + \theta)}{t_c (1 + t_c) d_G}$$  \hspace{1cm} (A.31)

$$\frac{\partial \ln H^*}{\partial t_c} = -\frac{\theta \gamma (1 - \delta) (1 - \eta) + (\sigma - \eta - \delta)}{(1 + t_c) d_G} + \frac{\delta \theta (1 + \eta)}{t_c (1 + t_c) d_G}$$ \hspace{1cm} (A.32)

$$\frac{\partial \ln r^*}{\partial t_c} = -\frac{\gamma (1 - \delta) (1 - \eta) + (\sigma - \eta - \delta)}{(1 + t_c) d_G} + \frac{\delta (1 + \eta)}{t_c (1 + t_c) d_G}$$ \hspace{1cm} (A.33)

$$\frac{\partial \ln w^*}{\partial t_c} = -\frac{\eta \gamma \theta (1 - \delta)}{(1 + t_c) d_G} + \frac{\eta \delta (1 + \theta)}{t_c (1 + t_c) d_G}$$ \hspace{1cm} (A.34)

---

20 So far we took the derivatives with respect to $\ln \tau_c = \ln (1 + t_c)$ instead of $t_c$ to simplify the notation. The equilibrium of the model with endogenous amenities includes the logarithm of both $t_c$ and $\tau_c$, which makes it more convenient to look at the gradient regarding $t_c$. Although there is a quantitative difference whether we look at $t_c$ or $\tau_c$, we are especially interested in the sign of the derivatives, which is the same for both measures.
B Appendix: Descriptive statistics

Figure B.1: Net Rents and Property Tax Multipliers by City Size Over Time

<table>
<thead>
<tr>
<th>Towns (&lt;100k)</th>
<th>Cities (100k-300k)</th>
<th>Large cities (&gt;300k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net rent (in EUR)</td>
<td>Property tax multiplier (in %)</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>300</td>
<td>400</td>
</tr>
</tbody>
</table>
| Note: Rents refer to medium quality apartments, construction year after 1948.
Figure B.2: Municipalities in the IVD Housing Sample

(a) Absolute Values

(b) Share in Sample

Figure B.3: Municipalities in the IVD Housing Sample by City Size

(a) Share of Observed Municipalities Over Time

(b) Number of Observed Municipalities