Tax Housing or Land? Distributional Effects of Property Taxation in Germany

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Abstract

Despite its theoretical merits, Land Value Taxation (LVT) is not a common policy instrument. One of the main reasons is uncertainty regarding its distributional impacts. Using a general equilibrium model with heterogeneous agents calibrated to an unique household level dataset of German homeowners in 2017, we assess the distributional effects of replacing a housing tax with a LVT. Our data shows the share of land value in property value to be 33%, on average, with considerable household heterogeneity, both within and across regions, and within income levels. Land values are more concentrated than property values, but, within regions, not as strongly correlated with income, making it less progressive than a standard property tax for homeowners. Results from the model show the introduction of a LVT increases residential investment substantially, reducing housing rents and benefiting renters. It also leads to migration from urban regions, promoting regional convergence. Landowners with high land holdings lose, in general, but most other landowners across income levels benefit, especially in non-urban regions. Overall, introduction of a LVT increases welfare, despite a minor regressive tendency in urban regions for homeowners.

Keywords: Land, Housing, Land Value Taxation, Property Taxation, Distributional Assessment

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1 Introduction

Land value taxation (LVT) is a type of property taxation which falls solely on the unimproved value of land, as opposed to standard property tax regimes which take the total value of property (unimproved land plus structures built upon it) as tax base. Since Adam Smith, numerous economists have pointed to the benefits of LVT over standard property taxation. Most importantly, being physically more inelastic than housing, land provides a far less distortionary revenue source for governments. In the present context of soaring public debt, the need to study growth friendly forms of taxation has never been higher.

Despite its theoretical merits, LVT is not widely used[1]. One reason for the small number of LVT regimes is that, historically, a standard property tax is perceived as more progressive. The implicit idea is that standard property taxation includes an additional part of a household's wealth in the tax base, in the form of structures. Due to this additional component, property values are commonly perceived as a better tag for prosperity than land values. However, in the last years, this view has been under scrutiny. The issue of land value appreciation has been identified as one of the main drivers of increasing wealth inequality through the channel of housing wealth .[2] These findings suggest taxing land values could, in general, be an effective way to redistribute from the top of the wealth distribution to the rest.

Empirical evidence is scarce and inconclusive. Some attempts have been made to evaluate the distributional impact of a LVT in different US metropolitan areas. The studies find conflicting evidence and suffer from data limitation problems. In this regard, the empirical literature on the distributional impact of a LVT is not yet settled. Our project contributes to this literature, offering fresh evidence from a unique data set for one of the bigger OECD countries, Germany, which collects detailed official data on land values.

At the same time, the lack of sound empirical evidence has also inhibited the de-

[1] In 2019, from the 36 OECD countries only Denmark, Estonia and Lithuania use some form of LVT.

[2] Rognlie (2015) demonstrates that Piketty's increasing share of capital income is, for the most part, a consequence of increasing value of housing. Furthermore, as pointed out by Stiglitz (2015a), this trend in housing wealth is driven primarily by the location premium, rather than by increases in construction costs, meaning land value accounts for an increasing share of total housing value and that its distribution is becoming increasingly more unequal.

velopment of complementary solid theoretical framework which can account for general equilibrium effects on prices of housing and land which would arise under a LVT. We construct such a model using the insights from our empirical analysis.

Armed with high quality data and a theoretical model, we provide an answer to the main research question of the paper: What are the aggregate and distributional impacts of replacing a housing tax with a land value tax in a developed country?

Despite housing being the most important asset for the majority of households, the necessary decomposition of house value has never been attempted in the literature with this level of detail, as data on land values is scarce. Our newly collected data set is superior to previous sources on two dimensions. First, instead of relying on own estimation to determine land values, we use official land value estimates directly, which are primarily based on the sale of empty lots of land[3]. Second, so far there exists no data set linking households' land values to other characteristics like income. We overcome this problem by using a geo-match approach to add data on land values to a high quality household survey containing a representative sample of German households.

However, a policy experiment based solely on current observed valuations of housing and land implicitly assumes a shift in property taxation policy would have no impact on market prices of housing and land. This is unlikely, as a shift towards land taxation eliminates the implicit capital tax on structures, presumably leading to higher structure accumulation in steady state, increasing housing supply and decreasing housing prices, while, at the same time, increasing the marginal productivity of land in the economy. To address this, we build a general equilibrium theoretical model which can replicate our main empirical findings and allow for more quantitatively accurate policy experiments.

The model features infinitely lived homogeneous Renters and heterogeneous owner-occupiers (Landowners), who differ with respect to their productivity and land holdings. Landowners thus face an intertemporal problem where higher structure investment leads to higher house value and thus higher tax burden under a housing tax, but not a land tax. Renters buy housing services from a representative housing firm which also pays property taxes and faces a similar intertemporal problem to the landowners.

[3] Estimation of land values can easily lead to bias, if a researcher's estimation procedure structurally differs from the potential official procedure, especially if the market for unimproved lots is thin.

In order to capture stark regional disparities in land values, the model features two regions, one where consumption good sector has high productivity and land is scarce (Urban) and one with low productivity and abundant land (Rural). Renters can move between regions to ensure real wage equalization. Modest differences in productivity can lead to large differences in land price and land value shares. The model is calibrated so that low income landowners have higher land value shares, on average, mimicking our empirical findings. This renders low income households the potential losers from the policy and creates a potential efficiency-equity trade-off due to higher marginal utility of low income households.

Empirical results first focus on identifying the distribution of land and property value independently. We find the differences between both distributions to be significant. In particular, land values are much more concentrated than property values. While for property values the Gini-coefficient is 0.35, for land values we find the coefficient to be 0.48, suggesting the distribution of tax burdens would be more concentrated under a LVT.

In a next step, we compute the land to property value ratio, the *Land Value Share*, for each household in our sample. We demonstrate that a household's Land Value Share, in relation to the average Land Value Share, is a sufficient statistic to determine winners and losers from a revenue-neutral switch to a LVT. A household with a Land Value Share lower than the average wins under a LVT regime and vice versa. Accordingly, if the Land Value Share was the same across households, a switch in tax regimes would not trigger any change in tax burden. We find the distribution of the Land Value Share exhibits a sizable variance around the sample mean of 33%, showing a switch in the tax regime triggers significant changes in burden for a large part of the population. In numbers, tax burden differs by at least 22% for half of the population. Relating those differences in tax burden to household income constitutes the distributional assessment of a LVT, the main objective of this paper.[4]

A prevalent characteristic of property taxation is its regional scope. In most countries property taxes are levied on a sub-federal level, in Germany it is one of the most important municipal taxes. We find substantial regional variation in average land value shares. For this reason, our main analysis works under the assumption of *regional* revenue-neutrality.

[4]Our data shows both LVT and property taxation to be progressive in nature. The distributional analysis, is therefore, designed to determine which of the two is more progressive.

Imposing that restriction, we estimate the income elasticity of Land Value Share to be -0.155. This means households with higher incomes statistically have lower land value shares, indicating a regressive impact of a LVT, compared to a property tax.

Results from the model show that, on aggregate, a LVT increases structures investment substantially, leading to more housing and lower rents. Moreover, these effects seem to be more pronounced in the rural region, where land scarcity is not an issue. This leads to some migration from the urban region and fosters regional convergence. Renters in both regions benefit from the switch in regime due to the lower price of housing. Unsurprisingly, landowners with the highest land holdings tend to lose with the measure. Overall, social welfare improve under a LVT, driven mostly by increased utility of renters and landowners in rural regions.

This paper contributes to the literature on several fronts. On the empirical side, it provides a valuable identification of the household level distribution of land and property values in a major developed country and the estimation of the distributional impacts of land value taxation and property taxation in relation to their progressivity. On the theoretical side, it develops a general equilibrium model which can replicate the inter and intra-regional heterogeneity which determines the distributional outcomes of different property tax regimes.

Besides the main contributions, we identify other relevant secondary contributions. First, the construction of a novel household level dataset with information on property and land holdings. Second, the computation of relevant measures of land value at the regional level, enabling the estimation of total taxable land value and revenue neutral land value tax rates for Germany. Finally, the decomposition of income elasticities of housing into income elasticities of structures and land value.

The rest of the paper is structured as follows. Section 2 discusses the literature on distributional aspects of land value taxation. Section 3 explains the construction of the data set used in our analysis. Section 4 presents a regional level empirical analysis. Section 5 contains the empirical distributional assessment at the household level. Section 6 presents the theoretical model. Section 7 contains the results from the model. Finally, Section 8 concludes.

2 Literature Review

Theoretical literature addressing the gains of implementing a LVT is relatively abundant. Standard property taxation contains an implicit tax on capital which hinders the accumulation of housing capital in the form of structures, creating an inefficiently low level of housing supply in the economy. In contrast, LVT taxes an asset in (quasi) fixed supply, so that a switch in tax base would remove the physical distortion. Aura and Davidoff (2012), for example, show how optimal property tax rates increase with the share of pure land rents to structures. Brueckner and Kim (2003) show how property tax distortions encourage inefficient urban sprawl when substitution between housing and other goods is low, unlike land taxation.

Empirically, there have been some successful attempts to assess the impact on housing supply of switching from a property tax to a LVT. These papers usually rely on using policy changes in specific cities where property taxation follows a two-rate system, taxing land and structures at different rates. Oates and Schwab (1997) focuses on the case of Pittsburgh in the US during the 1980s. Results show strong evidence that switching towards more land value taxation increases construction and overall housing supply against a control group of other cities with similar characteristics, corroborating theoretical arguments. Banzhaf and Lavery (2010) look at a panel of land uses and demographics in Pennsylvania and confirm the split-rate tax raises the capital/land ratio.

Although our paper focuses on the distributional impact of LVT, the model is built to incorporate efficiency gains from LVT due to housing taxes hindering the accumulation of housing structures. This channel allows for changes in equilibrium prices which influence the distributional outcomes.

Land value tax has been demonstrated to have other benefits. In their seminal work, Arnott and Stiglitz (1979) show that, under some conditions, investment in public goods can increase aggregate land rents and raises enough revenue to finance the (optimally chosen) level of public investment through a LVT, a result dubbed *Henry George Theorem*. Taxation of land rents has also been linked to economic growth. Building on Feldstein (1977), Petrucci (2015) outlines the theoretical conditions in which substituting capital and labor taxes with a LVT can foster wealth accumulation and economic growth.

Theoretical pros of LVT have justified its endorsement both in the literature and fiscal policy reports. Mirrlees et al. (2011), in an large scope effort to identify the desirable characteristics of a modern tax system in an open developed economy, conclude there is a strong case for the introduction of a land value tax as the primary form of property taxation and a relevant source of public revenue. However, as identified in Norregaard (2013) using a survey of property taxation regimes for a large sample of countries, taxes on property, in general, and immovable property in particular, remain a small fraction of total government revenues, on average. Reasons include salience of property tax, difficulty in the implementation of a valuation system and uncertain distributional impact.

Recently, more attention has been devoted to the link between land values and inequality. At a macro level, Stiglitz (2015b) identifies upward trend in value of land rents to be, alongside rents from market power, one of the root causes of wealth inequality identified by Piketty. The primary focus of the literature dealing with heterogenous impacts of a LVT focuses on generational heterogeneity through the use of Overlapping Generations models. The seminal paper in this strand of literature is Buiter (1989). More recent papers using this type of models are Petrucci (2015), Edenhofer et al. (2013), and Koethenbuerger and Poutvaara (2009). These papers address the impact of switching from labor income to land value taxation and, in general, demonstrate all generations, except for the owners of land at the time of the reform, benefit from the change. And even current land holders can benefit under certain conditions, namely if the increase in demand due to decreases in income taxation is large enough.

Papers dealing with distributional impacts of replacing a housing tax with a LVT across income levels are far more scarce. Schwerhoff et al. (2020) identifies the potential for an efficiency-equity trade-off in a theoretical setting, but lacks the empirical analysis to determine if the trade-off exists.

Empirically, evidence is scare and inconclusive. Few attempts have been made to quantify the distributional aspects of taxing land values instead of property values. England and Zhao (2005) and Plummer (2010) study changes in two-rate property tax systems and find conflicting results regarding the progressivity of the measure. The former finds evidence for a regressive tendency in the case of New Hamphshire, and the latter finds moving to a LVT in Texas would be slightly more progressive, while also shifting the tax burden away from single-family properties and unto other property classes. However, these papers rely on regional level data and thus are unable to pick up on cases of low income households in high income regions or vice-versa. We contribute to the literature by showing there is substantial household heterogeneity in property and land values even within narrow geographical areas and relate it to income levels.

Another relevant strand of literature deals with the problem of land valuation and potential revenues from land taxation. Larson (2015) estimates total value of land in the United states to be 23$ trillion in 2009, roughly 1.5 times GDP. Albouy et al. (2018) do the same for US metropolitan areas in 2006 and find land values are more than twice GDP, with a prevailing upward trend. These numbers are consistent with annual total land rents (and thus potential LVT revenue) between 5% and 10% of GDP. We perform similar estimations using our data for Germany using official land values estimates with high geographical precision and find a 1.2 land value to GDP ratio.

There has also been recent work on the issue in regards to Germany, specifically. During recent discussions on the introduction of a LVT in Germany[5], several policy reports stressed the importance of distributional consequences while providing initial evidence. A recent example of this kind is Fuest et al. (2018). The authors discuss distributional consequences between households living in multiple and single family houses, showing a LVT shifts a significant portion of the tax burden to single family house owners. Their study assumes representative type of houses, so that they cannot discuss the idiosyncratic differences in quality and size. Further, the authors are not able to quantitatively link the propensity of living in a given type of house to a household's income. We overcome this problem with our superior data.

In summary, this paper marks a significant advancement in the literature both on the empirical and theory fronts. Empirically, based on high quality official data at the household level, we tease out the distribution of land value holdings from the distribution of housing, and relate those distributions to household income, as well as estimate total land value and revenue equivalent LVT rates. Theoretically, through the construction of a model which incorporates the most relevant equilibrium channels and replicates the

[5] Property taxation in Germany is under a process of major reform. In early 2018, the German constitutional court has ruled the property tax must be replaced. Economic research institutes pointed to a LVT as an instrument to supersede it. In 2019, a new regime based on land values was approved.

main empirical findings, we arrive at sounder and more complete quantitative policy experiments regarding the implementation of a LVT.

3 Data

This section lays out in detail the construction of our unique data set, which allows us to perform the distributional analysis in the paper. Such a breakdown of total housing wealth in land and structures has not been attempted at a national scale. The data is constructed by combining a household survey, a database of land values, a database of land lots, and data on municipality characteristics. A diagram summarizing the construction of the data can be found in Appendix A

3.1 Household Survey

The socioeconomic panel (SOEP) is a German household survey conducted by *Deutsches Institut für Wirtschaftsforschung* (DIW). The SOEP provides the basic information on households in our project. We use SOEP data from 2017 (wave 34). For our analysis, the most important variables in the SOEP are those related to income and real estate property. Monthly income is a standard variable in the SOEP included every year. Information about property is less frequent as it is part of a specific wealth module which is only carried out every five years, at last in 2017. In this module, households provide information regarding their wealth holdings, including the value of their primary residence. The information for house value is only provided by owner-occupiers. As primary residence value is a necessary information for the later analysis, we are forced to restrict the sample to owner-occupiers.

The SOEP does not include a decomposition of property value in land and structures value. We use other sources of data to estimate the land component of the property value. In this decomposition, we employ other information from the SOEP, like the number of dwellings within the household's housing structure.

3.2 VALKIS + M

This section introduces the dataset we need to derive the land component of a household's property value, VALKIS + M. It combines information from three different data sources: the German land registry (*Amtliches Liegenschaftskataster*); the official dataset on land values (*Bodenrichtwerte*); and the German statistical offices' regional data base (*Regionaldatenbank des Statistischen Bundesamtes*). In this section, we introduce the individual parts in isolation and describe how they are merge in order to generate the dataset we called VALKIS + M.

3.2.1 ALKIS

ALKIS is the digitized version of the official German land registry. The smallest geographical unit entered in ALKIS is a *lot*. Our analysis proceeds by using the lot as the unit of observation. For each lot, ALKIS contains information on the type of usage as well as the addresses attributed to the lot. The usages range from residential, industrial and commercial land to forests, rivers and streets. An address is attached to a lot for every independent unit of housing that requires postal correspondence. Historically, a lot describes an economic or contextual unit: a river, a street, a piece of residential land owned by an individual. However, over time, this correspondence has been diluted, so that currently ALKIS contains lots with multiple usages, e.g. lots with farmland and residential land, as well as lots with multiple addresses. In order to later account for those incongruities, we keep the information on the number of addresses and the type of usages for all lots. Finally, ALKIS does not contain information on the size or characteristics of any potential structures on the lot. An illustration of the precision of the ALKIS data can be found in Appendix B.

In sum, we use ALKIS to generate a dataset with lots as the unit of observation. For each lot, we have precise information on the usage as well as the number of addresses. The geographic extent of our dataset spans the whole surface of five German states: Berlin, Hamburg, Niedersachsen, Nordrhein-Westfalen, Thüringen. Data on the remaining states was not available due to data privacy[6]. The states under consideration have a joint population of about 35 million. The sample of states is representative, consisting of

[6] Each state has specific policies regarding the availability of this data.

metropolitan as well as rural areas and states from former eastern and western Germany.

3.2.2 Official Land Value Data

Bodenrichtwerte are the results of annual assessments conducted by regional councils of real estate experts (*Gutachteraussschüsse für Immobilienwerte*). They are used as measure of land value throughout our project. In Germany, these land values are used frequently by banks to determine the value of a collateral or in insolvency proceedings to assess the wealth of a defaulting debtor. In the context of the current policy debate on the property tax reform in Germany, Bodenrichtwerte are designated to be used as a main source of information to assess a household's future tax burden. The derivation of the land values is twofold.

First, the regional councils define land value zones as narrow geographical areas for which the land value does not significantly differ within. The split is based on the experience of the council as well as historic and current information on sales prices of property and land. The area of land value zones depends on the heterogeneity of the neighborhood under consideration, however, it rarely spans an area of more than one square kilometer. Second, the regional councils determine the land values per land value zone. Land values are stated separately for agricultural, commercial and residential land[7]. The zone-specific land values are derived from the collection of land and property sales inside a land value zone within the last years. The preferred source of information is the price of unimproved lots. If not available, land values are derived from the price of improved lots, using hedonic price regressions, or the price of unimproved lots in different land value zones with similar characteristics. Figure 1 shows a map of land values in the municipality of Düsseldorf, where one can see the geographical precision of the land value districts.

[7]In certain cases, the land values even differ for residential land used for the construction of single or multiple family houses.

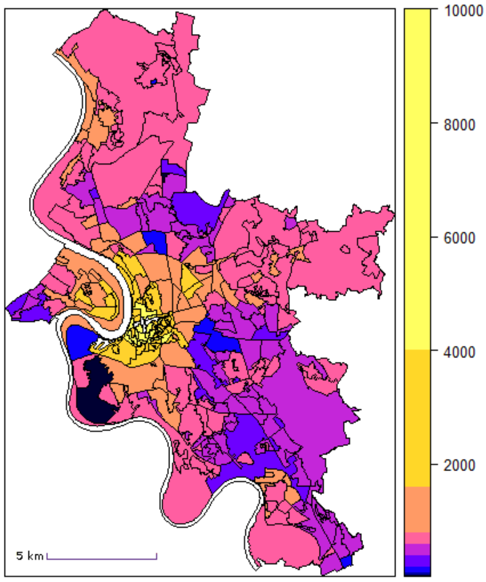

Figure 1: Residential land values (€ per square meter) in Düsseldorf
Regions in white are non-residential. Log scale, in order to capture high variability in low value regions.

In sum, we use the official land value statistics to generate a data set with land value zones as unit of observation. Each land value zone is defined so that land values within a zone do not significantly differ. Further, the data set contains information on different kind of land values within a zone: agricultural, commercial and residential land value.

3.2.3 VALKIS

VALKIS is the result of a spatial joint of ALKIS and the official land value data. The unit of observation is the lot. In particular, we take each lot from ALKIS and find the corresponding land value zone in the official land value data[8]. Conditional on the lot's actual usages, captured in ALKIS, we attach the relevant zonal land values to the lot, agricultural, commercial or residential. In sum, VALKIS is a geo-referenced data set with the lot as the unit of observation, the information per lot is: the actual usages, the number of addresses, the land value per m^2 for every type of lot usage.

[8]The correspondence is given by the spatial reference of both data sets and executed using standard spatial techniques of the statistical software program R.

