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The Amplifying Effect of Capitalization Rates on Housing Supply

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Abstract

We provide empirical evidence that increases in the periodic costs of housing lead to a larger supply response than price increases of the same magnitude. We rationalize this differential in supply responsiveness with an amplification mechanism arising from adjustments of capitalization rates to changes in the periodic costs. Buyers expect further periodic cost increases at places that have experienced a positive demand shock. We document that the amplification of the housing supply price elasticity is less pronounced in geographically constrained and tightly regulated neighborhoods and in areas having more sophisticated buyers. Our findings hold important lessons for public policies affecting the periodic cost of housing, such as rent control and housing subsidies.

Key words: housing supply, capitalization rate, land use regulation, geographic constraints

JEL classification: R1, R3, H7, R5

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1. Introduction

Existing research emphasizes the importance of housing supply price elasticity for various economic outcomes. In fact, the responsiveness of housing supply to price signals affects, among other things, housing cycles, the allocation of labor across space, and the capitalization degree of public policies such as place-based subsidies. [1] However, we know relatively little about the responsiveness of housing supply with respect to changes in the periodic cost of housing. This strikes as surprising as urban economic theory typically focuses on periodic costs and many public policies – such as rent control and housing subsidies – directly act on the periodic price paid by households to live in a given area. 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 how this supply differential varies across space.

To this end, we develop a partial equilibrium framework featuring housing supply and real estate capital asset markets. We show that local changes in expectations about the future growth of periodic housing costs and risk premia demanded by property buyers are decisive factors to explain differences in supply responses. Specifically, the housing supply responses to prices and periodic cost changes are identical *if* capitalization rates do not adjust to changes in the periodic costs. If capitalization rates do adjust to changes in periodic costs, housing supply price elasticities are either amplified or dampened by this adjustment.

To bring our conceptual framework to the data, we use a unique georeferenced data set 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 by exploiting spatial variation across small neighborhoods. By partialling out quality differences between rental and selling properties, we find that an increase in rents leads to an about twice as large supply increase than an increase of prices of the same magnitude: The supply response following a 10 percent increase in rents (prices) per square meter is approximately 13 percent (5 percent). The amplification of the supply price responsiveness is less pronounced in geographic constrained and tightly regulated markets, and in neighborhoods

[1] For instance, Glaeser et al. (2008) study 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.

having more sophisticated buyers. These results suggest that real estate buyers do revise local capitalization rates downward following a positive demand shock. The adjustment is heterogeneous across space, thereby amplifying the housing supply response with respect to prices.

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, building permits, 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 our setting, the owner-occupied and rental markets are approximately of equal size, which facilitates the estimation of rental and price supply elasticities throughout the country and allows us to study the role of capitalization rates for housing supply.[2]

Recent research has investigated the implications of housing supply elasticity for various economic outcomes and public policies.[3] Glaeser and Gottlieb (2008) argue that the most promising national place-based policy are those impeding highly productive areas to restrict their housing supply through land use restrictions. Aura and Davidoff (2008) investigate the role of individual versus coordinated regulatory constraints across jurisdictions for price dynamics. Solé-Ollé and Viladecans-Marsal (2012) show that political competition within local governments affects zoning of new land for residential development. Glaeser et al. (2013) point out that places with higher housing supply elasticities are less prone to sharp house price fluctuations. Hilber and Vermeulen (2016) empirically show that housing prices react more strongly to earnings shocks in areas where housing supply is more regulated. Using a structural model, Diamond (2017) argues that housing supply rigidity lowers the migration response of households, thereby increasing governments' ability to extract rents via local taxes. Favilukis and Van Nieuwerburgh (2018) expound that welfare costs imposed by out-of-town buyers are larger when housing supply elasticity is lower. Hsieh and Moretti (2019) find that the spatial misallocation of labor due to housing supply constraints significantly lowered US economic growth over the long run.

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

[3] See Glaeser and Gyourko (2018) for a review of the economic implications of heterogeneity in housing supply elasticities and Hilber (2017) for a synthesis of the implications of housing supply for the capitalization of public policies and amenities.

Our paper bridges two strands of the literature. Despite the importance of housing supply, research on the quantification of local housing supply price elasticities remains 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 US 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 US MSA's, obtaining estimates in line with those of Saiz (2010). Recently, Baum-Snow and Han (2019) adopt a structural approach to quantify cross- and within-city housing supply elasticities for US metropolitan areas, showing that housing supply elasticities increase monotonically with the distance to city centers. We contribute to this literature by estimating local supply responses not only with respect to prices but also with respect to periodic costs, and exploring the role of constraints for both elasticities.

The second strand of the literature focuses on real estate capital asset markets and buyers' expectations. Sivitanides et al. (2001) find that capitalization rates behave similarly to Price/Earnings ratios, with economic agents myopically forming price growth expectations based on past dynamics. 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 US price dynamics. Mayer and Sinai (2007) substantiate these findings by showing the effect of backward-looking expectations in house price booms. Glaeser and Nathanson (2017) construct a model where buyers are not fully rational in predicting future price dynamics, which explains their observed serial correlation.

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 people's 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. Homebuyers expect that places that have gained in attractiveness will continue to do so even further in future periods, leading to additional 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 not 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 2 introduces the conceptual framework motivating our empirical analysis. Section 3 presents the data, explains the data structure and provides descriptive statistics for the Swiss housing market. Section 4 contains the empirical analysis together with a discussion of the identifying assumption. Section 5 analyses the results. Section 6 discusses the robustness checks, and Section 7 concludes.

2. Conceptual framework

In this section, we conceptualize the link between housing supply and the real estate asset market. In particular, we link housing supply price elasticity to the supply responsiveness with respect to periodic costs through adjustments of expectations about local rent growth and local risk. This link allows us to rationalize observed differences in the supply responsiveness with respect price and periodic cost changes.

Our starting point is the framework by DiPasquale and Wheaton (1992), in which the economy is endowed with $N = \sum N_n$ households deciding in which neighborhood n to live. Households pay a periodic (annual) cost R_n to consume one unit of homogeneous housing in a given neighborhood. Buyers in the real estate asset market are willing to pay a present price P_n to earn a stream of rental income at a *local* capitalization rate c_n. Housing developers are price takers and supply a total quantity Q_n of identical housing units at a unitary price P_n. We assume that each local housing market clears, i.e. $Q_n = N_n$. Importantly, our framework is purely spatial in nature, such that variations in the endogenous variables, such as prices dP_n , rents dR_n, and housing supply dQ_n, occur across *space*.

We characterize housing supply as $Q_n = A_n P_n^{\frac{1}{\beta^p}}$, where A_n is a local supply shifter and $\epsilon^{Q,P} = \frac{1}{\beta^p}$ is the long-run housing supply price elasticity.[4] To investigate the supply response with respect to rent changes, we write prices as a function of rents $P_n(R_n)$ and compute the following rent elasticity:

$$\epsilon^{Q,R} = \frac{R_n}{Q_n}\frac{dQ_n}{dR_n} = \frac{R_n}{Q_n}\frac{1}{\beta^p}A_n P_n^{\frac{1}{\beta^p}-1}\frac{dP_n}{dR_n} = \frac{R_n}{P_n}\frac{1}{\beta^p}\frac{dP_n}{dR_n} = \epsilon^{Q,P}\epsilon^{P,R}, \tag{1}$$

[4] This supply function, which is used among others by Hsieh and Moretti (2019), has the advantage to represent housing supply elasticity with a single structural parameter.

where $\epsilon^{P,R}$ is the price elasticity with respect to rent changes. Equation 1 tells us that rental and price housing supply responses differ when the elasticity of prices to rent changes is not unitary. In markets where price signals amplify rental ones, i.e. $\epsilon^{P,R} > 1$, housing supply will respond, *ceteris paribus*, more strongly to rent changes than to price changes. An important question is what the determinants of the amplification coefficient $\epsilon^{P,R}$are. To answer this question, we explicitly model the relationship $P_n(R_n)$ between rent and prices using an asset pricing formula.[5]

According to the Gordon growth model $P_n = \frac{R_n}{c_n}$, where c_n is the local capitalization rate We can then write $\epsilon^{P,R}$ as

$$\epsilon^{P,R} = \frac{R_n}{P_n}\frac{dP_n}{dR_n} = \frac{R_n}{P_n}\frac{d}{dR_{nt}}\left(\frac{R_n}{c_n}\right) = \frac{R_n}{P_n}\left(\frac{1}{c_n} - \frac{R_n}{c_n^2}\frac{dc_n}{dR_n}\right) = 1 - \epsilon^{c,R}, \tag{2}$$

where $\epsilon^{c,R}$ is the rent elasticity of the capitalization rate to rent changes.[6] In the empirical part of the paper, we recover $\epsilon^{c,R}$, which according to Equation 1 is equal to $1 - \frac{\epsilon^{Q,R}}{\epsilon^{Q,P}}$.

