Who Bears the Burden of Local Taxes?*

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Abstract

We study the distributional effects of local taxes. Calibrating a structural model of heterogeneous households in a local labor market with plausibly causal elasticity estimates, we find that households with children have moderately stronger preferences for locally provided public goods and are considerably less mobile than households without children. Combined with capitalization of taxes into housing prices and non-homothetic housing demand, this implies that the incidence of local income taxes mainly falls on above-median income households without children. Property taxes turn out to be less progressive than local income taxes, even if income taxes are flat-rate.

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Introduction

The distributional effects of taxation are among the most prominent topics in public finance. Existing research has mainly focused on taxes at the national level. In this paper, we ask how local-level taxation affects the welfare of different household types. Local taxes account for important shares of public revenue in many countries. For example, taxes raised by cities, counties, school districts or municipalities represent 16% of total tax revenue in Switzerland, 15% in the United States, 10% in Canada, 9% in Spain and 8% in Germany.[1] Most local taxes are levied on the income or property of residents and are used to finance locally provided public goods, notably schooling.[2] This in turn affects resident households differently depending on their family status and income.

We consider two distinctive aspects of local taxes: at the local level, changes in taxation are typically linear or only weakly progressive, and tax bases are mobile – but not perfectly so. In addition, we allow preferences for housing and for locally funded public goods to be non-homothetic. In this setting, distributional effects arise because capitalization of tax rates into housing prices affects different households differently, and because households have unequal needs for locally funded public goods.[3]

We estimate a structural model using new panel data for Swiss municipalities, and we find substantial heterogeneity in the incidence of municipal taxation across family types. For childless households, an increase in the local income tax rate and associated local spending affects the welfare of households with incomes above the median negatively but is positive for households with below-median incomes. The incidence of a one-percent increase in the local tax rate ranges from $+0.36\%$ at the second income decile to -0.15% at the top income decile. When considering families with children, the incidence of a tax increase is more positive across all income classes, ranging from $+0.62\%$ for the poorest households to -0.05% at the top decile.

Underlying these welfare effects are two structural parameters that we estimate. On the one hand, we find that preferences for locally provided public goods are around 60% stronger for families with children than for households without children. On the other hand, estimated household mobility appears to be an order of magnitude higher for households without children than for households with children.

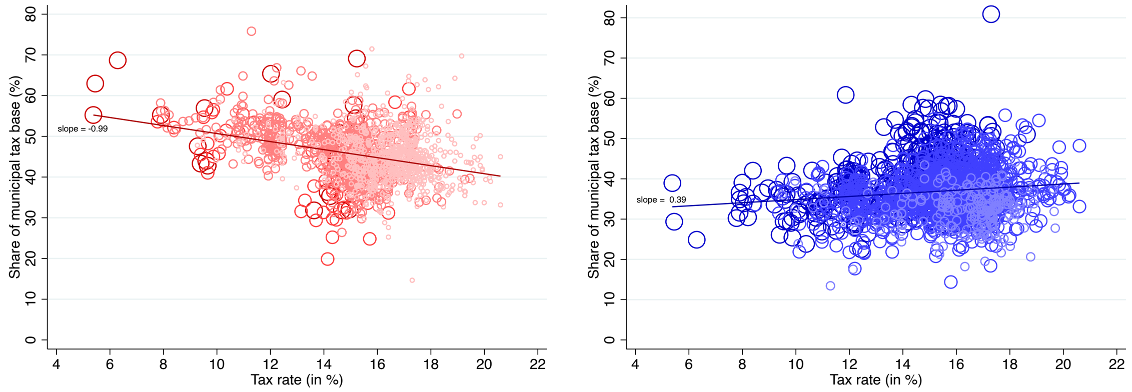
Our analytical framework allows us to consider scenarios that differ from our empirical setting, in particular by simulating the incidence of other types of local taxes. Estimating the effects of a property tax instead of the observed progressive-schedule local income tax or instead of a hypothetical proportional local income tax, we find that a local property tax is

[1] Data from the OECD Fiscal Decentralization Database for the period 2000-2017. This list includes only countries with a three-tier jurisdictional architecture. In some two-tier federations, the local share is even higher (e.g. 34% in Sweden, 28% in Denmark).

[2] In the United States, some 47% of local own-source general revenue are raised through property taxation, and some 3% are raised through income taxation. Primary and secondary education accounts for 40% of U.S. local government spending (Annual Survey of State and Local Government Finances, Tax Policy Center, 2020). In Switzerland, income and property taxation account for 43% and 5% of local governments' own revenue, respectively, and 27% of local expenditure are allocated to schooling (see Section 2.1). Municipalities account for 54% of spending on compulsory education (Education Finance, Swiss Federal Statistical Office, 2020).

[3] In contrast, at the national level, the tax system most evidently redistributes through the progressivity of rate schedules and because of differential avoidance opportunities.

Figure 1: Revealed locational preferences: family status, income and local tax rates



(a) Households without children

(b) Households with children

Notes: The figure presents the share of the municipal tax base accruing to working-age households without children (left panel) and with children (right panel). Within a panel, each circle represents a municipality. Municipalities are ranked according to the average tax rate on top 10%-income households. Circle size and color intensity varies with average income by family type and municipality. Four circle sizes are considered, denoting average incomes below 50,000 CHF, between 50,000 and 75,000 CHF, between 75,000 and 100,000 CHF, and above 100,000 CHF, respectively. Lines are OLS linear fits (robust standard error in both cases: 0.06). Data are for 2004.

effectively less progressive than a local income tax.

The central mechanism we study can be summarized as follows. Consider a linear increase in a locality's (income) tax rate, associated with a corresponding increase in local expenditure, e.g. on elementary schools and daycare facilities. Families with children – who may attach more weight to local public expenditure than childless households – will be attracted more (or repelled less) by the tax increase. As a result, the demographic composition of the jurisdiction shifts towards families with children. Suppose also that the tax increase leads to lower equilibrium housing demand and thus lower housing prices.If lower-income households with children spend a higher share of their budget on housing than higher-income childless households, then capitalization will reduce lower-income households' direct loss from the higher tax rate relatively more, and attract them (even more) to the higher-tax jurisdiction. Non-homothetic housing demand can thus imply a heterogeneous effect of a tax increase according to both income and family status. As a result, also a linear change in taxation will not be distributionally neutral. The ordering and even the sign of welfare effects on different household types will depend on their relative mobility and preferences for locally provided public goods – parameters that we estimate –, and on their relative housing needs – a parameter that we calibrate.

Figure 1 provides *prima facie* evidence of revealed preferences that systematically differ according to family status and income. Using our data for Swiss municipalities, we show the income share of working-age households without children (left panel) and with children (right panel). Each circle represents a municipality, ranked horizontally by its average tax rate. Circle size and color intensity reflect average household incomes in the given municipality. Average incomes differ considerably across municipalities, ranging from 32,000 USD to 166,000 USD.[4] The graph shows that poorer households of both types account for a larger population share in high-tax municipalities. Households with children sort disproportionately more into high-tax municipalities while childless households sort more strongly into low-tax jurisdictions. Poorer households and families with children thus appear to be deterred less by high local taxes.

The cross-sectional patterns illustrated by Figure 1 are purely correlational, and the direction of causation could run from household composition to tax rates. For a causal analysis of the effect of changing tax rates, we exploit the multi-layer Swiss fiscal architecture, which allows us to instrument changes in local tax rates. We follow Parchet (2019) by instrumenting municipal tax rates with neighboring state-level tax rates. We can thus estimate causal effects of changes in local taxes on income-class-specific municipal taxpayer counts, as well as on municipal housing prices inferred from 1.6 million transaction-level rental price postings between 2004 and 2014.

We find the sensitivity to local taxes to differ markedly across household types: tax base elasticities with respect to tax rates are positive for below-median income households (0.10 and 0.08 for households without and with children, respectively), strongly negative for top-quartile income households without children (-1.04), and not significantly different from zero for top-quartile households with children. The housing price elasticity with respect to local income tax rates is -0.32.

In a next step, we use these reduced-form elasticity estimates to calibrate a model with non-homothetic housing demand, household-type specific preferences for publicly provided goods, and household-type specific mobility in order to estimate those unobservable model parameters structurally. Residents are assumed to be imperfectly mobile and to rent housing from absentee landlords, with upward-sloping local housing supply. Households choose where to reside among jurisdictions that offer different public expenditure levels, financed by an income tax on residents. We allow residents' valuation of the locally provided public good to vary by family status, without imposing any prior restriction on this relationship. Household types are defined (a) in terms of the presence or absence of dependent children, to account for different needs for publicly provided goods and for different mobility, and (b) in terms of income, to allow for non-homothetic housing demand. In an extension, we in addition distinguish pension-age from working-age households. In this setting, the incidence of changes in local tax rates on households depends on their their type-specific 'bid-rent' price, i.e. their marginal willingness to trade off taxes and public spending against housing prices. We use equilibrium conditions for location choices and for local housing markets to derive theoretical reduced-form effects of a tax increase on the number of households per type and on housing prices. The theoretical reduced-form elasticities are determined by three key parameters: family-status-dependent preferences for the local public good, the price elasticity of housing supply, and the family-status-dependent dispersion of idiosyncratic locational preferences that captures residential mobility.

One specificity of our approach is that we focus on changes in local taxes *within* a given

[4] We use the 2014 exchange rate of 1.10 USD per 1 CHF. The stated range corresponds to the 1st and the 99th percentile of the distribution of per-capita incomes across municipalities.

functional labor market or commuting area. We therefore treat wages as exogenous with respect to location choices. This allows us to take account of residential mobility while assuming a constant labor income. The assumption of locally exogenous wages has empirical support: Löffler and Siegloch (2021) find no effect of local property taxes on local wages, which is all the more remarkable considering that their German sample municipalities are on average almost 20 times larger than our Swiss sample municipalities. Martínez, Saez and Siegenthaler (2021) find earnings responses to changed tax rates to be very small in Switzerland.[5] Even though we analyze sorting and tax incidence at small spatial scale, however, we consider a utility cost of moving. This contrasts with much of the literature on sub-national public finance, following Tiebout (1956) and Oates (1969), where residential mobility is costless. With perfect mobility, the incidence of local taxes is fully borne by landowners, the immobile factor. In reality, moving costs exist even at the local level, and hence the welfare of renter households will also be affected by changes in local taxation. We therefore assume households to have idiosyncratic prior preferences over locations, and thus non-zero moving costs, even within a given labor market. These moving costs are allowed to depend on family status.

Our paper connects to four main strands of the literature.

First, we build on and contribute to an active research program studying the incidence of subfederal taxation while taking careful account of capitalization effects. In a seminal paper, Suárez Serrato and Zidar (2016) use structural estimation to apportion the incidence of U.S. state corporate tax rates to workers, landowners and firm owners. They estimate that some 40 percent of the gain from state-level corporate tax cuts accrue to firm owners and 30-35 percent accrue to workers. The share of corporate-tax incidence falling on workers has been found to be even higher in smaller jurisdictions. Based on reduced-form empirical moments, Fuest, Peichl and Siegloch (2018) estimate that half of the gains from cuts to municipal business tax rates in Germany accrue to workers. This effect is mainly driven by small, single-plant (and thus immobile) firms. Löffler and Siegloch (2021) focus on local property taxation in Germany and find that property taxes are fully passed through on renter households.

Our paper differs from this work along the following main dimensions. Most importantly, we estimate distributional effects by disaggregating residents by family status and income (and, in an extension, age). To do so, we structurally estimate the relationship between revealed public-goods preferences and family status.[6] Methodologically, we address a key identification issue by instrumenting local tax rates. We moreover use housing demand shifters to estimate the housing supply elasticity – an important parameter governing the welfare effects of local policies (Kline and Moretti, 2014).

[5]This is of course not to deny that labor supply and wages are affected by subfederal income taxation at larger spatial scales, such as that of U.S. states (see, e.g., Zidar, 2019). We also abstract from strategic interactions among municipalities in their tax setting. Our thought experiment involves a shock to the tax rate of one municipality without taking account of possible second-round effects through strategic responses by neighboring municipalities.

[6]Suárez Serrato and Wingender (2016) study the incidence of federal government spending at the local level and structurally estimate separate preference parameters for skilled and unskilled workers. Fajgelbaum, Morales, Serrato and Zidar (2019) allow worker preferences for the public good to differ across U.S states. We also complement Eugster and Parchet (2019), who use the Swiss language border to show the effect of culture on preferred tax levels, without, however, considering heterogeneity across household types.

Second, we contribute to a well developed empirical literature on the capitalization of taxes into housing prices.[7] Like us, Basten, Ehrlich and Lassmann (2017) draw on Swiss micro-geographic data. In line with the empirical literature on the capitalization of local policies or amenities, they use a border discontinuity framework, assuming that, locally, households are perfectly mobile and housing demand is perfectly elastic.[8] Reduced-form estimates of house price responses then serve directly as a measure of willingness to pay (through housing prices), but the incidence of the tax is assumed to be fully borne by the immobile factor. Focusing on the expenditure side of local jurisdictions, Schönholzer (2021) exploits housing price differences in close proximity of local government boundaries and finds evidence of substantial valuations, especially of high-quality public schooling. The perfect-mobility assumption is implied also in the discrete choice framework developed by Bayer et al. (2007), where housing and neighborhood characteristics are interacted with household characteristics. We instead take a structural approach to estimate the elasticities that need to be quantified for an analysis of incidence on different types of imperfectly mobile households. We take account not only of non-homothetic demand for housing but also of heterogenous preferences for local public goods and differential mobility across household types.[9]

Third, we complement the empirical literature on the mobility response of households to tax changes.[10] This literature is largely focused on top-income taxpayers and leaves mobility responses of middle-income and lower-income households still to be explored. Tax-induced mobility has previously been found to be significant in the case of Switzerland, probably due to the combination of high degree of fiscal decentralization and a small spatial scale.[11] We link type-specific tax base elasticities to taxpayers' marginal willingness to pay and study the distributional effects of local tax changes.

Fourth, our results shed light on the empirical relationship between local spending and the demographic composition of local populations. A considerable prior literature exists on this issue.[12] In those papers, heterogeneous preferences are allowed, but no attempt is made to estimate deep type-specific preference parameters. We back out those parameters. In doing so, we show that mobility and preferences for locally provided public goods differ substantially across family types.[13]

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[7]Seminal studies of the capitalization of property taxes include Epple and Zelenitz (1981) and Yinger (1982). See Ross and Yinger (1999) and Hilber (2015) for comprehensive surveys.

[8]See, e.g., Black (1999); Reback (2005); Bayer, Ferreira and McMillan (2007); Fack and Grenet (2010); Cellini, Ferreira and Rothstein (2010); Black and Machin (2011); Boustan (2013); Gibbons, Machin and Silva (2013).

[9]Kim (2021) develops a spatial equilibrium framework with residential mobility and commuting, which he leverages to estimate valuations of local government spending. He does not explore heterogeneous valuations across worker types.

[10]See, e.g., Kleven, Landais and Saez (2013); Akcigit, Baslandze and Stantcheva (2016); Moretti and Wilson (2017); Agrawal and Foremny (2019); Kleven, Landais, Muñoz and Stantcheva (2020).

[11]See, e.g., Martínez (2017); Schmidheiny and Slotwinski (2018); Widmann (2019); Brülhart, Gruber, Krapf and Schmidheiny (2022).

[12]See, e.g., Harris, Evans and Schwab (2001); Hilber and Mayer (2009); Aaberge, Bhuller, Langørgen and Mogstad (2010); Figlio and Fletcher (2012); Aaberge, Eika, Langørgen and Mogstad (2019); Bertocchi, Dimico, Lancia and Russo (2020).

[13]On residential income segregation by households with and without children, see, e.g., Epple, Romano and Sieg (2012) and Owens (2016). For evidence on residential sorting by household type according to differences in exogenous local amenities (rather than local public goods), see, e.g., Chen and Rosenthal (2008) and Albouy and Faberman (2019).

The paper proceeds as follows.[14] In Sections 1 and 2, we present a model of local labor and housing markets as well as the data that will inform our empirical estimations. In Section 3, we estimate reduced-form elasticities of tax bases and housing prices with respect to local tax rates. Section 4 reports our baseline structural type-specific incidence estimates. In Section 5, we present some extensions of the baseline estimations, and Section 6 concludes.

1 Model

In this Section, we develop a model of residential location choice, housing markets and local public good provision. First, we assume a public sector that uses a proportional income tax to provide a potentially rival publicly provided good, and we characterize location choices and housing demand by households that differ by family status and income.[15] Second, we model housing supply in an absentee landlord setting. Third, we use the model to investigate the effect of tax rate changes on housing prices, on the number of residents in different family status-income class pairs ("household types"), and, most importantly, on the incidence of local taxes across household types.

1.1 Housing demand

We assume a functional labor market that consists of $\mathcal{J}$ municipalities. This labor market is populated by a unit continuum of $\mathcal{I}$ households that rent dwelling space from atomistic absentee landlords and take housing prices as given. Households have identical preferences for housing and public goods but are heterogeneous in their family status (with/without children) and income.[16] We assume Stone-Geary preferences with minimum levels of housing and public good consumption that depend on family status, thus capturing different needs for residential space and public services by families with and without children. We also assume that households derive idiosyncratic utility from exogenously given local amenities.

Specifically, each of the $i \in \mathcal{I}$ renter households belongs to a discrete family status $f \in \mathcal{F}$ and income class $m \in \mathcal{M}$. Within an income class, everybody's income equals w_m. Households maximize the log Stone-Geary utility of residing in municipality $j \in \mathcal{J}$ by choosing consumption levels of a freely tradable numeraire composite good z_{fmj} and dwelling size h_{fmj}, at a rental price p_j, subject to their after-tax income $(1-\tau_j)w_m$.

The indirect utility of household i with family status f and income w_m, based on its choice of location j, is

$$V_{ifmj} = \kappa + \ln\left[(1-\tau_j)w_m - p_j\nu_h^f\right] - \alpha\ln(p_j) + \delta\ln(g_j - \nu_g^f) + \ln(A_{ifj}), \qquad (1)$$

where κ is a constant, $\alpha \in (0,1)$ and δ are taste parameters for housing and the local public good, and $\nu_h^f \geq 0$ and $\nu_g^f \geq 0$ are Stone-Geary parameters capturing the family type-specific

[14] Appendix A.1 offers a schematic overview of the different building blocks of the paper.

[15] For simplicity, we use the term "public goods" as equivalent to "publicly provided goods". Our setting can easily be extended (a) to other residence-based taxes such as a property tax (as long as housing is modeled as a consumption good, see Section 4.4 and Appendix W.2), and (b) to homeowners as in, e.g., Epple and Romer (1991).

[16] When we take the model to the data, we shall in addition distinguish household types by age, that is, we consider three family statuses: non-pensioners without children, non-pensioners with children, and pensioners.

minimum amount of housing and public good required, respectively, and A_{ifj} denotes local amenities.[17] The Stone-Geary parameters play an important role. First, unlike e.g. a Cobb-Douglas function, they allow for a full range of housing demand elasticities with respect to the price of housing, i.e. $|\eta^{d,p}| \in (0, +\infty)$. Second, households with different family status and income have different expenditure shares on housing, such that the capitalization of higher tax rates into housing prices will affect them differently.[18] Third, ν_g^f allows for the fact that households with children have different needs in terms of goods such as schooling than childless households, and might therefore benefit more from an increase in the public good.

We furthermore assume a balanced budget for the public sector with $\tau_j \sum_f \sum_m w_m N_{fmj} = N_j^\theta g_j$, where $\theta \in [0,1]$ indicates the degree of rivalness in the consumption of the public good.[19] The number of residents, N_{fmj}, is defined below. We also assume local amenities A_{ifj} to be fixed.[20]

At this stage, it is useful to define the change in the housing price a household with family status f and income w_m would require to be indifferent toward a given change in the local tax rate ('bid-rent' price change):

$$\left.\frac{dp_j}{d\tau_j}\frac{\tau_j}{p_j}\right|_{dV_{ifmj}=0} = -\left[\frac{\tau_j}{(1-\tau_j)S_{fmj}} - \frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(1-\frac{\nu_h^f}{h^*_{fmj}}\right)\left(\frac{dg_j}{d\tau_j}\frac{\tau_j}{g_j}\right)\right], \tag{2}$$

where $S_{fmj} \equiv p_j h^*_{fmj}/(1-\tau_j)w_m$ represents the housing expenditure share and h^*_{fmj} is the household's Marshallian demand for housing space. $\frac{dg_j}{d\tau_j}\frac{\tau_j}{g_j}$ is the elasticity of public good provision with respect to the local tax rate. Using the balanced budget constraint, we have

$$\frac{dg_j}{g_j}\frac{\tau_j}{d\tau_j} = 1 + \sum_f \sum_m (\gamma_{fmj} - \theta s_{fmj})\frac{dN_{fmj}}{N_{fmj}}\frac{\tau_j}{d\tau_j}, \tag{3}$$

where $\gamma_{fmj} \equiv w_m N_{fmj} / \sum_f \sum_m w_m N_{fmj}$ represents household type $\{f, m\}$'s share of municipality j's tax base, s_{fmj} is the proportion of households of type $\{f, m\}$, and $\frac{dN_{fmj}}{N_{fmj}}\frac{\tau_j}{d\tau_j}$ is the elasticity of the number of residents belonging to household type $\{f, m\}$ with respect to the local tax rate.

Expression (2) determines household type $\{f, m\}$'s marginal willingness to pay rent (MWPR) for a (small) tax rate change. It differs across household types $\{f, m\}$ through the family status-specific minimum consumption of housing and public goods. In particular, if $\nu_h^f = \nu_g^f = 0$ then $S_{fmj} = \alpha$ and the MWPR becomes type-invariant.

We incorporate imperfect residential mobility by modeling local amenities A_{ifj}, consisting of a common location-specific component $\overline{A}_j$ and a location-specific idiosyncratic preference

[17] See Online Appendix W.1 for detailed derivations.

[18] See Appendix Figure A5.2 for empirical evidence on the decreasing share of housing expenditure with income in our empirical setting. The pattern observed in the Swiss data is very similar to those documented for the U.S (Ganong and Shoag, 2017) and France (Combes, Duranton and Gobillon, 2018).

[19] If $\theta = 0$, g_j is a pure public good. $\theta = 1$ in turn represents the fully rival case, where g_j is a publicly provided private good.

[20] The endogenous location-specific element of our model is the local publicly provided good, in contrast e.g. to Couture, Gaubert, Handbury and Hurst (2020), who model an endogenous private amenity.

component ξ_{ifj}. The household's objective is therefore to maximize

$$\max_j V_{ifmj} = \underbrace{\kappa + \ln\left[(1-\tau_j)w_m - p_j\nu_h^f\right] - \alpha\ln(p_j) + \delta\ln(g_j - \nu_g^f) + \overline{A}_j}_{\equiv u_{fmj}} + \xi_{ifj}\,, \tag{4}$$

where household i will choose municipality j if their indirect utility is higher there than in any other municipality $j' \neq j$. The variable u_{fmj} defines the systematic valuation of municipality j, common to all households of type $\{f, m\}$.

We make the standard assumption that the idiosyncratic component ξ_{ifj} follows an *i.i.d.* Gumbel distribution with mean zero, variance σ_f^2 and scale parameter $\lambda_f = \frac{\pi}{\sigma_f\sqrt{6}}$. The scale parameter serves to model residential mobility. At one extreme, as $\lambda_f \to \infty$ ($\sigma_f \to 0$), the idiosyncratic attachment to location disappears and all households with family status f choose identically. At the other extreme, as $\lambda_f \to 0$ ($\sigma_f \to \infty$), idiosyncrasies dominate the systematic valuation of locations u_{fmj}, and the population in each jurisdiction is fixed.[21]

The share of households of type $\{f, m\}$ who choose to reside in municipality j is then given by

$$N_{fmj} \equiv Pr\left(V_{ifmj} > V_{ifmj'} \;\; \forall\, j \neq j'\right) = \frac{\exp(\lambda_f u_{fmj})}{\sum_{j'}\exp(\lambda_f u_{fmj'})}\,, \quad \text{with} \sum_j\sum_f\sum_m N_{fmj} = 1\,. \tag{5}$$

Aggregate demand for housing in municipality j is

$$H_j^d = \sum_f\sum_m N_{fmj}\cdot h^*_{fmj}\,, \quad \forall\, j \in J\,, \tag{6}$$

which is the sum of households across all types $\{f, m\}$ who choose to live in municipality j, multiplied by their corresponding Marshallian demands for housing.

1.2 Housing supply

We model housing as a homogeneous good produced with constant returns to scale using non-land capital and land. Housing is supplied by developers at increasing marginal cost and sold to atomistic absentee landlords who then rent it out to residents.

The total dwelling stock in municipality j is equal to

$$H_j^s = B_j p_j^{\eta_j^{s,p}}\,, \quad \forall\, j \in J\,, \tag{7}$$

where B_j is a constant and $\eta_j^{s,p}$ represents the housing supply elasticity with respect to housing prices. Housing supply is allowed to vary across locations according to the tightness of topographical and administrative constraints on construction (Saiz, 2010; Hilber and Vermeulen, 2016).

[21] We allow λ_f to vary by family status but not by income class. This appears to be a reasonable assumption in the Swiss case. Basten et al. (2017) have observed the marginal willingness to migrate to be "remarkably homogeneous" (p. 677) across income quartiles. Evidence for the United States also points toward relatively minor heterogeneity in worker mobility across income classes, conditional on the intensity of relevant localized demand shocks (e.g. Notowidigdo, 2020; Suárez Serrato and Wingender, 2016; Bayer, McMillan, Murphy and Timmins, 2016).