3.2.4 + M

+ M summarizes information on the regional level, the unit of observation is the municipality. The data is collected from different sources and reflects the living conditions in a municipality in terms of amenities, prices and taxes.

A municipality's degree of urbanization is proxied by population density, a municipality's recent trend in attractiveness, by population growth between 2012-2017. Data on both is gathered from the German statistical offices' regional database. In order to get information on the price level, especially with regard to land prices, we determine the average land value within a municipality. For that, we take the average of a municipality's zonal land values, weighed by the share of residential land contained in a zone[9]. At last, we determine the revenue neutral land value tax rates. Any form of property taxation has traditionally been a municipal tax in Germany and will certainly remain so after the coming reform. Thus, the land value tax rates have to be chosen to guarantee revenue neutrality on the level of the municipality. If we denote by τ_i the revenue neutral tax rate in municipality i, it is defined by $\tau_i \times LV_i = TR_i$, where TR_i represents the current tax revenues and LV_i the aggregate land value of municipality i. Rearranging, the revenue neutral tax rate is given by $\tau_i = \frac{TR_i}{LV_i}$. We can derive the denominator, using the information stored in VALKIS. Regarding the numerator, we once again gather information from the regional database.

Finally, we spatially join VALKIS and +M. The final output is the geo-referenced data set VALKIS + M with the lot as the unit of observation, the information per lot is: the actual usages, the number of addresses, the land value per m^2 for every type of lot usage, Population Density, Population Growth, Average Land Value, Revenue-neutral land value tax rate.

3.3 SOEP 2.0

SOEP 2.0 is the product of a spatial join of SOEP and VALKIS+M, using the SOEPgeo dimension. This unique feature of the SOEP allows us to access the geo-coordinate of each

[9] For later sensitivity analysis we generate a second measure of average land value, using the weighed zonal land values within 20km distance of each lot.

household in the survey. The access is tightly regulated and must be carried out in the DIW facilities in Berlin. We use SOEPgeo to identify the lot in which a household lives and append the respective lot data from VALKIS+M to the original household survey data.

In addition to combining the information, we create additional variables which require the use of data from both of the sources. A crucial variable is the residential size per household. To construct the variable, we take the full lot residential size and divide it by the number of addresses in that lot, from the ALKIS. We further divide by the number of households in each address, which we obtain from the SOEP, to obtain the residential size per household. To exemplify, let's take the total residential size of the lot to be 1000 m^2. Then, if, for example, in the ALKIS the lot is associated with two addresses (two independent residential buildings), and if in the SOEP we observe there are four households in the building, we impute the residential size of our particular household in our sample to be $\frac{1.000m^2}{2\times4} = 125m^2$.

The computation relies on two assumptions, which should be addressed. First, splitting lot land size by the number of addresses in the lot assumes that, in case of multiple addresses, each address occupies an equal fraction of the lot's size. Second, we assume that for multiple family houses, households share the residential size equally. Although these assumptions will lead to errors in specific cases, both reflect the benchmark in the German housing market and, thus, should not influence overall results. The land value component of a household's property value then derives as the product of residential size and residential land value per m^2.

In sum, SOEP 2.0 is a data set with the household as the unit of observation. It carries the variables from the SOEP and augments them with a decomposition of property value in land and structure value. Further, for each household it adds regional information on: Average Land Value, Population Density and Growth, revenue neutral land value tax rate[10].

[10]Appendix A contains a diagram representing the construction of SOEP 2.0.

3.3.1 Quality of Matching

This section discusses the reliability of our geo-match approach in determining a household's land value component. The fact that our final data set was built from several unrelated sources, each with its own shortcomings, and using a self designed geographical matching algorithm, might raise doubts regarding the validity of our SOEP 2.0 data. We try to address such concerns by evaluating if the relation between self reported property values and imputed land values are consistent with each other.

Given that property value is the sum of land and structure value, an increase of one euro in land value, keeping constant the structure value, should imply an increase of one euro in property value. Thus, if our matching is accurate, we should be able to observe this relation in our sample. To test this hypothesis we run a regression of property value (from the SOEP) on the land value we imputed, controlling for structure value. We do not have a variable of structure value in the survey data. If we did, computing the land value component would have been trivial. Instead, we proxy structure value using SOEP variables with information on the quantity and quality of structures: size of the house (in m^2), and condition of the house (a categorical variable with four levels). We run the following model: $PV_i = \beta_0 + \beta_1 LV_i + \beta_2 size_i + \beta_3 condit_i + \epsilon_i$. Results from this regression show a coefficient for β_1 equal to 1.003, not statistically different from one, consistent with our conjecture. This result reassures us regarding the validity of our geo-match approach and the results we will discuss from here onward.

4 Regional Data Analysis

This section provides a summary of the data collected at a regional level, before proceeding to the household level data.

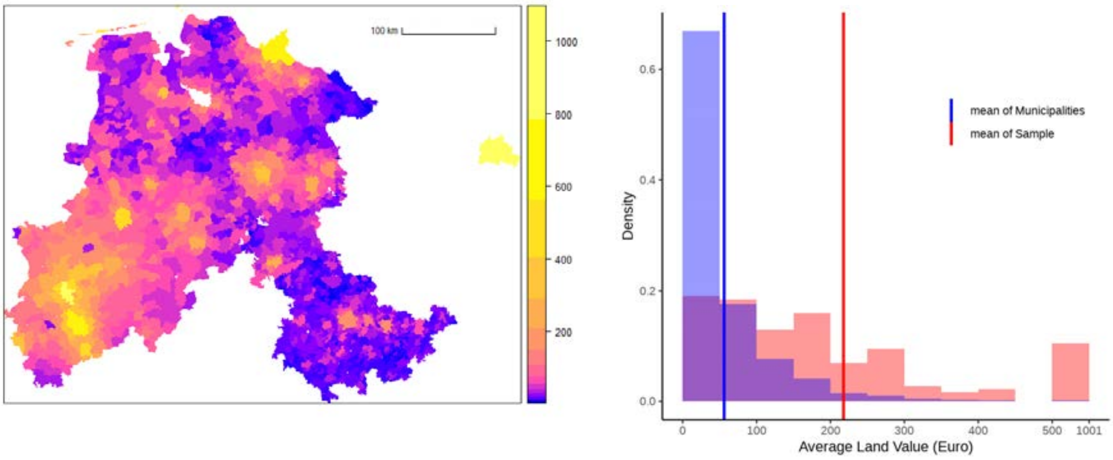

Figure 2: Municipal average land values

The blue (red) distribution in the right panel shows the distribution with municipalities (sample households) as the unit of observation. The vertical lines represent the mean of each of the distributions. Values are in Euro per m^2.

The map in Figure 2 shows average land value per municipality (*Gemeinde*) in the five states in our analysis, comprised of a total of 2214 municipalities. It presents a fairly large contiguous region of Germany (apart from Berlin), with different characteristics. The first thing to notice is the heterogeneity in average land values. The lowest municipal average land values in our sample are under 10€ per m^2, while for Berlin (the highest) the average is 1000€. Very few municipalities exhibit average land values higher than 200€, as can be seen from the blue distribution in the right panel of figure 2. Nevertheless, a substantial number of observations at the household level are from these municipalities, as can be seen from the red distribution in the same panel.

Our regional data allows for the computation of other interesting aggregate statistics. Total land value in the region we are considering is over 1.5€ trillion, 1.2 times the region's GDP. The magnitude is in line with recent estimates from the US, e.g. Larson (2015). 90% of the total land value is non-agricultural, the rest being agricultural. These numbers establish land value as a sizable, mostly untapped tax base.

Having computed total land values in each municipality and collected the respective current property tax revenues, we have computed the necessary land value tax rates which would ensure revenue neutrality. The histograms of these revenue neutral land value tax rates are presented in Figure 3. Again, in blue the distribution of municipalities, and in red the distribution of households in our sample. Around 70% of municipalities would need to set a tax rate between 0.25 and 1% of land value. The maximum revenue-neutral tax rates we find are around 2%. The household distribution is even more skewed to the left, as a result of more densely populated areas having lower revenue neutral tax rates, on average.

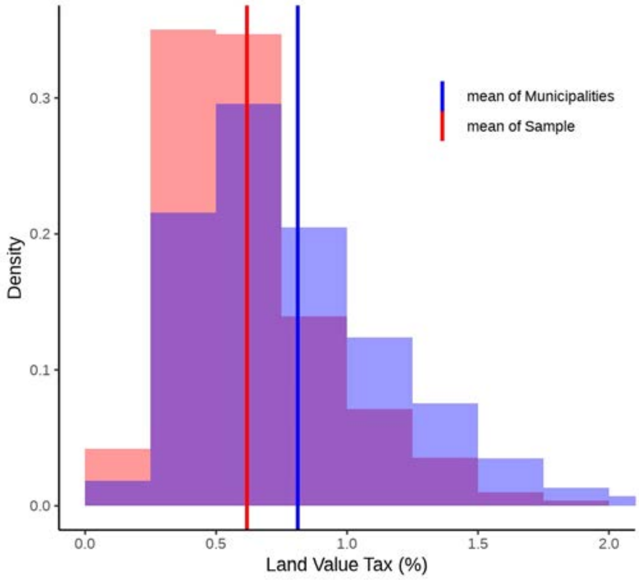

Figure 3: Distribution of revenue neutral land value tax rates
The blue (red) distribution shows the distribution with municipalities (sample households) as the unit of observation. The vertical lines represent the mean of each of the distributions.

5 Analysis of SOEP 2.0

This section contains the main analysis of our paper. We start by presenting the distribution of land and property value in the sample and introduce the concept of *Land Value Share*, which provides a sufficient statistic to qualitatively determine winners and losers from a LVT. We proceed by relating the change in tax burden to income and split up the mechanism in intuitive parts. Finally, the last subsection contains a quantitative assessment of the tax regimes.

5.1 Distributions of Land and Property Value

The first question we address is how the distributions of land and property values differ in our sample. Table 1 provides some initial statistics. Mean property value in our sample is 261.000€, while mean land value is 86.500€. The distribution of land exhibits a higher variance than the distribution of property when controlling for the level of each asset. Standard deviation of property value is 88% the value of the mean, while for land value this number is 124%. Looking at aggregate statistics for total holdings of property and land value in our sample, we see that aggregate land value is 204€ million. This accounts for 33% of aggregate property value, which stands at over 615€ million. The aggregate level of land or property values are important as they represent the size of the tax base of a land value or property tax.

	Property value (€)	**Land value** (€)	**Land value share**	**Lot size** (m^2)	**House size** (m^2)
Mean	260,793	86,495	0.33	603.41	134.14
St. dev	230,018	106,875	0.22	549.76	46.67
Minimum	4,590	980	0.01	7.56	20.00
1st Quartile	150,000	32,640	0.17	255.00	103.00
Median	220,000	58,927	0.27	500.00	126.00
3rd Quartile	300,000	105,300	0.44	779.00	155.00
Maximum	5,000,000	2,536,800	1.19	6,862.00	450.00
Sum	615,210,820	204,042,818			

Table 1: Housing statistics
The sample consists of homeowners in the DIW-SOEP, being residents of the German states Berlin, Hamburg, Lower Saxony, Northrhine-Westfalia und Thuringa. The sample size is 2,359. Lot and House size in m^2

To assess the concentration of these assets in our sample, we computed Gini coefficients. The value for property is 0.35, while for land it is 0.48. For reference, the Gini coefficient for income is 0.28. It seems land is significantly more concentrated than property in our sample, value wise. If one were to assume the distribution of these assets match the distribution of income on a household level (the household with highest income would also own the most valuable property and land, while the poorest the less valuable property and land), then taxing land would naturally be more progressive than taxing property value. However, this conclusion depends crucially on how these distributions relate to each other and how they relate to income. First, we investigate the link between land and property values.

5.2 Land Value Share

We define the Land Value Share (LVS) as the ratio of land to property value for a given household. This statistic allows one to have a first idea of the magnitude of potential distributional effects. If the distribution were concentrated at a single point there would be no scope for any household to win or lose from a LVT, comparing to a property tax. Dispersion of this measure signifies the existence of households with low (high) land value and high (low) property value, which would thus benefit from paying taxes on their land (property).

In the third column of Table 1 we see the statistics for the LVS. The mean is 0.33 while the standard deviation of this measure is 0.22, a considerably high number, indicating our sample has many households with low property value and high land value, and vice-versa. We can see this more clearly in Figure 4 showing the distribution of the LVS.

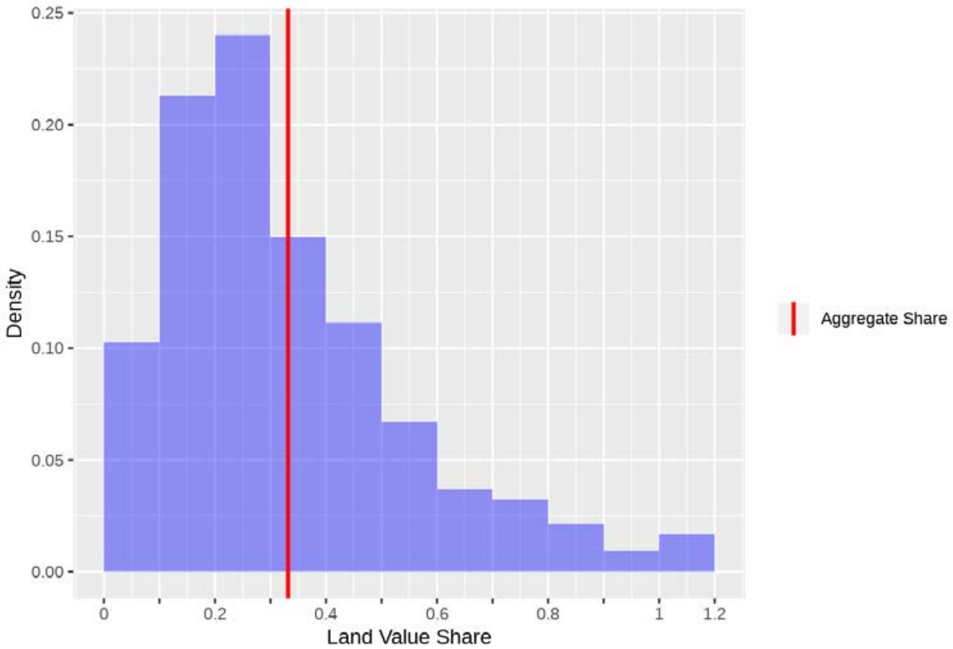

Figure 4: The distribution of land value share

Aggregate share is given by the ratio of total land value to total property value in the sample.

The plot shows the percentage of households in our sample which fall within the bins of LVS we have defined in intervals of 0.1. The distribution is skewed towards lower values, implying the majority of households lives in houses where land value accounts for a relatively low share of property value. Nevertheless, a significant number of households have high LVS as well, even close to 1. The plot shows a mass of around 2% with LVS greater than 1, implying the land is worth more than the property for these observations. While this may appear anomalous, it is entirely possible. A household owning a property which, were it to be sold in the market, would likely imply the demolishing of the existing structures to build new structures, could have a LVS greater than 1 to account for the cost of demolishing.

The vertical line in red depicts the aggregate LVS, meaning the total value of land divided by the total value of property in the sample which can be found in Table 1. This Aggregate LVS (ALVS) will be a centerpiece of the rest of the analysis as it is a crucial threshold defining winners and losers from land value taxation with respect to property value taxation. To understand this, we turn to some simple algebra.

To raise some exogenous level of revenue $\overline{TR}$, the government can choose to either tax land values at a rate τ_L or property values at a rate τ_P, such that $\tau_L \overline{LV} = \overline{TR}$ or $\tau_P \overline{PV} = \overline{TR}$. This means the ratio of the potential tax rates must satisfy

$$\frac{\tau_P}{\tau_L} = \frac{\overline{LV}}{\overline{PV}}$$

At the same time, a household i will pay lower taxes under LVT if $\tau_L LV_i < \tau_P PV_i$. Rearranging and substituting the ratio of tax rates by the ratio of aggregates we get the following condition for a lower tax burden under a LVT

$$\underbrace{\frac{LV_i}{PV_i}}_{\text{LVS}_i} < \frac{\tau_P}{\tau_L} = \underbrace{\frac{\overline{LV}}{\overline{PV}}}_{\text{ALVS}}$$

Households for which $\text{LVS}_i < \text{ALVS}$ (to the left of the red vertical line in Figure 4) will pay less tax under a LVT, those for which $\text{LVS}_i > \text{ALVS}$ (to the right) will pay more. More concretely, this simple result means that if a household owns, for example, a property worth 300.000€ with a land value of 150.000€, its land value share is 0.5, higher than the ALVS of 0.33. Despite its tax base is only half under a LVT, the household would still pay more, since the levied tax rate has tripled to guarantee revenue-neutrality.

The analysis of the distribution of the LVS reveals that the decision between a LVT or a property tax can create large differences in tax burdens under the different regimes for a substantial number of households. Next, we investigate how our measure of LVS differs with respect to our main characteristic of interest, income.

5.3 Land Value Share and Income

In Figure 5 we see the scatterplot and boxplots of LVS against income and quintiles of income respectively. Also in both plots is the aggregate LVS (in red), separating winners and losers of an LVT. Households below the red line are winners and those above are losers. We see a weak relation between the two. Applying a non-linear trend line reveals the existence of a flat U-shape relation, implying a slight regressive tendency for low income which flips into a slight progressive tendency for higher levels of income.

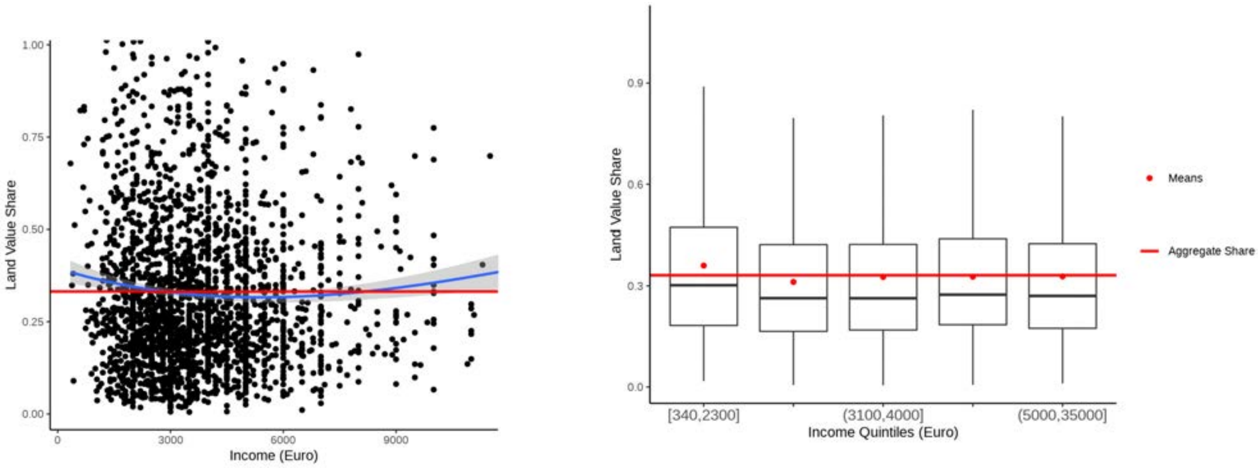

Figure 5: Land value share and income

Income is given as monthly income.

Running a simple OLS regression of the LVS on income proves the weak relation as the coefficient on income is not statistically different from zero. It is important to remember this does not mean LVT is not progressive in itself, only that it is not significantly more or less progressive than a tax on property values. Indeed, a simple regression of land value on income shows a very significantly positive coefficient indicating an increase of 1.000€ in monthly income is associated with an average increase of land value of 14.000€ in our sample.

A weak relation between LVS and income might be surprising, given the previous result showing land values are more concentrated in our sample than property values. An explanation for this would be that, while land is more concentrated, it is less correlated with income than property values. To investigate this hypothesis, we use Figure 6.

