How do economic forces affect the real estate market

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Preface

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"An economist is an expert who will know tomorrow why the things he predicted yesterday didn't happen today."
-Laurence J. Peter

To my parents Mabel and René, and my love Anette Maria

Introduction

Estimated to be worth more than 225 trillion USD in 2019, real estate is the world's largest investment class (Savills 2019). Yet, even within the same country, housing wealth is largely unequally distributed across space. Cities and high-amenity places typically account for the lion's share of it. This unequal distribution results from tension forces between the demand and supply side of the real estate market operating at the local level.

On the demand side, perhaps the most crucial factor is the decision of households about where to live and work according to a variety of subjective and economic factors. Naturally, the demand for real estate concentrates in high-amenity areas. These areas are typically more productive and feature desirable characteristics such as natural amenities and proper public good provision. Unfortunately, the desire of households to increase their utility by sorting into these high-amenity areas, is not always met with a likewise propensity to supply housing in these areas. On the contrary, in many high demand areas, the supply side of the market has failed to keep up with the demand side. This has lead to skyrocketing prices and affordability issues. In that regard, the observed unequal value of real estate across space is the result of a congestion force that drives people away from more productive areas, thus imposing a burden on the whole society.

A legitimate question is whether we can escape, or at least lessen, the congestion force coming from real estate markets. Many governments have tried to do so by implementing a variety of housing policies acting on both the demand and supply side of the market. Unfortunately, these policies usually neglect the local nature of the real estate and economic incentives driving the market. This has lead to unintended consequences. To understand these consequences, this thesis investigates the endogenous response of economic fundamentals in a spatial framework that accounts for the localized nature of housing demand and supply.

Specifically, I employ either a theoretical structural approach featuring local areas or an empirical approach using fine-scale housing data to investigate housing supply elasticities, housing subsidies, redevelopment option value, and regulation at the local level.

In Chapter 1, co-authored with Maximilian von Ehrlich and Olivier Schöni, we provide empirical evidence that increases in the periodic costs of housing lead to a larger supply response than price increases of the same percentage value. We rationalize this differential in supply responsiveness with an amplification mechanism arising from adjustments of capitalization rates to changes in the periodic costs. We document that the amplification of the housing supply price elasticity is less pronounced in geographically constrained and tightly regulated neighborhoods and areas having more sophisticated buyers. Our findings hold valuable lessons for public policies affecting the periodic cost of housing, such as rent control and housing subsidies.

In Chapter 2, co-authored with Yashar Blouri and Olivier Schöni, we analyze such a public policy. Specifically, we investigate the spatially heterogeneous impact of the U.S. federal mortgage interest deduction (MID) on the location and tenure decisions of households. We develop a general equilibrium model at the county level featuring an endogenous itemization of housing subsidies. Despite being a vital tax expenditure, repealing the MID would only slightly lower homeownership rates while leaving welfare mostly unchanged. The policy is ineffective because it targets locations with congested housing markets, creating a spatial shift of the housing demand toward areas that capitalize the subsidy into higher prices. We provide evidence that a repeal of the MID is to be preferred to an increase of standard tax deductions as recently implemented under President Trump's administration.

In Chapter 3, co-authored with Alex van de Minne, we analyze the impact of the redevelopment potential on commercial real estate transaction prices. First, using a probit model, we compute the fitted redevelopment potential. This potential is primarily determined by the difference in net operating income (NOI) per square foot of land (sql) to the potential highest and best use (HBU) of the property. This difference reflects the economic obsolescence of a property. Second, we run a 2SLS model with the fitted redevelopment potential as an instrument for the redevelopment dummy. We find that having a 100 percent redevelopment potential increases the property's price by nine to 17 percent.

In Chapter 4, I develop a methodology and the corresponding survey to construct a land-use regulation index for over 2200 Swiss municipalities. This index documents how regulation of residential buildings varies across space. It is composed of ten sub-indices that capture the different aspects and degrees of local regulation. To develop these indices, I suggest using land-use regulation data and complementing it with answers from a comprehensive survey. These indices provide harmonized information about what local regulation entails and the local regulatory environment across municipalities.

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The amplifying effect of capitalization rates on housing supply

joint with **Maximilian von Ehrlich and Olivier Schöni**

1.1 Introduction

Existing research emphasizes the importance of housing supply price elasticity for a variety of economic outcomes. The responsiveness of housing supply affects, among other things, housing cycles, the allocation of labor across space, and the degree of capitalization of public policies such as place-based subsidies.[1] However, to date, we know relatively little about the responsiveness of housing supply with respect to changes in the periodic cost of housing. This is surprising, as urban economic theory typically focuses on periodic housing costs and many public policies – such as rent control and housing subsidies – directly act on these costs. In this paper, we investigate under which circumstances the housing supply responsiveness to changes in periodic costs differs from the supply responsiveness to price changes, and why this supply differential varies across regions.

To rationalize our empirical approach, we start by developing a partial equilibrium framework featuring housing supply and demand as well as real estate investors. We show that local changes in the investors' expectations about periodic housing costs' growth and risk premia are decisive to explain differences in supply responses to price and rent dynamics. Specifically, housing supply responses to price and periodic cost changes are identical if capitalization rates do not adjust to changes in the periodic costs. If capitalization rates do adjust, housing supply price elasticities are either amplified or dampened by this adjustment.

Using detailed georeferenced data on advertised residential properties and building stock for Switzerland covering the 2005-2015 period, we estimate the responsiveness of housing supply with respect to price and rent changes. We find that an increase in rents leads to an about thrice as large supply increase than an increase of prices of the same percentage value: The supply response following a ten percent increase in rents (prices) per square meter is approximately 14 percent (four percent).

These results suggest that, on average, real estate investors revise capitalization

[1] For instance, Glaeser et al. (2008) investigate the role of housing supply elasticities for price dynamics, Diamond (2017) links the degree to which local governments can extract rents to housing supply elasticities, Kline and Moretti (2014) emphasize the importance of housing supply elasticity for the distributional effects of place-based policies, and Hsieh and Moretti (2019) focus on the implications of housing supply constraints for the spatial misallocation of labor. See Glaeser and Gyourko (2018) and Hilber (2017) for a synthesis on the importance of housing supply price elasticity for various economic outcomes.

rates downward following a positive demand shock. This amplifies the supply response to price changes. The supply amplification, and the corresponding adjustment of expectations, is heterogeneous across space, with geographic constrained and tightly regulated markets, and neighborhoods having more sophisticated buyers displaying lower values.

Switzerland is a good laboratory to investigate housing supply due to important heterogeneity in the local factors influencing it. The decentralized form of government grants low-tier political units (municipalities) large autonomy in matters relating to land-use planning and fiscal policies. Geographic features of the landscape, such as elevation, slope, and terrain ruggedness, also vary considerably across space. These characteristics of the country make the reaction of housing supply contingent to localized factors. Importantly, in Switzerland, the owner-occupied and rental markets are approximately of equal size, which facilitates the estimation of rental and price supply elasticities throughout the country, thereby allowing us to study the role of capitalization rates for housing supply.[2] Finally, the existence of detailed information on individual housing characteristics, allows us to rule out that differences in supply elasticities are driven by different attributes (e.g., quality gap) between selling and rental properties.

Our paper bridges two strands of the literature. The first strand focuses on the estimation of local housing supply price elasticities. Despite the importance of housing supply elasticity, papers quantifying it remain scarce. Gyourko and Molloy (2015) provide a comprehensive review of the literature investigating the estimation and determinants of housing supply. In his seminal article, Saiz (2010) estimates housing supply elasticities across U.S. Metropolitan Statistical Areas (MSAs) as a function of geographic and regulatory constraints. Using a Vector Error Correction Model, Wheaton et al. (2014) also estimate housing supply elasticities for U.S. MSA's, obtaining estimates in line with those of Saiz (2010). Our identification of local housing supply elasticities builds on recent work by Baum-Snow and Han (2019), who adopt a structural approach to quantify cross- and within-city housing supply elasticities for U.S. metropolitan areas, showing that housing supply elasticities increase monotonically with the distance to city centers. We follow a similar identification strategy and exploit variation within metro areas. Specifically, we identify housing supply elasticities using local demand shocks triggered by the

[2]Other countries with similar homeownership rates include, for example, Austria, Germany, and South Korea.

historic spatial distribution of sectoral employment shares and the connectivity of a neighborhood with local labor markets. As a complementary shift-share instrument, we use the historic distribution of language shares across Swiss neighborhoods in combination with the growth of language groups at aggregate levels.

The second strand of the literature focuses on real estate asset markets and investors' expectations. Sivitanides et al. (2010) find that capitalization rates behave similarly to price/earnings ratios, with economic agents myopically forming price growth expectations based on past dynamics. This is in line with our findings, which suggest that investors expect further rent growth in locations that have experienced demand increases in the recent past. By constructing a user cost model incorporating economic fundamentals, Himmelberg et al. (2005) show that expected house price appreciation plays an important role in explaining local U.S. price dynamics. Mayer and Sinai (2007) substantiate these findings by showing the effect of backward-looking expectations in house price booms. Kaplan et al. (2017) highlight the role of expectations for the movements in house prices and rents around the Great Recession. Glaeser and Nathanson (2017) construct a model where buyers are not fully rational in predicting future price dynamics, which explains their observed serial correlation.

We also relate to the literature on local geographic and regulatory constraints (e.g. Aura and Davidoff 2008 and Hilber and Vermeulen 2016) and show that not only price supply elasticities are determined by regulation but also the adjustment of capitalization rates.[3]

Our contribution to the literature is threefold. First, we empirically establish a link between housing supply responsiveness and buyers' expectations. This link is important, as public policies affecting periodic housing costs might lead to unanticipated consequences in the supply of housing due to changes in expectations. Second, our empirical analysis quantifies the spatial dynamics of local expectations. Specifically, we provide novel evidence that the adaptation of buyers' expectations occurs at the local level and that such adaptation is consistent with a path-dependent view of spatial development. Investors expect that places that have gained in attractiveness (i.e., experienced a positive demand shock) will continue to do so

[3]Relatedly, Solé-Ollé and Viladecans-Marsal (2012) analyze the role political competition for residential development. Lin and Wachter (2019) document spillover effects of local regulatory constraints on neighboring localities, Cosman et al. (2018) analyze housing appreciation and marginal land supply in a dynamic framework.

even further in future periods, leading to additional housing development. Third, we show that housing supply elasticity varies considerably within and across urban areas due to the fine-scale impact of geographic and regulatory constraints. This variation leads to a spatially heterogeneous capitalization of global demand shocks that is unlikely to be observed when estimating housing supply elasticity at the urban area level, as done by previous research.

The remainder of the paper is structured as follows. Section 1.2 introduces the conceptual framework motivating our empirical analysis. Section 1.3 explains our empirical identification strategy, and Section 1.4 presents the data and provides descriptive statistics for the Swiss housing market. We discuss the results in Section 1.5 and provide several robustness checks in Section 1.6. Section 1.7 concludes.

1.2 Conceptual framework

The following partial equilibrium framework allows us to formalize the identification assumptions underlying the empirical analysis and rationalize corresponding findings. We specify the supply and demand side of the housing market and outline the role played by real estate investors.[4]

1.2.1 Housing developers

As in Glaeser (2008), in each neighborhood n housing developers choose the amount of housing space to develop. To build housing, developers must pay a price P_n^{land} to acquire land, and a local construction cost c_n to purchase building materials and remunerate labor. Without loss of generality, we capture both local productivity of the construction sector, as well as unit cost of inputs, in c_n. The developers' profit optimization problem is given by

$$\max_h (P_n h l - c_n h^{\delta_n^{int}+1} l - P_n^{land} l), \tag{1.1}$$

where P_n is the local price of housing per unit of living space, l denotes the amount of land and h the building height. We assume that the cost component $c_n h^{\delta_n^{int}+1} l$ is convex with respect to building height ($\delta_n^{int} > 0$), describing the fact that the

[4]Appendix 1.A presents a more detailed derivation of the model.

construction of taller building becomes progressively costlier due to geographic and regulatory constraints limiting residential development on the intensive margin.[5]

Developers choose the optimal intensity of development for each homogeneous unit of land in the neighborhood. The zero profit condition is met and governs the equilibrium price of land P_n^{land}. Total housing supply is given by the product of h_n^* and the amount of developable land L_n available in the neighborhood. We assume that the quantity of land available for residential development in the neighborhood responds endogenously to housing prices according to $L_n = \bar{L}_n P_n^{\frac{1}{\delta_n^{ext}}+\frac{1}{\delta_n^{int}\delta_n^{ext}}}$, where $\bar{L}_n$ captures characteristics of locations shifting land supply and $\delta_n^{ext}, \delta_n^{int}$ govern the (inverse) responsiveness of residential land availability (see Appendix 1.A). Total housing supply in a neighborhood is then given by

$$Q_n^s = h_n^* L_n = \left(\frac{P_n}{(\delta_n^{int}+1)c_n} \right)^{\frac{1}{\delta_n^{int}}} \bar{L}_n P_n^{\frac{1}{\delta_n^{ext}}+\frac{1}{\delta_n^{int}\delta_n^{ext}}} = S_n P_n^{\epsilon_n^{Q,P}}, \tag{1.2}$$

where $S_n = S_n(\bar{L}_n, c_n, \delta_n^{int})$ summarizes exogenous housing supply shifters. The structural parameter $\epsilon_n^{Q,P} = \frac{1}{\delta_n^{int}} + \frac{1}{\delta_n^{ext}} + \frac{1}{\delta_n^{int}\delta_n^{ext}} \geq 0$ corresponds to the local housing supply price-elasticity, which depends on the local responsiveness of residential development on the *intensive* (δ^{int}) and *extensive* (δ^{ext}) margin.[6]

1.2.2 Real estate investors

We build on the framework proposed by DiPasquale and Wheaton (1992) and assume that investors are willing to pay a square meter price P_n for a property generating a periodic rental income R_n in neighborhood n. Investors thus mediate between the property market – in which households consume housing *services* – and housing developers.[7] Investors optimally choose whether to sell or rent out real estate assets, which implies that the capitalization rate of rental and selling properties is the same. If it were not so, arbitrage opportunities would arise, leading investors to shift their

[5]Tall and high-rise buildings typically require specific building materials and specialized workers, such as architects and engineers, that ensure the stability of its structure. Additionally, geographic, and regulatory constraints become more binding, as they are more likely to hinder vertical development.

[6]It is common in the literature to represent housing supply elasticity with a single structural parameter ϵ entering a housing supply function of the form $Q^s = SP^\epsilon$, see e.g., Hsieh and Moretti (2019), Baum-Snow and Han (2019), and Lin and Wachter (2019).

[7]In the case of owner-occupancy, the investor rents out the real estate asset to himself.

demand from one real estate asset to the other.[8]

We depart from the literature by assuming that investors form expectations about *local* risk-adjusted returns r_n and rent growth g_n according to observed *contemporaneous* rents and prices, i.e., $r_n = r_n(R_n, P_n)$ and $g_n = g_n(R_n, P_n)$. Across time periods, investors update their expectations based on the capital investment they have to make and the corresponding rental income they could potentially earn, thus leading to heterogeneous expectation adjustments across neighborhoods. This leads to the formula $P_n = \frac{R_n}{i_n(R_n,P_n)}$, where $i_n = r_n(R_n, P_n) - g_n(R_n, P_n)$ is the local capitalization rate.[9]

Using this simple framework, we can analyze the propagation of changes in the periodic costs of housing, i.e., rental income, on the supply of housing. The relative responsiveness of housing supply to rent changes is given by

$$\epsilon_n^{Q,R} = \frac{R_n}{Q_n^s}\frac{dQ_n^s}{dR_n} = \frac{P_n}{Q_n^s}\frac{dQ_n^s}{dP_n}\frac{R_n}{P_n}\frac{dP_n}{dR_n} = \epsilon_n^{Q,P}\epsilon_n^{P,R}, \tag{1.3}$$

where $\epsilon_n^{Q,P}$ is the standard housing supply price elasticity, and $\epsilon_n^{P,R}$ is an *amplification coefficient* that corresponds to the price elasticity with respect to rent changes. This latter is determined by the responsiveness of local capitalization rate to rent changes, i.e., $\epsilon_n^{P,R} = 1 - \epsilon_n^{i,R}$. Equation (1.3) tells us that housing supply responses to rent and price changes differ when the elasticity of prices to rent changes is not unitary. If the valuation of local real estate assets is very sensitive to local rent changes, i.e. $\epsilon_n^{P,R} > 1$, housing supply will respond more strongly to rent changes than to price changes. Investors' adjustment of growth expectations and local risk captured by the capitalization rate determine the elasticity of local prices to local rents. If these factors were independent of rent dynamics, we should observe identical supply responses to rent and price changes, which is a central hypothesis we test empirically.[10]

A parametrization of local capitalization rates is instructive to provide an

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[8]This no arbitrage assumption is at the core of the standard user cost approach employed by Hendershott and Slemrod (1983), Poterba (1984), and Mayer and Sinai (2007)

[9]Although the user cost approach is not strictly necessary to derive Gordon's present value formula, it is instructive to understand how and why rental and owner-occupied markets are linked. Importantly, in such a framework renters consume housing services and do not enter the arbitrage condition of the capital markets.

[10]Note that Equation (1.3) is valid for any supply function whose price elasticity is described by a single structural parameter. The structure imposed by Equation (1.2) only serves the purpose of understanding the identification assumptions underlying the empirical estimation.

intuition about the way we differ from the literature and to understand the identification assumptions exposed in the next section. Let us assume that $i_n = i_0 R_n^{\gamma_n^R} P_n^{\gamma_n^P}$, where i_0 is the "standard" capitalization rate, which the literature usually assumes to be exogenously determined by capital markets.[11] The parameters γ_n^R and γ_n^P represent the local elasticity of capitalization rates with respect to rent and price shocks, other things equal. It's easy to show that the amplification coefficient is pinned down by these two parameters via the equation $\epsilon_n^{P,R} = \frac{1-\gamma_n^R}{1+\gamma_n^P}$. This parametrization parsimoniously endogenizes capitalization rates while allowing for spatial differences in the investors' discount rate when evaluating real estate assets. If we set $\gamma_n^R = \gamma_n^P = 0$, we obtain the standard Gordon growth model. Empirically, we test whether this spatial generalization of the Gordon growth model is meaningful.[12]

1.2.3 Residents

The economy is endowed with a continuous measure of N individuals distributed across neighborhoods. Building on recent work of Monte et al. (2018), each individual working in industry k decides in which neighborhood n to live and in which area i to work. The idiosyncratic indirect utility U_{ni}^k of individual ω is given by

$$U_{ni}^k(\omega) = b_{ni}^k(\omega) \frac{\tilde{W}_{ni}^k}{R_n^\alpha}, \tag{1.4}$$

where we set the price of the tradable numéraire equal to unity and assume that individuals spend a share α on housing. The variable $\tilde{W}_{ni}^k$ denotes the industry-specific wage of workers living in n and commuting to i.

The utility component b_{ni}^k captures idiosyncratic preferences that do not depend on market fundamentals but, rather, on the exogenous tastes of workers for a given place of residence/place of work combination. We assume such preferences to be i.i.d. realizations of a Fréchet-distributed random variable with scale parameter B_{ni}^k and shape parameter $\varepsilon^k > 1$. The greater the value of ε^k, the less heterogeneous

[11] Our results generalize to a parametrization that allows for *local* exogenous capitalization rates i_{0n}. In Section 1.6, we check the robustness of our results when i_{0n} includes local measures of liquidity risks and uncertainty in the revenue generated by the property.

[12] The existing literature on capitalization rates empirically documents a strong heterogeneity in capitalization rates across space, with urban and high-amenity areas typically displaying lower capitalization rates. However, the existing urban literature largely neglects such differences. Our parametrization accommodates such features.

are locational preferences of workers in a given industry, thus implying a greater mobility across space.

We model $\tilde{W}_{ni}^k$ as wage per effective units of labor W_{ni}^k divided by commuting costs m_{ni}, implying that workers reduce labor supply when commuting from distant locations. Our focus being on housing markets, we do not explicitly model the demand side of labor markets, and consider wages W_{ni}^k as an exogenous variable.[13]

Given households' homothetic preferences, total housing demand Q_n^d in neighborhood n is given by

$$Q_n^d = \alpha \frac{\bar{W}_n}{R_n} N_n = \alpha \frac{1}{R_n^{\alpha(1+\epsilon^k)}} \frac{N}{\Phi} \sum\nolimits_{i,k} B_{ni}^k \left(\frac{W_{ni}^k}{m_{ni}} \right)^{\epsilon^k+1}, \tag{1.5}$$

where $\bar{W}_n = \frac{1}{N_n} \sum_{i,k} \frac{W_{ni}^k}{m_{ni}} N_{ni}^k$ is the weighted average income earned in neighborhood n and $N_n = \sum_{i,k} N_{ni}^k$ and is the total number of households living in n.[14] Equation (1.5) provides two insights that prove useful when constructing housing demand shifters. Specifically, we should expect higher housing demand in neighborhoods that are i) better connected to productive areas, and ii) attractive along one of the dimension captured by idiosyncratic tastes B_{ni}^k. In the next section, we derive two instruments that capture shifts in housing demand triggered by these two dimensions while remaining exogenous with respect to housing supply changes.

1.3 Empirical framework

Based on the above framework, we derive empirical specifications to estimate housing supply elasticities $\epsilon_n^{Q,P}$ and $\epsilon_n^{Q,R}$, and discuss the corresponding identification assumption. We start by imposing average supply elasticities $\epsilon^{Q,P}$ and $\epsilon^{Q,R}$ common to all neighborhoods. In the next step, we provide a parametrization allowing us to estimate heterogeneous housing supply responsiveness at the neighborhood level.

[13] Indeed, the identification strategy exposed in Section 1.3 relies on exogenous changes in local labor demand. For this reason, we refrain to model labor demand endogenously.

[14] Please refer to Appendix 1.A for a detailed derivation and a more detailed discussion of Equation (1.5).

1.3.1 Partialling out quality differences

The conceptual framework exposed in Section 1.2 implicitly assumes that the quality of housing goods is homogeneous within the same neighborhood and across rental and selling properties. The relatively small neighborhoods in our main empirical analysis justify this assumption to a certain extent as properties sharing similar housing characteristics tend to cluster together.

Yet, differences in the quality and type of housing goods may remain. To prevent potential quality bias, in what follows, we remove all price and rent variation across locations that originate from differences in observable housing characteristics. To this end, we construct local (log) price and rent indices from hedonic regressions. Specifically, in each period we separately estimate

$$\ln \tau_{jnt} = \gamma^{\tau}_{nt} + \beta^{\tau}_{t} \mathbf{A}_{jnt} + \epsilon^{\tau}_{jnt}, \quad \tau = R,\ P \tag{1.6}$$

where τ_{jn} denotes either the price or rent of property j in neighborhood n at time t. The vector $\mathbf{A}_{jnt}$ includes a comprehensive set of attributes such as housing surface, the average number of rooms, age, age squared, and an indicator for single-family vs. multi-family houses. ϵ^{τ}_{jnt} denotes the error term. We use the estimated neighborhood-time fixed-effects γ^{τ}_{nt} as quality-adjusted log-prices (log-rents) $\ln P_{nt}$ ($\ln R_{nt}$).[15] Note that the coefficients β^{τ}_{t} are time-variant, such that the valuation of housing characteristics can flexibly change from period to period.

1.3.2 Model-informed identification of average supply elasticities

Log-linearizing supply Equation (1.2), expressing prices as a function of quantities, and first differencing, in equilibrium[16] we obtain the following empirical specification

$$\Delta \ln P_n = \alpha^P + \frac{1}{\epsilon^{Q,P}} \Delta \ln Q_n + \Delta \ln S^P_n, \tag{1.7}$$

[15] Note that all our results are robust to allowing for region-specific valuations of housing attributes i.e., the inclusion of β_{rt} where regions r are defined as cantons or commuting zones containing a sufficient number of locations n.

[16] In equilibrium $Q^d_n = Q^s_n = Q_n$ holds, such that supply and demand superscripts are omitted in what follows.

where $\frac{1}{\epsilon^{Q,P}}$ is the average inverse housing supply elasticity common to all neighborhoods and Δ denotes a time difference between 2005 and 2015.[17] The term α^P denotes the average value of changes in observed supply shifters common to all neighborhoods and, in a slight abuse of notation, $\Delta \ln S_n^P$ represents the corresponding mean-centered variable. Time-invariant components are partialled out from $\Delta \ln S_n^P$ by first differencing, such that only *dynamic* supply shifters enter Equation (1.7).

Estimating Equation (1.7) by OLS likely leads to biased estimates of the parameter of interest due to the endogeneity of $\Delta \ln Q_n$ via the demand side. This is easily seen by using Equation (1.5) to write changes in housing demand as

$$\Delta \ln Q_n = \Delta \ln \bar{W}_n + \Delta \ln N_n - \Delta \ln R_n. \tag{1.8}$$

Therefore, estimates of $\frac{1}{\epsilon^{Q,P}}$ in Equation (1.7) are potentially biased due to i) a correlation of the components of housing demand changes – such as changes in average wages and number of residents – with changes of unobserved supply shifters in $\Delta \ln S_n^P$ (omitted variable bias), and ii) the impact of housing prices – via changes in rents – on housing demand (reverse causality).

According to Equation (1.2) (see Appendix 1.A), $\Delta \ln S_n^P$ can be decomposed into a sum of local construction cost changes, subsumed in $\Delta \ln c_n$, as well as changes in exogenous shifters of developable land $\Delta \ln \bar{L}_n$. Changes in the price of construction materials and the cost to make land available for residential development are unlikely to differ across space, mostly due to the small country size. On the contrary, shifts in housing demand via wages might affect construction costs.

To partially address differences in construction costs across neighborhoods, in a first step, we control for several supply shifters in Equation (1.7). Let $\mathbf{X}_n$ denote the vector containing such controls.[18] In particular, $\mathbf{X}_n$ includes construction cost indices – i.e., changes in labor and material costs – defined for the main

[17]Estimating the *inverse* supply function, rather than the direct one, is a common approach in the literature (e.g., Saiz 2010) that offers several advantages. First, using quality-adjusted prices and rents resulting from a hedonic regression as dependent variables does not require additional statistical treatment. This is not case if quality-adjusted prices are used as regressors, as their standard errors are not valid and need to be bootstrapped. Second, instrumental variables tend to be more relevant for quantities than for prices, improving the precision of the estimates. Third, it allows us to instrument the same variable (i.e., Q_n) to recover the responsiveness of housing supply to price and rent changes.

[18]Note that such controls might also partial out quality differences not fully captured by hedonic indices.

national construction markets, the intensity of historic development – as measured by development density in 1980 – and terrain ruggedness. According to Hilber and Robert-Nicoud (2013), the historic level of housing development proxies for the fact that high-amenity areas develop first and tend to adopt more stringent land-use regulations over time. Controlling for terrain ruggedness takes into account that plots of land featuring geographic characteristics favorable to development – such as flat and non-rocky surfaces – are likely developed before those showing adverse geographic characteristics. Therefore, we expect unfavorable geographic features to increase rents/prices over time, as developers face higher construction costs for providing additional housing units on the extensive margin of existing development. Similarly, we control for the elevation of the land. We further control for the distance to the nearest central business districts to capture potential time trend differentials in the labor supply (and demand) across space. These variables might also capture changes in transportation costs.[19]

Despite controlling for several supply shifters, omitted variables, and reverse causality may still bias the estimation of Equation (1.7). To solve this issue, we propose an instrumental variable approach that aims to exclusively shift housing demand while leaving housing supply unchanged. Specifically, we require an instrument, denoted $\Delta \ln Z_n$, which is relevant for housing demand changes while remaining exogenous to supply changes conditional on the set of controls in $\mathbf{X}_n$ i.e., $E(\Delta \ln Z_n \Delta \ln S_n^P | \mathbf{X}_n) = 0$.

As apparent from Equation (1.8), we cannot use observed changes in the components of the housing demand, as in equilibrium, they are affected by tension forces between housing demand and supply. Following the recent work by Baum-Snow and Han (2019), we isolate exogenous changes in *labor demand* given the spatial linkages (commuting cost) of a neighborhood with employment centers. We define

$$\Delta \ln Z_n = \sum_{i,k} \frac{\mathbf{1}(m_{nit_0} < 1 \text{ hour})}{m_{nit_0}} f_{nt_0}^k \Delta \ln F_{C(n)}^k, \tag{1.9}$$

where the indicator function $\mathbf{1}(m_{nit_0} < 1 \text{ hour})$ equals one for neighborhoods i that are located at most at 60 minutes travel time from neighborhood n, and zero

[19]Of course, these variables also affect housing demand. In this case, including them in the supply function, is even more important as they reduce endogeneity issues arising from changes in housing demand according to Equation (1.8).

otherwise.[20] The quantity $f^k_{nt_0}$ represents the share of employment belonging to sector k in neighborhood n at time t_0.[21] The term $\Delta \ln F^k_{C(n)}$ is the corresponding aggregate growth rate of employment in industry k over $[t, t_0]$ in region C in which neighborhood n is located.[22]

The intuition behind Equation (1.9) is straightforward. We compute a weighted employment growth of the predetermined sectoral composition in the proximity of a given neighborhood by imposing a common industry growth equal to the one that occurred in the region C in which the neighborhood is located. Taking into account the proximity – in terms of commuting time – to other neighborhoods is of particular relevance in the case of small spatial units e.g., neighborhoods, as most individuals likely do not work in the same neighborhood where they live. We use a one-hour radius for the benchmark analysis as this leads to the strongest predictive power of the instrument.

Two features in the way we compute $\Delta \ln Z_n$ support exogeneity claims with respect to unobserved supply dynamics. First, in line with Bartik (1991), we exclude neighborhood n itself from the computation of $\Delta \ln F_{C(n)k}$. Second, we exclude all sectors related to construction and real estate from $f^k_{nt_0}$ and $\Delta \ln F^k_{C(n)}$. Therefore, the instrument captures weighted changes in labor demand that are not related to the construction sector.

The instrument defined by Equation (1.9) is a shift-share instrument in line with Bartik (1991). Recently, Adão et al. (2018), Borusyak et al. (2018), and Goldsmith-Pinkham et al. (2019) investigated the econometric assumptions necessary for the validity of shift-share instruments. These instruments are valid if either initial shares are independent and randomly assigned across observations or initial shares are endogenous but growth shocks occur randomly across regions. In our setting, we argue that initial sectoral shares are exogenous with respect to changes in unobserved supply shifters and local rent/price dynamics. The sectoral distribution of employment is highly persistent and largely determined by natural amenities and market access, such that the historic sectoral distribution is unlikely to be correlated with recent *changes* of local housing supply shifters $\Delta \ln S^P$. Following Goldsmith-Pinkham et al. (2019), in Section 1.6 we asses the validity of the identifying variation

[20] Travel time within the same 2x2km neighbourhood has been set to 1 minute.

[21] We use the NOGA 1 sector classification, which comprises 16 different sectors in the case of Switzerland. This classification corresponds to the major SIC industry groups in the U.S.

[22] In our baseline results, we use Cantons as aggregate region C, which represent 26 upper-tier administrative units. Our results are robust using lower tier regions, such as districts (Bezirke).

by computing the Rotemberg weights for each sector.

We further support exogeneity claims regarding $\Delta \ln Z_n$ by comparing our results with those obtained using an alternative shift-share instrument based on the distribution of language shares.[23] Specifically, for each neighborhood we compute the historical share of language shares and interact them with the cantonal growth of the respective language group.[24] Assuming that the idiosyncratic utility shifter can be decomposed as $B_{ni}^k = B_n B_i^k$ in Equation (1.5), we can interpret this instrument as predicting demand changes via a shift in the idiosyncratic preferences B_n to live in a neighborhood n.

We close this subsection by briefly discussing the estimation of $\epsilon_n^{Q,R}$. By substituting the relationship between prices and rents arising from the parametrization of capitalization rates into Equation (1.7), and isolating R_n, we obtain

$$\Delta \ln R_n = \alpha^R + \frac{1}{\epsilon^{Q,R}} \Delta \ln Q_n + \Delta \ln S_n^R \tag{1.10}$$

where $\frac{1}{\epsilon^{Q,R}} = \frac{1}{\epsilon^{Q,P}\epsilon^{P,R}}$, and we assume that the vector $\mathbf{X}_n$ capturing observable supply shifters discussed above is controlled for. The new error term is $\Delta \ln S_n^R = \frac{1}{\epsilon^{P,R}} \Delta \ln S_n^P$. Because this new error term equals the one of Equation (1.7) times a constant structural parameter, the previous discussion of the identification assumptions still holds.[25]

1.3.3 Local supply responsiveness and the role of geographic and regulatory constraints

Equations (1.7) and (1.10) assume that inverse supply elasticities with respect to prices and rents are constant across locations. However, our conceptual framework suggests that housing supply elasticity varies at the local level, both at the intensive and extensive margin of residential development. On the intensive margin,

[23] Saiz (2007) uses a similar approach, who builds a shift-share instrument based on the number of immigrants moving into U.S. cities.

[24] See Appendix 1.C for a formal definition of the instrument.

[25] The exogenous component of the capitalization rate i_0 is captured by the rent-specific constant α^R in Equation (1.10). If we assume the parametrization of local capitalization rates exposed in Section 1.2 and allow for location-specific fundamental capitalization rates i_{0n}, the error term in Equation (1.10) becomes $\Delta \ln S_n^R + \frac{1}{\epsilon^{P,R}} \frac{1}{1+\gamma_n^P} \Delta \ln i_{0n}$, such that the exogeneity of the instrument must also hold with respect to location-specific exogenous capitalization rates. In Section 1.6, we show that including several controls proxying for i_{0n} do not affect our results.

the empirical literature points out that supply elasticity might vary considerably according to regulatory restrictions – such as height restriction, floor to area rations, etc. – adopted by local governments. According to Hilber and Robert-Nicoud (2013), attractive places are historically more developed and, as an outcome of the political game between land developers and owners of developed land, more regulated. On the extensive margin, Saiz (2010) points out that such constraints are empirically relevant only when there is enough development to make them binding.[26] To implement such considerations empirically, we thus follow Saiz (2010) and use the following approximation

$$\frac{1}{\epsilon_n^{Q,\tau}} \approx \beta^{avg,\tau} + \beta^{hist,\tau} \times Q_n^{1980} + \beta^{constr,\tau} \times \Lambda_n \times Q_n^{1980}, \quad \tau = R,\ P, \tag{1.11}$$

where the observed historic stock in 1980 Q_n^{1980} proxies for regulation constraints on the intensive margin, according to Hilber and Robert-Nicoud (2013) and Λ_n is a measure summarizing the most important geographic and regulatory constraints on the extensive margin. Inserting such approximation in Equations (1.7) and (1.10), we then estimate the following equation

$$\begin{aligned} \Delta\ln(\tau_n) = \alpha^\tau + \beta^{avg,\tau}\Delta\ln(Q_n) + \beta^{hist,\tau}\Delta\ln(Q_n) \times Q_n^{1980} + \\ \beta^{constr,\tau}\Delta\ln(Q_n) \times \Lambda_n \times Q_n^{1980} + \Delta\ln S_n^\tau, \quad \tau = R,\ P, \end{aligned} \tag{1.12}$$

where we control again for $\mathbf{X}_n$ (which includes historic development Q_n^{1980}) as well as for the main effect of extensive margin constraints Λ_n. Two remarks are worth noting. First, Λ_n is interacted with the historic stock level Q_n^{1980}, thus allowing the impact of regulatory constraints to become more binding in more-developed places. Having estimated the parameters $\beta^{avg,\tau}, \beta^{hist,\tau}$, and $\beta^{constr,\tau}$, we then recover $\epsilon_n^{Q,\tau}$ using Equation (1.11). Second, the identification assumptions of the price and rent equation in Equation (1.12) are the same as in Equations (1.7) and (1.10) provided Q_n^{1980} and Λ_n are exogenous with respect to $\Delta\ln S^\tau$.

[26]For example, protected forest likely hinder residential development only if no other type of developable land is available in the neighborhood.

1.4 Data and descriptive statistics

The empirical analysis relies on several data sources. Further information is available in Appendix 1.B.

1.4.1 Data sources

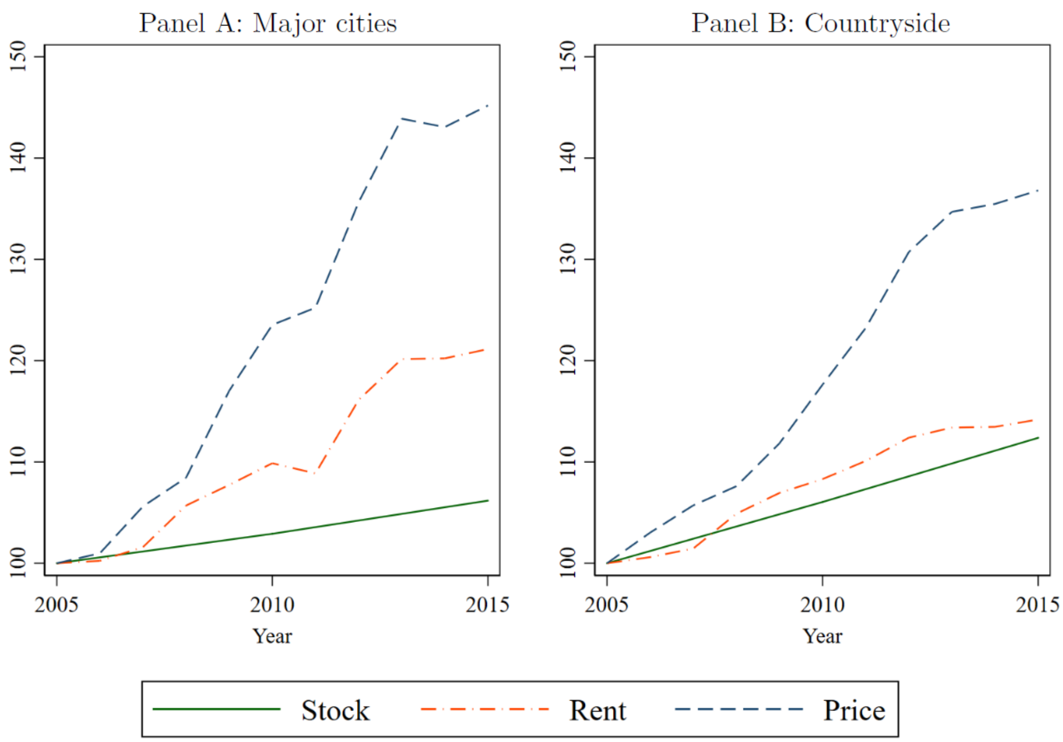
Housing data – We use proprietary geo-referenced data on advertised residential properties provided by Meta-Sys. The data set contains approximately 2.1 million postings of rental properties and about 0.8 million postings of selling residences for the whole of Switzerland from 2004 to 2016. In addition to asking rents and prices, the data set includes comprehensive information on housing characteristics. The Federal Register of Buildings and Habitations published by the Federal Statistical Office (FSO) provides a census of the residential housing stock of the country. Changes in the housing stock are measured every five years, providing three time periods – 2005, 2010, and 2015 – that overlap with our advertisement data. Up to 2015, the register contains approximately 4.8 million housing units for the whole of Switzerland, 11.5 percent of which were built between 2005 and 2015. The 2000 Building Census (FSO) provides information on whether a dwelling is a primary or secondary residence in that year.

Socio-demographic and economic data – We use the Federal Population Census of 2000 (FSO) as well as the Population and Households Survey from 2010 to 2015 (FSO) to infer geo-referenced homeownership rates and to obtain information on predetermined levels and changes in the local socio-demographic composition – i.e., nationality and language – of residents living in a given area. The 2000 Federal Population Census provides information on the type of building owner, distinguishing between institutional investors, private, and public owners. The FSO publishes a construction index tracking the cost evolution of material and labor in the construction sector for seven statistical areas. We obtained detailed information about the spatial distribution of employment and firms by sector from the Structural Business Statistics (STATENT). We combine this information with data about road travel time provided by *www.search.ch* to construct a local measure labor market access.

Regulatory and geographic data – The Land-Use Statistics of Switzerland (FSO) provides satellite-based land cover data, allowing us to identify geographic constraints, such as lakes, rocks, and glaciers, and areas subject to particular regulations. Information about regulations on the extensive margin – and protected areas in particular – is obtained from Cantonal offices of spatial planning and the Federal Office for the Environment (FOEN).

Other data – We complement the above data with a variety of data on Swiss administrative units and metropolitan areas (FSO) and elevation (European Environment Agency). We identify the agglomerations of the 15 main cities in Switzerland, as defined by the Swiss Federal Statistical Office (FSO), and compute the distance of each neighborhood to the closest city center.