In this simple framework, housing supply does not depend on local income tax rates. This may not be an accurate representation of many empirical settings (ours included) in which, for example, rental income is taxed in the jurisdiction where the dwelling is located. In Appendix Section A.2.1, we carefully address the implications of a dependence of housing supply on local income tax rates, used as demand shifters, for the empirical identification of $\eta^{s,p}$.

1.3 Equilibrium

The model's equilibrium is characterized by three main equations:

$$N_j = \sum_f \sum_m N_{fmj} \text{ with } N_{fmj} = \frac{\exp\left(\lambda_f u_{fmj}\right)}{\sum_{j'} \exp\left(\lambda_f u_{fmj'}\right)} \quad \forall j \in J, \tag{8a}$$

$$H_j^d = H_j^s \quad \forall j \in J, \tag{8b}$$

$$g_j = \tau_j N_j^{-\theta} \sum_f \sum_m w_m N_{fmj} \quad \forall j \in J, \tag{8c}$$

where (8a) describes the population, (8b) governs the housing market, and (8c) is the government budget constraint for each jurisdiction j.[22] In what follows, we concentrate on the first-order effects of a tax change in a jurisdiction j on its tax base and housing price. We therefore abstract from the effects of j's tax policy on housing prices and public good provision in other jurisdictions.[23] Totally log-differentiating these equations and stacking them into a system of equations yields

$$\underset{(\mathcal{F}\mathcal{M}+1)\times(\mathcal{F}\mathcal{M}+1)}{\mathbf{A}_j} \times \underset{(\mathcal{F}\mathcal{M}+1)\times 1}{\dot{\mathbf{y}}_j} = \underset{(\mathcal{F}\mathcal{M}+1)\times 1}{\mathbf{B}_j} \times \underset{1\times 1}{\dot{\tau}_j}, \tag{9}$$

where $\dot{\mathbf{y}}_j = \left[\dot{N}_{11j}, \cdots, \dot{N}_{1\mathcal{M}j}, \dot{N}_{21}, \cdots, \dot{N}_{\mathcal{F}\mathcal{M}j}, \dot{p}_j\right]'$ is the vector of endogenous variables and $\dot{\tau}_j$ is the exogenous variable.[24]

The elements of matrices $\mathbf{A}_j$ and $\mathbf{B}_j$ are given by

$$\mathbf{A_j} = \begin{bmatrix} \frac{1-\delta\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{11j}-\theta s_{11j})\lambda_1}{\alpha\lambda_1}\left(1-\frac{\nu_h^1}{h_{11j}^*}\right) & -\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{12j}-\theta s_{12j})\left(1-\frac{\nu_h^1}{h_{11j}^*}\right) & \cdots & -\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{\mathcal{F}\mathcal{M}j}-\theta s_{\mathcal{F}\mathcal{M}j})\left(1-\frac{\nu_h^1}{h_{11j}^*}\right) & 1 \\ -\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{11j}-\theta s_{11j})\left(1-\frac{\nu_h^1}{h_{12j}^*}\right) & \frac{1-\delta\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{12j}-\theta s_{12j})\lambda_1}{\alpha\lambda_1}\left(1-\frac{\nu_h^1}{h_{12j}^*}\right) & \vdots & \vdots & \vdots \\ \vdots & \cdots & \ddots & \vdots & \vdots \\ -\delta\left(\frac{g_j}{g_j-\nu_g^{\mathcal{F}}}\right)(\gamma_{\mathcal{F}1j}-\theta s_{\mathcal{F}1j})\left(1-\frac{\nu_h^{\mathcal{F}}}{h_{\mathcal{F}\mathcal{M}j}^*}\right) & \cdots & \cdots & \frac{1-\delta\left(\frac{g_j}{g_j-\nu_g^{\mathcal{F}}}\right)(\gamma_{\mathcal{F}\mathcal{M}j}-\theta s_{\mathcal{F}\mathcal{M}j})\lambda_{\mathcal{F}}}{\alpha\lambda_{\mathcal{F}}}\left(1-\frac{\nu_h^{\mathcal{F}}}{h_{\mathcal{F}\mathcal{M}j}^*}\right) & 1 \\ \pi_{11j} & \cdots & \cdots & \pi_{\mathcal{F}\mathcal{M}j} & -\left(\rho_j+\eta_j^{s,p}\right) \end{bmatrix}$$

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[22] We provide evidence in Section 5.2 that the balanced-budget assumption largely holds in Swiss municipalities.

[23] Like in Suárez Serrato and Zidar (2016), this is consistent with households being 'myopic': they do not anticipate the effect of their own and other households' location decision on public good provision and housing prices in other jurisdictions. Alternatively, one could assume an economy composed of an infinite number of small jurisdictions.

[24] In this paper, we use the notation $\dot{x} \equiv dx/x$ for any variable x.

and

$$\mathbf{B_j} = \begin{bmatrix} \frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)\left(1-\frac{\nu_h^1}{h^*_{11j}}\right)-\frac{\tau_j}{(1-\tau_j)S_{11j}} \\ \vdots \\ \frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^{\mathcal{F}}}\right)\left(1-\frac{\nu_h^{\mathcal{F}}}{h^*_{\mathcal{F}\mathcal{M}j}}\right)-\frac{\tau_j}{(1-\tau_j)S_{\mathcal{F}\mathcal{M}j}} \\ \alpha\frac{\tau_j}{(1-\tau_j)}\sum_f\sum_m\frac{\pi_{fmj}}{S_{fmj}} \end{bmatrix},$$

where $\pi_{fmj} \equiv H^d_{fmj}/H^d_j$ is household type $\{f,m\}$'s share of aggregate housing demand, $\gamma_{fmj} \equiv w_m N_{fmj}/\sum_f\sum_m w_m N_{fmj}$ represents household type $\{f,m\}$'s share of municipality j's tax base, and s_{fmj} is the proportion of households that belong to type $\{f,m\}$. The term $\rho_j \equiv \sum_f\sum_m \pi_{fmj}(1-(1-\alpha)\frac{\nu_h^f}{h^*_{fmj}})$ collects other parameters.

The diagonal elements of the upper block in matrix $\mathbf{A}_j$ represent how a given income class reacts to a tax rate shock, and off-diagonal elements in a given row represent how that same income class reacts to other income classes' location decision, i.e. they represent feedback effects between heterogeneous households through public good provision. The matrix $\mathbf{B}_j$ captures direct effects of tax rate changes on local tax bases and housing prices, holding fixed the between-equation interdependencies collected in matrix $\mathbf{A}_j$.

Pre-multiplying equation (9) by $\mathbf{A}_j^{-1}$ yields the reduced-form version of the system of equations, which is given by

$$\dot{\mathbf{y}}_j = \mathbf{A}_j^{-1}\mathbf{B}_j\dot{\tau}_j\,, \tag{10}$$

where $\mathbf{A}_j^{-1}\mathbf{B}_j$ represents the reduced-form theoretical moments that will be used in the structural estimation of the household type-specific parameters for public-goods preferences, $\tilde{\delta}_f \equiv \delta\left(1-\frac{\nu_g^f}{g}\right)^{-1}$, and interjurisdictional mobility, λ_f (see equation 16 below). For the moment, note that $\tilde{\delta}_f$ affects the utility a household of family type f gets by living in a given jurisdiction, while λ_f multiplies the utility. $\tilde{\delta}_f$ will therefore by identified by the level of the tax base elasticity, whereas λ_f will be identified by the differential tax base elasticity between (at least) two income groups.[25]

1.4 Incidence

We now have the elements in hand for analyzing welfare effects of local taxes on different household types.

We follow Kline and Moretti (2014) by defining aggregate renter household welfare as $\mathcal{W}^R \equiv \sum_f\sum_m s_{fm}\cdot E\left[\max_j\{u_{fmj}+\xi_{ifj}\}\right]$. Assuming location-specific idiosyncratic preferences to be Gumbel distributed, aggregate household welfare is then given by

$$\mathcal{W}^R = \sum_f\sum_m s_{fm}\cdot\frac{1}{\lambda_f}\log\left(\sum_j \exp(\lambda_f u_{fmj})\right)\,, \tag{11}$$

where s_{fm} is the population share of household type $\{f,m\}$.

Here, we concentrate on the effect of a small change in the income tax rate of municipality

[25] To see this last point, we can use equation (8a) to write the differential tax base elasticity between households of type $\{f,m\}$ and $\{f,m'\}$ as $\frac{\dot{N}_{fmj}}{\dot{\tau}_j}-\frac{\dot{N}_{fm'j}}{\dot{\tau}_j}=\lambda_f\left(\frac{du_{fmj}}{\dot{\tau}_j}-\frac{du_{fm'j}}{\dot{\tau}_j}\right)$.

j on the welfare of household type $\{f, m\}$, abstracting from general equilibrium effects on other jurisdictions. The welfare effect is given by

$$\frac{d\mathcal{W}_{fm}^{R}}{d\ln\tau_j} = \alpha N_{fmj}\left(1-\frac{\nu_h^f}{h_{fmj}^*}\right)^{-1}\left\{\underbrace{-\left[\frac{\tau_j}{(1-\tau_j)S_{fmj}}-\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(1-\frac{\nu_h^f}{h_{fmj}^*}\right)\left(1+\sum_f\sum_m(\gamma_{fmj}-\theta s_{fmj})\frac{dN_{fmj}}{d\tau_j}\frac{\tau_j}{N_{fmj}}\right)\right]}_{\text{MWPR}_{fm}}-\underbrace{\left(\frac{dp_j^*}{d\tau_j}\frac{\tau_j}{p_j^*}\right)}_{\eta^{p,\tau*}}\right\}, \tag{12a}$$

$$\frac{d\mathcal{W}_{fm}^{R}}{d\ln\tau_j} = N_{fmj}\left\{\underbrace{-\frac{\tau_j}{(1-\tau_j)}\left(\frac{1}{1-S_{fmj}^{min}}\right)}_{\text{direct effect }<0}\underbrace{+\delta\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(\frac{dg_j}{d\tau_j}\frac{\tau_j}{g_j}\right)}_{\text{public good effect }>0}\underbrace{-\left(\frac{S_{fmj}}{1-S_{fmj}^{min}}\right)\left(\frac{dp_j^*}{d\tau_j}\frac{\tau_j}{p_j^*}\right)}_{\text{capitalization effect }>0}\right\}, \tag{12b}$$

where $\eta^{p,\tau*}$ is the change in the equilibrium housing price, and $\frac{dN_{fmj}}{d\tau_j}\frac{\tau_j}{N_{fmj}}$ are tax base elasticities, given by solving the system of equations (10). The aggregate change in household welfare is then $\frac{d\mathcal{W}^R}{d\ln\tau_j} = \sum_f\sum_m s_{fm}\cdot\frac{d\mathcal{W}_{fm}^R}{d\ln\tau_j}$. We abstract from general equilibrium effects in other jurisdictions by assuming atomistic jurisdictions. Also, movers do not enter equation (12a) as a consequence of the envelope theorem (Busso, Gregory and Kline, 2013).[26]

Inspection of equation (12a) highlights that the sign of the incidence on a household of a given type $\{f, m\}$ is determined by the differential between the household's marginal willingness to pay rent and the change in equilibrium rental prices. Household welfare increases if the tax-induced change in the equilibrium housing price (i.e. capitalization) is larger in absolute value than the household's bid-rent price, and vice-versa.

The welfare effect of a linear tax increase can be decomposed into the direct effect of the tax increase and two indirect effects through changed public good provision and through capitalization into lower housing prices. To separate these effects, we can rewrite the welfare-effect as equation (12b), where $S_{fmj}^{min} \equiv p_j\nu_h^f/(1-\tau_j)w_m$ is the fraction of income spent on essential housing consumption.

The direct effect of a tax increase is regressive, as low-income taxpayers spend a higher fraction of their income on essential housing. Higher public good provision partly compensates the negative direct effect. The public good effect benefits rich and poor households equally but is arguably stronger for families with children. A second indirect effect operates through the capitalization of higher taxes into lower housing prices. This has a progressive effect, as lower-income households (with children) spend a higher share of their budget on housing than higher-income (childless) households. The regressivity or progressivity of a linear local tax depends on two parameters: the preferences for locally provided public goods (that we estimate) and housing needs (that we parameterize); and on two elasticities: the elasticity of public good provision with respect to the local tax rate, and the elasticity of equilibrium housing prices with respect to the local tax rate, both of which we obtain by solving

[26]The intuition is as follows. At equilibrium in this model, when a household i moves to a municipality j after a positive shock to an observable characteristic of that municipality, that household is choosing a jurisdiction with a more favorable common valuation, $u_{fmj} > u_{fmj'}$. However, this is offset by a less favorable idiosyncratic valuation, $\xi_{fmj} < \xi_{fmj'}$ (see equation 4). Second, movers differ in their idiosyncratic valuations. The indifferent household before the shock gains almost as much as the stayers while, after the shock, the new indifferent households loses as she gives up her surplus of living in her most preferred municipality. For small shocks, the welfare effects on movers are negligible relative to those on stayers.

the system of equations (10).

Landlords' utility is defined as rental revenue less the cost of supplying location-j housing. The inverse supply curve is $p_j = \left(\frac{H_j^s}{B_j}\right)^{1/\eta_j^{s,p}}$. Producer surplus is therefore given by

$$\mathcal{W}^L = \int_0^{H^*} \left(p_j^* - \left(\frac{x}{B_j}\right)^{1/\eta_j^{s,p}} \right) dx = \frac{p^* H^*}{(1+\eta_j^{s,p})} .$$

The change in landlords' welfare after a change in the local tax rate is then

$$\frac{d\mathcal{W}^L}{d \ln \tau_j} = p^* H^* \underbrace{\left(\frac{dp_j^*}{d\tau_j} \frac{\tau_j}{p_j^*} \right)}_{\eta^{p,\tau*}} . \tag{13}$$

Landlords' welfare is driven by changes in equilibrium housing prices: to the extent that changes in taxation capitalize into housing prices, their incidence is borne by the absentee owners.

1.5 From theory to empirics

The empirical analogue of equation (9) is

$$\mathbf{A}\dot{\mathbf{y}}_j = \mathbf{B}\dot{\tau}_j + \mathbf{e}_j , \tag{14}$$

where $\mathbf{e_j}$ represents structural error terms. The reduced-form version of the system of equations is given by

$$\dot{\mathbf{y}}_j = \underbrace{\mathbf{A}^{-1}\mathbf{B}}_{\equiv \boldsymbol{\eta}} \dot{\tau}_j + \mathbf{A}^{-1}\mathbf{e}_j , \tag{15}$$

where $\boldsymbol{\eta} = [\eta^{N_{11}}, \cdots, \eta^{N_{\mathcal{FM}}}, \eta^p]'$ is the vector of reduced-form moments.[27]

Two remarks are in order. First, the empirical estimates of reduced-form moments are j-invariant. We therefore drop the subscript j on matrices $\mathbf{A}$ and $\mathbf{B}$; i.e. our structural estimation is for a representative Swiss municipality. Second, while we can quite easily calibrate essential housing needs (ν_h^f), essential public goods needs (ν_g^f) for households with and without children are not observable. We therefore define $\tilde{\delta}_f \equiv \delta \left(1 - \frac{\nu_g^f}{g}\right)^{-1}$, as the family type-specific parameter for public goods preferences. We expect households with children to have greater needs for locally funded public services such as daycare and elementary schooling than households without children, such that $\tilde{\delta}_1 > \tilde{\delta}_0$, but we place no prior restriction on these structural parameters.

Our aim is to find the parameter vector $\boldsymbol{\vartheta} = [\tilde{\delta}_1, ..., \tilde{\delta}_{\mathcal{F}}, \lambda_1, ..., \lambda_{\mathcal{F}}]$ that best matches the moments $\mathfrak{m}(\boldsymbol{\vartheta}) = \boldsymbol{\eta}$ to their reduced-form empirical counterparts $\hat{\boldsymbol{\eta}}$. For a given set of calibrated parameters, we use classical minimum distance (CMD) structural estimation (Chamberlain, 1984) to find

[27] Hereinafter, reduced-form elasticities of a variable x with respect to τ are denoted η^x instead of $\eta^{x,\tau}$ to save on notation, unless explicitly stated otherwise.

$$\widehat{\boldsymbol{\vartheta}} = \arg\min_{\boldsymbol{\vartheta}\in\boldsymbol{\Theta}} \left[\hat{\boldsymbol{\eta}} - \mathbf{m}(\boldsymbol{\vartheta})\right]' \widehat{\mathbf{V}}^{-1} \left[\hat{\boldsymbol{\eta}} - \mathbf{m}(\boldsymbol{\vartheta})\right] , \tag{16}$$

where $\widehat{\mathbf{V}}^{-1}$ is the inverse of the variance-covariance matrix from the reduced-form empirical estimation of the vector $\hat{\boldsymbol{\eta}}$.

This structural estimation relies on two building blocks:

1. joint estimation of two responses to changes in taxation, contained in the vector $\hat{\boldsymbol{\eta}}$:
   - the elasticity of the tax base with respect to the local tax rate (the "tax base elasticity"), and
   - the elasticity of the housing price with respect to the local tax rate (the "capitalization elasticity"),

   and

2. the calibration of the elasticity of housing supply with respect to the housing price (the "housing supply elasticity", $\eta^{s,p}$).

We take advantage of the Swiss setting (Section 2) to identify and jointly estimate tax base and capitalization elasticities while instrumenting local income tax rates (Section 3). We also exploit (instrumented) local income tax variation as a demand shifter to estimate the housing supply elasticity (Appendix Section A.2). The other parameters of matrices **A** and **B** ($\gamma_{mj}, s_{mj}, \frac{\nu_h^f}{h_{mj}^*}, \pi_{mj}, \rho_j$ and S_{mj}) as well as income tax rates τ_j will be calibrated with observed values (Section 4). Appendix A.1 offers a schematic overview of the different building blocks of the paper.

2 Empirical setting

2.1 Institutional background

Switzerland is a highly decentralized country composed of 26 cantons and 2,352 municipalities.[28] The three layers of government enjoy significant autonomy in taxation and public spending. According to the OECD Fiscal Decentralization Database, Switzerland has the OECD's highest local revenue share, followed by the United States and Canada. Gauged by the share of autonomously raised municipal taxes, Switzerland is the third-most decentralized OECD country, after Finland and Iceland, but with a somewhat higher local tax share than the United States, Canada, Spain and Germany.[29]

Our focus in this paper is on the municipal ("local") level. Most municipalities are small. In 2014, the average municipal population was 3,256, with a maximum of 382,000 (city of Zurich). Nonetheless, municipalities are important in fiscal terms. In 2014, municipal spending accounted for 23% of consolidated public expenditure and 34% of consolidated personal

[28]The municipality count refers to 2014, our final sample year. Due to municipal mergers, this number has been gradually decreasing. In 2004, our first sample year, the municipality count stood at 2,780.

[29]See Brülhart, Bucovetsky and Schmidheiny (2015).

income tax revenue.[30] Municipalities are largely autonomous over most of their budget, including schooling (27% of average municipal expenditure), transport and environmental services (19%), general administration (11%) and recreation and culture (7%). In contrast, for some categories, the level of spending is mainly driven by canton-level or federal-level mandates. This primarily concerns social transfers (19% of municipal expenditure) and policing (6%).[31]

On the revenue side, municipalities have considerable decision-making powers as well. In 2014, some 64% of municipal revenue were raised through own taxes, of which 63% were personal income taxes. Property-related taxes, however, are relatively unimportant in international comparison, accounting for less than 5% of revenue.[32]

Municipal tax policy in most cases consists of setting a single number: a multiplier on the canton-level tax schedule that determines the municipal share of the sub-federal tax take. Local tax multipliers can be adapted annually by municipal parliaments or citizen assemblies. Hence, within-canton variation in local income tax rates is almost perfectly captured by municipal tax multipliers.[33]

Cantonal laws define statutory tax schedules and, combined with federal-level legislation, determine deductions and exemptions for the definition of the tax base. Municipalities, however, have no say over tax schedules, deductions and exemptions. Canton multipliers applied to the basic statutory tax schedule are determined annually by cantonal parliaments. Changes to the definition of the tax base or tax schedule are more infrequent, as they imply changes in cantonal tax laws and are thus typically subject to referenda.

Unlike income taxes, housing-related tax rates are mostly set at the canton level, with revenue sharing between cantons and municipalities.[34] Three such taxes are applied: First, 19 of the 26 cantons levy an annual property tax, computed as a fraction of the assessed value of the property.[35] Second, when property ownership is transferred, sellers pay a real estate-specific capital gains tax at a rate that is decreasing in ownership tenure. The real estate capital gains tax is levied in all cantons. Third, 18 out of the 26 cantons apply a property transaction tax.[36]

An important aspect of real estate taxation in all of Switzerland is that owner-occupiers pay income taxes on imputed rents. Imputed rents are generally set somewhat below esti-

[30] The summary statistics cited in this and the following paragraphs are taken from SFSO (2017).

[31] The precise allocation of responsibilites between cantons and municipalities is complex and varied. The most comprehensive available account is given by Rühli (2012). All municipal tasks are to some extent affected by canton-level regulations and co-financing, but in only 2 of the 13 tasks identified in that study (policing, and business development) does the average financial and executive weight of the canton dominate that of the municipalities. School districts perfectly overlap with municipalities in 21 of 26 cantons. In the remaining five cantons this is also the case for the majority of school districts, with a recent trend towards further integration of schooling into the general-purpose municipal administrations. Rühli (2012) also documents a trend towards increasing formal inter-municipal cooperation, with close to 40% of municipal tasks being shared through formal agreements with neighbor municipalities. In terms of our study this implies spatially correlated municipal policies.

[32] We can only state an upper bound for the share of property-related taxes, as the corresponding category in the financial statistics also includes tax revenue that is not related to property taxes.

[33] We also take account of the fact that parishes levy their own (small) tax multipliers.

[34] Thus, housing tax rates largely cancel out in estimations featuring canton fixed effects. We will however have to take account of the minority of municipalities that set their own property tax rate.

[35] The highest tax rate amounts to 0.3% of the assessed value (canton of Fribourg).

[36] The mean tax rate is 0.5% of the transaction price, with an upper bound of 3.3% (canton of Neuchâtel).

mated market values, with federal guidelines stipulating at least 70% of estimated market rent. Mortgage interest and maintenance costs are tax deductible. Hence, the implied tax subsidy for owning relative to renting is significantly smaller in Switzerland than in countries that do not tax imputed rents. Indeed, at a first approximation, the Swiss tax system can be considered roughly neutral between renting and owning.[37] Hence, our qualitative results should be informative not only for the considered population of renters but also for owner-occupiers, conditional on equal incomes and family status.

2.2 Data

We have assembled a unique municipality-level dataset covering the period 2004-2014. Our most important observed variables are personal income tax rates, housing prices, housing stocks, taxpayer counts by income bracket and local public expenditure. Table 1 provides summary statistics for all municipality-level variables. In columns (1)-(3), information is presented for the full sample of 1,815 municipalities for which we have housing price data in 2004/2005 and 2013/2014. Municipalities close to canton borders play a key role in our identification strategy. We therefore report separate summary statistics for this subsample of 814 municipalities in columns (4)-(6). In columns (7)-(8), we report differences between the sample means of border and non-border municipalities.

We first need a measure of household *income* to attribute taxpayers to income classes. We use net household income according to the definition used for federal income taxation, which offers us a measure that is consistent across years and cantons.[38] Our main focus is on three income classes: below-median income, the third quartile, and the top quartile. Quartiles are calculated annually using the universe of federal income tax records.[39] Importantly, we distinguish between households with and without dependent children. Among households without dependent children, we moreover distinguish between pensioner and non-pensioner households as a proxy for age. This last distinction is prone to some reporting errors (see Section 5.1) and available only for a subset of years. We will therefore not use it for our baseline estimates.

[37]The relative effect of the taxation of imputed rents on owners and renter households depends on the mortgage interest rate. As valuations on average remain fixed over 15 years but the mortgage interest deduction changes annually along with actual payments, the system favors homeowners in periods of high interest rates but disadvantages them in periods of low interest rates. According to estimations by the Swiss Federal Tax Administration, the system is approximately neutral for interest rates in the range 2.5-3.5%, which comprises Swiss mortgage rates over our sample period.

[38]Net income is defined as taxable income, to which standard federal-level deductions that depend on marital and family status have been added. As published tax rates are reported relative to gross income, we convert net income into gross income based on detailed deductions by income groups for the canton of Bern, as documented by Peters (2005), to obtain the tax rates shown in Panel B of Table 1.

[39]For example, the 75th (50th) percentile incomes for married households were CHF 111,000 (CHF 64,000) in 2014. This amounts to USD 122,000 (USD 70,000), using the 2014 exchange rate of 1.10 USD per 1 CHF, which we consider throughout this paper.