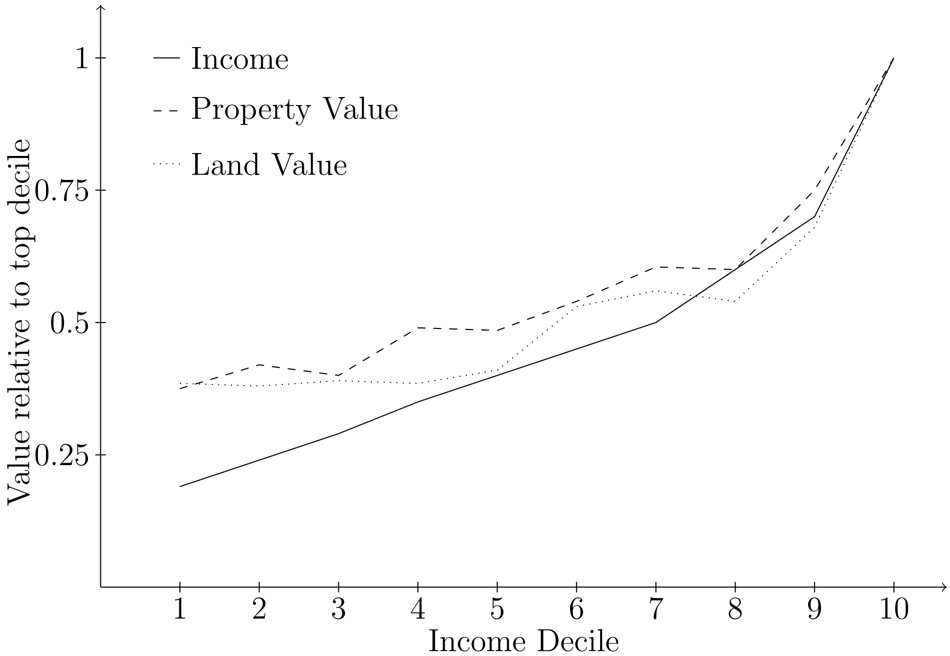

Figure 6: Distribution of income, land value and property value

The graph depicts the decile averages, relative to the value of the 10th decile.

Figure 6 represents how much each income decile holds in average income, land and property value with respect to the holdings of the highest income decile. To exemplify, the plot shows the ninth decile of income on average earns roughly between 60 and 65% of the average earnings in the tenth decile, while holding close to 70% of the value of the property holdings and close to 60% of the value of land holdings. Again, this points to a higher concentration of land values relative to property values. But the most interesting aspect of this plot is how the relative distribution of land values is basically flat for the first five deciles of income. While the fifth income decile earns on average twice as much as the lowest, both have similar levels of land holdings on average. On the other hand, distribution of relative property values exhibits some positive correlation with income even for low income levels. This pattern helps in explaining the flat U-shape found in the relation between LVS and income. For low levels of income, property is a better proxy for income than land, and thus taxing property is slightly more progressive, but in the highest deciles, land is more concentrated than property, so a tax on land values is more progressive as, on average, it hurts top income earners more than a property tax.

5.4 Regional analysis

So far we have been comparing the progressivity of a LVT and a property tax implicitly assuming all households in our sample would be subject to the same rate of each tax no matter where they live, similarly to what would happen if these taxes were levied at a federal level in Germany. However, property taxation is not carried out at a federal, but regional level, more specifically at a municipality (*Gemeinde*) level. For this reason, it is necessary to tailor our analysis accordingly.

Switching from a federal to a regional level analysis poses challenges. Our previous implicit ratio of tax rates was determined by the aggregate land value share in the sample, which is representative on a federal level. Ideally, we would like to do the same at a municipality level, however, for most municipalities we do not have the sufficient number of observations in the sample to reach a meaningful number. As a consequence, working with such a narrow geographical partition is not an option. Instead, we opt to pool municipalities with similar land values by splitting the observations into five quintiles of average municipal land values, in the hope of capturing most of the relevant structural differences. This way, our highest quintile will be comprised mostly of municipalities with the highest average land value (large cities such as Berlin, Hamburg, Düsseldorf, etc.), while the lowest quintile will be comprised of mostly rural municipalities, capturing most of the diverging characteristics of different municipalities. Figure 7 shows a couple of important structural differences across the average land value quintiles. Henceforth, for ease of exposition, these average land value quintiles will be referred simply as land value regions.

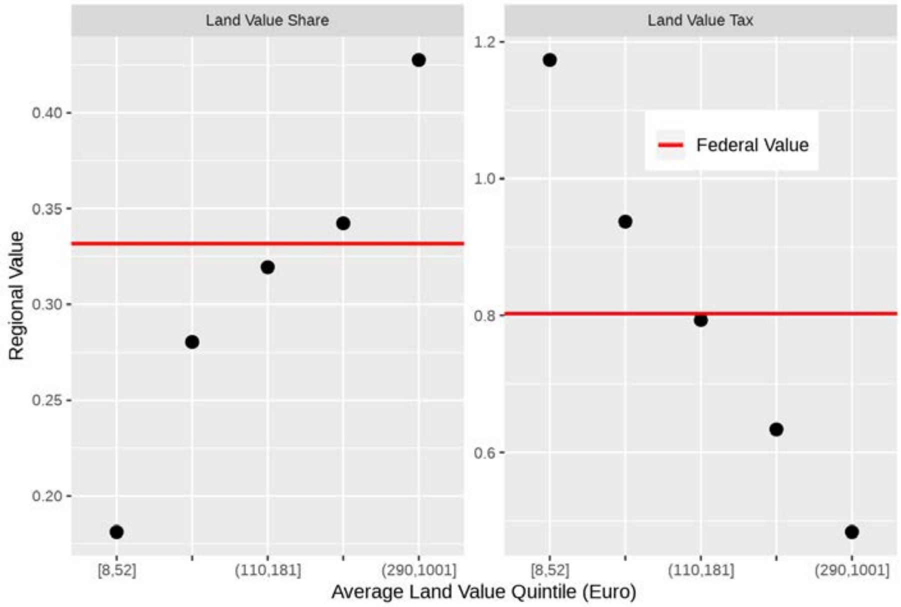

Figure 7: Regional Differences

Panel on the left shows aggregate land value shares computed within each average municipality land value quintile. Panel on the left shows the average revenue neutral land value tax rates within each average municipality land value quintile.

The left panel in Figure 7 shows the aggregate land value share previously discussed at a full sample level (red line), now also computed within each region (black dots). Highest land value region has an aggregate LVS of over 0.45, around 40% higher than the full sample (0.33), and almost three times higher than for the region with lowest average land values (0.16). These differences are decisive for our analysis. A household living in the highest land value region with an individual LVS of 0.4 would be a loser from a LVT implemented at a federal level (as it is above the threshold of 0.33), but would be a winner from a LVT implemented at a regional level (as it is below the relevant threshold of 0.45).

The right panel in Figure 7 shows the heterogeneity of revenue neutral LVT rates across regions. In line with the results in the section on regional differences, regions with higher average land value exhibit lower revenue neutral LVT rates. The highest of the five land value regions has on average a revenue neutral LVT rate below 0.4%, while for the lowest, this number is over 0.8%.

The heterogeneity in regional aggregate land value shares and tax rates indicates there is scope for substantial changes when moving from a federal to a regional analysis. This can be confirmed by a boxplot of LVS across the five land value regions, as seen in Figure 8.

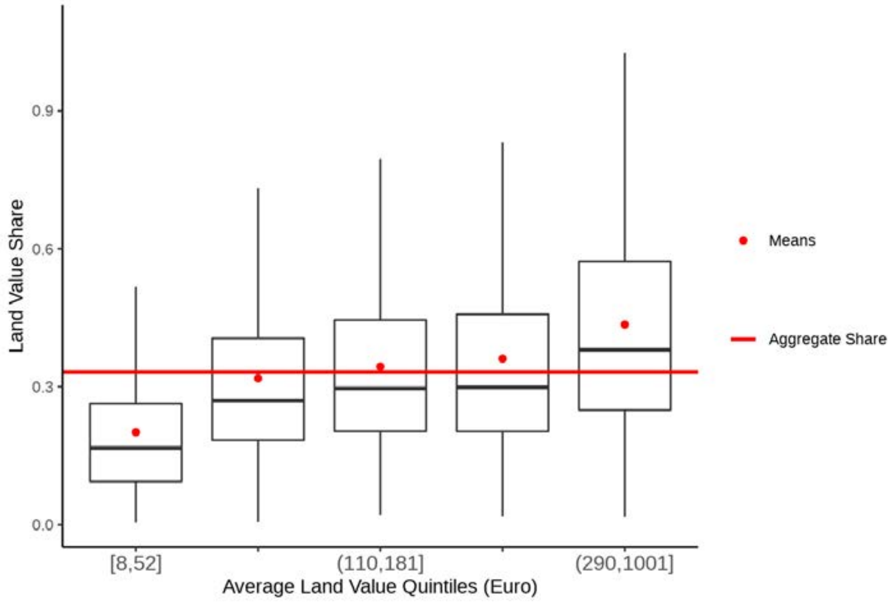

Figure 8: Land value share by average land value

Indeed, Figure 8 reveals stark differences between the two approaches. Using the full sample aggregate LVS (red line) as the threshold to identify winners and losers, one can see a LVT implemented at federal level would lead to more than 75% winners in rural areas (low land value regions) while creating a majority of losers in big cities (high land value regions). Forgetting about the red line and focusing instead on the within region aggregate LVS (red dots), one can see a very different picture, especially for the lowest and highest land value regions. The median of the distribution across the five regions (black line in the boxplot) is below its respective aggregate LVS, indicating more than 50% of households would benefit more from a LVT than a property tax, while with a federal tax the majority of households in cities would lose. Also, the percentage of winners in rural regions is considerably lower, even though more than 50% still win.

Implementing a LVT with a flat rate at a federal level implies substantial inter-regional transfers, from high land value regions to low land value regions. Overall tax neutrality is achieved, but with the burden falling primarily upon big cities. Implementing a LVT at a regional level naturally shuts down the channel of inter-regional transfers as tax neutrality is achieved also at a regional level.

The differences between federal and regional implementation are driven by the strong effect of regional differences in LVS. A log-log OLS regression of LVS on average municipality land value shows a very positive and significant coefficient. An increase of 1% in average land value is associated with an increase of 0.3% of LVS with an R^2 of 16.4%.

At this point, it is natural to ask if the regional implementation of taxes has any impact on the relation between income and the LVS which, with federal taxes, was virtually non-existing. This would imply conducting the analysis while conditioning on the average land value. Table 2 shows the results of a log-log regression of LVS on income including the average land value as a control.

	(1)	(2)
Intercept	-2.781***	-1.599***
	(0.068)	(0.224)
Average Land Value	0.294***	0.310***
	(0.014)	(0.014)
Income		-0.155***
		(0.028)
N	2359	2359
R^2	0.164	0.174
adj. R^2	0.164	1.174

Table 2: Land value share on income and average land value

The table presents the results of log-log OLS regressions. Standard errors in parenthesis.

Results of the regression in Table 2 show that, when controlling for average land value, income has a statistically significant negative impact on LVS. More specifically, an increase of 1% in income is associated with a decrease of 0.15% in land value share in our sample of homeowners. However, it should be noted the inclusion of income in the regression from an initial specification with only average land value modestly increases the R^2, indicating there is a wide dispersion of LVS for households with similar incomes within land value regions and thus that income is not a strong predictor of whether a household will pay more or less under a LVT compared to a property tax. The change in the coefficient for income after the inclusion of average land value in the regression suggests a positive correlation between income and average land value of the region.

Decomposing our LVS measure into different constitutive components (Size of lot, land price and house value), enables us to study in greater depth the channels through which income influences LVS. One would expect higher incomes to be correlated with both higher land value of housing (increasing the LVS) and with higher structures value of housing (decreasing the LVS). The final effect on the LVS will, therefore, depend on the magnitude of each of these channels. We find the negative coefficient of income on LVS (controlling for regional land value) to be a result of a larger negative contribution of income through structures value than through land value (through living in a higher land value area within the region, or through living in a larger lot). The elasticity of structures to income is estimated to be 0.35, while the elasticity of land value within the region is estimated to be 0.2. As far as we know, these estimates, decomposing income elasticity of land and structures value using household level data, are novel in the literature. A comprehensive explanation of the decomposition can be found in Appendix C.

5.5 Quantitative analysis

So far, we have focused our analysis around land value share as a sufficient statistic to determine who wins and loses from a LVT compared to a property tax. However, the LVS hides an important dimension: the magnitude of the change in tax burden. Distance of a household's LVS from the aggregate LVS is not an accurate measure of how much a specific household will be affected. Take two households with the same LVS, which is higher than the aggregate LVS, but where one has values of land and property which are half of the other. The household with the highest underlying value of assets stands to lose more from a LVT, in absolute terms.

Table 3 summarizes the quantitative impact of a regionally implemented LVT for the different income quintiles in our whole sample.

		Income Quintile				
		1	2	3	4	5
Percentage of losers	in %	54.2	44.8	44.1	42.2	37.2
Mean	in €	39.64	2.80	9.89	-6.64	-49.98
1st Quartile		-78.46	-128.23	-142.79	-159.81	-238.57
Median		21.18	-19.66	-30.45	-46.34	-78.26
3rd Quartile		143.72	102.13	131.10	128.39	109.95

Table 3: Winners and losers of a LVT (I)
The values are computed as the difference between LVT and property tax burden. Positive values indicate higher burden under a LVT.

In general, average LVT burdens range from around 300€ for the lowest income quintile to around 650€ for the highest. Regarding winners and losers, Table 3 picks up the regressive trend we have encountered in previous sections. While over half of the households in the lowest quintile pay more under LVT (54.2%), this number is 37.2% for the highest income quintile. On the quantitative dimension, the results show that implementing a LVT decreases the difference in the average tax burden between first and fifth income quintile by around 90€.

The quantitative results prove the intuition of our qualitative section, however, the effects turn out to be modest in magnitude. The reason is the traditionally low level of property taxation in Germany. In particular, the revenue neutral land value tax rates have a mean of 0.6%.

The significance of property taxes however has recently risen in Germany. Over the last years, tax rates have increased nationwide. Furthermore, in other countries, property taxation is a much more important source of revenue. Thus, in a next step we provide statistics to show our results potentially will have significant quantitative impact, if the importance of property taxation continues to rise.

In particular, we compute the variation in tax burden as a percentage of the value of one of the tax burdens in order to make it invariant to the scale of the total revenues being raised. This way one can say, for example, household i will pay 30% more under a LVT compared to a property tax. The corresponding monetary burdens depend on the magnitude of the tax rates, but the ratio between the tax burdens would remain unaffected. The results of such analysis are shown in Table 4, again broken into income quintiles.

		Income Quintile				
		1	2	3	4	5
Percentage of losers	in % of Sample	54.2	44.8	44.1	42.2	37.2
Mean	in % of PT Burden	24.49	6.31	8.16	3.88	-4.17
1st Quartile		-34.46	-40.97	-39.76	-40.33	-44.62
Median		8.01	-8.47	-8.31	-12.24	-18.60
3rd Quartile		64.50	36.05	38.51	37.66	22.33

Table 4: Winners and losers of a LVT (II)

The values are computed as the difference between LVT and property tax burden, relative to the property tax burden. Positive values indicate higher burden under LVT.

Table 4 shows considerable differences in tax burdens. The average change in tax burden for the lowest income quintile is 24.49%, meaning households in this quintile would pay, on average, 24.49% more under a LVT than under a housing tax. For other quintiles, average changes are below 10%. However, the numbers are substantially higher when looking beyond the mean. For more than half of the households in the sample, their burdens change at least 22% under the two different regimes. A quarter of households in the lowest income quintile would pay at least 65% more under a LVT, while another quarter would pay at least 35% less. This analysis confirms our initial assessment that the high dispersion in LVS can lead to significant differences in tax burdens across households.

The data also allows us to investigate in which average land value regions the biggest winners and losers reside. Although one might think the differences would be greater in the highest land value regions, we find the scope and magnitude of the change to be relatively similar across regions.

It is relevant to notice the median voter in our sample of homeowners would be for the implementation of the LVT. A result that holds also within each of the five land value regions we consider. The result that median household pays less under a LVT is a consequence of the higher concentration of land values in our sample of homeowners, leading to a greater share of the total tax burden being paid by fewer households.

6 Model

The empirical analysis carried out thus far has relied on the implicit assumption that valuations of land and housing would not change under different taxation regimes. Although there is value in such an immediate analysis, the likely effects of a switch on the marginal benefit of residential investment and consequent impact on equilibrium prices renders the assumption implausible. In order to capture this dimension, we build a theoretical model.

Our framework has features similar to recent housing models such as Knoll et al. (2017) and Garriga et al. (2019b). However, our model is less concerned about capturing fluctuations in housing prices throughout time, and more concerned about heterogeneous holdings of land and housing across the population.

The model features two regions[11], which differ with respect to their productivity levels and land scarcity, in order to capture the striking regional differences in the level of land prices and land value shares observed in the data. Land is in fixed supply in each region and, therefore, in the overall economy as well. The economy is populated by heterogeneous infinitely lived households. There exist two main types of households, renters and landowners, with the latter being subdivided into productivity and landholding subtypes. Landowners are split exogenously between two regions and between productivity levels. Renters can migrate between regions.

To capture the efficiency-equity trade-off, we calibrate the correlation between productivity and land holdings such that for low productivity landowners, land holdings represent a higher share of their housing wealth, on average.

Capital is used as input to produce structures and consumption good and is supplied from outside the economy at a constant interest rate r by international investors. Through this small open economy setup, the model abstracts from equilibrium effects stemming from changes in savings rate of households or firms' investment in capital and resulting impacts on equilibrium interest rates.

[11]Limiting regional heterogeneity to a minimum prevents a detailed quantification for regions with intermediate characteristics (such as small cities), but it greatly enhances tractability while being sufficient to capture the extremes of regional disparity.

6.1 Households

Households live in on of two regions (A and B, with A being more productive[12]). Total share of landowners in the economy is fixed, so is their distribution across regions. On the other hand, while the total amount of renters in all regions is fixed, their distribution across regions is a free parameter of the model designed to ensure real wage equalization across regions. Within each region, z, land ownership is exogenously split between landowners, who will own an amount of land $T_{L,z}$, and a housing firm, who owns $T_{F,z}$, with $T_{L,z}+T_{F,z} = T_z$. The landowners use their land to produce the housing they consume, while the housing firm produces housing and rents it either to the renter households or to the consumption good firm.

The exogenous split of land intends to capture the strong preference of owner-occupier households to remain in their residence and an inability to sell fractions of housing units. This enables us to replicate in the model the existence of households with low income but with high levels of land value, where in a model in which households could sell their land to another party to finance consumption, they would find it optimal to do so.[13] Although this is a strict assumption in the very long run, we find it fairly reasonable for medium to long run horizons and for relatively small changes in policy. Furthermore, given political resistance for adoption of policies which imply relocation of households, we believe there is value in an analysis which abstracts from that dimension.

We assume total labor supply and available land equal to 1, to be split between regions. Landowner households are heterogeneous and denoted by Li while renter households are homogeneous and denoted by R. The choice for considering only heterogeneity in landowners is due to the desire to primarily quantify the distributional effects of the policy on owners of land and housing. As renters are assumed not to own these assets, we assume homogeneity. We start by presenting the problem of the representative renter household.

[12] Productivity of a region is captured by the total factor productivity of consumption good firms in the region.

[13] A way to circumvent this would be to build into the model some heterogeneous cost of moving, such that a share of households would decide not to relocate. However, the additional layer would complicate the solution of the model and would be challenging to discipline, given that it is related with an heterogeneous unobservable cost of moving.

6.1.1 Renter

The renters derive utility from consumption of goods (C) and housing (H) and supply labor, L_R, inelastically at a net wage $(1-\tau^L)\theta_R w_{z,t}$. Renters problem is merely to choose how to split their wage earnings (net of labor taxes) between consumption good and housing. θ_R represents the relative productivity level of the renter with respect to the average productivity of the landowners. Consumption good is the numeraire and $p^H_{z,t}$ denotes the relative price of housing in region z at time t. The problem of the renter reads:

$$\max_{\{C_{R,z,t},H_{R,z,t}\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} \beta^t \frac{\left(C^{\gamma}_{R,z,t} H^{1-\gamma}_{R,z,t}\right)^{\sigma}}{\sigma} \tag{1a}$$

$$s.to$$

$$(1-\tau^L)\theta_R w_{z,t} L_R \geq C_{R,z,t} + p^H_{z,t} H_{R,z,t} \tag{1b}$$

The renter's problem is totally intratemporal. Combining the first order conditions we get the relative demand of housing by the renters.

$$H_{R,z,t} = \frac{1-\gamma}{\gamma} \frac{C_{R,z,t}}{p^H_{z,t}} \tag{2}$$

Plugging back in the budget constraint of the renter household we can find consumption as a function of the wage.

$$C_{R,z,t} = \gamma(1-\tau^L)\theta_R w_{z,t} \tag{3}$$

Thus, by plugging this result back into the relative demand for housing we found before, consumption of housing by renters in region z will be given by:

$$H_{R,z,t} = (1-\gamma)\frac{1}{p^H_{z,t}}(1-\tau^L)\theta_R w_{z,t} \tag{4}$$

6.1.2 Landowners

Landowners have the same utility function as the renters, but are subject to different constraints. This type of households owns land in the economy, T_L, which it uses to produce housing, H_L, which enters in its utility function. Besides land, housing production also requires structures, S_L, a stock variable which depreciates at a rate δ. The landowner households enters period t with a stock $S_{L,t-1}$. Thus, the budget constraint reflects how landowners finance their consumption of goods and investment in structures, s_L, with net revenues from labor minus potential taxes on the value of its flow of housing services at a rate τ^H, or on the value of its rents of land at a rate τ^T. This marks a slight difference regarding the empirical section which revolved around tax on the value of the stock of land or housing, instead of the period rents. However, in the absence of uncertainty in the model, there is a linear relation between the value of the rents and value of the stock, and thus, for simplicity, we conduct the equivalent analysis based on the value of flows. Finally, landowners also collect the profits of the housing firm in their region, $\Pi_{H,z}$.