For interpretation purposes, it is instructive to use the fact that $c_n = i + \pi_n - g_n$, where i is the countrywide risk-free interest rate, π_n is a local risk premium, and g_n captures expectations about future local rent growth. We can rewrite $\epsilon^{c,R}$ as a function of adjustments in local risk and local expectations

$$\epsilon^{c,R} = \frac{R_n}{c_n}\left(\frac{d\pi_n}{dR_n} - \frac{dg_n}{dR_n}\right) = \frac{1}{c_n}\left(\frac{d\pi_n}{dln(R_n)} - \frac{dg_n}{dln(R_n)}\right), \tag{3}$$

where we have used the fact that the risk-free rate i doesn't have spatial variation, i.e. $\frac{di}{dln(R_n)} = 0$. According to Equation 3, supply reacts identically to rent and price changes if investors consider real estate a risk-free asset ($d\pi_n \equiv 0$) and have homogeneous growth expectation across space ($\frac{dg_n}{dln(R_n)} = 0$), which implies $\epsilon^{P,R} = 1$.[7]

[5] Alternatively, we could use a standard user cost approach as suggested by Poterba (1984), in which the imputed periodic value of owner-occupancy equals rents. The interpretation of housing supply differences to changes in prices and periodic costs provided by our framework does not change.

[6] Note that Equation 2 is derived without specifying the demand/supply side of the housing market. It only belongs to the asset market.

[7] Note that it is not possible to empirically disentangle risk adjustments from expectation ones in Equation 3 without imposing further structure on the way buyers form expectations and perceive risk. Even when imposing such structure, it might not be possible to test it empirically. To lessen this limitation, we investigate how $\epsilon^{c,R}$ changes across types of investors, indirectly providing evidence on changes on expectations and perceived risk.

3. Data and descriptive statistics

The empirical analysis relies on several data sources. In this section, we summarize these data sources and provide descriptive statistics. Further information is available in Appendix A.

3.1. Data sources

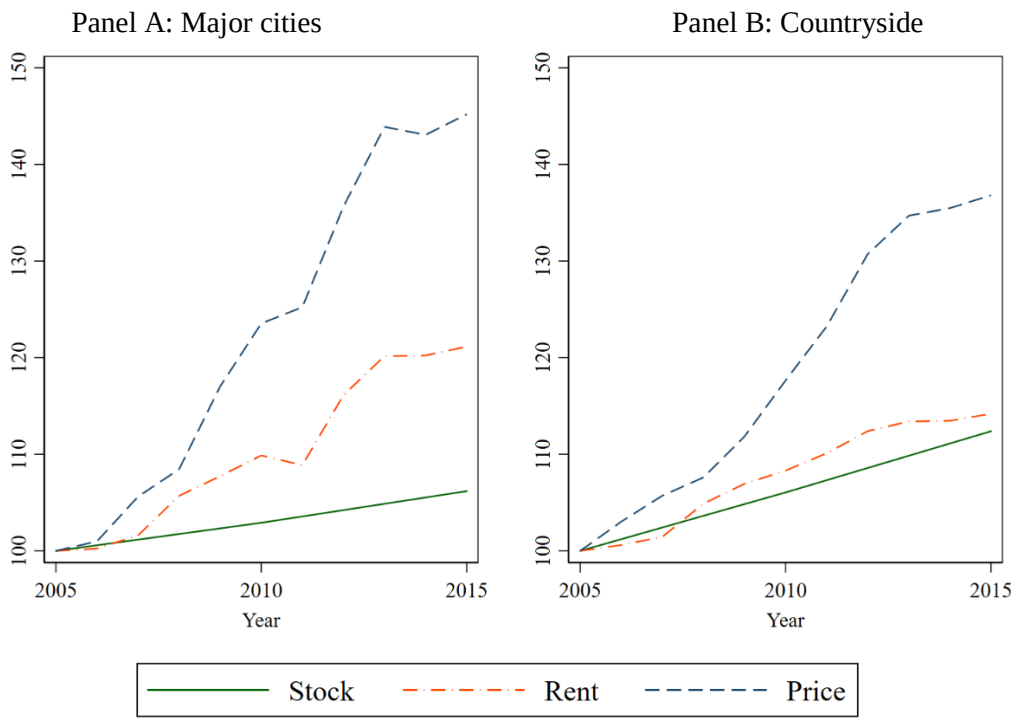
Housing data – We use proprietary geo-referenced data on advertised residential properties provided by Meta-Sys. The data set contains approximately 2.1 million postings of rental properties and about 0.8 million postings of selling residences for the whole of Switzerland from 2004 to 2016. In addition 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 5 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.

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.

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 from the Federal Office for the Environment (FOEN). Information about regulatory constraints on the intensive margin is inferred from municipality-level statistics on refusal rates provided by Meta-Sys.

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. The 2000 Building Census (FSO) provides information on whether a dwelling is a primary or secondary residence.

Figure 1 : Rent, price, and stock dynamics



Notes: Cities include 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.

3.2. Data structure and descriptive statistics

We structure the data into neighborhoods by partitioning the whole territory of the country into small square cells of 2x2 km. We aggregate residential transactions, housing stock, socio-demographic and economic data, and geographic and regulatory constraints within these neighborhoods.[8] 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.

[8] Our results are robust to alternative neighborhood sizes, as discussed in Section 6.

At the country level, rents have increased by approximately 14 percent while prices have increased by approximately 35 percent.[9] 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.[10] 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 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.[11] Undevelopable surfaces – comprising the Alps – and water bodies represent about 31.2 percent of the country area.

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[12], UNESCO cultural or natural heritage sites, parks, and other

[9] 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.

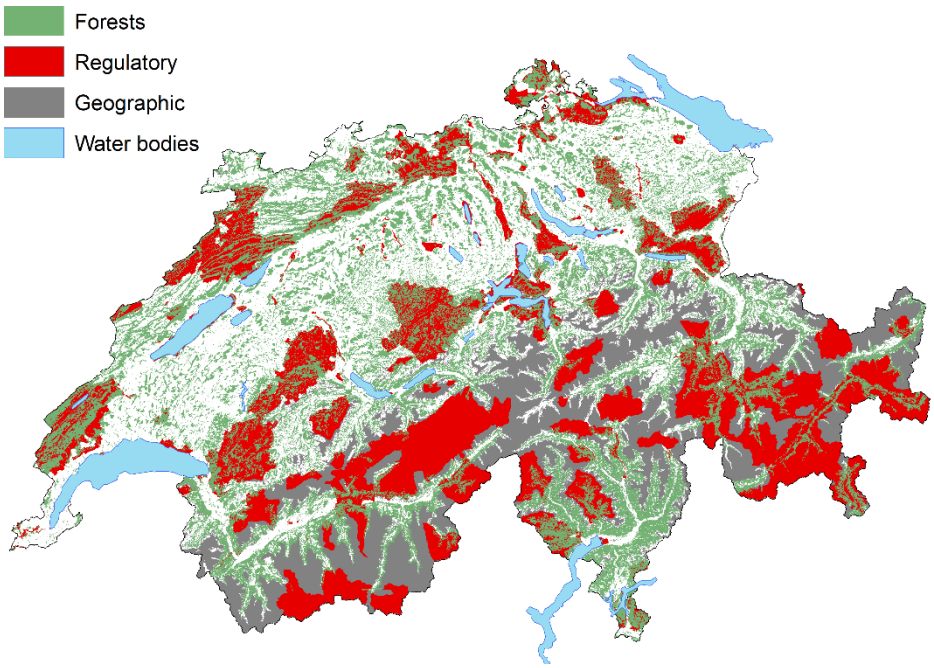
[10] See also Web Appendix A.