Figure 1.1: Rent, price, and stock dynamics



Notes: Cities include 2x2 km neighborhoods located in one of the 15 main municipalities of the corresponding biggest urban areas according to 2015 boundaries. The two panels show index growth from 2005 to 2015 of the considered variables, using 2005 as the base year (=100). Stock is measured as the total number of dwellings, and rents and prices are measured as advertised average rents and prices per square meter.

1.4.2 Data structure and descriptive statistics

We structure the data by partitioning the whole territory of the country into small square neighborhoods of 2x2 km. We aggregate residential transactions, housing stock, socio-demographic and economic data, and geographic and regulatory constraints within these neighborhoods.[27] We assign each neighborhood to one of 2,324 municipalities, which represent the lowest governmental tier in Switzerland and have some influence on land-use regulation.

From 2005 to 2015, rents have increased by approximately 14 percent while prices have increased by approximately 35 percent at the country level.[28] Over the same period, the housing stock grew by approximately 11 percent. Despite these general trends, stock, rent, and price dynamics are heterogeneous across space, as illustrated in Figure 1.1. Specifically, Figure 1 shows stock, rent, and price index growth in cities (Panel A) and the countryside (Panel B) from 2005 to 2015, using 2005 as the base year (=100). Over the considered period, housing stock grew almost twice as much in the countryside areas than in cities, hinting at the fact that in cities, further development is hindered by a lack of developable land in conjunction with geographic and regulatory constraints. Given this comparatively lower responsiveness of housing development in cities, it is not surprising that rents and prices grew more in these areas than in the countryside. Interestingly, from 2007 onward, rents and price dynamics have started to diverge considerably – with prices growing at a faster pace – which implies that capitalization rates have been revised downward in these locations.

In Figure 1.2, we show the most important geographic and regulatory constraints for housing development in Switzerland. Geographic features preventing any form of development are an important component of the Swiss landscape. We define *undevelopable land* as land that is located above 2000 meters and whose land cover corresponds to unproductive vegetation, vegetation-free areas, or rocks, and glaciers. Water bodies significantly reduce the amount of developable land in the proximity of major agglomerations, as virtually all major CBDs are adjacent to a lake or river.[29]

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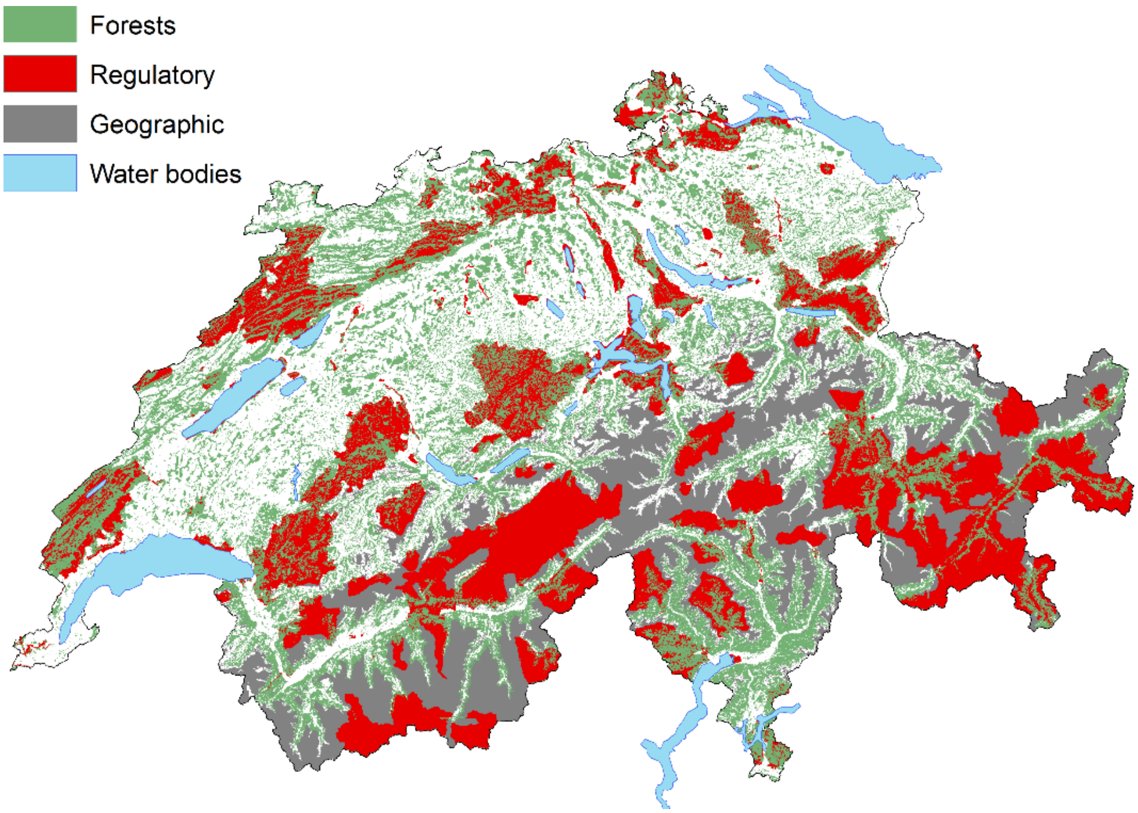
[27] Our results are robust to alternative neighborhood sizes, as discussed in Section 1.6.

[28] For *new* tenancy agreements market rents apply in Switzerland. To prevent abusive increases, property owners can adjust rents for *existing* tenancy agreements only if some formal criteria are met. However, several exceptions in the regulation allow landlords to adjust rents to local market levels.

[29] This is mainly due to the competitive advantage of areas in the proximity of water bodies during the Industrial Revolution and the subsequent urbanization of Switzerland.

Figure 1.2: Constraints to development



Notes: We define geographic constraints as *undevelopable land*, which corresponds to plot of land located above 2000 meter, or whose land use classification corresponds to unproductive vegetation, vegetation-free areas, or rocks and glaciers. Except for forests, red areas summarize regulatory constraints on the extensive margin. Swiss forests are protected areas since 1876.

In addition to geographic constraints, there are significant regulatory restrictions in place that prevent or hinder development in specific areas. We refer to measures that prevent new construction on undeveloped land as regulations on the extensive margin. Regulations on the extensive margin include forests[30], UNESCO cultural or natural heritage sites, parks, and other high value natural amenity areas. These restrictions account for approximately 49.1 percent of the Swiss territory. Total restricted areas – obtained by overlapping geographic and regulatory constraints at the extensive margin – amount to approximately 67.3 percent of the country's surface. The remaining 32.7 percent of the country's surface (white area in Figure

[30]In response to growing industrialization of the country, in 1876, Switzerland passed a federal law prohibiting further deforestation, de facto freezing forest areas to the level observed at that time. The law has remained mainly unchanged to the present day. As a consequence, forest areas in highly populated regions have remained practically unchanged since 1876.

1.2) is available for development under different regulatory measures determining the intensity and type of residential development.

1.5 Results

1.5.1 Supply elasticity estimates and amplification mechanism

Table 1.1 summarizes average supply elasticity estimates with respect to price (columns 1, 3, and 5) and rent (columns 2, 4, and 6) changes, respectively. Columns 1 and 2 report estimates based on the shift-share instrument $\Delta \ln Z_n$ derived from historic industry shares (used as a benchmark), columns 3 and 4 report the corresponding effects for the shift-share instrument derived from historic language shares, and columns 5 and 6 show the results when using the two instruments simultaneously. Since our model framework in Section 1.2 establishes labor market shocks as a source of shifts in housing demand, we refer to the results based on industry shares as our baseline estimates.

Responsiveness estimates based on the industry instrument are equal to $\epsilon^{Q,R} = \frac{1}{0.694} = 1.44$ for rent and $\epsilon^{Q,P} = \frac{1}{2.367} = 0.42$ for price changes. These results show that, on average, housing supply in Switzerland is relatively elastic to rent changes, but less so with respect to price ones. The corresponding amplification effect is $\epsilon^{P,R} = \frac{\epsilon^{Q,R}}{\epsilon^{Q,P}} = 3.43$. The country's average response of local capitalization rates to rent changes is thus $\epsilon^{i,R} = 1 - \epsilon^{P,R} = -2.43$, suggesting that investors revise local rent growth expectations (risk premium) upward (downward) following an exogenous positive demand shock.[31] These results remain mostly unchanged when using the instrument derived from historic language shares ($\epsilon^{P,R} = 2.68$) and when employing both instruments simultaneously ($\epsilon^{P,R} = 2.84$).

Reassuringly, the above results support our exogeneity claims about the instruments. This for two reasons. First, despite having the expected positive impact on $\Delta \ln Q$, the two instruments capture different variations while leading

[31] These spatial result are in line with recent findings investigating aggregate time dynamics. By simulating a dynamic model, Begley et al. (2019) find that a positive demand shock – as captured by higher population growth – leads to lower capitalization rates. It also aligns with the findings of Kaplan et al. (2017), who finds that a change in expectations drives the dynamics of price-rent ratios.

to very similar estimates.[32] In this case, it seems unlikely that if one or both instruments were endogenous, they would converge toward similar estimates. Second, the overidentification tests reported at the bottom of columns 5 and 6 do not point toward endogeneity issues. In Section 1.6 we further investigate the exogeneity of the instrument with respect to the inclusion of potential confounders.

Table 1.1: Inverse supply elasticities

	(1) ΔLog P	(2) ΔLog R	(3) ΔLog P	(4) ΔLog R	(5) ΔLog P	(6) ΔLog R
ΔLog Q	2.367***	0.694**	2.004***	0.747***	2.084***	0.735***
	(0.442)	(0.287)	(0.342)	(0.215)	(0.316)	(0.191)
Amplification	3.411		2.683		2.835	
Instruments	I	I	L	L	I & L	I & L
Observations	2,498	2,498	2,498	2,498	2,498	2,498
Kleibergen-Paap F	15.61	15.61	71.39	71.39	42.76	42.76
Overidentification	-	-	-	-	0.40	0.87

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The Adão et al. (2018) standard errors for columns (1), (2), (3), and (4) are 0.100, 0.048, 0.386, and 0.198, respectively. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Log rents and prices are quality-adjusted with respect to living surface, number of rooms, age, age squared, and building type. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs. See Appendix 1.E for detailed estimation results. Changes in housing stock ΔLog Q, are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

We now turn to the analysis of housing supply heterogeneity at the local level. Table 1.2 summarizes the results when all relevant constraints on the extensive margin – including water bodies, undevelopable land, forest, and other protected areas – are considered together in the total restricted area Λ_n. We follow the same structure as in Table 1.1 and report the results using the instruments based on industry shares (columns 1 and 2), language shares (columns 3 and 4), and the

[32]See first-stage results reported in Appendix 1.E. The coefficients for the two instruments are positive and highly significant.

two instruments simultaneously (columns 5 and 6). In addition to the extensive margin restrictions, we account for the historic level of building development Q_n^{1980}, thus allowing the impact of regulatory constraints to become more binding in more-developed places.

Table 1.2: Inverse supply elasticities – heterogeneity

	(1)	(2)	(3)	(4)	(5)	(6)
	ΔLog P	ΔLog R	ΔLog P	ΔLog R	ΔLog P	ΔLog R
ΔLog Q	1.001**	0.095	1.578***	0.519***	1.307***	0.321*
	(0.411)	(0.218)	(0.305)	(0.197)	(0.306)	(0.176)
$Q^{1980} \times$ ΔLog Q	0.690***	0.302***	0.842***	0.446***	0.678***	0.319***
	(0.189)	(0.089)	(0.200)	(0.109)	(0.151)	(0.082)
$\Lambda \times Q^{1980} \times$ ΔLog Q	0.241**	0.122**	0.330***	0.192***	0.255***	0.134***
	(0.110)	(0.049)	(0.115)	(0.059)	(0.099)	(0.048)
Instruments	I	I	L	L	I & L	I & L
Observations	2,498	2,498	2,498	2,498	2,498	2,498
Kleibergen-Paap F	12.98	12.98	23.48	23.48	19.46	19.46
Overidentification	-	-	-	-	0.56	0.49

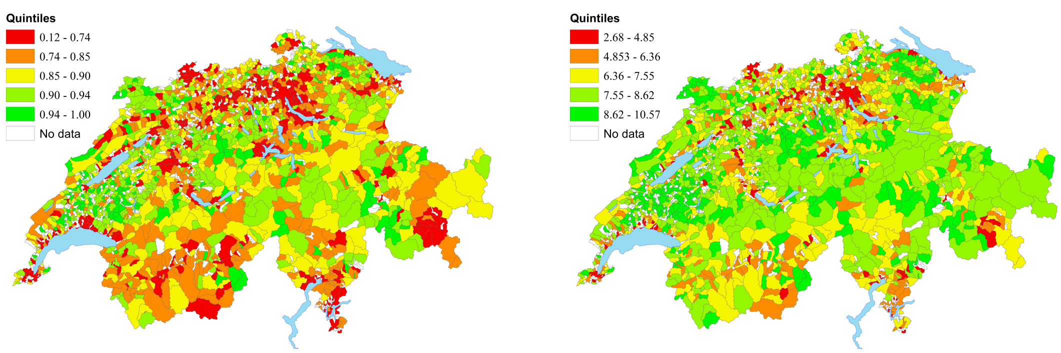
Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Log rents and prices are quality-adjusted with respect to living surface, number of rooms, age, age squared, and building type. All regressions control for supply shifters, which include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change in construction costs from 2005 to 2015. Total restricted area (Λ) is standardized and contains constraints on the extensive margin – water bodies, undevelopable land, forest, and other protected areas. See 1.E for detailed estimation results. Changes in housing stock ΔLog Q including interaction terms thereof are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

The coefficients of the double and triple interaction terms, which capture local supply heterogeneity, are all highly significant for rental and selling properties. These estimates suggest that i) historically developed places have more inelastic housing markets both with respect to rent and price changes, and ii) geographic and regulatory constraints on the extensive margin are more binding in more-developed places.[33] The double interaction coefficients are systematically lower for rental than selling properties. This implies that previous development patterns decrease the supply elasticity of selling properties to a larger extent than that of rental properties.

Having estimated the coefficients $\beta^{avg,\tau}$,$\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ for rental and selling properties, we compute supply elasticities coefficients at the neighborhood level according to Equation (1.11). To facilitate the visual representation of these parameters, we aggregate these local supply elasticities at the municipality level by using the mean values. In Figure 1.3 we show the spatial distribution of local housing supply price elasticity $\epsilon_n^{Q,P}$ (Panel A) and of the corresponding amplification coefficient $\epsilon_n^{i,R}$ (Panel B).[34]

Figure 1.3: Local supply elasticities and amplification coefficient

Panel A: Prices $\epsilon^{Q,P}$ Panel B: Amplification coefficient $\epsilon^{P,R}$



Notes: Supply elasticity interval defined according to quintiles of the distribution. Local estimates are computed using Equation (1.12) for 2km side country grid data. Heterogeneity is due to the sum of relevant geographic and regulatory constraints on the extensive margin and due to the historic housing stock. Elasticities for cells in which transactions occurred only in 2005 or 2015 – which are thus not included in Equation 3 due to first differencing – are imputed according to their value of geographic and regulatory constraints. No data corresponds to municipalities whose area is not the largest relative share of a grid cell.

As apparent from Figure 1.3 (Panel A), housing supply price elasticity varies considerably across space. Major agglomerations – and even more so areas near major CBDs – are particularly inelastic, with the municipality of Zurich and its neighboring agglomerations accounting for the largest area displaying inelastic

[33] Note that the heterogeneity arising from geographic and regulatory constraints alone is never significant. To compute our estimates, we always include geographic/regulatory constraints as a control, thus partialling out a direct effect of this variable on rent and price dynamics. For the detailed results, see Appendix 1.E.

[34] We do not report the spatial distribution of $\epsilon_n^{Q,R}$ as it is a function of $\epsilon_n^{Q,P}$ and $\epsilon_n^{i,R}$.

housing supply.[35] In contrast, countryside areas generally display comparatively higher elasticity values. However, this is not always true for Alpine regions. Some alpine regions, especially touristic ones, have low price elasticity values, likely due to the importance of geographic constraints in conjunction with high levels of historic development.[36]

Compared to the housing supply elasticities estimated by Saiz (2010) for the major U.S. metropolitan areas, the supply side of the Swiss housing market is significantly more inelastic to price changes. This unresponsiveness can be explained by the intensive and extensive margin constraints to development. On the intensive margin, housing development in Switzerland is constrained to low density. Even major cities, such as Zurich and Geneva, high-rise buildings (i.e., buildings counting more than seven stories) are the exception rather than the rule. On the extensive margin, widespread geographic and regulatory constraints hinder new development even in the countryside.[37]

As shown in Figure 1.3 (Panel B), the amplification mechanism displays considerable spatial heterogeneity, with values ranging from 2.68 to 10.57. These results suggest that central places display the lowest value of $\epsilon_n^{P,R}$, whereas countryside areas the highest. Following a shock to periodic housing costs, investors thus revise their expectations and risk premia more in remote areas than in central ones. This heterogeneous adaptation across space might be explained by the fact that attractive, and typically heavily restricted and regulated, central places already command high rent growth expectations and low risk premia. In such places, a positive demand shock is unlikely to modify investors' expectations strongly. On the contrary, it is more likely that investors revise their expectations substantially following a demand shock in elastic countryside areas where previous demand has been scarce. This is in line with the hypothesis of a path dependent view of spatial development. Investors myopically anticipate that places having experienced low (high) demand in the past will continue to do so in the future, thus (not) updating their beliefs when such places are indeed subject to a positive demand shock.

[35]The distribution of both rent and price elasticities is skewed to the left. Average supply elasticities at a given aggregation level are thus affected by a few extremely inelastic places. In Table 1.D.1 in Appendix 1.D.1, we rank the responsiveness of housing markets at three different aggregation levels: cantons, agglomerations, and municipalities.

[36]The municipalities of Zermatt (VS) and St. Moritz (GR), both famous ski resorts, count among the 10 percent most-inelastic Swiss municipalities.

[37]In Appendix 1.D.2, we provide a more detailed comparison of our estimates with those obtained in the literature, adding further credibility to our estimates.

1.5.2 Buyers' sophistication and the revision of local expectations

Our explanation for observed spatial differences in the revision of investors' expectations is that investors do not (perfectly) anticipate future demand shocks. To empirically test this proposition, let us assume that some investors are more sophisticated than others. In particular, more sophisticated investors have access to a better information set, which allows them to predict future demand growth more precisely. Given these assumptions, we expect that in places where more sophisticated investors buy properties, the amplification mechanism (capitalization rate update) is lower (less negative).

We proxy the presence of sophisticated investors in a given neighborhood with the share of institutional investors – which include real estate firms, construction firms, insurers, and pension funds – and second-home buyers. Institutional investors are professional buyers investing in real estate, mainly to realize capital gains or benefit from rental income and typically devote considerable resources to conduct market studies to optimize their investment strategies. In the case of second-home buyers, Bernstein et al. (2019) have documented that these type of buyers tends to exhibit fewer biases in their investment decisions.

In the next step, we estimate the following cross-sectional relationship

$$\epsilon_n^{P,R} = \alpha + \beta\omega_n + \mathbf{\Theta}_n\gamma + \upsilon_n, \tag{1.13}$$

where $\epsilon_n^{P,R}$ represents the amplification coefficient in neighborhood n (computed relying on the industry share instrument), and ω_n is the predetermined share of either institutional investors or second homeowners in 2000. The vector $\mathbf{\Theta}_n$ contains the same time-invariant controls as in Table 1.2, which include elevation, elevation standard deviation, log-distance to the nearest CBD, construction costs, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs. The variable υ_n is a stochastic error term.

Table 1.3 shows the estimation results. In columns 1 and 3 we report results based on the same sample as in Table 1.2, whereas in columns 2 and 4 we perform out-of-sample predictions based on the elasticity estimates of Table 1.2.[38] We perform such

[38] More precisely, we use the estimates of $\beta^{avg,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ reported in Table 1.2 together with observed values of Q_n^{1980} and Λ_n to predict local housing supply elasticities according to Equation (1.11) in places where there was not a sufficient number of advertised rental or selling

out-of-sample predictions to include a larger number of neighborhood containing shares of sophisticated investors, which provides a greater variation in the observed investor types that we can exploit empirically.

Table 1.3: Investors' sophistication and amplification effect

	(1)	(2)	(3)	(4)
	Amplification effect			
Share of inst. investor	-0.419	-1.273***		
	(0.295)	(0.194)		
Share of second home			-0.483***	-0.606***
			(0.164)	(0.118)
Observations	2,498	5,054	2,498	5,168
R-squared	0.86	0.88	0.86	0.87

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Controls include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs.

The results in Table 1.3 show that a higher share of institutional investors is indeed associated with a lower amplification effect, although the correlation is barely not significant in the case of the restricted sample. Similarly, a higher share of second homeowners predicts a lower amplification effect, albeit the lower magnitude (in absolute value) of the coefficient seems to suggest that, for a given share of investor's type, institutional investors anticipate future demand shocks better than second home investors, which seems plausible. Interestingly, the relationship between the amplification effect and second home investors is robust across samples.

1.6 Robustness checks

1.6.1 Modifiable areal unit problem

One may question the stability of our results for different definitions or areal units. More specifically, according to Briant et al. (2010), our point estimates of (inverse)

properties in the years 2005 and 2015.

supply elasticities in Table 1.1 might vary depending on the aggregation level. We thus verify the robustness of our estimates by both decreasing (down to 1 km) and increasing (up to 3 km) the sides of square the neighborhoods. Additionally, because they represent the lowest-tier political units in Switzerland, we estimate our specifications also at the municipality level.

Panels A to C of Table 1.4 illustrate the results. As before, we report estimates based on the industry instrument (columns 1 and 2), language instrument in (columns 3 and 4), and both instruments simultaneously (columns 5 and 6). The average supply elasticity estimates for rents and prices, are quite stable for 1 km, 3 km side cells, as well as at the municipality level. The magnitude of the elasticities increases somewhat for the 1 km side neighborhoods while they decrease somewhat at the municipality level. Importantly, for all levels of aggregation, we find evidence of stronger supply response to rent than price changes, with amplification coefficients quite stable across specifications and similar to those of Table 1.1.[39]

1.6.2 Frequency of rent and price observations

We investigate whether grid-cells containing a small number of rental and selling properties, typically located remote areas, are driving our main results. In Panel D of Table 1.4 we thus report estimation results when restricting the sample of our main analysis to 2x2km grid cells containing at least twenty observations for *both* rental and selling properties. The estimated coefficients remain almost identical to those in the benchmark Table 1.1.

1.6.3 Local risk

A further concern might be that local factors influence the fundamental capitalization rate i_0 introduced above. In this case, local changes Δi_{0n} are captured by the error term in Equation (1.10), and, if correlated with the instrument, they might bias our results. Even though there are no obvious factors that determine local fundamental capitalization rates that correlate with initial industry shares, we may analyze this concern by controlling for potential local determinants of $\Delta \ln i_{0n}$. This includes, most likely, factors describing local risk perceptions of investors.

[39]For space reason, we do not report them in Table 1.4.

Table 1.4: Robustness

	(1) ΔLog P	(2) ΔLog R	(3) ΔLog P	(4) ΔLog R	(5) ΔLog P	(6) ΔLog R
			Panel A: 1km			
ΔLog Q	4.742**	2.263	2.779***	0.902***	2.855***	0.955***
	(2.411)	(1.788)	(0.618)	(0.282)	(0.614)	(0.290)
Observations	3,958	3,958	3,958	3,958	3,958	3,958
Kleibergen-Paap F	1.23	1.23	23.21	23.21	12.15	12.15
Overidentification	-	-	-	-	0.22	0.30
			Panel B: 3km			
ΔLog Q	2.359***	0.996***	1.940***	0.655***	2.027***	0.725***
	(0.529)	(0.376)	(0.287)	(0.200)	(0.284)	(0.188)
Observations	1,667	1,667	1,667	1,667	1,667	1,667
Kleibergen-Paap F	11.56	11.56	93.89	93.89	52.80	52.80
Overidentification	-	-	-	-	0.36	0.34
			Panel C: Municipalities			
ΔLog Q	1.902***	0.395**	1.992***	0.498**	1.959***	0.460***
	(0.297)	(0.193)	(0.257)	(0.204)	(0.241)	(0.173)
Observations	1,673	1,673	1,673	1,673	1,673	1,673
Kleibergen-Paap F	86.93	86.93	118.89	118.89	75.63	75.63
Overidentification	-	-	-	-	0.74	0.62
			Panel D: 20 ads			
ΔLog Q	2.082***	0.594**	2.255***	1.127***	2.215***	1.004***
	(0.579)	(0.283)	(0.463)	(0.282)	(0.408)	(0.242)
Observations	1,304	1,304	1,304	1,304	1,304	1,304
Kleibergen-Paap F	21.46	21.46	36.50	36.50	24.69	24.69
Overidentification	-	-	-	-	0.80	0.15

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. For Panels A, B, and, D the units of observations are obtained by partitioning Switzerland in 1x1, 3x3, and 2x2 km neighborhoods, respectively. The units of observations for Panel C are the Swiss municipalities. For Panel D we restrict the sample to units that have at least 20 selling and rental advertisements. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs. Changes in housing stock ΔLog Q, are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

Table 1.5: Robustness confouders

	(1)	(2)	(3)	(4)	(5)	(6)
	ΔLog P	ΔLog R	ΔLog P	ΔLog R	ΔLog P	ΔLog R
			Panel A: Confounders 1			
	ΔLog P	ΔLog R	ΔLog P	ΔLog R	ΔLog P	ΔLog R
ΔLog Q	2.116***	0.909**	2.366***	0.695**	2.503***	0.697**
	(0.493)	(0.355)	(0.440)	(0.289)	(0.463)	(0.295)
Confounder	VR		TOMR		TOMP	
Observations	2,158	2,158	2,498	2,498	2,498	2,498
Kleibergen-Paap F	11.08	11.08	15.52	15.52	15.52	15.52
			Panel B: Confounders 2			
ΔLog Q	2.429***	0.641**	1.963***	0.582**	2.236***	0.636**
	(0.454)	(0.289)	(0.379)	(0.275)	(0.417)	(0.280)
Confounder	Unem		GOwn		Own00	
Observations	2,498	2,498	2,498	2,498	2,467	2,467
Kleibergen-Paap F	14.67	14.67	16.89	16.89	16.10	16.10

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs. Changes in housing stock ΔLog Q, are instrumented using a shift-share instrument for industries I in all columns. Panel A columns (1) and (2) control for the vacancy rate in 2000 VR, columns (3) and (4) control for the time on market for rental properties TOMR, and columns (5) and (6) control for the time on market for selling properties TOMP. Panel B columns (1) and (2) control for the ownership rate in 2000 Own00, columns (3) and (4) control for the growth in ownership (2005-2015) GOwn, and columns (5) and (6) control for the share of unemployment in 2000 Unem.

Panels A and B of Table 1.5 report estimation results when we proxy local risk by using local vacancy rates (VR, columns 1 and 2 of Panel A), local time on the market of advertised rental units ($TOMR$, columns 3 and 4 of Panel A) and selling units ($TOMP$, columns 5 and 6 of Panel A), and local unemployment rates (Unem, columns 5 and 6 of Panel B). Vacancy rates and unemployment rates proxy for the uncertainty associated with the rental income of a property located in a given area, whereas time on market captures its liquidity.[40]

As is evident from Table 1.5, we can confirm a significantly higher responsiveness of housing supply to rent changes than to price changes when we individually control for the above variables. The corresponding amplification effects are very similar to those of our benchmark results.

1.6.4 Local variation in the type of housing units

As discussed in Section 1.3.1, we partial out differences in the attributes of renting and selling units across regions. However, one might worry that the observed housing characteristics that we use for adjusting quality differences might not fully capture dissimilarities between rental and selling properties. Note that this problem only matters to the extent that unobserved quality differences correlate with our benchmark instrument based on industrial composition, which seems unlikely. Nevertheless, we address this potential concern by controlling for i) the predetermined level of homeownership rates in 2000 ($Own00$), and ii) the change in ownership rates between 2005 and 2015 ($GOwn$). Controlling for these two variables allows us to take explicitly into account variations in the composition of housing goods across neighborhoods. Panel B of Table 1.5 documents that the results remain mostly unchanged.

1.6.5 Rotemberg weights

The identification of both our shift-share instruments (industry and language) comes from the initial shares. More precisely, we assume that initial shares of industries and languages measure the differential exogenous exposure to a corresponding global shock (growth in industries and languages at the cantonal level). Since the predetermined shares are equilibrium outcomes that are affected by price and rent levels, they probably correlate with the price and rent levels *in that period*. However, as shown by Goldsmith-Pinkham et al. (2019), the validity of the instrument hinges on the assumption that the initial shares are exogenous to *changes* in prices and rents, not to the initial levels.

To test this assumption in our framework, we follow Goldsmith-Pinkham

[40] Sivitanidou and Sivitanides (1999) and Chen et al. (2004) document that vacancy rates and unemployment can affect local capitalization rates.

et al. (2019) and compute the Rotemberg weights for the different industries and languages.[41] These weights indicate which industries/languages entering the instruments are driving the results. In our case, the five most important sectors are information and communication, wholesale and retail trade, administrative and support service activities, accommodation and food service activities, and financial and insurance activities. The three most important languages are German, Italian, and Portuguese. In the interest of brevity, we report the results in Appendix 1.E.

As suggested by Goldsmith-Pinkham et al. (2019), we test the exclusion restriction by checking the correlation of the five most important initial share and possible confounders. As confounders, we use the change (2005-2015) in vacancy rate, the change (2005-2015) in time on market for rental properties, the change (2005-2015) in time on market for selling properties, the ownership rate in 2000, the growth (2005-2015) in ownership rate, and the share of unemployment in 2000. Reassuringly, this analysis shows that the initial shares are not related to possible confounders.

1.7 Conclusions

In this paper, we investigate the response of housing supply with respect to rent and price changes across space. Workhorse models in urban economics typically feature periodic housing costs entering the utility function of individuals, whereas the empirical literature on housing supply elasticities focuses on prices. This discrepancy calls for a better understanding of the link between the responsiveness of housing supply with respect to price and rent dynamics.

Our empirical results indicate that, on average, residential housing supply in Switzerland reacts more than thrice as strongly to rent changes than to price ones. We attribute this "amplification effect" to an adjustment of capitalization rates – which reflect investors' expectations concerning future rent growth and risk premia – following an exogenous demand shock. This adjustment is consistent with a myopic path-dependent view of residential development in the sense that investors believe that the places that grew more (less) in the past will continue to do so also in the future. An unexpected positive demand shock to a historically less attractive area thus triggers a considerable downward revision of investor's capitalization rates,

[41] These weights are based on Rotemberg (1983) and Andrews et al. (2017).

which further increases prices and, in the end, boosts the amount of supplied housing.

Due to geographic and regulatory constraints, we document considerable spatial heterogeneity in the local supply elasticity with respect to rent and price changes, respectively. Major urban centers and alpine tourist areas display very inelastic housing supply, whereas countryside areas usually have a relatively more responsive housing supply with respect to prices and rents.

We also document that the amplification effect is lower in urban and tourist areas and higher in the countryside. This spatial variation holds interesting insights about the way investors perceive and influence residential development across space. First, investors seem to form expectations regarding future rents growth and/or assess risk premia heterogeneously across space and at a fine scale (neighborhood) level, which in turn influences local housing supply. Second, investors seem to revise expectations and/or risk assessments only to a limited extent in tightly regulated and geographically constrained places – typically represented by highly developed urban areas – whereas in less constrained areas belonging to the countryside, they revise their expectations significantly.

Our results hold an important lesson for policy makers. The impact of policies aiming to affect the periodic cost of housing – such as housing subsidies and rent control – seem to have a much larger impact on housing supply, ceteris paribus, than policies that act on the price of housing goods. Neglecting this impact might lead to severe unintended consequences for housing policies aiming to stimulate or curb the housing market via the demand side.

Our analysis is conducted over a period of growing housing demand in the Swiss market. Whether the estimated supply amplification effect is symmetric and thus will turn into a dampening effect of housing supply during a downturn of the real estate market remains an open question. Since housing is durable, we suspect that a negative demand shock of a similar magnitude as the one we investigated might even lead to a larger decrease of housing prices and, subsequently, of housing supply. Testing this hypothesis, however, remains a task for future research covering a different phase of the housing cycle.

Appendix

1.A Model's derivations

1.A.1 Housing developers

The first order condition (FOC) of the profit function π described in Equation (1.1) and its corresponding zero-profit condition are given by

$$\frac{\partial \pi}{\partial h} = P_n l - c_n(\delta_n^{int} + 1)h^{\delta_n^{int}} l = 0 \tag{1.14}$$

$$P_n h - c_n h^{\delta_n^{int}+1} - P_n^{land} = 0 \tag{1.15}$$

From Equation (1.14), we have $h_n^* = (\frac{P_n}{c_n(\delta_n^{int}+1)})^{\frac{1}{\delta_n^{int}}}$. Substituting the optimal development intensity in Equation (1.15), we have that the price of land is given by

$$\begin{aligned} P_n^{land} &= P_n h - c_n h^{\delta_n^{int}+1} = \\ &= P_n(\frac{P_n}{(\delta_n^{int}+1)c_n})^{\frac{1}{\delta_n^{int}}} - c_n(\frac{P_n}{(\delta_n^{int}+1)c_n})^{\frac{\delta_n^{int}+1}{\delta_n^{int}}} = \\ &= (\frac{1}{(\delta_n^{int}+1)c_n})^{\frac{1}{\delta_n^{int}}} - c_n(\frac{1}{(\delta_n^{int}+1)c_n})^{\frac{\delta_n^{int}+1}{\delta_n^{int}}} P_n^{\frac{\delta_n^{int}+1}{\delta_n^{int}}} = \\ &= C_L(\delta_n^{int}, c_n) P_n^{1+\frac{1}{\delta_n^{int}}} \end{aligned} \tag{1.16}$$

Where the constant $C_L(\delta_n^{int}, c_n)$ captures shifters of the price of land. To determine the amount of land supplied for development, we assume that local landowners pay a lobbying cost c_n^{land} to convince local authorities to zone land for new development. Their maximization problem is given by

$$\max_l (P_n^{land} l - c_n^{land} l^{\delta_n^{ext}+1}), \tag{1.17}$$

where the parameter $\delta_n^{ext} > 0$ captures the fact that higher level of development require higher expenditure. It seems likely that the higher the level of development, the stronger the opposition of residents (voters) to preserve green areas, thus pushing owners of undeveloped land to invest more money to convince municipalities to zone new land for development.

An alternative interpretation of convex land supply costs, likely pertinent in the case of Switzerland, is that landowners bear the costs of making a plot of land fit for residential development. For example, in Switzerland municipalities – which very often own a considerable amount of land that is zoned for residential development – bear the costs to connect residential areas to the sewerage system, electric network, roads, etc. These costs likely increase more than linearly the more new development occurs far from the center of the municipality.

The FOC for the maximization of the profit of landowners π_l is

$$\frac{\partial \pi_l}{l} = P_n^{land} - c_n^{land}(\delta_n^{ext} + 1) l^{\delta_n^{ext}} = 0, \tag{1.18}$$

Which provides the total amount of supplied land

$$L = \left(\frac{P_n^{land}}{c_n^{land}(\delta_n^{ext} + 1)} \right)^{\frac{1}{\delta_n^{ext}}}. \tag{1.19}$$

Substituting Equation (1.16) in Equation (1.19), we have that the total amount of developable land depends on housing prices as follows

$$\begin{aligned} L &= \left(\frac{1}{c_n^{land}(\delta_n^{ext} + 1)} \right)^{\frac{1}{\delta_n^{ext}}} C_L^{\frac{1}{\delta_n^{ext}}} P_n^{\frac{1}{\delta_n^{ext}} + \frac{1}{\delta_n^{int}} \frac{1}{\delta_n^{ext}}} = \\ &= \bar{L}_n(\delta_n^{int}, \delta_n^{ext}, c_n, c_n^{land}) P_n^{\frac{1}{\delta_n^{ext}} + \frac{1}{\delta_n^{in}} \frac{1}{\delta_n^{ext}}}, \end{aligned} \tag{1.20}$$

where $\bar{L}_n(\delta_n^{int}, \delta_n^{ext}, c_n, c_n^{land})$ captures shifters of the land supply function.

1.A.2 Residents

Given that individuals' idiosyncratic preferences $b_{ni}^k(\omega)$ are Fréchet distributed, it can be shown that the probability π_{ni}^k of living in n and working in i for a worker in industry k is given by

$$\pi_{ni}^k = \frac{B_{ni}^k m_{ni}^{-\epsilon^k} R_n^{-\alpha\epsilon^k} (W_{ni}^k)^{\epsilon^k}}{\sum_{rs} B_{rs}^k m_{rs}^{-\epsilon^k} R_r^{-\alpha\epsilon^k} (W_{rs}^k)^{\epsilon^k}} = \frac{\Phi_{ni}}{\Phi}, \tag{1.21}$$

such that the number of residents commuting from n to i and working in industry k is $N_{ni}^k = N\pi_{ni}^k$. The number of residents in neighborhood n working in industry k

is obtained by summing over all commuting destinations, i.e.

$$N_n^k = N \sum_i \pi_{ni}^k = \frac{N}{\Phi} \sum_i B_{ni}^k m_{ni}^{-\epsilon^k} R_n^{-\alpha\epsilon^k} (W_{ni}^k)^{\epsilon^k} \tag{1.22}$$

and the total number of residents is $N_n = \sum_k N_n^k$. Total housing demand is thus given by

$$Q_n^d = \alpha \frac{\bar{W}_n}{R_n} N_n = \alpha \frac{1}{R_n} \sum_{ik} \frac{W_{ni}^k}{m_{ni}} N_{ni}^k = \alpha \frac{1}{R_n} \sum_{ik} \frac{W_{ni}^k}{m_{ni}} L \frac{\Phi_{ni}}{\Phi} = \tag{1.23}$$

$$= \alpha \frac{1}{R_n^{\alpha+\alpha\epsilon^k}} \frac{L}{\Phi} \sum_{ik} B_{ni}^k \left(\frac{W_{ni}^k}{m_{ni}} \right)^{\epsilon^k+1}.$$

1.A.3 Amplification coefficient: Detailed derivations

Using the fact that $P_n = \frac{R_n}{i_n}$, we have that

$$\epsilon_n^{P,R} = \frac{R_n}{P_n} \frac{dP_n}{dR_n} = \frac{R_n}{P_n} \frac{d}{dR_n} \left(\frac{R_n}{i_n} \right) = \frac{R_n}{P_n} \left(\frac{1}{i_n} - \frac{R_n}{i_n^2} \frac{di_n}{dR_n} \right) = 1 - \epsilon_n^{i,R} \tag{1.24}$$

Using the present value formula $P_n = R_n / i_n$ and the endogenous parametrization of capitalisation rates $i_n = i_0 R_n^{\gamma_n^R} P_n^{\gamma_n^P}$, we have that

$$P_n = \frac{R_n}{i_n} = i_0^{-1} R_n^{-\gamma_n^R} P_n^{-\gamma_n^P} \Longrightarrow P_n^{1+\gamma_n^P} = i_0^{-1} R_n^{1-\gamma_n^R} \Longrightarrow \tag{1.25}$$

$$P_n = i_0^{-\frac{1}{1+\gamma_n^P}} R_n^{\frac{1-\gamma_n^R}{1+\gamma_n^P}}.$$

This implies

$$\epsilon_n^{P,R} = \frac{R_n}{P_n} i_0^{-\frac{1}{1+\gamma_n^P}} \frac{1-\gamma_n^R}{1+\gamma_n^P} R_n^{\frac{1-\gamma_n^R}{1+\gamma_n^P}-1} = \frac{1-\gamma_n^R}{1+\gamma_n^P}. \tag{1.26}$$

Table 1.B.1: Descriptive statistics

	2005				2015			
	Mean	Min	Max	SD	Mean	Min	Max	SD
Endogenous variables								
Price (CHF/m^2)	4357	1000	10848	1270	5884	1261	13062	1809
Rent (CHF/m^2)	17.00	6.47	43.90	3.85	19.35	6.11	39.83	3.96
Cap rate	0.05	0.02	0.18	0.01	0.04	0.01	0.13	0.01
Stock[a]	1298	3	33753	2399	1445	3	34294	2531

	Time invariant			
	Mean	Min	Max	SD
Intruments				
Industry intrument[b]	1.33	-1.38	6.72	0.88
Language instrument[b]	0.09	-0.28	0.30	0.07
Controls Elevation (m)	0.62	0.20	2.31	0.25
Elevation SD[c]	0.06	0.00	0.47	0.06
Distance from nearest CBD (km)	25.03	0.44	121.41	20.48
Stock 1980[a]	952	3	30147	2088
Construction costs growth (2005-2015)	0.13	0.12	0.17	0.02
Constraints				
Undevelopable[d]	0.04	0.00	0.81	0.08
Forest	0.26	0.00	0.94	0.18
Other regulations[e]	0.15	0.00	1.00	0.31
Total restricted[f]	0.38	0.00	1.00	0.28
Type of buyer				
Share of institutional investors	0.07	0.00	1.00	0.09
Share of second-home buyers	0.11	0.00	0.81	0.12

Notes: [a]Measured as the number of individual housing units. Note that the historic stock also serves as a proxy for the intensity of regulation. [b]Because our instruments are weighted growth rates, they do not have physical units. [c]SD=standard deviation. [d]Share of water bodies and undevelopable land within the neighborhood. [e]Other regulations include parks, UNESCO areas, and BLN restrictions. [e]Computed as the sum of geographic and regulatory constraints on the extensive margin. The sample is restricted to units of observations for which rents and prices per square meter are available both in 2005 and 2015.