Landowners are heterogeneous in three dimensions: labor productivity (θ), land holdings (η_T) and housing firm holdings, (η_F). It is assumed that the average productivity of renters is equal to one. Each landowner subtype has a specific mass and supplies labor inelastically. Furthermore, it is assumed that $\sum_i \eta_{T,i} = \sum_i \eta_{F,i} = 1$, meaning landowners in region z own all the shares of the housing firm in the region and all of $T_{L,z}$. It is assumed landowners only own shares in their region's housing firm.

The problem for a owner-occupier landowner identified with the subscript Li, denoting, for simplicity, a particular combination of θ_i and $\eta_{T,i}$ in region z, is as follows:

$$\max_{\{C_{Li,t},S_{Li,t}\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} \beta^t \frac{\left(C_{Li,t}^{\gamma} H_{Li,t}^{1-\gamma}\right)^{\sigma}}{\sigma} \tag{5a}$$

$$s.to$$

$$(1-\tau^L)\theta_{Li} w_{z,t} L_{Li} - \tau_z^H p_{z,t}^H H_{Li,t} - \tau_z^T p_{z,t}^T \eta_{T,i} T_{L,z} + \eta_{F,i}\Pi_{H,z} \geq C_{Li,t} + p_{z,t}^S s_{Li,t} \tag{5b}$$

$$H_{Li,t}^S = G(\eta_{T,i} T_{L,z}, S_{Li,t}) = \phi_H \left[a S_{Li,t}^{\chi} + (1-a)(\eta_{T,i} T_{L,z})^{\chi}\right]^{\frac{1}{\chi}} \tag{5c}$$

$$S_{Li,t} = (1-\delta) S_{Li,t-1} + s_{Li,t} \tag{5d}$$

The assumption of a CES production function of housing is corroborated by recent literature, such as Garriga et al. (2019b), and is important to capture the degree of imperfect substitutability between land and structures which is necessary to generate a greater degree of price sensitivity of land than under unitary elasticity.

The first order conditions in period t are the following.

$$C: \quad (C_{Li,t}^{\gamma} H_{Li,t}^{1-\gamma})^{\sigma-1} \gamma C_{Li,t}^{\gamma-1} H_{Li,t}^{1-\gamma} = \lambda_{Li,t} \tag{6}$$

$$S: \quad \frac{\partial U}{\partial H}\frac{\partial H}{\partial S} + \beta(1-\delta)\frac{\partial U}{\partial H}\frac{\partial H}{\partial S} = \lambda_{L,t}\left[p_{z,t}^{S} + \tau^{H} p_{z,t}^{H}\frac{\partial H}{\partial S}\right] + \lambda_{L,t+1}\left[\tau^{H} p_{z,t+1}^{H}(1-\delta)\frac{\partial H}{\partial S}\right] \tag{7}$$

The condition of consumption is standard. In (7) we see the effect of a housing tax in the decision of landowners. The housing tax has a intratemporal impact by increasing the marginal cost of structures investment through the increase in the tax burden in the period of the investment, and an intertemporal impact by increasing the tax burden tomorrow through the increase in value of the undepreciated housing stock next period. This increase in the value of taxes caused by higher investment, explains how a tax on housing stock can be distortionary, leading to a inefficiently low level of housing stock to avoid paying higher taxes, which translates into a lower aggregate level of structures and housing. This is not the case under a tax on the land value, since the total amount of land is fixed, although it might shift resources between agents.

At the household level, although it is true a tax on land would increase tax burden which could be eased by selling land, the value at which the land would be sold on the market would incorporate the decrease in the net present value of the land due to the associated tax obligations, making the owner of the land indifferent between paying the tax each period or selling the land at a lower market price, and leaving household choices unaffected.[14]

Given the intertemporal nature of the landowner's problem, we resort to dynamic programming to find numerical solutions. The Bellman equation of the landowner reads as follows.

$$\max_{\{C_{Li}, S'_{Li}\}} V_0(S_{Li}) = U(C_{Li}, H_{Li}(S'_{Li})) + \beta V_0(S'_{Li}) \tag{8a}$$

$$s.to$$

$$(1-\tau^{L})\theta_{Li} w_z L_{Li} - \tau_z^{H} p_z^{H} H_{Li} - \tau_z^{T} p_z^{T} \eta_{T,i} T_{L,z} + \eta_{F,i}\Pi_{H,z} \geq C_{Li} + p_z^{S} s_{Li} \tag{8b}$$

$$H_{Li}^{S} = G(T_{Li,z}, S'_{Li}) = \phi_H\left[a S'^{\chi}_{Li} + (1-a) T_{Li}{}^{\chi}\right]^{\frac{1}{\chi}} \tag{8c}$$

$$S'_{Li} = (1-\delta)S_{Li} + s_{Li,t} \tag{8d}$$

[14] As demonstrated by Petrucci (2006) in the context of a small open economy with non-productive government spending, such as the one in this paper.

Here, the state S_L denotes the level of structures in the previous period. C_L and S'_L denote the decision variables, consumption and structures this period. Using the constraints, it is possible to rewrite the problem to feature only S'_L as a decision variable and solve the problem with only one decision variable.

6.1.3 Landowner Heterogeneity

Landowners are assumed to be heterogeneous along two dimensions, productivity, θ_i and land holdings, $\eta_{T,j}$. Landowners are distributed across five levels of productivity and five levels of land holdings, making up a total of 25 $\{\theta_i, \eta_j\}$ pairings. We choose five levels as to match the analysis in the empirical section.

Concerning the distribution of land holdings, it should be noted that the relevant dimension to capture is the distribution of value, rather than the distribution of quantity of physical land. A household owning a small apartment in a high land value neighbourhood in the center of a big metropolis could thus have a higher level of land holdings in the model than a household living in a bigger single-family-house in the suburbs.

Landowners also differ with respect to holdings of shares of the regional housing firm, however, holdings of these shares are assumed to be a function of the productivity and land holdings, for simplicity, given that due to the lack of data on the location of real estate holdings other than primary residence, it was impossible to accurately determine the corresponding land holdings.

The distribution of landowners across the two dimensions is assumed to follow a bivariate normal distribution where the means and variances are chosen to match empirical counterparts and where the covariance between the two is calibrated to match the within region income and land value share, which is slightly negative, with a coefficient of -0.16 in a log-log regression of land value share on income, as shown in Section 5.

6.2 Migration

In this model, landowners are assumed to be geographically fixed. However, this is not the case for renters. The model features a dimension of internal migration, in the vein of much work in urban economy and works by Robert E. Lucas (2004) and, more recently, in

Garriga et al. (2019a) about rural-urban migration with fixed land supply. The mechanism in our paper is simple and hinges on migration to ensure wages are in line with different price of housing across regions. Renters in the economy are distributed across regions. The share of renters in total population is exogenously determined to be half of total population, reflecting German numbers on homeownership. ψ denotes the share of renters living in region A, while the share of renters living in region B is given by $1 - \psi$. Thus, given total amount of households in the economy is normalized to one, the quantity of renters in region A is given by 0.5ψ. ψ is endogenous and determined as to ensure the real wage between regions is equalized. In a model with only consumption good, this would imply perfect wage equalization across regions, since price of consumption good is the same across regions. However, the basket of consumption includes a non-tradable good, housing, which has a lower price in less productive regions.

The migration assumption is important in capturing the empirical regularity that cities, while being much more productive than rural areas, do not exhibit the same discrepancy in terms of real wage. There is, however a growing divergence in housing and land prices. Without this assumption, wages would tend to grow at similar rate to land prices, since labor would also be in fixed supply. Having migration in the model ensures a more productive region is more attractive for renters who migrate there to earn higher wages, which increases labor supply in the region and ends up dampening the effect of higher productivity on wages. At the same time, new workers coming into cities imply a higher demand for housing in cities, driving up the price of housing and land. These effects are corroborated by the fact that the share of urban population has been steadily increasing in developed countries, including Germany, for decades.

This mechanism provides a channel for elastic labor supply on the extensive margin, even if the model does not allow for adjustments on the intensive margin. It also provides a channel for increased efficiency as labor will naturally relocate to more productive regions with higher real wages. A transition from housing tax to a land value tax can effectively increase housing supply, leading to lower price of housing, allowing more renters to move to more productive regions.

Since households have Cobb-Douglas preferences, we know $(1 - \gamma)$ % of their income is spent on housing. Thus, we define the relation between wages in two regions, A and B, to be given by:

$$\gamma(1-\tau^L)w_{A,t} + (1-\gamma)\frac{(1-\tau^L)w_{A,t}}{p^H_{A,t}} = \gamma(1-\tau^L)w_{B,t} + (1-\gamma)\frac{(1-\tau^L)w_{B,t}}{p^H_{B,t}} \tag{9}$$

This expression is merely an average of costs weighed by consumption shares. For $\gamma = 1$ (no housing consumption) we have perfect wage equalization, while for $\gamma = 0$, the ratio of wages would be the same as the ratio of housing prices. Solving for $w_{A,t}$ yields

$$w_{A,t} = \frac{p^H_{A,t}}{p^H_{B,t}} \frac{1-\gamma(1-p^H_{B,t})}{1-\gamma(1-p^H_{A,t})} w_{B,t} \tag{10}$$

The idea is to solve the model while imposing this restriction on the wages between regions. If (10) holds with inequality, $w_{A,t}$ being too high, for example, then the share of renters living in region A must increase, leading to higher labor supply in region A, driving down equilibrium wage, while the opposite happens for region B.

6.3 Firms

6.3.1 Housing Firm

The housing firm holds an exogenous level of land in the region, $T_{F,z}$, and uses it, along with structures, $S_{F,z,t}$ to produce housing, which it rents to renter households and to the consumption firm. Housing market equilibrium is given by

$$H_{F,z,t} = H_{R,z,t} + H_{C,z,t}. \tag{11}$$

One can intuitively think of this split as a plot of land being used as apartment buildings or office buildings. Having the consumption firm using housing is an important component of the model, as it provides the channel through which increases in firm productivity lead to increases in house and land prices. Increases in goods productivity increase the marginal productivity of housing, increasing the price of housing which then feeds into the marginal productivity and price of land. Production function of housing is identical to that of the owner occupier. The housing firm solves the following maximization problem.

$$\max_{\{S_{F,z,t}\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} \beta^t \left[(1-\tau_z^H) p_{z,t}^H H_{F,z,t} - p_{z,t}^S s_{F,z,t} - \tau_z^T p_{z,t}^T T_{F,z}\right] \tag{12a}$$

$s.to$

$$H_{F,z,t} = H(T_{F,z}, S_{F,z,t}) = \phi_H \left[a S_{F,z,t}^{\chi} + (1-a) T_{F,z}{}^{\chi}\right]^{\frac{1}{\chi}} \tag{12b}$$

$$S_{F,z,t} = (1-\delta) S_{F,z,t-1} + s_{F,z,t} \tag{12c}$$

Profits in a given period t represent the revenues (net of housing taxes) from renting housing to the renters and the consumption good firm minus the costs of investing in new structures and a potential tax on the land owned by the housing firm. The housing firm faces property tax rates equal to the landowner households[15]. It should be noted profits will be positive, despite operating in a competitive market, since the housing firm owns the inputs and therefore keeps the rents associated with them. The only input cost incurred in by the housing firm is the investment in new structures, $s_{F,t}$. Structures owned by the housing firm follow the same law of motion as the owner-occupier.

Solving the problem of the housing firm yields the following first order condition on structures investment.

$$(1-\tau_z^H) p_{z,t}^H \frac{\partial H_{F,z,t}}{\partial S_{F,z,t}} + (1-\delta)(1-\tau_z^H) p_{z,t+1}^H \frac{\partial H_{F,z,t+1}}{\partial S_{F,z,t+1}} \lambda_{F,t+1} = \lambda_{F,t} p_{z,t}^S$$

Here, again, we can see how increases in the housing tax lead to lower levels of structures by decreasing the marginal benefit of structures investment, both in the period the structures are purchased and in the following period through the persistent effect on non-depreciated stock of structures.

Similarly to the landowners, we write the housing firm's problem in recursive form. Dropping region and time indices, the problem becomes

$$\max_{S_F'} V(S_F) = (1-\tau^H) p_{z,t}^H H(T_F, S_F') - p^S (S_F' - (1-\delta) S_F) - \tau^T p^T T_{F,z} + \beta V(S_F') \tag{13}$$

$$s.to$$

$$H_{F,z,t} = H(T_{F,z}, S_{F,z,t}) = \phi_H \left[a S_{F,z,t}^{\chi} + (1-a) T_{F,z}{}^{\chi}\right]^{\frac{1}{\chi}}. \tag{14}$$

[15]In some countries, the burden of paying property taxation falls upon the renter rather than the owner. However, here we take the most common case where the owner must pay the tax. Additionally, it is also possible for commercial property to be taxed a different rate from residential property. We also abstract from this possibility.

In this model, the price of land is required to determine taxes. As there is no market for land in the model, we obtain it by computing the marginal productivity of land for the housing firm, as this is the value for which any additional ϵ amount of land would be sold by a landowner willing to sell its land to a housing firm operating in a competitive environment.

$$p^T_{z,t} = \frac{(1-\tau^H)}{(1+\tau^T)} p^H_{z,t} \frac{\partial H_{F,z,t}}{\partial T_{F,z}} \tag{15}$$

From (15) we can immediately see that a switch from a positive housing tax to a positive land tax will have ambiguous effects on price of land. While, on one hand, removing the tax on housing increases the marginal benefit of holding land, the increase in land tax increases the marginal cost, while also potentially altering equilibrium price of housing and the marginal productivity of land through changes in equilibrium stock of structures.

6.3.2 Structures Firm

The structures firm uses capital it rents to produce structures using a linear production function and sells it in a competitive market to the landowner households and to the housing firm so they can use it as an input for housing production. The problem of the structure firm is very standard and reads as follows.

$$\max_{\{K_{S,z,t}\}} \quad p^S_{z,t} s_{z,t} - r K_{S,z,t} \tag{16a}$$

$$s.to$$

$$s_{z,t} = s(K_{S,z,t}) = \phi_z K_{S,z,t} \tag{16b}$$

Note the quantity sold by the structures firm is $s_{z,t}$ (lowercase), meaning the structures firm only supplies new investment in structures each period, with the rest of the stock of structures being undepreciated structures already available in the previous period. Thus, equilibrium in the structures market in region z is given by

$$s_{z,t} = s_{L,z,t} + s_{F,z,t}, \tag{17}$$

where s_L denotes total structure demand by landowners and s_F denotes structure demand by the housing firm. Solving the trivial maximization problem of the firm yields the expression for equilibrium price of structures:

$$p^S_{z,t} = \frac{r}{\phi_z} \tag{18}$$

Given the constant returns to scale assumption, the structures firm are willing to sell any quantity at this exogenous price.

Admittedly, a version of the model where labor were included as a input of the structures sector would probably be more realistic.[16] However, this inclusion would reduce the tractability of the model as the wages in consumption good and structure sectors would have to be equalized by endogenously splitting total labor in a region between sectors. In a regime with land taxes rather than housing taxes, we expect the level of housing structures to be higher in steady state. This would imply slightly more labor in the structures sector under a LVT than under a housing tax. However, we believe the contribution of this channel to the overall equilibrium to be small and not worth the loss in tractability.

6.3.3 Consumption Good Firm

The consumption good firm behaves competitively and rents out capital from the world market, labor from the households and housing services from the housing firm to produce a consumption good which it sells exclusively to all type of households. Although the firm produces locally, meaning it uses local inputs, it potentially sells beyond the local level since it is a tradable good, which implies price of consumption good is equalized across regions. In particular, given consumption is taken to be the numeraire good in the economy, its price is equalized to one.

The introduction of housing as an input in production introduces an important mechanism in the model. Besides being a simple acknowledgment that production requires a physical space, it links the higher productivity of consumption good firms (whether across space or time) to higher prices of housing and, consequently, land, due to an assumption of equal marginal productivity of land in housing and production of goods in a Beaumol disease type of effect. This effect creates stark differences in land values between different regions which we want to capture. Eliminating housing as an input from the production of goods would mean higher productivity would increase prices of housing and land

[16] Employment in construction sector in the US is around 5% of total employment.

mostly due to an income effect, where households having higher earnings increase their demand for housing. The assumption of housing as an input means a more productive consumption good sector will demand more housing, which, due to the land being in fixed supply, will imply a higher concentration of structures for unit of land, capturing the agglomeration effects in cities.

The firm produces according to a Cobb-Douglas production function with constant returns to scale. For the consumption good firm operating in region z at period t, solves the following intratemporal problem:

$$\max_{\{K_{C,z,t},H_{C,z,t},L_{C,z,t}\}} \quad C_{z,t} - rK_{C,z,t} - p^H_{z,t}H_{C,z,t} - w_{z,t}L_{C,z,t} \tag{19a}$$

$$s.to$$

$$C_{z,t} = Y(K_{C,z,t}, H_{C,z,t}, L_{C,z,t}) = \phi_{C,z}K^{\alpha_1}_{C,z,t}H^{\alpha_2}_{C,z,t}L^{\alpha_3}_{C,z,t} \tag{19b}$$

Here, $C_{z,t}$ denotes the production of consumption good in region z at time t, while $K_{C,z,t}$, $H_{C,z,t}$ and $L_{C,z,t}$ denote inputs demands for foreign capital, housing and labor, respectively, in region z at time t. In this notation, $\phi_{C,z}$ captures the region specific productivity of the firm and to obey constant returns to scale, $\alpha_1 + \alpha_2 + \alpha_3 = 1$.

The price-taking firm chooses relative input levels as determined by the set of first order conditions:

$$\begin{aligned} K_C: &\quad \phi_{C,z}\alpha_1 K^{\alpha_1-1}_{C,z,t}H^{\alpha_2}_{C,z,t}L^{\alpha_3}_{C,z,t} = r \\ H_C: &\quad \phi_{C,z}\alpha_2 K^{\alpha_1}_{C,z,t}H^{\alpha_2-1}_{C,z,t}L^{\alpha_3}_{C,z,t} = p^H_{z,t} \\ L_C: &\quad \phi_{C,z}\alpha_3 K^{\alpha_1}_{C,z,t}H^{\alpha_2}_{C,z,t}L^{\alpha_3-1}_{C,z,t} = w_{z,t} \end{aligned}$$

Solving the firms' problem does not give us the factor demands in closed form due to the CRS assumption. However, one can back out the relative factor demands (in units of L_C):

$$K_{C,z,t} = \frac{\alpha_1}{\alpha_3}\frac{w_{z,t}}{r}L_{C,z,t} \tag{20}$$

$$H_{C,z,t} = \frac{\alpha_2}{\alpha_3}\frac{w_{z,t}}{p^H_{z,t}}L_{C,z,t} \tag{21}$$

Substituting the factor demands in the production function we can write the production of consumption good in region r as a function of L_C.

$$C_{z,t} = \phi_{C,z}\left(\frac{\alpha_1}{\alpha_3}\frac{w_{z,t}}{r}\right)^{\alpha_1}\left(\frac{\alpha_2}{\alpha_3}\frac{w_{z,t}}{p^H_{z,t}}\right)^{\alpha_2}L_{C,z,t} \tag{22}$$

Furthermore, due to the CRS assumption and under a competitive market, the zero profit condition of the Consumption firm in region z and period t can be written as:

$$\phi_{C,z} = \left(\frac{r}{\alpha_1}\right)^{\alpha_1} \left(\frac{p^H_{z,t}}{\alpha_2}\right)^{\alpha_2} \left(\frac{w_{z,t}}{\alpha_3}\right)^{\alpha_3} \tag{23}$$

6.4 Government

There are two levels of government in the model. The tax on labor income in the model, τ_L is set exogenously by a central government and is uniform across regions. The labor tax is included in the model to measure the potential increase in government revenues due to to the efficiency gains of switching to a land tax. The more relevant agents are the local governments who wish to maximize welfare in their region using one of the property taxes at their disposal, τ_H and τ_T, to finance unproductive spending. The problem of each local government can be written as follows.

$$\max_{\{\tau^H_z, \tau^T_z\}} \quad \sum_{t=0}^{\infty} \sum_i \beta^t \frac{\left(C^{\gamma}_{i,z,t} H^{1-\gamma}_{i,z,t}\right)^{\sigma}}{\sigma} \tag{24a}$$

$$s.to$$

$$G_z = \tau^H_z p^H_{z,t} H_{z,t} + \tau^T_z p^T_{z,t} T_z. \tag{24b}$$

The objective function of the government is simply the discounted sum of utilities of all households (landowners and renters). The budget constraint forces a balance between the exogenous level of unproductive[17] regional government expenditures, G_z, and the revenues from housing taxes and land taxes in each region. We exogenously set the taxation of labor to a fixed value, and focus on the decision between the level of property or land taxation.