Table 1: Summary statistics

	Main sample (border & non-border municipalities)			IV border sample			Border vs non-border sample	
	Mean (S.D.)	Min	Max	Mean (S.D.)	Min	Max	Difference (S.E.)	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: **Housing prices and quantities**								
Rental price (CHF/m^2)	16.70	4.15	43.72	16.23	6.00	34.63	-0.849	0.000
	(3.97)			(3.35)			(0.158)	
Dwelling space (1000's m^2)	192.33	3.15	16356.00	168.42	3.15	3828.54	-43.323	0.048
	(500.88)			(249.26)			(21.855)	
Panel B: **Consolidated canton plus municipal plus church tax rates (%)**								
Married couples with children (50% income)	3.52	0.26	7.39	3.74	0.26	7.39	0.411	0.000
	(1.45)			(1.38)			(0.054)	
Married couples with children (60% income)	5.41	0.74	9.73	5.60	0.76	9.34	0.345	0.000
	(1.66)			(1.49)			(0.066)	
Married couples with children (90% income)	11.94	2.92	17.45	12.00	2.98	17.29	0.107	0.225
	(2.02)			(2.05)			(0.088)	
Unmarried taxpayer without children (50% income)	11.20	3.77	15.77	11.21	3.78	15.77	0.030	0.730
	(1.89)			(1.93)			(0.086)	
Unmarried taxpayer without children (60% income)	12.76	4.28	17.70	12.77	4.28	17.70	0.005	0.955
	(1.98)			(2.07)			(0.091)	
Unmarried taxpayer without children (90% income)	17.65	5.74	23.70	17.55	5.74	23.42	-0.177	0.118
	(2.50)			(2.60)			(0.113)	
Pensioner couples without children (50% income)	8.65	0.38	14.42	8.52	0.38	13.71	-0.222	0.076
	(2.79)			(2.44)			(0.125)	
Pensioner couples without children (60% income)	10.38	3.29	16.45	10.23	3.29	15.63	-0.271	0.027
	(2.72)			(2.48)			(0.122)	
Pensioner couples without children (90% income)	16.01	4.69	22.78	15.58	4.69	22.34	-0.774	0.000
	(3.00)			(3.06)			(0.132)	
Average tax rate (90% income)	14.75	4.86	20.60	14.73	4.86	20.23	-0.045	0.651
	(2.19)			(2.27)			(0.099)	
Panel C: **Number of taxpayers**								
Total	2404.41	37	254158	2021.22	37	53171	-694.48	0.036
	(7615.96)			(3335.45)			(330.27)	
With children (below-50% income)	93.81	0	11075	75.32	0	2111	-33.52	0.013
	(316.78)			(131.09)			(13.48)	
With children (50%-75% income)	148.41	1	11625	129.79	1	2700	-33.74	0.036
	(369.83)			(187.91)			(16.09)	
With children (top-25% income)	273.00	0	23557	242.03	0	4150	-56.14	0.056
	(677.96)			(326.17)			(29.35)	
Without children (below-50% income)	1098.05	13	111521	888.98	13	25003	-378.91	0.014
	(3545.34)			(1551.11)			(153.73)	
Non-pensioners	768.92	11	76058	612.95	11	17243	-287.36	0.009
	(2452.38)			(1033.71)			(109.97)	
Pensioners	342.50	1	35463	264.39	1	8819	-143.79	0.007
	(1194.31)			(496.94)			(53.16)	
Without children (50%-75% income)	454.68	5	52675	395.41	5	12266	-107.41	0.112
	(1553.52)			(708.10)			(67.52)	
Non-pensioners	323.68	3	39635	278.57	4	9074	-83.12	0.113
	(1161.40)			(504.95)			(52.39)	
Pensioners	139.38	0	13945	114.38	0	3256	-46.02	0.022
	(445.61)			(201.21)			(20.03)	
Without children (top-25% income)	336.46	0	45121	289.70	0	7436	-84.76	0.109
	(1223.53)			(494.94)			(52.89)	
Non-pensioners	249.98	0	36570	214.25	0	5351	-65.82	0.133
	(974.66)			(365.39)			(43.82)	
Pensioners	94.67	0	10029	75.81	0	2090	-34.74	0.012
	(306.90)			(144.89)			(13.80)	
Panel D: **Public expenditure (in CHF million)**								
Total	27.38	0.13	8541.32	17.84	0.13	654.78	-18.788	0.073
	(209.18)			(39.22)			(10.472)	
Education	5.60	0.00	1020.63	4.88	0.00	145.98	-1.439	0.300
	(25.89)			(9.13)			(1.387)	
Social	5.23	0.02	1407.00	3.44	0.02	132.93	-3.603	0.077
	(37.79)			(8.29)			(2.032)	
Administration	2.74	0.03	832.37	1.86	0.03	88.54	-1.785	0.072
	(19.50)			(4.24)			(0.993)	
Roads	2.16	0.01	998.72	1.12	0.01	81.49	-2.351	0.172
	(26.05)			(3.60)			(1.721)	
Police	1.51	0.00	584.54	0.78	0.00	51.29	-1.456	0.089

Continued on next page

	Main sample (border & non-border municipalities)			Border sample			Border vs non-border sample	
	Mean (S.D.)	Min	Max	Mean (S.D.)	Min	Max	Difference (S.E.)	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(15.88)			(2.56)			(0.855)	
Health	1.82	0.00	1089.62	0.76	0.00	127.24	-2.419	0.186
	(27.82)			(4.51)			(1.830)	
***Panel E:* Time-invariant control variables (municipality-level)**								
Share of developed land (1979-1985)	0.23	0.03	1.00	0.20	0.04	0.99	-0.047	0.000
	(0.18)			(0.15)			(0.008)	
Time-to-permit fixed effect coefficients (1997-2003)	-0.81	-3.60	5.09	-0.83	-2.29	5.09	-0.044	0.207
	(0.76)			(0.68)			(0.035)	
Index of accessibility	4.83	1.00	10.00	4.12	1.00	8.00	-1.293	0.000
	(2.13)			(1.76)			(0.093)	
Index of exposure to natural risks	5.27	1.00	10.00	5.71	1.00	10.00	0.809	0.000
	(2.41)			(2.33)			(0.112)	
Index of architectural heritage	6.70	1.00	30.00	6.41	1.00	30.00	-0.526	0.090
	(6.60)			(6.48)			(0.310)	
Hours of sunlight	6.74	0.00	8.10	7.03	0.00	8.10	0.542	0.000
	(1.47)			(1.04)			(0.065)	
***Panel F:* Local autonomy in property taxation (canton-level)**								
No common multiplier	0.82	0.00	1.00	0.86	0.00	1.00	0.069	0.000
	(0.38)			(0.35)			(0.018)	
Property tax	0.68	0.00	1.00	0.54	0.00	1.00	-0.263	0.000
	(0.46)			(0.50)			(0.022)	
Transaction tax	0.36	0.00	1.00	0.30	0.00	1.00	-0.103	0.000
	(0.48)			(0.46)			(0.022)	

Notes: The main sample consists of all border and non-border municipalities for which rental prices are available in both 2004/2005 and 2013/2014. It includes 1,815 municipalities (1,603 for public expenditure data). The border sub-sample contains 814 municipalities (786 for public expenditure data). In Panel C, the information on pension status is not available for all years, hence means do not always add up. The share of developed land is the ratio of developed land to developable land (total surface minus unproductive areas, taking into account topography). Time-to-permit fixed effects are municipality fixed effect coefficients from a regression of building permit approval time on observable characteristics of the project, municipality and year fixed effects. *No common multiplier* indicates municipalities that are allowed to set a different multiplier for their income tax and real estate capital gains taxes. *Property tax* and *Transaction tax* are dummy variables for municipalities that are allowed to levy a property tax or a real-estate transaction tax, respectively. (S.D.) means standard deviation and (S.E.) means standard error. Standard errors in column (7) are clustered at the municipality level.

For each of the nine household types (by family status and income class), we compute a representative average *tax rate* using the consolidated cantonal, municipal and church tax liability as a percentage of gross wage income for representative households.[40]

We focus on the following three main representative tax rates:

- *households with children (non-pensioners)*: consolidated tax rates on income of married couples with an average of 1.7 dependent children and a taxable income at, respectively, the median, the 65th and the 90th percentile of the nationwide distribution,[41]
- *households without children (non-pensioners)*: corresponding tax rates for unmarried tax-payers without dependent children,
- *pensioner households*: corresponding tax rates for married pensioners without dependent children.

[40] Representative tax rates for the different household types are based on tax rates computed by the Swiss Federal Tax Administration for discrete taxable income levels that range from CHF 10,000 to CHF 1,000,000 (USD 11,000 to USD 1,100,000 in 2014). These data are published for a sample of the largest municipalities. We draw on earlier work, where we have extended this dataset to all municipalities (Parchet, 2019). Tax rates for specific income values (quartile boundaries) are obtained through linear interpolation between the nearest income levels reported in the official statistics.

[41] The average number of children in households with children equals 1.7 in the federal income tax records. We therefore proxy the tax rate of those households though linear interpolation between the published tax rates for married couples without children and the tax rates for married couples with two children.

In our baseline estimates, where we do not distinguish between pensioner and non-pensioner households, we use non-pensioner tax rates for households without dependent children. For childless households, we use a weighted average of tax rates for unmarried taxpayers without children and tax rates for pensioner couples without children, where the weights are based on the nation-wide tax base shares in 2004. Finally, as a measure of the overall representative tax rate in a municipality and year (needed, e.g., for estimating the elasticity of housing prices), we compute weighted averages of the 90th-percentile tax rates for married taxpayers with two children, unmarried taxpayers without children and pensioner couples without children.

Panel B of Table 1 shows that there exists considerable variation in local income tax rates within Switzerland, with the highest rate exceeding the lowest rate by a factor of around five for most of our representative tax rates. Figure 2 illustrates this variation in the cross-section and over time, mapping the local tax rates for unmarried taxpayers without children at the 90th income percentile (approximately CHF 148,500 in 2004). Figure 2a shows that tax rates can vary within geographically small regions, thus allowing residents to change their tax bill by relocating within commuting zones. In our empirical analysis, we exploit time variation, illustrated in Figure 2b. This variation is substantial as well: the scale attached to the map shows that tax rate changes ranged from -6.3 to +3.3 percentage points, for a sample average tax rate of 17.5 percent (Table 1, Panel B).

Figure 3 further illustrates the identifying variation, for our main sample of 814 border municipalities. The left-hand panel of Figure 3 shows that tax rates are changed frequently: the modal number of tax changes within our 11-year time window is 3. The left-hand panel of Figure 3 shows that most local tax rate changes in our sample are negative, but there is considerable variation.

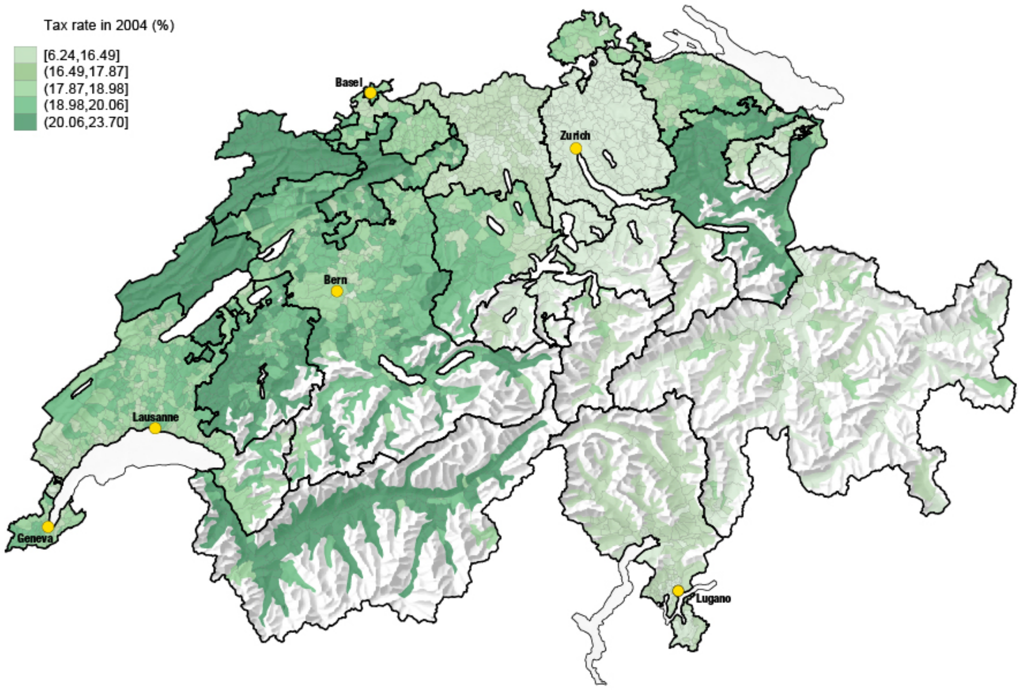
Information on *housing prices* is taken from rental postings. The basic dataset available to us covers very close to the universe of Swiss online and print offers – some 1.6 million rental postings in total. The mean monthly rent for a 100 m^2 appartment is CHF 1,655 (USD 1,820), but price variations are large (see the summary statistics in Panel A of Table 1).[42] In addition to rental prices, postings report object-level characteristics including floor space, the number of rooms and information on recent renovations. Rental prices provide an accurate measure of market prices, because posted rents are very close to transaction rental prices in Switzerland, where negotiation over posted rents is rare.[43] In order to control for heterogeneous housing characteristics, we use residuals from an object-level regression of log rental prices on floor size (cubic polynomial), the number of rooms, the interaction between size and number of rooms, a dummy for recent renovations, municipality and year fixed effects.

We also collected time-invariant municipality-level amenity measures including indices for accessibility, exposure to natural risks (e.g. landslides), architectural heritage and winter

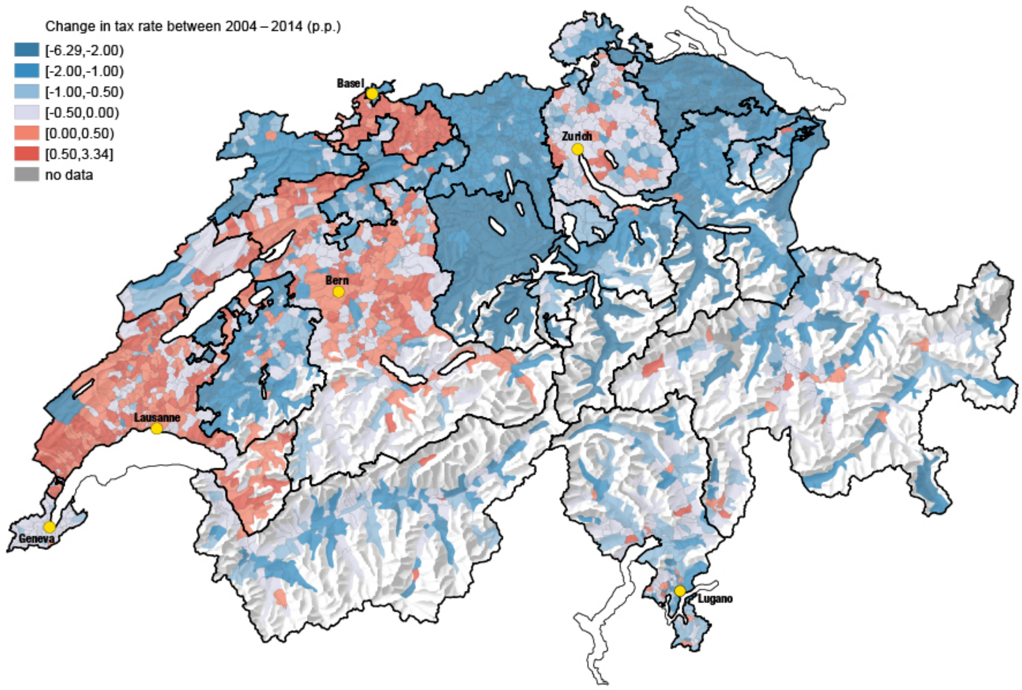
[42]Maps of average housing prices per municipality and of changes in these prices over time are presented in Appendix Figure A5.3. These are raw prices per square meter, without conditioning on dwelling characteristics. Data on rental postings, building permit requests and amenities are confidential and were kindly provided by Wüest Partner AG. This consultancy firm collects property advertisement information daily from all relevant websites and newspapers. Our dataset therefore covers essentially all arm's-length rental offers. Exceptions not covered by our data include some postings in case of simultaneous new rentals in multi-unit buildings, and offers publicized only via informal local notice boards or word-of-mouth.

[43]Negotiation over purchase prices, however, is as common in Switzerland as it is elsewhere. Hence, posted prices are a more reliable measure in the rental market than in the owner market.

Figure 2: The geography of local taxes in Switzerland



(a)



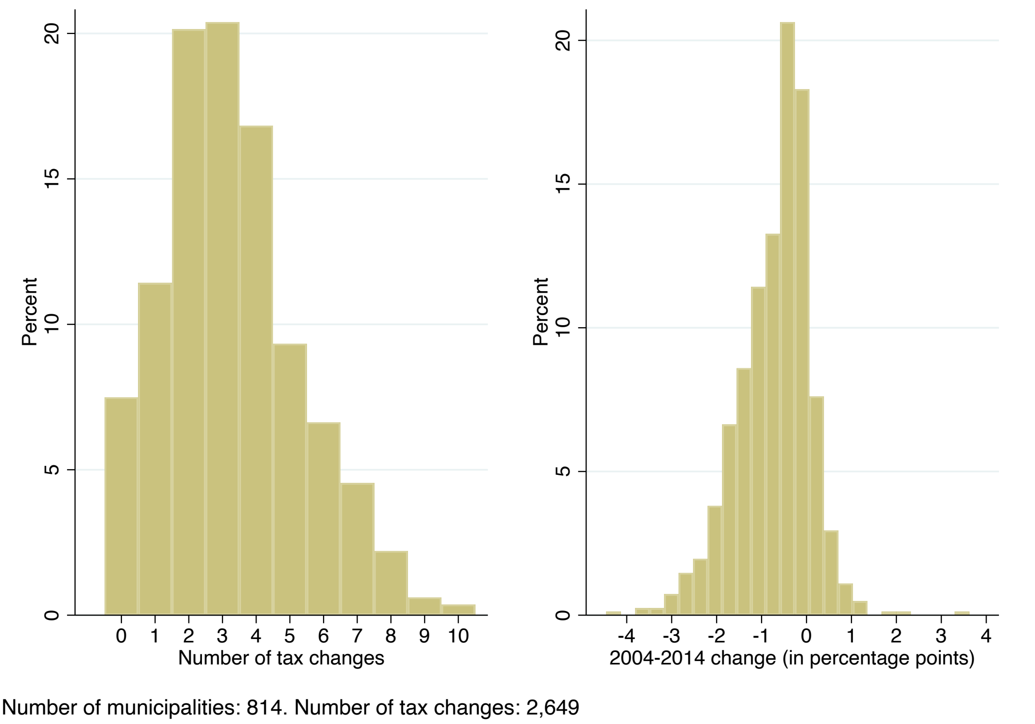
(b)

Notes: Panel (a) shows the consolidated cantonal, municipal and church income tax rates (in %) for unmarried taxpayers without children at the 90th income percentile. Panel (b) shows the difference in the consolidated income tax rates between 2014 and 2004. Gray lines represent municipality borders. Thick black lines represent canton borders. White areas are lakes, and light gray shaded areas are uninhabited mountains.

sunlight hours (Panel E of Table 1).

For the estimation of the housing supply elasticity, reported in Appendix A.2, we compute the municipal *housing stock* as habitable residential floor space net of demolitions (dwelling

Figure 3: Identifying sample variation in local tax rates



Notes: Data for sample of border municipalities, 2004-2014. The left-hand panel reports the number of municipality-level tax changes implied by a change in the municipal tax multiplier. The right-hand panel shows the distribution of long differences (2014 value minus 2004 value) of the municipal tax income tax rate for unmarried taxpayers without children at the 90th income percentile.

space) at annual intervals for 2004-2014.[44] We use municipal tax rates as demand shifters. This implies that we need to take account of the fact that cantons differ in the autonomy they grant to their municipalities with respect to property taxation. Where municipalities are allowed to set specific taxes on property values or transactions, these taxes will likely affect supply as well as demand, and local tax multipliers can no longer be interpreted as pure demand shifters (see Appendix Section A.2.1). We capture the degree of local autonomy through three binary variables. First, the *no common multiplier* variable is set to one for cantons that allow municipalities to apply a different multiplier for the income tax and for real estate capital gains taxes, and to zero where municipalities do not have that option. Second, the *property tax* variable is set to one where municipalities are allowed to levy an annual tax on property values, and to zero otherwise. Third, the *transaction tax* variable is set to one where municipalities are allowed to levy a real-estate transaction tax or such a tax exists at the cantonal level, and to zero otherwise. In the housing-supply regressions, we in addition control for local *administrative efficiency* and for *topographic constraints*.[45]

Finally, we collected data on municipal public expenditure. Except for some 170 large municipalities, municipal public accounts are reported only to the cantonal authorities but not to the federal level. This forced us to gather these data from cantonal and, in some cases,

[44]We thank the Federal Statistical Office for granting us access to confidential data from the Swiss Federal Registry for Buildings and Housing.

[45]See Appendix Section A.2.1 for details on data construction.

municipal archives. We succeeded in obtaining broadly comparable expenditure data for 1,603 municipalities. The summary statistics in Panel D of Table 1 confirm that schooling (which includes pre-school facilities) is the largest municipal expenditure category, followed by social spending (which is largely non-discretionary) and administration.[46]

Columns 7 and 8 of Table 1 show differences in means of our municipality-level variables between the border and non-border sub-samples. Municipalities in the border sample have lower housing prices than those in the non-border sample. They have higher tax rates for households with children, but lower ones for childless households, especially for pensioner couples. They are also less populous, which explains the lower share of developed land in the border sample. As a consequence, housing supply elasticities might differ between the two samples. We investigate the implications of different housing supply elasticities in Section 4.5.

3 Reduced-form responses to tax changes

Based on the data described in Section 2, we can estimate the vector of reduced-form moments $\hat{\boldsymbol{\eta}}$ of equation (15): elasticities with respect to local income tax rates (a) of municipality-level counts of taxpayers for each our six household types (tax-base elasticities) and (b) of municipality-level average housing prices.

Identifying causal effects of local tax rates is challenging for two reasons. First, local tax rates are decided by residents and could therefore respond directly to changes in the tax base. For example, an inflow of high-income taxpayers could strengthen the position of residents favoring lower tax rates; or municipalities could decide to lower their tax rate to mitigate the outflow of such taxpayers. Second, changes in local tax rates could be correlated with unobserved time-varying factors that also influence location decisions, giving rise to omitted variable bias. We therefore implement an instrumental variable strategy to address the potential endogeneity of local tax rates.

3.1 Empirical model

Following the approach developed in Parchet (2019), we take advantage of the fact that, in Switzerland, three layers of government tax the same tax base. Cantonal borders create spatial discontinuities in fiscal policies across areas that are otherwise highly integrated. We implement a cross-border pairwise-comparison strategy and exploit changes in neighbor-canton tax rates as a source of exogenous variation. This variation is used to instrument differential changes in tax rates between neighboring municipalities located on opposite sides of canton borders. In Appendix A.3, we develop this identification strategy step-by-step, starting from OLS panel estimation across all municipalities.

In our preferred specification, the long first-differences cross-border IV design, we restrict the sample to municipalities that are located close to a canton border. Specifically, we pair each municipality with its nearest neighbor-canton counterpart, provided their population

[46] The lower share of expenditure for schooling in our main sample (20%) compared to the aggregated statistics reported by SFSO (2017) (27%) is largely explained by the existence in five cantons of single-purpose school districts, for which we do not have data. The average expenditure share for schooling in our border sample (27%), however, is consistent with aggregate statistics.

centroids are located within no more than 10 kilometers' road distance from each other.[47] We then apply a cross-canton spatial difference estimation strategy, instrumenting the difference of the consolidated municipal tax rates with the corresponding difference in cantonal tax rates.

We jointly estimate long-first-difference models for the period 2004-2005 to 2013-2014. Specifically, we estimate the reduced-form moments $\boldsymbol{\eta} = [\eta^{N_1}, \ldots, \eta^{N_6}, \eta^{P}]'$ using the three-stage least squares (3SLS) estimator, and instrumenting municipality-pair-level differences in consolidated tax rates with the corresponding difference in canton-level tax rates.

Specifically, the seven estimating equations are

$$\nabla \Delta \ln N^1_{jk} = \eta^{N_1} \nabla \Delta \ln \tau^1_{jk} + \boldsymbol{\mu}^{N_1} \boldsymbol{\nabla} \mathbf{X}_{jk} + \phi^{N_1}_c + \varepsilon^{N_1}_{jk}, \tag{17a}$$

$$\vdots$$

$$\nabla \Delta \ln N^6_{jk} = \eta^{N_6} \nabla \Delta \ln \tau^6_{jk} + \boldsymbol{\mu}^{N_6} \boldsymbol{\nabla} \mathbf{X}_{jk} + \phi^{N_6}_c + \varepsilon^{N_6}_{jk}, \tag{17f}$$

$$\nabla \Delta \ln P_{jk} = \eta^{P} \nabla \Delta \ln \tau^P_{jk} + \beta_1 \nabla SDL_{jk} + \beta_2 \nabla TTP_{jk} + \boldsymbol{\mu}^{P} \boldsymbol{\nabla} \mathbf{X}_{jk} + \phi^{P}_c + \varepsilon^{P}_{jk}, \tag{17g}$$

where ∇ denotes the difference within pairs of municipalities jk in two neighboring cantons, c and d, with $(j \in c) \neq (k \in d \neq c)$ and Δ represents the long difference between the averages for 2013-2014 and 2004-2005. N^{fm} and P respectively denote the count of taxpayers belonging to a specific household type fm and housing prices. τ^{fm} is the consolidated (canton + municipal + church) tax rate as relevant to the associated regressand. We also control for the vector $\mathbf{X}$ of time-invariant municipal characteristics (accessibility, exposure to natural risks, architectural heritage and winter sunlight hours). In the housing-price elasticity equation 17g, we in addition control for topographical constraints and local administrative efficiency.[48]

The long-first-difference strategy has the advantage of removing municipality-pair fixed effects for the joint estimation of the seven equations. Moreover, it parallels our identification of the housing demand elasticity (for which we use cross-sectional variation in supply shifters) in Appendix A.2. Last, ϕ_c is an origin canton fixed effect such that our identification comes from municipalities in the same canton but bordering different neighboring cantons. Changes in differentials of local tax rates, $\nabla \Delta \ln \tau_{jk}$, are instrumented with the corresponding changes of canton-level tax rates $\nabla \Delta \ln \tau_{cd}$. Since housing price data are more reliable in larger municipalities, regressions are weighted by the log of population in 2000 of the smaller municipality in the pair.