[11] 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.

[12] In response to a 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.

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 surface.

Figure 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. With the exception of forests, red areas summarize regulatory constraints on the extensive margin. Swiss forests are protected areas since 1876.

The remaining 32.7 percent of the country surface (white area in Figure 2) is available for development under different regulatory measures determining the intensity and type of residential development. We refer to these latter measures as regulations on the intensive margin. As a proxy for intensive margin regulation, we collected information about the building refusal rates at the municipal level.[13] The refusal rates reflect the effective restrictiveness of local governments regarding residential development and show significant spatial variation, with an average refusal rate of 15 percent.

[13] 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 comprehensive and harmonized information about the type of zoning policies implemented across cantons and municipalities.

4. Empirical framework

In this section, we start by illustrating the empirical specification used to estimate average supply responses at the country level. In a next step, we discuss the identifying assumptions underlying this specification. Finally, we illustrate how we estimate heterogeneous housing supply responsiveness at the neighborhood level.

4.1. Estimating average housing supply elasticities

To quantify supply responses with respect to changes in prices and periodic costs, we estimate the following First Difference (FD) model

$$\Delta \ln(\tau_{nt}) = \alpha^{\tau} + \beta^{\tau} \Delta \ln(Q_{nt}) + \gamma^{\tau} s_{nt} + u_{nt}^{\tau}, \tag{4}$$

where τ_{nt} represents average asking rents ($\tau = R$) or asking prices ($\tau = P$) per square meter in neighborhood n at time t, and Q_{nt} is the *total* housing stock. We denote by Δ the time difference between 2005 and 2015. The error term u_{nt}^{τ} captures unobserved dynamic components affecting housing supply. Because (4) is a FD model, local time-invariant unobservable at the neighborhood level are partialled out and are not contained in u_{nt}^{τ}. The structural parameters $\beta^{R} = 1/\epsilon^{Q,R}$ and $\beta^{P} = 1/\epsilon^{Q,P}$ represent inverse housing supply elasticities with respect to rent and price changes, respectively.[14] In line with our conceptual framework, these parameters are estimated relying solely on spatial variation across neighborhoods and are not affected by short-term dynamics.

The vector s_{nt} contains a number of supply shifters, which might affect the inverse housing supply function. Because dynamics of asking rents and prices per square meter might differ if systematic quality differences – not captured by the living surface – between rental and selling properties appear over time, we control for changes in average building age, average number of rooms, and the share of advertised single-family houses in a given neighborhood.

To account for the impact of previous development on rent and price dynamics, we control for the log of the housing stock in the 1980s. According to Hilber and Robert-Nicoud (2013), the level of historic housing development proxies for the contemporaneous restrictiveness of land use regulations implemented in a given area. High-amenity areas develop first and, because of

[14] Following Saiz (2010), we estimate inverse supply elasticities – instead of regressing quantity changes on price changes – because available exogenous demand shifters tend to be more relevant for quantity changes.

the political game played between land developers and owners of developed land, tend to adopt more stringent land use regulations. These stringent regulations likely have a direct impact on supply price dynamics. Furthermore, Saiz (2010) argues that in more developed places geographic constraints are more binding due to a lack of developable land.

To control for spatial patterns in the regulatory restrictiveness of housing supply not captured by the historic housing stock, we partial out the distance of each neighborhood from the closest administrative center of one of the 15 major agglomerations. We do this because many suburban areas that were largely undeveloped in the 1980s have progressively become better connected with the CBD and have started to zone low-density residential land to attract wealthy taxpayers, thus imposing regulatory constraints on land developers.

Finally, we control for geography-based supply shifters, such as elevation and terrain ruggedness. Within a given area, 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 asking rents/prices over time, as developers face higher construction costs for providing additional housing units on the extensive margin of existing development.

Equilibrium changes of the housing stock $\Delta \ln(Q_{nt})$ are endogenous via changes in the housing demand. Because housing demand negatively correlates with rent and price growth, we expect OLS estimates to be downwardly biased, thus implying overestimated supply elasticities. To overcome this problem, we instrument for $\Delta \ln(Q_{nt})$ by constructing a shift-share instrument z_{nt} of the eight most spoken languages in Switzerland, which in decreasing order of importance are German, French, Italian, Portuguese, English, Serbian, Albanian, and Spanish (remaining languages are included in a ninth category). These languages account for approximately 97 percent of the Swiss population. In line with the approach suggested by Bartik (1991), we define the 'Bartik language' instrument as the weighted average of cantonal growth rates between 2000 and 2015 of these main spoken languages, where the weights are the predetermined shares of main spoken languages in a given neighborhood in 2000. Appendix B provides further details on the computation of the instrument.

Because individuals tend to migrate into areas where people share the same cultural values, local predetermined shares of main spoken languages serve as a predictor of the spatial distribution of future immigration inflows as well as relocation within the country, such that

$E(\Delta \ln(q_{nt})\, z_{nt}) \neq 0$. The fact that cultural and ethnic networks play a crucial role in the location choice of immigrants has been documented in the literature, for example, by Altonji and Card (1989), Carrington et al. (1996) and Winters et al. (2001). Saiz (2007) exploits a similar argument, relying on the share of new immigrants relative to the initial population to instrument changes in the housing demand across US Metropolitan Statistical Areas (MSAs). Immigration has been pronounced in Switzerland in the last decades with the residential population increasing by approximately 27 percent between 1980 and 2015.

The standard identifying assumption to obtain an unbiased estimate of β^{τ} is that $E(z_{nt} u_{nt}^{\tau}) = 0$. Because time-invariant unobservables affecting supply prices at the local level are eliminated by first differencing, the instruments must be exogenous only with respect to the unobservable supply dynamics contained in u_{it}. Supply dynamics not controlled for in our base specification include changes in the factors of production of the housing sector. However, the cost of capital and the price of construction materials are determined at the international level, such that they are uncorrelated to the local dynamics of main spoken languages.

The identifying assumption is thus not satisfied if changes in the spatial distribution of spoken languages affect the cost of producing housing vial labor markets. For example, if individuals speaking specific languages tend to supply labor in the construction industry, thereby shifting equilibrium wages, this causes construction costs to also change, leading to a correlation between z_{nt} and u_{nt}^{τ}. However, such a correlation seems unlikely due to the small size of the country. On the labor supply side, local differentials in wage dynamics tend to disappear due to the elasticity of labor supply via commuting flows. Put differently, if wages in the construction sector were to suddenly increase/decrease in a given area following a labor supply shock, workers can decide to supply labor elsewhere without relocating. On the labor demand side, the competition that characterizes the construction sector – which has very limited entry barriers – also makes wage dynamics homogeneous across space. To empirically test these claims, in Section 6 we show that our results are robust when controlling for long-run construction cost changes and initial price levels. Additionally, in Section 6, we show that an alternative instrument, which exploits a different source of variation, leads to similar results, therefore reinforcing our claim concerning the exogeneity of the instrument.