1.B Data

1.B.1 Summary statistics

Table 1.B.1 summarizes all variables used in our analysis. We report descriptive statistics for the 2x2 km neighborhoods used in our benchmark specifications. Variables are classified as endogenous variables, instruments, controls, and moderator variables, i.e. development constraints and type of investors. For ease of exposition, we exclusively classify the standard deviation of elevation and the housing stock in 1980 as controls. However, in our analysis of local supply elasticities based on country grid data, we also use these variables to proxy for geographic and regulatory constraints.

1.B.2 Switzerland

Figure 1.B.1: Major Swiss agglomerations in 2015

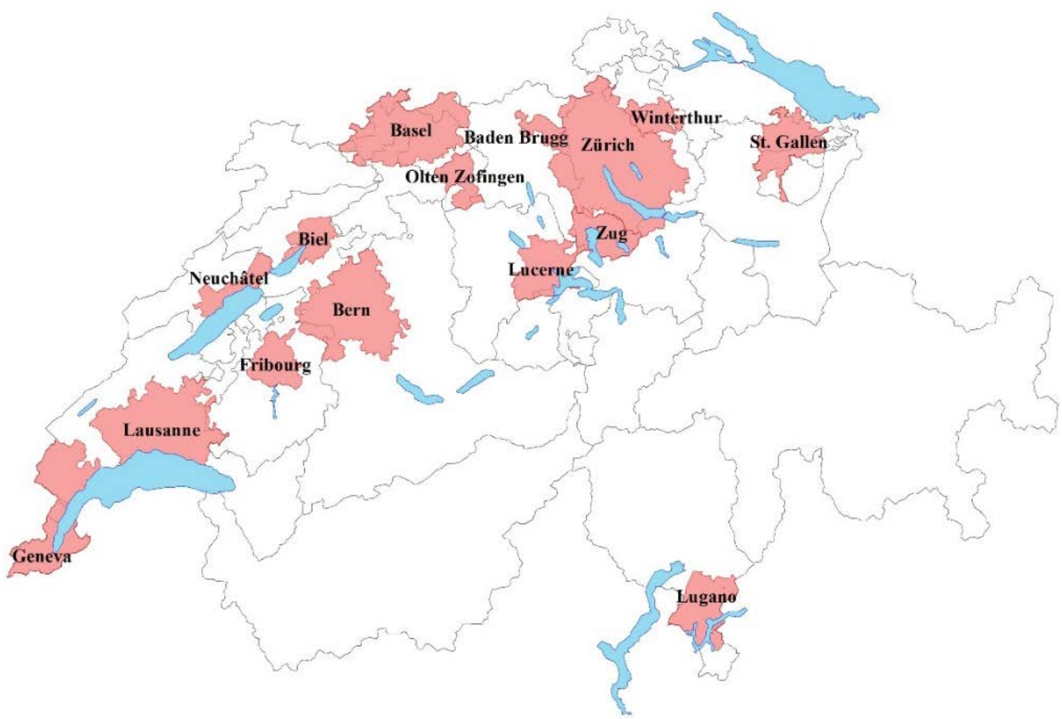


Figure 1.B.1 shows the country and cantonal boundaries, as well as the 15

major agglomerations in 2015, according to the Federal Statistical Office (FSO). Unsurprisingly, in 2015, the larger part of the housing stock was concentrated in major agglomerations. Approximately 46 percent of the country's housing stock was located within 10 km of one of the 15 largest CBDs.

1.B.3 Housing advertisements

Advertisement data for rental and selling properties were provided by *Meta-Sys*, a consultancy firm. By gathering daily advertisements from virtually all real estate platforms in Switzerland, the proprietary data set consists of approximately 2.1 million postings of rental housing units and 0.8 million postings of selling properties from 2004 to 2016. Importantly, *Meta-Sys* cleans the data from cross-platform duplicates such that each advertised housing unit is counted only once in the data. Table 1.B.2 illustrates the main variables contained in the data set.

Table 1.B.2: Housing advertisements

Variable	**Units**	**Description**
x-coordinate	WGS-1984	x-coordinate of the residence.
y-coordinate	WGS-1984	y-coordinate of the residence.
Rent	CHF	Asking rent per month including additional costs. Used to compute the rent/m^2.
House price	CHF	Asking price. Used to compute the house price/m^2.
Floor space	m^2	Floor space of residence. Used to compute the rents/house prices/m^2.
Number of rooms		Number of rooms per residence.
Rent/m^2	CHF/m^2	Monthly asking rent/m^2 of floor space.
House price/m^2	CHF/m^2	Asking price/m^2 of floor space.
Age	Year	Age of the residence
Time on market	Days	The days a rental or selling property is on the market.

Approximately 10 percent of the advertisements do not have precise geo-coordinates. Only a particular "geographical center" is available for these observations, such as the municipality, canton, or country centroid. Since our analysis relies on precise geo-coordinates, we drop these advertisements.

Additionally, we lose observations when computing rents or house prices per square meter, since not all advertisements contain information on the floor space of the housing unit. Our final data set comprises approximately 1.6 million postings of rental properties and approximately 0.65 million postings of selling properties. These postings are aggregated over our within-agglomeration sample, each country-grid cell, and municipalities in 2004-2005 and 2014-2015.

1.B.4 Federal register of buildings and habitations (GWR)

The Federal Register of Buildings and Habitations takes a census of the entire residential housing stock of Switzerland. Two features of the data set are worth noting. First, each building is georeferenced. Second, the register contains information on the housing stock spanning the last century. From the 1980s, the building period is recorded every five years. We aggregate data on the housing stock for our within-agglomeration sample, country-grid cells, and municipalities in the periods 1980, 2005, 2010, and 2015. Table 1.B.3 describes the variables used from the building register.

Table 1.B.3: Federal register of buildings and habitations

Variable	**Units**	**Description**
x-coordinate	WGS-1984	x-coordinate of the residence.
y-coordinate	WGS-1984	y-coordinate of the residence.
Ground floor area	m^2	Ground floor area of building.
Habitation floor area	m^2	Floor area of each habitation.
Type	Category	Single-family, attached/flats, mixed-use (residential and commercial).

1.B.5 Federal population census and the population and households survey

Table 1.B.4: Households characteristics

Variable	**Units**	**Description**
x-coordinate	WGS-1984	x-coordinate of the residence.
y-coordinate	WGS-1984	y-coordinate of the residence.
Language	Language code	Main language spoken at home. Each language has a different language code. Used to compute the shift-share instrument for languages.
Homeownership	Dummy	Dummy variable. 1 if an individual is a homeowner, 0 if not. Used to compute the homeownership rate in 2000 and to impute the homeownership rate in 2005, 2010, and 2015.

Information on households' socio-demographic characteristics is provided by the Federal Population Census (FPC) and the Population and Households Survey (STATPOP). The FPC is a census of the Swiss population that was conducted with decadal frequency until 2000. From 2010 onward, STATPOP replaced the census. Each year, STATPOP consists of a representative sample of at least 200,000 households. Both data sources share common information on household characteristics such as housing expenditure and tenure mode, employment, mobility, education, language, and religion. Table 1.B.4 describes the variables used in this study.

Because the FPC provides geo-coded information for the entire Swiss population, we can compute precise homeownership rates in 2000 for our within-agglomeration sample, for each country-grid cell, and municipalities. Due to the limited sample size of STATPOP, this is not possible in the following years. Therefore, we impute homeownership rates as follows. First, STATPOP allows us to compute reliable homeownership rates at the district level in 2015 (districts are composed of several municipalities, remaining fairly small in size). Using the FSO 2015 definition of districts, we compute the corresponding homeownership rates in 2000 at the district level. Second, we compute the growth rate in homeownership at the district level between 2000 and 2015. Finally, we multiply the initial homeownership rates in 2000 at the neighborhood level with the computed growth rates, thus obtaining the imputed homeownership rates in 2015.

1.B.6 Regulatory constraints

Table 1.B.5: Supply constraints

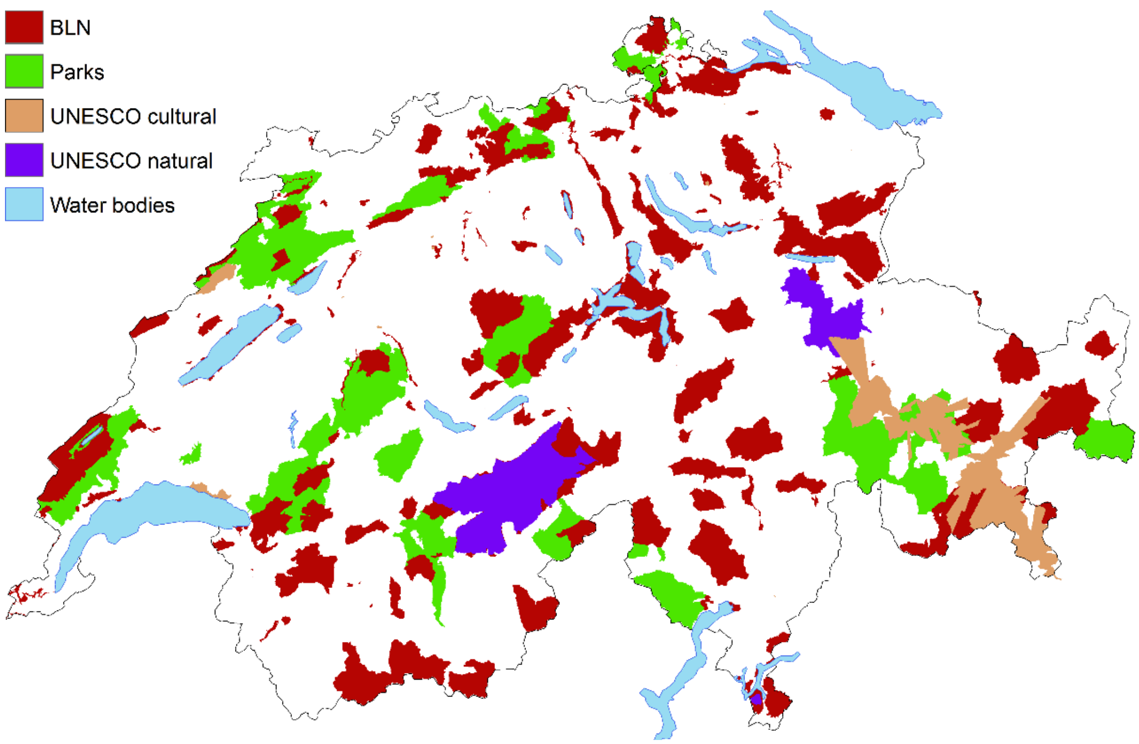
Type of heterogeneity	Label	Area share of Switzerland	Source
Panel A: Geographic constraints			
Water and undevelopable land	Undevelopable	31.2%	Arealstatistik Schweiz
Standard deviation of elevation (land ruggedness)	Elevation SD	–	Arealstatistik Schweiz
Panel B: Regulatory constraints – extensive margin			
Forests	Forest	27.5%	Arealstatistik Schweiz
Other protected areas	Other protected areas	30.7%	Federal Office for the Environment (FOEN)
Panel C: Regulatory constraints – intensive margin			
Intensity of regulation	Stock1980	-	Federal Register of Buildings and Habitations (GWR)
Panel D: Total restricted area			
Geographic + extensive margin regulatory constraints	Total restricted	67.3%	

Table 1.B.5 summarizes the protected areas, as well as the corresponding data sources used in the present study. One of the objectives of the United Nations Educational, Scientific and Cultural Organization (UNESCO) is to protect the cultural and natural heritage of outstanding universal value. Currently, UNESCO recognizes 981 cultural or natural heritage sites worldwide, 11 of which are located in Switzerland. These areas mostly consist of buildings of particular architectural interest, historic towns, and areas with valuable natural amenities.

The Federal Inventory of Landscapes and Natural History (BLN) classifies the most typical and most valuable landscapes of Switzerland. The aim of the inventory – which was progressively introduced from 1977 to 1998 – is to protect Switzerland's scenic diversity and to ensure that the distinctive features of these landscapes are preserved.

Finally, parks of national importance are characterized by beautiful landscapes, rich biodiversity, and high-quality cultural assets. Municipalities and cantons preserve these values and ensure their sustainment for the economic and social development of their regions.

Figure 1.B.2: UNESCO, BLN, and Parks



Notes: Data source: FOEN. Own graph. Except for lakes, colored areas corresponding to extensive margin regulations may overlap.

1.C Shift-share instrument of main spoken languages

Following Bartik (1991), we compute the shift-share instrument of main spoken languages according to the following formula

$$\Delta \ln Z_n^{language} = \sum_{j=1}^{J} f_{nt_0}^j \Delta \ln F_{C(n)}^j, \tag{1.27}$$

where $f_{nt_0}^j$ represents the share of residents speaking language j within neighborhood n at time t_0. The term $\Delta \ln F_{C(n)}^j$ denotes the growth rate of residents speaking language j in the canton in which neighborhood n is located over $[t, t_0]$. Importantly, we exclude the neighborhood n itself from the computation of $\Delta \ln F_{C(n)}^j$. To implement Formula (1.27), we use the share of the eight most spoken language in Switzerland according to the 2000 population census (remaining languages are included in a ninth category), and compute the corresponding growth of these languages at the cantonal level from 2000 to 2015. These languages are in decreasing order of importance German, French, Italian, Portuguese, English, Serbian, Albanian, and Spanish. They account for approximately 97 percent of the Swiss population. See 1.B.5 for further detail on the population census.

1.D Assessing housing supply elasticity estimates

In this section, we aggregate neighborhood-level housing supply elasticity estimates obtained from Equation (1.11) at the municipal, agglomeration, and cantonal level and provide a ranking. In the next step, we compare these housing supply elasticity estimates to other estimates provided in the literature.

1.D.1 Ranking housing supply elasticities

Table 1.D.1 contains a ranking of different areal units, from most to least inelastic, according to their housing supply responsiveness with respect to price and rent changes, respectively. These areal units correspond to three levels of aggregation: cantons, major urban areas, and municipalities. Cantons and municipalities are second and third-tier political units in Switzerland, whereas urban areas are defined

by the FSO. Note that the ranking for the three levels of aggregation is nearly the same with respect to price and rent changes, such that we do not distinguish between the two changes in the following discussion.

Columns 1-3 of Table 1.D.1 show the ranking for cantons. Except for Basel City, all cantons feature a rental supply elasticity above one. Unsurprisingly, Basel City, Geneva, and Zurich appear in the top five most inelastic cantons. These cantons are among the most urbanized ones in Switzerland, and, additionally, housing markets of Geneva and Basel City are constrained by country boundaries. The presence of Ticino and Basel-Landschaft in the upper part of the ranking is justified by the fact that terrain ruggedness and forests play a major role in constraining housing supply in these cantons. The most-elastic cantons are Luzern, Thurgau, Appenzell Innerrhoden, Fribourg, and Jura. In contrast to the most-inelastic cantons, these five cantons are characterized by a lower degree of urbanization and a comparatively lower degree of regulatory constraints.

Columns 4-6 of Table 1.D.1 illustrate the supply elasticity ranking of the 15 largest Swiss agglomerations. Note that all agglomerations feature rental supply responsiveness above one. The agglomeration of Baden-Brugg is the most inelastic, whereas the agglomerations of Basel and Geneva rank only eighth and ninth, respectively. Lugano is the second most inelastic major agglomeration in Switzerland. This is hardly surprising, as its agglomeration area is constrained by the Lugano Lake and the surrounding hills. Zurich also counts among the most-inelastic agglomerations. We interpret this ranking of agglomerations with due caution because the definition of the boundaries of a given agglomeration seems to be arbitrary with respect to price and rent dynamics. For example, the FSO defines the agglomeration of Baden-Brugg by a relatively small surface that closely surrounds the respective city centers. Therefore, it is not surprising that this agglomeration displays lower supply elasticities than that of Zurich, which has a considerably larger surface. Similarly, the agglomeration of Geneva and Lausanne incorporates countryside areas that make the aggregate supply elasticity considerably more elastic.

Finally, columns 7-9 of Table 1.D.1 show the supply elasticity ranking of municipalities. To save space, we only report the ten most inelastic and the ten most elastic municipalities.

Table 1.D.1: Ranking by supply elasticities

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Cantons			Major agglomerations			Municipalities		
Rank	Price	Rent	Rank	Price	Rent	Rank	Price	Rent
BS	0.26	0.93	Baden Brugg	0.56	3.17	Biel/Bienne	0.12	0.33
GE	0.70	4.94	Lugano	0.67	3.86	Genveva	0.12	0.35
ZH	0.74	5.07	Zurich	0.71	4.65	Carouge (GE)	0.15	0.43
TI	0.76	5.06	Neuchâtel	0.71	4.94	Onex	0.18	0.52
BL	0.77	5.38	Winterthur	0.72	5.12	Vevey	0.20	0.57
AG	0.80	5.71	Olten Zofingen	0.74	4.97	Binningen	0.20	0.59
VS	0.81	5.80	Biel/Bienne	0.74	5.22	Basel	0.20	0.62
ZG	0.81	6.02	Genveva	0.75	5.4	Vernier	0.21	0.60
SH	0.81	6.24	Basel	0.76	5.37	Rennens (VD)	0.21	0.65
SO	0.82	6.12	Luzern	0.76	5.77	Olten	0.24	0.69
AR	0.83	6.15	Bern	0.79	5.78			
NE	0.83	6.65	St. Gallen	0.80	5.93			
NW	0.84	6.23	Zug	0.82	6.16			
BE	0.84	6.46	Lausanne	0.85	6.94			
SG	0.84	6.52	Fribourg	0.86	7.04			
GL	0.85	6.65						
SZ	0.85	6.73				Remigen	0.99	10.20
VD	0.85	6.86				Flaach	0.99	10.26
UR	0.86	6.76				Roche (VD)	0.99	10.26
GR	0.87	7.01				Orny	0.99	10.35
OW	0.87	7.08				Perrefitte	0.99	10.38
LU	0.87	7.14				Rebévelier	1	10.40
TG	0.88	7.12				Sisikon	1	10.40
AI	0.90	7.52				Niederried b.I.	1	10.42
FR	0.90	7.67				Frasco	1	10.44
JU	0.91	7.84				Zwischbergen	1	10.57

Notes: Elasticity estimates are obtained by averaging neighborhood-level housing supply elasticity estimates. Only elasticity values of the ten most inelastic/elastic municipalities are reported. Major urban areas are identified according to the FSO.

Among the most-inelastic areas are major urban municipalities such as Biel/Bienne (BE), Geneva (GE), Basel (BS), and Olten (SO). The remaining ones are suburban areas located within the proximity of urban municipalities. In contrast, the ten most elastic municipalities are mostly located in remote areas displaying large land availability and few geographic/regulatory constraints.

1.D.2 Comparison to literature

We compare our estimated *price* supply elasticities with those obtained by Saiz (2010) and Caldera and Johansson (2013).[42] We contextualize our results according to these two papers for the following reasons. Because our methodological approach is mainly based on Saiz (2010), we can investigate how housing supply elasticities computed for major U.S. metropolitan areas generalize to the case of Switzerland. On the other hand, despite adopting a completely different approach that relies on country-level time series data to estimate a system of simultaneous demand-supply equations, Caldera and Johansson (2013) provide an average supply elasticity for Switzerland. To the best of the author's knowledge, this is the only paper providing such an estimate for Switzerland.

Saiz (2010) finds an average supply elasticity of 1.54 (=1/0.65) for U.S. metropolitan areas when heterogeneity is not considered, suggesting that U.S. metropolitan areas are more than two times more elastic as Switzerland's 15 largest agglomerations, which have an average supply elasticity of 0.75 without heterogeneous effects.[43] When considering housing supply heterogeneity with respect to prices, we also observe differences with Saiz (2010). Taking into account geographic and regulatory constraints, housing supply elasticities of U.S. Metropolitan Statistical Areas (MSAs) vary between 0.6 in Miami (FL) and 5.45 in Wichita (KS). As shown in Table 1.D.1, for Switzerland we obtain supply elasticities estimates ranging from 0.26 and 0.91 at the cantonal level, from 0.56 to 0.86 for major agglomerations, and from 0.12 to 1 at the municipal level.

We impute this difference to two factors. The first factor is the vast difference in the aggregation level of the units of observation used in the two empirical analyses. Saiz (2010) works at a more aggregate level: the smallest U.S. MSA is much larger

[42] Because the literature has focused on the estimation of supply elasticity relative to price changes, in what follows, we do not discuss our supply elasticity estimates with respect to rent changes.

[43] We compute this value by averaging the elasticities of column 5 in Table 1.D.1.

in terms of area, population, and housing transactions than in any of the 2x2 km neighborhoods in our data. The aggregation level, in turn, strongly affects the variation across units of observations. It is reasonable to assume that there is vast supply heterogeneity within the U.S. MSAs that is eliminated by aggregating data for these areas.

As shown in Table 1.D.1, the distribution of supply price elasticities changes according to the aggregation level, with lower and higher values becoming more uncommon at a higher level of aggregation (i.e., the variance of the estimates decreases).[44]

The second factor is the difference in the magnitude of geographic and regulatory constraints of the two countries. As illustrated in Figure 1.2, Switzerland's geographic and regulatory constraints hindering extensive margin development are extremely widespread across the country's territory, making housing supply inelastic by international comparison even in countryside areas. Except for a few extremely constrained MSAs, in the U.S. there are ample quantities of open land are still available for residential development.

Interestingly, Caldera and Johansson (2013) find that Switzerland has the lowest supply price elasticity among a panel of 21 OECD countries, with an average supply elasticity of 0.15 with respect to price changes. Their estimate is similar to the supply elasticity estimates of the most inelastic municipalities. Indeed, besides differences in the magnitude due to the methodological approach, we argue that the estimate computed by Caldera and Johansson (2013) is strongly influenced by core municipalities located in Swiss cities. Caldera and Johansson (2013) use countrywide price indices whose dynamics are driven by core cities – such as Geneva, Zurich, Lausanne, Basel, and Bern – as these are the places where most properties are transacted.

1.E Detailed estimation results

Tables 1.E.1 and 1.E.3 replicate the results of Tables 1.1 and 1.2, respectively, and show all the coefficients. Tables 1.E.2 and 1.E.4 report the first stage results for the

[44] Despite working at a more aggregate geographical level, Saiz (2010) supply elasticities vary to a larger degree than in our case. The main reason for this larger variance is likely because his units of observation (U.S. MSAs) represent a small share of the country's surface and of the state in which they are located.

second stage results shown in Tables 1.1 and 1.2, respectively.

Table 1.E.1: Details: Inverse supply elasticities

	(1) ΔLog P	(2) ΔLog R	(3) ΔLog P	(4) ΔLog R	(5) ΔLog P	(6) ΔLog R
ΔLog Q	2.367***	0.694**	2.004***	0.747***	2.084***	0.735***
	(0.442)	(0.287)	(0.342)	(0.215)	(0.316)	(0.191)
Elev	0.212***	0.032	0.187***	0.035	0.193***	0.034
	(0.042)	(0.031)	(0.037)	(0.029)	(0.036)	(0.028)
Elev SD	0.176	0.069	0.121	0.077	0.133	0.075
	(0.149)	(0.097)	(0.125)	(0.095)	(0.127)	(0.093)
Log Dist. CBD	-0.047***	-0.009	-0.040***	-0.010	-0.042***	-0.009
	(0.012)	(0.008)	(0.011)	(0.007)	(0.010)	(0.007)
Log Q^{1980}	0.008	0.012***	0.007	0.012***	0.007	0.012***
	(0.006)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)
Constr. Cost	-0.377	-0.753***	-0.137	-0.789***	-0.190	-0.781***
	(0.516)	(0.272)	(0.428)	(0.222)	(0.430)	(0.216)
Constant	0.083	0.133***	0.115	0.128***	0.108	0.129***
	(0.077)	(0.045)	(0.071)	(0.045)	(0.071)	(0.044)
Instruments	I	I	L	L	I & L	I & L
Observations	2,498	2,498	2,498	2,498	2,498	2,498
Kleibergen-Paap F	15.61	15.61	71.39	71.39	42.76	42.76
Overidentification	-	-	-	-	0.40	0.87

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs. Changes in housing stock ΔLog Q, are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

1.E.1 Rotemberg weights

The sectors that receive the highest Rotemberg weights (rw) in our baseline estimates are information and communication ($rw = 2.601$), wholesale and retail trade ($rw = 2.063$), administrative and support service activities ($rw = 1.997$), accommodation and food service activities ($rw = 0.2843$), and financial and insurance activities ($rw = 0.2571$). Table 1.E.5 shows the correlations of the initial employment shares across neighborhoods of the five sectors with the highest Rotemberg weights with a number of potential confounders.

Table 1.E.2: First stage: Inverse supply elasticities

	(1) ΔLog P	(2) ΔLog R	(3) ΔLog P	(4) ΔLog R	(5) ΔLog P	(6) ΔLog R
Industries	0.015***	0.015***			0.009***	0.009***
	(0.004)	(0.004)			(0.003)	(0.003)
Languages			0.271***	0.271***	0.239***	0.239***
			(0.032)	(0.032)	(0.033)	(0.033)
Observations	2,498	2,498	2,498	2,498	2,498	2,498

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs.

Table 1.E.3: Details: Inverse supply elasticities heterogeneity

	(1) ΔLog P	(2) ΔLog R	(3) ΔLog P	(4) ΔLog R	(5) ΔLog P	(6) ΔLog R
ΔLog Q	1.001**	0.095	1.578***	0.519***	1.307***	0.321*
	(0.411)	(0.218)	(0.305)	(0.197)	(0.306)	(0.176)
$Q^{1980} \times \Delta$Log Q	0.690***	0.302***	0.842***	0.446***	0.678***	0.319***
	(0.189)	(0.089)	(0.200)	(0.109)	(0.151)	(0.082)
$\Lambda \times Q^{1980} \times \Delta$Log Q	0.241**	0.122**	0.330***	0.192***	0.255***	0.134***
	(0.110)	(0.049)	(0.115)	(0.059)	(0.099)	(0.048)
Elev	0.120***	-0.006	0.159***	0.022	0.140***	0.009
	(0.038)	(0.029)	(0.036)	(0.029)	(0.034)	(0.028)
Elev SD	-0.082	0.041	-0.042	0.070	-0.061	0.056
	(0.112)	(0.093)	(0.134)	(0.101)	(0.119)	(0.095)
Log Dist. CBD	-0.012	0.005	-0.022*	-0.001	-0.018*	0.001
	(0.010)	(0.007)	(0.011)	(0.007)	(0.010)	(0.006)
Log Q^{1980}	-0.056***	-0.018**	-0.064***	-0.026***	-0.052***	-0.017**
	(0.013)	(0.008)	(0.018)	(0.010)	(0.012)	(0.008)
Constr. Cost	0.099	-0.493**	-0.375	-0.866***	-0.098	-0.659***
	(0.394)	(0.238)	(0.503)	(0.261)	(0.378)	(0.211)
Λ	-0.023	-0.054***	-0.021	-0.053**	-0.016	-0.049**
	(0.030)	(0.021)	(0.039)	(0.023)	(0.033)	(0.021)
Constant	0.533***	0.346***	0.539***	0.368***	0.491***	0.329***
	(0.094)	(0.059)	(0.134)	(0.076)	(0.097)	(0.063)
Instruments	I	I	L	L	I & L	I & L
Observations	2,498	2,498	2,498	2,498	2,498	2,498
Kleibergen-Paap F	12.98	12.98	23.48	23.48	19.46	19.46
Overidentification	-	-	-	-	0.56	0.49

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change in construction costs from 2005 to 2015. Total restricted area is standardized and contains constraints on the extensive margin – water bodies, undevelopable land, forest, and other protected areas. Changes in housing stock ΔLog Q including interaction terms thereof are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

Table 1.E.4: First stage: Inverse supply elasticities heterogeneity

	(1) ΔLog P	(2) ΔLog R	(3) ΔLog P	(4) ΔLog R	(5) ΔLog P	(6) ΔLog R
I	-0.012	-0.012			-0.016	-0.016
	(0.009)	(0.009)			(0.010)	(0.010)
$Q^{1980} \times$ I	0.012***	0.012***			0.007***	0.007***
	(0.002)	(0.002)			(0.002)	(0.002)
$\Lambda \times Q^{1980} \times$ I	0.020***	0.020***			0.006**	0.006**
	(0.004)	(0.004)			(0.003)	(0.003)
L			-0.144***	-0.144***	-0.041	-0.041
			(0.048)	(0.048)	(0.064)	(0.064)
$Q^{1980} \times$ L			0.348***	0.348***	0.223*	0.223*
			(0.095)	(0.095)	(0.128)	(0.128)
$\Lambda \times Q^{1980} \times$ L			0.776***	0.776***	0.653***	0.653***
			(0.078)	(0.078)	(0.108)	(0.108)
Observations	2,498	2,498	2,498	2,498	2,498	2,498

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005-2015) in construction costs.

Table 1.E.5: Correlation of initial employment shares and potential confounders

Sector	J	G	N	I	K
Change in vacancy rate	0.030	-0.047	0.026	0.013	0.029
Change in time on market (rental)	-0.004	-0.009	0.012	0.090	-0.012
Change in time on market (selling)	-0.008	-0.012	0.001	0.047	0.033
Ownership rate	-0.080	-0.033	-0.055	0.135	-0.138
Growth in ownership rate	0.090	-0.044	0.064	-0.218	0.097
Unemployment	0.020	0.029	0.002	-0.026	0.075

Changes and growth rates refer to the period 2005-2015; ownership and unemployment refer to the year 2000. Sector J denotes information and communication, G denotes wholesale and retail trade, N denotes administrative and support service activities, I denotes accommodation and food service activities, and K denotes financial and insurance activities.

2

The geography of housing subsidies

joint with **Yashar Blouri and Olivier Schöni**

2.1 Introduction

Every year, the U.S. federal government forgoes tens of billions of tax revenue to subsidize homeownership. In 2013, the Mortgage Interest Deduction (MID) represented about six percent of the U.S. federal income tax revenue, that is about 98.5 billion USD. Yet this substantial tax expenditure is far from being equally distributed across the country's territory. In 2013, the average owner-occupier living in New York County (NY) received 1,813 USD in housing subsidies – about 2.13 times as much as the average owner-occupier in the U.S., whereas owner-occupiers of Sheridan County (WY) received an average of 222 USD per capita – about one fourth of the U.S. average housing subsidy. In this paper, we investigate how this unequal geographic distribution of MID subsidies affects local labor and housing markets and, ultimately, welfare.

To this end, we start by developing a spatial general equilibrium model featuring the main characteristics of the U.S. federal income tax system. In our model individuals respond endogenously to tax incentives by choosing where to live, where to work, and tenure mode. If they become owner-occupiers, they can decide whether to deduct from their taxable income a standard deduction, common to both renters and owners, or the interests paid on a mortgage loan. We calibrate our model to replicate the observed distribution of renters, owner-occupiers, commuting flows, and income across U.S. counties. Keeping federal public expenditure constant, we find that suddenly repealing the MID would lower homeownership rates by only 0.19 percentage points, implying that the Federal Government has to forgo approximately $32,000$ USD of yearly income tax revenue to create a single new owner-occupier. The repeal would even slightly increase welfare by 0.01 percent, suggesting that every year U.S. citizens would willingly pay about 37 million USD to abandon the MID.

The slightly positive welfare effect of the repeal is the aggregate result of heterogeneous responses occurring at the local level, which are mainly given by the migration response of residents from congested housing markets to more elastic ones, by a shift of the housing demand from the owner-occupied to the rental market, and by a decrease of costly commuting flows across counties. As a result of these responses, the spatial inequality of the income distribution across counties is lowered by 0.46 percent. When using the structure of the model to quantify the importance of spatial spillovers for the migration response of renters and owner-occupiers to the repeal, we find that approximately 33 percent of the residents' elasticity is due to non-local indirect effects. These non-local effects are mostly due to the spatial linkages between locations via commuting, whereas migration and trade are less important.

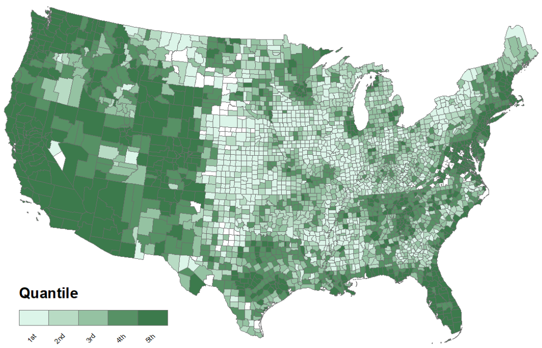
In our spatial framework, we allow locations to differ in terms of productivity, housing supply elasticity, and amenities. The spatial distribution of renters and owner-occupiers is determined by the opposing effect of agglomeration and dispersion forces. The accessibility via commuting to productive locations and home markets effects lead people to concentrate in some locations, whereas housing markets and idiosyncratic tastes for location and tenure disperse them. In this baseline setting, MID subsidies counter the dispersion force of housing markets for homeowners, as they are proportional to the periodic cost of ownership. Due to commuting linkages between locations, congested housing markets of productive locations do not necessarily prevent people from working in that location and, vice versa, low-productivity places might still attract residents. We match our model to observed data on the distribution of renters, owners, and commuting flows, as well as to estimated parameters for local housing supply elasticities, trade and commuting costs elasticities. The unique equilibrium solution of the model allows us to recover location fundamentals – productivity and individuals' taste for locations and tenure – that perfectly mimic the geographic distribution of the observed data.

Housing supply elasticities are of particular importance in our setting, as they affect the equilibrium response of local housing markets to shifts in the housing demand. In order to analyze demand shifts between rental and onwer-occupied markets, we model two separate supply functions for these markets. This allows us to track tenure-specific equilibrium changes in the periodic costs of housing.[1] Following Saiz (2010) methodology, we use U.S. Census data on housing prices and stock changes between 1980 and 2000 to estimate housing supply elasticities at the county level. Specifically, we use housing demand shifters exogenous to the economic channels present in the structural framework to recover the shape of the housing supply function. Complementing the existing literature, we find novel evidence that county-level housing supply elasticities show important spatial variation within urban areas and between urban areas and the countryside.

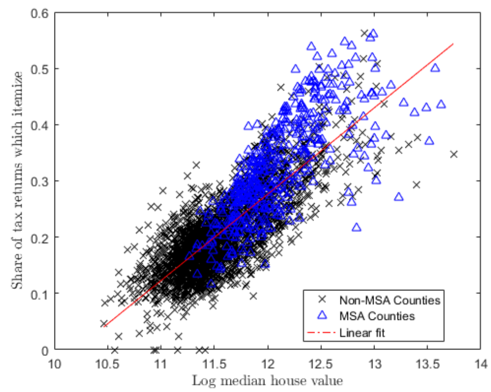
[1] A similar approach has been adopted by Glaeser and Gottlieb (2008) in the case of skilled and unskilled workers consuming heterogeneous types of housing goods that are produced by separate supply functions.

Figure 2.1.1: County-level MID descriptives in 2013

(a) Average subsidy per homeowner



(b) Probability of itemization



Notes: Tax and MID subsidy data stem from Internal Revenue Service (IRS). Housing values provided by the American Community Survey (ACS) are averaged over 2009-2013. MSAs areas are defined according to Saiz (2010).

Our spatial framework entails several advantages. First, it allows us to investigate a variety of tax policies affecting the way housing subsidies are distributed across U.S. counties. As shown in Figure 2.1.1, a spatial approach seems pertinent, as the distribution of per capita MID subsidies varies considerably across locations (Panel A) and itemization rates are spatially concentrated in congested housing markets displaying high housing prices (Panel B).[2] Existing research has mostly focused on aggregate (MSAs) areas comprising these congested markets and estimated the average effect of a homogeneous marginal change in MID subsidies. Second, the spatial linkages present in the structure of the model allow us to understand and quantify local spatial spillovers generated by the initial heterogeneous shock of the MID repeal. This quantification is important to determine the aggregate welfare response of the repeal. In that regard, empirical research has to suppose that the Stable Unit Treatment Value Assumption (SUTVA) is fulfilled to estimate the causal impact of MID subsidies, which precludes the possibility of spatial spillovers within treated areas and from treated areas to non-treated ones.[3] Third, our model allows us to investigate the joint decision of where

[2] Gyourko and Sinai (2003) point out that the distribution of income-tax subsidies benefiting to owner-occupiers remains stable over time.

[3] A standard approach in the literature has been to use a high level of aggregation, such as MSAs, to alleviate these spatial spillovers. However, as pointed out by Monte et al. (2018), spatial linkages between locations remain important when using this level of aggregation.

to live, where to work, and tenure mode. This is a novel mechanism not explored in the existing structural literature. In the real world, we do expect individuals to react to tax incentives by adapting their location and tenure choices, thereby altering the geographic distribution of residents and workers across space.

Simulation results suggest that an unexpected MID repeal would lead to a slight welfare increase. However, such a repeal would likely be met with hostility by owner-occupiers. A legitimate question is thus whether the federal government might want to implement alternative policies to reduce the disparity in the tax treatment of renters and owner-occupiers. Despite not being its main aim, a recent example of such a policy is provided by the Tax Cuts and Jobs Act (TCJA), which was promoted by President Trump's administration and came into force in January 2018. One of the major elements of President Trump's tax reform is the doubling of the standard deduction that households (both renters and owner-occupiers) can deduct from their taxable income.[4] We use the general applicability of our structural framework to evaluate the welfare impact of this increase of the standard deduction. Following President Trump's reform, we find that homeowners' MID itemization rates drop from 30.4 percent to 0.65 percent and homeownership rates increase by 0.03 percentage points, leading to a welfare decrease of 0.07 percent for the whole of the country. Put differently, every year U.S. citizens would willingly pay about 544 million USD to avoid this specific feature of the TCJA. The welfare decrease is mainly due to the subsidization of housing in the countryside, which diverts workers from productive areas.

The present paper contributes to three strands of the literature. The first strand investigates the impact of the MID on ownership attainment and various economic outcomes.[5] Recent empirical research suggests that the MID is an ineffective instrument to increase homeownership. Hilber and Turner (2014) empirically show that the U.S. federal and state MIDs capitalize into higher prices in major urban areas characterized by tightly regulated housing market, thus achieving little to improve homeownership rates. By endogenizing tenure choices and calibrating a two-region framework for Boston (MA), Binner and Day (2015) argue that it might be possible to reform the MID while leaving homeownership rates unchanged. Gruber et al. (2017) empirically analyse a major policy reform in Denmark, which led to

[4]Some features of the reform, such as the doubling of the standard deduction, are expected to come to an end in 2025.

[5]See Hilber and Turner (2014) for a comprehensive review of the literature.

a substantial reduction of the MID for top-rate taxpayers. Their findings provide strong evidence that removing the subsidy mainly lowered housing prices and had no effects on homeownership attainment. Sommer and Sullivan (2018) use a dynamic macroeconomic model to show that abolishing the MID in the U.S. would lead to a higher welfare. The equilibrium channels driving this welfare gain are lower house prices, higher homeownership rates, and lower mortgage debt.

Another strand of the literature investigates the spatial (mis)allocation of workers and the role of housing supply. Calibrating a model for U.S. metropolitan areas, Albouy (2009) analyses the impact of the U.S. federal income taxation on the allocation of workers across space. He persuasively shows that for a given real income, workers in high-density areas end up paying more taxes than those in more remote areas. Adopting a structural approach, Diamond (2016, 2017) investigates the link between housing supply and labor markets. In particular, these studies show that, because affecting the migration response of workers, housing supply elasticities can be exploited to identify the slope of the labor demand curve. Fajgelbaum et al. (2019) investigate how the dispersion of U.S. state income tax rates affects the location choices of households across states. The authors show that the more pronounced the differences in income tax rates between U.S. states are, the higher the welfare loss for the society, as workers spatially misallocate across space due to tax differentials. Hsieh and Moretti (2019) find that housing supply constraints misallocate workers by preventing them from working in productive areas, thereby hindering economic growth.