To be valid, this estimation strategy has to satisfy several conditions. First, tax base changes in border municipalities should not systematically affect canton-level fiscal policy. The implied assumption is that border municipalities are small compared to the overall (population) size of the canton.[49] Second, canton-level tax changes should not be driven by un-

[47]For a map of the border-municipality sample, see Appendix Figure A5.4. Summary statistics are given in Table 1.

[48]See Appendix A.2 for details.

[49]Note that, due to spatial differencing, the identifying assumption requires the neighboring cantonal policy to be independent from the tax base in municipalities *j and k*, and not only from municipality j as in Parchet (2019).

Table 2: Tax base and rental price elasticities: 3SLS estimation

	Households without children			Households with children			Housing prices
	Bottom 50	Next 25	Top 25	Bottom 50	Next 25	Top 25	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
***Panel A:* unweighted regression, bootstrapped standard errors**							
Income tax rate	0.102**	-0.196***	-1.064***	0.083***	0.069***	-0.064	-0.329***
	(0.047)	(0.054)	(0.090)	(0.019)	(0.024)	(0.052)	(0.075)
***Panel B:* weighted regression, homoskedastic disturbances**							
Income tax rate	0.102***	-0.177***	-1.041***	0.083***	0.063***	-0.067	-0.323***
	(0.040)	(0.046)	(0.086)	(0.017)	(0.021)	(0.049)	(0.060)
Controls				YES			
Origin canton FE				YES			
# of observations				3,530			
# of municipalities				812			
Instrument				Cantonal income tax rate differential			
Estimator				3SLS			

Notes: Standard errors reported in parentheses. Each column refers to an equation from 17a-17g. The equations are estimated jointly using three stage least squares. The sample consists of cross-canton pairs of municipalities with a pairing road distance of 10 km. Panel A bootstraps the standard errors with 250 iterations of the unweighted 3SLS estimations. Panel B regressions are weighted by the log population in 2000 of the smallest municipality in the pair. The consolidated personal income tax rate differentials are instrumented by the cantonal personal income tax rate differentials. Controls include (time-invariant) indices of accessibility, exposure to natural risks, architectural heritage, and hours of sunlight. In column (7) we in addition control for topographical constraints and local administrative efficiency. ***p<0.01, **p<0.05, *p<0.1.

observed factors that also change the attractiveness of border municipalities. In that respect, spatial differencing controls for common shocks at the local level (in, e.g., the local labor market) and at the cantonal level (due to tax competition for example), and canton fixed effects (in a first-difference setting) control for changes in canton-wide policies.

For the exclusion restriction to be valid, taxpayers should react to changes in cantonal tax differentials only because of the changed consolidated tax rates. A concern would arise if municipal and cantonal tax rates were used to provide different types of public goods that are valued unequally by taxpayers. We can assume here that taxpayers care only about their total tax bill (and a "consolidated" public good), irrespective of whether the public services they consume are financed at the municipal or the cantonal level. A less stringent version of this assumption is that taxpayers do not distinguish the levels of government involved in the financing of specific public services. This is a reasonable assumption given the complexity of the financing of sub-federal public expenditure. With this identification strategy, we depart from our modeling assumption of a public good provided by one level of government. In our empirical setting, households consume locally (i.e. through their residence) a bundle of public services potentially provided by different levels of governments, and we structurally estimate their valuation of this bundle of public goods.

3.2 Results

Table 2 presents 3SLS estimates of equations 17a-17g. In Panel A, we show the results with standard errors bootstrapped at the municipality-pair level. Bootstrapping comes at the cost of not being able to weight regressions by municipality size. Panel B presents the results for weighted regression with standard errors assumed to be homoskedastic. Both specifications lead to similar results. Our structural estimation in Section 4 will be based on the weighted regression estimates of Panel B.

We find that reduced-form tax base elasticities decrease strongly and monotonically with income for households without children. Estimated elasticities also decrease monotonically with income for households with children, but the magnitudes are much smaller. Moreover, we find estimated elasticities to be positive for below-median income households and for households with children in the third income quartile. These results strongly suggest (a) that households perceive taxes not as net income losses but consider them jointly with the public goods supplied in return, (b) that they hold heterogeneous preferences over those public goods, and (c) that they have a non-zero propensity to move. Note also that our estimated tax base and housing price elasticities are close to the long-difference estimates presented of Table A3.3. The housing price elasticity of -0.323 is also well within the range of estimates reported by Basten et al. (2017), based on a border discontinuity framework.

4 Estimation of structural parameters and incidence: baseline

With the reduced-form elasticities in hand, we can progress towards estimating the structural model given by equation (16).

4.1 Calibration

In order to implement our structural estimation, we need to calibrate a number of parameters. Panel A of Table 3, presents these calibrated values.

First, we draw on data from the Swiss Household Panel (SHP) to calibrate taste and expenditure parameters related to housing. The housing taste parameter α follows from households' Marshallian housing demand equation $h^*_{fmj} = \nu^f_h + \frac{\alpha\left[(1-\tau_j)w_m - p_j\nu^f_h\right]}{p_j}$, which can be rewritten as $S_{fmj} = S^{min}_{fmj} + \alpha\left[1 - S^{min}_{fmj}\right]$, where $S^{min}_{fmj} \equiv p_j\nu^f_h/(1-\tau_j)w_m$ is the expenditure share of essential housing consumption. We compute α as $\frac{\bar{S}-\bar{S}^{min}}{1-\bar{S}^{min}}$, where $\bar{S}$ is the average expenditure share of housing (defined as annual rent over disposable income) calculated using SHP data for the years 2000 to 2004 ($\bar{S} = 0.24$). We proxy the expenditure share on essential housing needs, $\bar{S}^{min}$, using the average rent paid by bottom-5% income renter households in the SHP data, computed separately for different household types. Similarly, the type-specific expenditure share on essential housing needs ($\frac{\nu^f_h}{h^*_m}$) is obtained by the average rent paid by bottom-5% income renters (differentiating by family status) over the average rent paid in each income class. Aggregate housing shares (π_{fm}) are likewise calculated directly from the SHP data.

We calibrate proportional income tax rates τ_j in matrix $\mathbf{B}_j$ (Section 1.3) by the group-averaged consolidated income tax rates for 2000-2004.[50] Table 3 shows that these representative tax rates range from 5% (bottom-50 households with children) to 21% (top-25 households without children). The progressivity of tax rates is determined by the canton-level tax schedules. We investigate the implications of progressivity for our welfare estimates in Section

[50]Consolidation is across the federal, cantonal, municipal and parish levels. In the calibrations, we include the federal income tax rate that in Section 3 and Appendix Section A.2 is absorbed by fixed effects.

Table 3: Structural parameter and elasticity estimates

	Households without children			Households with children		
	Bottom 50 (1)	Next 25 (2)	Top 25 (3)	Bottom 50 (4)	Next 25 (5)	Top 25 (6)
***Panel A:* Calibration using:**						
Swiss Household Panel						
Housing tastes (α)	0.11	0.11	0.11	0.11	0.11	0.11
Minimal housing expenditure (ν_h/h^*)	0.75	0.68	0.56	0.80	0.71	0.60
Expenditure share on housing (S)	0.38	0.23	0.16	0.37	0.25	0.18
Aggregate housing share (π)	0.13	0.14	0.17	0.16	0.18	0.21
Tax rate database						
Income tax rates (τ)	0.11	0.13	0.18	0.05	0.07	0.13
Simultaneous equation IV estimates (Table A2.2)						
Housing supply price elasticity (η_s)			0.33			
Tax base database						
Taxpayer population share (s)	0.45	0.17	0.13	0.05	0.08	0.12
Share of tax base (γ)	0.18	0.18	0.30	0.02	0.07	0.25
Other parameter						
Congestion parameter (θ)			0.50			
***Panel B:* Structural parameters**						
Preference for public goods ($\tilde{\delta}$)		0.074			0.119	
		(0.015)			(0.076)	
Idiosyncratic location preference dispersion parameter (λ)		6.968			0.569	
		(0.528)			(0.234)	
Panel C: Structural elasticities						
Tax base elasticities	0.148	-0.253	-0.883	0.092	0.052	-0.009
	(0.036)	(0.038)	(0.062)	(0.016)	(0.015)	(0.035)
Marginal willingness to pay rent	-0.230	-0.403	-0.915	0.042	0.018	-0.342
	(0.025)	(0.043)	(0.062)	(0.114)	(0.186)	(0.263)
Resident incidence	0.021	-0.036	-0.127	0.161	0.092	-0.015
	(0.004)	(0.007)	(0.008)	(0.054)	(0.055)	(0.056)
Landlord incidence ($\eta^{p,\tau*}$)			-0.273			
			(0.022)			

Notes: Standard errors reported in parentheses.

4.3.

The housing supply elasticity comes from estimates presented in Appendix Section A.2.2. Our estimated value of 0.33 implies that to assume perfectly inelastic housing supply would not be appropriate in our setting.

Population shares s_{fm} and tax base shares γ_{fm} are computed from federal income tax statistics. Population shares take into account the marital status of households, that is, married households are counted as two people. Of our six baseline household types, 45% belong to the category "bottom-50 without children". The least frequent household type are bottom-50 taxpayers with children, accounting for only 5% of the total. This difference reflects the fact that households with children on average have higher incomes than households without children. Tax base shares reflect the unequal distribution of income: households in the top income quartile together account for 55% of overall income.

We calibrate the congestion parameter θ to the midpoint between the pure public good ($\theta = 0$) and full-rivalry ($\theta = 1$) cases. We explore the sensitivity of our structural estimation to this parameter in Section 4.5.

4.2 Estimates of structural parameters

Armed with the reduced-form parameter estimates of Section 3 and the calibrated values of Section 4.1, we can estimate the structural parameters for public-good preferences and for the dispersion of idiosyncratic locational preferences through the minimization of equation (16). The minimum is selected after a random search of starting values to ensure a global minimum. Standard errors of the structural elasticities are calculated with the delta method.[51]

Panels B and C of Table 3 show point estimates and standard errors of our baseline structural estimation, and Figure 4 provides a corresponding illustration of our main incidence results. In Panel B of Table 3, we present our estimates of the preference parameter for the public good, $\tilde{\delta}$, and of the idiosyncratic location preference parameter λ for households with and without children. We find preferences for locally provided public goods to be stronger for households with children than for childless households. Conversely, households with children are less mobile than childless households, their idiosyncratic location preference parameter λ being an order of magnitude smaller than that of childless households. Both results are consistent with expectations.

Implied structural elasticities are shown in Panel C of Table 3. The structural tax base elasticities are reassuringly close to the reduced-form elasticities presented in Table 2, with high-income households without children the most strongly deterred by higher local taxes and bottom-50 households without children responding positively to higher taxes.

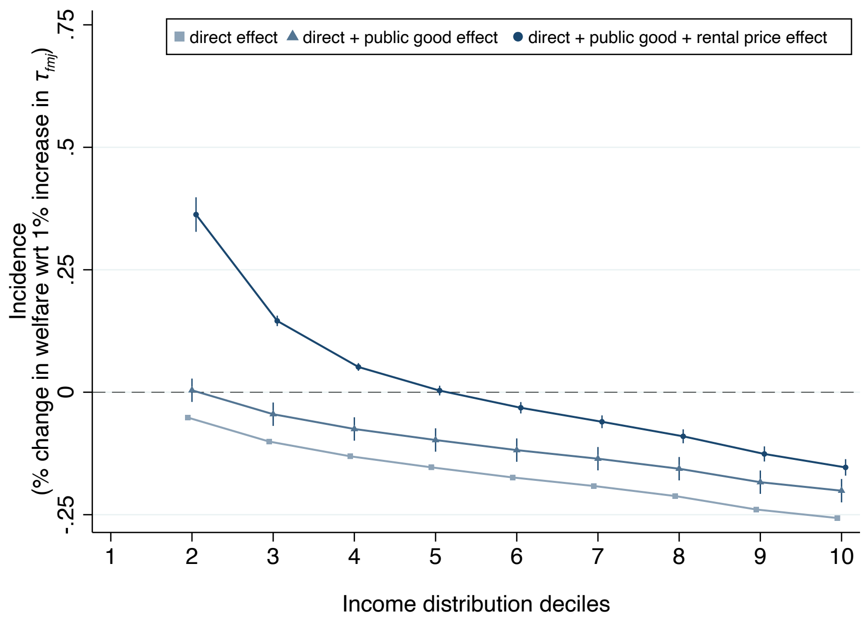
Panel C of Table 3 also reports the estimated marginal willingness to pay rent (MWPR) to compensate for higher taxes per group, as defined by equation (2). Our estimates are negative for four of the six household types; the exception being households with children in the first three quartiles of the income distribution, whose preferences for local public goods outweigh their disutility from higher tax burdens. Conversely, we obtain large negative estimates of the MWPR for top-25% households without children. Hence, at the margin, these households derive greater disutility from taxation and its effect on the cost of housing than the utility provided by local public goods. Within each family status, we observe – as expected – a negative relationship between income and the MWPR. For households with children, however, these differences are not statistically significant.

Equipped with the structural parameters of Panel B in Table 3, we compute the household type-specific welfare effects of an increase in local tax rates for households grouped by deciles of the income distribution.[52] These effects are illustrated in Figure 4 for households without children (upper panel) and households with children (lower panel). The total welfare effect is decomposed into the direct welfare effect of the local tax increase, the effect of the related

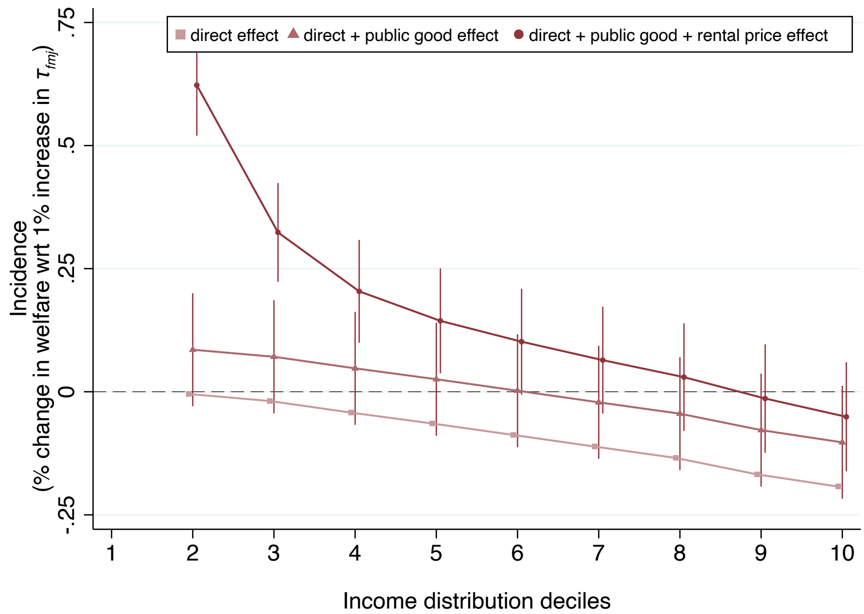
[51]Standard errors of the structural parameters are given by $\boldsymbol{J}[\mathfrak{m}(\boldsymbol{\vartheta})]'\widehat{\mathbf{V}}^{-\mathbf{1}}\boldsymbol{J}[\mathfrak{m}(\boldsymbol{\vartheta})]$ where $\boldsymbol{J}[.]$ denotes the Jacobian of the moments $\mathfrak{m}(\boldsymbol{\vartheta})$ with respect to the parameter vector $\boldsymbol{\vartheta}$. Because of the complexity of the moments, the Jacobian is very involved. Hence, we resort to symbolic computation in Mathematica. The delta method for the standard errors of the structural elasticities is implemented through the function 'uncertainty propagation' in Mathematica.

[52]These effects are computed using equation (12a), calibrating expenditure shares and tax rates for each decile of the income distribution instead of the three income groups used in our reduced-form regressions. Note that the elasticity of public good provision with respect to the local tax rate $\left(\sum_f \sum_m (\gamma_{fmj} - \theta s_{fmj}) \frac{dN_{fmj}}{N_{fmj}} \frac{\tau_j}{d\tau_j}\right)$ is computed with the structural tax base elasticities presented in Panel C of Table 3. The first decile is not reported because no data are available in the SHP for this group.

Figure 4: Wefare effects of a local income tax increase



(a) Households without children

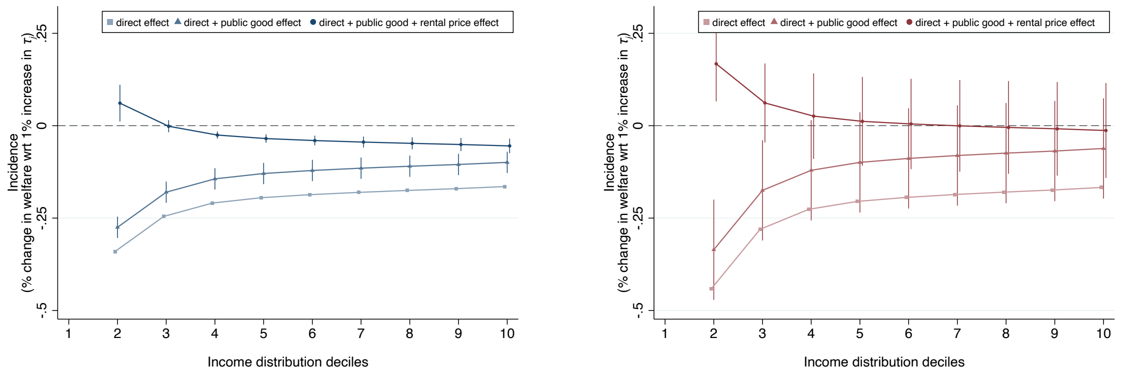


(b) Households with children

Notes: The figures show the tax incidence experienced by households without children (a) and with children (b). Households are grouped according to the deciles of the income distribution.

increase in public good provision and capitalization into lower housing prices. Among inframarginal (non-moving) residents, the negative incidence of local taxes is borne entirely by above-median income households without children. All other non-mover household types are either indifferent or would gain from a marginal increase in local taxation and the associated

Figure 5: Welfare effects of an increase in a (hypothetical) proportional local income tax



(a) Households without children (b) Households with children

Notes: The figures show the tax incidence of a proportional tax experienced by households without children (a) and with children (b). Households are grouped according to the deciles of the income distribution. The proportional tax is computed as a weighted sum of households-type tax rates $\left(\tau = \sum_f \sum_m \gamma_{fmj} \tau_{fm}\right)$.

local public goods (the negative welfare effects for households with children and incomes in the top-20% are not statistically significantly different from zero).

These effects are all smaller than the structural estimate of the housing price elasticity of -0.273. In our model, this is entirely borne by absentee landlords. In reality, available data suggest that around a third of landlords are resident in the same municipality.[53] Private landlords likely belong to the top income classes. Considering the effect on locally resident landlords would therefore exacerbate the negative incidence we estimate for the top income classes, but it would not qualitatively affect the different welfare effects we estimate across household types.

Figure 4 moreover shows how the total welfare of a local tax increase can be divided into (a) a direct effect, which is nonpositive as tax rates are nonnegative, (b) a public good effect, which is positive as we assume all households to derive utility from local public goods, and (c) a rental price effect, which is positive, as higher tax rates lead to lower rental prices (see equation 12b). It can be gleaned from Figure 4 that the public good effect and the rental price effect are stronger for households with children, while the direct effect is weaker (thanks to family deductions). Hence, all three forces contribute to childless household bearing more of the tax incidence than households with children.

4.3 Tax progressivity

Figure 4 shows that a local tax increase is progressive: it benefits low-income households more than high-income households. This effect is in part mechanically driven by the underlying graduated tax schedule of Swiss cantons as well as by differential tax rates according to family status. In Figure 5, we switch off the effect of statutory tax progressivity and instead investigate the welfare effects of a counterfactual change in a hypothetical flat tax, the level of which we compute as the weighted mean of household-type average tax rates $\left(\tau = \sum_f \sum_m \gamma_{fm} \tau_{fm}\right)$.

[53]See `https://www.bfs.admin.ch/bfsstatic/dam/assets/4262589/master`.

That is, we estimate equation (12b) where the change in the equilibrium housing price and tax base elasticities are obtained by solving the system of equations (10) for a hypothetical revenue-equivalent proportional tax rate and our estimated structural parameters.

These counterfactual results are shown in Figure 5. Removing statutory tax progressivity switches the direct effect from being progressive to being regressive: in utility terms a proportional increase from a given tax rate hurts poor households more than rich households. Interestingly, our model suggests the rental price effect to be sufficiently progressive to offset the regressive direct effect. This confirms that capitalization into housing prices plays an important part in shaping the distributional effects of local taxes.[54]

4.4 Property taxes

In some countries, including the United States and Canada, local governments mainly tax real estate rather than personal income. We therefore now use our framework to explore the welfare effects of a change in a hypothetical local property tax instead of a local income tax.

The welfare effect derived in equation (12b) is not specific to a local income tax and can easily be adapted to the case of a property tax. In that case, the indirect utility of household i with family status f and income w_m reads

$$V_{ifmj} = \kappa + \ln\left[w_m - (1+t_j)p_j\nu_h^f\right] - \alpha\ln\left[(1+t_j)p_j\right] + \delta\ln(g_j - \nu_g^f) + \ln(A_{ifj})\,,$$

where t_j is a proportional property tax levied on rental prices (see Online Appendix Section W.2 for a detailed derivation). The effect of a small change in the property tax rate t_j of municipality j on the welfare of household type $\{f, m\}$ is then given by

$$\frac{d\mathcal{W}^R_{fm}}{d\ln t_j} = \alpha N_{fmj}\left(1 - \frac{\nu_h^f}{h_{fmj}}\right)^{-1}\left\{-\left[\frac{t_j}{1+t_j} - \frac{\delta}{\alpha}\left(\frac{g_j}{g_j - \nu_g^f}\right)\left(1 - \frac{\nu_h^f}{h_{fmj}}\right)\left(\frac{dg_j}{dt_j}\frac{t_j}{g_j}\right)\right] - \left(\frac{dp_j}{dt_j}\frac{t_j}{p_j}\right)\right\}.$$

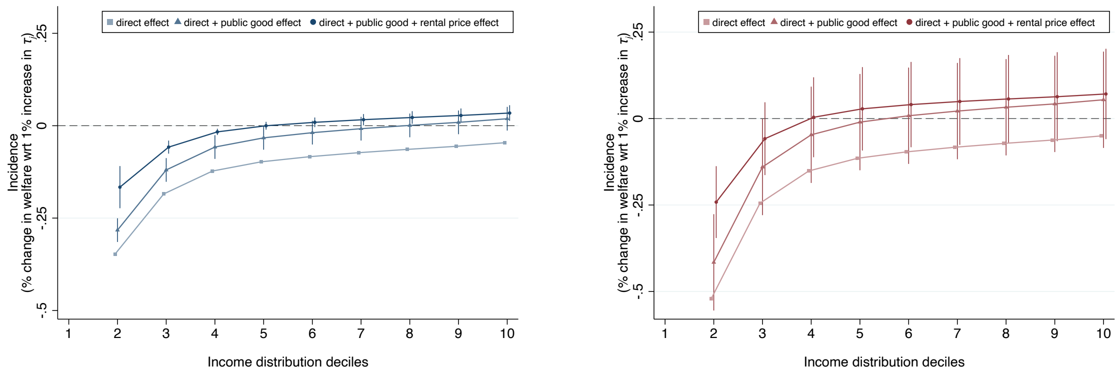
Equipped with our estimated structural parameters λ_m and $\tilde{\delta}_m$, we can estimate the two key elasticities $\frac{dg_j}{dt_j}\frac{t_j}{g_j}$ and $\frac{dp_j^*}{dt_j}\frac{t_j}{p_j^*}$ by solving the system of equilibrium equations corresponding to the model with a property tax (see equation W.19).[55] Figure 6 presents the results.

Not surprisingly, we find the direct effect of the property tax to be regressive, due to low-income households spending a higher share of their income on housing. In contrast to the local income tax case, however, house price capitalization turns out to be insufficient to overturn the regressivity of a property tax. The main difference is that property tax revenue depends less on the tax-sensitive behavior of top-income taxpayers than local income tax revenue. As a result, and given the balanced-budget constraint, public expenditure increases more strongly with a property tax increase (estimated elasticity = 0.88, s.e. = 0.05) than with an income tax increase (estimated elasticity $=$ 0.76, s.e. $=$ 0.02). Resident households are

[54]Note that the vertical position of the curves in Figure 5 cannot be readily compared to that of the corresponding curves in Figure 4, because the former depends on the the assumed level of the hypothetical proportional tax rate.

[55]The hypothetical property tax is calibrated such as to substitute fully for cantonal plus municipal income tax revenue absent behavioral effects. This implies an assumed tax rate of 36% on rents, which corresponds to a rate of 1.4% of housing value.