4.2. Local supply responsiveness and the role of geographic and regulatory constraints

Equation 4 assumes that inverse supply elasticities are, on average, constant across locations. This assumption seems too restrictive for two reasons. First, supply elasticity in a given area might vary considerably according to regulatory restrictions adopted by local governments. According to Hilber and Robert-Nicoud (2013), attractive places are more developed and, as an outcome of the political game between land developers and owners of developed land, more regulated. To proxy for this regulation effect, we interact the housing stock level in the 1980s with contemporaneous stock growth. Second, in addition to regulatory restrictions we allow land availability to influence housing supply elasticities. However, as argued by Saiz (2010), geographic constraints are binding only in places where development levels are high enough. To investigate these propositions, we thus estimate the following equation

$$\Delta \ln(\tau_{nt}) = \alpha^{\tau} + \beta^{s,\tau}\Delta \ln(Q_{nt}) + \beta^{hist,\tau}\Delta \ln(Q_{nt}) \times Q_{n1980} + \beta^{constr,\tau}\Delta \ln(Q_{nt}) \times \Lambda_n \times Q_{n1980} + \gamma^{\tau} s_{nt} + u_{nt}^{\tau}, \quad (5)$$

where Λ_n represents a given geographic/regulatory restriction in location n. We assume that Λ_n is exogenous throughout our analysis. Note that Λ_n is interacted with the historic stock level, thus allowing the impact of regulatory constraints to become more binding in more-developed places. In some of our specifications, Λ_n includes the sum of regulatory constraints on the extensive margin and geographic constraints, whereas in Saiz (2010), these two dimensions are specified separately. This seems reasonable in our setting, as many regulatory constraints prevent residential development on the extensive margin, de facto playing a role similar to that of the geographic constraints used in Saiz (2010). Intuitively, because geographic and regulatory constraints on the extensive margin limit new residential development, we expect $\beta^{hist,\tau}$ and $\beta^{constr,\tau}$ to be positive.

Having estimated $\beta^{s,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ for rental and selling properties, we can compute local supply elasticities for neighborhood n as

$$\epsilon_n^{Q,\tau} = \frac{1}{\beta^{s,\tau} + \beta^{hist,\tau} Q_{n1980} + \beta^{constr,\tau}\Lambda_n \times Q_{n1980}}, \tau = R, P. \quad (6)$$

Accordingly, the estimated coefficients together with the spatial distribution of the historic stock Q_{n1980} and the distribution of geographic and regulatory constraints collected in Λ_n determine the local value of the supply elasticity $\epsilon_n^{Q,\tau}$.

5. Results

5.1. Supply elasticity estimates and amplification mechanism

Panel A of Table 1 summarizes average supply elasticity estimates with respect to rent (columns 1-2) and price (columns 3-4) changes, respectively. Using point estimates reported in columns 1 and 3 of Panel A, we obtain supply elasticities equal to $\epsilon^{Q,\mathrm{R}} = 1/0.7454 = 1.34$ for rent and $\epsilon^{Q,\mathrm{P}} = 1/2.1257 = 0.47$ for price changes. These results suggest that, on average, housing supply in Switzerland is relatively elastic to rent changes, but less so with respect to price changes.

Table 1: Inverse supply elasticities

Panel A: Average supply elasticities				
	(1)	(2)	(3)	(4)
Outcome	ΔLog Rent/m2		ΔLog Price/m2	
Instrument	Bartik languages			
$\Delta\mathrm{Log}Q$	0.7454***	0.4750**	2.1257***	2.7845***
	(0.2881)	(0.2202)	(0.3592)	(0.4780)
Kleibergen-Paap F	69.49	61.07	69.49	50.18
Observations	2261	1419	2261	1419
Panel B: Heterogeneous supply elasticities				
$\Delta\mathrm{Log}Q$	0.4481*	0.0058	1.4627***	1.5412***
	(0.2674)	(0.2236)	(0.3631)	(0.4285)
Stock 1980 × $\Delta\mathrm{Log}Q$	0.5656***	0.5153**	1.2609***	1.2697***
	(0.1665)	(0.2036)	(0.3175)	(0.4825)
Total restricted ×	0.2208**	0.1651*	0.4879***	0.4264**
Stock 1980× $\Delta\mathrm{Log}Q$	(0.0867)	(0.0918)	(0.1738)	(0.2011)
Kleibergen-Paap F	19.05	11.14	19.05	13.74
Observations	2261	1419	2261	1419
Controls				
Supply shifters	Yes	Yes	Yes	Yes
ΔHousing characteristics	No	Yes	No	Yes

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. In columns 1-4 supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, and total restricted areas. Total restricted area is standardized and contains constraints on the extensive margin – water bodies, undevelopable land, forest, and other protected areas. In columns 2 and 4 housing characteristics include share of single-family housing and for the housing characteristics age and number of rooms. See Web Appendix B for detailed estimation results. Changes in housing stock $\Delta\mathrm{Log}Q$, including interaction terms thereof, are instrumented using a shift-share instrument for main spoken languages.

These estimates are robust to the inclusion of housing characteristics capturing potential quality differences between rental and selling properties, as shown in columns 2 and 4 of Table 1A. Note that we lose part of the sample due to the unavailability of traded properties' housing characteristics in some neighborhoods. This reduction in the number of observations reduces the variation in our variables, which makes the instrument comparatively less relevant.

Using average housing supply elasticity estimates, we obtain an amplification coefficient $\epsilon^{\mathrm{P,R}} = \frac{\epsilon^{\mathrm{Q,R}}}{\epsilon^{\mathrm{Q,P}}} \cong \frac{1.34}{0.47} \cong 2.85$, implying that for a given relative rent growth housing supply increases by about 2.85 times more than with respect to an equivalent price change. The average country response of local capitalization rates to rent changes is then $\epsilon^{\mathrm{c,R}} = 1 - \epsilon^{\mathrm{P,R}} = -1.85$. According to Equation 3, this negative response of capitalization rates suggests that investors revise local rent growth expectations (risk premium) upward (downward) following an exogenous positive demand shock.[15]

We now turn to the analysis of housing supply heterogeneity at the local level. Columns 1 and 3 of Table 1B summarize the results when all relevant constraints on the extensive margin – including water bodies, undevelopable land, forest, and other protected areas – are considered together in Λ_n.[16] As before, columns 2 and 4 show estimates of specifications accounting for detailed characteristics of housing units. The coefficients of the double and triple interaction terms, which capture local supply heterogeneity, are 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 are more binding in more-developed places.[17] The double interaction coefficients are systematically lower for rental than selling properties, suggesting that previous development patterns seem to decrease the supply elasticity of selling properties to a larger extent than that of rental properties.

Having estimated the coefficients $\beta^{s,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ for rental and selling properties, we compute supply elasticities and amplification coefficients at the neighborhood level according to Equation 6. 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 3 we show the spatial distribution of local housing supply price elasticity $\epsilon_n^{Q,P}$ (Panel A) and of the amplification coefficient $\epsilon_n^{c,R}$ (Panel B).[18]

[15] Interestingly, this result is in line with Begley et al. (2019). By simulating a dynamic model, they find that a positive demand shock – as captured by a higher population growth – leads to lower capitalization rates.

[16] We designate this term as "Total restricted" in Table 1B.

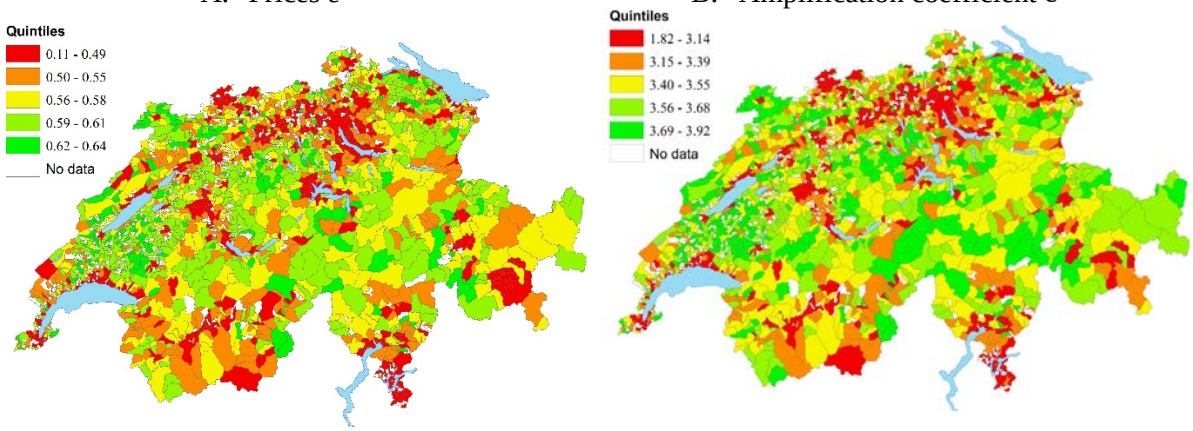
[17] Note that the heterogeneity arising from geographic and regulatory constraints alone is never significant. To compute our estimates, we always include geographic/regulatory constraints as a control, thus partialling out a direct effect of this variable on rent and price dynamics.