Finally, we contribute to the structural literature that investigates quantitative economic geography models by introducing several model extensions, such as households' joint decision of residential location, working place, and housing tenure. Monte et al. (2018) integrate the spatial interdependence of trade, commuting, and migration in a tractable model. Similarly, Favilukis and Van Nieuwerburgh (2018) assess the effect of out-of-town home buyers on major cities like New York in a model where heterogeneous households choose tenure and an optimal portfolio. Employing a structural framework, Blouri and Ehrlich (2019) characterize optimal regional policies that a central government can implement under budgetary constraints to improve welfare and reduce income inequality across locations.

The remainder of the paper is structured as follows. Section 2.2 presents the spatial equilibrium model. Section 2.3 describes the data, illustrates the estimation of county-level housing supply elasticities, and explains the counterfactual analysis. Section 2.4 investigates the impact of repealing the MID and analyzes the role played by spatial spillovers to determine the migration response of local residents to the repeal. Section 2.5 investigates the welfare implications of making MID itemization less attractive via a doubling of the standard deduction. Section 2.6 concludes.

2.2 A quantitative spatial model featuring housing subsidies

We consider an economy populated by a continuous measure $\bar{L}$ of workers that are distributed across N locations (U.S. counties). Extending the theoretical framework by Monte et al. (2018), each worker decides in which location i to live, in which location j to supply one unit of labor inelastically, and its tenure model $\omega \in \{\mathcal{O}, \mathcal{R}\}$. The federal government levies income taxes at an average rate τ and uses the collected tax revenue to provide public goods G.[6] Workers earn a tenure-specific after-tax income y_{ni}^{ω} which is affected by the tax subsidies provided by the federal government.

2.2.1 Households' heterogeneous preferences

The indirect utility $V_{ni}^{\omega}(h)$ of a household h living in location n, working in location i, and having a tenure mode ω is given by the following Cobb-Douglas form

$$V_{ni}^{\omega}(h) = \frac{b_{ni}^{\omega}(h)}{\kappa_{ni}} G^{\beta} \left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}} \right)^{1-\beta}, \tag{2.1}$$

where $b_{ni}^{\omega}(h)$ is an idiosyncratic taste component for a specific combination of place of residence, place of work, and tenure. We assume that the scalar utility shifter $b_{ni}^{\omega}(h)$ is the i.i.d. realization of a random variable b_{ni}^{ω} having a Fréchet distribution with a cumulative density function $\Omega_{ni}^{\omega}(b) = e^{-B_{ni}^{\omega} b^{-\epsilon}}$. The scale parameter $B_{ni}^{\omega} > 0$ determines the average idiosyncratic value workers attach to a specific $n/i/\omega$ combination, whereas the shape parameter $\epsilon > 1$ characterizes the taste dispersion for such a combination. The higher the value of ϵ, the less dispersed the distribution

[6] In Appendix 2.D we extend our framework to include a progressive tax schedule and show that our main results are left unchanged.

of tastes.

The remaining components of the indirect utility are deterministic factors common to all workers having chosen a specific combination. The variable κ_{ni} denotes exogenous commuting costs in terms of utility beared by workers living in location n and working in i. Public good consumption is denoted by G and real after-tax income is given by $y^{\omega}_{ni}/P^{\alpha}_{n} r^{\omega 1-\alpha}_{n}$, where y^{ω}_{ni} denotes after-tax labor income, P_n is the price index of a basket of tradable goods, and r^{ω}_{n} is the tenure-specific cost of housing per unit of surface. The share of income spent for the composite consumption good is given by the parameter $\alpha \in [0, 1]$ and $\beta \in [0, 1]$ governs the workers' fondness for public good provision with respect to real after-tax income.

Each location specializes in the production of a single tradable consumption good. Workers consume a composite basket of goods C_n according to the following CES function

$$C_n = \left(\sum_{i \in N} c_{ni}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{2.2}$$

where c_{ni} denotes the aggregate consumption in location n of the good produced in i. The parameter σ governs the elasticity of substitution between tradable goods. In equilibrium, we have that $c_{ni} = \alpha \bar{y}_n R_n p_{ni}^{-\sigma} P_n^{\sigma-1}$, where R_n is the number of residents in location n and $\bar{y}_n$ is location's n per-capita disposable income. The price index P_n depends on the price of individual varieties p_{ni} according to $P_n = \left[\sum_{i \in N} p_{ni}^{1-\sigma} \right]^{1/(1-\sigma)}$. In turn, prices p_{ni} equal a local price p_i, determined where the good is produced, multiplied by iceberg trade costs d_{ni} between any two locations.

2.2.2 Location-specific disposable income

The amount of per capita disposable income $\bar{y}_n$ available in location n for tradable goods and housing consumption is given by the after-tax income of households and by the redistribution of public expenditure, mortgage interests, and rental payments to that location. We start by describing the per capita income $y^{\mathcal{O}}_{ni}$ of owner-occupiers living in n and working in i, which differs in three important aspects from the one of renters having chosen the same commuting pattern. First, owner-occupiers have to pay mortgage interests to the financial institution providing the mortgage loan. Second, owner-occupiers receive an additional source of income in the form of an imputed rent, which corresponds to the rent they would have to pay if they were to rent the house in which they currently live in.[7] Third, owner-occupiers choose between itemizing the MID or claiming a standard tax deduction. The after-tax income of an owner-occupier is thus given by

$$y_{ni}^{\mathcal{O}} = w_i - \tau(w_i - \zeta_{ni}) + \frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}} - m_{ni}, \tag{2.3}$$

where

$$\zeta_{ni} = \max(s, \theta m_{ni}). \tag{2.4}$$

The term w_i denotes labor income, $\tau \in [0,1]$ is the flat income tax rate set by the federal government, and m_{ni} is the periodic interest paid on the mortgage loan. The income component $\frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}}$ is the imputed rent, which depends on the share λ_{ni}^{O} of owner-occupiers living in n and working in i and their corresponding aggregate housing consumption $H_{ni}^{\mathcal{O}}$.[8] The tax subsidy ζ_{ni} is affected by two exogenous parameters, the standard tax deduction s and $\theta \in [0,1]$, which governs the share of MID deductible from the taxable income. We introduce this second parameter to simulate changes in the deductibility of housing subsidies.[9] Because renters can only claim the standard tax deduction, their per capita disposable income is given by

$$y_{ni}^{\mathcal{R}} = w_i - \tau(w_i - s). \tag{2.5}$$

Note that in contrast to a standard user-cost approach, Equation (2.3) is not necessarily equal to Equation (2.5). This because workers' idyonsincratic preferences for location and tenure cause frictions between the rental and owner-occupied market, thereby leading to income differentials.

We now discuss the redistributive component of location's n income. We assume that public good expenditure, mortgage interests, and rental payments do not leave the economy. Rather, they accrue to a global portfolio held by a mix of federal contractors, financial institutions, and landlords. We follow Monte et al. (2018) and assume that in each location the holders of the portfolio consume tradable goods and

[7] As pointed out in literature, for example by Sinai and Gyourko (2004) and Sommer et al. (2013), the non-taxation of imputed rental income represents a fiscal disincentive for owner-occupiers to become landlords and rent out their property.

[8] In our setting, owner-occupiers benefit from capital gains in the housing market via an increase in their imputed rental income. In Appendix 2.D.1 we extend the model to include property taxes, which decrease imputed rental income.

[9] A repeal of MID subsidies, as implemented in our counterfactual simulations, corresponds to the case $\theta = 0$ such that ζ_{ni}=s.

housing proportionally to the number of residents in that location. The portfolio income Π that a location receives for each one of its residents is given by

$$\Pi = G + \frac{\sum_{n,i \in N} (\bar{L}\lambda_{ni}^{O} m_{ni} + H_{ni}^{R} r_{n}^{R})}{\bar{L}}, \tag{2.6}$$

where H_{kf}^{R} is the total housing consumption of renters living in n and working in i, such that the term $\sum_{n,i \in N} (\bar{L}\lambda_{ni}^{O} m_{ni} + H_{ni}^{R} r_{n}^{R})$ represents the total amount of mortgage interest and rental payments in the economy.

Total disposable income of region n is

$$\bar{y}_n R_n = \bar{y}_n^{\mathcal{O}} R_n^{\mathcal{O}} + \bar{y}_n^{\mathcal{R}} R_n^{\mathcal{R}}, \tag{2.7}$$

where R_n^{ω} is the tenure-specific number of residents. Expected disposable income $\bar{y}_n^{\omega}$ is given by tenure-specific income and per capita income from the global portfolio

$$\bar{y}_n^{\omega} = \sum_{k \in N} \lambda_{nk|n}^{\omega} y_{nk}^{\omega} + \Pi, \tag{2.8}$$

where $\lambda_{ni|n}^{\omega}$ is the tenure-specific share of workers residing in n and working in i, conditional on living in n, i.e. $\lambda_{ni|n}^{\omega} = \frac{\lambda_{ni}^{\omega}}{\sum_k \lambda_{nk}^{\omega}}$.[10]

2.2.3 Federal public good provision

Federal tax revenue is levied on the taxable labor income of renters and owner-occupiers. Provision of the federal public good G entering the utility of workers equals the per-capita tax revenue, such that

$$G = \frac{1}{\bar{L}} \sum_{n \in N} \left(\tau \bar{L} \sum_{k \in N} \lambda_{nk}^{\mathcal{R}} (w_k - s) + \tau \bar{L} \sum_{k \in N} \lambda_{nk}^{\mathcal{O}} (w_k - \zeta_{nk}) \right). \tag{2.9}$$

The provision of G varies according to tax subsidies s and ζ_{nk} that renters and owner-occupiers deduct from their wages. Higher subsidies imply a lower tax revenue

[10]There are two reasons for not adding portfolio income Π to the income y_{nk}^{ω} of renters and owner-occupiers. First, we don't want the real portfolio income to modify location and tenure choices of workers. If this were not the case, a household could decide to move to a given location to earn a higher portfolio income, which seems unrealistic. Second, according to the American Community Survey, over 2009-2013 about 81 percent of owner-occupiers in the U.S. did not get any income from interests, dividends, or rental income.

and thus lower public good provision. Counterfactual simulations based on the parameters s and θ are thus unable to isolate the direct income effect of housing subsidies on workers' decisions. To solve this problem, we follow Fajgelbaum et al. (2019) and allow the federal government to adjust the average income tax rate to keep the provision of the public good unaffected by changes in the subsidies.[11]

2.2.4 Housing markets

Households' housing expenditure in our baseline model is tenure specific due to their idiosyncratic tastes for a given tenure mode in a specific location, and the fiscal incentive provided by housing subsidies. Given Cobb-Douglas preferences, the tenure-specific expenditure for housing of workers living in location n and working in i is

$$r_n^\omega H_{ni}^\omega = (1-\alpha) y_{ni}^\omega \bar{L} \lambda_{ni}^\omega, \tag{2.10}$$

where H_{ni}^ω is the aggregate tenure-specific housing demand of workers living in n and working in i and r_n^ω is the periodic housing cost. The tenure-specific total housing expenditure H_n^ω in location n is obtained by adding the expenditure of renters/owner-occupiers over all workplaces i and by including housing consumption from the holders of the portfolio. This leads to

$$r_n^\omega H_n^\omega = (1-\alpha) \bar{y}_n^\omega R_n^\omega, \tag{2.11}$$

where the right-hand side of Equation (2.11) is equal to $\sum_i (1-\alpha)(y_{ni}^\omega + \Pi)\bar{L}\lambda_{ni}^\omega$.

Owner-occupiers subscribe mortgages with an absent financial institution charging periodic mortgage interests at an exogenous rate χ set by international capital markets. Aggregate mortgage interests of owner-occupiers living in location n and working in i are a constant fraction of the total owner-occupied housing value in that location

$$\bar{L}\lambda_{ni}^{\mathcal{O}} m_{ni} = H_{ni}^{\mathcal{O}} \mathcal{P}_n^{\mathcal{O}} \cdot \xi \cdot \chi, \tag{2.12}$$

where $\mathcal{P}_n^\omega$ is the value of housing per unit of surface and ξ is the loan-to-value ratio.[12]

[11] In Appendix 2.C.3 we relax this assumption and carry out counterfactual simulations where we allow public good provision to adjust in response to a change in the housing subsidies.

[12] Note that the global portfolio affects mortgage payments only via the periodic cost of owner-occupation. If this were not the case, a higher portfolio income would increase mortgage payments, which seems unrealistic.

To convert the house value $\mathcal{P}_n^\omega$ into a periodic (annual) cost r_n^ω, we use the usual finite horizon present value formula $r_n^\omega = \iota \mathcal{P}_n^\omega$, where $\iota = \frac{\chi}{(1+\chi)(1-(1+\chi)^{-t})}$ and t is the lifespan of the residential unit.

We now turn to the supply side of the housing market. To analyze demand shifts between rental and owner-occupied markets, we divide the two markets by modelling two separate supply functions. This allows us to track tenure-specific equilibrium changes in the periodic costs of housing. In line with Hsieh and Moretti (2019) and Monte et al. (2018), we define tenure-specific housing supply in location n as

$$H_n^\omega = \bar{H}_n^\omega \mathcal{P}_n^{\omega,\ \eta_n}, \tag{2.13}$$

where $\bar{H}_n^\omega$ in an unobserved scale parameter and $\eta_n \in [0, \infty]$ is the local housing supply elasticity. Note that we make the simplifying assumption that the elasticity of the two markets is the same. Put differently, we allow for unobserved supply shifters contained in $\bar{H}_n^\omega$, such as housing characteristics, to affect the supply of rental and owner-occupied properties, but we restrict the relative supply responsiveness to a price shock to be the same across the two markets. The hypothesis of same responsiveness seems reasonable if we assume that factors such as regulatory and geographic constraints do not impact the supply elasticity of the two markets differently. In equilibrium, housing demand equals housing supply, leading to the following expression

$$r_n^\omega = \left(\frac{(1-\alpha)\bar{y}_n^\omega R_n^\omega}{\bar{H}_n^\omega \iota^{\eta_n}} \right)^{\frac{1}{1+\eta_n}}. \tag{2.14}$$

2.2.5 Production

Under perfect local competition and constant returns to scale as in Armington (1969), each location specializes in the production of one type of tradable consumption good. Production amenities of region n are

$$a_n = \bar{a}_n L_n^\nu, \tag{2.15}$$

where $\bar{a}_n$ is a local exogenous productivity fundamental and L_n is the amount of workers. External agglomeration economies are captured by the parameter $\nu \geq 1$, which increases the productivity of workers. Due to this agglomeration parameter, workers supplying labor in larger labor markets are more productive, earning, ceteris paribus, higher nominal wages.

Because of the constant elasticity of substitution in Equation (2.2) the aggregate value of bilateral trade flows X_{ni} is

$$X_{ni} = p_{ni} c_{ni} = \alpha \bar{y}_n R_n \frac{p_{ni}^{1-\sigma}}{P_n^{1-\sigma}}, \tag{2.16}$$

where profit maximizing firms cause prices to equal marginal production costs: $p_{ni} = \frac{d_{ni} w_i}{a_i}$. Using these profit-maximizing prices, we can compute location's n expenditure share for goods produced in location i

$$\pi_{ni} = \frac{\left(\frac{d_{ni} w_i}{a_i}\right)^{1-\sigma}}{\sum_{k \in N} \left(\frac{d_{nk} w_k}{a_k}\right)^{1-\sigma}}, \tag{2.17}$$

and the corresponding price index of the composite consumption good is given by

$$P_n = \left(\frac{1}{\pi_{nn}}\right)^{1/(1-\sigma)} \frac{d_{nn} w_n}{a_n}. \tag{2.18}$$

To clear traded goods markets, location's n workplace income must equal its expenditure on the goods produced in that location

$$w_n L_n = \alpha \sum_{k \in N} \pi_{kn} \bar{y}_k R_k. \tag{2.19}$$

2.2.6 Labor mobility and tenure choice

Workers are mobile and jointly choose the location n where to live, the location i where to work, and tenure mode ω to maximize their indirect utility V_{ni}^{ω} across all possible choices. Let $\bar{V}(h)$ denote this maximum utility level:

$$\bar{V}(h) = \max_{n,i,\omega} V_{ni}^{\omega}(h). \tag{2.20}$$

As explained in Section 2.2.1, the stochastic nature of the indirect utility $V_{ni}^{\omega}(h)$ comes from an idiosyncratic preference term b_{ni}^{ω} that is Fréchet distributed. Because b_{ni}^{ω} shifts multiplicatively the deterministic component of V_{ni}^{ω}, the indirect utility is also Fréchet distributed. We can thus write its cumulative distribution Ψ as

$$\Psi_{ni}^{\omega}(v) = e^{-\frac{B_{ni}^{\omega}}{\kappa_{ni}^{\epsilon}}\left(G^{\beta}\left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}}\right)^{1-\beta}\right)^{\epsilon} v^{-\epsilon}}. \tag{2.21}$$

The share of workers λ_{ni}^{ω} living in n, working in i, and having tenure ω is given by the probability that the utility provided by this specific combination exceeds the maximal attainable utility across all other choices, i.e. $\lambda_{ni}^{\omega} = Pr(V_{ni}^{\omega} \geq \max_{r,k,l} V_{rk}^{l},\ \forall r,k,l)$. Using the fact that the variable $\max_{r,k,l} V_{rk}^{l}$ is also Fréchet distributed and that $\lambda_{ni}^{\omega} = E[P(\max_{r,k,l} V_{rk}^{l} \leq v | V_{ni}^{\omega} = v)]$, we have that

$$\lambda_{ni}^{\omega} = \frac{\frac{B_{ni}^{\omega}}{\kappa_{ni}^{\epsilon}}\left(G^{\beta}\left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}}{\sum_{k\in N}\sum_{f\in N}\sum_{l\in\omega}\frac{B_{kf}^{l}}{\kappa_{kf}^{\epsilon}}\left(G^{\beta}\left(\frac{y_{kf}^{l}}{P_k^{\alpha} r_k^{l1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}}. \tag{2.22}$$

The parameter ϵ, which governs the dispersion of idiosyncratic tastes, affects the mobility degree of workers. In the case of no taste heterogeneity across locations and tenure ($\epsilon \to \infty$), local labor supply is perfectly elastic, implying perfect population mobility. The expected utility for residence n and workplace i is

$$E[\bar{V}(h)] = \bar{V} = \delta\left[\sum_{k\in N}\sum_{f\in N}\sum_{l\in\omega}\frac{B_{kf}^{l}}{\kappa_{kf}^{\epsilon}}\left(\left(G\right)^{\beta}\left(\frac{y_{kf}^{l}}{P_k^{\alpha} r_k^{l1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}\right]^{\frac{1}{\epsilon}}, \tag{2.23}$$

where the expectation is computed according to the distribution of idiosyncratic preferences and $\delta = \Gamma(\frac{\epsilon-1}{\epsilon})$ is a Gamma function which depends on ϵ. Inserting commuting shares Equation (2.22) into expected utility for the residence and workplace combination Equation (2.23) yields

$$E[V_{ni}^{\omega}] = \delta\left(\frac{1}{\lambda_{ni}^{\omega}}\frac{B_{ni}^{\omega}}{\kappa_{ni}^{\epsilon}}\right)^{\frac{1}{\epsilon}}\left(G\right)^{\beta}\left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}}\right)^{1-\beta}. \tag{2.24}$$

In equilibrium, we assume that workers do not want to change their place of residence, place of work, and tenure. This implies that the observed number of workers having chosen a specific combination must be equal to the corresponding number resulting from the distribution of idiosyncratic tastes. More precisely, summing over the probabilities across workplaces k, yields the number of tenure-specific residents in location n

$$R_n^w = \bar{L} \sum_{k \in N} \lambda_{nk}^w. \tag{2.25}$$

Similarly, summing over the probabilities across place of residence k, yields the numbers of tenure-specific workers in location n

$$L_n^w = \bar{L} \sum_{k \in N} \lambda_{kn}^w. \tag{2.26}$$

Finally, we ease notation and define the share of workers commuting from n to i as $\lambda_{ni} = \lambda_{ni}^{\mathcal{R}} + \lambda_{ni}^{\mathcal{O}}$, the total number of workers as $L_n = L_n^{\mathcal{R}} + L_n^{\mathcal{O}}$ and the total numbers of residents as $R_n = R_n^{\mathcal{R}} + R_n^{\mathcal{O}}$.

2.2.7 Equilibrium characterization

Given the set of parameters $\{\alpha, \beta, \nu, \sigma, \epsilon, \xi, \chi, s, \tau, \bar{L}\}$ and observed or estimated values for $\{\lambda_{ni}^\omega, w_n, r_n^\omega, \bar{y}_n^\omega, y_{ni}^\omega, R_n^\omega, L_n^\omega, \eta_n, d_{ni}\}$, we characterize the equilibrium of the baseline model with the following set of conditions. The budget of the federal government is balanced according to Equation (2.9), local housing markets clear according to Equation (2.14), local labor markets clear according to Equation (2.17), tradable goods market clears according to Equation (2.19), the price index formula is given by Equation (2.18), and the spatial distribution of workers/ residents satisfies Equation (2.22).

These conditions represent a system of $3N + 3N^2 + 1$ equations, where N is the number of locations (U.S. counties), allowing us to recover the location fundamentals $\{a_n, B_{ni}^\omega, \pi_{ni}, G, \bar{H}_n^\omega\}$. All endogenous variables can be expressed in terms of these location fundamentals, exogenous variables, and parameters.[13]

As shown by Monte et al. (2018), this theoretical framework can be reformulated such that Allen et al. (2016) theorem can be applied to ensure the existence and uniqueness of the equilibrium.

[13] Appendix 2.C provides further details on how to use the structure of the baseline model to perform counterfactual simulations.

2.3 Data and estimation

In this section, we describe the data sources available at the U.S. county level.[14] Additionally, we discuss the calibration and estimation of the exogenous parameters required to conduct counterfactual simulations.[15]

2.3.1 Data

Parameters provided by the literature: We set the elasticity of substitution between different varieties of tradable goods equal to $\sigma = 5$, as suggested by Simonovska and Waugh (2014). Following Davis and Ortalo-Magne (2011) and Redding (2016), we set the share of income spent by households for consumption goods equal to $\alpha = 0.7$. We set the taste dispersion parameter equal to $\epsilon = 3.3$, as in Monte et al. (2018) and Bryan and Morten (2018). Following Fajgelbaum et al. (2019), the propensity to public goods consumption is given by $\beta = 0.22$. The strength of the agglomeration force is $\nu = 0.1$, as in Allen and Arkolakis (2014). Trade costs depend on the geographic distance between counties and on an average trade cost elasticity ψ, such that $d_{ni}^{1-\sigma} = dist_{ni}^{\psi}$. The former is computed using GIS data, whereas the latter is calibrated according to Monte et al. (2018), who estimate $\psi = -1.29$. We conservatively set the lifespan of a house equal to $t = 40$, which corresponds to the median age of buildings according to the American Community Survey (ACS) over 2009-2013.

Housing data: Based on data published by Federal Reserve Economic Data (FRED), we set the country mortgage interest rate equal to $\chi = 0.04$. This rate corresponds to the mean mortgage interest rate offered by financial institutions in 2013 for a 30-year fixed mortgage. Using the American Community Survey (ACS), we collect the share of owner-occupiers at the county level. We calibrate the loan to value ratio to $\xi = 0.51$ using the balance sheet of households and nonprofit organizations provided the Financial Accounts of the Board of Governors of the Federal Reserve System (BGFRS). Specifically, we compute the LTV as the ratio of outstanding home mortgages to the value of real estate assets. Monthly rents and

[14] Due to data unavailability, we exclude 87 (2.8 percent) out of 3,143 U.S. counties from our analysis.

[15] A summary of the calibrated parameters is provided in Appendix 2.A.1. Additionally, in Appendix 2.A.2 we present descriptive statistics and maps of exogenous and recovered variables.

the value of owner-occupied houses are provided by the ACS.

Labor and income tax rates: From the Bureau of Economic Analysis (BEA) we collect data on wages by place of work and the number of employees in 2013. By dividing total wages by employment, we obtain per capita wages by workplace w_i. We use information on average federal income tax rates τ provided by the TaxSim database of the National Bureau of Economic Research (NBER) in 2013.

Commuting flows: Data on bilateral commuting flows λ_{ni} at the county level stems from ACS for the years 2009-2013. Because the ACS does not report bilateral commutes by housing tenure, we assume identical commuting flows for owner-occupiers and renters in each county.[16] We calculate tenure-choice specific commuting shares λ_{ni}^{ω} by multiplying the share of owner-occupiers and renters per county with the commuting flow matrix λ_{ni}.

Income and subsidy data: To obtain disposable income of renters $y_{ni}^{\mathcal{R}}$, we use Equation (2.5) together with data on renters per capita wages w_i and tax rates τ. Owner-occupiers disposable income $y_{ni}^{\mathcal{O}}$ follows from Equation (2.3) together with data on per-capita wages w_i, where we set $\theta = 1$ in the baseline case. Next, we derive the mortgage interest rate m_{ni} to finance owning properties, which follows from substituting Equation (2.10) and Equation (2.2.4) into Equation (2.12) and data on income $y_{ni}^{\mathcal{O}}$. We substitute bilateral income y_{ni}^{ω}, conditional commuting shares $\lambda_{ni|n}$, and the total number of workers $\bar{L}$, into Equation (2.8) to recover $\bar{y}_n^{\omega}$. We solve for per capita expected disposable income $\bar{y}_n$ using Equation (2.7) and the bilateral income of owner-occupiers $y_{ni}^{\mathcal{O}}$ and renters $y_{ni}^{\mathcal{R}}$. Finally, using the Internal Revenue Service (IRS) data we calibrate $s = 6,358$ USD to ensure that the share of households that itemize in the model matches the one observed in 2013.

Recovering location fundamentals: We recover regional productivity by substituting trade shares Equation (2.17) in the market clearing condition Equation (2.19). Given values for $\{L_n, R_n, d_{ni}, w_n, \bar{y}_n\}$, parameter values for $\{\sigma, \alpha\}$, and estimates of d_{ni}, we recover productivity a_n, production amenities $\bar{a}_n$ and equilibrium values for bilateral trade shares. To solve for net regional consumption amenities

[16] This hypothesis is supported by descriptive evidence provided by the ACS Micro-data on travel time by housing tenure, which suggests that, on average, renters commute daily only 1.2 minutes more than owner-occupiers, making it unlikely that their commuting flows significantly differ at the county level.

$^{B^{\omega}_{ni}}/_{\kappa_{ni}}$, we substitute prices from Equation (2.18) and rents Equation (2.14) in commuting shares Equation (2.22).

2.3.2 Estimation of county-level housing supply elasticities

Following Saiz (2010), we parsimoniously parameterize the inverse local housing supply elasticity as $\frac{1}{\eta_n} = \eta + \eta^{\text{built}} S_n^{\text{built}}$, where S_n^{built} is the predetermined share of developed land in a given county. The parameters η and η^{built} represent the common and local components of the (inverse) supply responsiveness at the county level, respectively, which have to be estimated. Specifically, the interaction with the share of developed land proxies the combined effect of geographic and regulatory constraints on local supply elasticities.[17]

In the Appendix 2.B.1, we show that the inverse housing supply elasticity $\frac{1}{\eta_n}$ can be estimated using the following regression equation

$$\Delta \log \mathcal{P}_n = \alpha + \eta \Delta \log Q_n + \eta^{\text{built}} S_n^{\text{built}} \Delta \log Q_n + \bar{h}_n^*, \tag{2.27}$$

where $\Delta \log \mathcal{P}_n$ and $\Delta \log Q_n$ represent price per square meter and stock growth from 1980 to 2000, respectively.[18] The error term $\bar{h}_n^*$ represents unobserved price dynamics. Note that Equation (2.27) exclusively exploits spatial (cross-sectional) variation to identify supply elasticity parameters, such that time dynamics are exclusively used to partial out time-invariant unobservables at the county level.

Estimating Equation (2.27) by OLS likely leads to biased estimates due to the simultaneous effect of housing demand and supply in determining equilibrium prices and stock quantities. To solve this issue, we instrument changes in the housing stock $\Delta \log Q_n$ using exogenous demand shocks that are not modeled in our structural framework. Specifically, we predict shifts in housing demand at the county level using i) mean temperature levels in January, ii) fertility rates, and iii) a shift-share instrument for changes in the ethnic composition of residents.

We motivate the choice of instruments as follows. Counties having attractive

[17] According to Hilber and Robert-Nicoud (2013), more attractive places are developed first and, as a consequence, are more tightly regulated. On the other hand, Saiz (2010) argues that geographic constraints become binding only in developed places.

[18] Due to limited data availability, we use the average surface of consumed housing at the region level provided by the U.S. census to compute prices per square meter. In the Appendix 2.B.3, we conduct a robustness check by including additional housing characteristics measured at the county level.

amenities have progressively become more desirable over time, as pointed out by Glaeser et al. (2001) and Rappaport (2007). We thus expect temperature to positively correlate with an increase in demand over time. To the extent that individuals decide to live in the same county in which they are born – due for example to high idiosyncratic migration costs – predetermined fertility rates are also expected to shift housing demand upward as young adults start to bid on local housing markets, as argued by Chapelle and Eyméoud (2018). Finally, as argued by Altonji and Card (1991) and Saiz (2007), housing demand is also expected to evolve according to the (predetermined) ethnic composition of local residents. We follow and build on this proposition, and assume that the growth in local residents can be predicted by a weighted average of the growth (at the state level) of individuals belonging to a specific ethnicity, where the weights are given by the initial distribution of ethnic groups.[19]

Median housing prices of owner-occupied housing units and total housing stock at the county level are provided by decennial U.S. censuses and available on IPUMS (Manson et al. 2017). GIS raster data on the share of developed land comes from the "Enhanced Historical Land-Use and Land-Cover Data Sets" provided by the U.S. Geological Survey. This data set exploits high-altitude aerial photographs collected from 1971 to 1982.[20] Mean January temperature comes from the Natural Amenities Scale data published by the Department of Agriculture. County-level fertility rates, measured as live births by place of residence divided by the total population, are downloaded from IPUMS, which contains the Vital Statistics: Natality & Mortality Data and the population decennial census data. To calculate the shift-share instrument, we use ethnicity information using census data from IPUMS.

Table 2.3.1 shows estimated values of the parameters η and η^{built} in Equation (2.27). In columns 1 to 3 we report estimation results when using each instrument separately. Column 4 show estimation results when all three instruments are used simultaneously. As required by the theory, the sign of estimated parameters is positive. In particular, the higher the share of developed land in a given county, the higher η_n, thus resulting into a lower local housing supply elasticity. Additionally, the magnitude of the estimated coefficients is relatively stable across the instruments

[19]We use the following main ethnic groups: White, Black or African American, American Indian and Alaska Native, and Asian and Pacific Islander, and a category encompassing remaining ethnic groups. See Appendix 2.B.2 for further computational details.

[20]Because the large majority of the data is collected before 1980, we consider it predetermined with respect to our period of analysis.

used to predict housing demand growth.

Table 2.3.1: County-level housing supply elasticity estimates

Dependent variable: Growth of housing prices per m^2 between 1980 and 2000 ($\Delta \log \mathcal{P}$)				
Instruments:	Log-temperature	Fertility rate	Shift-share ethnicity	All three instruments
	(1)	(2)	(3)	(4)
$\Delta \log Q$	0.685***	0.443***	0.353**	0.444***
	(0.215)	(0.144)	(0.151)	(0.147)
$S_n^{\text{built}} \Delta \log Q$	1.908**	2.026***	1.909**	2.088**
	(0.788)	(0.715)	(0.845)	(0.815)
Observations	3.098	3.098	3.098	3.098
Underidentification[a]	0.002	0.000	0.001	0.004
Weak identification[b]	8.963	13.890	10.252	15.697
Overidentification[c]	.	.	.	0.514

Notes: Clustered standard errors at the state level in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. a) P-value of the Kleibergen-Paap LM statistic. b) Kleibergen-Paap F-statistic. The critical values for 10/15/20 percent maximal IV size are 7.03/4.58/3.95 in columns 1 to 3 and 26.68/12.33/9.10 in column 4, respectively. c) P-value of Hansen J statistic.

Using the estimates of our preferred specification (column 4 of Table 2.3.1), we compute county-level supply elasticities as $\eta_n = 1/(\eta + \eta^{\text{built}} S_n^{\text{built}})$. We obtain supply elasticity values ranging from 0.39 (Queens county, NY) to 2.25 (Banner county, NB). In Appendix 2.B.3 and 2.B.4, we provide further evidence about the reliability of our estimates by controlling for potential supply shifters and comparing our estimates with those of Saiz (2010).

2.3.3 Counterfactual analysis

We use the theoretical framework presented in Section 2.2 to undertake model-based counterfactual simulations about the spatial implications of the MID. Specifically, we evaluate two alternative policies that modify how housing subsidies are allocated to individuals. With the first policy we analyze the economic impacts of suddenly repealing the MID. In the second counterfactual simulation, we investigate the general equilibrium effects of a doubling of the standard deduction, as recently implemented in the Tax Cuts and Jobs Act (TCJA) under President Trump's administration.

To quantify the welfare impact of modifying existing housing subsidies, we introduce the counterfactual 'hat' notation developed by Dekle et al. (2007) and denote a counterfactual change as $\hat{x} = \frac{x'}{x}$, where x is the observed variable and x' its counterfactual value. To avoid modeling potentially complex changes in the allocation of public good provision by the federal government, we follow Fajgelbaum et al. (2019) and keep public good provision constant in all our counterfactual simulations. Using Equation (2.24), we can then write spending-constant ($\hat{G} = 1$) counterfactual changes in U.S. welfare as

$$\hat{\hat{V}} = \left(\frac{1}{\widehat{\lambda^{\omega}}_{ni}}\right)^{\frac{1}{\epsilon}} \left(\frac{\widehat{y^{\omega}}_{ni}}{\hat{P}_n^{\alpha} \widehat{r^{\omega}}_n^{1-\alpha}}\right)^{1-\beta}. \tag{2.28}$$

Equation (2.28) makes apparent that a cost-benefit analysis of modifying existing housing subsidies should take into account not only real income changes, but also changes in the commuting flows between local areas. A complete description of the system of equations characterizing counterfactual simulations is presented in Appendix 2.C.1. To provide a better intuition of our results, in what follows we separately report counterfactual changes for each one of the endogenous variables entering Equation (2.28).

2.4 Repealing the mortgage interest deduction

We start our analysis by investigating the welfare impacts of repealing the MID for owner-occupiers. To this end, we shock the economic system by setting $\theta = 0$ in Equation (2.4).[21]

2.4.1 Overall impact

Table 2.4.1 shows aggregate results for the whole of the country. We compute aggregate counterfactual changes of a given welfare component by computing a weighted average of changes at the county level. The weighting scheme is

[21] In Appendix 2.C we provide further details on our counterfactual simulations. In the Appendix 2.D, we show the results of a repeal of the MID in presence of property taxes and a progressive tax schedule.

adapted depending on the considered welfare component.[22] Columns 1 to 3 show counterfactual results when location (place of residence and place of work) and tenure choices are kept fixed as in the baseline scenario. Keeping location and tenure choices fixed, allows us to investigate the initial income impact of repealing the MID without diving into the sorting and tenure response of individuals. In columns 4 to 6 we do allow individuals to adapt their location and tenure choices to the repeal of the subsidy.[23]

In columns 1 to 3, owner-occupiers experience a negative income shock, while renters a positive one. This is because owner-occupiers that were itemizing the MID cannot do so anymore and renters are those that mostly benefit from a tax rate reduction of 1.00 percent following the increase in the tax revenue of the federal government. Because owner-occupiers are more numerous than renters, the overall income effect is negative. This, in turn, leads to a decrease in the consumption of tradable goods and to a corresponding decrease in wages. Housing costs also decrease (increase) for owner-occupiers (renters) following the initial income shock. The increase in housing costs for renters does not compensate the decrease in the price of tradable goods and the income increase, resulting in a real income increase.

When individuals are allowed to relocate and choose their tenure mode, repealing the MID leads to a welfare increase of 0.01 percent. We observe a shift of the housing demand from the owner-occupied towards the rental market, as shown by the change in the number of residents reported in columns 4 and 5. In total, homeownership rate decreases by 0.19 percentage points due to the repeal. This shift of the housing demand amplifies the response of housing cost changes, leading to even higher (lower) periodic costs of renting (owning) a property. For renters, the increase in housing costs considerably dampens the positive real income increase, which only amounts to 0.03 percent. The decrease in regional income of owner-occupiers outweighs the decrease in housing cost and price index, leading their real income to decrease by 0.04 percent. Population mobility thus dilutes the real income gain experienced by renters, allowing owner-occupiers to also benefit – or limit their losses – following

[22] We weight using the level of the relevant outcome variable observed in the baseline scenario. Changes in commuting are weighted using baseline commuting flows, changes in residents, income, price indices, housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

[23] The baseline outcomes for the two groups of columns (1 to 3 and 4 to 6) are the same, which allows us to compare their changes when pertinent. Because location and tenure choices are fixed in columns 1 to 3, thus leading to a welfare disequilibrium between renters and owner-occupiers, we do not report counterfactual changes in welfare, commuting flows, and residents for these columns.

the repeal.[24]

Table 2.4.1: Repealing the MID

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0.01	0.01	0.01
Commuting ($\sum_{n\neq i}\lambda'_{ni}/\sum_{n\neq i}\lambda_{ni}$)	-	-	-	0.79	-0.59	-0.14
Residents ($\hat{R}_n$)	-	-	-	0.79	-0.43	-
Regional income ($\hat{y}_{ni}$)	0.15	-0.09	-0.01	0.14	-0.15	-0.08
Wages ($\hat{w}_i$)	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03
Housing costs ($\hat{r}_n$)	0.05	-0.05	-0.02	0.44	-0.30	-0.03
Price index ($\hat{P}_n$)	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03
Real income ($\hat{y}_{ni}/\hat{P}_n^{\alpha}\hat{r}_n^{1-\alpha}$)	0.16	-0.05	0.02	0.03	-0.04	-0.05

Notes: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns 1 to 3 workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns 4 to 6. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Albeit the considerable size of the MID policy, we attribute the relatively small decline in homeownership rates to three main factors. First, in contrast to other studies, in our model workers have idiosyncratic preferences for tenure and locations, implying that they are imperfectly mobile and do not fully react to real income changes. Second, those areas in which owner-occupiers do not itemize the MID because housing values are not high enough are not affected by the repeal. Additionally, even in extremely expensive locations owner-occupiers can still claim the standard deduction. Third, in line with the reasoning of Hilber and Turner (2014), our estimated housing supply elasticities suggest that counties belonging to

[24]Note that because they face a unique local market price, differences in counterfactual price index changes between renters and owner-occupiers are exclusively due to differences in the weighting scheme.

MSAs are fairly inelastic, thus leading to a capitalization on the subsidy in to higher housing prices.

Welfare changes presented in Table 2.4.1 draw a global portrait of the welfare consequences of repealing the MID. However, as noted before, housing subsidies are unevenly distributed across space, with high productive areas receiving most of them. This uneven distribution implies that the repeal affects some areas more than others. In that regard, it is difficult to explain changes in incoming commuting flows in Table 2.4.1 without considering the geography of the repeal. In the next section, we thus analyze how the impact of the repeal changes across space and, in particular, how it affects the location and tenure decision across MSA and countryside counties. To this end, we exclusively focus on the case with varying location and tenure choices.

2.4.2 Changes in the spatial distribution

Figure 2.4.1 shows selected counterfactual changes that are particularly relevant for our analysis.[25] As it can be seen, the negative impact of the MID repeal on the after-tax income of owner-occupiers (Panel A) is mostly concentrated in MSAs such as New York, San Francisco, and Chicago. Unsurprisingly, these are the places where homeownership rates and housing prices decrease the most (Panels B and C). In fact, these areas feature high MID itemization rates and low housing supply elasticities. On the contrary, as shown in Panel A, onwer-occupiers in the countryside experience even a positive income shock, an effect which was masked by the aggregation scheme in Table 2.4.1. In countryside areas the decrease in homeownership rates is more contained (Panel B) and is mostly due to an increase in the periodic cost of ownership (Panel C) caused by a shift of the housing demand. As evident from Figure 2.4.1, the impact of the repeal strongly varies between metropolitan areas and the countryside. In what follows we thus investigate counterfactual changes across these two areas.