Figure 6: Welfare effects of an increase in a (hypothetical) local property tax



(a) Households without children

(b) Households with children

Notes: The figures show the tax incidence of an hypothetical property tax experienced by households without children (a) and with children (b). Households are grouped according to the deciles of the income distribution. The hypothetical property tax rate is calibrated to raise revenue equivalent to that raised by cantonal plus municipal income taxes absent behavioral effects.

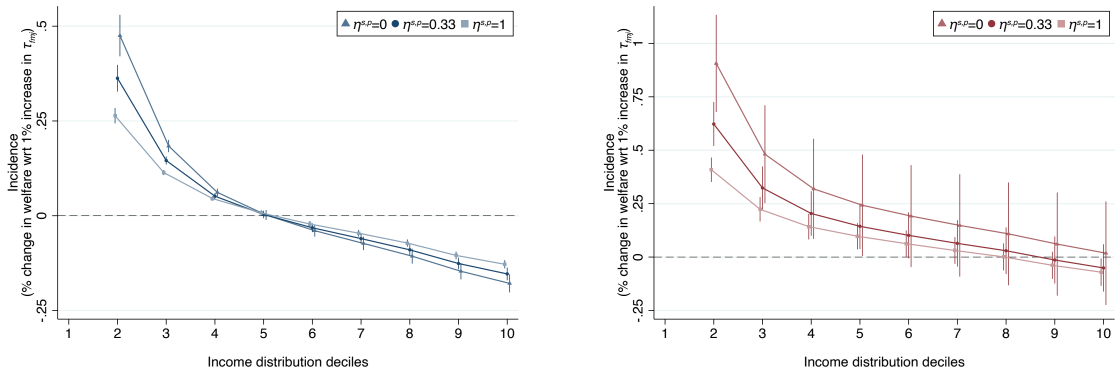
therefore 'compensated' with public goods more strongly in the case of property tax increase than in the case of an income tax increase. This in turn implies that residential property demand and thus housing prices are affected less by a rise in a local property tax than by an equivalent rise in a local income tax. Local income taxes are therefore capitalized into housing prices more strongly than local property taxes. Indeed, our estimated elasticity of rental prices with respect to a local property tax equals -0.09 (s.e. $= 0.03$), whereas the corresponding elasticity with respect to a local income tax equals -0.27 (s.e. $= 0.02$, see Table 3).

The weakness of the local income tax – its reliance on the behavioral response of high-income households – is therefore a boon to redistribution (in our framework, the incidence is largely shifted to absentee landlords). Conversely, a local property tax is more efficient for raising public revenue but more regressive due to lower capitalization into housing prices. Again, we find the capitalization channel to play an important role in determining the effective progressivity of local taxes.

4.5 Robustness: housing supply and rivalness of public goods

In Figure 7, we investigate the sensitivity of our welfare estimates to different calibrated values of the housing supply elasticity $\eta^{s,p}$ (see Table A4.4 for results on the full set of structural parameters and elasticities). The Figure presents the welfare effect for two extreme scenarios: completely inelastic and a unit-elastic housing supply, with our baseline as the intermediate case. As expected, the incidence on resident renters is more progressive the less elastic the housing supply, as low-income households benefiting the most from lower housing prices (housing prices decrease by -0.394% after a 1% increase in local taxes when housing supply is completely inelastic and by -0.164% when housing supply is unit-elastic, see Table A4.4, Panels A and B) The effects of changing housing supply are less precisely estimated for families with children (Figure 7b), but in their case too the progressivity-enhancing effect of

Figure 7: Welfare effects for different housing supply elasticities



(a) Households without children

(b) Households with children

Notes: The figures show the tax incidence experienced by households without children (a) and with children (b) for different calibrated values for the housing supply elasticity. Households are grouped according to the deciles of the income distribution.

stronger house price capitalization is evident.

In Table A4.4, Panels C and D, we also present results for different values of the congestion parameter, while keeping the housing supply elasticity at its baseline value. It turns out that the congestion parameter affects only our estimation of the public goods preference parameter but neither the idiosyncratic location preference dispersion parameter nor the structural elasticities. Hence, implied welfare effects do not hinge on the calibration of this parameter.

5 Extensions

5.1 Decomposition by age

So far, we have posited that family status in terms of the presence of children is the key dimension driving the heterogeneity of households' valuation of local public goods and of the idiosyncratic location preference dispersion parameter. Another dimension likely to be important is age category. In this subsection, we therefore divide childless households into pensioner and non-pensioner (i.e. working age) categories, based on a variable in the federal income tax statistics indicating whether households receive a pension. This variable is recorded with some inconsistencies, forcing us to clean the dataset and to exclude several years from the sample.[56]

Table 4 presents the 3SLS reduced-form estimates for the nine household types and hous-

[56] One source of measurement error is that the pension variable includes invalidity benefits. On average, 9% of "pensioner" households are below the pension age (64 for women and 65 for men). The median age of invalidity benefit recipients is around 53. Another source of imprecision is that cantonal tax authorities have different reporting practices (especially for married couples) that in some cases change over time. The calculated share of pensioner households at the canton level can therefore jump between years by several percentage points (up to 13 percentage points, for an average pensioner share of 23%). We dropped observations for cantons where such jumps occurred at the beginning (Thurgau and Ticino) or end (St. Gallen) of our sample period, and where they affected a single year (Basel-Stadt). We also dropped observations for the canton of Vaud between 2005 and 2008 because of evident reporting errors. For the cantons in which discrete jumps happened in the middle of our observation period, we inferred for each municipality the number of pensioner households with the canton-level increase netted out (Geneva, Glarus, Fribourg, Solothurn, Valais).

Table 4: Tax base elasticities for pensioners and non-pensioners: 3SLS estimation

	Households without children						Households with children			Housing prices
	Non-pensioners			Pensioners						
	Bottom 50	Next 25	Top 25	Bottom 50	Next 25	Top 25	Bottom 50	Next 25	Top 25	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Income tax rate	0.309***	-0.165**	-1.341***	0.249***	-0.271***	-0.284***	0.080***	0.056***	-0.047	-0.352***
	(0.064)	(0.071)	(0.106)	(0.026)	(0.054)	(0.090)	(0.017)	(0.021)	(0.048)	(0.059)
Controls	YES									
Origin canton FE	YES									
# of observations	3,526									
# of municipalities	811									
Instrument	Cantonal income tax rate differential									
Estimator	3SLS									

Notes: Homoskedastic standard errors reported in parentheses. The equations are estimated jointly using three stage least squares. The sample consists of cross-canton pairs of municipalities with a pairing road distance of 10 km. Regressions are weighted by the log population in 2000 of the smallest municipality in the pair. The consolidated personal income tax rate differentials are instrumented by the cantonal personal income tax rate differentials. Controls include (time-invariant) indices of accessibility, exposure to natural risks, architectural heritage, and hours of sunlight. In column (10) we in addition control for topographical constraints and local administrative efficiency. ***p<0.01, **p<0.05, *p<0.1.

ing prices.[57] Results for housing prices and for households with children are similar to our baseline reduced-form estimates reported Table 2. Elasticity estimates for childless working-age households are larger, and those for pensioner households are smaller, in absolute values, than in the baseline, where the two categories are combined. While the estimates in Tables 4 and 2 are not exactly comparable, as the samples are different, they suggest that high-income households are more strongly deterred by higher taxes when they are of working age than when they are of pension age.

The welfare effects of a tax increase are shown in Figure 8.[58] It turns out that separating out pensioner households does not add much to our insights. Among households without children and for any given income class, our estimated tax incidence very similar for working-age and pensioner households (see Panels (a) and (b) of Figure 8). For households with children, we obtain a tax incidence that is reassuringly similar to our baseline estimate.

5.2 The local budget constraint

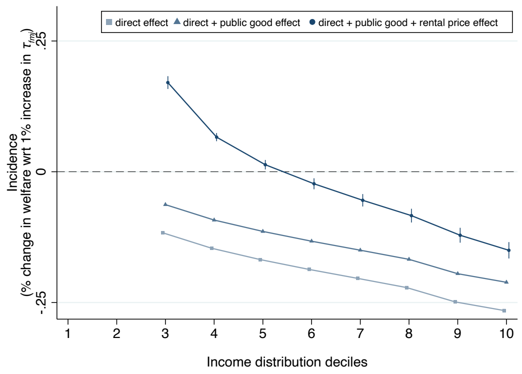
Our identification of the distributional effects of local tax changes relies on a key simplification: the municipal budget is balanced, such that there exists a one-to-one relationship between increased tax revenue following a local income tax hike and increased availability of the local public good. In reality, changes in tax revenue might not always map one-for-one into changes in public good provision, e.g. in the presence of public-sector rent extraction or corruption (Diamond, 2017), or in the case of net public (dis-)saving (Pettersson-Lidbom, 2010). Here, we therefore employ our IV strategy to test for the appropriateness of the implied municipal balanced budget constraint.

Our identification strategy exploits upper-level tax changes in neighboring cantons as a source of exogenous variation for consolidated tax differentials. Hence, an exogenous increase in the consolidated tax differential between two municipalities located in adjacent cantons is driven by a decrease in the neighboring cantonal tax rate. Consistent with our negative tax base elasticities for top-income households, we expect that higher tax differentials lead to a

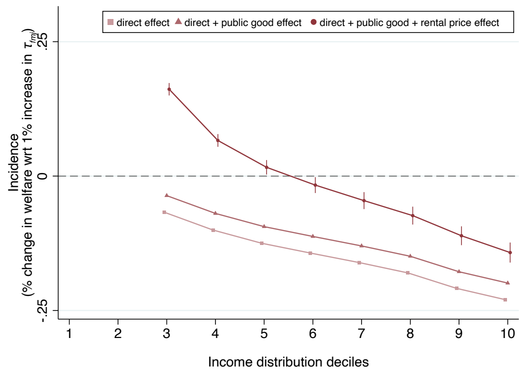
[57] Analogous to Table A3.3, Appendix Table A4.5 shows the corresponding OLS and 2SLS specifications for non-pensioners and pensioner households without children.

[58] For details of the calibrated values and of the structural elasticities, see Appendix Table A4.6. In Figure 8 the first two deciles are not reported because no data are available in the SHP for some groups.

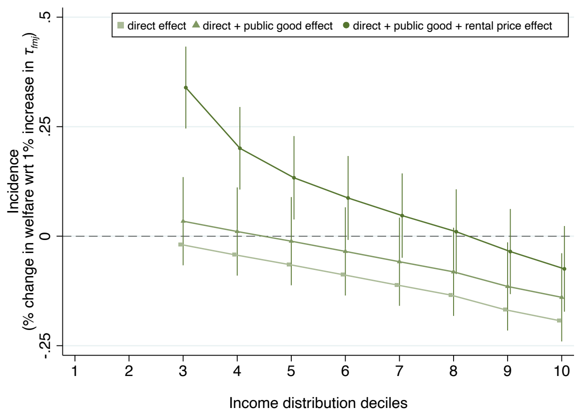
Figure 8: Welfare effects: pensioners and non-pensioners



(a) Households without children: non-pensioners



(b) Households without children: pensioners



(c) Households with children

Notes: The figures show the tax incidence of a local tax change on non-pensioners households without children (a), pensioner households without children (b) and households with children (c). Households are grouped according to the deciles of the overall income distribution.

worsening in municipal tax revenue (differentials). This is what we find in the first column of Table 5, which reports the results of our long first difference model for total municipal revenue.[59]

In column (2), we test the effect on total expenditure. Importantly, we find an effect that is similar to column (1), consistent with a binding local budget constraint.[60] In columns (3) to (8) we test for (endogenous) changes in the composition of expenditure. Results unfortunately are not informative, as standard errors are large and often exceed the estimated coefficients. Taken at face value, the results suggest that lower tax revenue is associated with a decrease in educational spending but to a lesser extent than other categories.

[59]In all specifications of Table 5, we use as dependent variable the residuals from a regression on canton-year fixed effects in order to take into account canton-level changes in public accounting standards for municipality finances as well as changes of task allocations between different levels of governments.

[60]Note that total expenditure is also directly affected by the change in the composition of the tax base. Hence, we cannot directly test the local budget constraint as expressed in equation (8c). Note also that we cannot use total expenditure directly in our structural model, as we do not know how much cantons spend in a given municipality.

Table 5: Public good elasticities

	Total		Expenditure per category					
	Revenue	Expenditure	Education	Social	Admin.	Roads	Police	Health
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Income tax rate	-0.505***	-0.408**	-0.181	-0.756	-0.217	-0.033	0.235	0.326
	(0.206)	(0.191)	(0.268)	(0.560)	(0.253)	(0.354)	(0.393)	(1.083)
# of observations	3,849	3,849	3,546	3,546	3,546	2,872	3,546	2,862
# of municipalities	781	781	681	681	681	550	681	548
Kleibergeb-Paap F Stat	126	126	236	236	236	198	236	201
Controls				YES				
Origin canton fixed effect				YES				
Instrument			Cantonal income tax rate differential					

Notes: This table reports the results of the IV pairwise long first difference estimation model for border municipalities. Cluster robust standard errors at origin and destination municipality level are reported in parentheses. The sample consists of cross-canton pairs of municipalities with a pairing road distance of 10 km. Regressions are weighted by the log population in 2000 of the smallest municipality in the pair. The consolidated personal income tax rate differentials are instrumented by the cantonal personal income tax rate differentials. Controls include (time-invariant) indices of accessibility, exposure to natural risks, architectural heritage, and hours of sunlight.***p<0.01, **p<0.05, *p<0.1.

6 Conclusion

We have studied the differential welfare effects of local-level taxation on heterogeneous households and absentee landlords. This issue is important for three reasons. First, according to the standard assumption of locally perfectly mobile residents, land, the immobile factor, bears the full incidence of local policies. However, residential mobility is costly, even at the local level, and hence welfare effects on resident non-owners need to be considered. Second, in this literature, preferences for local public goods have hitherto been studied without considering household heterogeneity. In this paper, we show that public-good preferences differ substantially by family status. Third, studies of taxpayer mobility typically focus on top-income households. We consider taxpayers along the entire income distribution, and we link type-specific tax base elasticities to measures of households' willingness to trade off housing costs against local tax burdens.

We estimate the incidence of local tax changes in three main steps. First, we allow for heterogeneous households to have different valuations for locally tax-funded public goods. Second, we exploit cross-section and time variation in Swiss municipal tax rates at canton borders that we instrument with neighboring canton-level tax rates. This enables us to obtain plausibly causal reduced-form elasticities of tax bases and housing prices with respect to local tax rates, and of housing supply with respect to housing prices. Third, we search for the preference parameters that best match our theoretical moments with those reduced-form elasticities.

We find large variation in the incidence of local income tax increases: for childless households, the incidence is positive for the bottom-50% income households – both of working age and of pension age – and negative for the upper half of the income distribution. For households with children, the estimated incidence is more positive than for childless households across all income classes. The structural estimates imply a stronger preference for local public goods, and much weaker mobility, by families with children. We show that households with children on the whole have more to gain from higher local taxes, for two main reasons: house-price capitalization benefits them more as they have greater housing needs, and local public goods are more valuable to families with children.

Our results show that local taxation – be it on income or on property – has distributional effects even in the absence of a progressive rate schedule. This has two reasons. First, to the extent that households exhibit non-homothetic housing demand, the capitalization of tax rates into housing prices will affect them differently. Second, heterogeneous preferences for publicly provided goods imply that different households perceive local tax changes differently. This might help explain the absence of empirical evidence for perfect income sorting of households: households at different income levels will differ significantly in their valuation of local bundles of tax rates and public goods depending on their family status.

Our analysis is predicated on the implicit assumption that residents update their optimal location choice. In reality, residential moves are infrequent, consistent with our assumption that households are not perfectly mobile. The average tenancy of renter households in Switzerland is around 6 years.[61] This time span is somewhat smaller than the ten-year intervals we use to identify our elasticity estimates. Thus, our estimates ought to be interpreted as long-run welfare effects.

More detailed data could conceivably offer even deeper insights. For instance, it would be useful to allow for different housing-market segments to have unequal relevance across household types. We leave such an extension for future work.

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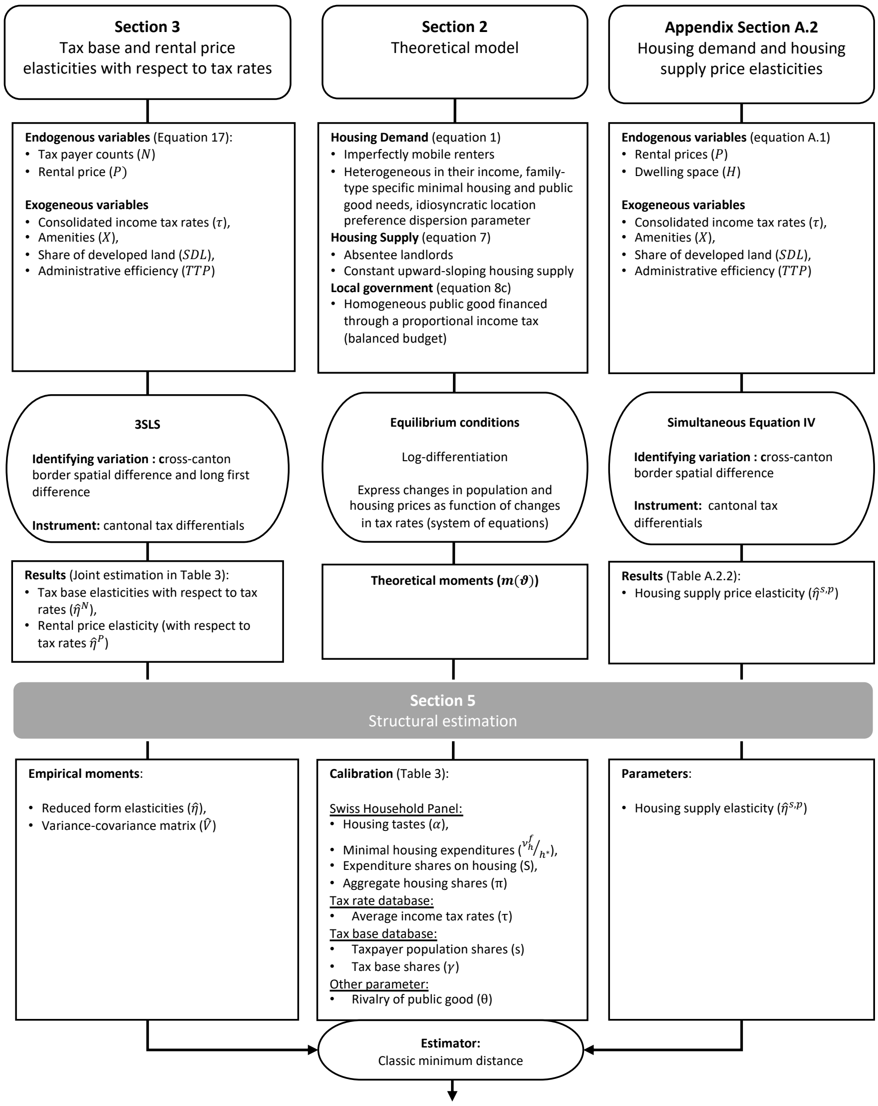
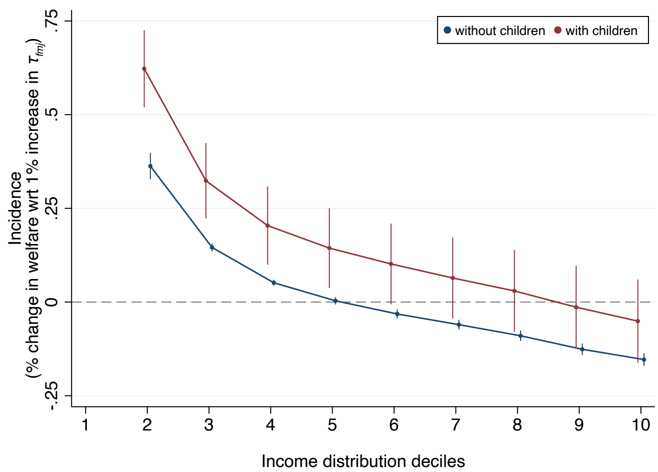
A Appendix

A.1 Schematic overview





A.2 Housing supply and demand

Here, we describe our estimation of the price elasticity of housing supply, a parameter required for our structural estimation. We use instrumented changes in local income tax rates as a demand shifter allowing us to identify supply responses.

A.2.1 A simultaneous-equation IV framework

Our starting point is the following simultaneous-equation model for a cross-section of municipalities j:

$$\Delta \ln P_j = \frac{1}{\eta^{d,p}} \Delta \ln H_j + \eta^p \boldsymbol{\Delta} \ln \tau_j + \boldsymbol{\mu} \mathbf{X}_j + \phi_c + \epsilon_j^d \tag{A.1a}$$

and

$$\Delta \ln P_j = \frac{1}{\eta^{s,p}} \Delta \ln H_j + \beta_1 SDL_j + \beta_2 TTP_j + \boldsymbol{\mu} \mathbf{X}_j + \phi_c + \epsilon_j^s\,, \tag{A.1b}$$

where Δ represents long first differences. P denotes residual housing prices, H the residential housing stock, τ the personal income tax rate, **X** is a vector of local amenities, SDL is the share of developed land, TTP ("time to permit") is a proxy for local administrative efficiency, and ϕ_c are canton fixed effects.

For our administrative efficiency measure, we draw on the universe of individual-level building permits issued in Switzerland over the 1997-2003 period (i.e. prior to our main data period of 2004-2014). Our permits data include the projected costs, building type (e.g. a garage), type of project (e.g. renovation), and the number of structures (e.g. two garages). We compute, for all successful applications, the duration from the initial request to the award of the building permit, measured in months. We then perform a hedonic regression of time-to-permit on the observable characteristics of the project and municipality and year fixed effects. The estimated coefficients on the municipality fixed effects then serve as our proxy for local administrative efficiency (TTP).

As a second determinant of housing supply, we consider *topographic constraints*. We draw on a cross section of data indicating the most relevant form of land use within 100×100m grid cells across Switzerland for the period 1979 to 1985. We combine this information with digital height model data that report the gradient of the surface.[62] We define 'developable' land as the total surface area minus unproductive areas, forests and remaining unbuilt land with a slope greater than 20 percent (gradient of 11.3 degrees).[63] The ratio of developed land to developable land yields the share of developed land (SDL).

[62] Both data sets are produced by the Swiss Federal Statistics Office. The land use data are publicly available here. They distinguish 17 land-use types, which we aggregate into four broader categories. The first category is 'developed land', consisting of (i) industrial and commercial areas, (ii) residential and public buildings, (iii) transport areas, (iv) special infrastructure and (v) recreational areas. The second category is 'agricultural land' and consists of (i) horticultural and viticultural areas, (ii) arable land, (iii) meadows and (iv) pastures. The third category contains forests. Finally, we define 'unproductive areas' as including (i) lakes, (ii) rivers, (iii) unproductive vegetation, (iv) barren land and (v) glaciers and perpetual snow. The Digital Height Model (DHM25) data have been developed by the Geographic Information System group at the University of Lausanne.

[63] Forest areas in Switzerland are protected by federal law and can only be cleared in case of an evident public interest, in which case an identical surface has to be reforested within the same region.

The model described by equations (A.1a) and (A.1b) identifies the elasticity of housing supply ($\eta^{s,p}$), contingent on a set of exclusion restrictions and validity conditions.

The exclusion restrictions we impose are that housing demand shifters do not affect housing supply, that is, we need that $cov(\Delta \ln \tau, \epsilon^s) = 0$. One concern is that changes in local income tax rates $\Delta \ln \tau$ could also lead to shifts in the supply curve. The atomistic absentee landlord described in Section 1.2 differs from our empirical setting insofar as rental income in Switzerland is taxed by the jurisdiction where the dwelling is located. We show in Online Appendix W.3 that the supply side of the model is independent of changes in income taxes if landlords' running costs are tax deductible or taxed at the same rate as income. While mortgage interest, property tax payments and maintenance costs can be deducted from income taxes in Switzerland, transaction taxes are not deductible, and capital gains are in some places taxed at a different rate than the income tax. We exploit the heterogeneity in tax laws across Swiss cantons to filter out jurisdictions where changes in income tax rates are statutorily linked to changes in taxes that affect supply. Specifically, we replace $\Delta \ln \tau_j$ in (A.1a) by a vector $\boldsymbol{\Delta \ln \tau}_j = [\Delta \ln \tau_j \quad \Delta \ln \tau_j \times NCM_c \quad \Delta \ln \tau_j \times PT_c \quad \Delta \ln \tau_j \times TT_c]'$ and $\boldsymbol{\eta^p} = [\eta^{d,p} \quad \eta^{d,p \times NCM} \quad \eta^{d,p \times PT} \quad \eta^{d,p \times TT}]$. Dummy variables indicate the cantons in which municipalities are not restricted to use the same multiplier for capital gains and personal income taxes (NCM, for no common multiplier), and cases in which municipalities have autonomy to set property tax rates (PT) and transaction tax rates (TT). The main effect $\Delta \ln \tau_j$ then measures the effect of local income taxes as measured in jurisdictions where changes in these taxes directly affect housing demand but not housing supply.

Valid identification furthermore requires that the demand shifter be exogenous to the system of equations, i.e. $cov(\Delta \ln \tau, \epsilon^d) = 0$. We however expect that local tax rates are endogenous with respect to local housing demand, in first-differences as well as in levels. To address the endogeneity of the tax rate, we turn to a two-step estimation on our sample of border municipalities.