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

As apparent from Figure 3A, housing supply price elasticity varies considerably across space. Major agglomerations – and even more so, areas near major CBDs – are particularly inelastic. In contrast, countryside areas generally display comparatively higher elasticity values. However, this is not always true for Alpine regions. Some alpine regions have low elasticity values – both for rent and price changes – likely due to the importance of geographic constraints in conjunction with historic development.[19] Concerning the spatial distribution of supply elasticities, Zurich and its neighboring agglomerations account for the largest area displaying inelastic housing supply. Even farther away from CBDs, housing supply remains fairly inelastic.[20]

Figure 3: Local supply elasticities and amplification coefficient

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



Notes: Supply elasticity interval defined according to quintiles of the distribution. Local estimates are computed using Equation 4 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.

Compared to US the housing supply elasticities estimated by Saiz (2010), the Swiss housing market is significantly less responsive to price changes. This reflects the widespread geographic and regulatory constraints hindering extensive margin development even in the countryside of the country. In Appendix C, we provide a more detailed comparison of our estimates with those obtained in the literature, adding further credibility to our estimates.

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

[20] 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. Figure C1 in Appendix C shows the distribution of the computed elasticities. In Table C1 in Appendix C, we rank the responsiveness of housing markets at three different aggregation levels: cantons, agglomerations, and municipalities.

As shown in Figure1B, the amplification mechanism also displays considerable spatial heterogeneity, with values ranging from 1.82 to 3.92. Central places display the lowest value of $\epsilon_n^{P,R}$, whereas countryside areas the highest. This seems to suggest that following a shock to periodic housing costs investors adapt their expectations and risk premia more in remote areas than in central ones. This because attractive central places, in particular heavily restricted/regulated ones, already command high rent growth expectations and low risk premia. A positive demand shock is thus unlikely to strongly modify these expectations. On the contrary, investors revise their expectations substantially following a demand shock in elastic countryside areas, in line with the hypothesis of a path dependent view of spatial development.

5.2. Buyers' sophistication and local expectations

In this section, we provide further evidence about the way buyers adjust their rent growth expectations and perceived risk to observed changes in the period cost of housing. To this end, we investigate how the local amplification coefficient $\epsilon_n^{P,R}$ varies according to buyers' sophistication. We proxy such sophistication by measuring the presence of institutional investors – which include real estate firms, construction firms, insurers, and pension funds – and second-home buyers in a given neighborhood. Because these buyers are individuals and professional firms investing in real estate mainly to realize capital gains or benefit from rental income, we assume that they are more sophisticated than private buyers.[21]

We proceed in two steps. First, to investigate whether the presence of sophisticated buyers affects the observed spatial distribution of the amplification coefficient, we estimate the following simple relationship:

$$\epsilon_n^{P,R} = \alpha + \beta\omega_n + \gamma s_n + v_n, \tag{7}$$

where $\epsilon_n^{P,R}$ represents the amplification coefficient in neighborhood n, ω is either the predetermined share of institutional investors ($\omega = I$) or second home owners ($\omega = O$) in 2000, and s_n contains time-invariant controls including elevation, elevation standard deviation, log-distance to the nearest CBD, and log-housing stock in 1980. The variable v_n is a stochastic

[21] For example, second-home buyers have been found to be more sophisticated than primary home buyers (Bernstein et al., 2018).

error term. Table 2 shows the estimation results for the presence of institutional investors (Panel A) and second-home buyers (Panel B).

Table 2: Investor sophistication as a determinant of heterogeneous supply elasticities

Panel A: Share of institutional investors			Panel B: Share of second-home owners		
	(1)	(2)		(1)	(2)
	OLS	OLS		OLS	OLS
Dependent variable	Amplification effect		**Dependent variable**	Amplification effect	
Share of inst. investor	-1.5706***	-0.3525***	Share of second home	0.0090	-0.0445***
	(0.1066)	(0.0267)		(0.0253)	(0.0144)
Constant	3.0648***	3.7159***	Constant	3.0076***	3.6747***
	(0.0044)	(0.0115)		(0.0071)	(0.0131)
Other controls	No	Yes	Other controls	No	Yes
R-squared	0.2930	0.8513	R-squared	0.0001	0.8175
Observations	5054		Observations	5,168	

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 2x2 km. In columns 2 and 4 we control for elevation, elevation standard deviation, log-distance to the nearest CBD, and log-housing stock in 1980.

The results in Table 2A show that a higher share of institutional investors reduces the amplification effect. Similarly, in Table 2B, a higher share of second home owners yields a lower amplification effect, albeit the reduction in the amplification coefficient is less significant and less pronounced compared with the role of institutional investors. Note that this analysis explores only variation in $\epsilon_n^{P,R}$ that stems from observable characteristics of locations as included in Equation 5.

In a second step, to further substantiate the role of buyers' sophistication, we estimate Equation 4 with respect to price and rent changes by restricting the sample of neighborhoods according to the presence of institutional investors and second-home owners. We compute the amplification effect for each one of the restricted samples. Specifically, for the share of institutional investors we restrict the sample to the 50th, 75th, and 90th percentile. For the share of second home owners we restrict the sample to the 10th, 30th, 50th percentile. We choose different percentiles because the share of institutional investors is close to zero for a large part of the distribution.[22]

To rule out the differences across subsamples that are merely driven by the fact that institutional investors mostly focus on agglomerations, and agglomerations display different levels of risk and rental growth expectations independent of the type of investors, we augment the controls

[22] The 50th, 75th, and 90th percentile of the share of institutional investors corresponds to 0.01, 0.06, and 0.15, respectively. The 10th, 30th, and 50th percentile of the share of second-home owners corresponds to 0.04, 0.06, and 0.08, respectively.

in Equation 4 with an interaction between the change of housing supply and the historic housing stock $\Delta \ln(Q_{nt}) \times Q_{n1980}$. Table 3 shows the results.

Table 3: Amplifications effect by percentiles of investor sophistication

Panel A: Amplification effect restricting by share of institutional investors				
	(1)	(2)	(3)	(4)
Percentile inst. investor	Full sample	P50	P75	P90
Amplification effect	2.85	2.95	2.28	2.06
Amplification effect with interaction term	2.86	3.05	2.47	2.19
Observations	2261	1639	906	375
Panel B: Amplification effect restricting by share of second home owners				
Percentile second home	Full sample	P10	P30	P50
Amplification effect	2.85	2.62	2.97	2.24
Amplification effect with interaction term	2.86	2.65	2.97	2.22
Observations	2261	2073	1472	881

Notes: The regressions estimated to compute the amplification effect have standard errors that are clustered at the municipality level. The units of observations are obtained by partitioning the whole territory of the country in small square cells of 2x2 km. All the point estimates are estimated controlling for elevation, elevation standard deviation, log-distance to the nearest CBD, and log-housing stock in 1980.

Column 1 of Table 3 shows the amplification coefficient without restricting the sample. The results in columns 2 to 4 of Table 3A and 3B show that the amplification effect is markedly lower at places with a high share of more sophisticated investors as proxied by institutional investors or second home investors, respectively. This holds true independently of whether we control for the interaction term or not. The upper 10 percent of municipalities according to their share of institutional investors displays a more than 50 percent lower than the corresponding sample mean.