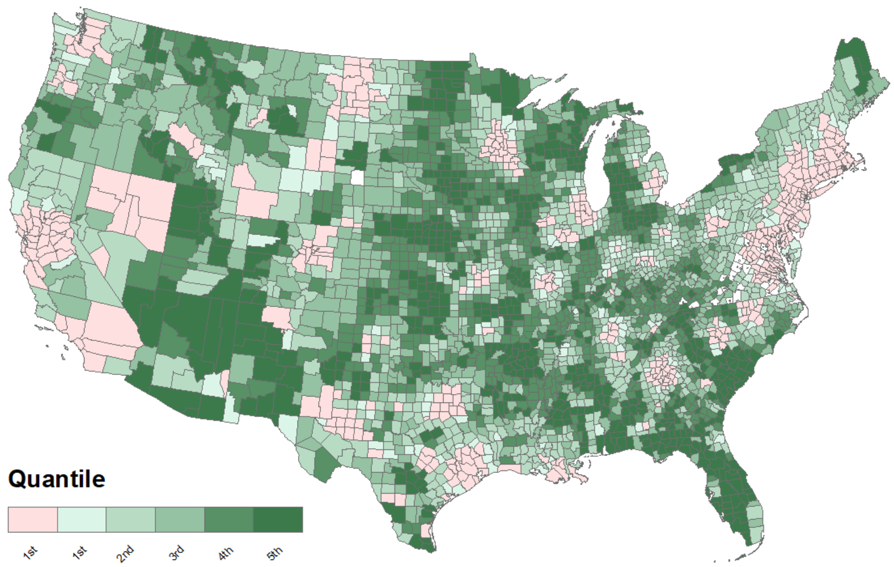
Figure 2.4.2 shows a stacked barplot of the impact of repealing the MID for renters (Panel A) and owner-occupiers (Panel B) living in counties located within and outside major urban areas. Specifically, Panels A and B of Figure 2.4.2 correspond to columns 4 and 5 of Table 2.4.1, respectively. Panels A and B show that the largest part of the impacts documented in columns 4 and 5 of Table 2.4.1 are driven by MSA regions. Non-MSA areas experience, in general, the same type of

[25] The interested reader might refer to Appendix 2.C.2 for the full set of maps representing counterfactual changes.

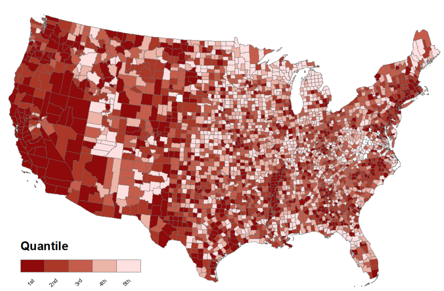
welfare impact (same sign) but of lower magnitude. A notable exception to this rule is the real income of owner-occupiers, which decreases in MSA areas but increases in the countryside. We explain this opposite effect with the fact that most owner-occupiers living in counties located in the countryside were not itemizing the MID in the baseline specification and thus fully benefit from the income tax rate decrease following the MID repeal.

Figure 2.4.1: Repealing the MID: County-level counterfactual changes

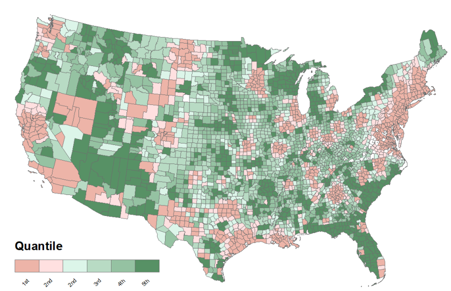
(a) After-tax income of owner-occupiers ($\hat{\tilde{y}}_n^O$)



(b) Homeownership rate ($\hat{R}_n^O/\hat{R}_n$)



(c) Periodic cost of ownership ($\hat{r}_n^O$)

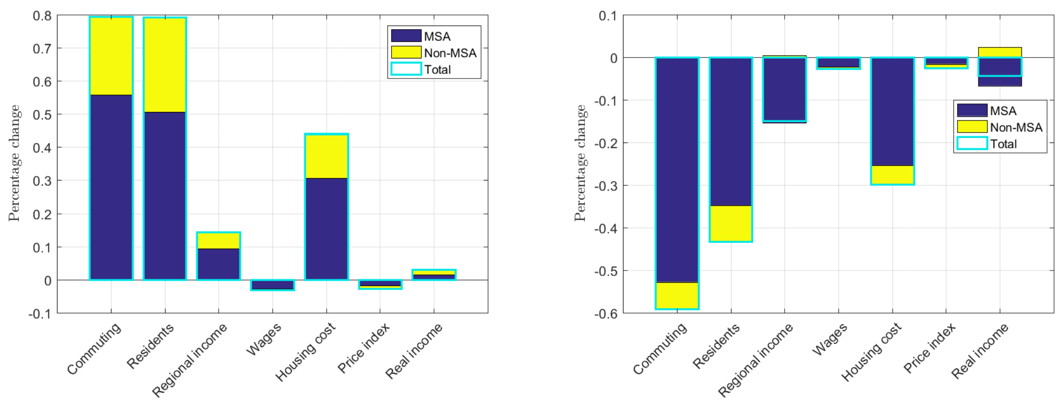


Notes: We compute counterfactual changes by setting $\theta = 0$. Workers can change place of residence, place of work, and tenure mode. We depict positive (negative) growth in green (red). A darker shading represents a stronger effect.

When computing the aggregate effect of Panels A and B of Figure 2.4.2, counterfactual changes for the welfare components of owner-occupiers dominate those of renters, mostly because they are more numerous. Because the MID repeal makes MSA counties which previously claimed the MID relatively less attractive compared to the baseline scenario, the aggregate effect also shows a clear shift of total residents from MSA to non-MSA areas (see Figure 2.C.1 in the appendix). A simple analysis of concentration (Gini) indices reveals that the repeal systematically lowers spatial inequalities of income across counties by 0.46 percent. We observe a similar reduction in spatial inequality for workers, and residents (see Table 2.C.1 in the Appendix).

Figure 2.4.2: Repealing the MID: MSAs vs. countryside

(a) Renters (b) Owners



Notes: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. Workers can change place of residence, place of work, and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Notably, because the wage response is approximately the same for columns 1 to 3 and 4 to 6, we argue that that increases in agglomeration economies occurring in the countryside due to the relocation of workers partially counter the loss in productivity occurring in MSAs. Indeed, renters counter the increase of rental costs by commuting over longer distances, whereas the decrease of ownership cost allows owner-occupiers to live closer to their place of work, resulting in a 0.59 percent decrease in commuting. Overall, commuting decreases by 0.14 percent. Because commuting is costly in terms of welfare, this overall commuting decrease improves welfare.

2.4.3 Housing subsidies and spatial spillovers

An important body of empirical work in economics aims to quantify the causal impact of place-based policies on a variety of economic outcomes. Recently, researchers have started to raise doubts about the reliability of empirical estimates describing the (average) treatment effect of place-based policies due to a potential violation of the Stable Unit Treatment Value Assumption (SUTVA).[26] Questioning the validity of the SUTVA seems natural when investigating policies affecting determined areas due to the spatial linkages between regions. In fact, these linkages might create spatial spillovers from treated to non-treated areas and from treated areas to other treated areas, thus biasing treatment effect estimates.

As discussed in the previous sections, MID subsidies are itemized, on average, only in places with congested housing markets displaying high housing costs. Moreover, housing subsidies are usually unequally distributed across itemizing areas, creating heterogeneous treatment effects. Virtually all studies aiming to quantify the impacts of housing subsidies across space rely on empirical analyses exploiting this variation in the magnitude of the subsidies among recipient regions. However, the aggregate efficiency of spatially targeted housing subsidies critically depends on migration and commuting responses, the shift between rental and owner-occupied demand, and local prices in general. Ignoring the spatial spillovers of the subsidies to other regions amounts to quantifying partial equilibrium effects.[27] In our structural model, spatial spillovers take the form of complex general equilibrium responses through labor mobility and trade linkages. Because we calibrate labor mobility with real-world patterns, these spillovers are not necessarily limited to neighboring regions.

In this section, we suggest a model-based strategy allowing to quantify the magnitude of spatial spillovers for residential location choices and thus, indirectly, to

[26] See Baum-Snow and Ferreira (2015) for a comprehensive review of the issue.

[27] Some empirical studies try to alleviate the issue of spatial spillovers by excluding observations in the immediate proximity of treated regions from the control group. From a general equilibrium perspective, this is unsatisfactory for two reasons. First, spatial linkages are not necessarily limited to neighboring areas. Second, spillovers also occur within treated areas.

determine whether they represent a sizable limitation of empirical studies.[28] To this end, in a first step we formalize the general equilibrium elasticity of local residents to housing subsidies. In a second step, we disentangle the impact of local and non-local effects (spatial spillover) on this elasticity.

Understanding residential location choices

Let $\gamma^{R_n^\omega,\theta} = \frac{dR_n^\omega}{d\theta}\frac{\theta}{R_n^\omega}$ denote the tenure-specific elasticity of local residents to housing subsidies. By computing the total derivative of Equation (2.25) with respect to θ, we have

$$\begin{aligned}\gamma^{R_n^\omega,\theta} =&(1-\beta)\epsilon\left(\sum_{k\in N}\frac{\bar{L}^\omega\lambda_{nk}^\omega}{R_n^\omega}\gamma^{y_{nk}^\omega,\theta} - \sum_{k\in N}\sum_{f\in N}\lambda_{kf}^\omega\gamma^{y_{kf}^\omega,\theta}\right)\\ &-(1-\beta)\epsilon\alpha\left(\gamma^{P_n,\theta} - \sum_{k\in N}\frac{R_k^\omega}{\bar{L}^\omega}\gamma^{P_k,\theta}\right)\\ &-(1-\beta)\epsilon(1-\alpha)\left(\gamma^{r_n^\omega,\theta} - \sum_{k\in N}\frac{R_k^\omega}{\bar{L}^\omega}\gamma^{r_k^\omega,\theta}\right) + \gamma^{\bar{L}^\omega,\theta}.\end{aligned} \tag{2.29}$$

where $\gamma^{\cdot,\theta}$ denotes the elasticity of a given variable with respect to housing subsidies.

Equation (2.29) tells us that the relative change in the spatial distribution of residents due to a relative change in housing subsidies is determined by three main channels. The first channel is the income response to the subsidy. The second and third channels describe the relationship between housing subsidies and the price of tradable goods and housing costs, respectively.[29]

The first term within the large parentheses always represents a change in the local attractiveness of a location with respect to income, tradable goods prices, and housing costs. The second term within the parentheses relates to a counterfactual change in the attractiveness of all other locations, as their income and prices also change. Put differently, residents in n might react to changes in housing subsidies even if location n is not directly affected by the repeal, but its relative attractiveness is. As such, even in counties where owners do *not* itemize the MID, the elasticity of residents might be different from to zero due to spatial spillovers. A few remarks

[28] A similar analysis can be performed for the elasticity of other outcomes. We focus on the elasticity of local residents because of its relevance for the policy we analyze.

[29] As before, we assume that the federal government adjusts tax rates to keep public good provision constant, such that the elasticity of public goods to housing subsidies is identically zero.

are worth noting. First, each of the channels in Equation (2.29) is tenure specific and, as such, can have opposite sign across tenure.

Second, a crucial role in the change of residents is played by the taste dispersion ϵ and the share of private expenditure $1-\beta$. Both parameters govern the degree of mobility of people, affecting their responsiveness to housing subsidies. For example, when $\epsilon \to 1$, individual taste is all that matters and residents do not respond to housing subsidies. When ϵ is higher, people are sensitive to a change in the subsidy. In a similar vein, the more people care about real income over public good provision, the stronger the incentives to relocate according to housing subsidies.

Third, the magnitude of the elasticities $\gamma^{\cdot,\theta}$ depends on exogenous location characteristics. For example, the income elasticity $\gamma^{y^{\omega}_{nk},\theta}$ is expected to be positive and large in magnitude in highly productive places located in MSA areas, which typically have congested housing markets. Similarly, changes in consumption prices $\gamma^{P_n,\theta}$ are linked to trade costs. The housing cost response to housing subsidies $\gamma^{r^{\omega}_n,\theta}$ depends on local housing supply elasticities.

Quantifying the importance of spatial spillovers

As shown by Equation (2.29), the elasticity of local residents in county n is composed of *local* effects – originating from elasticities where $k=n$, i.e. $\gamma^{y^{\omega}_{nn},\theta}, \gamma^{P_n,\theta}$ and $\gamma^{r^{\omega}_n,\theta}$ – and *non-local* effects that arise from elasticities in other locations, where $k \neq n$, namely $\gamma^{y^{\omega}_{nk},\theta}, \gamma^{P_k,\theta}$ and $\gamma^{r^{\omega}_k,\theta}$. We use this distinction to separately quantify the role played by local and non-local income, consumption prices, and housing cost effects in the determination of local resident elasticities with respect to housing subsidies. Specifically, we investigate how much of the observed spatial variation of local resident elasticities is explained by local and non-local effects.

Specifically, we quantify local resident elasticities and the corresponding local and non-local components of Equation (2.29) by simulating the MID repeal of Section 2.4. In a second step, we perform a Shorrocks-Shapley decomposition by regressing local resident elasticities on all possible combinations of the elasticity components and computing the corresponding R^2 for each combination. For each component, we then calculate the average improvement of the R^2 when adding that component as a covariate to the regression. This average improvement is interpreted as the relative importance of the component to explain the variation in the elasticity of residents. Table 2.4.2 shows the results.

Table 2.4.2: Importance of spatial spillovers for residents' elasticity

		Renters (1)	Owners (2)
Panel A: All channels			
	local	0.68	0.67
	non-local	0.32	0.33
Total[a]		1	1
Panel B: Individual channels			
Income	local	0.33	0.36
Income	non-local	0.21	0.18
Price index	local	0.14	0.03
Price index	non-local	0.03	0.03
Housing costs	local	0.25	0.33
Housing costs	non-local	0.05	0.07
Total[a]		1	1

Notes: We compute counterfactual changes by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. The reported values correspond to the contribution of a given channel in a Shorrocks-Shapley decomposition of the residents' elasticity. [a] Because Equation (2.29) is an analytical relationship, linearly regressing local resident elasticities on the full set of components leads to a perfect fit.

Panel A of Table 2.4.2 evaluates the overall importance of local and non-local channels for renters and owner-occupiers, without distinguishing which endogenous channel responds to the subsidies. Our results suggest that 32 percent and 33 percent of the observed spatial variation in the elasticity of renters and owner-occupiers is due to responses having occurred in other areas, respectively. When assessing the relative importance of local and non-local effects for each channel entering Equation (2.29), as shown in Panel B, we find that income and housing costs represent the most important channels affecting the residential elasticities of renters and owner-occupiers, whereas the price index of tradable goods only plays a minor role. A good part of the importance of the income channel comes from non-local effects stemming from spatial linkages of the labor market via commuting flows. On the contrary, non-local effects do not represent a major component of the housing costs channel, implying that the migration response of residents is mostly affected when housing subsidies directly affect local housing markets.

These results seem to suggest that spatial spillovers are an important component of local elasticities of renters and owner-occupiers to housing subsidies. This importance highlights potential shortcomings of empirical analyses aiming to quantify the causal impact of the MID on economic outcomes and welfare.

2.5 Making MID itemization less attractive

Up to now we have concerned ourselves with the evaluation of the welfare impact of repealing the MID. Despite a repeal seems to be beneficial for the country, it would likely be met with hostility by voters and owner-occupiers in particular. A legitimate question is thus whether a government that aims to reduce the disparity in the tax treatment between renters and owner-occupiers can overcome this hostility by implementing a policy that makes MID itemization less attractive.

Despite not being its main purpose, a recent example of such a policy is provided by the TCJA, which was promoted by President Trump's administration and came into force in January 2018. One of the major elements of this tax reform is the doubling of the standard deduction that households can deduct from their taxable income.[30] The areas that benefit the most from the increase in the standard deduction in real terms are those located in the countryside, where President Trump's received most votes during the 2016 U.S. presidential election. Unsurprisingly, most pundits expect an important drop in MID itemization rates.

In this section, we thus investigate the welfare impact of doubling the standard deduction s.[31] As in the previous section, we adjust income tax rates to keep federal public good provision constant.

Table 2.5.1: Doubling the standard deduction

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	-0.07	-0.07	-0.07
Commuting ($\sum_{n\neq i} \lambda'_{ni} / \sum_{n\neq i} \lambda_{ni}$)	-	-	-	-0.43	-0.55	-0.51
Residents ($\hat{R}_n$)	-	-	-	-0.05	0.03	-
Regional income ($\hat{y}_{ni}$)	-0.09	-0.09	-0.09	-0.47	-0.51	-0.51
Wages ($\hat{w}_i$)	-0.31	-0.24	-0.26	-0.18	-0.13	-0.15
Housing costs ($\hat{r}_n$)	-0.16	-0.15	-0.16	-0.40	-0.38	-0.38
Price index ($\hat{P}_n$)	-0.33	-0.27	-0.30	-0.13	-0.12	-0.13
Real income ($\hat{y}_{ni} / \hat{P}_n^{\alpha} \hat{r}_n^{1-\alpha}$)	0.19	0.15	0.16	-0.26	-0.32	-0.31

Notes: We compute counterfactual changes by setting $s = 12,717$ USD. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns 1 to 3 workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns 4 to 6. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

2.5.1 Overall impact

Table 2.5.1 shows the simulation results when doubling the calibrated value of the standard deduction s – which increases from $6,358$ USD to $12,717$ USD – in Equation (2.4). Columns 1 to 3 show the impact of the tax reform when individuals cannot adapt location and tenure choices in response to the increase of the standard deduction, whereas in columns 4 to 6 we allow for such a response.

[30]Other key elements of the tax reform are reductions in tax rates for businesses and individuals, family tax credits, limiting deductions for state and local income taxes (SALT) and property taxes, reducing the alternative minimum tax for individuals and eliminating it for corporations, reducing the number of estates impacted by the estate tax, and repealing the individual mandate of the Affordable Care Act.

[31]Despite our model is calibrated with 2013 data, changes in the tax system between 2013 and 2017 have been minor.

In our simulations the share of owner-occupiers itemizing the MID drops from 30.4 percent to 0.65 percent after the tax reform comes into force, with only counties having highly congested housing markets continuing to claim the deduction. Doubling the standard deduction considerably decreases the tax revenue of the federal government, which to keep public good provision constant is forced to increase income tax rates. This increase in tax rates negatively affects the after-tax income of residents that continue to claim the MID. Taxpayers for which the doubling of the standard deduction is only marginally beneficial are also hurt by the increase in tax rates and experience an income decrease. This negative income shock decreases the consumption of tradable and housing goods, negatively affecting the economy of the country and leading to a generalized wage decrease. However, because the cost of living decreases more than the decrease in the after tax income, renters and owner-occupiers experience a real income increase, with renters experiencing the biggest increase.

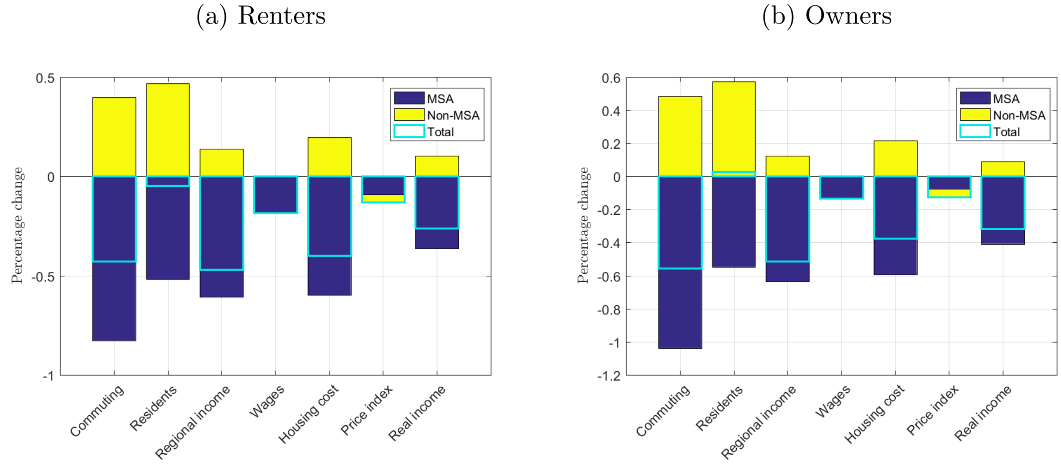
In the case of immobile renters and owner-occupiers, our analysis seems to suggest that doubling the standard deduction is beneficial, at least in terms of real income. When people can adapt location and tenure choices with respect to the baseline scenario, however, we find that the welfare of the country decreases by 0.07 percent. We explain these results as follows. In the mobility scenario, because being an owner-occupier becomes relatively less attractive in most locations, many individuals switch tenure and/or relocate to areas displaying more elastic housing markets.[32] This migration response to less productive areas further reinforces the regional income decrease, which lower the demand of tradable and housing goods even further with respect to the immobility case. The decrease in the price of tradable and housing goods is not strong enough to compensate the income decrease, which leads to a real income decrease, with renters experiencing a slightly less negative decrease. In turn, because the decrease in commuting flows does not compensate outweigh the decrease in real income, welfare decreases. Some of remaining owner-occupiers take advantage of lower housing costs to move closer to their work place, which results in a decrease of in-commuting.

Because, Table 2.5.1 only shows aggregate results for the whole of the country, in the next section we provide further evidence on the spatial displacement of the housing demand from MSAs to non-MSAs caused by the doubling of the standard

[32]The countrywide ownership rate is slightly reduced by 0.02 percentage points.

deduction.

Figure 2.5.1: Impact of doubling the standard deduction: MSAs vs. countryside



Notes: We compute counterfactual changes by setting $s = 12,717$ USD. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. Workers can change place of residence, place of work, and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

2.5.2 Changes in the spatial distribution

Figure 2.5.1 shows the impact for renters (Panel A) and owner-occupiers (Panel B) living within/outside MSAs of doubling the standard deduction . As it can be seen, non-MSAs counties are strongly affected by the policy, with a clear shift of residents to less productive areas. In fact, countryside counties – which usually display more elastic housing markets – become relatively more attractive than counties located within MSAs for two reasons. First, the real value of the standard deduction is considerably higher in the countryside. Second, in these places the standard deduction capitalizes less into housing costs than in counties with a lower housing supply elasticity. As is shown in Figure 2.5.1, the shift to the countryside decreases housing costs in MSAs counties, while housing costs in the countryside increase. The shift to places with lower agglomeration economies reinforces the decrease in regional income of owner-occupiers and renters observed in Table 2.5.1. Because people have to move outside MSAs to benefit from the doubling of the standard deduction, we observe that incoming commuting flows of MSA counties strongly decrease, whereas those of countryside counties increase.

2.6 Conclusions

Over the last decades, the staggering tax expenditure generated by the mortgage interest deduction has fueled a lively debate among politicians and academicians regarding its allocative efficiency. Evidence on the economic impacts of the unequal geographic distribution of housing subsidies is currently missing. To analyze the economic effects of this unequal distribution, we develop a spatial general equilibrium model in which individuals respond endogenously to tax incentives by choosing where to live, where to work, and tenure mode. We calibrate our model with data for U.S. counties, estimating, in particular, local housing supply elasticities. The general applicability of the framework allows investigating a variety of simulations related to income-tax subsidies.

Simulation results suggest that repealing MID subsidies while keeping public expenditure constant leads to a moderate decrease in homeownership rates while slightly increasing the country welfare. The welfare gain is mostly due to a spatial displacement of the housing demand from congested housing markets in urban areas to more elastic housing markets in the countryside, and to a reduction in commuting flows between these areas. In contrast to previous research, we quantify the importance of spatial spillovers for the displacement response of residents due to a change in the subsidies, finding that they explain about one third of the response. In a separate simulation exercise, we show that a repeal of the MID is to be preferred to a lessening of its attractiveness via an increase of standard deductions as recently implemented under President Trump's administration.

Our results hold important lessons for the evaluation of housing and tax policies. Providing housing subsidies or income tax incentives significantly alters the geographic distribution of residents and workers across space, which in turn affects the aggregate efficiency of the policy. Non-local effects, arising via labor and goods markets, also influence the efficiency of the policy, especially in areas having strong spatial linkages with other ones. This prompts for a serious costs-benefits analysis of policies that target well-connected regions, such as major urban areas.

2.A Data appendix

This section contains further information about data calibration, as well as additional descriptive statistics of the outcome variables of the model.

2.A.1 Model calibration

Table 2.A.1: Calibration of the parameters

Description	Notation	Value	Reference / Source
Share of consumption expenditure	α	0.7	Davis and Ortalo-Magne (2011)
Share of public expenditure	β	0.22	Fajgelbaum et al. (2019)
Agglomeration force	ν	0.1	Allen and Arkolakis (2014)
Elasticity of substitution	σ	5	Simonovska and Waugh (2014)[a]
Heterogeneity of preferences	ϵ	3.3	Monte et al. (2018)
Loan to house value ratio	ξ	0.51	BGFRS
Mortgage interest rate	χ	0.04	ACS
Trade cost elasticity	ψ	-1.29	Monte et al. (2018)
Life span of housing structures	t	40 years	ACS
Standard deduction	s	6,358$	IRS
Housing supply elasticity	η_n	-	Own estimation

Notes: ACS: American Community Survey, BGFRS: Board of Governors of the Federal Reserve System, IRS: Internal Revenue Service. a) Simonovska and Waugh (2014) estimate $1 - \sigma$ equal to a value of -4, which implies $\sigma = 5$.

2.A.2 Summary statistics

We present summary statistics of our exogenous and recovered variables in Table 2.A.2. Figure 2.A.1 shows the spatial distribution of selected observed and recovered variables of the model.

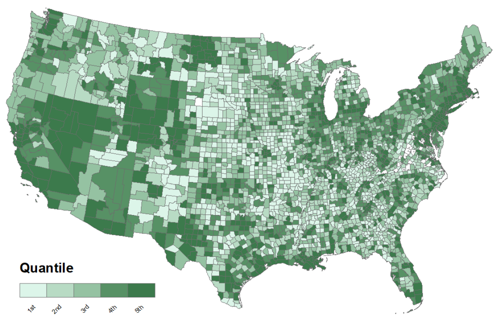
Table 2.A.2: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Production amenities ($\bar{a}_n$)	1.56	0.68	0.55	10.64	3056
Commuters ($\bar{L}\sum_{n\neq i}\lambda_{ni}$)	15.87	61.27	0.01	2143.83	3056
Renters ($\bar{L}^R\sum_{n\neq i}\lambda_{ni}^R$)	5.2	26.36	0	1156.34	3056
Owners ($\bar{L}^O\sum_{n\neq i}\lambda_{ni}^O$)	10.67	36.56	0.01	987.49	3056
Own trade shares, in % (π_{nn})	41.91	21.99	1.58	99.57	3056
Housing supply elasticity (η_n)	1.69	0.44	0.39	2.25	3056
Wages per-capita (w_n)	37.23	8.08	20.14	104.37	3056
Income per-capita ($\bar{y}_n$)	54.85	7.4	40.38	112.07	3056
Owners ($\bar{y}_n^O$)	56.94	7.97	42	119.85	3056
Renters ($\bar{y}_n^R$)	49.46	6.53	37.15	100.66	3056
Workers (L_n)	58.57	206.16	0.14	5939	3056
Owners (L_n^O)	37.89	117.28	0.1	2876.75	3056
Renters (L_n^R)	20.68	92.27	0.04	3062.25	3056
Residents (R_n)	58.57	189.32	0.08	5734.31	3056
Owners (R_n^O)	37.89	106.3	0.04	2689.48	3056
Renters (R_n^R)	20.68	87.21	0.04	3044.83	3056
Periodic cost of renting (r_n^R)	8.1	2.16	2.95	20.8	3056
Periodic cost of ownership (r_n^O)	6.26	3.66	1.7	45.17	3056
Price index (P_n)	7.5	1.15	2.19	10.31	3056
Tax rates, in % (τ)	11.36	0	11.36	11.36	3056
Owner's tax deduction (ζ_n)	6.48	0.55	6.36	14.36	3056
Ownership rate (R_n^O/R_n)	0.72	0.08	0.19	0.94	3056
Sh. of commuters ($\bar{L}\sum_{n\neq i}\lambda_{ni}/L_i$)	0.26	0.11	0.02	0.91	3056
Owners ($\bar{L}^O\sum_{n\neq i}\lambda_{ni}^O/L_i^O$)	0.25	0.12	0.02	0.93	3056
Renters ($\bar{L}^R\sum_{n\neq i}\lambda_{ni}^R/L_i^R$)	0.28	0.13	0.02	0.91	3056

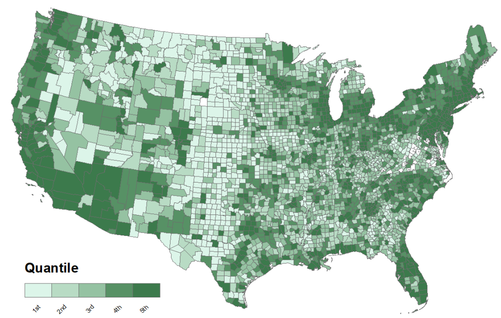
Notes: Commuters, residents and workers are measured in thousand inhabitants, per capita wages, per capita income and rents are reported in thousand Dollars, Public good provision in million Dollars, and tax rates and trade shares in percent.

Figure 2.A.1: Overview of variables at the county level

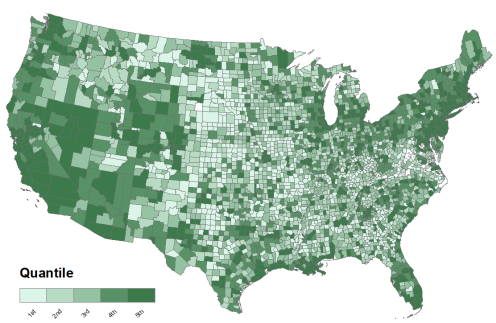
(a) Wages (w_n)



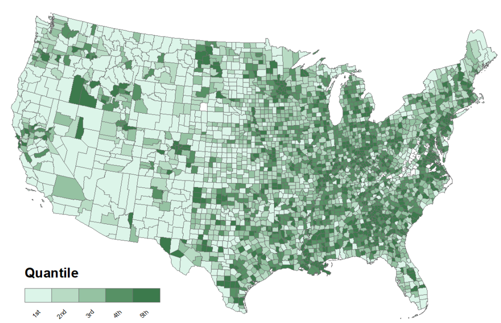
(b) Residents (R_n)



(c) Productivity (a_n)



(d) Sh. of commuters - Owners ($\sum_{n \neq i} \lambda_{ni}^{O} / L_i^{O}$)



Notes: We depict positive (negative) growth in green (red). A darker shading represents a stronger effect.

2.B Estimation of county-level housing supply elasticities

In this section, we provide further information on the estimation of county-level housing supply elasticities and on the reliability of our estimates.

2.B.1 From structure to empirics

We show how the supply Equation (2.13) can be used to derive the empirical specification Equation (2.27). There are three main reasons to use Equation (2.27) to estimate (inverse) housing supply elasticities. First, it is based on directly observable variables, namely changes in housing prices and housing stock growth. Second, it corresponds to Saiz (2010) specification of housing suppy elasticities, which allows us to investigate the validity of our estimates at the MSA level (see Section 2.B.4). Third, it is easier to find instruments that capture relevant cross-sectional variation of the total housing stock.

Log-linearizing Equation (2.13), first differencing, and rearranging the terms leads to

$$\Delta \log \mathcal{P}_n^\omega = \alpha^\omega + \frac{1}{\eta_n}\Delta \log H_n^\omega + \bar{h}_n^\omega, \tag{2.30}$$

where the error term $\bar{h}_n^\omega$ corresponds to mean-centered changes of the supply shifter $\bar{H}_n^\omega$. According to the Cobb-Douglas utility function, the term $\Delta \log H_n^\omega$ represents tenure-specific changes of the total consumption of housing surface. We decompose this total housing consumption as $\Delta \log H_n^\omega = \Delta \log \mathrm{Q}_n + \Delta \log \text{Share of } \omega_n + \Delta \log \text{Per capita } H_n^\omega$, where Q_n denotes the total housing stock in a given county. We can thus rewrite Equation (2.30) as

$$\Delta \log \mathcal{P}_n^\omega = \alpha^\omega + \frac{1}{\eta_n}\Delta \log Q_n + \bar{h}_n^{\omega,*}. \tag{2.31}$$

The error term $\bar{h}_n^{\omega,*}$ now includes changes in the share of residents according to a given tenure mode and per capita housing consumption. Parametrizing the inverse housing supply elasticity $\frac{1}{\eta_n}$, we obtain

$$\Delta \log \mathcal{P}_n^{\omega} = \alpha^{\omega} + \eta \Delta \log Q_n + \eta^{\text{built}} S_n^{\text{built}} \Delta \log Q_n + \bar{h}_n^{\omega,*} \tag{2.32}$$

Because we assume the same housing supply elasticity for the rental and owner-occupied market, we drop the ω notation in the main text and use housing prices per square meter as dependent variable.

2.B.2 Shift-share instrument based on ethnicity

To calculate the shift-share instrument we follow Bartik (1991) and construct an exogenous housing demand shock by interacting the predetermined local ethnic composition of the population with the corresponding growth rates at the state level. The instrument should capture exogenous shifts of a given ethnicity at the county level while avoiding endogeneity issues associated with using local growth rates.

Denoting the shift-share ethnicity instrument for changes in the housing stock with $Z_n^{\Delta \log H}$, we use the following formula

$$Z_n^{\Delta \log H} = \sum_k \gamma_{n,k} \eta_k, \tag{2.33}$$

where $\eta_k = \frac{Pop_{k,-n,1990} - Pop_{k,-n,1970}}{Pop_{k,-n,1970}}$ represents the average ethnicity growth at the state level, excluding residents of county n, and $\gamma_{n,k} = \frac{Pop_{kn,1970}}{Pop_{n,1970}}$ denotes the local residential share of ethnicity k at the beginning of the period. Ethnicity k is defined according to the classification used in our data source assigning population to White, Black or African American, American Indian and Alaska Native, and Asian and Pacific Islander and other ethnicity residents.

2.B.3 Controlling for local supply shifters

One concern of our empirical specification is that unobserved supply dynamics contained in the error term of Equation (2.27) correlate with the instruments, violating the exogeneity assumption necessary for the identification of the parameters. Therefore, in this section we analyze the stability of the estimated coefficients to the inclusion of control variables in Equation (2.27) that might proxy changes in the construction cost of housing *and* potentially correlate with demand changes. In particular, we control for changes of per capita payroll in the construction sector and for changes in the quality of the housing stock over the considered period. The housing characteristics we investigate are the median number of rooms, median building year, and share of detached single-family houses in the county. Data on per capita payroll from 1980 to 1997 stems from County Business Patterns (CBP), while housing characteristic in 1980 and 2000 is published by the US census. Both data sets are provided by IPUMS. In addition to housing characteristics, we control for relative changes in homeownership rates that are included in the dynamics of the error term according to Section 2.B.1.

Table 2.B.1: County-level housing supply elasticity estimates including controls

Dependent variable: Change in log housing prices (per m^2) between 1980 and 2000 ($\Delta \log \mathcal{P}$)				
Instruments:	Log-temperature	Fertility rate	Shift-share ethnicity	All three instruments
	(1)	(2)	(3)	(4)
$\Delta \log Q$	0.550**	0.267	0.248*	0.299**
	(0.246)	(0.187)	(0.151)	(0.151)
$S_n^{\text{built}} \Delta \log Q$	2.196***	2.654***	2.470***	2.629***
	(0.737)	(0.666)	(0.746)	(0.759)
Controls	Yes	Yes	Yes	Yes
Observations	2.599	2.599	2.599	2.599
Underidentification[a]	0.002	0.000	0.002	0.002
Weak identification[b]	7.986	12.342	7.709	21.342
Overidentification[c]	.	.	.	0.685

Notes: Clustered standard errors at the state level in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. a) P-value of the Kleibergen-Paap LM statistic. b) Kleibergen-Paap F-statistic. The critical values for 10/15/20 percent maximal IV size are 7.03/4.58/3.95 in columns 1 to 3 and 26.68/12.33/9.10 in column 4, respectively. c) P-value of Hansen J statistic.

Table 2.B.1 shows the results. Despite losing about 16 percent of the sample due to data unavailability at the county level, controlling for supply shifters does not strongly affect our main elasticity estimates. The coefficient of the main effect does become less significant for the different instruments, but it remains approximately within one and a half standard deviation of our main estimates. On the contrary, the

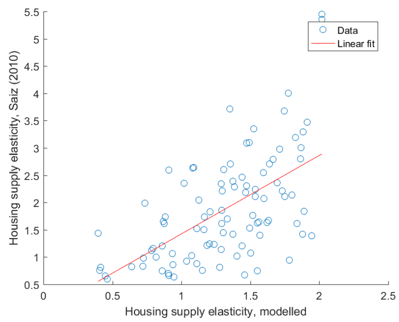
coefficient of the interaction effect responsible for the heterogeneity of housing supply elasticities becomes even more significant while displaying the same magnitude. This seems to suggest that these observed dynamics of the construction sector do not considerably affect the value of our housing supply elasticities estimates.

2.B.4 Comparison with Saiz (2010) MSAs elasticities

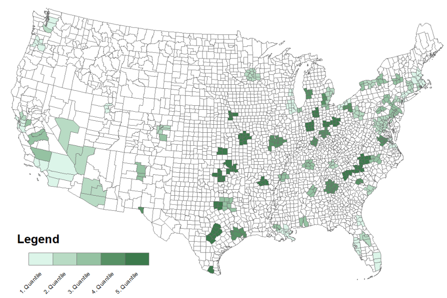
In this section, we compare our housing supply elasticity estimates with those computed by Saiz (2010). To this end, we assign each county to a Metropolitan Statistical Area (MSA) and aggregate county-level elasticity using population weighted averages. As Figure 2.B.1a illustrates, our estimates show a strong positive correlation of about 0.6 with those of Saiz (2010). However, as evident from this figure, we tend to recover higher housing supply elasticities as Saiz (2010). The reason for this higher number is that Saiz (2010) potentially underestimates housing supply elasticities, as housing transactions occurring within MSAs likely occur in dense and more inelastic places.

Figure 2.B.1: Comparison of housing supply elasticity with Saiz (2010)

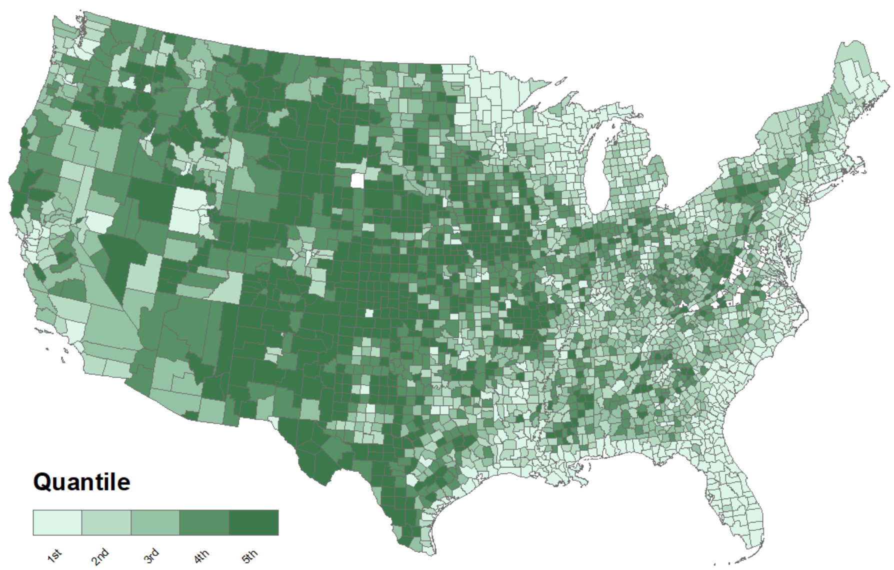
(a) Comparison with Saiz (2010)



(b) Saiz (2010)



(c) Own-computation (η_n)



Notes: In Panel A and B we compare our housing supply elasticity with estimates described in Saiz (2010), which are based on US metropolitan statistical areas (MSA)and in b) estimates of Saiz (2010), respectively. A darker shading in the map indicates a higher quantile, i.e. more elastic places. In Panel C we show recovered housing supply elasticities of our model reported by quantiles. We compute the median value for counties belonging to the same MSA and get a correlation coefficient between Saiz (2010) and our measures of 0.6.

2.C Counterfactual analysis

This section describes the system of equations that we use to simulate counterfactual policy experiments. Additionally, we provide complementary information on the simulation results presented in Section 2.4 and 2.5 of the main text.

2.C.1 System of equations

Let $\hat{x} = \frac{x'}{x}$ denote a counterfactual change, where x is an endogenous outcome variable of the baseline model and x' is its unobserved counterfactual value after a shock to the tax subsidies through θ or s. We solve the following system of equations with respect to counterfactual changes $\hat{x}$, where observed outcomes x of the baseline specification play the role of parameters.