Specifically, we back out the implied housing supply elasticity by estimating the following reduced-form equations separately,

$$\nabla \Delta \ln H_j = \boldsymbol{\eta^s} \boldsymbol{\nabla \Delta \ln \tau}_{jk} + \beta_1 \nabla SDL_{jk} + \beta_2 \nabla TTP_{jk} + \boldsymbol{\mu} \boldsymbol{\nabla X}_{jk} + \phi_c + \varepsilon_{jk} \tag{A.2}$$

$$\nabla \Delta \ln P_{jk} = \boldsymbol{\eta^p} \boldsymbol{\nabla \Delta \ln \tau}_{jk} + \beta_1 \nabla SDL_{jk} + \beta_2 \nabla TTP_{jk} + \boldsymbol{\mu} \boldsymbol{\nabla X}_{jk} + \phi_c + \varepsilon_{jk}, \tag{A.3}$$

where ∇ indicates the cross-canton spatial difference within pairs of municipalities jk in two neighboring cantons, c and d, with $(j \in c) \neq (k \in d \neq c)$. The vector $\boldsymbol{\nabla \Delta \ln \tau}_{jk}$ is instrumented with the vector $\boldsymbol{\nabla \Delta \ln \tau}_{cd}$. The parameter vectors are $\boldsymbol{\eta^s} = [\eta^s \quad \eta^{s \times \text{ncm}} \quad \eta^{s \times \text{pt}} \quad \eta^{s \times \text{tt}}]$, $\boldsymbol{\eta^p} = [\eta^p \quad \eta^{p \times \text{ncm}} \quad \eta^{p \times \text{pt}} \quad \eta^{p \times \text{tt}}]$ and coefficients of interest are η^s and η^p, respectively. The implied housing supply elasticity is given by

$$\widehat{\eta}^{s,p} = \frac{\widehat{\eta}^s}{\widehat{\eta}^p},$$

where standard errors can be calculated using the delta method.

Table A2.1: Simultaneous equation estimates

	Rental price growth rate		
	(1)	(2)	(3)
Demand equation (A.1a):			
Housing stock ($\widehat{\eta}^{d,p}$)	-1.627	-1.284**	-1.311**
	(1.594)	(0.587)	(0.616)
Local income tax ($\widehat{\eta}^{p,\tau}$)	-0.406***	-0.446***	-0.726*
	(0.151)	(0.120)	(0.379)
Supply equation (A.1b):			
Housing stock ($\widehat{\eta}^{s,p}$)	0.649***	0.657***	0.910***
	(0.227)	(0.220)	(0.353)
Share of developed land ($\widehat{\beta}_1$)	0.076***	0.155***	0.125***
	(0.027)	(0.043)	(0.037)
Time-to-permit ($\widehat{\beta}_2$)	0.000	-0.003	-0.002
	(0.006)	(0.006)	(0.005)
Canton FE	YES	YES	YES
Amenity controls	NO	YES	YES
Fiscal controls	NO	NO	YES
# of observations	1,815	1,815	1,815

Notes: Standard errors in parentheses. Weighted by log municipal population in 2000. Housing demand and supply elasticities have already been transformed for direct interpretation. Amenity controls include indices of accessibility, exposure to natural risks, architectural heritage, and hours of sunlight. Fiscal controls include the interactions between the income tax rate and dummy variables NCM, PT, and TT. ***p<0.01, **p<0.05, *p<0.1.

A.2.2 Results

Table A2.1 presents the results of the simultaneous-equation model using the full set of municipalities. Column (1) does not include any control. In column (2), we control for amenities differentials among municipalities that are likely to influence housing demand, and for our two supply shifters, the share of developed land and the time-to-permit. The estimated housing supply elasticity varies between 0.65 (column 1) and 0.91 (column 3) depending on the inclusion of fiscal controls. The share of developed land is also statistically significant, while the time-to-permit does not seem to impact housing supply.

Table A2.2 presents our estimates of the housing supply elasticity that address the endogeneity of tax rates. Columns (1) and (2) show the OLS and 2SLS estimations of equation (A.2), while columns (3) and (4) show the OLS and 2SLS estimations of equation (A.3). Taking the ratio of the point estimates of columns (1) and (3), or (2) and (4), yields an implied estimate of the price elasticity of housing supply. The OLS estimate is lower in our border municipality sample compared to the full set of municipalities (see column 3 of Table A2.1). The IV implied elasticity equals 0.33, half the size of the OLS estimate. We retain this value for our calibration of the structural model.

Table A2.2: Supply equation IV estimates

	Spatial difference of dwelling space growth rate		Spatial difference of rental price residual growth rate	
	(1)	(2)	(3)	(4)
Dwelling space elasticity of income taxes ($\widehat{\eta}^{s,\tau}$)	-1.125*** (0.284)	-0.505 (0.411)		
Rental price elasticity of income taxes ($\widehat{\eta}^{p,\tau}$)			-1.465*** (0.321)	-1.542*** (0.523)
Implied Housing Supply Elasticity $(\widehat{\eta}^{s,p})_{OLS}$: 0.768*** (0.257)				
Implied Housing Supply Elasticity $(\widehat{\eta}^{s,p})_{IV}$: 0.327 (0.289)				
Amenity controls	YES	YES	YES	YES
Fiscal controls	YES	YES	YES	YES
Origin canton FE	YES	YES	YES	YES
# of observations	3,534	3,534	3,534	3,534
# of origin clusters	814	814	814	814
# of dest. clusters	814	814	814	814
Instrument	–	Canton tax differential	–	Canton tax differential
Kleibergen-Paap F Stat	–	21.81	–	21.81
Estimator	OLS	2SLS	OLS	2SLS

Notes: Two-way cluster robust standard errors at origin and destination municipality level in parentheses. The sample consist of cross-canton pairs of municipalities with a pairing road distance of 10 km. Regressions are weighted by the log population in 2000 of the smallest municipality in the pair. Columns (1) and (2) come from the estimation of equation (A.2), while columns (3) and (4) come from the estimation of equation (A.3). The implied housing supply elasticity $(\widehat{\eta}^{s,p})_{OLS}$ comes from the ratio of point estimate in column (1) and column (3). The implied housing supply elasticity $(\widehat{\eta}^{s,p})_{IV}$ comes from the ratio of point estimate in column (2) and column (4). The corresponding standard errors are calculated using the delta method.Amenity controls include indices of accessibility, exposure to natural risks, architectural heritage, and hours of sunlight. Fiscal controls include the interactions between the income tax rate and dummy variables NCM, PT, and TT. ***p<0.01, **p<0.05, *p<0.1.

A.3 Building blocks of the empirical model

In this Section, we gradually build up to our preferred specification, the long first-differences cross-border IV design, starting from panel OLS estimations for the full sample of Swiss municipalities. We begin the analysis by estimating a standard panel model featuring municipality and canton-year fixed effects. We then turn to an instrumental variable strategy to address the endogeneity of local tax rates.

A.3.1 OLS estimation

As a natural starting point, we first estimate a standard panel-data model:

$$\ln y_{jt} = \eta^y \ln \tau^y_{jt} + \phi_j + \phi_{ct} + \varepsilon^y_{jt}, \tag{A.4}$$

where y_{jt} is either the count of taxpayers belonging to a specific household type, or the price of housing in municipality j and canton c at time $t \in [2004, ..., 2014]$, and $\ln \tau^y_{jt}$ is the log consolidated (canton + municipal + church) tax rate as relevant to the associated regressand y. Municipality fixed effects, ϕ_j, absorb time-invariant factors, and ϕ_{ct} is a canton-year fixed effect such that our identification comes from municipalities in the same canton changing their tax multipliers at different points in time. Standard errors are clustered at the municipality level. Since housing price data are more reliable in larger municipalities, we weight our main regressions by the log of population in 2000.

A.3.2 Instrumenting local tax rates

Eventually, we restrict the sample to municipalities that are located close to a canton border, following the IV approach developed in Parchet (2019). We apply a cross-canton spatial difference estimation strategy, instrumenting the differential in the consolidated tax rate with the differential in the cantonal tax rate.

Our baseline panel-data estimating equation thus becomes (see also equations 17a– 17g):

$$\nabla \ln y_{jkt} = \eta^y \nabla \ln \tau^y_{jkt} + \phi_{jk} + \phi_{ct} + \varepsilon^y_{jkt}, \tag{A.5}$$

where ∇ indicates the cross-canton spatial difference within pairs of municipalities jk in two neighboring cantons, c and d, with $(j \in c) \neq (k \in d \neq c)$. Municipality-pair directional fixed effects, ϕ_{jk}, absorb time-invariant factors, and ϕ_{ct} is an origin canton-year fixed effect such that our identification comes from municipalities in the same canton but bordering different neighboring cantons. Differentials in local tax rates, $\nabla \ln \tau_{jkt}$, are instrumented with the corresponding differential in canton-level tax rates $\nabla \ln \tau_{cdt}$. Standard errors are clustered two-ways, at the level of origin and destination municipalities. Regressions are weighted by the log of population in 2000 of the smaller municipality in the pair.

A.3.3 Results

Table A3.3 presents a range of estimation results, beginning with OLS estimations on the full data sample and then gradually building up towards our preferred empirical model.

First, we report estimates from the panel OLS models featuring municipality and a canton-year fixed effects. For the results shown in Panel A of Table A3.3, we use all municipalities for which housing prices are available. In Panel B, we restrict the sample to the border municipalities later retained in IV estimations. The two samples yield very similar results: a mostly negative correlation between changes in local tax rates and changes in taxpayer counts, with the magnitude of the correlation increasing with income. Similarly, local tax increases are associated with lower housing prices.

Panel C of Table A3.3 presents results for the cross-border spatial difference specification of equation (A.5). Most of the estimated coefficients are smaller in absolute value than in Panel B, suggesting that spatial differencing controls for time-varying confounding factors that are common among proximate jurisdictions.

Instrumenting local tax differentials with canton-level tax differentials in Panel D of Table A3.3 does not change the estimated coefficients by much. We still find negative and statistically significant tax base elasticities for households without children and above-median income. For below-median-income households without children, we moreover observe that instrumenting turns the tax elasticity from negative to positive. This is consistent with two-way causation, whereby the arrival of such households allows municipalities to lower their tax rates as these households' (current) consumption of local public goods is below-average, but such households nonetheless prefer to move to municipalities with higher tax rates and thus more generous provision of local public goods.

Conversely, estimated tax-base and capitalization elasticities are biased towards zero to the extent that it takes time for households to move and for rental prices to adjust. In Panel E of Table A3.3, we therefore augment equation (A.5) with two lags, themselves instrumented with the corresponding lags of the cross-border canton-level tax differentials. We report implied long-term effects and their standard errors, based on the sum of the contemporaneous and the lagged coefficients. As expected, estimated three-year tax-base and house-price capitalization elasticities are larger in absolute value than their one-year counterparts.

Next, we turn to the long first-differences model. Panel F of Table A3.3 presents estimates based on differences between the averages for 2013-2014 and 2004-2005. Results are qualitatively similar to the distributed lag model presented in Panel E, with estimated tax base elasticities of households without children and the housing price elasticity larger in the 10-year first-difference model. In Panel G, we in addition control for differences in amenities across municipalities, and, in the rental-price regressions, for differences in topographical constraints and local administrative efficiency. Estimated coefficients are not sensitive to the inclusion of these variables as controls.

Finally, we test the validity of our instrumental variable strategy with an event-study design. Specifically, we exploit the panel structure of our data to explore the dynamics of the effect of our instrument over time, both before and after changes in canton-level tax rates. Building on equation (A.5), we estimate the following distributed lag model:

$$\nabla \ln N_{jkt}^{fm} = \sum_{n=-2}^{+6} \eta_n^{fm} \nabla \ln \tau_{cdt-n}^{fm} + \phi_{jk} + \phi_{ct} + \varepsilon_{jkt}^{fm}, \qquad \text{(A.6)}$$

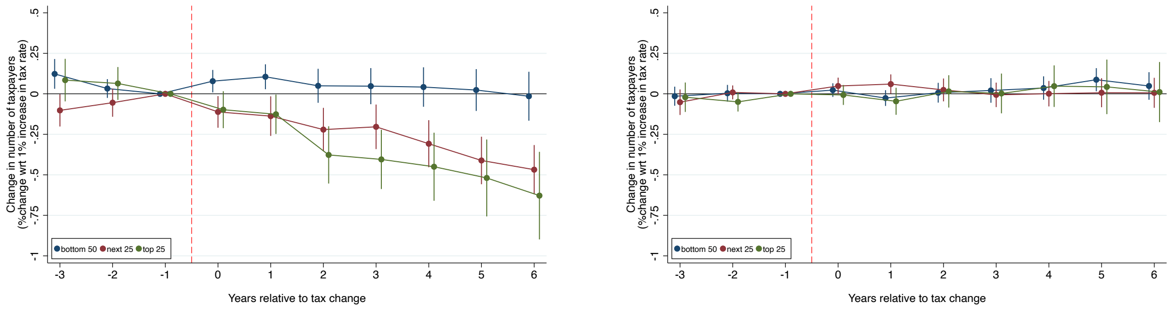
where ϕ_{jk} are municipality-pair directional fixed effects, ϕ_{ct} is an origin canton-year fixed effect and $t \in [2004, ..., 2014]$. To estimate this model, we extend our tax rate data to the

Table A3.3: Tax base and rental price elasticities: OLS and 2SLS results

	Households without children			Households with children			Housing Prices
	Bottom 50	Next 25	Top 25	Bottom 50	Next 25	Top 25	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fixed effect panel model							
***Panel A:* OLS estimation on all municipalities**							
Income tax rate	-0.056	-0.339***	-0.693***	0.275***	0.098	-0.228***	-0.177***
	(0.039)	(0.051)	(0.059)	(0.096)	(0.072)	(0.066)	(0.045)
# of observations	18,477	18,477	18,477	18,477	18,477	18,477	18,317
# of municipalities	1,815	1,815	1,815	1,815	1,815	1,815	1,815
Municipality fixed effect				YES			
Canton-year fixed effect				YES			
***Panel B:* OLS estimation on border municipalities**							
Income tax rate	-0.051	-0.333***	-0.688***	0.128	-0.013	-0.310***	-0.202***
	(0.055)	(0.070)	(0.083)	(0.145)	(0.096)	(0.094)	(0.056)
# of observations	8,342	8,342	8,342	8,342	8,342	8,342	8,306
# of municipalities	813	813	813	813	813	813	813
Municipality fixed effect				YES			
Canton-year fixed effect				YES			
***Panel C:* OLS pairwise difference estimation on border municipalities**							
Income tax rate	-0.029	-0.225***	-0.639***	0.032	0.050*	-0.043	-0.146***
	(0.042)	(0.059)	(0.075)	(0.023)	(0.028)	(0.056)	(0.039)
# of observations	38,874	38,874	38,874	38,874	38,874	38,874	34,584
# of municipalities	814	814	814	814	814	814	813
Municipality-pair directional fixed effect				YES			
Origin canton-year fixed effect				YES			
***Panel D:* IV pairwise difference estimation on border municipalities**							
Income tax rate	0.095	-0.159*	-0.664***	0.029	0.048	-0.014	-0.147**
	(0.058)	(0.082)	(0.150)	(0.024)	(0.031)	(0.068)	(0.075)
# of observations	38,874	38,874	38,874	38,874	38,874	38,874	34,584
# of municipalities	814	814	814	814	814	814	813
Kleibergen-Paap F Stat	166.95	146.23	81.84	19601.32	6097.84	68.32	54.80
Municipality-pair directional fixed effect				YES			
Origin canton-year fixed effect				YES			
Instrument				Cantonal income tax rate differential			
***Panel E:* IV pairwise difference estimation on border municipalities: distributed lag model**							
Income tax rate	0.094	-0.325***	-0.997***	0.043	0.028	0.005	-0.168**
	(0.078)	(0.109)	(0.187)	(0.031)	(0.038)	(0.084)	(0.082)
# of observations	38,874	38,874	38,874	38,874	38,874	38,874	34,584
# of municipalities	814	814	814	814	814	814	813
Kleibergen-Paap F Stat	22.90	45.35	15.75	1785.97	961.78	11.47	11.20
Municipality-pair directional fixed effect				YES			
Origin canton-year fixed effect				YES			
Instrument				Cantonal income tax rate differential			
Long difference model between the averages 2013-2014 and 2004-2005							
***Panel F:* IV pairwise difference estimation on border municipalities**							
Income tax rate	0.088	-0.285**	-1.334***	0.047	0.027	-0.061	-0.368***
	(0.095)	(0.139)	(0.241)	(0.047)	(0.061)	(0.113)	(0.156)
# of observations	3,534	3,534	3,534	3,534	3,534	3,534	3,534
# of municipalities	814	814	814	814	814	814	814
Kleibergen-Paap F Stat	202.61	147.78	134.91	7998.86	4943.75	420.24	122.44
Controls				NO			
Origin canton fixed effect				YES			
Instrument				Cantonal income tax rate differential			
***Panel G:* IV pairwise difference estimation on border municipalities**							
Income tax rate	0.092	-0.306**	-1.271***	0.075	0.068	-0.088	-0.341**
	(0.095)	(0.137)	(0.247)	(0.046)	(0.059)	(0.110)	(0.166)
# of observations	3,534	3,534	3,534	3,534	3,534	3,534	3,534
# of municipalities	814	814	814	814	814	814	814
Kleibergen-Paap F Stat	202.61	147.78	134.91	7998.86	4943.75	420.24	122.44
Controls				YES			
Origin canton fixed effect				YES			
Instrument				Cantonal income tax rate differential			

Notes: Cluster robust standard errors reported in parentheses. In panels A and B, standard errors are clustered at the municipality level. In the remaining panels, standard errors are two-way clustered at origin and destination municipality level. In municipalities with zero taxpayer in a given category, ln(0) has been replaced by 0 (15 occurrences). Regressions in panel E employ a standard distributed lag approach estimating $\nabla \ln y_{jkt} = \eta^y \nabla \ln \tau_{jkt} + \sum_{s=1}^{2} \beta_s \left(\nabla \ln \tau_{jkt-s} - \nabla \ln \tau_{jkt}\right) + \phi_{jk} + \phi_{ct} + \varepsilon_{jkt}$, so that we may interpret $\hat{\eta}$ directly as the long-term effect. Controls in Panel G include (time-invariant) indices of accessibility, exposure to natural risks, architectural heritage, and hours of sunlight. In column (7) we in addition control for topographical constraints and local administrative efficiency. ***p<0.01, **p<0.05, *p<0.1.

Figure A3.1: The effect of canton-level tax changes on tax bases



(a) Households without children

(b) Households with children

Notes: The figures show the cumulative effect of our instrument on the number of households without children in different income groups (upper panel) and on the number of households with children in different income groups (lower panel). It plots the sum of the coefficients and their corresponding standard errors from estimating equation (A.6). Standard errors are clustered two-ways, at the level of origin and destination municipalities. Regressions are weighted by the log of population in 2000 of the smaller municipality in the pair.

period 1998 to 2016.

Figure A3.1 shows the cumulative effect of canton-level tax differentials on (a) the number of households without children (in our three income groups) and (b) the number of households with children (in our three income groups). Interpreting our panel estimates as a combination of individual event studies, and as a check of the assumption of common pre-trends, we plot the sum of the coefficients and their corresponding standard errors from 3 years before a tax change (the reference year being -1) to 6 year after.[64] We find no evidence of changes in the municipality-level number of high-income and potentially mobile households in advance of canton-level tax changes. Results also show that it is above-median income households without children who move in response to tax differentials, whereas households with children do not respond statistically significantly to local tax changes. Absolute values of the estimated elasticities grow over time after the tax change, consistent with delayed mobility responses.

[64]Distributed lag models are equivalent to an event study design in which all years after $+7$ are binned together, and similarly for all years prior to -2, See Schmidheiny and Siegloch (2020).

A.4 Supplementary tables

Table A4.4: Structural parameter and elasticity estimates for different values of $\eta^{s,p}$ and θ

	Households without children			Households with children		
	Bottom 50 (1)	Next 25 (2)	Top 25 (3)	Bottom 50 (4)	Next 25 (5)	Top 25 (6)
Panel A: $\eta^{s,p} = 0$						
Preference for public goods (δ)		0.012			0.171	
		(0.022)			(0.158)	
Idiosyncratic location preference dispersion parameter (λ)		5.018			0.347	
		(0.431)			(0.186)	
Tax base elasticities	0.171	-0.243	-0.747	0.094	0.061	0.020
	(0.037)	(0.035)	(0.056)	(0.017)	(0.015)	(0.033)
Marginal willingness to pay rent	-0.324	-0.567	-1.148	0.133	0.164	-0.134
	(0.036)	(0.063)	(0.090)	(0.247)	(0.401)	(0.567)
Resident incidence	0.034	-0.048	-0.149	0.269	0.176	0.058
	(0.005)	(0.009)	(0.011)	(0.120)	(0.122)	(0.123)
Landlord incidence ($\eta^{p,\tau*}$)			-0.394			
			(0.034)			
Panel B: $\eta^{s,p} = 1$						
Preference for public goods (δ)		0.137			0.125	
		(0.008)			(0.046)	
Idiosyncratic location preference dispersion parameter (λ)		9.711			0.844	
		(0.678)			(0.301)	
Tax base elasticities	0.121	-0.220	-1.009	0.090	0.049	-0.033
	(0.035)	(0.038)	(0.069)	(0.016)	(0.015)	(0.038)
Marginal willingness to pay rent	-0.138	-0.245	-0.690	0.044	0.021	-0.337
	(0.016)	(0.027)	(0.038)	(0.067)	(0.108)	(0.153)
Resident incidence	0.012	-0.023	-0.104	0.106	0.058	-0.039
	(0.003)	(0.004)	(0.005)	(0.031)	(0.032)	(0.033)
Landlord incidence ($\eta^{p,\tau*}$)			-0.164			
			(0.013)			
Panel C: $\theta = 0$						
Preference for public goods (δ)		0.077			0.197	
		(0.023)			(0.127)	
Idiosyncratic location preference dispersion parameter (λ)		3.579			0.400	
		(0.253)			(0.157)	
Tax base elasticities	0.182	-0.310	-1.003	0.095	0.051	-0.018
	(0.040)	(0.034)	(0.072)	(0.017)	(0.018)	(0.040)
Marginal willingness to pay rent	-0.211	-0.584	-1.469	0.112	0.009	-0.493
	(0.042)	(0.051)	(0.071)	(0.165)	(0.236)	(0.324)
Resident incidence	0.051	-0.086	-0.280	0.238	0.127	-0.044
	(0.009)	(0.010)	(0.012)	(0.081)	(0.083)	(0.084)
Landlord incidence ($\eta^{p,\tau*}$)			-0.332			
			(0.027)			
Panel D: $\theta = 1$						
Preference for public goods (δ)		0.068			0.173	
		(0.023)			(0.114)	
Idiosyncratic location preference dispersion parameter (λ)		3.579			0.400	
		(0.253)			(0.157)	
Tax base elasticities	0.182	-0.310	-1.003	0.095	0.051	-0.018
	(0.040)	(0.034)	(0.072)	(0.017)	(0.018)	(0.040)
Marginal willingness to pay rent	-0.211	-0.584	-1.469	0.112	0.009	-0.493
	(0.042)	(0.051)	(0.071)	(0.165)	(0.236)	(0.324)
Resident incidence	0.051	-0.086	-0.280	0.238	0.127	-0.044
	(0.009)	(0.010)	(0.012)	(0.081)	(0.083)	(0.084)
Landlord incidence ($\eta^{p,\tau*}$)			-0.332			
			(0.027)			

Table A4.5: Tax base elasticities for households without children: pensioners and non-pensioners

	Households without children					
	Non-pensioners			Pensioners		
	Bottom 50	Next 25	Top 25	Bottom 50	Next 25	Top 25
	(1)	(2)	(3)	(4)	(5)	(6)
Fixed effect panel model						
***Panel A:* OLS estimation on all municipalities**						
Income tax rate	-0.074	-0.397***	-0.733***	0.028	-0.127	-0.580***
	(0.049)	(0.067)	(0.069)	(0.112)	(0.156)	(0.176)
# of observations	17,652	17,652	17,652	17,646	17,646	17,646
# of municipalities	1,815	1,815	1,815	1,815	1,815	1,815
Municipality fixed effect	YES					
Canton-year fixed effect	YES					
***Panel B:* OLS estimation on border municipalities**						
Income tax rate	-0.081	-0.378***	-0.660***	0.138	0.032	-0.431
	(0.073)	(0.091)	(0.101)	(0.193)	(0.295)	(0.321)
# of observations	8,098	8,098	8,098	8,092	8,092	8,092
# of municipalities	813	813	813	813	813	813
Municipality fixed effect	YES					
Canton-year fixed effect	YES					
***Panel C:* OLS pairwise difference estimation on border municipalities**						
Income tax rate	-0.042	-0.273***	-0.860***	0.172***	-0.174**	-0.290**
	(0.044)	(0.080)	(0.101)	(0.062)	(0.082)	(0.129)
# of observations	36,256	36,256	36,256	36,228	36,228	36,228
# of municipalities	814	814	814	814	814	814
Municipality-pair directional fixed effect	YES					
Origin canton-year fixed effect	YES					
***Panel D:* IV pairwise difference estimation on border municipalities**						
Income tax rate	0.062	-0.237**	-0.970***	0.142**	-0.271***	-0.283*
	(0.070)	(0.109)	(0.177)	(0.067)	(0.098)	(0.159)
# of observations	36,256	36,256	36,256	36,228	36,228	36,228
# of municipalities	814	814	814	814	814	814
Kleibergen-Paap F Stat	230.43	188.08	168.30	3855.03	1433.49	348.25
Municipality-pair directional fixed effect	YES					
Origin canton-year fixed effect	YES					
Instrument	Cantonal income tax rate differential					
***Panel E:* IV pairwise difference estimation on border municipalities: distributed lag model**						
Income tax rate	0.238**	-0.437***	-1.344***	0.061	-0.365***	-0.428**
	(0.107)	(0.160)	(0.234)	(0.073)	(0.118)	(0.193)
# of observations	36,256	36,256	36,256	36,228	36,228	36,228
# of municipalities	814	814	814	814	814	814
Kleibergen-Paap F Stat	12.71	44.98	19.16	482.38	242.07	36.60
Municipality-pair directional fixed effect	YES					
Origin canton-year fixed effect	YES					
Instrument	Cantonal income tax rate differential					
Long difference model between the averages 2013-2014 and 2004-2005						
***Panel F:* IV pairwise difference estimation on border municipalities**						
Income tax rate	0.304**	-0.426*	-1.730***	0.224***	-0.376***	-0.453**
	(0.148)	(0.227)	(0.302)	(0.084)	(0.131)	(0.227)
# of observations	3,530	3,530	3,530	3,530	3,530	3,530
# of municipalities	813	813	813	813	813	813
Kleibergen-Paap F Stat	103.74	95.82	157.33	7070.49	1819.75	851.78
Controls	NO					
Origin canton fixed effect	YES					
Instrument	Cantonal income tax rate differential					
***Panel G:* IV pairwise difference estimation on border municipalities**						
Income tax rate	0.355**	-0.424*	-1.681***	0.220***	-0.378***	-0.433*
	(0.154)	(0.232)	(0.310)	(0.084)	(0.128)	(0.227)
# of observations	3,530	3,530	3,530	3,530	3,530	3,530
# of municipalities	813	813	813	813	813	813
Kleibergen-Paap F Stat	103.74	95.82	157.33	7070.49	1819.75	851.78
Controls	YES					
Origin canton fixed effect	YES					
Instrument	Cantonal income tax rate differential					

Notes: Cluster robust standard errors reported in parentheses. In panels A and B, standard errors are clustered at the municipality level. In the remaining panels, standard errors are two-way clustered at origin and destination municipality level. In municipalities with zero taxpayer in a given category, $\ln(0)$ has been replaced by 0. Regressions in panel E employ a standard distributed lag approach estimating $\nabla \ln y_{jkt} = \eta^y \nabla \ln \tau_{jkt} + \sum_{s=1}^{2} \beta_s \left(\nabla \ln \tau_{jkt-s} - \nabla \ln \tau_{jkt}\right) + \phi_{jk} + \phi_{ct} + \varepsilon_{jkt}$, so that we may interpret $\hat{\eta}$ directly as the long-term effect. Controls in panel G include (time-invariant) indices of accessibility, exposure to natural risks, architectural heritage, and hours of sunlight. ***p<0.01, **p<0.05, *p<0.1.