5.3. Quantifying the importance of individual geographic and regulatory constraints

In the previous sections, we have seen that geographic and regulatory constraints do reduce the responsiveness of local housing supply. As shown in Figure 2, such constraints are unevenly distributed across the country territory. In the following, we quantify the importance of *individual* geographic/regulatory constraints at the local level.

To quantify the importance of regulatory constraints on the extensive margin, we re-estimate models equivalent to Equation 5, but substitute Λ_n with a specific constraint instead of considering all constraints together. We then evaluate local supply elasticities at the average value of the historical development Q_{n1980} and set the value of the respective constraint contained in Λ_n of Equation 6 equal to its 25th and 75th quantiles, respectively. Comparing these two elasticities allows us to infer the impact of the constraint for an average developed

neighborhood. In the case of supply heterogeneity arising only due to historic development, we compute Equation 5 fixing $\Lambda_n = 0$ and setting the housing stock in the 1980s to the 25th and 75th quantile values. Table 4 contains the results of these computations.

As is evident from this table, geographic constraints preventing development, although significant for rents, decrease supply elasticities only to a relatively small extent. On the other hand, the standard deviation of elevation decreases housing supply elasticities in a more important way, with a -11.3 percent and -10.7 percent reduction in rent and price elasticities. Terrain ruggedness is more important than undevelopable area, likely because in those areas where land availability is strongly restricted by geographic constraints, development is scarcer and only a few advertisements are available in our data.

Table 4: Contributions of geographic and regulatory constraints to supply heterogeneity

	25th quantile	75th quantile	% change	25th quantile	75th quantile	% change
	Panel A: Rents			Panel B: Prices		
Geographic constraints						
Undevelopable	1.24	1.20	-3.60*	0.44	0.43	-1.20
Elevation SD	1.25	1.11	-11.30*	0.45	0.40	-10.70**
Regulatory constraints-extensive margin						
Forests	1.16	1.05	-9.50	0.42	0.37	-11.50**
Other protected areas	1.21	1.07	-11.10*	0.44	0.41	-6.50
Total regulatory	1.16	0.89	-22.90**	0.42	0.34	-18.70**
Regulatory constraints-intensive margin						
Stock1980 [a]	1.62	1.23	-24.20***	0.54	0.44	-19.30***
Refusal rate	1.36	1.20	-11.80***	0.43	0.42	-1.40
Total						
Total restricted (geographic + regulatory constraints extensive margin)[b]	1.17	0.88	-25.10**	0.421	0.33	-21.10***

Notes: *** p<0.01, ** p<0.05, * p<0.1. [a] Note that the historic stock serves as a proxy for the intensity of regulation. [b] Total restricted includes all geographic constraints and all regulatory constraints on the extensive margin.

Regulatory constraints on the extensive margin seem to have, in general, a greater impact on supply elasticities, especially when all significant restrictions added together. Places whose total regulated area belongs to the 75th quantile of the regulation distribution, have a supply rent (price) elasticity that is 22.9 percent (18.7 percent) lower than those areas that belong to the 25th quantile of the regulation distribution.

Intensive margin regulations also play a significant role, the most important of which is the level of historic development, which proxies for the intensity of current regulations. Places that are historically more developed display a 24.2 percent and 19.3 percent lower supply elasticity

with respect to rent and price changes, respectively. Refusal rates seem to matter only for rent changes. For price elasticities, their impact is insignificant and close to zero.[23]

Finally, we consider the joint impact of geographic and extensive margin regulatory constraints. It makes sense to consider these two categories together, as they both prevent new development on the extensive margin. The combined effect is highly statistically significant and has the largest magnitude among all the restrictions we have investigated. Areas with more total restricted areas have rent (price) supply elasticities that are 25.1 percent (21.1 percent) lower than that of less-restricted areas.

6. Robustness checks

In this section, we verify the robustness of our baseline results presented in Section 5.

6.1. Controlling for construction costs dynamics

As pointed out in Section 4, our instrumental variable approach hinges on the assumption that language dynamics do not relate to unobserved rent and price dynamics via labor markets. Therefore, we verify the robustness of our main results when including a construction cost index as a control. The construction cost index we use is published by the FSO and measures changes in development costs for Swiss statistical areas.[24]

Following Saiz (2010), we divide the cost growth observed in these regions between 2005 and 2015 by the 2005 local level of rents/prices per square meter, which corresponds to changes in construction costs as a share of initial rents/prices. Despite being potentially endogenous, including initial rents/prices allow us to proxy for unobservable initial supply shifters in the rental and selling markets, respectively. Table 5 replicates the main results of Table 1.

As it can be seen, dynamic changes in construction costs relative to initial rents/prices are highly significant for the two markets when not controlling for housing characteristics, but it does not affect our results. The robustness of our results to this inclusion supports the

[23] A word of caution is in order concerning the impact of refusal rates. Throughout our analysis, we have assumed that the variable Λ_n is exogenous to unobserved rent and price dynamics. However, despite measuring them prior to rent and price dynamics (from 2001 to 2004), refusal rates are potentially correlated with the error term of Equation 5 via anticipation mechanisms. For this reason, we exclude such regulation proxy from all other analyses.
[24] These areas are the Lake of Geneva, Espace Mittelland, Northwestern Switzerland, Zurich, East Switzerland, Central Switzerland, and Ticino. Note that due to high mobility and a highly integrated market variation in construction costs is only minor.

hypothesis that the labor market of the construction industry in Switzerland is relatively homogeneous and its dynamics do not affect our estimates of housing supply elasticities.

Table 5: Controlling for construction cost dynamics

Panel A: Average supply elasticities				
	(1)	(2)	(3)	(4)
Outcome	ΔLog Rent/m2		ΔLog Price/m2	
Instrument	Bartik languages			
$\Delta\text{Log}Q$	0.7536***	0.4288**	2.7845***	2.7882***
	(0.2876)	(0.1851)	(0.4780)	(0.4798)
Construction costs	0.1590***	0.0033***	0.9944***	-0.0003
	(0.0514)	(0.0003)	(0.0765)	(0.0006)
Kleibergen-Paap F	69.52	61.08	69.52	50.21
Observations	2261	1419	2261	1419
Panel B: Heterogeneous supply elasticities				
$\Delta\text{Log}Q$	0.5277**	-0.0637	1.4706***	1.5513***
	(0.2156)	(0.2186)	(0.3236)	(0.4275)
Stock 1980 × $\Delta\text{Log}Q$	0.6374***	0.5339**	1.3246***	1.2656***
	(0.2108)	(0.2374)	(0.3524)	(0.4799)
Total restricted ×	0.2074**	0.1549	0.4844***	0.4273**
Stock 1980× $\Delta\text{Log}Q$	(0.1045)	(0.1079)	(0.1852)	(0.1995)
Construction costs	0.0048***	0.0032***	0.9983***	-0.0005
	(0.0003)	(0.0003)	(0.0747)	(0.0005)
Kleibergen-Paap F	18.74	11.22	18.74	13.92
Observations	2261	1419	2261	1419
Controls				
Supply shifters	Yes	Yes	Yes	Yes
ΔHousing characteristics	No	Yes	No	Yes

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the Swiss 2x2 km neighborhoods. In columns 1-4 supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, and total restricted area. Total restricted area is standardized and contains constraints on the extensive margin – water bodies, undevelopable land, forest, and other protected areas. In columns 2 and 4 housing characteristics include share of single-family housing and for the housing characteristics age and number of rooms. Changes in housing stock $\Delta\text{Log}Q$, including interaction terms thereof, are instrumented using a shift-share instrument for main spoken languages.

6.2. Alternative Instruments

We investigate the robustness of our results when using an alternative variable to instrument changes in the housing demand. In line with Saiz (2007), we compute a shift-share instrument for the nationality of Swiss residents. To this end, we rely again on Formula B.1 in Appendix B but instead of considering changes in the geographic distribution of main spoken languages, we analyze changes in the distribution of nationality, which in decreasing order of importance include Switzerland, Italy, Serbia, Portugal, Germany, Spain, Turkey, France, Macedonia, Bosnia, Croatia (a last category includes all other nationalities). Specifically, the shares s_{njt_0} in Formula B.1 are given by the share of residents in a neighborhood having a specific

nationality according to the 2000 population census, and g_{cjt} is given by the corresponding growth of such residents at the cantonal level from 2000 to 2015.