The counterfactual equation for wages directly follows from equilibrium wages Equation (2.19):

$$\hat{w}_i w_i \hat{L}_i L_i = \alpha \sum_{n \in N} \hat{\pi}_{ni} \pi_{ni} \hat{R}_n R_n \hat{\bar{y}}_n \bar{y}_n. \tag{2.34}$$

Counterfactual changes in the tenure-specific number of residents and workers are given by counterfactual changes in commuting flows, which can be derived from Equation (2.25) and Equation (2.26), respectively. This leads to

$$\hat{R}_n^\omega R_n^\omega = \bar{L} \sum_{k \in N} \hat{\lambda}_{nk}^\omega \lambda_{nk}^\omega, \tag{2.35}$$

$$\hat{L}_n^\omega L_n^\omega = \bar{L} \sum_{k \in N} \hat{\lambda}_{kn}^\omega \lambda_{kn}^\omega. \tag{2.36}$$

As a consequence, the total number of residents and workers is

$$\hat{R}_n R_n = \hat{R}_n^{\mathcal{R}} R_n^{\mathcal{R}} + \hat{R}_n^{\mathcal{O}} R_n^{\mathcal{O}}, \tag{2.37}$$

$$\hat{L}_n L_n = \hat{L}_n^{\mathcal{R}} L_n^{\mathcal{R}} + \hat{L}_n^{\mathcal{O}} L_n^{\mathcal{O}}. \tag{2.38}$$

We now turn to counterfactual changes to the per capita labor income of owner-occupiers. Because they have Cobb-Douglas preferences, households spend a constant fraction $(1-\alpha)$ of their income for housing consumption. It follows that $\frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}} = (1-\alpha) y_{ni}^{\mathcal{O}}$. Using the definition of mortgage interest in Equation (2.12) and expressing prices into a periodic cost as in Equation (2.2.4), we obtain that

$m_{ni} = (1-\alpha)\phi y^{\mathcal{O}}_{ni}$, where $\phi = \xi\chi\frac{(1+\chi)(1-(1+\chi)^{-t})}{\chi}$ defines the size of mortgage interests. Substituting these terms into Equation (2.3) and rearranging yields the following elegant expression

$$y^{\mathcal{O}}_{ni} = \frac{w_i - \tau(w_i - \zeta_{ni})}{\alpha + \phi(1-\alpha)}.$$

Using this equation, we can write the counterfactual equation of the per-capital labor income of owner-occupiers as

$$\hat{y}^{\mathcal{O}}_{ni} y^{\mathcal{O}}_{ni} = \frac{\hat{w}_i w_i - \hat{\tau}\tau(\hat{w}_i w_i - \hat{\zeta}_{ni}\zeta_{ni})}{\alpha + \phi(1-\alpha)}, \tag{2.39}$$

where counterfactual changes in tax subsidies are given by

$$\hat{\zeta}_{ni}\zeta_{ni} = max(s, \theta \hat{m}_{ni} m_{ni}). \tag{2.40}$$

Note that because they represent exogenous parameters, we do not employ the hat notation for s and θ. However, depending on the simulation exercise, the reader must interpret s or θ in Equation (2.40) as the new value of the parameter that generates the initial shock to the system of equations.

Renters per capita labor income directly follows from Equation (2.5)

$$\hat{y}^{\mathcal{R}}_{ni} y^{\mathcal{R}}_{ni} = \hat{w}_i w_i - \hat{\tau}\tau(\hat{w}_i w_i - s). \tag{2.41}$$

Using Equation (2.8), we can write counterfactual changes in the tenure-specific total income, which includes both labor income and a redistributive term from the global portfolio, as

$$\hat{\bar{y}}^{\omega}_n \bar{y}^{\omega}_n = \bar{L}\frac{\sum_{k\in N} \lambda^{\omega}_{nk}\hat{\lambda}^{\omega}_{nk}(\hat{y}^{\omega}_{nk} y^{\omega}_{nk} + \Pi\hat{\Pi})}{\hat{R}^{\omega}_n R^{\omega}_n}, \tag{2.42}$$

where counterfactual changes in the portfolio are given by

$$\Pi\hat{\Pi} = \hat{G}G + \sum_{k,f}(\hat{\lambda}^{\mathcal{O}}_{kf}\lambda^{\mathcal{O}}_{kf} m_{kf}\hat{m}_{kf} + (1-\alpha) y^{\mathcal{R}}_{kf}\hat{y}^{\mathcal{R}}_{kf}\hat{\lambda}^{\mathcal{R}}_{kf}\lambda^{\mathcal{R}}_{kf}), \tag{2.43}$$

Using Equation (2.7), counterfactual changes of total income must satisfy

$$\hat{\bar{y}}_n \bar{y}_n = \frac{1}{\hat{R}_n R_n} \left(\hat{\bar{y}}_n^{\mathcal{R}} \bar{y}_n^{\mathcal{R}} \hat{R}_n^{\mathcal{R}} R_n^{\mathcal{R}} + \hat{\bar{y}}_n^{\mathcal{O}} \bar{y}_n^{\mathcal{O}} \hat{R}_n^{\mathcal{O}} R_n^{\mathcal{O}} \right). \tag{2.44}$$

Using Equation (2.15), we obtain a counterfactual productivity given by

$$\hat{a}_n = \hat{L}_n^{\nu}. \tag{2.45}$$

Changes in the consumption price index are derived from Equation (2.18) and must satisfy

$$\hat{P}_n = \left(\frac{1}{\hat{\pi}_{nn}} \right)^{1/(1-\sigma)} \frac{\hat{w}_n}{\hat{a}_n}. \tag{2.46}$$

Counterfactual changes in the tenure-specific cost of housing follow from Equation (2.14) and are equal to

$$\hat{r}_n^{\omega} = \left(\hat{\bar{y}}_n^{\omega} \hat{R}_n^{\omega} \right)^{\frac{1}{1+\eta_n}}. \tag{2.47}$$

We compute counterfactual changes in mortgage interest by substituting Equations (2.10) and (2.2.4) into Equation (2.12), such that

$$\hat{m}_{ni} = \hat{y}_{ni}^{\mathcal{O}}. \tag{2.48}$$

Counterfactual trade shares are obtained using Equation (2.17), which leads to

$$\hat{\pi}_{ni} = \frac{\left(\frac{\hat{w}_i}{\hat{a}_i} \right)^{1-\sigma}}{\sum_{k \in N} \left(\frac{\hat{w}_k}{\hat{a}_k} \right)^{1-\sigma} \pi_{nk}}. \tag{2.49}$$

Finally, we express tenure-specific counterfactual changes in commuting flows by dividing the counterfactual population mobility condition by the equilibrium mobility condition Equation (2.22):

$$\hat{\lambda}_{ni}^{\omega} = \frac{\left(\hat{G} \right)^{\beta\epsilon} \left(\frac{\hat{y}_{ni}^{\omega}}{\hat{P}_n^{\alpha} \hat{r}_n^{\omega 1-\alpha}} \right)^{(1-\beta)\epsilon}}{\sum_{l \in \omega} \sum_{f \in N} \sum_{k \in N} \left(\hat{G} \right)^{\beta\epsilon} \left(\frac{\hat{y}_{kf}^{l}}{\hat{P}_k^{\alpha} \hat{r}_k^{l 1-\alpha}} \right)^{(1-\beta)\epsilon} \lambda_{kf}^{l}}. \tag{2.50}$$

Note that Equation (2.45) to Equation (2.50) are expressed in terms of counterfactual changes (and not values) because the baseline level of the considered outcome is simplified.

We compute changes in the provision of the public good using Equation (2.9)

$$\hat{G}G = \frac{1}{\bar{L}} \sum_{n \in N} \Bigg(\bar{L}\tau\hat{\tau} \sum_{k \in N} \hat{\lambda}^{\mathcal{R}}_{nk} \lambda^{\mathcal{R}}_{nk} (w_k \hat{w}_k - s) + \bar{L}\tau\hat{\tau} \sum_{k \in N} \hat{\lambda}^{\mathcal{O}}_{nk} \lambda^{\mathcal{O}}_{nk} (w_k \hat{w}_k - \hat{\zeta}_{nk} \zeta_{nk}) \Bigg). \tag{2.51}$$

Equations (2.34)-(2.51) hold for each location and allow us to solve the system for counterfactual changes in commuting $\hat{\lambda}^{\omega}_{ni}$, public good provision $\hat{G}$, and real income $\frac{\hat{y}^{\omega}_{ni}}{\hat{P}^{\alpha}_{n} \hat{r}^{\omega 1-\alpha}_{n}}$. These changes build up the counterfactual value of the welfare, which using Equation (2.24) is given by

$$\widehat{\bar{V}} = \left(\frac{1}{\widehat{\lambda^{\omega}}_{ni}} \right)^{\frac{1}{\epsilon}} \left(\hat{G} \right)^{\beta} \left(\frac{\widehat{y^{\omega}}_{ni}}{\hat{P}^{\alpha}_{n} \widehat{r^{\omega}}^{1-\alpha}_{n}} \right)^{1-\beta}, \tag{2.52}$$

where counterfactual changes in utility are equalized across space and tenure such that no welfare arbitrage is possible across location and tenure mode.

2.C.2 Changes in the spatial distribution: Further details

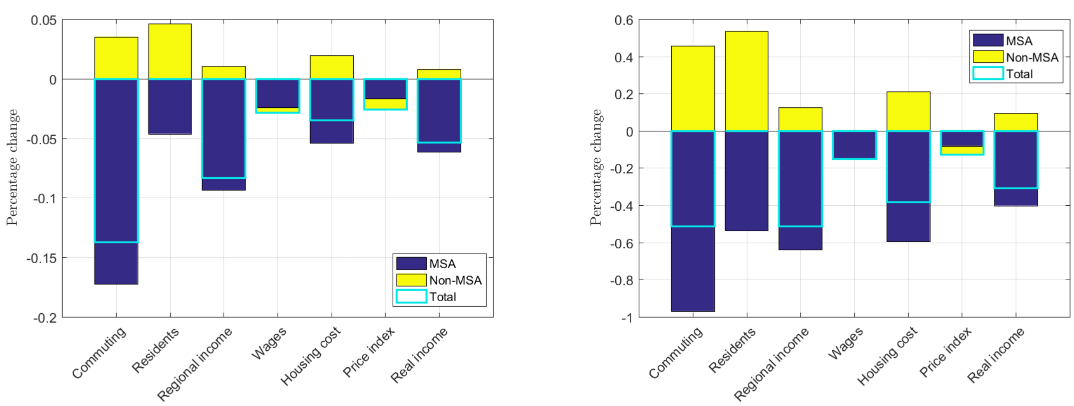
To complement our counterfactual analysis of Section 2.4 and 2.5, we show how tax subsidy reforms affects the spatial distribution of people, wage, and income across space when adding renters and owner-occupiers together. Figure 2.C.1 shows decomposition between MSAs and non-MSAs counties in the case of a repeal of the MID (Panel A) and for a doubling of the standard deduction (Panel B), respectively. Additionally, in Table 2.C.1, we illustrate how these changes in the tax subsidies affect the spatial dispersion of income across locations. Finally, figure 2.C.2 shows additional maps on the spatial distribution of main outcomes in the case of a repeal of the MID.

2.C.3 MID repeal: Varying public good provision

The MID repeal directly impacts the tax revenue of the federal government. In our benchmark model, the federal government adjusts tax rates to maintain public good provision constant. In this section, we validate our main results by assessing the welfare impact of the repeal when the federal government does adjust public good provision in response to the repeal while keeping income tax rates constant. Table 2.C.2 shows the results. As it can be seen, in this setting the repeal leaves the response of location and tenure choices mostly unaffected and leads to a higher welfare increase. However, renters experience a negative (real) income change, as they do not benefit from lower income tax rates anymore. Figure 2.C.3 shows that our results concerning the shift of economic activity from MSA to non-MSA counties are still valid.

Figure 2.C.1: MSAs vs. countryside: Renters and owner-occupiers

(a) Repealing the MID (b) Doubling the standard deduction



Notes: Panel A depicts counterfactual changes by setting $\theta = 0$ and Panel B depicts counterfactual changes by setting $s = 12,717$ USD. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Table 2.C.1: Impact of tax-subsidy reforms on spatial concentration

	Repealing the MID			Doubling the standard deduction		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Workers ($\widehat{Gini}(L_n)$)	−0.01	−0.06	−0.03	−0.26	−0.39	−0.34
Residents ($\widehat{Gini}(R_n)$)	−0.01	−0.06	−0.03	−0.24	−0.38	−0.33
Income ($\widehat{Gini}(y_{ni})$)	−0.05	−0.59	−0.46	−3.04	−3.55	−3.46
Real income ($\widehat{Gini}(y_{ni}/P_n^{\alpha} r_n^{1-\alpha})$)	−0.04	−0.40	−0.31	−2.21	−2.56	−2.52

Notes: Columns 1 to 3 report counterfactual changes obtained by setting $\theta = 0$, and columns 4 to 6 report counterfactual changes obtained by setting $s = 12,717$ USD. Workers can change place of residence, work and tenure mode.

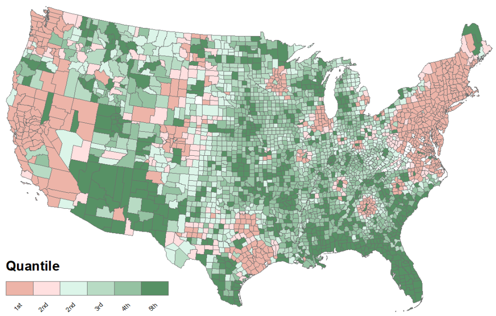
Table 2.C.2: Repealing the MID (varying public good provision)

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0.28	0.28	0.28
Commuting ($\sum_{n\neq i} \lambda'_{ni} / \sum_{n\neq i} \lambda_{ni}$)	-	-	-	0.78	−0.59	−0.14
Residents ($\hat{R}_n$)	-	-	-	0.78	−0.43	-
Regional income ($\hat{y}_{ni}$)	−0.05	−0.28	−0.21	−0.03	−0.32	−0.25
Wages ($\hat{w}_i$)	−0.05	−0.04	−0.04	−0.04	−0.03	−0.04
Housing costs ($\hat{r}_n$)	0.02	−0.08	−0.05	0.41	−0.32	−0.06
Price index ($\hat{P}_n$)	−0.06	−0.05	−0.05	−0.04	−0.03	−0.03
Real income ($\hat{y}_{ni}/\hat{P}_n^{\alpha} \hat{r}_n^{1-\alpha}$)	−0.02	−0.23	−0.16	−0.13	−0.20	−0.21

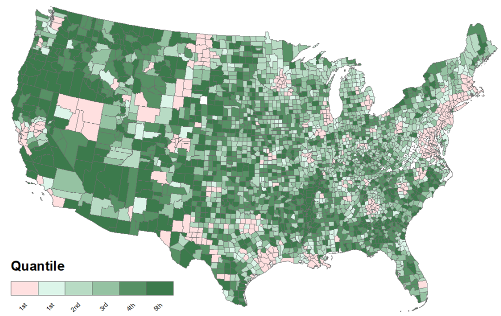
Notes: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns 1 to 3 workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns 4 to 6. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Figure 2.C.2: Repealing the MID (varying public good provision): County-level counterfactual changes

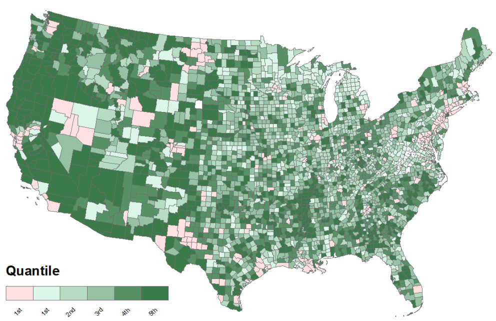
(a) Wages ($\hat{w}_n$)



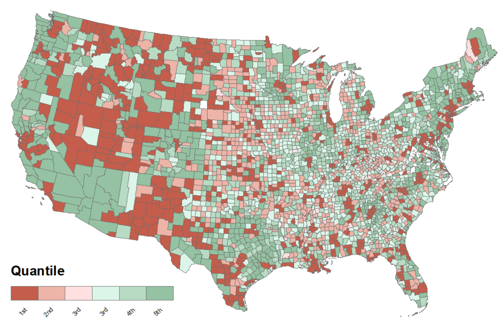
(b) Residents ($\hat{R}_n$)



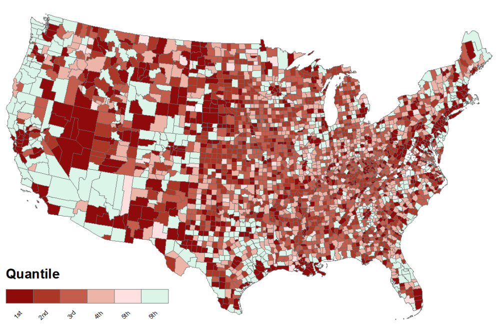
(c) Productivity ($\hat{a}_n$)



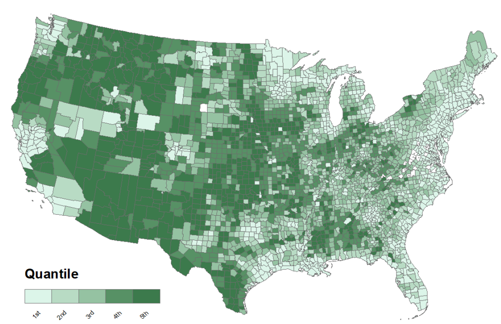
(d) In-commuters sh. - Own. ($\widehat{\sum_{n \neq i} \lambda^O_{ni}}/\hat{L}^O_i$)



(e) In-commuters - Owners ($\widehat{\sum_{n \neq i} \lambda^O_{ni}}$)



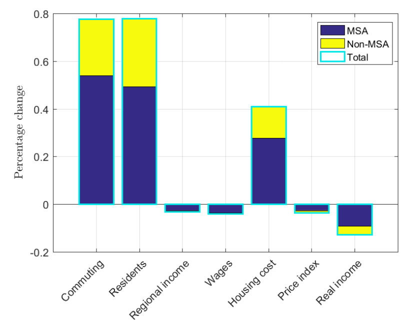
(f) Periodic housing cost - Renters ($\hat{r}^R_n$)



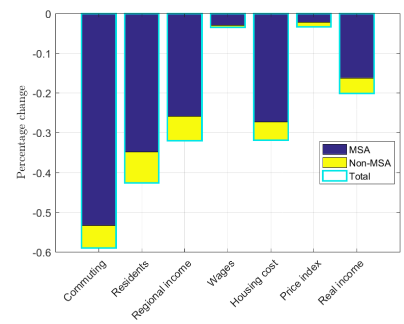
Notes: We compute counterfactual changes by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. Workers can change place of residence, place of work, and tenure mode. We depict positive (negative) growth in green (red). A darker shading represents a stronger effect.

Figure 2.C.3: Repealing the MID (varying public good provision): MSAs vs. countryside

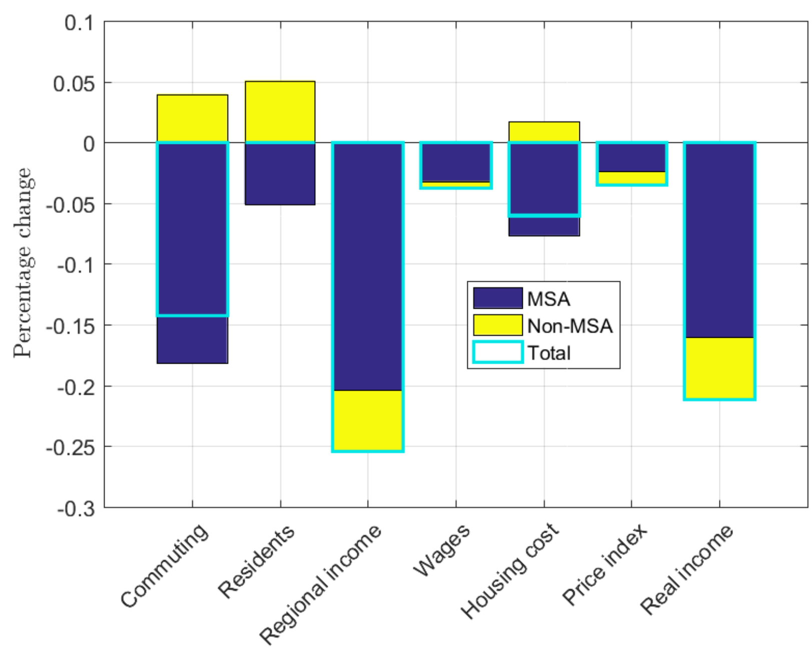
(a) Renters



(b) Owners



(c) Renters and owners



Notes: The figure depicts counterfactual changes obtained by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

2.D Model's extensions

In this section, we formalize two model extensions and present counterfactual results in the case of a MID repeal.

2.D.1 Property taxation

Property taxes account for less than one percent of the US federal tax revenue. However, because deductible from the taxable income at the federal level, *local* property taxes might affect the welfare and sorting decisions of individuals according to MID subsidies. In this section, we thus investigate the robustness of our results when households can deduct local property taxes from their taxable income in addition to MID subsidies.

In what follows we outline which equations of our baseline model change. Let τ_n^p denote local (county-level) property tax rates. Because owner-occupiers pay property taxes on the local housing value $\frac{1}{\iota}\frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}}$, their regional income is

$$y_{ni}^{\mathcal{O}} = w_i - \tau(w_i - \zeta_{ni}) + (1 - \frac{\tau_n^p}{\iota})\frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}} - m_{ni}, \tag{2.53}$$

where ζ_{ni} is given by

$$\zeta_{ni} = max\left(s, \theta m_{ni} + \frac{\tau_n^p}{\iota}\frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}}\right). \tag{2.54}$$

When choosing whether to itemize, owner-occupiers thus weigh the mortgage interests and property taxes against the standard deduction. We can rewrite the disposable income of owner-occupiers as

$$y_{ni}^{\mathcal{O}} = \frac{w_i - \tau(w_i - \zeta_{ni})}{\alpha + (\frac{\tau_n^p}{\iota} + \phi)(1 - \alpha)}. \tag{2.55}$$

From Equation (2.55) it is apparent that property taxation decreases the income of owner-occupiers with respect to our benchmark model.

To keep our model parsimonious , we assume that the tax revenue generated by property taxation is collected by the federal government and equally redistributed to workers. The federal budget must be balanced, such that

$$G = \frac{1}{\bar{L}} \sum_{n \in N} \left(\tau \bar{L} \sum_{k \in N} \lambda^{\mathcal{R}}_{nk} (w_k - s) + \tau \bar{L} \sum_{k \in N} \lambda^{\mathcal{O}}_{nk} (w_k - \zeta_{nk}) + \frac{\tau^p_n}{\iota} H^{\mathcal{O}}_n r^{\mathcal{O}}_n \right). \tag{2.56}$$

This approach allows us focus on the effect of the increase in tax deductions caused by property taxation without diving into considerations regarding the amount of local public good provision provided by local governments. In fact, note that the denominator in Equation (2.55) simplifies in our counterfactual simulations, such that ζ_{ni} is the main terms through which property taxation acts on workers' choices.

In our counterfactual simulations we set $\tau^p_n = 0.01$ across all location, This rate, which is based on the ACS 2009-2013, corresponds to the median payment of real estate taxes for the median housing value. We adjust the standard deduction to 8857 USD to match the observed itemization rate of individuals itemizing the MID. Table 2.D.1 and Figure 2.D.1 reports simulation results for repealing the MID in the presence of property taxes.

2.D.2 Progressive tax schedule

In general, tax deductions become more valuable with rising income due to the progressivity of the tax system. Because tax progressivity makes the MID a regressive subsidy, it creates an additional systematic link between a location's productivity and the tax incentives for owner-occupiers to live in that location. We test the robustness of our main results with respect to this additional sorting effect.

In what follows we illustrate how a progressive income taxation affects the equations of our baseline model. In line with the literature, we model progressive tax rates by introducing a parameter $\upsilon > 0$ governing the progressivity.[33] The per-capita income of owner-occupiers is

$$y^{\mathcal{O}}_{ni} = w_i - \tau^{O}_{ni} (w_i - \zeta_{ni}) + \frac{H^{\mathcal{O}}_{ni} r^{\mathcal{O}}_n}{\bar{L} \lambda^{\mathcal{O}}_{ni}} - m_{ni}, \tag{2.57}$$

where $\zeta_{ni} = max(s, \theta m_{ni})$ and the tax rate relevant for homeowners is given by

[33] see Eeckhout and Guner (2015), Heathcote et al. (2017) or Fajgelbaum et al. (2019).

$1 - \tau_{ni}^{O} = (1-\tau)(w_i - \zeta_{ni})^{-\upsilon}$. Renters' income is

$$y_{ni}^{\mathcal{R}} = w_i - \tau_i^{R}(w_i - s), \tag{2.58}$$

where the relevant tax rate is given by $1 - \tau_i^{R} = (1-\tau)(w_i - s)^{-\upsilon}$. The MID thus creates a tax rate differential between owner-occupiers and renters because it shifts taxable labor income according to tenure mode. Tax payments of owner-occupiers and renters are given by

$$T_{ni}^{\mathcal{O}} = w_i - (1-\tau)(w_i - \zeta_{ni})^{1-\upsilon} \tag{2.59}$$

and

$$T_i^{\mathcal{R}} = w_i - (1-\tau)(w_i - s)^{1-\upsilon}, \tag{2.60}$$

respectively. Per capita tax revenue of the federal government must equal per capita public good provision, such that

$$G = \frac{1}{\bar{\bar{L}}} \sum_{n \in N} \left(\bar{L} \sum_{\omega} \sum_{k \in N} \lambda_{nk}^{\omega} T_k^{\omega} \right). \tag{2.61}$$

A tax schedule is defined as progressive if marginal tax rates $\frac{\partial T^{\omega}}{\partial w}$ exceed the average tax rates $\frac{T^{\omega}}{w}$ for every level of wages w_n. This is true for renters and owner-occupiers if $\upsilon > 0$ and MID subsidies do not exist ($\theta = 0$). However, if $\upsilon > 0$ and MID subsidies are fully deductible ($\theta = 1$), the tax schedule is not necessarily progressive over the entire wage distribution of owner-occupiers. In fact, because owner-occupiers spend a constant share of their income for housing, the MID counteracts the progressive nature of the tax schedule. In this setting, at a specific cut-off point of the income distribution the tax schedule changes from regressive to progressive.

Our benchmark model features no tax progressivity ($\upsilon = 0$), thus imposing that marginal tax rates are equal to average tax rates. To introduce tax rate progressivity, we calibrate the progressivity parameter according to Eeckhout and Guner (2015), who estimate $\upsilon = 0.12$ for the US income tax system. We adapt the standard deduction to 6341 USD to match the observed share of people itemizing MID subsidies according to IRS data. Additionally, we calibrate the tax shifter τ to match the government revenue of our benchmark chase, such that the results in the case of progressive tax rates are not affected by changes in public expenditure at the federal level. Table 2.D.2 and Figure 2.D.2 report the results of repealing the MID in the presence of tax progressivity.

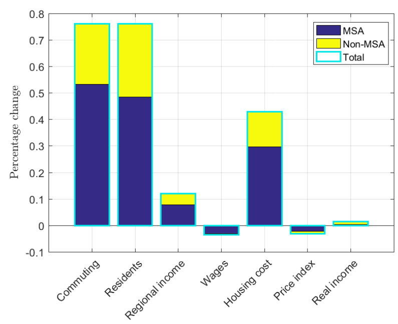
Table 2.D.1: Repealing the MID (property taxes)

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0	0	0
Commuting ($\sum_{n\neq i} \lambda'_{ni} / \sum_{n\neq i} \lambda_{ni}$)	-	-	-	0.76	-0.57	-0.13
Residents ($\hat{R}_n$)	-	-	-	0.76	-0.42	-
Regional income ($\hat{y}_{ni}$)	0.13	-0.10	-0.03	0.12	-0.16	-0.10
Wages ($\hat{w}_i$)	-0.04	-0.03	-0.03	-0.04	-0.03	-0.03
Housing costs ($\hat{r}_n$)	0.04	-0.06	-0.02	0.43	-0.28	-0.03
Price index ($\hat{P}_n$)	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03
Real income ($\hat{y}_{ni} / \hat{P}_n^{\alpha} \hat{r}_n^{1-\alpha}$)	0.15	-0.06	0.01	0.01	-0.06	-0.07

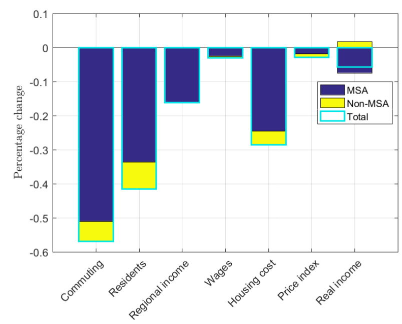
Notes: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns 1 to 3 workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns 4 to 6. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Figure 2.D.1: Impact of eliminating MID (property taxes): Decomposing welfare effects

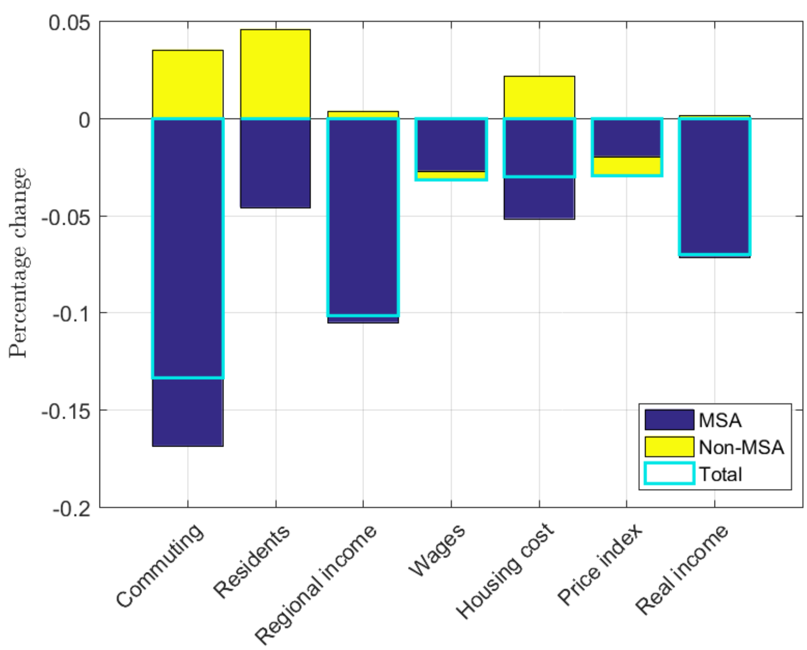
(a) Renters



(b) Owners



(c) Renters and owners



The figure depicts counterfactual changes obtained by setting $\theta = 0$. The header ‘owners’ denotes owner-occupiers. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

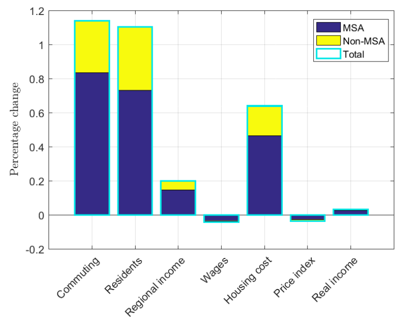
Table 2.D.2: Repealing the MID (tax progressivity)

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0.01	0.01	0.01
Commuting ($\sum_{n\neq i}\lambda'_{ni}/\sum_{n\neq i}\lambda_{ni}$)	-	-	-	1.14	-0.81	-0.17
Residents ($\hat{R}_n$)	-	-	-	1.10	-0.60	-
Regional income ($\hat{y}_{ni}$)	0.21	-0.13	-0.03	0.20	-0.21	-0.15
Wages ($\hat{w}_i$)	-0.03	-0.03	-0.03	-0.04	-0.04	-0.04
Housing costs ($\hat{r}_n$)	0.08	-0.07	-0.02	0.64	-0.40	-0.02
Price index ($\hat{P}_n$)	-0.04	-0.03	-0.04	-0.04	-0.04	-0.04
Real income ($\hat{y}_{ni}/\hat{P}_n^{\alpha}\hat{r}_n^{1-\alpha}$)	0.21	-0.09	0.01	0.03	-0.06	-0.11

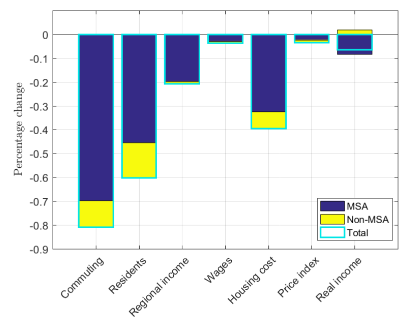
Notes: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns 1 to 3 workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns 4 to 6. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Figure 2.D.2: Impact of eliminating MID (tax progressivity): Decomposing welfare effects

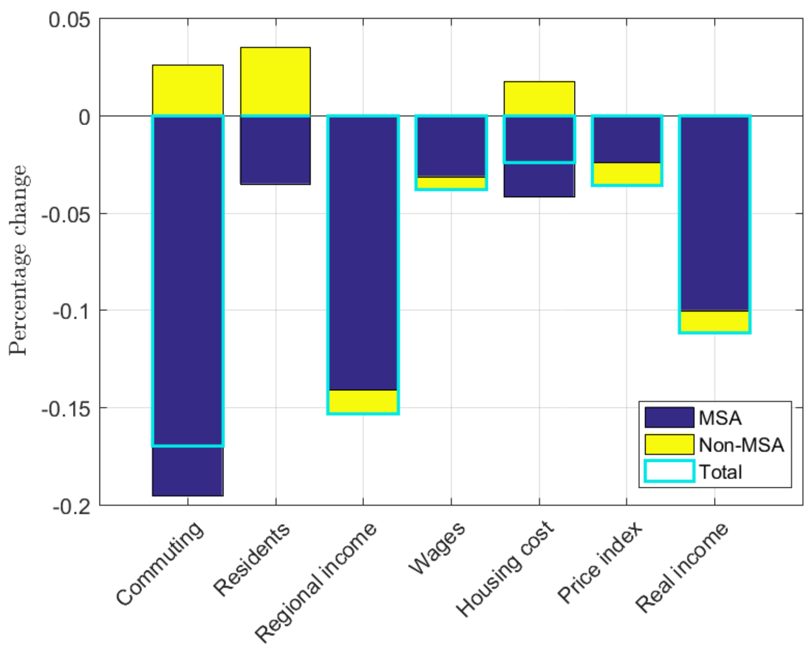
(a) Renters



(b) Owners



(c) Renters and owners



The figure depicts counterfactual changes obtained by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

3

Redevelopment option value for commercial real estate

joint with **Alex van de Minne**

3.1 Introduction

Land is a fundamental input in production and store of wealth of a country. Land values are critical to understanding the development of urban economies, and they are an essential source of revenue for local governments. Therefore, it is imperative to advance our knowledge of what constitutes land values. Location, characteristics, and the redevelopment option value determine the land value. However, the latter is often disregarded. The redevelopment option value is the option, without obligation, of changing the use of land and the physical structure built on that land to the highest and best use (HBU). Thus, the redevelopment potential affects property prices and plays a crucial role in how cities evolve.

In this study, we investigate the impact of the *redevelopment potential* on the individual value of commercial real estate properties within more than 30 American cities. We proceed as follows. Using Real Capital Analytics (RCA) data, we first measure the redevelopment potential as the stated intention by buyers to buy a property for redevelopment. To deal with the potential reverse causality bias between redevelopment potential and transaction prices, we instrument the redevelopment dummy with the fitted redevelopment potential. In the next step, we thus run a probit model to predict the redevelopment potential of a given property. We find that the difference between the current net operating income (NOI) per square foot of land (sfl) and the one associated with the potential highest and best use (HBU) of the property is a strong predictor of the redevelopment potential. Finally, we determine the impact of the redevelopment potential on transaction prices. Results show that having a 100 percent redevelopment potential increases the property's price by nine to 17 percent.

Because the choice to redevelop by investors mimics an American call option[1], it can be analyzed in an option pricing framework. Titman (1985) uses the real options approach to develop a simple equation for pricing vacant land. He shows that under uncertainty about the optimal future building intensity, it is often beneficial to delay investment and maintain the option to develop in the future. This is because the development call option is a levered derivative of the HBU, and this makes it very volatile. By applying a real option-pricing model to real estate development, Williams (1991) shows that the optimal date and intensity at which to develop a

[1] An American option can be exercised at any time up to the maturity date, whereas a European option can only be exercised at maturity.

property depends on the uncertain future revenues it generates and on its costs of development. Quigg (1993) is the first study to assess the empirical validity of the real option-pricing model in the case of real estate assets. Using data on land transactions for Seattle, she finds that investors are willing to pay a six percent price premium for plots of land having a development option. Using a similar framework, Grovenstein et al. (2011) theoretically and empirically determine the real option values of development and delay for vacant land in the City of Chicago. They find that the magnitude of the option premium varies substantially across individual land-use types.

Clapp and Salavei (2010), Clapp et al. (2012a), and Clapp et al. (2012b) devise a smart technique to estimate the redevelopment option value within the standard hedonic framework developed by Rosen (1974). They do that by adding the call option to the net present value of a property and using a measure of development intensity as a proxy for the redevelopment option value.[2] With this approach, the redevelopment option value is separated from the value of the property in its current use. However, both values are related to the characteristics of the property. For example, the present value of the property in its current use decreases with age, but its redevelopment option value increases with age. The authors also point out that the quantity of structural capital increases the value of the property in its current use but decreases the redevelopment option value. In contrast, McMillen and O'Sullivan (2013) find that under uncertainty over the future price of structural capital, the redevelopment option value may increase with the quantity of structural capital.

Munneke and Womack (2018) estimate the redevelopment option value by introducing the probability of redevelopment into the hedonic model. More specifically, they estimate the probability of redevelopment with a probit model and include it as an explanatory variable in a hedonic regression. The authors find that location is a significant determinant of redevelopment and that the redevelopment option values vary substantially across space.

We contribute to the literature in several ways. First, we estimate the redevelopment option value using a novel strategy relying on three different proxies for redevelopment. These proxies are the difference in NOI, floor-to-area ratio (FAR), and property type to those of surrounding properties developed at the HBU.

[2] As intensity measures the authors use the maximum floor space allowed minus the floor space already built, lagged assessed building value divided by assessed land value, and the ratio of the square footage of the property to the square footage of neighboring new constructions.

Second, using these proxies, we investigate the determinants leading investors to buy a property for redevelopment. Third, we examine *renovations* as a competing risk to redevelopments. This helps us document the differences in depreciation channels of a property. Finally, we fill the existing gap in studies analyzing the redevelopment option value for commercial real estate. In doing so, we differentiate between residential, office, retail, and industrial properties.

The remainder of the paper is structured as follows. Section 3.2 illustrates the conceptual framework for the valuation of redevelopment options. Section 3.3 presents the empirical methodology and discuses the identifying assumptions. Section 3.4 describes the rich data on commercial real estate and the construction of the proxy variables. Section 3.5 analyzes the results for the different estimation models and Section 3.6 concludes.

3.2 Conceptual framework

In this section, we lay out the fundamental mechanisms behind the valuation of redevelopment options. Figure 3.2.1 illustrates how the redevelopment option value is linked to land and property values over several real estate cycles. The horizontal axis shows the time, and the vertical axis shows the value of the property's components. At the points indicated by "D," the property is (re)developed. Each time this implies a large investment of capital to build a physical structure on a given plot of land.

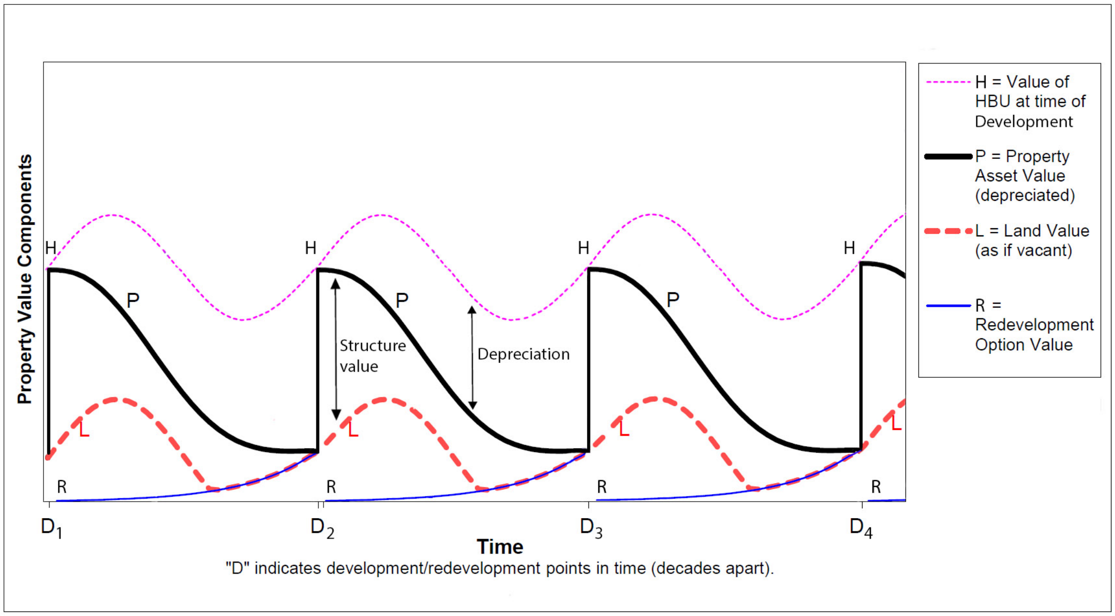
As Geltner et al. (2014) persuasively show with a real option value model, land is always developed or redeveloped at its HBU as-if-vacant. In other words, the developer builds the most profitable structure possible for that location at that point in time.[3] The dotted pink line "H" shows the HBU value over time. This value depends on the location's surroundings, secular trends, and capital flows that affect the property value. In our stylized figure, the fluctuations in H represent the volatility and cyclicality in the real estate market.