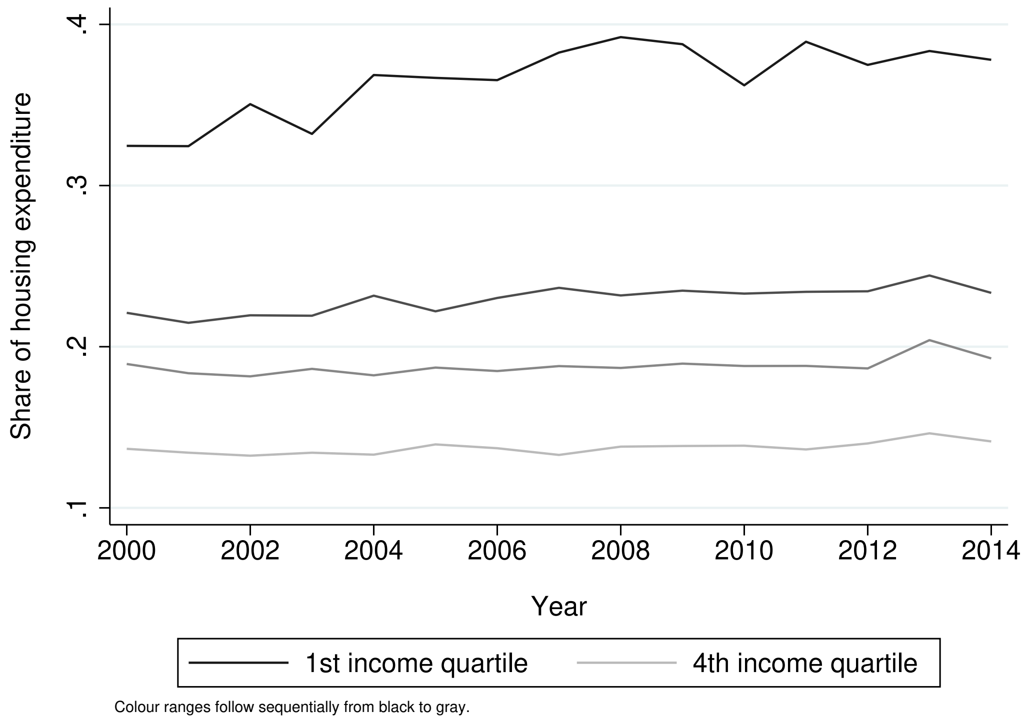
Table A4.6: Structural parameter and elasticity estimates: pensioners and non-pensioners

	Households without children						Households with children		
	Non-pensioners			Pensioners					
	Bottom 50	Next 25	Top 25	Bottom 50	Next 25	Top 25	Bottom 50	Next 25	Top 25
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
***Panel A:* Calibration using:**									
Swiss Household Panel									
Housing tastes (α)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Minimal housing expenditure (ν_h/h^*)	0.76	0.61	0.45	0.76	0.57	0.42	0.78	0.64	0.50
Expenditure share on housing (S)	0.37	0.23	0.16	0.40	0.24	0.17	0.37	0.25	0.18
Aggregate housing share (π)	0.09	0.10	0.12	0.09	0.11	0.12	0.11	0.12	0.14
Tax Rate Database									
Income tax rates (τ)	0.12	0.13	0.18	0.09	0.11	0.16	0.05	0.07	0.13
Simultaneous equation IV estimates (Table A2.2)									
Housing supply price elasticity (η_s)					0.33				
Tax Base Database									
Taxpayer population share (s)	0.30	0.11	0.09	0.15	0.06	0.03	0.05	0.08	0.12
Share of tax base (γ)	0.12	0.13	0.23	0.06	0.05	0.07	0.02	0.07	0.25
Other parameter									
Congestion parameter (θ)					0.50				
***Panel B:* Structural parameters**									
Preference for public goods ($\bar{\delta}$)		0.078			0.044			0.076	
		(0.016)			(0.018)			(0.073)	
Idiosyncratic location preference dispersion parameter (λ)		10.335			4.830			0.555	
		(0.772)			(0.408)			(0.214)	
***Panel C:* Structural elasticities**									
Tax base elasticities	0.337	-0.309	-1.272	0.235	-0.107	-0.540	0.086	0.041	-0.021
	(0.058)	(0.052)	(0.085)	(0.026)	(0.041)	(0.069)	(0.016)	(0.016)	(0.035)
Marginal willingness to pay rent	-0.260	-0.428	-0.918	-0.226	-0.410	-0.892	-0.029	-0.097	-0.488
	(0.024)	(0.040)	(0.057)	(0.027)	(0.048)	(0.065)	(0.099)	(0.159)	(0.222)
Resident incidence	0.033	-0.030	-0.123	0.049	-0.022	-0.112	0.155	0.075	-0.037
	(0.004)	(0.006)	(0.008)	(0.006)	(0.008)	(0.009)	(0.048)	(0.049)	(0.050)
Landlord incidence ($\eta^{p,\tau*}$)					-0.327				
					(0.022)				

Notes: Standard errors reported in parentheses.

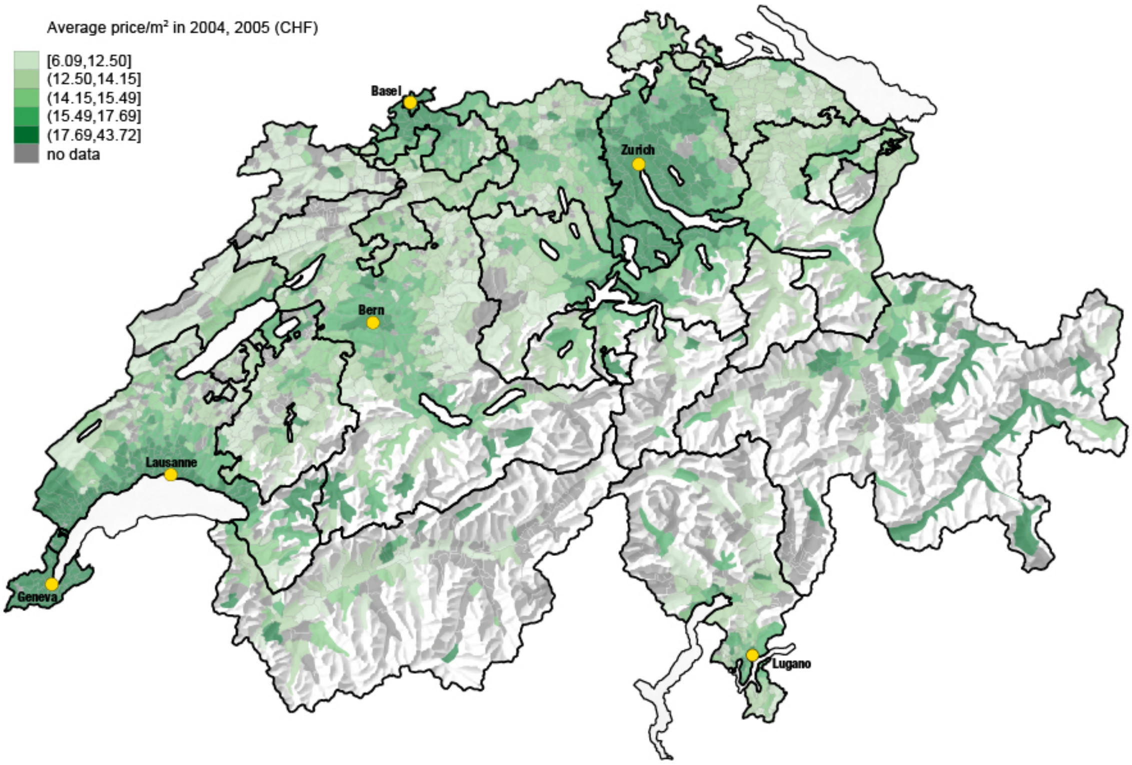
A.5 Supplementary figures

Figure A5.2: Expenditure shares on housing

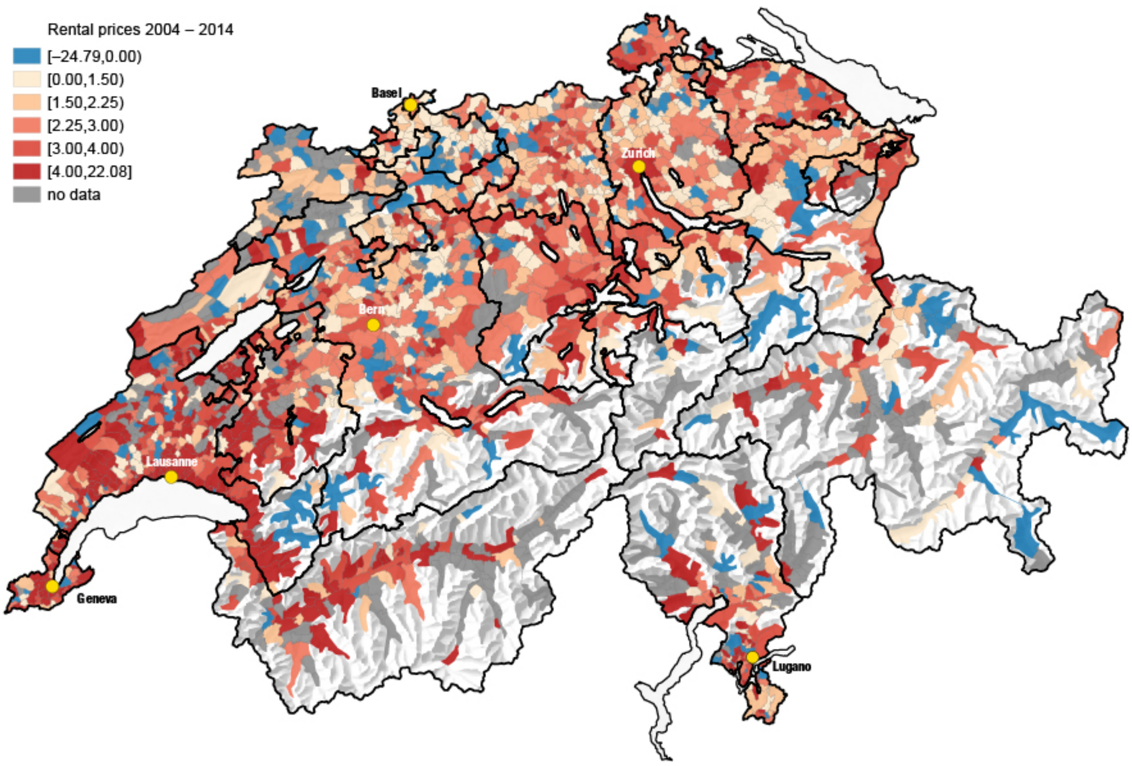


Notes: This figure reports the evolution of housing expenditure shares (defined as annual rent over disposable income) by income quartile. Source: Swiss Household Panel data.

Figure A5.3: The geography of housing prices in Switzerland



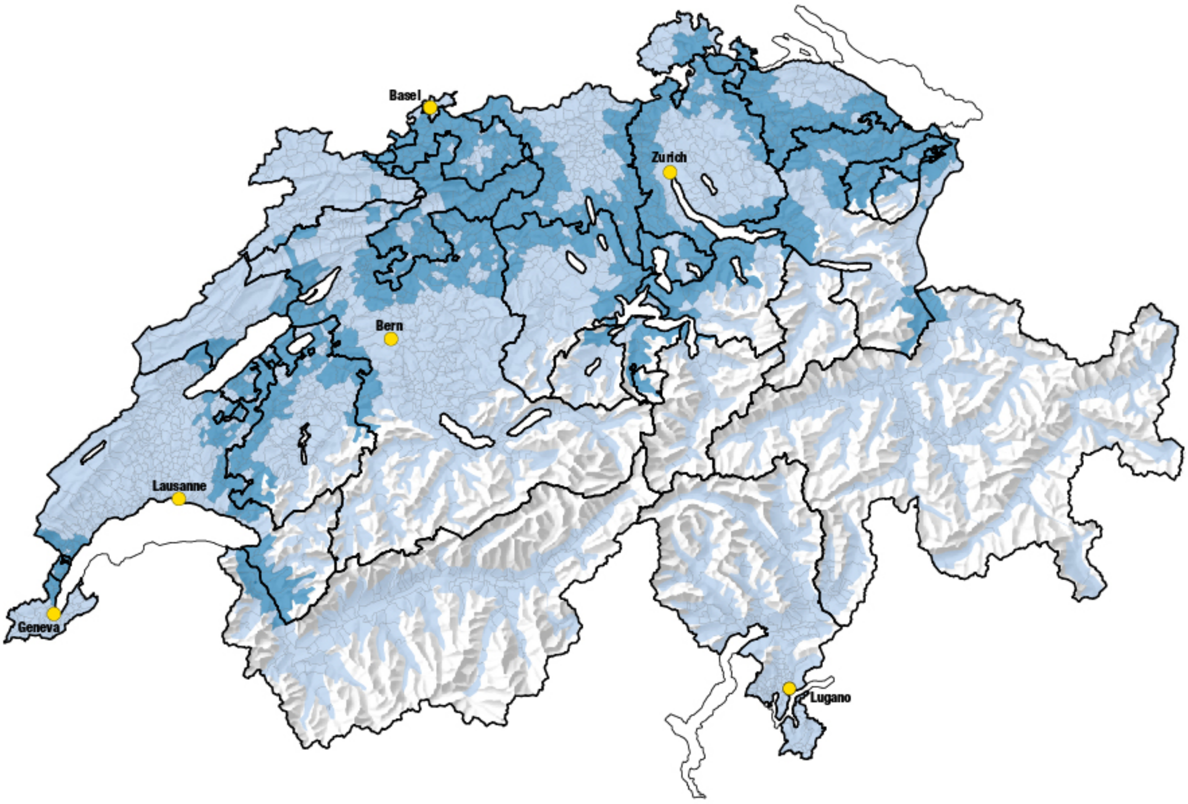
(a)



(b)

Notes: Panel (a) depicts the average rental prices in CHF per square meter, for the initial years 2004 and 2005. Panel (b) represents the difference in rental prices between the average of 2004, 2005 and 2013, 2014. The averages over the initial and final period serve to ensure the largest sample of municipalities. The white lines represent municipal administrative borders. The black lines represent cantonal administrative borders.

Figure A5.4: IV estimation sample at cantonal borders



Notes: Black lines are cantonal borders. Dark blue municipalities used in the instrumental variable estimations. They are selected using a 10km road distance criteria between municipality population centroids.

Who Bears the Burden of Local Taxes?

– Online Appendix –

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March 9, 2022

Contents

W.1 Technical derivations

This section contains the detailed derivations of our baseline model. In Subsection W.1.1, we characterize the individual's marginal willingness to pay rent (MWPR) for a small tax change. In Subsection W.1.2, we derive our system of equations characterizing the effect of a small change in the tax rate on the equilibrium number of residents in different income classes and on equilibrium housing prices. In Subsection W.1.3, we derive the incidence of a change in the tax rate on residents' and landlords' welfare.

W.1.1 The marginal willingness to pay rent (MWPR)

The optimization problem of household i of type $\{f, m\}$ and residing in location j can be written as follows:

$$\max_{h_{fmj}, z_{fmj}} U_{ifmj} = \alpha \ln(h_{fmj} - \nu_h^f) + (1-\alpha)\ln(z_{fmj} - \nu_z^f) + \delta \ln(g_j - \nu_g^f) + \ln(A_{ifj})$$
$$\text{s.t.} \quad z_{fmj} + p_j h_{fmj} = (1-\tau_j) w_m \,. \tag{W.1}$$

The individual Marshallian demands of this program are

$$h^*_{fmj} = \nu_h^f + \frac{\alpha\left[(1-\tau_j)w_m - p_j\nu_h^f - \nu_z^f\right]}{p_j}\text{, and} \tag{W.2}$$
$$z^*_{fmj} = \nu_z^f + (1-\alpha)\left[(1-\tau_j)w_m - p_j\nu_h^f - \nu_z^f\right]\,, \tag{W.3}$$

where $\nu_h^f \geq 0$, $\nu_z^f \geq 0$ and $\nu_g^f \geq 0$ can be thought of, respectively, as existential needs for housing, the non-housing composite good and the public good, which may differ depending on family status. For simplicity, and without loss of generality, we assume $\nu_z^f = 0$. Unlike with a standard Cobb-Douglas utility, the elasticity of individual housing demand with respect to prices is not constant. It is given by

$$\left|\frac{\partial h^*_{fmj}}{\partial p_j}\frac{p_j}{h^*_{fmj}}\right| = 1 - \frac{(1-\alpha)\nu_h^f}{h^*_{fmj}}\,,$$

which is equal to one only if $\nu_h^f = 0$ and less than one otherwise.

It is also useful to rewrite the individual Marshallian demand for housing space (W.2) as fraction of income spent on housing

$$S_{fmj} = (1-\alpha)S^{min}_{fmj} + \alpha\,, \tag{W.4}$$

where

$S_{fmj} \equiv p_j h^*_{fmj}/(1-\tau_j)w_m$ is the fraction of income spend on housing consumption and $S^{min}_{fmj} \equiv p_j \nu^f/(1-\tau_j)w_m$ is the fraction of income spent on minimum housing consumption.

The household's indirect utility, given its choice of location j, is

$$V_{ifmj} = \kappa + \ln\left[(1-\tau_j)w_m - p_j\nu_h^f\right] - \alpha\ln(p_j) + \delta\ln(g_j - \nu_g^f) + \ln(A_{ifj})\,, \tag{W.5}$$

where $\kappa = \alpha \ln(\alpha) + (1-\alpha)\ln(1-\alpha)$.

We define as marginal willingness to pay rent the change in the housing price ('bid-rent' price change) a household of type $\{f, m\}$ would require to be indifferent toward a given change in the local tax rate:

$$dV_{ifmj} = \left[\frac{\partial V_{ifmj}}{\partial p_j} dp_j + \frac{\partial V_{ifmj}}{\partial \tau_j} d\tau_j + \frac{\partial V_{ifmj}}{\partial g_j} dg_j \right]$$
$$dV_{ifmj} = \left[-\alpha \left(\frac{h^*_{fmj}}{h^*_{fmj} - \nu^f_h} \right) \frac{dp_j}{p_j} - \alpha \frac{\tau_j}{(1-\tau_j)S_{fmj}} \left(\frac{h^*_{fmj}}{h^*_{fmj} - \nu^f_h} \right) \frac{d\tau_j}{\tau_j} + \delta \left(\frac{g_j}{g_j - \nu^f_g} \right) \frac{dg_j}{g_j} \right]$$
$$dV_{ifmj} = \alpha \left(\frac{h^*_{fmj}}{h^*_{fmj} - \nu^f_h} \right) \left[-\frac{dp_j}{p_j} - \frac{\tau_j}{(1-\tau_j)S_{fmj}} \frac{d\tau_j}{\tau_j} + \frac{\delta}{\alpha} \left(\frac{g_j}{g_j - \nu^f_g} \right) \left(1 - \frac{\nu^f_h}{h^*_{fmj}} \right) \frac{dg_j}{g_j} \right].$$

Hence,

$$\left. \frac{dp_j}{d\tau_j} \frac{\tau_j}{p_j} \right|_{dV_{ifmj}=0} = - \left[\frac{\tau_j}{(1-\tau_j)S_{fmj}} - \frac{\delta}{\alpha} \left(\frac{g_j}{g_j - \nu^f_g} \right) \left(1 - \frac{\nu^f_h}{h^*_{fmj}} \right) \frac{dg_j}{d\tau_j} \frac{\tau_j}{g_j} \right], \tag{W.6}$$

where

$$\frac{dg_j}{d\tau_j} \frac{\tau_j}{g_j} = 1 + \sum_f \sum_m (\gamma_{fmj} - \theta s_{fmj}) \frac{dN_{fmj}}{N_{fmj}} \frac{\tau_j}{d\tau_j}, \tag{W.7}$$

with $\gamma_{fmj} \equiv w_m N_{fmj} / \sum_f \sum_m w_m N_{fmj}$ and $s_{fmj} \equiv N_{fmj}/N_j$.

W.1.2 Equilibrium

The model's equilibrium is characterized by three main equations:

$$N_j = \sum_f \sum_m N_{fmj} \text{ with } N_{fmj} = \frac{\exp(\lambda_f u_{fmj})}{\sum_{j'} \exp(\lambda_f u_{fmj'})} \quad \forall j \in J, \tag{W.8a}$$

$$H^d_j = H^s_j \text{ with } H^d_j = \sum_f \sum_m N_{fmj} \cdot h^*_{fmj} \text{ and } H^s_j = B_j p_j^{\eta^{s,p}_j} \quad \forall j \in J, \tag{W.8b}$$

$$g_j = \tau_j N_j^{-\theta} \sum_f \sum_m w_m N_{fmj} \quad \forall j \in J, \tag{W.8c}$$

where (W.8a) describes the population, (W.8b) governs the housing market, and (W.8c) is the government budget constraint for each jurisdiction j.