For simplicity, we assume the choice for the local governments to be between taxing only housing, or only land. This comparison constitutes the main policy experiment to be carried out. Thus, we ignore the possibility of two tier property tax regimes in which both land and structures are taxed, albeit at different rates. It should be noted that,

[17] A relevant extension of this model would be to include provision of public goods and study to which extent different types of property taxation can capture the value of the public goods as tax revenue. Arnott and Stiglitz (1979) shows how, under particular conditions, a LVT can raise enough revenue to finance optimal level of public goods investment.

given to the concavity of the utility function, variations in consumption for lower income levels are bound to create larger fluctuations in utility.

6.5 Competitive Equilibrium

The competitive equilibrium of this model for a given period will be given by a vector of tax policies $\{\tau^L, \tau_z^H, \tau_z^T\}$ equilibrium prices $\{w_z, p_z^H p_z^S, p_z^T\}$ and allocations $\{C_i, H_i, S'_F, S'_L, K_C, H_C\}$, for $z \in \{A, B\}$, such that, given prices and initial conditions on stock of structures in the economy $(S_{F,z}, S_{L,z})$, the allocation solves the maximization problems of households (renters and landowners) and firms (Housing, Structures and Consumption Good) in each region in the economy, as well as ensure all markets (consumption, housing, structures, labor and capital) are in equilibrium, that the migration condition on wages of different regions is satisfied, and the budget constraint of governments is satisfied.

The model is solved for a two-dimensional grid of the relevant states in the economy, the initial stock of structures for the housing firm and households (S_F, S_L). The computational algorithm used to solve the model can be found in Appendix E.

6.6 Calibration

Calibration of the model requires the determination of a set of parameters related to the distribution of land and households across different regions. In order to establish these parameters we use statistics computed from the ALKIS, land values and SOEP datasets which allowed for the empirical analysis, as well as other aggregate statistics for Germany.

In order to split the total mass of land in the model ($\bar{T} = 1$), we used the municipal data on average land value, size of municipality and population we have constructed. First, we determined the cutoff average land value which separates urban from non-urban municipalities using the aggregate value of urban population for Germany of 77%. This cutoff was determined to be approximately 90€. Next, we determined the share of total urban land by summing the total area of the municipalities previously determined to be urban (average land value above 90€), and dividing it by the total area of all municipalities in our sample. This yielded a number of roughly 25%. This means 77% of the population in our sample of German states lives approximately 25% of the land area. Therefore, we split total land in the model accordingly, with the high productivity region comprising 25% of total land.

The trickiest split to estimate is the one concerning the division of land within each region between landowners and the housing firm. In order to calibrate this value for each region we choose the share of land owned by the housing firm such that the average Land Value Share of the landowners matches our empirical observations. Specifically, we calibrate the share of land owned by the landowners in the high productivity region in order to match an average Land Value Share in the region of 0.44, and we do the same for the low productivity region to match an average land value share of 0.18. These numbers are in line with the results for land value share in the highest and lowest average land value quintiles. This calibration implies a share of 34% of land in region A owned by landowners and a share of 74% in region B.

We exogenously split our unit mass of households between renters and landowners to reflect the average homeownership rate in Germany, which is close to 50%, one of the highest in OECD countries.

According to our household survey data, homeownership rate in urban areas is 45%. In order to exogenously split our mass of owner-occupier landowners, we compute the share of landowners in cities by multiplying the share of urban population (77%) by the urban homeownership rate (44%). From here, we arrive at the conclusion that roughly 35% of households are urban landowners with the rest of the landowners (15% of total households) being located in the non-urban region. Given this distribution of landowners and the 77/23 split in urban/non-urban population, we can easily calculate the corresponding share of renters in each region as well. 84% of renters live in urban region and only 16% in the non-urban region.

In order to compute the productivity differential between the urban and non-urban region, we determine what level of regional productivities justify the observed split between urban and non-urban population, given the migration condition must hold. We first set the productivity of the high productivity region exogenously. Next, we pin down the relative productivity of the low productivity region, $\phi_{C,B}$ by matching the distribution of renter households. We estimate the model given the exogenous split of renters and landowners between regions (namely that 84% of renters live in the urban, high productivity region), adjusting the productivity level of the low productivity region as to ensure the migration condition is met. Using this method, the estimated productivity in the low productivity region is estimated to be 14% lower. This differential between productivity across regions is then kept fixed for the policy experiments carried out later, with the share of renter in each region allowed to fluctuate to ensure the migration condition is satisfied.

The exponent of housing in the production function of the consumption good is calibrated to match a of housing share of output equal to 16%. The share of labor is exogenously determined to be 0.6, and the share of capital is set at 0.32 in order to accommodate a constant elasticity of substitution.

Initial level of regional housing tax rates is set so as to raise revenues equal to 1.2% of total output[18] in the steady state of the model under the housing tax. This translates into levels of τ_H close to 0.07 for both regions. In the policy experiment, the land value tax is chosen in order to raise the same absolute level of revenue as the housing tax in the benchmark mode, G_z (not the same ratio to total output).

In Table 5 we have the parameters for the benchmark model. Parameters which haven't been addressed are chosen to match standard values in the literature, namely Garriga et al. (2019b), which uses a similar setup, including for technology for the production of housing.

Another set of parameters concerns the distribution of productivity and land holdings across landowner households. The productivity levels are set based on the average of the five quintiles of earnings and built to replicate the concentration visible in Figure 6. Average productivity of landowners is normalized to 1 and the variance is scaled accordingly. The productivity level of renters is set based on the ratio of average earnings of renters to average earnings of landowners in the SOEP data for 2017, which is roughly equal to 0.7. Thus productivity of renters in the model is set to 70% that of the average landowner. A similar approach is used to set the level of land holdings across landowners.[19]

Given the five levels of productivity and five levels of land holdings, landowners are

[18]in accordance with OECD statistics of fiscal revenues. https://www.oecd.org/tax/revenue-statistics-germany.pdf

[19]A plot of the distributions from which the levels are calculated can be found in Appendix D

Parameter	Intuition	Value	Target
Land distribution			
$\bar{T}$	Total land	1	-
T_A	Land in Region A	0.25	-
T_{LA}	% Land owned by HH in A	0.34	LVS in A
T_{LB}	% Land owned by HH in B	0.74	LVS in B
Household Distribution			
$\bar{L}$	Total mass of households	1	-
L_L	Mass of landowners	0.5	German homeownership
L_{LA}	Landowners living in A	0.35	Urban homeownership
Household preferences			
β	Discount factor	0.96	Garriga et. al
σ	Intertemporal Substitution	0.5	Garriga et. al
γ	Consumption share	0.75	-
Housing Production			
ϕ_H	Productivity	12	-
δ	Structures depreciation	0.1	Garriga et. al
χ	Substitution in Housing	-1	Garriga et. al
Consumption Firm			
$\phi_{C,A}$	Productivity in A	15	-
$\phi_{C,B}$	Productivity in B	0.86	Share of renters in A
α_1	Capital parameter	0.32	1 - α_2 - α_3
α_2	Housing parameter	0.08	Share of housing in output
α_3	Labor parameter	0.6	-
Structures Firm			
ϕ_S	Productivity	0.001	Share of land in Output
Capital Market			
r	Interest rate	0.04	-
Taxes			
τ_L	Tax rate on labor	0.2	-
$\tau_{H,A}$	Tax rate on housing in A	0.07	1.2% of Output
$\tau_{H,B}$	Tax rate on housing in B	0.075	1.2% of Output
$\tau_{T,A}$	Tax rate on land in A	0	-
$\tau_{T,B}$	Tax rate on land in B	0	-

Table 5: Parameter values of the benchmark model.

distributed across 25 possible combinations along these two dimensions. In order to determine this distribution we resort to calibrating a discretized bivariate normal distribution, with means equal to the means of landowner productivity and a variance-covariance matrix where the variances of productivity and land holdings match empirical observation and where the covariance between the two variables is calibrated to replicate the empirical relation between income and Land Value Share. We do this by running a log-log regression[20] of land value shares (which are an output of the model) on income levels of households in the model, controlling for the region. As the covariance increases, more

[20]Weighed by the respective mass of households in the model.

mass is attributed to the landowner subtypes close to the diagonal of the matrix (low-income/low-land and high-income/high-land) leading to less mass for subtypes off the diagonal. Strengthening this correlation leads to a stronger link between income and land value share in the model, as, conditional on income, higher land holdings will be associated with higher land value share, on average. Achieving a coefficient on income of -0.16 like in our empirical analysis implies a positive correlation of 70% between productivity levels and land holdings. Figure 9 depicts a 3D bar plot of the resulting distribution of landowners.

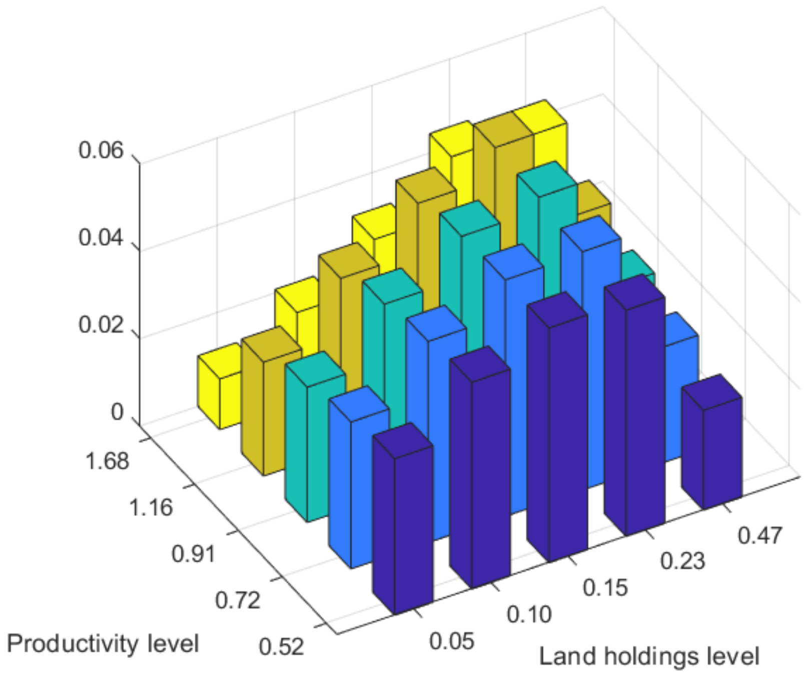

Figure 9: Landowners' distribution across productivity and land holding levels.

Average and standard deviations of productivity and land holdings are ($\mu = 1, \sigma = 0.711$) and ($\mu = 0.2, \sigma = 0.49$), respectively. Covariance is 0.24, implying a correlation of 70%.

The final distributional decision concerns the shares of the housing firm across landowners which determines how its profits are distributed. Empirical data on how income from renting other housing units was distributed across income and land value holdings was not available. We decided to distribute housing firm profits equally across subtypes (accounting for their different mass). Given the distribution of other secondary residences is highly concentrated and correlated with income, this assumption will likely lead to an underestimation of the progressivity of property taxation.

7 Model Results

7.1 Optimal Policies

We begin by analysing the solution to the intertemporal problem faced by the landowners and the housing firm, as it constitutes the core of the dynamics we are attempting to capture. Figures 10 and 11 show the policy functions resultant of the dynamic problems faced by housing firm and landowners for our benchmark model (here we show the policy function for an arbitrary landowner, as the policy functions across landowners display the same general shape, differing primarily in regards to their level, with more productive households and those holding higher level of land finding it optimal to maintain a higher stock of structures). The x-axis contains the grid of possible levels of structures with which the agents can enter any given period. The y-axis contains the level of structures after depreciation and investment in new structures. The plots show sensible behaviour. For low initial levels of structures, it is optimal for the agents to invest quite heavily in new structures. The steady state is found for the level of structures where the line depicting the optimal policy crosses the 45 degree line (dashed line), as it marks the point where the level of structure the agents starts the period with is the same with which it ends the period, having to invest in enough new structures to counteract the effect of depreciation. For initial values of structures substantially above the steady state level, the investment in new structures is zero and thus the level of structures is reduced by the amount of depreciation, as it is assumed it is not possible to have negative investment in structures. After a certain point, the optimal level of structures coincides with the $(1-\delta)S_{t-1}$ dotted line, which is slightly flatter than the 45 degree line.

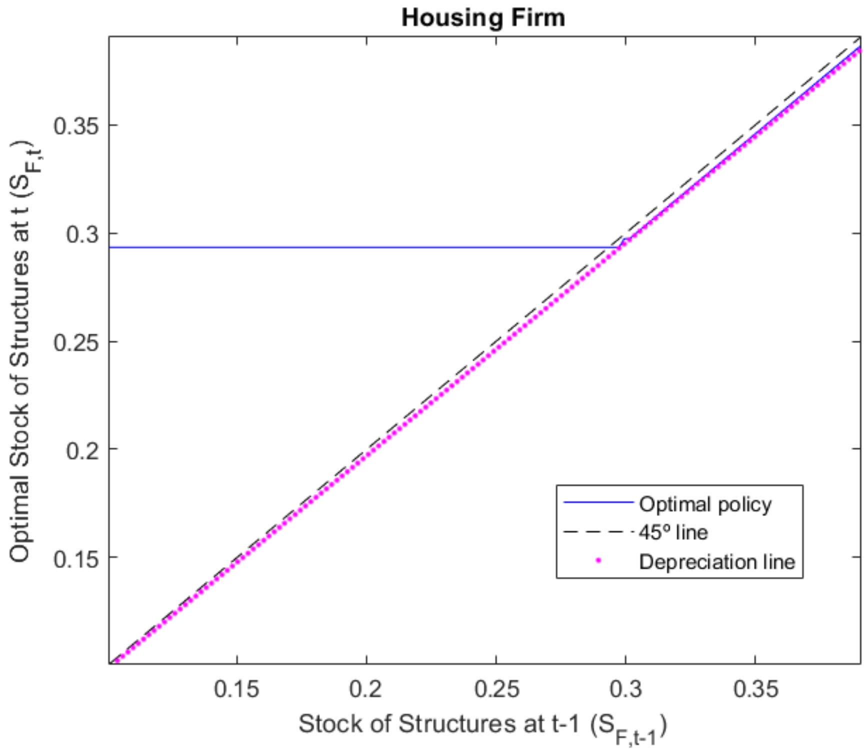

Figure 10: Housing Firm's optimal policy for investing in structures.

Figure depicts the optimal policy function of the housing firm in the urban region (A).

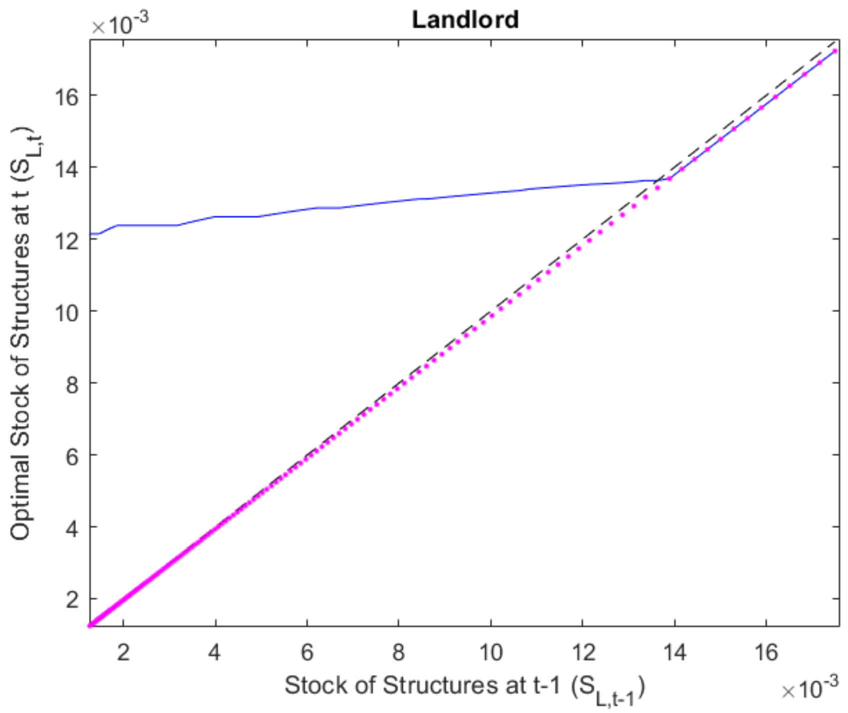

Figure 11: Landowners' optimal policy for investing in structures

Figure depicts the optimal policy function of a landowner living in the urban region (A) with highest productivity level and highest land holding level.

The policies of the housing firm and the landowners differ with respect to their behaviour for low initial level of structures. For the housing firm, the marginal cost of investing in structures is constant as it comprises only the price which must be paid for the investment in structures, which is also the only expenditure of the housing firm (besides paying property taxes). This investment lowers current profits, but since the firm is maximizing the stream of profits and does not weigh present profits more heavily than future profits, the firm finds it optimal to jump to the steady state level of structures immediately[21]. For households, however, a higher level of investment in structures must be compensated by a lower level of consumption of the tradable good in order for the budget constraint to hold. Given the concavity of the household's utility function, investing enough to get to the steady state immediately would imply an inefficiently low level of tradable consumption today. Instead, households will smooth their consumption of tradable good and housing. Nevertheless, the exogenous level of land holding by landowners creates a very high marginal utility of structures investment for low initial level of structures. Intuitively, this makes sense. It is akin to a family which must completely rebuild their house after a tornado. It might take a few years for the family to recreate the lost house, but the bulk investment is made shortly after the house has been lost.

7.2 Regional Differences in Steady State

7.2.1 Aggregate

We now compare the steady state of the model in region A (Urban/City) and region B (Rural/Village), in order to demonstrate that the model can replicate some of the most important empirical findings uncovered in sections 4 and 5, among other established differences between urban and rural areas.

Table 6 shows the level of some important variables and statistics, as well as the difference between the urban and rural regions, measured by their ratio. Concerning prices, our model can replicate the observed differences in magnitudes. Price of housing in the urban region is three times higher than in the rural region. Meanwhile, the ratio of

[21] This could be relaxed by the introduction of a convex adjustment cost to reflect some time-to-build constraints which are likely to exist. However, it is unlikely to meaningfully change the steady state, and thus, for simplicity, we abstract form that dimension.

land prices, measured by the marginal productivity of land for the housing firm operating in each region, greatly exceeds the ratio for housing prices, with land price in cities being 27 times higher. Average land values in our municipalities ranged from below 10€ to over 1000€ in Berlin, a ratio of over 100, meaning the results of the model are well within a reasonable range. At the same time, our model also delivers a wage premium for renters living in the city (close to 12%) in order to compensate the higher cost of housing. As a result of this difference in relative prices of housing to tradable goods, the model produces differences in relative consumption of housing across regions. In the urban region, renters consume a higher quantity of the tradable good and less housing services than renters living in the rural region. Intuitively, this result captures the standard empirical fact that urban households, especially in big cities, live in small apartments, while at the same time enjoying the access to a higher variety and, often, quality of goods and services in cities.