The solid black line "P" depicts the property asset value. This is the value the property would sell for in a well-functioning market. The dashed red line "L" illustrates the land value as if it were vacant. Following the residual theory of land value, this must equal the value of current HBU minus the cost of the physical

[3]Note that the developer takes the construction and demolition costs into account.

structure required to attain this HBU.[4] The jumps in the property asset value at times D reflects the investment of financial capital to develop or redevelop the physical structure.

Figure 3.2.1: Property and location value components over time



Notes: This figure is based on Figure 1 from Geltner et al. (2018).

Over time, the property depreciates due to physical, functional, and/or economic obsolescence. Physical obsolescence refers to the physical wear down of property, e.g., the chipping or fading of the paint. Functional obsolescence refers to changes in technology, tastes, and user requirements, e.g., building's sustainability has become increasingly important. Lastly, economic obsolescence refers to the case when the building's structure is no longer suitable to the HBU, and therefore is the wrong type. As pointed out by Geltner et al. (2018), this last type of obsolescence reflects the redevelopment option value.[5] When the value of the existing structure and land is equal (or less) to the value of vacant land and the demolition costs, the property is redeveloped. Brueckner (1980) and Wheaton (1982) outline this discernment theoretically.[6]

[4]In this figure, we assume that the construction costs remains approximately constant over time.

[5]Note that the redevelopment option value increases, over time, as the building structure depreciates, and the HBU evolves away from the current building structure.

[6]In bust periods, the HBU may be so low that it is not profitable to redevelop. This was the

The solid blue line “R” shows the redevelopment option value. Note that the redevelopment option value is not a separate asset or legal claim, but it is embedded in the land value. This call option can be exercised at any time upon payment of the physical structure to attain the HBU. The strike price of the redevelopment call option includes the demolition cost and the opportunity cost of the existing structure. This opportunity cost is the loss in NOI during the redevelopment. Right after a (re)development, the redevelopment option value is very low, because the opportunity cost of the new existing structure is very high. As time elapses and the HBU evolves, the redevelopment option value gets deeper in the money.

3.3 Empirical analysis

We build on Clapp and Salavei (2010) and express the (log) price per square foot P of a property as a linear function of redevelopment potential r and a vector of market and physical characteristics X:

$$P = \beta_0 + \beta_1 r + \beta_2 X + \epsilon, \tag{3.1}$$

where ϵ is the error term.[7] The sale price P includes the price of land and the value of the existing structure.

To consistently estimate (3.1) with OLS, the assumption $E[r\epsilon|X] = 0$ must hold. However, the literature tells us that the redevelopment potential r is a function of the price per sf P, implying that OLS estimates are plagued by reverse causality bias. Since, *ceteris paribus*, we expect that a higher price reduces the redevelopment potential, the OLS estimate $\hat{\beta}_{1,OLS}$ is biased downwards.

Typically, reverse causality is dealt with 2SLS models, instrumenting for the endogenous variable. However, we do not observe redevelopment potential r (a continuous variable). We only observe a binary variable r_d indicating whether or not a property was bought to be redeveloped. Since our variable of interest is an **endogenous dummy** (Vytlacil and Yildiz 2007), we follow Heckman (1978), Angrist and Krueger (2001), and Adams et al. (2009), and employ the following

case, e.g., in certain areas in Detroit after the Great Recession. In such cases, the redevelopment option value is zero. The right without obligation of the redevelopment option value means it cannot be negative.

[7]We omit property-level subscripts for readability.

procedure. First, we estimate a probit model of the determinants of redevelopment r_d. The model is given by:

$$Pr(r_d = 1|X, Z) = \Phi(\theta_0 + \theta_1 X + \theta_2 Z + \rho), \tag{3.2}$$

where $\Phi(.)$ is the cumulative standard normal distribution function, Z defines proxies for the determinants of redevelopment not included in (3.1), and ρ is the error term. After estimating (3.2), we derive a continuous redevelopment potential $\hat{r_p}$ by predicting fitted values according to the considered variables.

In the next step, we estimate a 2SLS model using the continuous fitted redevelopment potential $\hat{r_p}$ as an instrument for the redevelopment dummy r_d. More precisely, we estimate the equation

$$P = \beta_0 + \beta_1 r_d + \beta_2 X + \epsilon, \tag{3.3}$$

where the first stage is given by

$$r_d = \gamma_0 + \gamma_1 \hat{r_p} + \gamma_2 X + \epsilon', \tag{3.4}$$

where ϵ' is the error term. Our procedure is valid if our proxies Z only affect price P through the redevelopment option value. Note that this is different from just plugging in the fitted potential $\hat{r_p}$ directly into Equation (3.3) and running an OLS, i.e., regressing P on $\hat{r_p}$ and X directly. As pointed out by Angrist and Krueger (2001) this could lead to misspecification and inconsistent estimates. Our specification has several advantages. First, the IV standard errors are still asymptotically valid (Kelejian 1971). Second, we take the nature of the endogenous redevelopment dummy r_d into account. Third, we transform the redevelopment dummy r_d into a continuous redevelopment potential $\hat{r_d}$, which allows us to estimate the redevelopment option value for all the properties according to their characteristics.

3.4 Data and stylized facts

We rely on RCA georeferenced transaction data on commercial properties from 2001 to 2018. RCA captures over 90 percent of all commercial real estate transactions in the institutional investor space. This unique data set covers more than 30

American cities. It features property characteristics such as sales prices, NOI, size of land, FAR, year of sale, property type, location, and construction year. The data also contains information on the intent of purchase, i.e., whether it is used as an investment, or if the property will be redeveloped (see Bokhari and Geltner (2018)).

First, we split the data into two subsets. The first subset is data on newly developed properties, defined as everything built after 2001. This data is used to construct the proxies Z and is further discussed in Section 3.4.1. The second subset, are all the properties built before 2001 and is described in this Section. After filtering out extreme values and dropping missing values, we are left with almost 46,000 transactions between 2001 and 2018 of properties built before 2001. Of these nearly 46,000 properties, over five percent were purchased with the intent to be redeveloped, see Table 3.4.1. We split our data in 2001 because of two reasons. First, the data covers transaction prices from 2001 onwards. Second, commercial real estate cycles can span decades (Wheaton 1999).

All data comes directly from RCA, except for the NOI per sfl for the redevelopment properties. In approximately 70 percent of the cases, these properties have either missing or zero NOI, as the properties were already vacated for redevelopment.[8] Given that we are interested in the potential NOI per sfl of the existing structure, we impute the missing and zero NOIs as follows. First, we find the closest ten properties that are not being redeveloped, were built within ten years, were sold within five years, are within five kilometers, and are the same property type as the target property. Subsequently, we impute the weighted average NOI per sfl. The weight is determined by the inverse of the distance to the target property. We use market and property type-specific NOI indexes provided to us by RCA to correct the imputed NOIs if the year of sale of the "comparable" is different from the year of sale of the target property. Note that we only allow for a five-year difference and that we impute the NOI per square foot of **land** (sfl) and not structure. This is because investors want to maximize the income per sfl when they redevelop. The top panel of Table 3.4.1 shows descriptive statistics of all the transactions in this data set. The middle panel shows the same descriptive statistics of redevelopment properties, and the bottom panel shows the descriptive statistics of non-redevelopment properties.

[8]As is apparent from the data, the structure of properties with missing or zero NOI is still standing. We exclude development sites from the data.

Table 3.4.1: Descriptive statistics of data set

variable	**mean**	**SD**	**10%**	**90%**
Full sample (45,732 obs.)				
Redevelopments	0.055	0.227	0.000	0.000
Sales price per sfl	225.347	538.199	15.089	525.123
NOI per sfl	12.560	28.487	1.190	29.194
Distance to closest CBD (km)	24.464	30.583	5.190	50.056
Age	38.823	23.663	16.000	81.000
Floor area ratio (FAR)	0.940	1.383	0.217	2.410
Redevelopment properties (2,494 obs.)				
Sales price per sfl	389.875	823.417	14.954	980.137
NOI per sfl	24.038	45.162	1.576	69.154
Distance to closest CBD (km)	19.217	23.502	2.315	44.855
Age	47.561	26.812	18.000	91.000
Floor area ratio (FAR)	1.232	1.795	0.215	3.232
Non redevelopment properties (43,238 obs)				
Sales price per sfl	215.857	515.385	15.100	504.606
NOI per sfl	11.898	27.069	1.174	27.431
Distance to closest CBD (km)	24.767	30.915	5.371	50.290
Age	38.319	23.369	16.000	79.000
Floor area ratio (FAR)	0.923	1.354	0.217	2.350

Notes: All data provided to us by Real Capital Analytics (RCA) for the years 2001 until 2018, for properties built before 2001. SD is the standard deviation, lower is the 10^{th} quantile quantile and higher is the 90^{th} quantile. NOI is the Net Operating Income of the property. The floor area ratio is the amount of square foot divided by the sfl. CBD is the Central Business District, as defined by RCA. Age is the construction year of a property minus the year sold. The middle panel gives the descriptive statistics of a subset of our full sample (top panel) of redevelopment properties. The bottom panel gives the descriptive statistics of the subset of non-redevelopment properties.

Table 3.4.1 contains some interesting stylized facts. There are some clear differences between redevelopment properties and non-redevelopment properties. Note that the NOI and sales price per sfl for redevelopment properties are both approximately double the ones for non-redevelopment properties, while the FAR is only slightly larger. The FAR is 0.9 for non-redevelopment properties and 1.2 for redevelopment properties, whereas the NOI is $12 and $24 per sfl, respectively. Sales prices per sf are slightly less than double for redevelopment properties ($390) than for non-redevelopment properties ($215). Redevelopment properties are, on average, also closer to the central business district (CBD). All of this is consistent with the literature, i.e., redevelopments are triggered by high land values. As expected, the age of redevelopment properties is also higher than for non-redevelopment properties. This is because the redevelopment option value increases with age.

In our estimations, we include matrix X to control for the differences between redevelopment and non-redevelopment properties. This matrix contains the property's current NOI per sfl, which captures most of the unobserved heterogeneity; current $FAR = \frac{\text{Structure size}}{\text{Land size}}$; the property type; the age of the property[9]; time dummies; and location dummies. Thus, including X addresses the selection bias.

3.4.1 Constructing our proxies

As explicated in Section 3.3 the decision to redevelop is endogenous to the price of the property. To address the reverse causality we construct three proxies for redevelopment (relevance) that only affect prices through an increase in redevelopment potential (exogeneity).

We start by looking at the potential HBU of every property in our data. We construct the HBU, by assessing newly developed properties, making the (non-controversial) assumption, that developers always maximize their profits and thus, built according to the location's HBU. Therefore, we use the sample of newly constructed properties (constructed after 2001) to construct HBU metrics for our target properties (constructed before 2001). Our primary variable of interest is the NOI per sfl of the HBU property. We use this variable to compute the difference between the current (imputed) NOI of the existing structure, and the current (imputed) NOI of the HBU structure. This difference is a perfect proxy, as it is not affected by the property, nor the investor itself. The assumption is that the higher the potential gains of redevelopment, the higher the redevelopment potential.

For every property constructed before 2001 in our data, we match the closest ten newly developed properties (properties constructed after 2001), as long as they are within five kilometers, and are sold and built within five years of the target

[9]Note that most of the depreciation is captured by the current NOI of the property. What is left is the deprecation of the capitalization rate. This is sometimes also referred to as the "caprate creep".

property's transaction. To compute the potential NOI of these properties, we use the same weighted averaging approach as previously described. We also correct the imputed NOIs of the newly developed properties using the RCA NOI index if their transaction year differs the one of comparable properties. Note that the RCA NOI index are market and property type specific. Our first proxy variable is labeled N, and is defined as;

$$N = \left(\frac{\overline{NOI}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}} \right) - \left(\frac{NOI^{\text{current}}}{LS^{\text{current}}} \right),$$

where LS is the land size. Note that in theory NOI should capture all the characteristics of the property. Thus, the difference in NOI to the HBU is an excellent proxy for redevelopment.

We also construct two additional proxies, which are similar. The first one is related to the FAR of HBU properties. If newly constructed properties have higher densities compared to the target property, the land can achieve higher sales prices. This density proxy is similar to the intensity measures used in previous redevelopment option value literature for single-family housing, see Clapp et al. (2009, 2012a), Clapp and Salavei (2010) among others. This variable, labeled F, is given by:

$$F = \left(\frac{\overline{SS}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}} \right) - \left(\frac{SS^{\text{current}}}{LS^{\text{current}}} \right),$$

where SS is the structure size.

The second auxiliary proxy compares the type of the property, to the comparable HBU type of properties and takes a value between zero and one. RCA differentiates between four property types: residential, retail, industrial, and office. For example, if the comparable HBU properties are 80 percent residential and 20 percent retail, and the corresponding property is residential, the variable takes the value 0.8. If the corresponding property were retail, the value of the variable would be 0.2. A value of zero (one) for the property type variable indicates that none (all) of the newly developed properties are of the same property type. That is, the higher the value, the less economic obsolete is the property. In this case, we assume that the HBU use of the site can change. All three proxies capture the economic obsolescence channel that reflects the redevelopment option value. Table 3.4.2 shows some descriptive statistics of the proxies.

The descriptive statistics in Table 3.4.2 give a clear picture. The difference

Table 3.4.2: Descriptive statistics of our constructed proxies

variable	**mean**	**SD**	**10%**	**90%**
Full sample (45,732 obs.)				
$N = \left(\frac{\overline{NOI}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{NOI^{\text{current}}}{LS^{\text{current}}}\right)$	22.603	45.595	1.014	59.186
$F = \left(\frac{\overline{SS}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{SS^{\text{current}}}{LS^{\text{current}}}\right)$	0.504	1.511	-0.254	1.651
HBU property type similarity	0.354	0.259	0.000	0.700
Redevelopment properties (2,494 obs.)				
$N = \left(\frac{\overline{NOI}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{NOI^{\text{current}}}{LS^{\text{current}}}\right)$	39.190	61.628	1.410	124.204
$F = \left(\frac{\overline{SS}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{SS^{\text{current}}}{LS^{\text{current}}}\right)$	1.207	2.657	-0.298	4.252
HBU property type similarity	0.273	0.249	0.000	0.600
Non redevelopment properties (43,238 obs)				
$N = \left(\frac{\overline{NOI}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{NOI^{\text{current}}}{LS^{\text{current}}}\right)$	21.646	44.306	0.997	55.537
$F = \left(\frac{\overline{SS}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{SS^{\text{current}}}{LS^{\text{current}}}\right)$	0.463	1.406	-0.252	1.530
HBU property type similarity	0.359	0.259	0.000	0.700

Notes: All variables are the difference between the current existing structures, and the newly constructed HBU (highest and best use) structures. NOI is the net operating income, LS is the land size (in square foot), and SS is the size of the structure (in square foot). The "HBU property type similarity" is computed by looking at what percentage of the HBU properties is the same as the target property. The middle panel gives the descriptive statistics of a subset of our full sample (top panel) of redevelopment properties. The bottom panel gives the descriptive statistics of the subset of non-redevelopment properties.

of NOI to the HBU is, on average, \$40 per sfl for redevelopment properties. In contrast, it is only \$20 per sfl for non-redevelopment properties. Note that the magnitude of these differences are large, considering that the average NOI per sfl for the existing (redevelopment) property is \$24 (revisit Table 3.4.1). For our FAR variable, we find similar magnitudes. Newly constructed properties have a FAR that is 1.2 higher compared to the existing redevelopment properties, as opposed to "only" 0.5 higher FARs compared to the existing non-redevelopment properties. The descriptive statistics of our property type proxy show that of all the newly built properties, 27 percent (36 percent) are of the same property type as the target redevelopment (non-redevelopment) properties. This indicates that when the HBU property type changes in an area, the amount of redevelopments increase.

We argue that our three proxies satisfy the exclusion restriction because these measures epitomize “call options” that only materialize if the property is redeveloped. These proxies do not have a direct effect on prices. The higher the value of these “call options” the higher the redevelopment potential. Thus, they only affect the prices through the redevelopment potential.

3.5 Results

3.5.1 Determinants of redevelopment

Table 3.5.1 shows the results for our (reduced form) probit Equation (Equation 3.2). In the first column of Table 3.5.1 we show the results of the probit model for redevelopments when we include the log difference between the HBU NOI and the current NOI of every property ($\log N$). We find that the larger ($\log N$), the higher the potential of redeveloping. Our two other proxies also have the expected sign, see the second column of Table 3.5.1. The redevelopment potential increases with the HBU density measure (variable F) and decreases with the property type similarity proxy. In the third column, we combine all the proxies. Because of the high collinearity between NOI and square footage of the structure, combining the variables N and F results in insignificant estimates for N. Still, looking at our proxies separately, we find t-statistics of 4.2 for N in the first column, and 10.1 and -14.9 for the proxies in the second column. Thus, we conclude that our proxies not only move the redevelopment variable in the predicted direction but also that they are relevant. Note that the second model (ii) is the one with the best fit in terms of the Akaike information criterion (AIC).

The estimates of the remaining determinants X also have the expected sign. First, higher NOI per sfl increases the potential of the redevelopment. This is because higher NOI entails higher land values (higher economic activity), which in turn increases the redevelopment potential. However, note that holding NOI (and other variables) constant, an increase in density (FAR) results in a lower redevelopment potential. This is because it is more costly to demolish large structures. The further away a property is from the CBD, the lower the redevelopment potential, even after controlling for property level NOI and HBU

Table 3.5.1: Probit model: Determinants of redevelopments

Variable	**(i)**	**(ii)**	**(iii)**
(Intercept)	-2.632***	-2.291***	-2.306***
	(-11.56)	(-10.24)	(-10.06)
$\ln N = \ln\left(\left(\frac{\overline{NOI}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{NOI^{\text{current}}}{LS^{\text{current}}}\right)\right)$	0.037***		0.003
	(4.20)		(0.30)
$\ln F = \ln\left(\left(\frac{\overline{SS}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \left(\frac{SS^{\text{current}}}{LS^{\text{current}}}\right)\right)$		0.091***	0.090***
		(10.06)	(9.19)
HBU property type similarity		-0.681***	-0.681***
		(-14.93)	(-14.93)
$\ln \frac{\text{NOI}}{\text{LS}}$	0.298***	0.276***	0.276***
	(15.02)	(13.70)	(13.68)
ln Distance to closest CBD	-0.119***	-0.097***	-0.096***
	(-7.71)	(-6.36)	(-6.16)
Age	0.027***	0.023***	0.023***
	(13.70)	(11.54)	(11.52)
	(-11.24)	(-9.16)	(-9.15)
$\ln \frac{\text{SS}}{\text{LS}}$ (FAR)	-0.333***	-0.294***	-0.294***
	(-14.00)	(-12.36)	(-12.36)
Time fe	Yes	Yes	Yes
Metro fe	Yes	Yes	Yes
Property type fe	Yes	Yes	Yes
AIC	17,125	16,773	16,775

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Dependent variable is a 1/0 dummy indicating whether or not the property was bought with the intent of redeveloping it. NOI is the properties net operating income, LS is the size of the land (in square foot), and SS is the size of the structure (in square foot). CBD is the closest central business district, as defined by RCA. HBU is the highest and best use, measured by looking at newly developed properties surrounding the target property. The "HBU property type similarity" is computed by looking at what percentage of the HBU properties is the same as the target property. AIC is the Akaike Information Criterium.

variables. Similarly, age and age squared are also significant after controlling for property level NOI and HBU variables. It is well established that most depreciation is embedded into the NOI (which we control for); see Bokhari and Geltner (2018). Thus, the fact that we still find significant estimates for distance to closest CBD, age, and age squared, is most likely caused by "cap rate creep" (the depreciation of the cap rate). In other words, investors **expect** that older properties will generate less NOI in the future, therefore increasing the redevelopment potential.

The fixed effects for year of sale, property types, and MSAs are shown in Tables 3.A.1 – 3.A.2 in the Appendix. The year of sale dummies control for the macro-economic environment, which is not explained by the NOI. The highest redevelopment potential was in 2005, with an estimate of 0.995. The results show a similar redevelopment potential at the beginning and the end of our data sample. Although, as previously noted, we control for NOI, and the average NOI increased considerably between 2000 – 2018. Of all the property types, *ceteris paribus*, industrial properties are the most likely to be redeveloped, followed by retail, office, and residential properties. Since industrial properties are typically cheaper to demolish, this result is unsurprising. Finally, the MSA dummies control for local zoning, and the competitiveness of the development industry. Most of these estimates are not significant. Interestingly, all coefficients for MSAs in Florida are positive and significant, indicating that there is more development in Florida than can be explainable by NOI alone. The MSA with the least development, *ceteris paribus*, is Portland, Oregon. This is unsurprising, given that Portland is known to have stringent zoning and geographic restrictions (Saiz 2010).

3.5.2 Redevelopment option value

Table 3.5.2 shows the estimates of the redevelopment option value model. The first column of Table 3.5.2 shows the OLS results, where redevelopment is a dummy indicating if a property was bought to be redeveloped. This estimation ignores the reverse causality between redevelopment and prices. We find a significant and negative price-redevelopment elasticity of -0.072. However, as argued throughout this paper, we do not believe this to be a causal relationship. To estimate the causal relationship between prices and redevelopment, we apply our methodology described in Section 3.3, and use the fitted values for the redevelopment potential from Table 3.5.1 as an instrument. The second to the fourth column of Table 3.5.2 shows these results. When instrumenting for redevelopments, we find a strong and positive coefficient for redevelopment. In the second column we find that whenever a property has a 100 percent redevelopment potential, the price of the property, *ceteris paribus*, increases by 17 percent. Using the other proxies slightly attenuates this effect. A 100 percent redevelopment potential increases the price of the property by nine percent. From the Hausman (1978) test (not shown here, but available upon request), we conclude that the difference between the IV model estimates (second to fourth column) and the standard OLS model (first column) estimate are statistically significant. The first IV model (second column) features the largest t-statistic, although the fit is equal between the models. See the adjusted R^2 and the root mean squared errors (RMSE) at the bottom of Table 3.5.2.

The remaining estimates have the expected sign and magnitude and hardly change between the models. Higher NOI and more square feet result in higher prices. We also find evidence of "cap rate creep", i.e., the depreciation of cap rates. Even when controlling for NOI the distance to the CBD is still significant. This means, that properties further away from the CBD trade with a higher cap rate, resulting in lower prices.

The year fixed effects (see Table 3.A.3 in the Appendix) reveal that prices increased until 2007/2008, then dropped, and subsequently increased again after 2011. Given that we already control for NOI, we interpret the year fixed effect estimates as the inverse of cap rates. As such, cap rates are at its lowest at the end of our sample in 2018. Furthermore, the property type fixed effects (see Table 3.A.3 in the Appendix) show that apartments trade with the lowest cap rates, followed by retail, office, and industrial properties. Comparing the MSAs with each other (see Table 3.A.4 in the Appendix), we conclude that most West coast MSAs trade with a relatively low cap rate (San Francisco, Los Angeles, San Diego, but also Seattle), as well as New York, Boston, and Washington DC. We find the highest cap rate in Jacksonville.

3.5.3 Auxiliary Regressions

As robustness, we estimate two additional models. In the first one, we sightly change our redevelopment option value proxies. In our primary model we use the log absolute differences in NOI and FAR per sfl between the HBU and the current property. For this model, we use the log relative difference in NOI and FAR per sfl between the HBU and the current property. The additional two variables ΔN and

Table 3.5.2: Redevelopment option value model

Variable	**OLS**	**IV (i)**	**IV (ii)**	**IV (iii)**
(Intercept)	3.122***	3.122***	3.122***	3.122***
	(99.29)	(99.19)	(99.19)	(99.19)
Redevelopment	-0.072***	0.173***	0.094**	0.105***
	(-9.19)	(3.68)	(2.43)	(2.70)
$\ln \frac{\text{NOI}}{\text{LS}}$	0.788***	0.776***	0.780***	0.780***
	(220.71)	(184.46)	(194.53)	(194.40)
ln Distance to closest CBD	-0.034***	-0.030***	-0.031***	-0.031***
	(-13.71)	(-11.49)	(-12.18)	(-12.11)
Age	-0.011***	-0.012***	-0.012***	-0.012***
	(-34.04)	(-32.94)	(-33.25)	(-33.35)
	(31.28)	(31.14)	(31.18)	(31.26)
$\ln \frac{\text{SS}}{\text{LS}}$ (FAR)	0.267***	0.281***	0.276***	0.277***
	(60.03)	(54.84)	(56.29)	(56.41)
Time fe	Yes	Yes	Yes	Yes
Metro fe	Yes	Yes	Yes	Yes
Property type fe	Yes	Yes	Yes	Yes
R^2	0.93	0.93	0.93	0.93
RMSE	0.37	0.37	0.37	0.37

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Dependent variable is log of transaction price per sfl $\ln P$. NOI is the properties net operating income, and SS is the size of the structure (in square foot). CBD is the closest central business district, as defined by RCA. For the IV models we instrument for the redevelopment dummy with the fitted redevelopment potential. In the first IV (i) model we only use the fitted redevelopment potential estimated with the log difference in NOI of the HBU properties and the target property, or $\ln N$. In the second model we use the fitted redevelopment potential estimated with the log difference in FAR between the HBU and the current property, or $\ln F$, and the percentage of properties built within our defined area that are of the same property type as the target property. In the third IV (iii) we use the fitted redevelopment potential estimated with all proxies.

ΔF are given by[10]:

$$\Delta N = \ln\left(\frac{\overline{NOI}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \ln\left(\frac{NOI^{\text{current}}}{LS^{\text{current}}}\right),$$

$$\Delta F = \ln\left(\frac{\overline{SS}^{\text{hbu}}}{\overline{LS}^{\text{hbu}}}\right) - \ln\left(\frac{SS^{\text{current}}}{LS^{\text{current}}}\right).$$

[10]Note that our proxy HBU property type similarity remains identical.

We omit the discussion of the results of the probit model and the fixed effects here. These are available upon request. Table 3.5.3 shows the results of our auxiliary redevelopment option value model. We find that all the estimates remain robust. The price of a property with 100 percent redevelopment potential increases between 11 percent and 21 percent. The fit does not change according to the adjusted R^2, and root mean squared error (RMSE) (see bottom of Table 3.5.3).

For our second auxiliary model, we utilize RCA data on renovations. RCA's definition of renovation is widely defined, and can be anything from a new lobby area to an entirely new interior for a property. Still, there are many similarities between renovations and redevelopments. Most importantly, they both entail considerable capital expenditures that are not related to the day to day maintenance of the property. However, there are also extensive differences. Renovations cannot redress economic obsolescence. If HBU densities and property type use change, the property owner will need to redevelop. Rather, renovations redress physical and functional obsolescence (Francke and Van de Minne 2017), meaning modernizing the existing structure in such a way that they match current day tastes and preferences (without changing property type). Therefore, we see renovations as a **competing risk** to redevelopments. In other words, at any time, an investor can decide whether to renovate or redevelop a property (or sell it as an investment property obviously), but not both simultaneously. This does not mean we expect similar signs or magnitudes with this model. For example, properties that are very economically obsolete might not be worth renovating. In contrast, more expensive properties - in the right area - are expected to be renovated instead of redeveloped.

In our data, we find that approximately six percent of the properties were bought to be renovated, slightly more than to be redeveloped (which is 5.5 percent, see Table 3.4.1). We use the same procedures and proxies (i.e., the log of the absolute differences in NOI and FAR to the HBU) as in our primary model. In general, we expect that properties that are more disparate from their potential HBU, are not worth renovating.

Determinants of renovations

Table 3.5.4 shows the results of the probit model for renovations. Comparing the results from the probit model for redevelopments (Table 3.5.1) with the one for renovations (Table 3.5.4) yields some interesting insights. Compared to the

Table 3.5.3: Auxiliary redevelopment option value model

Variable	**IV (i)**	**IV (ii)**	**IV (iii)**
(Intercept)	3.122***	3.122***	3.122***
	(99.21)	(99.19)	(99.20)
Redevelopment	0.206***	0.108***	0.138***
	(5.53)	(2.74)	(3.48)
ln $\frac{\text{NOI}}{\text{LS}}$	0.772***	0.780***	0.778***
	(183.63)	(193.42)	(193.10)
ln Distance to closest CBD	-0.029***	-0.031***	-0.031***
	(-10.93)	(-12.07)	(-11.87)
Age	-0.012***	-0.012***	-0.012***
	(-33.77)	(-33.28)	(-33.57)
	(31.81)	(31.23)	(31.45)
ln $\frac{\text{SS}}{\text{LS}}$ (FAR)	0.285***	0.277***	0.279***
	(55.80)	(56.22)	(56.55)
Time fe	Yes	Yes	Yes
Metro fe	Yes	Yes	Yes
Property type fe	Yes	Yes	Yes
R^2	0.93	0.93	0.93
RMSE	0.37	0.37	0.37

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Dependent variable is log of transaction price per sfl $\ln P$. NOI is the properties net operating income, and SS is the size of the structure (in square foot). CBD is the closest central business district, as defined by RCA. For the IV models we instrument for the redevelopment dummy with the fitted redevelopment potential. In the first IV (i) model we only use the fitted redevelopment potential estimated with the log relative difference in NOI of the HBU properties and the target property, or ΔN. In the second model we use the fitted redevelopment potential estimated with the log relative difference in FAR between the HBU and the current property, or ΔF, and the percentage of properties built within our defined area that are of the same property type as the target property. In the third IV (iii) we use the fitted redevelopment potential estimated with all proxies.

redevelopment model, the renovation model estimates flip sign, are attenuated, or are insignificant altogether. Remarkably, our NOI proxy (log N) does not impact the renovation potentials. Nor does the current NOI. FAR has a positive effect on the renovation potential, whereas it was negative on the redevelopment potential. Larger structures are more costly to redevelop, and as such, the only way to increase

Table 3.5.4: Probit model: Determinants of renovations

Variable	**(i)**	**(ii)**	**(iii)**
(Intercept)	-1.948***	-1.836***	-1.884***
	(-9.53)	(-9.14)	(-9.14)
$\ln N = \ln\left(\left(\frac{NOI^{\text{hbu}}}{LS^{\text{hbu}}}\right) - \left(\frac{NOI^{\text{current}}}{LS^{\text{current}}}\right)\right)$	-0.004		0.009
	(-0.45)		(1.03)
$\ln F = \ln\left(\left(\frac{SS^{\text{hbu}}}{LS^{\text{hbu}}}\right) - \left(\frac{SS^{\text{current}}}{LS^{\text{current}}}\right)\right)$		-0.018**	-0.021***
		(-2.36)	(-2.57)
HBU property type similarity		-0.261***	-0.265***
		(-6.16)	(-6.23)
$\ln \frac{\text{NOI}}{\text{LS}}$	0.007	0.022	0.022
	(0.33)	(1.06)	(1.03)
ln Distance to closest CBD	0.003	-0.006	-0.002
	(0.21)	(-0.39)	(-0.16)
Age	0.005***	0.005**	0.005**
	(2.60)	(2.52)	(2.45)
$\ln \frac{\text{SS}}{\text{LS}}$ (FAR)	0.056**	0.061**	0.061**
	(2.16)	(2.37)	(2.35)
Time fe	Yes	Yes	Yes
Metro fe	Yes	Yes	Yes
Property type fe	Yes	Yes	Yes
AIC	19,368	19,325	19,326

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Dependent variable is a 1/0 dummy indicating whether or not the property was bought with the intent of renovating it. NOI is the properties net operating income, LS is the size of the land (in square foot), and SS is the size of the structure (in square foot). CBD is the closest central business district, as defined by RCA. HBU is the highest and best use, measured by looking at newly developed properties surrounding the target property. The “HBU property type similarity” is computed by looking at what percentage of the HBU properties is the same as the target property. AIC is the Akaike Information Criterium.

NOI is by renovating the current property. An increase in the difference of FAR to the HBU decreases the renovation potential. The competing risk of redevelopment most likely causes this. If an investor can considerably increase its NOI by increasing the FAR through redevelopment, she will likely not deem any renovations worth it. Our third proxy, the proxy, HBU property type similarity, remains significant and negative, although the effect is attenuated (compared to redevelopment). If the current structure has the same use as the HBU property, the renovation potential decreases. Given that our NOI proxy (log N) is insignificant in all renovation models, we can conclude that it is not relevant. For the sake of consistency, we still report the results when using this proxy in the renovation model.

Price of renovation properties

In Table 3.5.5 we present the estimates for the renovation model. Note that the variable “renovation” is a binary variable indicating properties that were bought to be renovated and not properties that were recently renovated. The OLS model (which ignores the endogeneity issues) yields a small but significant negative effect of renovations on prices (see first column of Table 3.5.5). The results for the first IV model (IV (i)) are insignificant. This is hardly surprising, given that the proxy used in this column (log N) is insignificant in the probit model (see Table 3.5.4). Using the highly significant proxies in the second IV model (IV (ii)) we find that a property that needs to be renovated (100 percent renovation potential) trades with a 44 percent discount compared to a newly renovated property (zero percent renovation potential). Since the renovation model captures the physical and functional obsolescence channels, this is hardly surprising. This discount represents the investment of financial capital needed to bring to reverse the physical and functional depreciation. The final column shows the results if we use all the proxies, including the insignificant one (log N). These results indicate that a 100 percent renovation renovation potential decreases the price by 28 percent. All other estimates remain mostly unchanged compared to our earlier findings with the redevelopment option value model. The fixed effects estimates (for both the probit and renovation model) are available upon request.

3.6 Conclusions

As urban areas age, redevelopment and renovation become ever more critical. To analyze how the redevelopment potential affects commercial property prices, we employ a novel strategy that addresses the reverse causality and sample selection bias. Moreover, we provide information on the determinants of redevelopment and renovation.

Table 3.5.5: Renovation model

Variable	**OLS**	**IV (i)**	**IV (ii)**	**IV (iii)**
(Intercept)	3.123***	3.121***	3.139***	3.133***
	(99.25)	(98.64)	(99.29)	(99.07)
Renovation	-0.032***	0.037	-0.441***	-0.280***
	(-4.24)	(0.45)	(-5.50)	(-3.49)
$\ln \frac{NOI}{LS}$	0.785***	0.785***	0.786***	0.785***
	(220.83)	(220.51)	(220.87)	(220.73)
ln Distance to closest CBD	-0.033***	-0.033***	-0.033***	-0.033***
	(-13.22)	(-13.23)	(-13.13)	(-13.16)
Age	-0.011***	-0.011***	-0.011***	-0.011***
	(-34.82)	(-34.61)	(-33.85)	(-34.11)
	(31.79)	(30.75)	(29.19)	(29.74)
$\ln \frac{SS}{LS}$ (FAR)	0.272***	0.271***	0.274***	0.273***
	(61.19)	(60.82)	(61.41)	(61.21)
Time fe	Yes	Yes	Yes	Yes
Metro fe	Yes	Yes	Yes	Yes
Property type fe	Yes	Yes	Yes	Yes
R^2	0.93	0.93	0.93	0.93
RMSE	0.37	0.37	0.37	0.37

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. Dependent variable is log of transaction price per sfl $\ln P$. NOI is the properties net operating income, and SS is the size of the structure (in square foot). CBD is the closest central business district, as defined by RCA. For the IV models we instrument for the renovation dummy with the fitted renovation potential. In the first IV (i) model we only use the fitted renovation potential estimated with the log difference in NOI of the HBU properties and the target property, or $\ln N$. In the second model we use the fitted renovation potential estimated with the log difference in FAR between the HBU and the current property, or $\ln F$, and the percentage of properties built within our defined area that are of the same property type as the target property. In the third IV (iii) we use the fitted renovation potential estimated with all proxies.

We find that a larger difference to the HBU in NOI and FAR, as well as being the wrong type of property, significantly increase the redevelopment potential for commercial real estate. These three proxies capture the economic obsolescence channel. Moreover, the redevelopment potential increases with the property's NOI, age, and proximity to the CBD. In contrast, higher FAR decreases the redevelopment potential because it leads to higher demolition costs. Industrial properties are most likely to be redeveloped, followed by retail, office, and residential properties. Our estimations suggest that having a 100 percent redevelopment potential increases the property's price by nine to 17 percent. We also find that the redevelopment option value is very heterogeneous across American cities.

Further, we find that neither the difference to the HBU in NOI nor the property's NOI drives the renovation potential. Property's FAR has a positive impact on the renovation potential, while the difference to the HBU in FAR has a negative one. As with redevelopments, being the wrong property type increases the renovation potential, although the effect is much smaller. On average, a property that needs to be renovated trades with a 28 to 44 percent discount compared to a newly renovated property. This reflects the physical and functional obsolescence of the property.

Our results hold essential lessons for the understanding of the development of urban economies. First, potential NOI is one of the main drivers of redevelopment for commercial real estate. Second, high land values trigger redevelopments.

3.A Fixed effect tables

Table 3.A.1: Probit model: Year and property type fixed effects

Variable	**(i)**	**(ii)**	**(iii)**	**Obs.**
Year of Sale				
2000 (Ref.)	0.000	0.000	0.000	574
2001	0.062	0.064	0.064	730
2002	0.055	0.059	0.059	899
2003	0.199	0.193	0.194	1,127
2004	0.610***	0.603***	0.604***	1,775
2005	0.995***	0.994***	0.994***	3,893
2006	0.789***	0.806***	0.807***	3,888
2007	0.533***	0.549***	0.549***	3,675
2008	0.408***	0.432***	0.433***	1,815
2009	0.295*	0.322*	0.323*	833
2010	0.251	0.281*	0.281*	1,282
2011	0.424***	0.431***	0.431***	2,204
2012	0.431***	0.452***	0.452***	2,998
2013	0.631***	0.660***	0.661***	3,278
2014	0.402***	0.418***	0.418***	3,557
2015	0.300**	0.310**	0.310**	3,819
2016	0.227	0.241	0.241	3,464
2017	0.105	0.106	0.106	3,085
2018	-0.019	-0.019	-0.019	2,836
Property type				
Apartment (Ref.)	0.000	0.000	0.000	23,491
Industrial	0.635***	0.549***	0.549***	6,623
Office	0.214***	0.149***	0.149***	8,038
Retail	0.224***	0.211***	0.212***	7,580

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. This table shows the year fixed effects results for the Probit model in Table 3.5.1. The frequency of the variables is also given by Obs. Ref. gives the reference (omitted) category.

Table 3.A.2: Probit model: Metro area fixed effects

Variable	**IV (i)**	**IV (ii)**	**IV (iii)**	**Obs.**
Metro area				
Atlanta (Ref.)	0.000	0.000	0.000	2,221
Baltimore	0.059	0.075	0.076	375
Boston Metro	0.208**	0.228**	0.227**	580
Charlotte	0.100	0.117	0.118	512
Chicago	0.215***	0.257***	0.257***	1,098
Co Springs	0.151	0.120	0.124	253
Dallas	0.036	0.006	0.007	1,289
Denver	-0.128	-0.067	-0.066	1,475
Houston	-0.089	-0.130	-0.129	832
Jacksonville	0.294**	0.354***	0.356***	435
Los Angeles	-0.107	-0.067	-0.068	7,990
Las Vegas	-0.061	-0.046	-0.046	910
Miami/So Fla	0.489***	0.457***	0.457***	2,041
Minneapolis	0.176*	0.176*	0.176*	515
Nashville	0.105	0.079	0.080	383
New York	0.054	0.060	0.059	3,897
Orlando	0.309***	0.339***	0.340***	605
Philly Metro	0.042	0.053	0.053	545
Phoenix	0.200***	0.200***	0.202***	2,669
Portland	-0.252**	-0.288**	-0.287**	658
Raleigh/Durham	-0.185	-0.192	-0.190	526
Rest	0.009	0.023	0.025	5,434
San Diego	0.099	0.110	0.110	1,476
Seattle	0.081	0.067	0.066	1,943
San Francisco	-0.092	-0.115	-0.118	4,043
St Louis	0.207	0.200	0.203	200
Tampa	0.335***	0.317***	0.318***	1,059
Tucson	0.036	0.042	0.044	388
Washington DC	-0.081	-0.016	-0.018	1,380

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. This table shows the metro area fixed effects results for the Probit model in Table 3.5.1. The frequency of the variables is also given by Obs. Ref. gives the reference (omitted) category. We only include Metro areas with at least 10 redevelopments. The remaining ones are are combined in the "rest" category.