Totally log-differentiating equation (W.8c) and using the notation $\dot{x} = dx/x$ yields:

$$
\begin{aligned}
d\ln g_j &= \frac{\partial \ln g_j}{\partial \tau_j} d\tau_j + \sum_f \sum_m \frac{\partial \ln g_j}{\partial N_{fmj}} dN_{fmj} - \theta \sum_f \sum_m \frac{\partial \ln g_j}{\partial N_{fmj}} dN_{fmj} \\
\frac{dg_j}{g_j} &= \frac{d\tau_j}{\tau_j} + \sum_f \sum_m \frac{w_m dN_{fmj}}{\sum_f \sum_m w_m N_{fmj}} - \theta \sum_f \sum_m \frac{N_{fmj}}{N_j} \frac{dN_{fmj}}{N_{fmj}} \\
\dot{g}_j &= \dot{\tau}_j + \sum_f \sum_m \gamma_{fmj} \dot{N}_{fmj} - \sum_f \sum_m \theta s_{fmj} \dot{N}_{fmj} \\
\dot{g}_j &= \dot{\tau}_j + \sum_f \sum_m (\gamma_{fmj} - \theta s_{fmj}) \dot{N}_{fmj} \,.
\end{aligned}
$$

Totally log-differentiating equation (W.8b) yields:

$$
dH_j^d = dH_j^s
$$

$$
\sum_f \sum_m \left[\frac{\partial H_{fmj}^d}{\partial N_{fmj}} dN_{fmj} + N_{fmj} \frac{\partial h_{fmj}^*}{\partial p_j} dp_j + N_{fmj} \frac{\partial h_{fmj}^*}{\partial \tau_j} d\tau_j \right] = \frac{\partial H_j^s}{\partial p_j} dp_j
$$

$$
\sum_f \sum_m \left[H_{fmj}^d \dot{N}_{fmj} + H_{fmj}^d \underbrace{\left(\frac{\partial h_{fmj}^*}{\partial p_j} \frac{p_j}{h_{fmj}^*} \right)}_{-1+(1-\alpha)\frac{\nu_h^f}{h_{fmj}^*}} \dot{p}_j + H_{fmj}^d \underbrace{\left(\frac{\partial h_{fmj}^*}{\partial \tau_j} \frac{\tau_j}{h_{fmj}^*} \right)}_{-\frac{\alpha}{S_{fmj}} \frac{\tau_j}{(1-\tau_j)}} \dot{\tau}_j \right] \frac{1}{H_j^d} = \eta_j^{s,p} \dot{p}_j
$$

$$
\sum_f \sum_m \pi_{fmj} \dot{N}_{fmj} - \left(\rho_j + \eta_j^{s,p} \right) \dot{p}_j = \alpha \frac{\tau_j}{(1-\tau_j)} \sum_f \sum_m \dot{\tau}_j \frac{\pi_{fmj}}{S_{fmj}} \,,
$$

where $\pi_{fmj} \equiv H_{fmj}^d / H_j^d$ is household type $\{f, m\}$'s share of aggregate housing demand, and $\rho_j \equiv \sum_f \sum_m \pi_{fmj} (1 - (1-\alpha) \frac{\nu_h^f}{h_{fmj}^*})$ collects other parameters.

Finally, totally log-differentiating equation (W.8a) for a given municipality j and household type $\{f, m\}$, yields:

$$
\begin{aligned}
dN_{fmj} &= \lambda_f N_{fmj} \left[\frac{\partial V_{ifmj}}{\partial p_j} dp_j + \frac{\partial V_{ifmj}}{\partial \tau_j} d\tau_j + \frac{\partial V_{ifmj}}{\partial g_j} dg_j \right] \\
\frac{1}{\lambda_f} \dot{N}_{fmj} &= -\alpha \left(\frac{h_{fmj}^*}{h_{fmj}^* - \nu_h^f} \right) \dot{p}_j - \frac{\alpha \tau_j}{(1-\tau_j) S_{fmj}} \left(\frac{h_{fmj}^*}{h_{fmj}^* - \nu_h} \right) \dot{\tau}_j + \delta \left(\frac{g_j}{g_j - \nu_g^f} \right) \dot{g}_j \\
\frac{1}{\alpha \lambda_f} \left(1 - \frac{\nu_h^f}{h_{fmj}^*} \right) \dot{N}_{fmj} + \dot{p}_j &= -\frac{\tau_j}{(1-\tau_j) S_{fmj}} \dot{\tau}_j + \frac{\delta}{\alpha} \left(\frac{g_j}{g_j - \nu_g^f} \right) \left(1 - \frac{\nu_h^f}{h_{fmj}^*} \right) \left[\dot{\tau}_j + \sum_f \sum_m (\gamma_{fmj} - \theta s_{fmj}) \dot{N}_{fmj} \right] \\
\frac{1 - \delta \left(\frac{g_j}{g_j - \nu_g^f} \right) (\gamma_{fmj} - \theta s_{fmj}) \lambda_f}{\alpha \lambda_f} \left(1 - \frac{\nu_h^f}{h_{fmj}^*} \right) \dot{N}_{fmj} - \mathcal{O} + \dot{p}_j &= \left[\frac{\delta}{\alpha} \left(\frac{g_j}{g_j - \nu_g^f} \right) \left(1 - \frac{\nu_h^f}{h_{fmj}^*} \right) - \frac{\tau_j}{(1-\tau_j) S_{fmj}} \right] \dot{\tau}_j
\end{aligned}
$$

where $\mathcal{O} \equiv \frac{\delta}{\alpha} \left(\frac{g_j}{g_j - \nu_g^f} \right) \left(1 - \frac{\nu_h^f}{h_{fmj}^*} \right) \sum_{f' \neq f} \sum_{m' \neq m} (\gamma_{f'm'j} - \theta s_{f'm'j}) \dot{N}_{f'm'j}$.

Stacking the $\mathcal{F} \times \mathcal{M}$ population equations and the equilibrium rental price solution into a system of equations yields

$$
\mathbf{A_j} \dot{\mathbf{y}}_\mathbf{j} = \mathbf{B_j} \dot{\tau}_j \,, \tag{W.9}
$$

where

$$
\mathbf{A_j} = \begin{bmatrix}
\frac{1-\delta\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{11j}-\theta s_{11j})\lambda_1}{\alpha\lambda_1}\left(1-\frac{\nu_h^1}{h_{11j}^*}\right) & -\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{12j}-\theta s_{12j})\left(1-\frac{\nu_h^1}{h_{11j}^*}\right) & \cdots & -\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{\mathcal{FM}j}-\theta s_{\mathcal{FM}j})\left(1-\frac{\nu_h^1}{h_{11j}^*}\right) & 1 \\
-\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{11j}-\theta s_{11j})\left(1-\frac{\nu_h^1}{h_{12j}^*}\right) & \frac{1-\delta\left(\frac{g_j}{g_j-\nu_g^1}\right)(\gamma_{12j}-\theta s_{12j})\lambda_1}{\alpha\lambda_1}\left(1-\frac{\nu_h^1}{h_{12j}^*}\right) & \vdots & \vdots & \vdots \\
\vdots & \cdots & \ddots & \vdots & \vdots \\
-\delta\left(\frac{g_j}{g_j-\nu_g^{\mathcal{F}}}\right)(\gamma_{\mathcal{F}1j}-\theta s_{\mathcal{F}1j})\left(1-\frac{\nu_h^{\mathcal{F}}}{h_{\mathcal{FM}j}^*}\right) & \cdots & \cdots & \frac{1-\delta\left(\frac{g_j}{g_j-\nu_g^{\mathcal{F}}}\right)(\gamma_{\mathcal{FM}j}-\theta s_{\mathcal{FM}j})\lambda_{\mathcal{F}}}{\alpha\lambda_{\mathcal{F}}}\left(1-\frac{\nu_h^{\mathcal{F}}}{h_{\mathcal{FM}j}^*}\right) & 1 \\
\pi_{11j} & \cdots & \cdots & \pi_{\mathcal{FM}j} & -\left(\rho_j+\eta_j^{s,p}\right)
\end{bmatrix}
$$

and

$$
\mathbf{B_j} = \begin{bmatrix}
\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)\left(1-\frac{\nu_h^1}{h_{11j}^*}\right)-\frac{\tau_j}{(1-\tau_j)S_{11j}} \\
\vdots \\
\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^{\mathcal{F}}}\right)\left(1-\frac{\nu_h^{\mathcal{F}}}{h_{\mathcal{FM}j}^*}\right)-\frac{\tau_j}{(1-\tau_j)S_{\mathcal{FM}j}} \\
\alpha\frac{\tau_j}{(1-\tau_j)}\sum_f\sum_m\frac{\pi_{fmj}}{S_{fmj}}
\end{bmatrix}.
$$

W.1.3 Incidence

Overall renter household welfare is given by

$$
\mathcal{W}^R = \sum_f\sum_m s_{fm}\cdot\frac{1}{\lambda_f}\log\left(\sum_j \exp(\lambda_f u_{fmj})\right).
$$

The effect of a change in the tax rate of municipality j on the welfare of household type $\{f, m\}$, abstracting from general equilibrium effects on other jurisdictions, is given by

$$
\begin{aligned}
d\mathcal{W}_{fm}^R &= N_{fmj}\left[\frac{\partial u_{fmj}}{\partial p_j}dp_j + \frac{\partial u_{fmj}}{\partial\tau_j}d\tau_j + \frac{\partial u_{fmj}}{\partial g_j}dg_j\right] \\
d\mathcal{W}_{fm}^R &= \alpha N_{fmj}\left[-\left(\frac{h_{fmj}^*}{h_{fmj}^*-\nu_h^f}\right)\frac{dp_j}{p_j} - \frac{\tau_j}{(1-\tau_j)S_{fmj}}\left(\frac{h_{fmj}^*}{h_{fmj}^*-\nu_h^f}\right)\frac{d\tau_j}{\tau_j} + \frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\frac{dg_j}{g_j}\right] \\
\frac{d\mathcal{W}_{fm}^R}{d\ln\tau_j} &= \alpha N_{fmj}\left\{\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(\frac{dg_j}{d\tau_j}\frac{\tau_j}{g_j}\right) - \frac{\tau_j}{(1-\tau_j)S_{fmj}}\left(\frac{h_{fmj}^*}{h_{fmj}^*-\nu_h^f}\right) - \left(\frac{h_{fmj}^*}{h_{fmj}^*-\nu_h^f}\right)\left(\frac{dp_j^*}{d\tau_j}\frac{\tau_j}{p_j^*}\right)\right\} \\
\frac{d\mathcal{W}_{fm}^R}{d\ln\tau_j} &= \alpha N_{fmj}\left(1-\frac{\nu_h^f}{h_{fmj}}\right)^{-1}\left\{\underbrace{-\left[\frac{\tau_j}{(1-\tau_j)S_{fmj}} - \frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(1-\frac{\nu_h^f}{h_{fmj}}\right)\left(\frac{dg_j}{d\tau_j}\frac{\tau_j}{g_j}\right)\right]}_{\text{MWPR}_{fm}} - \underbrace{\left(\frac{dp_j^*}{d\tau_j}\frac{\tau_j}{p_j^*}\right)}_{\eta^{p,\tau*}}\right\},
\end{aligned} \tag{W.10}
$$

where $\eta^{p,\tau*}$ is the observed change in the equilibrium housing price. The overall change in household welfare is then $\frac{d\mathcal{W}^R}{d\ln\tau_j} = \sum_f\sum_m s_{fm}\cdot\frac{d\mathcal{W}_{fm}^R}{d\ln\tau_j}$.

Note that $\left(1-\frac{\nu_h^f}{h_{fmj}}\right) = \left(1-\frac{S_{fmj}^{min}}{S_{fmj}}\right)$, and by using (W.4), one can rewrite equation (W.10) as

$$
\frac{d\mathcal{W}_{fm}^R}{d\ln\tau_j} = N_{fmj}\left\{-\frac{\tau_j}{(1-\tau_j)}\left(\frac{1}{1-S_{fmj}^{min}}\right) + \delta\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(\frac{dg_j}{d\tau_j}\frac{\tau_j}{g_j}\right) - \left(\frac{S_{fmj}}{1-S_{fmj}^{min}}\right)\left(\frac{dp_j^*}{d\tau_j}\frac{\tau_j}{p_j^*}\right)\right\}. \tag{W.11}
$$

The producer surplus is given by

$$\mathcal{W}^L = \int_0^{H^*} \left(p_j^* - \left(\frac{x}{B_j} \right)^{1/\eta_{s,p}} \right) dx = \frac{p^* H^*}{(1+\eta_{s,p})} .$$

The change in the landlord's welfare after a change in the local tax is then

$$\begin{aligned}
d\mathcal{W}^L &= \left(\frac{1}{1+\eta_{s,p}} \right) \left(\frac{\partial \mathcal{W}^L}{\partial p_j^*} dp_j^* + \frac{\partial \mathcal{W}^L}{\partial H_j^*} dH_j^* \right) \\
d\mathcal{W}^L &= \left(\frac{1}{1+\eta_{s,p}} \right) \left(H_j^* dp_j^* + p_j^* dH_j^* \right) \\
\frac{d\mathcal{W}^L}{d\tau_j}\tau_j &= \left(\frac{p_j^* H_j^*}{1+\eta_{s,p}} \right) \left(\left(\frac{dp_j^*}{d\tau_j} \frac{\tau_j}{p_j^*} \right) + \left(\frac{dp_j^*}{d\tau_j} \frac{\tau_j}{p_j^*} \right) \left(\frac{dH_j^*}{dp_j^*} \frac{p_j^*}{H_j^*} \right) \right) \\
\frac{d\mathcal{W}^L}{d\ln\tau_j} &= p_j^* H_j^* \underbrace{\left(\frac{dp_j^*}{d\tau_j} \frac{\tau_j}{p_j^*} \right)}_{\eta_{p,\tau}^*} .
\end{aligned} \tag{W.12}$$

As a result, landlords' welfare is fully determined by changes in equilibrium rental prices.

W.2 A model with property taxes

Here, we show the derivations of a variant of our model in which local governments levy a local property tax t on rental prices, instead of an income tax.

The optimization problem of household i of type $\{f, m\}$ and residing in location j can be written as:

$$\max_{h_{fmj}, z_{fmj}} \; U_{ifmj} = \alpha \ln(h_{fmj} - \nu_h^f) + (1-\alpha)\ln(z_{fmj} - \nu_z^f) + \delta \ln(g_j - \nu_g^f) + \ln(A_{ifj})$$
$$\text{s.t.} \quad z_{fmj} + (1+t_j)p_j h_{fmj} = w_m \,. \tag{W.13}$$

The individual Marshallian demands of this program are

$$h^*_{fmj} = \nu_h^f + \frac{\alpha\left[w_m - (1+t_j)p_j\nu_h^f - \nu_z^f\right]}{(1+t_j)p_j}\text{, and} \tag{W.14}$$

$$z^*_{fmj} = \nu_z^f + (1-\alpha)\left[w_m - (1+t_j)p_j\nu_h^f - \nu_z^f\right]. \tag{W.15}$$

For simplicity, and without loss of generality, we assume $\nu_z^f = 0$. The household's indirect utility, given its choice of location j, is

$$V_{ifmj} = \underbrace{\kappa + \ln\left[w_m - (1+t_j)p_j\nu_h^f\right] - \alpha\ln((1+t_j)p_j) + \delta\ln(g_j - \nu_g^f) + \overline{A}_j}_{\equiv u_{fmj}} + \xi_{ifj}\,. \tag{W.16}$$

W.2.1 Equilibrium

The model's equilibrium is characterized by three main equations:

$$N_j = \sum_f \sum_m N_{fmj} \text{ with } N_{fmj} = \frac{\exp\left(\lambda_f u_{fmj}\right)}{\sum_{j'} \exp\left(\lambda_f u_{fmj'}\right)} \quad \forall\, j \in J\,, \tag{W.17a}$$

$$H_j^d = H_j^s \text{ with } H_j^d = \sum_f \sum_m N_{fmj} \cdot h^*_{fmj} \text{ and } H_j^s = B_j p_j^{\eta_j^{s,p}} \quad \forall\, j \in J\,, \tag{W.17b}$$

$$g_j = t_j p_j N_j^{-\theta} H_j^d \quad \forall\, j \in J\,. \tag{W.17c}$$

Totally log-differentiating equation (W.17c) and using the notation $\dot{x} = dx/x$ yields:

$$\dot{g}_j = \dot{t}_j + (1+\eta_j^{s,p})\dot{p}_j - \theta \sum_f \sum_m s_{fmj}\dot{N}_{fmj}\,. \tag{W.18}$$

Totally log-differentiating equation (W.17b) yields:

$$\sum_f \sum_m \pi_{fmj}\dot{N}_{fmj} - \left(\rho_j + \eta_j^{s,p}\right)\dot{p}_j = \frac{t_j}{1+t_j}\rho_j \dot{t}_j\,,$$

where $\pi_{fmj} \equiv H^d_{fmj}/H^d_j$ is household type $\{f, m\}$'s share of aggregate housing demand, and $\rho_j \equiv \sum_f \sum_m \pi_{fmj}(1 - (1-\alpha)\frac{\nu_h^f}{h^*_{fmj}})$ collects other parameters.

Finally, totally log-differentiating equation (W.17a) for a given municipality j and household type $\{f,m\}$, yields:

$$\frac{1}{\alpha\lambda_f}\left(1-\frac{\nu_h^f}{h^*_{fmj}}\right)\dot{N}_{fmj}+\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(1-\frac{\nu_h^f}{h^*_{fmj}}\right)\theta\sum_f\sum_m s_{fmj}\dot{N}_{fmj}+\left[1-\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(1-\frac{\nu_h^f}{h^*_{fmj}}\right)\left(1+\eta_j^{s,p}\right)\right]\dot{p}_j=\left[\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(1-\frac{\nu_h^f}{h^*_{fmj}}\right)-\frac{t_j}{1+t_j}\right]\dot{t}_j\,.$$

Stacking the $\mathcal{F}\times\mathcal{M}$ population equations and the equilibrium rental price solution into a system of equations yields

$$\mathbf{A_j}\dot{\mathbf{y}}_\mathbf{j}=\mathbf{B_j}\dot{\tau}_j\,, \tag{W.19}$$

where

$$\mathbf{A_j}=\begin{bmatrix}
\frac{1+\delta\left(\frac{g_j}{g_j-\nu_g^1}\right)\theta s_{11j}\lambda_1}{\alpha\lambda_1}\left(1-\frac{\nu_h^1}{h^*_{11j}}\right) & \frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)\left(1-\frac{\nu_h^1}{h^*_{11j}}\right)\theta s_{12j} & \cdots & \frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)\left(1-\frac{\nu_h^1}{h^*_{11j}}\right)\theta s_{\mathcal{F}\mathcal{M}j} & 1-\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)\left(1-\frac{\nu_h^1}{h^*_{11j}}\right)\left(1+\eta_j^{s,p}\right)\\
\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)\left(1-\frac{\nu_h^1}{h^*_{12j}}\right)\theta s_{11j} & \frac{1+\delta\left(\frac{g_j}{g_j-\nu_g^1}\right)\theta s_{12j}\lambda_1}{\alpha\lambda_1}\left(1-\frac{\nu_h^1}{h^*_{12j}}\right) & \vdots & \vdots & \vdots\\
\vdots & \cdots & \ddots & \vdots & \vdots\\
\delta\left(\frac{g_j}{g_j-\nu_g^\mathcal{F}}\right)\left(1-\frac{\nu_h^\mathcal{F}}{h^*_{\mathcal{F}\mathcal{M}j}}\right)\theta s_{\mathcal{F}1j} & \cdots & \cdots & \frac{1+\delta\left(\frac{g_j}{g_j-\nu_g^\mathcal{F}}\right)\theta s_{\mathcal{F}\mathcal{M}j}\lambda_\mathcal{F}}{\alpha\lambda_\mathcal{F}}\left(1-\frac{\nu_h^\mathcal{F}}{h^*_{\mathcal{F}\mathcal{M}j}}\right) & 1-\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^\mathcal{F}}\right)\left(1-\frac{\nu_h^\mathcal{F}}{h^*_{\mathcal{F}\mathcal{M}j}}\right)\left(1+\eta_j^{s,p}\right)\\
\pi_{11j} & \cdots & \cdots & \pi_{\mathcal{F}\mathcal{M}j} & -\left(\rho_j+\eta_j^{s,p}\right)
\end{bmatrix}$$

and

$$\mathbf{B_j}=\begin{bmatrix}
\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^1}\right)\left(1-\frac{\nu_h^1}{h^*_{11j}}\right)-\frac{t_j}{1+t_j}\\
\vdots\\
\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^\mathcal{F}}\right)\left(1-\frac{\nu_h^\mathcal{F}}{h^*_{\mathcal{F}\mathcal{M}j}}\right)-\frac{t_j}{1+t_j}\\
\frac{t_j}{1+t_j}\rho_j
\end{bmatrix}.$$

W.2.2 Incidence

Overall renter household welfare is given by

$$\mathcal{W}^R=\sum_f\sum_m s_{fm}\cdot\frac{1}{\lambda_f}\log\left(\sum_j\exp(\lambda_f u_{fmj})\right).$$

The effect of a change in the property tax rate of municipality j on the welfare of household type $\{f,m\}$, abstracting from general equilibrium effects on other jurisdictions, is given by

$$\frac{d\mathcal{W}^R_{fm}}{d\ln t_j}=\alpha N_{fmj}\left(1-\frac{\nu_h^f}{h_{fmj}}\right)^{-1}\left\{-\left[\frac{t_j}{(1+t_j)}-\frac{\delta}{\alpha}\left(\frac{g_j}{g_j-\nu_g^f}\right)\left(1-\frac{\nu_h^f}{h_{fmj}}\right)\left(\frac{dg_j}{dt_j}\frac{t_j}{g_j}\right)\right]-\left(\frac{dp_j^*}{dt_j}\frac{t_j}{p_j^*}\right)\right\}, \tag{W.20}$$

where $\frac{dg_j}{dt_j}\frac{t_j}{g_j}$ and $\frac{dp_j^*}{dt_j}\frac{t_j}{p_j^*}$ are given by equation (W.18) and by solving the system of equations (W.19).

W.3 A modified housing supply

In this section, we present a modified version of the setting proposed in (Brueckner, 2011, Ch.6). Atomistic absentee landlords own a stock of dwelling space with a net-of-tax rental revenue of $(1-\tau_j)p_j H(k, l_j)$, where p_j is the rental price per square meter, which is considered as given.[1] $H(k, l_j)$ represents a concave constant returns to scale housing production function, using non-land capital k and land l_j as inputs.[2] Non-land capital is rented at price r_k and land rent per unit is r_l.[3] The cost of housing is given by $C(k, l_j) = r_k k + r_l l_j$, which is financed entirely with mortgage debt. Non-land capital is assumed to be supplied perfectly elastically, making r_k an exogenously fixed parameter.

Landlords need to cover running costs when supplying the rental market. To simplify notation, let x_j denote the capital-land ratio k/l_j, which can be interpreted as building density or height. Substituting x_j, a landlord's profit maximization program is

$$\max_{x_j} l_j \left[(1-\tau_j) p_j h(x_j) - a c(x_j) \right], \tag{W.21}$$

where $h(x_j) \equiv H(x_j, 1)$ and $c(x_j) \equiv C(x_j, 1)$ denote the dwelling space and housing cost per unit of land, and γ represents the fraction costs effectively borne by landlords after consideration of tax deductions. The h function satisfies $h'(x_j) \equiv H_1(x_j, 1) > 0$ and $h''(x_j) \equiv H_{11}(x_j, 1) < 0$.

Given a fixed parcel of land, l_j, the landlord chooses x_j to maximize profit per unit of land, given by equation (W.21), while land prices adjust until profits per unit of land are zero. Due to the fact that profits are zero, for any value of l_j, the scale of the landlord's building is indeterminate. The maximization of (W.21) with respect to x_j and the zero profit condition are

$$(1-\tau_j) p_j h'(x_j^*) = a r_k, \tag{W.22a}$$

$$(1-\tau_j) p_j h(x_j^*) - a r_k x_j^* = a r_l^*. \tag{W.22b}$$

The landlord's profit-maximizing dwelling stock per unit of land is given by $h(x_j^*)$, with x_j^* being the optimal structural density determined by (W.22a).

The total dwelling stock in municipality j, using a Cobb-Douglas production function, is equal to

$$H_s^j = l_j \cdot h(x_j^*) = l_j \left[\frac{B(1-\tau_j)}{a} \frac{p_j}{r_k} \right]^{\eta^{s,p}}, \quad \forall j \in J, \tag{W.23}$$

where $\eta^{s,p} \equiv B/(1-B)$ represents the housing supply elasticity of rental prices and $B \in [0, 1)$ is the Cobb-Douglas share of capital expenditure in housing production.[4] Furthermore,

[1] While landlords are absentee, to be consistent with our simplifying assumption, we assume that they pay a tax on rental income in the jurisdiction in which their dwelling is located, to be consistent with our empirical setting.

[2] As in Brueckner (1987), the building is implicitly being split up into housing units (apartments) that consumers can then rent from the landlord.

[3] Factor prices are assumed to be strictly positive.

[4] See Combes, Duranton and Gobillon (2021) for a discussion on the choice of the production function.

the endogenous price of land is r_l^*, which is determined by replacing x_j^* into (W.22b). Finally, movements along the supply curve are measured by the housing supply elasticity with respect to rental prices. The partial derivative of equation (W.23) with respect to p_j yields

$$\frac{\partial H_s^j}{\partial p_j}\frac{p_j}{H_s^j} = \eta^{s,p} \geq 0\,. \tag{W.24}$$

Tax deductibility assumptions In the model, the landlord incurs running costs when supplying the rental market with dwelling space. Mortgage interest payments are equal to $i \cdot C(k, l_j)$, where i denotes the interest rate. Over time, the landlord's housing stock depreciates at rate $\check{d}$, representing a cost of $\check{d} \cdot C(k, l_j)$. In addition, property taxes need to be paid, which amount to $b_1 \cdot C(k, l_j)$, where b_1 is the property tax rate. Furthermore, transaction taxes b_2 are due if housing stock is sold and amount to $b_2 \cdot C(k, l_j)$, in the event of a sale. Finally, capital gains through appreciation of housing prices reduce costs by $g \cdot C(k, l_j)$.[5] If all costs are deductible and capital gains are taxed at the same rate as income, we can collect the various running costs and define the fraction of the housing stock's value allocated to running costs as

$$a = (1 - \tau_j)\check{a}\,,$$

with $\check{a} = (i + d + b_1 + b_2 - g)$.

In this case, equation W.23 becomes

$$H_s^j = l_j \left[\frac{B}{\check{a}}\frac{p_j}{r_k}\right]^{\eta^{s,p}}\,,$$

and housing supply is independent of changes in income tax rates.

[5]Capital gains g represent the expected rate of increase in housing value. Bear in mind that this source of revenue is only realized at the sale of the housing stock, but is still anticipated.