The housing output to total regional output is 16% in both regions, broadly consistent with the value for developed economies which is close to 15%. Regional output in the model is measured by adding up total production of the tradable good, which is the numeraire, production of new structures times the price of structures and total housing production (Housing firm plus landowners[22]) multiplied by the price of housing in the region. Due to the greater scarcity of land and housing in the urban region and greater demand by the majority of renters, profits of the housing firm are considerably higher than in the rural region. However, as a share of output, housing firm profits stand at around 10% of output.

The ratio of total regional land rents to output presents a higher disparity than that of housing rents. The model generates a value of 9% for the urban region and a much lower 4% for the rural region, consistent with empirical data in the literature, showing the majority of land value is concentrated in large metropolitan areas. This value is important for the analysis as it constitutes the ceiling for land value tax revenues and because it gives some insight into the disparity between LVT revenue neutral tax rates in urban and rural areas. In the model, 90% of total land value in the economy is coming from land in the urban region.

Due to the calibration, average land value shares (LVS) of landowners in our regions

[22]We include the implicit rents of owner-occupiers, as is standard in national accounts.

	Urban (A)	Rural (B)	Ratio (A)/(B)
Prices			
Wage	95.84	85.67	1.12
Price of Housing	4.91	1.75	2.80
Price of Land	45.62	1.68	27.13
Quantities			
Structures (Firm)	0.29	0.15	1.93
Housing Produced (Firm)	2.83	1.90	1.49
Structures (Landlords)	0.12	0.10	1.22
Housing Produced (Landlords)	1.25	1.31	0.95
Tradable Good Produced	103.32	29.59	3.49
Total Output	123.34	35.22	3.50
Housing share of Output	0.16	0.16	1.02
Land share of Output	0.09	0.04	2.58
Housing Firm Profits	12.71	2.99	4.26
Revenues from Housing Tax	1.46	0.42	3.46
Land Value Share			
Average Landlord LVS	0.44	0.19	3.46
Firm LVS	0.39	0.05	2.36

Table 6: Regional differences in benchmark model with tax rate on housing calibrated to generate revenues equal to 1.2% of Output.

match our empirical counterparts. The urban region has a land value share close to 44% and the rural region 18%. The housing firm's land value shares are 39 and 5%. This is a number for which the empirical analysis does not provide a term of comparison. Nevertheless, it seems intuitive that firms and renters, who wouldn't have such an attachment to location as landowners, would relocate more easily if land prices became too high, and thus exhibit lower levels of land value share. We now move on to the analysis of the distributional heterogeneity across regions.

7.2.2 Distributional

Renters in the rural region consume more than twice the housing services of those in the urban region, however, they also experience a steady state level of consumption of tradable good which is 10% lower. Comparative to the landowners, the utility level of renters in the model closely resembles that of the least productive landowners with low levels of land holdings. The lowest landowners have a lower productivity level than the renters, but they don't have to use their income to buy housing, only for the upkeep of their structures, which is a much lower cost, resulting in similar levels of utility.

Figure 12 shows a boxplot of Land Value Shares generated by the model. This boxplot is designed to allow one to quickly grasp differences both across regions and income levels intuitively. The plot is first divided into regions in the x-axis, with the urban region (A) on the left and the rural region (B) on the right. Within each region the plot is further subdivided into different income/productivity levels. Within each region/income group, the box plot shows the distribution of land value share across land holding subtypes. The tail end of the whiskers marks the land value share of the first and fifth levels. The edge of the boxes mark the value for the second and fourth levels and the dark line within each box represents the level of the third level. Additionally, the plot shows an additional dot within each box representing the weighted average of land value share for the region/productivity level subtype.

As we had seen before, the model can capture the disparity of land value share found in the data, with the average share in urban region being more than twice that of the rural region. More interesting is the heterogeneity within regions. The model replicates the empirical pattern whereby land value share decreases, on average, in income, although with large heterogeneity within income level. The range of LVS within the first income level in the urban region goes from 35 to 65% between the lower and higher level of land holdings. For the most productive households it goes from just under 30% to just over 50%. This reduced variance of the Land Value Share along higher income levels is also a feature of the data.

As a term of comparison, Figure D.2 in the appendix shows the empirical counterparts of Figure 12. It depicts empirical land value shares for 5 quintiles of average land value. To the left the regions with lowest average land value (more rural), to the right the most

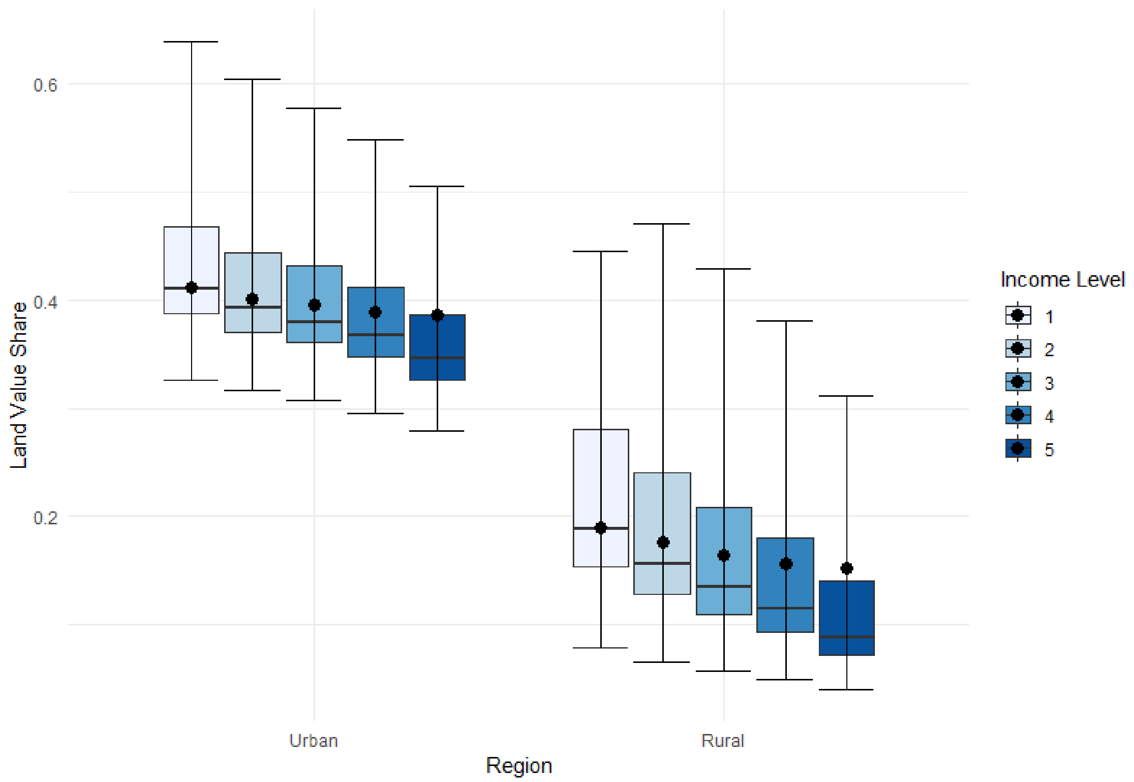

Figure 12: Land value shares of Landowners across regions and income levels.

urban regions. Most of the mass of households in the highest land value quintile ranges from 25 to 60%, broadly consistent with the pattern for our urban region in the model. As for the rural region, it presents a pattern which resembles an average of the two lowest land value quintiles,[23] with land value shares between 15% and 40%. Model results also do a good job of capturing the slight negative correlation with income.

Differences in consumption levels across regions reflect the differences in the relative price of housing. Landowners in the rural region consume less tradable good, but higher housing, same as the renters. Variation in consumption within income level is small. This makes sense, since investment in structures is equally small as only 1.5% of the stock of structures depreciates every period. In the extreme case there were no depreciation, once households achieved their steady state stock of structures, they would never have to invest in structures again and variation in consumption would be totally accounted for by variation in income. Variation in housing across income levels is much more substantial,

[23]This makes sense, as our cutoff for splitting population according to average land value in the model is 90€, and the cutoff between the first and second quintles of average land value in the empirical analysis is only 50€.

driven by exogenous differences in land holdings. Boxplots similar to Figure 12 for the level of tradable and housing consumption levels can be found in Appendix F.

It is worthwhile to remark that these stark differences in outcomes between regions in the model are obtained while maintaining most parameters constant across regions. Differences are being driven by a relatively modest productivity gap in the production of the tradable good, allied with a higher relative scarcity of productive land in cities due to cities representing only 25% of the land mass in the model. Indeed, the model assumes regions are equivalent in some characteristics in which reality would probably disprove such an assumption. For example, one would expect the distribution of productivities to be different across regions, with cities attracting the most productive households due to a matching effect. However, due to the challenges in isolating difference in wages coming from higher price level and higher level of productivity we opted to keep productivity distribution equal in both regions. The same holds for distribution of land holdings and potential heterogeneous concentration across regions. Price of structures is also assumed to be equal even if differences in the wage level could lead one to think price of structures would be higher in cities. These are all potential aspects where more regional heterogeneity would improve the results of the model, however, for simplicity and due to a lack of credible priors, we assume homogeneity along these dimensions.

7.3 Policy Experiments

7.3.1 Aggregate Impact

The policy experiment to be carried out consists in the replacement of the tax on housing with a revenue neutral tax on land rents. The first step in running the policy experiment is simulating the model in order to find the revenue neutral land tax rates. Given the similarity of the share of output to total output between regions, the tax rate on housing rents was almost the same in both regions. For a land tax, that is not the case. Land rents constitute a much higher share of total output in the urban region A, than in region B. For this reason, in order to generate the same revenue for local government, the tax rate in the rural region will have to be higher than in the urban region. This is consistent with our empirical finding illustrated in Figure 7, showing that revenue neutral land tax rates in high average land value regions are less than half those in low average land value regions. Land rent tax neutral rates in the model are 11.2 % in the urban region (from a tax rate on housing of 7%) and 31% in the rural region (from a tax rate on housing of 7.5%).

Table 7 shows the percentage changes in steady state level of relevant variables in the model for both regions, after switching from a tax on housing to a tax on land rents. The first effect to notice is the one on the steady state level of structures. As expected, the optimal stock of structures under a land tax is considerably higher in both regions, as the reduction in the marginal cost of investment in structures increases the equilibrium level structures and housing. Contrary to initial intuition, introduction of a land tax actually promotes a greater increase in structures in the rural region. This intuition was justified by the fact that high productivity regions would be the ones where removing the inefficiency of the property tax would lead to a largest relative increase in structures investment due to higher housing prices in the urban region and, thus, a higher return on investment. Although this effect exists, it is only half of the story, as high productive regions also suffer from a higher scarcity of land, meaning each additional increment in structures results in less housing produced. This can be observed by comparing the increases in housing across regions resulting from the respective increases in structures. An increase in structures of the housing firm of almost 8% in the rural region leads to increased housing supply of almost 7%, while a 2% increase in the urban region results in only 0.84% more housing. So, even if one more unit of housing is worth more in the urban region, the investment in structures required to achieve an extra unit of housing is also much higher in the urban region. Indeed, this scarcity effect seems to dominate, leading to greater increase in structures in the rural region.

Despite the more pronounced increase in housing supply in the rural region, price of housing falls more in the urban region. This is a result of migration. Absent migration, price of housing would fall more in the rural region, however the inflow of renters seeking these lower rents depresses rents in cities and increases rents in the rural region. In the end, price of housing decreases by 2.14% in the urban region and by 0.78% in the rural region while urban population decreases from 77% to 76%. This represents a decrease of 1.2% of total population in the Urban region and a compensating increase of 4.3% in the rural region. Wages increase, though only slightly, compared to house prices, meaning

	Urban	Rural
Prices		
Wage	0.28	0.31
Price of Housing	-2.14	-0.78
Price of Land	-3.59	7.17
Quantities		
Population	-1.30	4.35
Structures (Firm)	2.06	7.93
Housing (Firm)	0.84	6.96
Structures (Landlords)	2.36	5.18
Housing (Landlords)	1.77	5.04
Output	-0.84	3.78
Renters		
Consumption	0.29	0.11
Housing	2.48	0.90
Utility	1.11	0.40
LVS (Landlord)	-3.35	1.54

Table 7: Changes (in %) from steady state of model with regional housing taxes to one with revenue equivalent regional land rent taxes.

Change in utility of renters measured using consumption equivalent variation.

real wages increase in both regions. Again, without migration wage increase in the rural region would be larger, but the increase in the labor supply dampens the effect.

Land prices change the most and with different sign across regions. In the urban region the price of land falls 3.59% which is driven by the fall in the price of housing. In the rural region, price of land goes up 7.17%, even though price of housing decreases slightly, due to the robust increase in the equilibrium stock of structures which increases the marginal productivity of land. As a consequence of changes in the price of land, the introduction of the land tax reduces land value share in the urban region and increases it in rural region.

As for the consumption good sector, effects are asymmetric across regions, with output slightly decreasing in the urban region and increasing in the rural region. Decrease in production in the urban region is due to the migration of renters, which reduces the equilibrium labor supply. This is slightly offset by higher use of housing in production due the decrease in housing cost. The rural region, on the other hand, experiences two positive shocks, more and cheaper housing and an inflow of labor from cities.

Overall, the switch to a land tax regime creates some convergence between the two regions with the price differentials we observed in Table 7 being reduced across the board. Additionally, the central government experiences a very slight overall increase in revenues from labor taxation (around 0.2%) due to increased efficiency.

It should be noted, the magnitude of the general equilibrium effects are naturally a function of the size of initial level of property taxation, which in Germany is small (little over 1% of output) compared to other OECD countries where property tax revenues are on average between two and three times higher. Replacing property taxes in countries which rely more on property taxation is bound to lead to magnified effects.

7.3.2 Distributional Impact

As can be seen in the bottom of Table 7, renters in both regions benefit with the change in property taxation regime, with those living in the urban region benefiting the most, 1.11% vs. 0.40%, in consumption equivalence terms. This measure is merely a calculation of how much the consumption of tradable good would have to change from benchmark in order to replicate the same variation in utility brought about by the introduction of the revenue neutral land tax. The variations in utility are a result of renters in the urban region experiencing an increase in consumption of tradable good and housing services of 0.29 and 2.48%, respectively, near three times the increases for renters in the rural region.

In order to study the impact on landowners, we once again resort to a boxplot. Figure 13 shows the consumption equivalent variations for renters across regions and income levels. The consumption equivalent variations are much more substantial for the rural region than for the urban region. This follows from the fact that percentage changes in aggregate quantities are also much more pronounced in the rural region.[24] As we have seen, changes in steady state stock of structures and housing is much higher in

[24]Box plots with variation in consumption levels can be found in Appendix F.

the rural region where land is more abundant. But, more importantly, much more of the adjustment in tax burdens is happening through landowners in the rural region than through the housing firm, which owns much less land and produces much less housing than the housing firm in the urban region. To understand this, imagine landowners in the urban region own only a very small percentage of total land, and, therefore, also produce little housing. In this case, changes in property taxation cannot produce large changes in utility of landowners directly since landowners own very little property to begin with and thus pay a small proportion of total property taxes in the region.

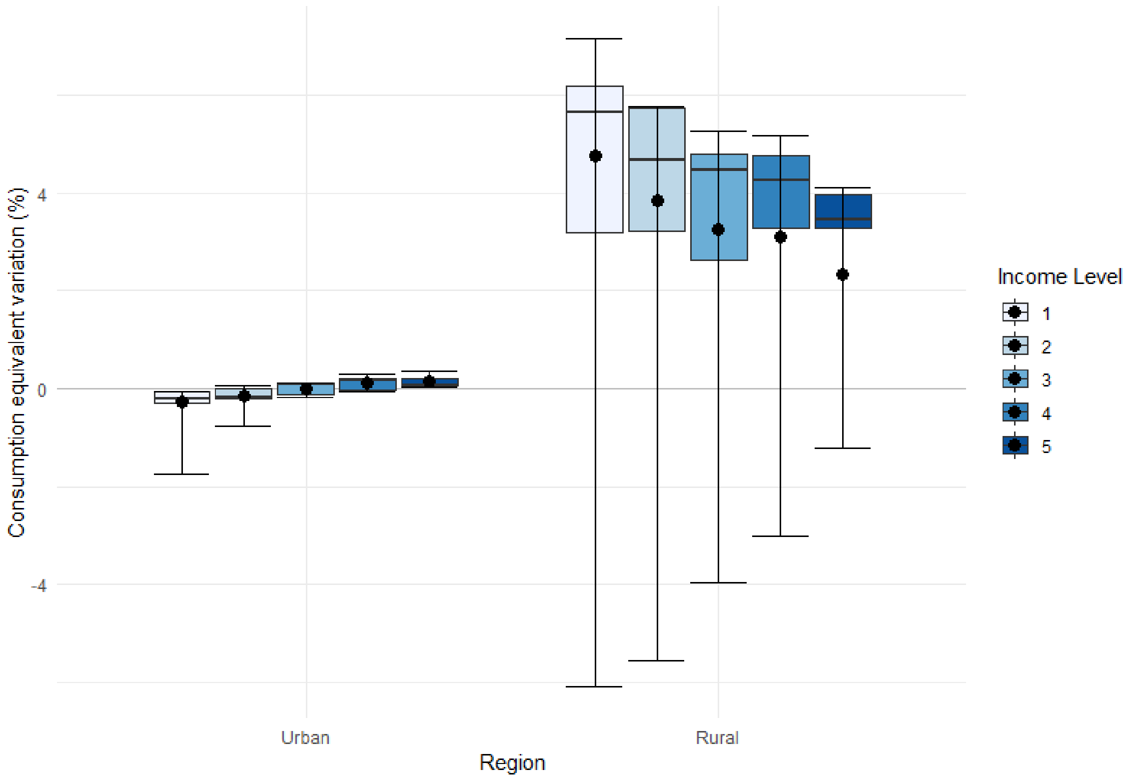

Figure 13: Consumption equivalent variations of landowners across regions and income levels for a switch towards land value tax.

Within the urban region, we observe a pattern that is very much similar to the one we arrived at in the empirical analysis. Changes are small, mostly below 0.5%, with lower income landowners being, on average, slightly hurt by the introduction of the LVT. Meanwhile, landowners in the highest income levels experience slight welfare gains, on average. The only landowners which experience significant variations (greater than one 1%) are the low income landowners with the highest levels of land holdings, experiencing a utility loss equivalent to a reduction of almost 2% in consumption of tradable goods.

In the rural region the story is quite different. The households with the most land holdings are still losers from the measure, even experiencing much sharper falls in utility (between 1% and 6% of consumption equivalent variation). However, other landowners gain from the measure substantially. The range of gains and losses is higher for the lower income landowners due to a scaling effect in which the same absolute variation in consumption implies a higher relative variation for low income households which exhibited lower initial levels of consumption. Another difference in relation to the urban region is the pattern of average consumption equivalent variation across income levels. Besides all income levels benefiting from a LVT, on average, it seems low income landowners benefit the most, driven by larger utility gains of households with low levels of land holdings.

It should be noted the model offers some limitations concerning the capture of heterogeneous fluctuations of land prices within regions, especially urban regions where the disparity in land values from city center to suburban regions can be large. The model implicitly assumes variations in land prices will affect all households equally as land is homogeneous within each region. However, research shows increases in land prices are stronger in city centers, causing the geographical concentration of land values observed in the data. The model therefore misses the channel through which increases in land prices are likely to lead to higher concentration, and vice-versa. However, given price variations in the city are relatively small, the influence of this channel is likely to be equally small.

We turn to the analysis of social welfare measured by (24b). Replacement of the housing tax with the land value tax results in a welfare improvement in the model. This is not surprising, given our distributional results. Breaking down this result in terms of regional variation and renter/landowner disparities gives a clearer picture of its drivers. Welfare increases more in the rural region, due to the considerable welfare gains by landowners, who are predominant in the rural region. Aggregate welfare of landowners in the urban region remains fairly constant. As for renters, their welfare increases in both regions, although more in the urban region. In the end the only losers are landowners with large land holdings (irrespective of income level, although the effect is magnified for lower incomes), especially in the rural area. However, these losses do not offset the gains of renters and lower land holding landowners.

Finally, we performed a transition analysis in which the economy starts from the steady state of the benchmark model with a housing tax and transitions into the steady state of the model under a tax on land rents. Given the modest magnitude of the change in tax regimes and the relative rapid convergence resulting from the nature of the policy functions of the housing firm and landowners (the model reaches the new steady state after two periods), the results of the welfare analysis remain largely unchanged.