Table 3.A.3: Redevelopment option value model: Year and property type fixed effects

Variable	**OLS**	**IV (i)**	**IV (ii)**	**IV (iii)**	**Obs.**
Year of Sale					
2000 (Ref.)	0.000	0.000	0.000	0.000	574
2001	0.085***	0.084***	0.084***	0.084***	730
2002	0.127***	0.127***	0.127***	0.127***	899
2003	0.210***	0.209***	0.209***	0.209***	1,127
2004	0.329***	0.321***	0.324***	0.323***	1,775
2005	0.476***	0.456***	0.463***	0.462***	3,893
2006	0.540***	0.527***	0.531***	0.530***	3,888
2007	0.573***	0.567***	0.569***	0.569***	3,675
2008	0.531***	0.529***	0.530***	0.529***	1,815
2009	0.326***	0.325***	0.325***	0.325***	833
2010	0.287***	0.287***	0.287***	0.287***	1,282
2011	0.354***	0.350***	0.351***	0.351***	2,204
2012	0.381***	0.378***	0.379***	0.378***	2,998
2013	0.455***	0.447***	0.449***	0.449***	3,278
2014	0.543***	0.541***	0.542***	0.541***	3,557
2015	0.629***	0.629***	0.629***	0.629***	3,819
2016	0.681***	0.683***	0.682***	0.683***	3,464
2017	0.716***	0.721***	0.719***	0.719***	3,085
2018	0.780***	0.788***	0.785***	0.786***	2,836
Property type					
Apartment (Ref.)	0.000	0.000	0.000	0.000	23,491
Industrial	-0.243***	-0.261***	-0.255****	-0.256***	6,623
Office	-0.160***	-0.163***	-0.162***	-0.162***	8,038
Retail	-0.029***	-0.032****	-0.031***	-0.031***	7,580

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. This table shows the year fixed effects results for the 2SLS model in Table 3.5.2. The frequency of the variables is also given by Obs. Ref. gives the reference (omitted) category.

Table 3.A.4: Redevelopment option value model: Metro area fixed effects

Variable	**OLS**	**IV (i)**	**IV (ii)**	**IV (iii)**	**Obs.**
Metro area					
Atlanta (Ref.)	0.000	0.000	0.000	0.000	2,221
Baltimore	0.108***	0.110***	0.110***	0.110***	375
Boston Metro	0.279***	0.272***	0.275***	0.274***	580
Charlotte	0.032*	0.032*	0.032*	0.032*	512
Chicago	0.076***	0.072***	0.073***	0.073***	1,098
Co Springs	-0.029	-0.028	-0.028	-0.028	253
Dallas	-0.003	-0.005	-0.004	-0.004	1289
Denver	0.132***	0.139***	0.137***	0.137***	1,475
Houston	-0.015	-0.015	-0.015	-0.015	832
Jacksonville	-0.061***	-0.065***	-0.063***	-0.064***	435
Los Angeles	0.446***	0.452***	0.450***	0.451***	7,990
Las Vegas	0.030**	0.034**	0.033	0.033	910
Miami/So Fla	0.260***	0.248***	0.252***	0.251***	2,041
Minneapolis	0.050***	0.048***	0.049***	0.049***	515
Nashville	0.006	0.004	0.005	0.005	383
New York	0.331***	0.331***	0.331***	0.331***	3,897
Orlando	0.055***	0.051***	0.052***	0.052***	605
Philly Metro	0.104***	0.106***	0.106***	0.106***	545
Phoenix	0.081***	0.079***	0.079***	0.079***	2,669
Portland	0.151***	0.157***	0.155***	0.155***	658
Raleigh/Durham	0.079***	0.083***	0.082***	0.082***	526
Rest	-0.012	-0.012	-0.012	-0.012	5,434
San Diego	0.400***	0.402***	0.401***	0.401***	1,476
Seattle	0.310***	0.310***	0.310***	0.310***	1943
San Francisco	0.498***	0.505***	0.503***	0.503***	4,043
St Louis	-0.004	-0.006	-0.005	-0.005	200
Tampa	0.046***	0.040***	0.042***	0.042***	1,059
Tucson	-0.015	-0.015	-0.015	-0.015	388
Washington DC	0.259***	0.265***	0.263***	0.263***	1,380

Notes: Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. This table shows the metro area fixed effects results for the 2SLS model in Table 3.5.2. The frequency of the variables is also given by Obs. Ref. gives the reference (omitted) category. We only include Metro areas with at least 10 redevelopments. The remaining ones are are combined in the "rest" category.

4

A methodology to quantify land-use regulation in Switzerland

4.1 Introduction

Local land-use regulations affect the extension, location, and architecture of residential development. The existing literature establishes a clear relationship between land-use regulations and inelastic housing supply.[1] As documented by Glaeser and Gyourko (2018), the inelastic housing supply has deep economic implications. Inelastic housing supply leads to higher house prices (Cosman et al. 2018, Hilber and Vermeulen 2016), spatial misallocation of labor (Hsieh and Moretti 2019), and lower migration response of households (Diamond 2017). However, land-use regulations also foster economic, environmental, and social goals. They limit the negative externalities arising from congestion, pollution, and overbuilding. Therefore it is essential that policymakers find the right balance in land-use regulation. To analyze the impact of land-use regulation it is paramount to first understand the regulatory environment. In this paper, I develop a methodology to construct a residential regulatory constraints index for Switzerland.

Pendall et al. (2006) use a survey to discern how the 50 largest metropolitan areas in the U.S. regulate land use and promote housing affordability. They find that the instruments employed by these areas vary widely across space. Also using a survey, Gyourko et al. (2008) develop a comprehensive residential land-use regulatory index for over 2,600 communities across the U.S..[2] The authors expound that the coastal markets are more highly regulated. Gyourko et al. (2019) renew this index with a new survey. The new results show that the Great Recession did not lead to significant changes in regulation. Glaeser and Ward (2009) examine the causes and consequences of land-use regulations in Greater Boston. Their analysis establishes a positive link between historical density and regulations. Additionally, they corroborate that regulations like minimum lot size requirements are associated with reductions in new construction activity. Brueckner and Singh (2018) compute a land-use regulatory stringency measure for five U.S. cities. Specifically, they estimate the elasticity of the land price with respect to floor to area ratio (FAR). Their estimates indicate that New York and Washington, D.C. suffer the stringiest height regulations.

The literature for Switzerland is scarce. Kaiser et al. (2016) surveys Swiss

[1] See Gyourko and Molloy (2015) for a literature review.

[2] The authors call this measure the Wharton Residential Land-Use Regulation Index (WRLURI).

municipalities to identify how the 2014 revision of the Federal Act on Spatial Planning (RPG 1) affected them. Their focus lies on the administrative structures, and the instruments municipalities employ to regulate spatial planning. Buechler et al. (2019) evaluate the role of geographic and regulatory constraints on the Swiss housing supply elasticity. They distinguish between regulatory constraints on the intensive and extensive margin. However, due to a lack of data, they rely on proxies to quantify the intensive margin regulatory constraints. Unfortunately, there is still no comprehensive and harmonized information on the local regulatory environment for Switzerland. To help fill this gap, I develop a methodology to construct an aggregate index that documents how regulation of residential buildings varies across the 26 cantons and more than 2200 municipalities in Switzerland.

In Switzerland, cantons regulate land use by defining their zoning plans. These zoning plans are subject to general guidelines dictated by the federal government.[3] However, land-use regulations are primarily under the municipalities' control. Municipalities have a wide array of instruments to control residential development. Most evidently, they can set regulation that simply bans development. However, regulation can also obstruct development by restricting the intensity and type of development, or by delaying a project. Moreover, regulation may be influenced by local residents. To cover the most critical factors of this complex regulatory environment, I propose an index that comprises several sub-indices. These sub-indices concentrate on the processes, rules, and outcomes of local regulation. The sub-indices can be combined into a single aggregate measure of regulatory constraint, using factor analysis. I name this measure the CRED[4] Residential Regulatory Constraints Index (CRRCI). The methodology for this index builds on Gyourko et al. (2008) and Gyourko et al. (2019).

In this paper, I describe the available regulation data and create a survey on land-use regulation that provides the necessary information to construct the sub-indices. The sub-indices are divided into three categories. The first one pertains to the process of local regulation. In this category, I document who is involved in the regulatory process and how much influence they have over it. The second category captures the rules of extensive margin, intensive margin, and financial

[3]The concepts and plans set according to Article 13 of the Federal Act on Spatial Planning (RPG) represent the most important spatial planning instruments of the federal government.

[4]Note that CRED stands for Center for Regional Economic Development of the University of Bern.

regulatory constraints. The last category relates to the outcomes of the regulatory process and rules. By comprising these three categories the CRRCI indicates, with a simple number, how restrictive the regulations of local housing markets are across Switzerland. Note that a lower number indicates a less restrictive environment.

The remainder of the paper is structured as follows. Section 4.2 introduces the methodology to construct the sub-indices and the CRRCI. Section 4.3 presents the land-use regulation data. Section 4.4 briefly concludes.

4.2 Methodology

To outline the most crucial aspects and the heterogeneity of local land-use regulations, I proceed as follows. First, I document the process, rules, and outcome of land-use regulations with ten sub-indices. To construct these sub-indices, I suggest using land-use regulation data (see Section 4.3) and answers from a comprehensive survey (see Appendix 4.A). Second, using factor analysis, these sub-indices can be combined into a single index. This final index, named CRRCI, captures the degree of land-use restrictiveness across municipalities. My methodology is based on Gyourko et al. (2008) and Gyourko et al. (2019).

4.2.1 Land-use regulation process

The involvement of actors and stakeholders in the land-use regulation process differs across municipalities and cantons. The following three sub-indices reflect this involvement.

Citizens involvement index (CII): The CII measures how citizens influence the regulatory process. As argued by Frieden (1979), what we today know as NIMBYism can be a significant deterrent of development. I use the answers to the following questions to construct this index. Question 1 item (d) asks how involved voting citizens are in affecting residential building activities and/or growth management processes. Question 2 item (c) asks how important the cooperation/coordination with voting citizens is, for spatial planning in the municipality. Question 5 item (f) asks the importance of citizen opposition to growth for the regulation of residential housing developments for single-family and multi-family dwellings. Question 10 asks how many objections to building permit applications did the municipality receive in the year 2019. The first component of the CII is based on the sum of the individual responses to Question 1 item (d), Question 2 item (c), and Question 5 item (f). The second component is the number of objections to building permit applications in 2019 (Question 10) divided by the number of building permit applications (provided by *Documedia*).

Municipality involvement index (MII): Switzerland's federalist structure leaves municipalities considerable freedoms in affecting the regulatory process. This index captures the municipalities' involvement in this process. The following questions provide the basis for the MII. Question 1 items (a), (b), (c), and (e) ask how involved the municipality executive body, legislative body, municipal secretary, and municipal administrative unit are in affecting residential building activities and/or growth management processes. Question 2 items (a) and (b) ask how important the cooperation/coordination with municipalities in the same canton and in neighboring cantons is, for spatial planning in the municipality. Question 5 item (e) asks the importance of municipality executive body opposition to growth for the regulation of residential housing developments for single-family and multi-family dwellings. The index is composed of the sum of the individual responses to Question 1 items (a), (b), (c), and (e), Question 2 items (a), (b), and Question 5 item (e).

Cantonal involvement index (CII): The CII looks at the cantonal involvement in the regulatory process. This index only varies at the cantonal level. I use the answers of the following questions to construct the index. Question 1 items (f), (g) and (h) ask how involved the inter-municipal administrative unit, cantonal administrative unit, and external planning office are in affecting residential building activities and/or growth management processes.[5] Question 5 item (g) asks the importance of monument protection for the regulation of residential housing developments for single-family and multi-family dwellings. Note that the cantons manage the monument protection authorities. To construct the CII, I first sum up the individual responses to Question 1 items (f), (g), and (h) and Question 5 item (g). Second, I average these sums at the cantonal level because municipalities may view the cantonal involvement differently. For example, a municipality in the country side may underestimate the cantonal involvement because the restrictions are not

[5]Note that the inter-municipal administrative unit is technically not managed by the cantons. Nonetheless, I include it in the CII because the cantons often coordinate these units.

binding.

4.2.2 Rules of regulatory constraints

Land-use regulations affect residential developments on the extensive, intensive, and financial margin. Extensive margin regulatory constraints are measures that prevent new construction on developed land. One example is the protected forests. Intensive margin regulatory constraints govern the intensity and type of residential development. They include regulations on, e.g., height restriction or open space requirements. Financial regulatory constraints include, e.g., affordable housing requirements or the requirement to pay for pertinent infrastructure. The following six sub-indices capture the rules of regulatory restrictions.

Zoning approval index (ZAI): This index captures the required organizations to approve a zoning or rezoning change. The answers to Question 3 provide the basis for the ZAI. The listed organizations range from the municipal executive body to the environmental examining board. The ZAI is the simple sum of the organizations required to approve a zoning or rezoning change. The more organizations have approval rights, the higher the potential of denial. Thus, a higher value for this sub-index indicates a stricter regulatory environment.

Project approval index (PAI): The PAI looks at the required organizations to approve a new construction project. The answers to Question 4 provide the basis for this sub-index. The listed organizations range from the municipal executive body to the monument protection authority. The PAI is the simple sum of the organizations required to approve a new construction project that does not need a rezoning. Like the ZAI, a higher value for the PAI indicates stricter regulations.

Extensive margin regulation index (EMRI): An important form of regulation is the protection of certain areas from development. The regulations on the extensive margin include crop rotation areas, forests, high amenity value areas, and UNESCO cultural and natural heritage sites (see Section 4.3 for a detailed description). The first component of the EMRI is the share of land that is protected by the regulations on the extensive margin (provided by Büchler et al. (2018)). The second component is the response to Question 5 item (a). This question asks the importance of land supply for the regulation of residential housing developments for single-family and multi-family dwellings.

Density restrictions index (DRI): Density restriction comes in many forms. In Switzerland, the most prevalent density restrictions are height restrictions, limits to the number of floors, FAR restrictions, and limits to boundary distances. The DRI has two components. The first one, relies on harmonized zoning data. This data set describes the land use attributed to undeveloped plots (see Section 4.3 for a detailed description). The second component relies on a series of questions about how binding these density restrictions are. Question 5 item (b) asks the importance of density restrictions for the regulation of residential housing developments for single-family and multi-family dwellings. Question 6 specifies and asks which of the prevalent density restrictions are the most important for the regulation of residential housing developments for single-family and multi-family dwellings. Question 7 items (a) and (b) ask if developers have to meet minimum lot size and/or FAR requirements to be able to build.

Open space and affordable housing index (OSAHI): The OSAHI is the sum of two dummy variables. The first variable takes the value of one if a developer has to include affordable housing to be able to build (Question 7 item (c)). The second variable takes the value of one if a developer has to supply mandatory open space requirements to be able to build (Question 7 item (d)).

Cost index (EI): Another important facet of local land-use regulations is the costs concerning development. Developers have to pay for the building permit and allocable share of the expenses of infrastructure improvement. A study conducted by the Swiss Federal Department of Economic Affairs, Education and Research (EAER), shows that these costs vary widely across municipalities (Preisüberwacher 2014). The CI comprises two components. The first component uses the data from the study Preisüberwacher (2014). This set includes the building permit fees, sewerage connection fees, and water connection fees, for the 30 most populous municipalities.[6] The second component relies on the answers to a set of questions about the fees concerning development. Question 5 items (c) and (d) ask the

[6]The first component only relates to the 30 most populous municipalities. The CI for the remaining municipalities only comprises the second component.

importance of new infrastructure costs, and fees and duties for the regulation of residential housing developments for single-family and multi-family dwellings. Question 7 item (e) asks if developers have to pay an allocable share of the costs of infrastructure improvement to be able to build. Question 9 asks for the criteria for determining the building permit fees. Question 11 asks how much the building permit and infrastructure access fees increased in the last ten years.

4.2.3 Outcomes of regulation process and rules

The third category focuses on the outcome of the regulation process and rules. It quantifies, e.g., how easy it is and how long it takes to get a building permit. This category comprises the following index.

Outcome index (OI): The OI comprises two components. The first component is the building permit refusal rate. To construct this rate at the municipality level, I use the building permit data provided by *Documedia*. The second component builds on the answers to the following questions. Question 5 items (h) and (i) ask the importance of the duration of the review process for zoning and land development plan and the review process for building permits for the regulation of residential housing developments for single-family and multi-family dwellings. Question 14 asks how the duration from the review to the approval of development changed for single-family and multi-family dwellings in the last ten years. Question 15 asks how long a building permit procedure currently takes for single-family and multi-family dwellings.

4.2.4 CRED residential regulatory constraints index (CR-RCI)

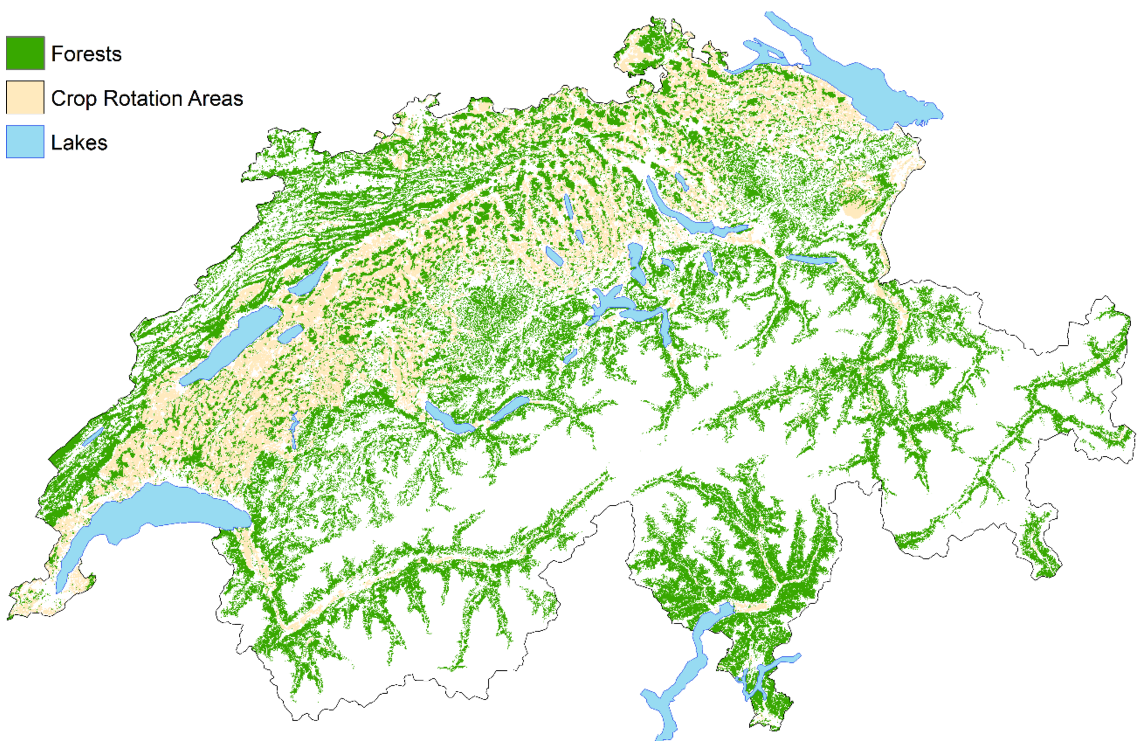
To combine the ten sub-indices into the final CRRCI, I suggest using factor analysis. Specifically, to use the first factor form each sub-index. Factor analysis ensures that the variation of the ten-sub indices does not reflect the variation in unobserved variables. This methodology allows capturing the local regulatory environment for each municipality in a single dimension. Moreover, it enables the ranking of municipalities according to their regulatory restrictiveness regarding residential development. The CRRCI should be standardized and have a sample mean of zero and a standard deviation of one. A higher (lower) value in the CRRCI implies more (less) regulation. The readers interested in the different dimensions of the regulatory environment can exploit the sub-indices.

4.3 Data

Regulatory constraints limit housing development. In this section, I describe the available data on the extensive and intensive margin regulatory constraints. Table 4.3.1 summarizes the data sources, definitions, and importance of these data sets.

Regulations on the extensive margin include crop rotation areas, forests, high amenity value areas, and UNESCO cultural and natural heritage sites, as illustrated in Panel A of Table 4.3.1. Figures 4.3.1 and 4.3.2 show the spatial extent of these restrictions. Note that in general, regulations on the extensive margin are not mutually exclusive. For example, the UNESCO classification of an area of particular natural value might partly overlap with the boundary of a regional park.

Figure 4.3.1: Forests and crop rotation areas



Notes: Forests and crop rotation areas may overlap due to imprecision of the FFF data. In total only 1.2% of the forest area overlaps with the FFF.

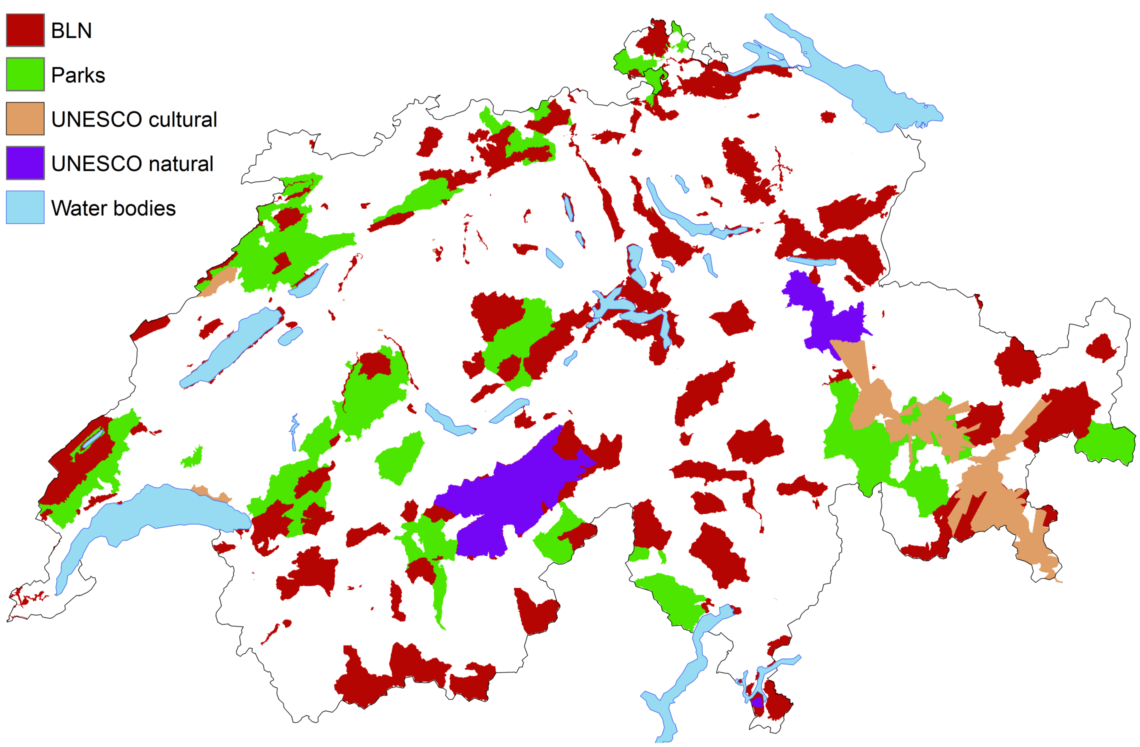
Table 4.3.1: Data on regulatory constraints

Data	Description	Area share of Switzerland	Source
Panel A: Regulatory constraints - extensive margin			
Crop rotation areas	Areas best suited for agriculture	12.3%	Cantonal offices for spatial development
Forests	Protected forest	27.7%	Arealstatistik Schweiz
Federal inventory of landscapes and natural monuments	Most valuable landscapes for Switzerland	18.9%	Federal Office for the Environment (FOEN)
Regional and national parks	Parks of national importance	12.7%	Federal Office for the Environment (FOEN)
UNESCO cultural sites	Buildings of particular architectural merit, entire towns, and sites created by the emergence of industrialisation	2.8%	Federal Office for the Environment (FOEN)
UNESCO natural sites	Natural sites with outstanding universal value	2.8%	Federal Office for the Environment (FOEN)
Panel B: Regulatory constraints - intensive margin			
Building zone statistics	Land use attributed to undeveloped plots	-	ARE Bauzonenstatistik
Building permit refusal rate	Share of building permits that were rejected	-	Documedia
Building permit fees	Building permit, sewerage connection, and water connection fees	-	Preisüberwacher

Notes: Regulations on the extensive margin are not mutually exclusive. Overall, these protected areas cover approximately 60 percent of the Swiss territory.

Crop Rotation Areas (FFF, Fruchtfolgeflächen) are plots of land best suited for agriculture use. These areas comprise approximately 4,400 km^2 of cultivable land. Their purpose - as stipulated by the Swiss Federal Law on Spatial Planning (Bundesgesetz über die Raumplanung) from 1979 - is to secure nutrition in Switzerland in the long run and case of emergency. In 1992, the Swiss Federal Council fixed the minimal amount of FFF for each canton according to stringent soil quality criteria relating to the physical and biological properties, such as soil texture, arable suitability, pollutant load, and the shape of the land parcel. For example, alpine cantons having high shares of unproductive surfaces typically have smaller FFFs. Cantons were then responsible for defining the precise location of FFFs within their boundaries. Since FFFs are allocated for agricultural use, they must not be developed. Cantons can make exceptions in this regard provided that the municipality in which the FFF is located manages to replace it with an equivalent plot of land fulfilling soil quality criteria. Given the stringency of such rules, developers rarely employ this burdensome process.

Figure 4.3.2: UNESCO, BLN, and Parks



Notes: With the exception of lakes, colored areas correspond to extensive margin regulations. They may overlap

In response to industrialization in Europe and Switzerland, in 1876, Switzerland passed a law prohibiting further deforestation, de facto freezing forest areas to the level observed at that time. The law has remained mainly unchanged to the present day.[7] As a result of these laws, the forest area in the highly populated regions has remained practically unchanged since 1876.

The Federal Inventory of Landscapes and Natural History (BLN, Bundesinventar der Landschaften und Naturdenkmäler) classifies the most typical and most valuable landscapes in Switzerland. The aim of the inventory - which was progressively introduced from 1977 to 1998 - is to protect Switzerland's scenic diversity and to ensure that the distinctive features of these landscapes are preserved.

Parks of national importance are characterized by beautiful landscapes, rich biodiversity, and high-quality cultural assets. The communities and cantons preserve these values and ensure their sustainment for the economic and social development of their regions.

One of the objectives of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) is to protect the cultural and natural heritage of outstanding universal value. Currently, UNESCO recognizes 981 cultural or natural heritage sites worldwide, 11 of which are located in Switzerland. These areas mostly consist of buildings of particular architectural interest, historic towns, and areas with valuable natural amenities. Overall, areas protected by FFF, forest, UNESCO, regional and national parks or BLN regulations cover approximately 60 percent of the Swiss territory (see Figures 4.3.1 and 4.3.2).

Governments also regulate the intensity of residential development in Switzerland. In particular, Cantons define zoning plans - which typically regulate the intensity of residential development - according to general guidelines dictated by the federal government. Municipalities have to comply with cantonal plans and adapt their zoning policies accordingly. However, there is no source of comprehensive information about the type of zoning policies implemented across cantons and municipalities. Panel B of Table shows 4.3.1 the few available data sets on intensive margin regulatory constraints.

[7] The law was revised in 1991 as part of the Federal Act on Forestry (Bundesgesetz über den Wald). The revision introduced minor exceptions allowing development. For example, buildings with public utility - such as rangers' cabins - can be built within forest areas. However, the construction of such buildings is very infrequent because i) the federal government very rarely grants building permits and ii) cleared forest areas must be replaced with new equally sized plots of land.

The 2012 official zoning data, harmonized for the whole of Switzerland, reveals the land use attributed to undeveloped plots of land (ARE 2012). More specifically, the data differentiates between nine different building zone types.[8]

Documedia provides data to compute building refusal rates at the municipality level. This refusal rate is defined as the number of refused buildings and renovation permits divided by their total number. It reflects the effective restrictiveness of local governments regarding residential development.

Finally, Preisüberwacher (2014) compares the building permit, sewerage connection, and water connection fees for the 30 most populous municipalities. They collect the data for three pre-defined house types: a single-family house, a multi-family dwelling with five apartments, and a multi-family dwelling with 15 apartments.

4.4 Conclusions

Land-use regulations can have far-reaching consequences for the economy. However, the heterogeneity in land-use regulation in Switzerland complicates the assessment of these regulations. To this day, Switzerland does not have harmonized information on the local regulatory environment across municipalities.

This paper provides a methodology and the corresponding survey to construct a land-use regulation index for the over 2200 Swiss municipalities. First, I propose the construction of ten sub-indices that capture the different aspects and degrees of local regulation. These indices provide harmonized information about what local regulation entails. Second, I suggest factor analysis to combine these indices into a single index documenting how regulation of residential buildings varies across space.

[8]The zone types are residential, commercial, mixed, central business districts (CBD), public, restricted, tourism, traffic, and others. Note that residential (47 %) and commercial (14%) comprise more than 60 percent of the building zones.

4.A Survey

1. In your municipality, how involved are the following organizations/stakeholders in affecting residential building activities and/or growth management processes? Please rate the importance of each on a scale from 1 to 10. (1 = not involved at all; 10 = very involved)

   (a) Municipality executive body

   (b) Municipality legislative body (community assembly or parliament)

   (c) Municipal secretary

   (d) Voting citizens

   (e) Municipal administrative unit (e.g. local planning office)

   (f) Inter-municipal administrative unit (e.g. inter-municipal planning office)

   (g) Cantonal administrative unit (e.g. cantonal planning office)

   (h) External planning office

2. How important is cooperation/coordination with the following organizations/stakeholders for spatial planning in your municipality? Please rate the importance of each on a scale from 1 to 10. (1 = not important at all; 10 = very important)

   (a) Municipalities in the same canton

   (b) Municipalities in neighboring cantons

   (c) Voting citizens

   (d) Others (Please specify which ones)

3. In your municipality, which of the following are required to approve a zoning or rezoning change?

   (a) Municipality executive body

   (b) Municipality legislative body (community assembly or parliament)

   (c) Voting citizens

   (d) Municipal administrative unit (e.g. local planning office)

   (e) Inter-municipal administrative unit (e.g. inter-municipal planning office)
   (f) Cantonal administrative unit (e.g. cantonal planning office)
   (g) External planning office
   (h) Environmental examining board

4. In your municipality, which of the following are required to approve a new construction project (which does not need rezoning)?
   (a) Municipality executive body
   (b) Municipality legislative body (community assembly or parliament)
   (c) Voting citizens
   (d) Municipal administrative unit (e.g. local planning office)
   (e) Inter-municipal administrative unit (e.g. inter-municipal planning office)
   (f) Cantonal administrative unit (e.g. cantonal planning office)
   (g) Environmental examining board
   (h) Monument protection authority

5. On a scale of 1 to 10, please rate the importance of the following factors for the regulation of residential housing developments in your municipality for single-family and multi-family dwellings. (1 = not important at all; 10 = very important)
   (a) Supply of land
   (b) Density restrictions (e.g. height restrictions, number of floors, floor area ratio, and boundary limit distances)
   (c) New infrastructure costs (e.g. infrastructure access costs)
   (d) Fees/duties
   (e) Municipality executive body opposition to growth (e.g. due to crowded schools)
   (f) Citizen opposition to growth
   (g) Monument protection
   (h) Duration of the review process for zoning and land development plan

(i) Duration of the review process for building permits

6. On a scale of 1 to 10, please rate the importance of the following factors for the regulation of residential housing developments in your municipality for single-family and multi-family dwellings. (1 = not important at all; 10 = very important)

   (a) Height restrictions
   (b) Number of floors
   (c) Floor area ratio
   (d) Boundary limit distances
   (e) Green space requirements

7. In your municipality, do developers have to meet these requirements to be able to build? (Yes or no)

   (a) Meet minimum lot size (e.g. 1000 square meters) requirements
   (b) Floor to area ratios requirements
   (c) Include affordable housing (however defined)
   (d) Supply mandatory open space
   (e) Pay allocable share of costs of infrastructure improvement

8. In your municipality, how does the supply of zoned land compare to the demand for the following land uses? (Far more than required; More than required; Roughly enough; Less than required; Far less than required)

   (a) Single-family
   (b) Multi-family
   (c) Commercial
   (d) Industrial

9. In your municipality, what are the criteria for determining the building permit costs?

   (a) Construction costs (How many percent)

(b) Others (Please specify which ones)

10. Approximately how many objections to building permit applications did your municipality receive in the year 2019?

11. In the last 10 years, how much have the building permit and infrastructure access fees increased in your municipality? (0-10%, 11-20%, 21-30%, 31-40%, 41-50%, >50%)

12. In the last 10 years, how much have the costs of a single-family house increased in your municipality? (0-10%, 11-20%, 21-30%, 31-40%, 41-50%, >50%)

13. In the last 10 years, how much have the costs of an apartment increased in your municipality? (0-10%, 11-20%, 21-30%, 31-40%, 41-50%, >50%)

14. In the last 10 year, how has the duration from the review to the approval of a development changed in your municipality? (No change; A little longer; Considerably longer)
    (a) Single-family dwelling
    (b) Multi-family dwelling

15. In your municipality, how long does a building permit procedure for the following currently take? (Weeks)
    (a) Single-family dwelling
    (b) Multi-family dwelling

4.B Survey (German)

1. Wie stark sind die folgenden Organisationen in Ihrer Gemeinde an den Wohnbauaktivitäten und/oder Wachstumsmanagementverfahren beteiligt? Bitte bewerten Sie die Wichtigkeit auf einer Skala von 1 bis 10. (1 = überhaupt nicht beteiligt; 10 = sehr beteiligt)
    (a) Exekutivorgan der Gemeinde
    (b) Legislativorgan der Gemeinde (Gemeindeversammlung oder -parlament)
    (c) GemeindeschreiberIn

(d) Die StimmbürgerInnen

(e) Kommunale Verwaltungseinheit (z.B. Bauamt)

(f) Interkommunale Verwaltungseinheit (z.B. interkommunales Bauamt)

(g) Kantonale Verwaltungseinheit (z.B. kantonales Amt für Raumplanung)

(h) Externes Planungsbüro

2. Wie wichtig ist die Kooperation/Koordination mit den folgenden Organisationen für die Raumplanung in Ihrer Gemeinde? Bitte bewerten Sie die Wichtigkeit auf einer Skala von 1 bis 10. (1 = überhaupt nicht wichtig; 10 = sehr wichtig)

   (a) Gemeinden im selben Kanton

   (b) Gemeinden in einem Nachbarskanton

   (c) Die StimmbürgerInnen

   (d) Andere (Bitte geben Sie an, welche)

3. Das Einverständnis welcher der folgenden Organisationen ist erforderlich, um eine Umzonung/Einzonung in Ihrer Gemeinde zu genehmigen?

   (a) Exekutivorgan der Gemeinde

   (b) Legislativorgan der Gemeinde (Gemeindeversammlung oder -parlament)

   (c) Die StimmbürgerInnen

   (d) Kommunale Verwaltungseinheit (z.B. Bauamt)

   (e) Interkommunale Verwaltungseinheit (z.B. interkommunales Bauamt)

   (f) Kantonale Verwaltungseinheit (z.B. kantonales Amt für Raumplanung)

   (g) Externes Planungsbüro

   (h) Umweltprüfungsausschuss

4. Das Einverständnis welcher der folgenden Organisationen ist erforderlich, um ein neues Bauprojekt (für das keine Umzonung erforderlich ist) in Ihrer Gemeinde zu genehmigen?

   (a) Exekutivorgan der Gemeinde

   (b) Legislativorgan der Gemeinde (Gemeindeversammlung oder -parlament)

(c) Die StimmbürgerInnen

(d) Kommunale Verwaltungseinheit (z.B. Bauamt)

(e) Interkommunale Verwaltungseinheit (z.B. interkommunales Bauamt)

(f) Kantonale Verwaltungseinheit (z.B. kantonales Amt für Raumplanung)

(g) Umweltprüfungsausschuss

(h) Denkmalschutz

5. Bitte bewerten Sie auf einer Skala von 1 bis 10 die Bedeutung der folgenden Faktoren für die Regulierung der Wohnsiedlungen in Ihrer Gemeinde für Einfamilienhäuser und Mehrfamilienhäuser. (1 = gar nicht wichtig; 10 = sehr wichtig).

   (a) Landangebot

   (b) Dichteeinschränkungen (z.B. Bauhöhe, Anzahl Stockwerke, Ausnützungsziffern, und Grenzabstände)

   (c) Kosten für neue Infrastruktur (z.B. Erschliessungskosten)

   (d) Gebühren/Abgaben

   (e) Widerstand des Gemeinderats gegen Wachstum (z.B. wegen überfüllte Schulen)

   (f) Bürgeropposition gegen Wachstum

   (g) Denkmalschutz

   (h) Dauer des überprüfungsverfahrens für Einzonung und Landentwicklungsplan

   (i) Dauer des überprüfungsverfahrens für Baugenehmigungen

6. Bitte bewerten Sie auf einer Skala von 1 bis 10 die Bedeutung der folgenden Dichteeinschränkungen für die Regulierung der Wohnsiedlungen in Ihrer Gemeinde für Einfamilienhäuser und Mehrfamilienhäuser. (1 = gar nicht wichtig; 10 = sehr wichtig).

   (a) Bauhöhe

   (b) Anzahl Stockwerke

   (c) Ausnützungsziffern

(d) Grenzabstände

(e) Grünflächenanteil

7. Müssen Bauherren diese Anforderungen erfüllen, um in Ihrer Gemeinde bauen zu können? (Ja oder nein)

   (a) Anforderung von Mindestgrundstückgrösse (z.B. 1000 Quadratmeter)

   (b) Anforderung von Nutzungsziffern

   (c) Gemeinnützingen Wohnungsbau einbeziehen (wie auch immer definiert)

   (d) Obligatorische Freiflächen zur verfügung stellen

   (e) Anrechenbaren Anteil an den Kosten der Infrastrukturverbesserung zahlen

8. Wie steht das Angebot an Baufläche für die folgenden Landnutzungen im Vergleich zur Nachfrage in Ihrer Gemeinde? (Weit mehr als erforderlich; Mehr als erforderlich; Ungefähr genug; Weniger als erforderlich; Weit weniger als erforderlich)

   (a) Einfamilienhäuser

   (b) Mehrfamilienhäuser

   (c) Gewerbeimmobilien

   (d) Industrieimmobilien

9. Nach welchen Kriterien werden die Baubewilligungskosten in Ihrer Gemeinde festgesetzt?

   (a) Baukosten (Wie viel Prozent)

   (b) Andere (Bitte geben Sie an, welche)

10. Ungefähr wie viele Einsprachen gegen Baugesuche sind im Jahr 2019 in Ihrer Gemeinde eingegangen?

11. Wie stark sind in Ihrer Gemeinde die Baugenehmigungs- und Erschliess-ingskosten, in den letzten 10 Jahren gestiegen? (0-10%, 11-20%, 21-30%, 31-40%, 41-50%, >50%)

12. Wie stark sind in Ihrer Gemeinde die Kosten für Einfamilienhäuser, in den letzten 10 Jahren gestiegen? (0-10%, 11-20%, 21-30%, 31-40%, 41-50%, >50%)

13. Wie stark sind in Ihrer Gemeinde die Kosten für Stockwerkseigentum, in den letzten 10 Jahren gestiegen? (0-10%, 11-20%, 21-30%, 31-40%, 41-50%, >50%)

14. Wie hat sich in Ihrer Gemeinde die Dauer von der überprüfung bis zur Genehmigung eines Wohnprojektes, in den letzten 10 Jahren verändert? (Keine änderung; Etwas länger; Erheblich länger)

    (a) Einfamilienhaus

    (b) Mehrfamilienhaus

15. Wie lange dauert derzeit ein Baubewilligungsverfahren in Ihrer Gemeinde? (Wochen)

    (a) Einfamilienhaus

    (b) Mehrfamilienhaus

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Bern, 31.01.2020 Simon Camilo Büchler