Table 6: Alternative instrument

Panel A: Average supply elasticities				
	(1)	(2)	(3)	(4)
Outcome	ΔLog Rent/m2		ΔLog Price/m2	
Instruments	Bartik nationality	Bartik nationality and languages	Bartik nationality	Bartik nationality and languages
$\Delta\text{Log}Q$	0.9454***	0.8082***	1.4165***	1.9032***
	(0.2512)	(0.2329)	(0.4334)	(0.3245)
Construction costs				
Kleibergen-Paap F	25.91	42.18	25.91	42.18
Observations	2261	2261	2261	2261
Panel B: Heterogeneous supply elasticities				
$\Delta\text{Log}Q$	0.3653**	0.3791*	0.3740	0.9653***
	(0.1784)	(0.1993)	(0.3185)	(0.2931)
Stock 1980 × $\Delta\text{Log}Q$	0.4047***	0.3795***	0.7304***	0.6500***
	(0.1203)	(0.1062)	(0.1742)	(0.1498)
Total restricted ×	0.1002	0.1092*	0.1842**	0.1768*
Stock 1980× $\Delta\text{Log}Q$	(0.0637)	(0.0591)	(0.0918)	(0.0954)
Kleibergen-Paap F	15.80	21.14	15.80	21.14
Observations	2261	2261	2261	2261
Controls				
Supply shifters	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. In columns 1-4 supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, and total restricted area. Total restricted area is standardized and contains constraints on the extensive margin – water bodies, undevelopable land, forest, and other protected areas.

The rationale motivating the instrument is similar to the one of the shift-share instrument based on languages. We expect immigrants and Swiss citizens to value the proximity to individuals sharing the same culture and ethnic origins, thereby shifting the housing demand in those places with a high share of residents having the same nationality.

Note that the correlation between the shift-share instrument based on languages and the one based on nationality amounts to 0.26, implying that the two instruments exploit different sources of variation. We explain the low correlation as follows. First, the shift-share instrument based on languages is able to capture a larger variation in the dynamics of the type of residents with respect to the one based on nationality. In fact, Switzerland has four official languages (German, French, Italian, and Romansch). Additionally, Swiss citizens having immigrated from other countries might have a non-official language as main one. Such heterogeneity within Swiss citizens is not captured by the shift-share instrument based on nationality. Second, many foreigners of second and third generation speak a national language and are perfectly integrated. This also affects the corresponding growth of nationalities at the cantonal level.

Table 7: Inverse supply elasticities estimates using country grid data

	Panel A: IV-second stage – country grid 1km side			
	(1)	(2)	(3)	(4)
Dependent variable	ΔLog Rent/m2		ΔLog Price/m2	
$\Delta\text{Log}Q$	0.4567*	-0.0526	2.2452***	1.1156***
	(0.2539)	(0.2115)	(0.4267)	(0.3323)
Stock 1980 × $\Delta\text{Log}Q$		1.6806***		3.6864***
		(0.5725)		(1.2706)
Total restricted ×		0.8545**		1.8337**
Stock 1980 × $\Delta\text{Log}Q$		(0.3808)		(0.8022)
Instruments	Bartik languages	Bartik languages	Bartik languages	Bartik languages
Kleibergen-Paap F	39.45	8.22	39.45	8.22
Observations	3,449			
	Panel B: IV-second stage – country grid 3km side			
$\Delta\text{Log}Q$	0.7586***	0.5522***	2.3604***	2.0897***
	(0.2172)	(0.2143)	(0.3241)	(0.3367)
Stock 1980 × $\Delta\text{Log}Q$		0.3174***		0.4546***
		(0.0783)		(0.1218)
Total restricted ×		0.1094**		0.1643**
Stock 1980 × $\Delta\text{Log}Q$		(0.0449)		(0.0701)
Instruments	Bartik languages	Bartik languages	Bartik languages	Bartik languages
Kleibergen-Paap F	81.80	24.04	81.80	24.04
Observations	1,555			

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 1x1 km for Panel A and 3x3 km for Panel B. All the point estimates are estimated controlling for elevation, elevation standard deviation, log-distance to the nearest CBD, and log-housing stock in 1980. Total restricted area is standardized and contains all relevant constraints on the extensive margin – including water bodies, undevelopable land, forest, and other protected areas.

Table 6 replicates the results of Table 1 when using the shift share instrument based on nationality. Columns 1 and 3 report the results of Table 1 when using the alternative instrument alone, and columns 2 and 4 show estimation results when using the two shift-share instruments together. As it can be seen, the results of columns 1 and 3 of Table 6 are similar to those of the corresponding columns of Table 1, although the shift-share instrument based on nationality is weaker than the one based on languages. When using the two instruments together in columns 2 and 4, we achieve a higher relevance of the instruments, especially when estimating average supply elasticities in Panel A.

6.3. Modifiable Areal Unit Problem

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

might vary depending on the aggregation level. We thus change the surface covered by our units of observation.

We verify the robustness of our estimates by both decreasing (down to 1 km) and increasing (up to 3 km) the sides of the neighborhoods. Table 7 illustrates the results. The average and heterogeneous supply estimates for rents and prices are quite stable for both 1 km and 3 km side cells. Overall, the heterogeneous supply estimates for both rents and prices are a bit more stable for the 3 km side neighborhoods than for the 1 km side ones. This instability is probably fueled by the irrelevance of extensive margin constraints at the very fine scale. Put differently, 1 km side neighborhoods in which geographic or protected areas are important probably drop out of our sample, as no housing transactions occur in these areas. On the other hand, aggregating at a higher level (3 km side) does not seem to affect the direction, magnitude, and statistical significance of our inverse supply elasticities much.

7. Conclusions

In the present paper, we investigate the response of housing supply with respect to rent and price changes across space. Workhorse models in urban economic theory typically feature periodic costs of housing, whereas the empirical literature on housing supply elasticities focuses on prices. This discrepancy calls for a better understanding of the empirical link between the responsiveness of housing supply with respect to price and rent dynamics. Our empirical results indicate that, on average, housing supply of the Swiss residential housing market reacts twice 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 is consistent with path-dependent spatial development in the sense that investors believe that the places that grew in the past continue to be the ones that see positive demand growth.

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. This supply heterogeneity leads to significant spatial variation in the local amplification effect, which is lower in urban and tourist areas and higher in the countryside.

The spatial variation in the local amplification mechanism holds interesting insights about the way investors perceive and influence residential development. 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 adapt expectations and/ or risk assessments according to a path-dependent view of residential development. Following a demand shock, they only slightly revise their expectations in supply-constrained places, typically represented by highly developed urban areas, whereas in elastic 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 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 the housing market through the demand side.

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A. Data Appendix

A.1 Summary statistics

Table A1 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.