8 Conclusion

This paper provides the first empirical identification of the distribution of property and land values at a household level and their relation to income in order to assess the distributional effects of switching from a property tax based on house values to one based on land values. To complement this analysis, a theoretical model is developed to capture general equilibrium effects of this transition. Land value taxation offers various theoretical advantages over property taxation, but the distributional consequences at a household level remained unknown, making its implementation hard to justify. Using geographical matching, official land values and lot data for five German states, we estimate the land value associated with the household's primary property value for a sample of close to 2400 homeowners in the German household survey for 2017.

At a municipal level, we find revenue neutral property tax rates on average around 0.6%, with considerable regional differences (lower rates the more densely populated). We find the aggregate level of land value to be substantially high, around 1.2 times GDP for the whole region.

At a household level we find considerable heterogeneity in the relative distributions of land and property with an average value of 33% for the share of land value to property value, which was shown to be a sufficient statistic to determine winners and losers from a switch to LVT. We also find no distributional impact from a switch to LVT at a federal implementation level, but a regressive impact at a regional level. Given that property taxation has traditionally been executed at a regional level, the regressive result is our preferred one. Although the quantitative impact in absolute terms for our sample is modest, due to low reliance on property taxes in Germany, in relative terms, we find households in the first income quintile can experience an increase of around 25%, on average, on their tax burden.

The empirical analysis does not capture the efficiency gains of implementing a LVT, namely through higher housing investment and subsequent lower rents, ignoring effects on renters. We address this by using the insights from the empirical analysis to build a theoretical model with heterogeneous households and regions where a housing tax discourages investment in residential structures. We use the model to study the general equilibrium and distributional effects of switching towards a tax on land rents.

Results from the model show that a tax on land fosters substantial investment in structures, leading to more housing and reductions in housing rents. This effect is more pronounced in non-urban regions where land scarcity is less of a problem, leading to some migration from higher to lower population density regions and generally lead to regional convergence. Land prices decrease in urban regions and increase in rural ones. Distributionally, renters experience welfare gains in both regions, though more so in cities. Welfare of landowners in urban regions does not change considerably, on average. Most landowners in rural regions benefit considerably. Nevertheless, there are welfare losses for landowners with high land value holdings, especially for low income households and those living in rural regions. Overall impact on welfare is positive, driven mostly by renters and improved welfare in non-urban regions for most landowners.

It is also worthwhile to discuss the idiosyncrasies of the German reality and how they might affect these results. First Germany does not rely heavily on property taxes, meaning the efficiency gains of a transition to a LVT are likely to be smaller than in other countries. Second, Germany has a low homeownership rate, meaning the positive effects through the rental market are likely to be smaller in other countries, and the landowner effects more important. Third, Germany is a multipolar country with many medium sized cities, in contrast to France or England where Paris and London dominate. Regional differences are likely to be even more important in countries where population is more concentrated.

Looking ahead, if recent trends of increased gentrification continue, it might lead to an allocation of households across land value areas more in line with household income, making LVT more naturally progressive than property value tax. Regardless, both are likely to produce winners and losers across all income classes, creating the need for careful implementation. This can be accomplished, for example, through exemptions, phase-in periods or the implementation of complementary policies targeted at low income households.

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A Construction of SOEP 2.0

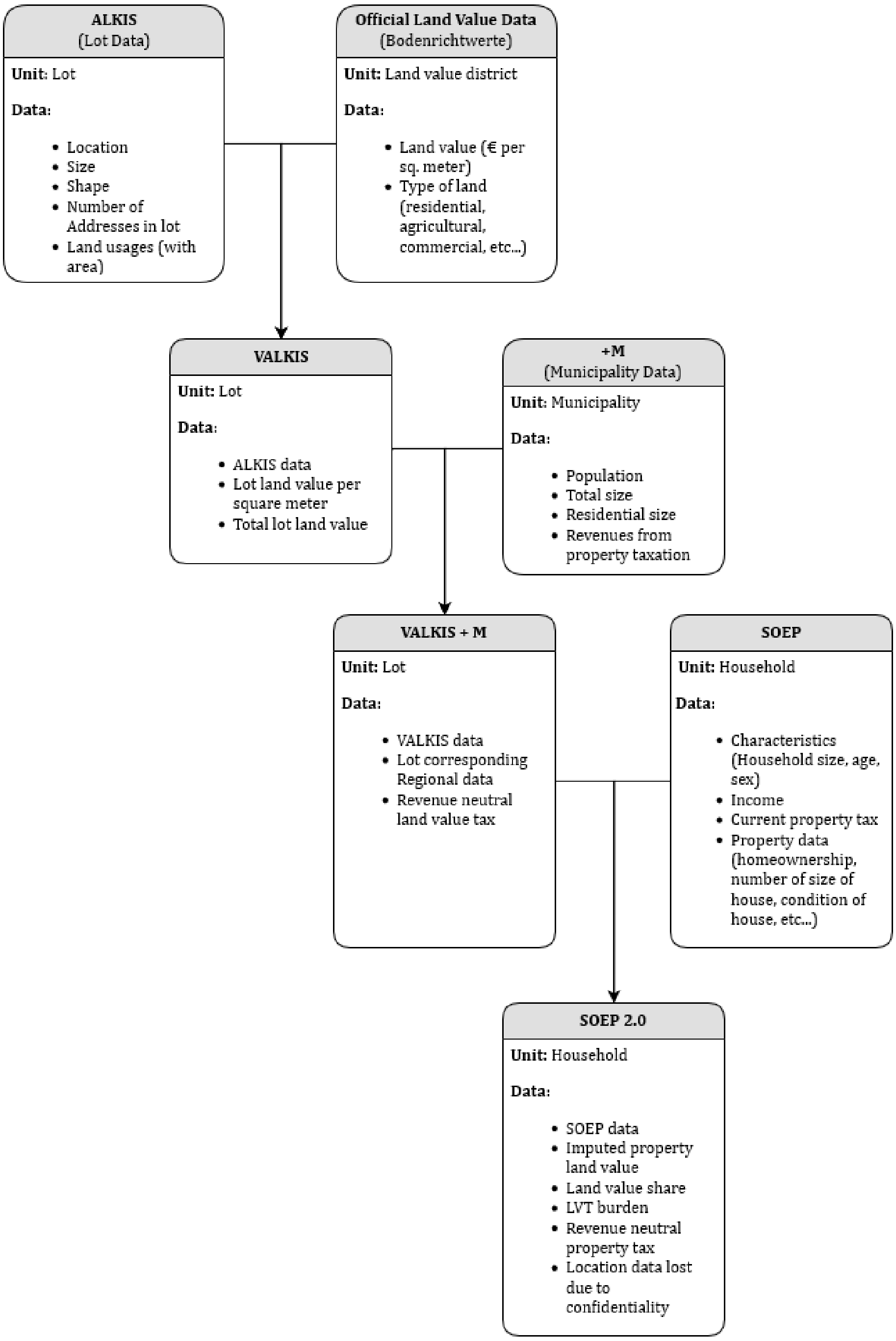

Figure 14: Data construction flowchart.

B ALKIS - Example

To illustrate the level of precision in our ALKIS lot data, we show a random street in our data as it appears in satellite imagery obtained with GoogleMaps, in Figure B.1, and its representation in our GIS data, Figure B.2. One can easily see how the ALKIS data constitutes an accurate representation of reality as the delimitation of the lots in the data lines up with the boundaries between properties observed from satellite imagery. It should be noted that the ALKIS data can even differentiate between two lots associated with semi-detached houses.

Figure B.1: Seidelbastweg, Hamburg in GoogleMaps.

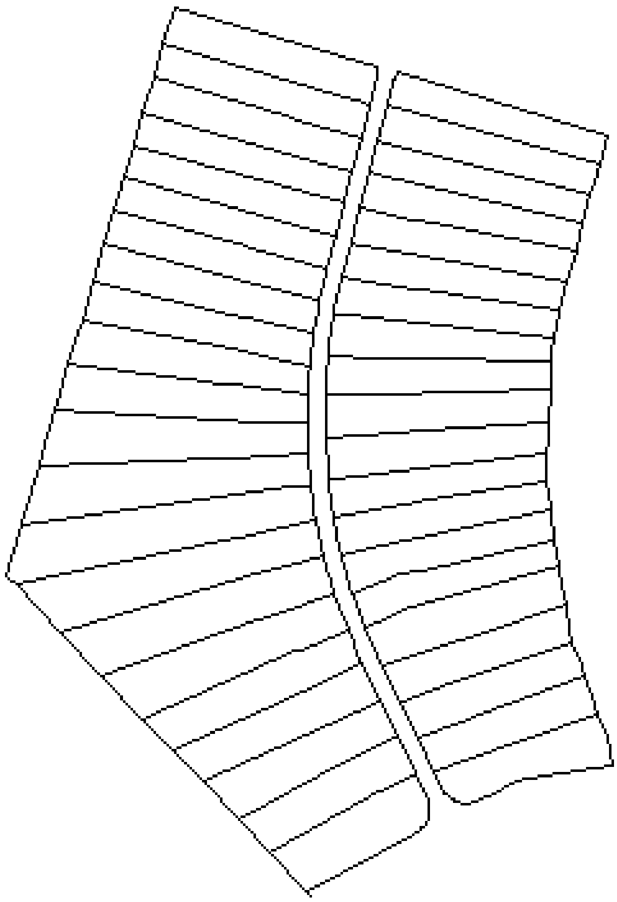

Figure B.2: Seidelbastweg, Hamburg in ALKIS data.

C Decomposing the Income Elasticity of the Land Value Share

In this section we lay out a simple analytic framework to decompose the effect of income on the land value share in several intuitive channels. The decomposition sheds light on the origins of the distributional effect and once again accentuates the importance of a regional consideration. We present our results in terms of elasticities and estimate the main parameters using data from SOEP 2.0.

The LVS of household i is given by $LVS_i = LV_i/PV_i$. Accordingly, income has an impact on the LVS through the denominator (land and structures value) and the nominator (land value). Within the scope of our paper, we keep the effect of income on structure value as a whole, but decompose the effect on land value. Mechanically, we can decompose the household's land value into its constituent components according to our calculation:

$$LV_i = lv_i \frac{lot.size_i}{hh_i}$$

lv_i denotes the land value per m^2, $lot.size_i$ denotes the size of the lot the house of the household is built and hh_i denotes the number of households sharing the lot given by the product of number of addresses and number of neighbours per address. Substituting this expression back into our identity of LVS in logs we get

$$\log(LVS_i) = \log\left(lv_i \frac{lot.size_i}{hh_i}\right) - \log(PV_i)$$

We can further break down this identity until we arrive at a linear relation between the logs of these variables.

$$\log(LVS_i) = \log(lv_i) + \log(size_i) - \log(PV_i)$$

Here, $lot.size_i/hh_i$ was kept as a single variable and renamed $size_i$. In a next step, we break down lv_i into a regional component which is the average land value of the region (Alv_i) and a factor capturing the deviation from the regional average (Rlv_i), which henceforth we denote as relative land value (as in relative to the average of the municipality). So, if household i resides in a lot with a land value per m^2 of 120€, located in a municipality where the average land value per m^2 is 100€, we can rewrite the 120 as

100×1.2. Applying this decomposition to our LVS expression and once again separating the resulting multiplication inside the log, we arrive at:

$$\log(LVS_i) = \log(Alv_i) + \log(Rlv_i) + \log(size_i) - \log(PV_i) \tag{25}$$

So far, we have decomposed the land value in three components. We continue by setting up a Structural Equation Model (SEM) to quantify the impact of income on LVS through each of them. In order to determine the full impact of each component, we have to quantify their impact through property value, too. We perform the relevant corrections ex post.

From (25) the income elasticity of the share can be decomposed to:

$$\frac{\partial \log(LVS_i)}{\partial \log(I_i)} = \frac{\partial \log(Alv_i)}{\partial \log(I_i)} + \frac{\partial \log(Rlv_i)}{\partial \log(I_i)} + \frac{\partial \log(size_i)}{\partial \log(I_i)} - \frac{\partial \log(PV_i)}{\partial \log(I_i)} \tag{26}$$

The first three terms of (26) are denoted as: Regional Effect (RE), Neighborhood Effect (NE), Size Effect (SE). Broadly, they capture the impact of income on the LVS through: the correlation between the regional price level and income (RE), the decision to live in a neighborhood with a certain level of amenities (NE), the decision to live in a bigger lot and a Single or Multiple Family House (SE). The last term of (26) captures the full impact of income on the LVS through property value and it will be decomposed ex post. Initially, we estimate the individual terms by using the following set of equations in the framework of a SEM:

$$\log(Alv_i) = \alpha_1 + \beta_1 \log(I_i) + \epsilon_{1,i} \tag{27a}$$

$$\log(size_i) = \alpha_3 + \beta_3 \log(I_i) + \gamma_3 \log(Alv_i) + \epsilon_{3,i} \tag{27b}$$

$$\log(Rlv_i) = \alpha_2 + \beta_2 \log(I_i) + \gamma_2 \log(Alv_i) + \epsilon_{2,i} \tag{27c}$$

$$\log(PV_i) = \alpha_4 + \beta_4 \log(I_i) + \gamma_4 \log(Alv_i) + \epsilon_{4,i} \tag{27d}$$

In our SEM-framework, it is important to not only incorporate the direct impact through Alv_i in (27a). In (27c) the inclusion of Alv_i corrects for the fact that in areas with high average land values, mostly cities, the highest land values are measured in zones where residential and commercial usages are mixed, e.g. in city centers. Thus, fewer households live in these zones and so, the relative land value in cities is structurally underestimated. In (27b) the inclusion corrects for the fact that in municipalities with high average land value, mostly cities, the average lot size is structurally smaller. Finally, in (27d) the Alv_i is included to control for different levels of construction costs in cities versus villages.

Using the results of the SEM in (26), the average elasticity is given by:

$$\frac{\partial \log(LVS)}{\partial \log(I)} = (1 + \gamma_2 + \gamma_3 - \gamma_4)\beta_1 + \beta_2 + \beta_3 - \beta_4 \tag{28}$$

The effect through property value, β_4, still carries the effect through land and structure value. We decompose the effect in a structure value effect β_5 and the different land value effects, using the identity $PV_i = SV_i + LV_i$. After some reformulations, explaied in detail in the subsection C.1, the structure value effect is given by:

$$\beta_5 = \overline{\left(\frac{PV_i}{SV_i}\right)} (\beta_4 + \gamma_4 \beta_1) - \overline{\left(\frac{LV_i}{SV_i}\right)} \left((1 + \gamma_2 + \gamma_3)\,\beta_1 + \beta_2 + \beta_3\right) \tag{29}$$

Using the results in (28), the income elasticity of the LVS finally reads:

$$\frac{\partial \log(LVS)}{\partial \log(I)} = \underbrace{\overline{\left(\frac{SV_i}{PV_i}\right)} (1 + \gamma_2 + \gamma_3)\,\beta_1}_{\text{RE}} + \underbrace{\overline{\left(\frac{SV_i}{PV_i}\right)} \beta_2}_{\text{NE}} + \underbrace{\overline{\left(\frac{SV_i}{PV_i}\right)} \beta_3}_{\text{SE}} - \underbrace{\overline{\left(\frac{SV_i}{PV_i}\right)} \beta_5}_{\text{HE}} \tag{30}$$

The intuition of the first three terms was introduced before. Their magnitude is now corrected for presence in denominator and nominator. The fourth effect is denoted as House Effect (HE). It captures the impact of income on the LVS through the decision to invest in the structure value, by renovation or buildup.

The Regional Effect is a special case in two ways. First, due to simultaneity, the Regional Effect cannot be interpreted causally. Only households with a sufficiently high income can afford to live in cities and surrounding municipalities given the soaring land prices over the last years. However, at the same time, firms in cities tend to pay higher wages in order to compensate for the higher living costs in these areas. Second, as argued in the previous sections, the Regional Effect is irrelevant for a distributional assessment as property taxes are collected on a municipal level.

Our preferred interpretation of the income elasticity of the LVS is the sum of NE, SE and HE, the (regional) net elasticity. However, to accentuate the importance of the regional component and to hinge our analysis to previous sections, we run the full model and present gross and net elasticity separately.

Figure D.1 shows the results of our decomposition of the income elasticity of the LVS through a structural equation model. Given the identity-based approach of this section, the estimates of the full elasticities (Gross Elasticity, Net Elasticity) match the results of the log-log OLS regressions of LVS on income previously presented. The gross income elasticity of LVS is not statistically different from zero, while after filtering out the Regional Effect the net income elasticity is -0.15, significantly different from zero.

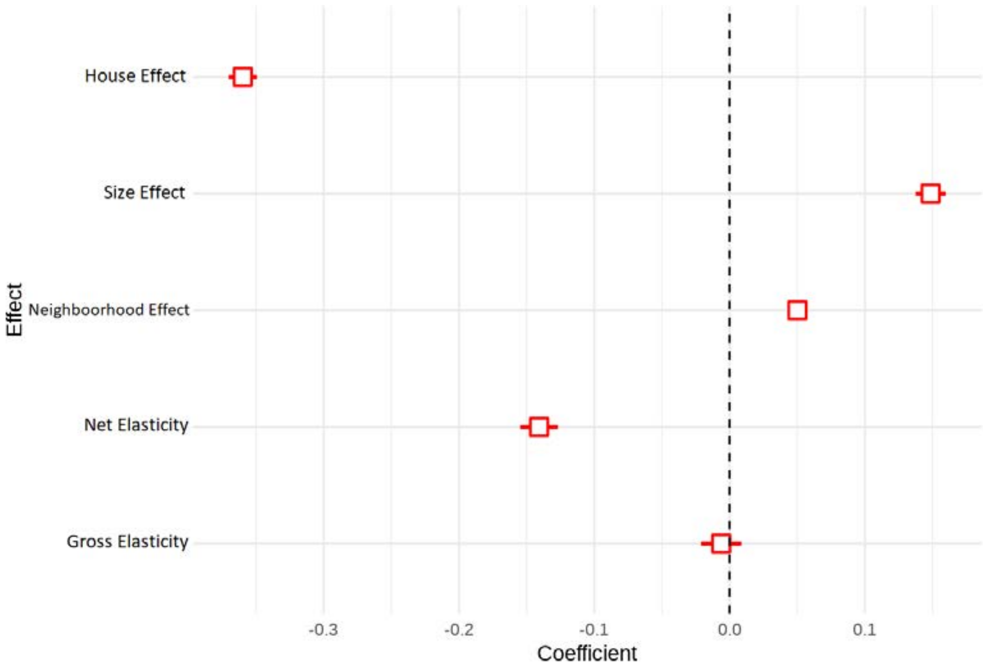

Figure C.1: Decomposition of the income elasticity of the land value share.
Gross effect includes effect of income through average land value effect (region effect). Net effect excludes this channel.

We interpret the net effect and its components. The House Effect is close to -0.36, dominating Neighborhood and Size Effect, which are at 0.15 and 0.05. The reason is that structure value is easier to adjust than land value. Changing the land value by altering the lot size is oftentimes not feasible due to physical constraints, changing the land value by moving to a different neighborhood triggers moving costs. In general, the argument applies independent of the direction of adjustment. However, in particular for the Neighborhood Effect we find an accentuated downward rigidity. This means although it is difficult to find high income households in low land value neighbourhoods, it is not uncommon to find low income households in high land value neighbourhoods.

In sum, this section shows that on average households with higher income: occupy larger lots, live in more expensive areas, invest more in renovation and buildup of their houses. Comparing the magnitudes, our analysis reveals that the house margin is the dominant one. Thus property value is a better 'tag' for income than land value, making a Land Value Tax less progressive than a property tax within regions. Finally, to capture this relation it is important to remove the regional veil.

C.1 Reformulation of Income effect on Structures Value

Given the construction of Land Value and Property Value, the following equation holds by identity:

$$\log(\mathrm{LVS}) = \log(\mathrm{Alv}) + \log(\mathrm{Rlv}) + \log(\mathrm{size}) - \log(\mathrm{PV})$$

See that throughout the presentation of the results, we drop the subscripts to ease the exposition.

Accordingly, the income elasticity of the Land Value Share is given by:

$$\frac{\partial \log \mathrm{LVS}}{\partial \log \mathrm{I}} = \frac{\partial \log \mathrm{Alv}}{\partial \log \mathrm{I}} + \frac{\partial \log \mathrm{Rlv}}{\partial \log \mathrm{I}} + \frac{\partial \log \mathrm{size}}{\partial \log \mathrm{I}} - \frac{\partial \log \mathrm{PV}}{\partial \log \mathrm{I}}$$

We can use the results of the regressions (27a) to (27d) in order to reformulate:

$$\frac{\partial \log \mathrm{LVS}}{\partial \log \mathrm{I}} = \beta_1 + \left(\beta_2 + \gamma_2 \frac{\partial \log \mathrm{Alv}}{\partial \log \mathrm{I}}\right) + \left(\beta_3 + \gamma_3 \frac{\partial \log \mathrm{Alv}}{\partial \log \mathrm{I}}\right) - \left(\beta_4 + \gamma_4 \frac{\partial \log \mathrm{Alv}}{\partial \log \mathrm{I}}\right)$$

Once again using the result from regression (27a) that $\frac{\partial \log \mathrm{Alv}}{\partial \log \mathrm{I}} = \beta_1$, we arrive at:

$$\frac{\partial \log \mathrm{LVS}}{\partial \log \mathrm{I}} = (1 + \gamma_2 + \gamma_3 - \gamma_4)\,\beta_1 + \beta_2 + \beta_3 - \beta_4$$

In a next step, we want to decompose the income elasticity of property values in parts, regarding the income elasticity of land value (LV) and structures value (SV). The steps are:

$$\frac{\partial \log \mathrm{PV}}{\partial \log \mathrm{I}} = \frac{\frac{\partial \mathrm{PV}}{\partial \log \mathrm{I}}}{\mathrm{PV}} = \frac{\frac{\partial (\mathrm{SV} + \mathrm{LV})}{\partial \log \mathrm{I}}}{\mathrm{PV}} = \frac{\mathrm{SV}}{\mathrm{PV}} \frac{\frac{\partial \mathrm{SV}}{\partial \log \mathrm{I}}}{\mathrm{SV}} + \frac{\mathrm{LV}}{\mathrm{PV}} \frac{\frac{\partial \mathrm{LV}}{\partial \log \mathrm{I}}}{\mathrm{LV}} = \frac{\mathrm{SV}}{\mathrm{PV}} \frac{\partial \log \mathrm{SV}}{\partial \log \mathrm{I}} + \frac{\mathrm{LV}}{\mathrm{PV}} \frac{\partial \log \mathrm{LV}}{\partial \log \mathrm{I}}$$

Now, define the income elasticity of structures, such that $\beta_5 \equiv \frac{\partial \log \mathrm{SV}}{\partial \log \mathrm{I}}$. Furthermore, by our identities it holds that $\frac{\partial \log \mathrm{LV}}{\partial \log \mathrm{I}} = \frac{\partial \log \mathrm{Alv}}{\partial \log \mathrm{I}} + \frac{\partial \log \mathrm{Rlv}}{\partial \log \mathrm{I}} + \frac{\partial \log \mathrm{size}}{\partial \log \mathrm{I}}$. Using the definitions and the results from (27a) - (27b), we can reformulate:

$$\frac{\partial \log \mathrm{PV}}{\partial \log \mathrm{I}} = \frac{\mathrm{SV}}{\mathrm{PV}} \beta_5 + \frac{\mathrm{LV}}{\mathrm{PV}} \left((1 + \gamma_2 + \gamma_3)\,\beta_1 + \beta_2 + \beta_3\right)$$

Finally, from (27d) we also know that it holds that $\frac{\partial \log \mathrm{PV}}{\partial \log \mathrm{I}} = \beta_4 + \gamma_4 \beta_1$. Putting the equations together, we derive:

$$\beta_4 = \frac{\mathrm{SV}}{\mathrm{PV}}\beta_5 + \frac{\mathrm{LV}}{\mathrm{PV}}\left(\left(1+\gamma_2+\gamma_3\right)\beta_1 + \beta_2 + \beta_3\right) - \gamma_4\beta_1$$

Using this result, the income elasticity of the land value share derives as:

$$\frac{\partial \log \mathrm{LVS}}{\partial \log \mathrm{I}} = \frac{\mathrm{SV}}{\mathrm{PV}}\left(1+\gamma_2+\gamma_3\right)\beta_1 + \frac{\mathrm{SV}}{\mathrm{PV}}\beta_2 + \frac{\mathrm{SV}}{\mathrm{PV}}\beta_3 - \frac{\mathrm{SV}}{\mathrm{PV}}\beta_5$$

In this formulation, β_5 can be recovered from results of (27a) - (27d) and multiplied by $\frac{\mathrm{SV}}{\mathrm{PV}}$ it constitutes the income elasticity of the land value share through the elasticity of the structures value, our house effect.

D Additional Empirical Results

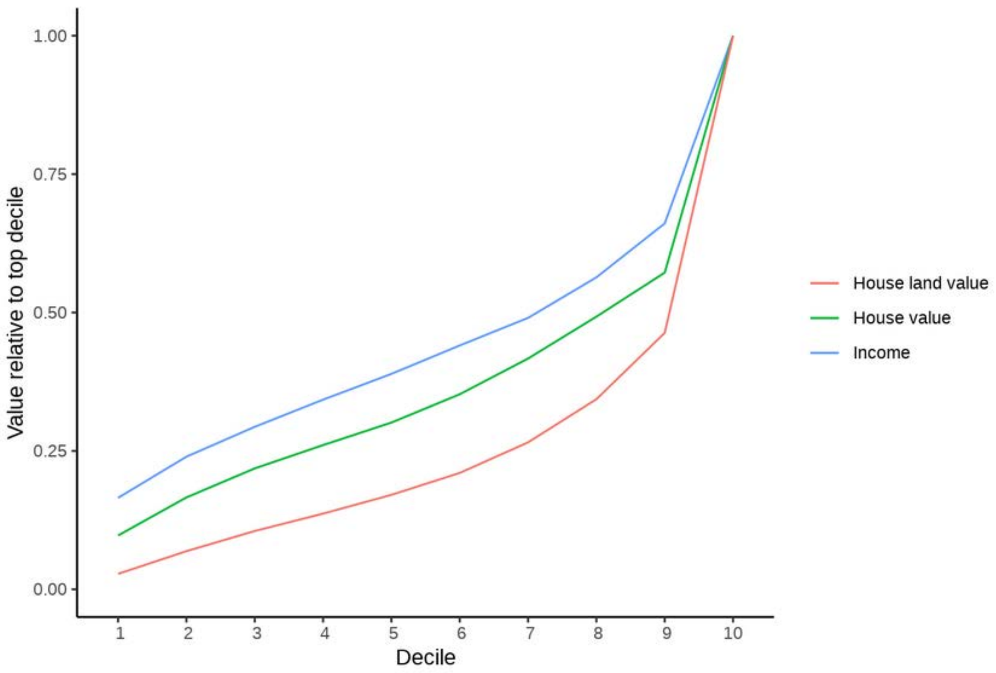

Figure D.1: Concentration of earnings, housing value and land value holdings in the data, by deciles.

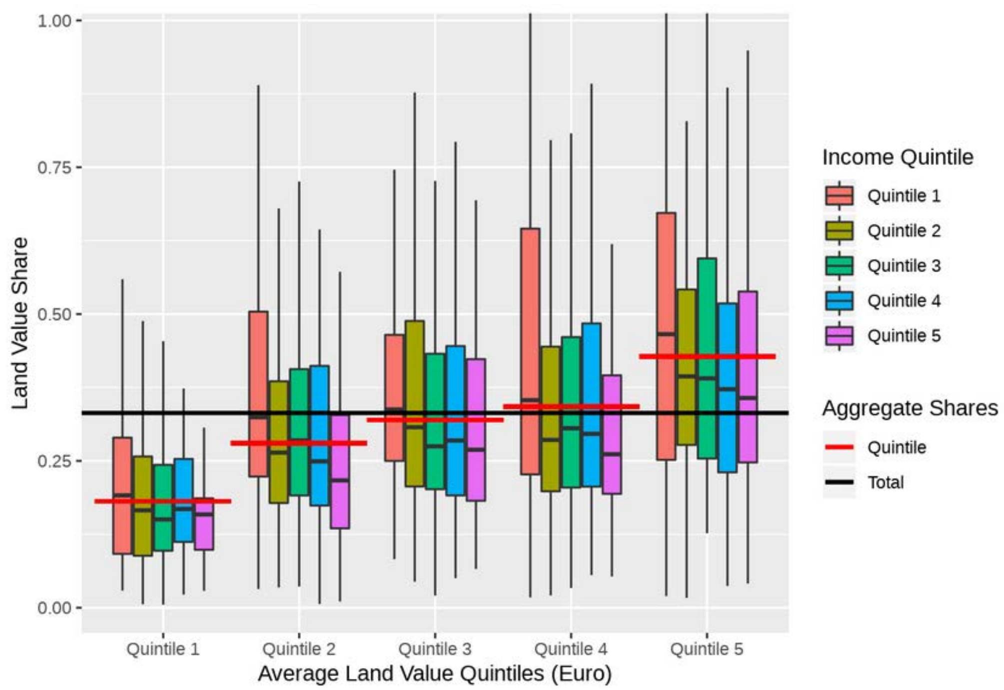

Figure D.2: Land value share by income quintiles within average land value quintiles.

E Solving for the Competitive Equilibrium of the Model

The algorithm, implemented in Matlab, to solve the equilibrium in period t for a given vector of tax rates proceeds as follows:

1. Guess a level of share of renters in region A, ψ.

2. Compute p_t^S directly from (18).

3. Construct a grid for $S_{F,z,t}$.

4. For each region z:

   (a) Plug $S_{F,z,t}$ into production function of Housing Firm to find supply of housing $H_{F,z,t}$ as a function of $S_{F,z,t}$.

   (b) Construct a grid for $p_{z,t}^H$.

   (c) Using zero profit condition of housing firm, (23), write $w_{z,t}$ as a function of $p_{z,t}^H$.

   (d) Using (4), write housing demand of renters as a function of p_t^H.

   (e) Using (21), write housing demand of consumption firm as a function of p_t^H.

   (f) Using housing market equilibrium, find the p_t^H which equilibrates housing market for each possible level of $S_{F,t}$.

   (g) Solve the dynamic problem of the firm, using value function iteration, to get the optimal choice of $S_{F,z,t}$ as a function of the state $S_{F,z,t-1}$.

   (h) Use equilibrium level of $S_{F,z,t}$ to identify corresponding values of prices.

5. Using equilibrium levels of w_t and p_t^H in both regions, check if the real wage condition, (10), is met. If not, go back to 1. and guess a new ϕ_A accordingly. If yes, proceed with the rest of the algorithm.

6. Use equilibrium prices to find $H_{C,z,t}$ and $H_{R,z,t}$ from (4) and (21).

7. Find $K_{C,z,t}$, and $C_{z,t}$ from input demand, (20), and production function, (19b).

8. Find C_R and H_R and from (3) and (4).

9. Solve the dynamic problem of landowners in the state space (S_F, S_L) to get policy functions for S'_L.

10. Use housing production function, (12b) to find $H_{L,z,t}$.

11. Use budget constraint of landowners and equilibrium prices and policy function to find C_L.

12. Compute Government revenue levels and check if initial tax rates raise the desired level, if not, adjust accordingly.

F Additional Model Results

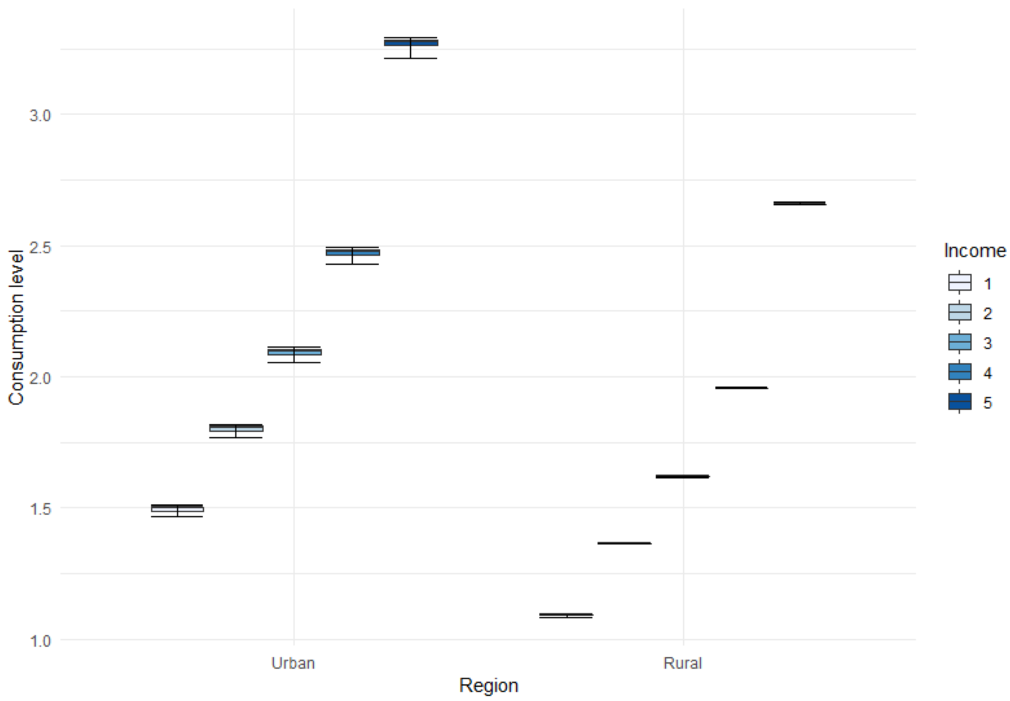

Figure F.1: Tradable good consumption across regions and income levels.

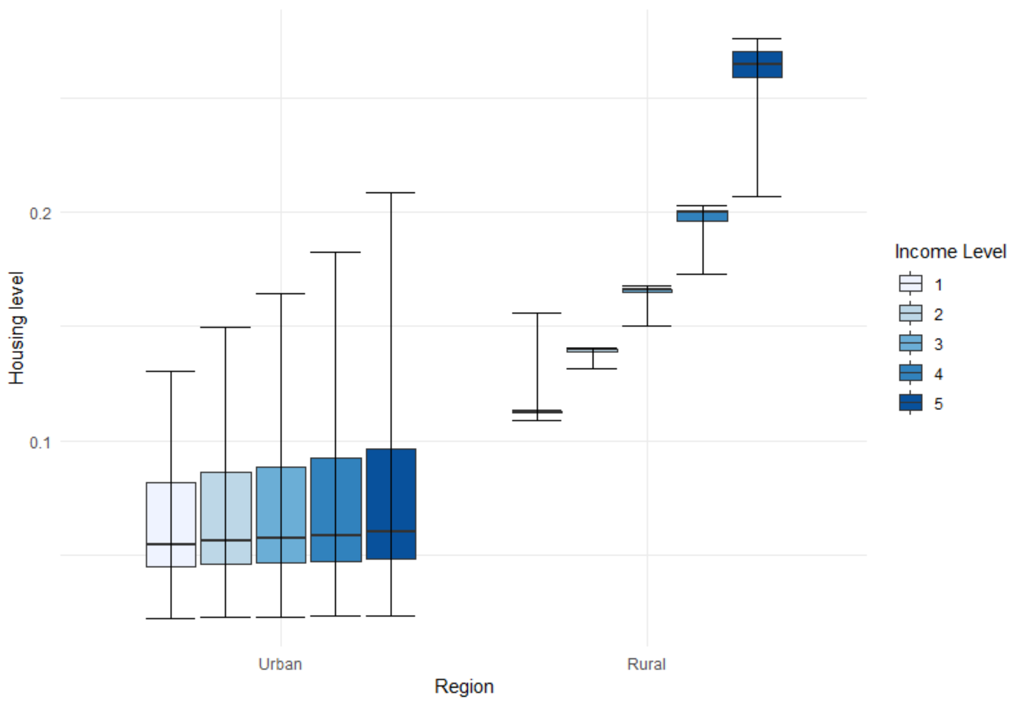

Figure F.2: Tradable good consumption across regions and income levels.

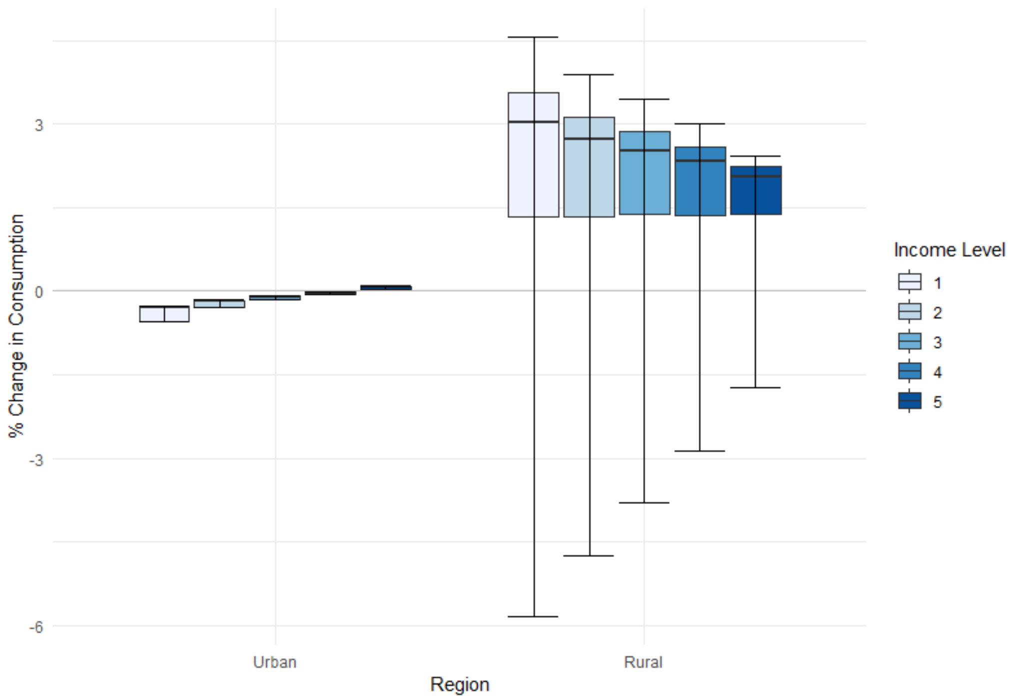

Figure F.3: Change in tradable good consumption after introduction of a revenue neutral land value tax across regions and income levels.

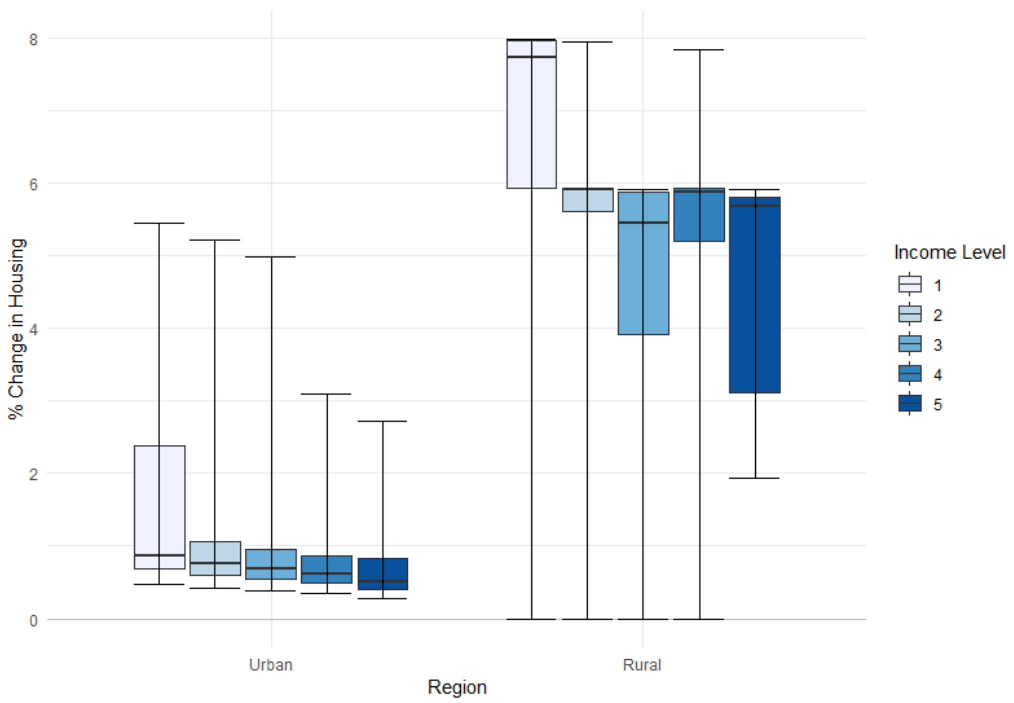

Figure F.4: Change in housing services consumption after introduction of a revenue neutral land value tax across regions and income levels.