Table A1: Descriptive statistics – country grid (n=2261)

	2005				2015			
	Mean	Min	Max	SD	Mean	Min	max	SD
Endogenous variables								
Rent (CHF/m2)	17.05	6.47	43.90	3.82	19.43	6.36	39.83	3.92
Price (CHF/m2)	4’362	828	11’679	1’270	5’884	2’216	13’062	1’795
Cap rate (Rent/ Price)	0.048	0.016	0.191	0.012	0.042	0.012	0.273	0.011
Stock[a] (number of units)	1’393	2	33’753	2’496	1,551	2	34’294	2’631

	Time invariant			
	Mean	Min	Max	SD
Instruments				
Bartik language[b]	0.09	-0.44	0.30	0.07
Bartik nationality[b]	0.07	0.00	0.57	0.05
Controls				
Elevation (m)	600	204	2,174	228
Elevation SD[d] (m)	59	1	469	57
Distance from nearest CBD (km)	18.53	0.51	101.79	15.37
Stock1980[a] (number of units)	1’024	1	30’147	2’179
Geographic constraints				
Undevelopable[e]	0.04	0	0.75	0.08
Regulatory constraints – extensive				
Forest	0.25	0	0.94	0.18
Other regulations[c]	0.15	0	1	0.30
Total restricted[d]	0.34	0	1	0.28
Regulatory constraints – intensive				
Refusal rate	0.15	0	1	0.3
Type of buyers (in 2000)				
Share of institutional investors	0.07	0	0.65	0.08
Share of second-home buyers	0.10	0	0.81	0.11

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 Bartik instruments are weighted growth rates, they do not have physical units. [c] Share of children up to five years old in the year 1990 at the municipality level. [d] SD=standard deviation. [e] Share of water bodies and undevelopable land within the cell. [c] Other regulations include parks, UNESCO areas, and BLN restrictions. [d] 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. The number of observations for refusal rate is lower (2215 obs.) due to missing values.

A.2 Housing advertisements

Advertisement data for rental and selling properties were provided by *Meta-Sys*, an information provider. 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 A2 illustrates the main variables contained in the data set.

Table A2: 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 per square meter.
House price	CHF	Asking price. Used to compute the house prices per square meter.
Floor space	m2	Floor space of residence. Used to compute the rents/house prices per square meter.
Rent per square meter	CHF/m2	Monthly asking rent per square meter of floor space.
House price per square meter	CHF/m2	Asking price per square meter of floor space.
Building period	Year	Year the residence was built. This variable is missing for about 50 percent of the observations.

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, 2009-2010, and 2014-2015.

A.3 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. The precise construction year is missing for many buildings, but the FSO attributes a specific construction period to all of them. These time intervals are large for early periods (1919 or older, 1919-1945, and 1945-1960, 1960-1970, and 1970-1980). 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 A3 describes the variables used from the building register.

Table A3: Federal register of buildings and habitations

Variable	Units	Description
x-coordinate	WGS-1984	x-coordinate of the building
y-coordinate	WGS-1984	y-coordinate of the building
Building year	Year	Year a building was built. This variable is missing for about 50 percent of the observations.
Ground floor area	m2	Ground floor area of building.
Habitation floor area	m2	Floor area of each habitation.
Type	Category	Single-family, attached/flats, mixed-use (residential and commercial)

A.4 Federal Population Census and the Population and Households Survey

Table A4: Households characteristics

Variable	Units	Description
x-coordinate	WGS-1984	x-coordinate of residence
y-coordinate	WGS-1984	y-coordinate of residence
Nationality	Country code	Nationality of individuals. Each country has a different country code. Used to compute the shift-share instrument for nationality.
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 home owner, 0 if not. Used to compute the home ownership 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 A4 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 for 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). 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. Using a linear interpolation, we then impute homeownership growth rates for the periods 2000-2005 and 2000-2010. Finally, we multiply the initial homeownership rates in 2000 at a given level (within-agglomeration, country-grid, or municipality) with the computed growth rates, thus obtaining the imputed homeownership rates in 2005, 2010, and 2015 at each of the considered levels.

A.5 Regulatory Constraints

Table A5: Supply constraints

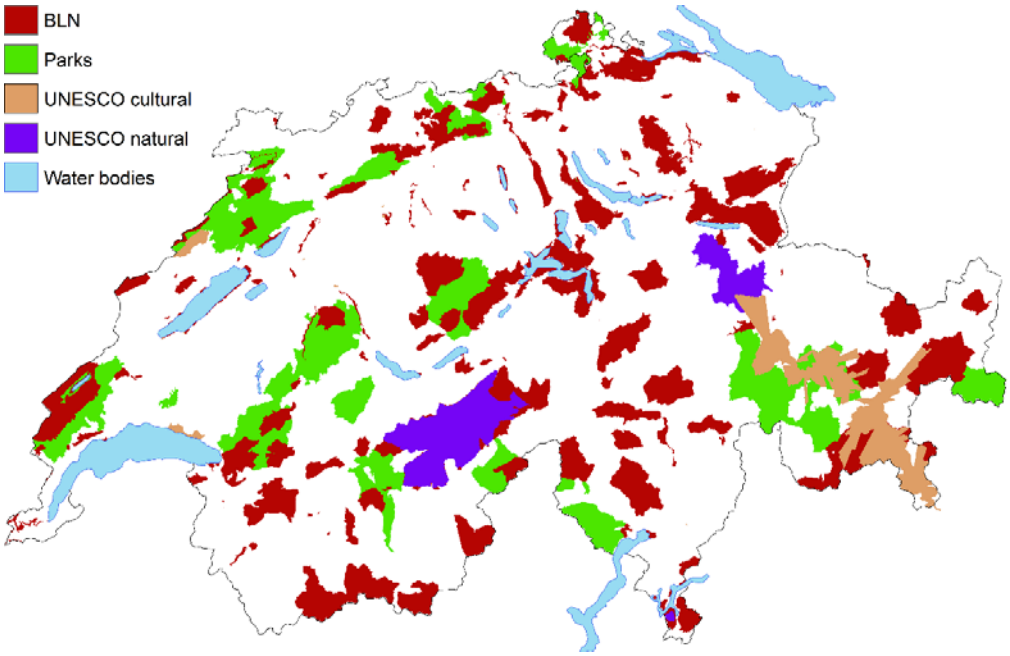
Type of heterogeneity	Label	Description	Area share of Switzerland	Source
Panel A: Geographic constraints				
Water and undevelopable land	Undevelopable	Water bodies + rocks, and glaciers above 2000	31.2%	Land Use Statistics of Switzerland
Standard deviation of elevation (land ruggedness)	Elevation SD	Within grid cells of 2 km	-	Land Use Statistics of Switzerland
Panel B: Regulatory constraints - extensive margin				
Forests	Forest	Protected forest	27.5%	Land Use Statistics of Switzerland
Other protected areas	Other protected areas	BLN, Parks, UNESCO cultural and natural	30.7%	Federal Office for the Environment (FOEN)
Panel C: Regulatory constraints - intensive margin				
Intensity of regulation	Stock1980	Proxy for the intensity of regulation (cf. Saiz, 2010)	-	Federal Register of Buildings and Habitations (GWR)
Building permits refusal rate	Refusal rate	Share of building permits that were rejected	-	Meta-Sys
Panel D: Total restricted area				
Geographic + extensive margin regulatory constraints	Total restricted		67.3%	

Table A5 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 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 A5: UNESCO, BLN, and Parks



Notes: Data source: FOEN. Own graph. With the exception of lakes, colored areas corresponding to extensive margin regulations may overlap.

B. Shift-share instrument of main spoken languages

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

$$z_{nt} = \sum_{j=1}^{J} \frac{f_{njt_0}}{f_{nt_0}} \frac{f_{cjt} - f_{cjt_0}}{f_{cjt_0}} = \sum_{j=1}^{J} s_{njt_0}\, g_{cjt}, \tag{B.1}$$

where f_{njt_0} and f_{cjt_0} represent the number of residents speaking language j within neighborhood n and canton c at time t_0, respectively. Let f_{nt_0} denote the total number of residents living in neighborhood n at time t_0, and t define the time interval over which we compute the growth of a given language since t_0. Therefore, $s_{njt_0} = \frac{f_{njt_0}}{f_{nt_0}}$ is the share of residents speaking a main spoken language in neighborhood *n* at time t_0 and $g_{cjt} = \frac{f_{cjt} - f_{cjt_0}}{f_{cjt_0}}$ is the corresponding growth rate of that language at the cantonal level over $[t, t_0]$. To implement Formula B.1, 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.

Recently, while mainly focusing on labor markets and industrial composition, a number of papers investigating the econometric assumptions necessary for the validity of Bartik instruments has emerged.[25] To summarize, these papers argue that Bartik instruments are valid if either i) initial shares are independent and randomly assigned across observations, which is likely if the number of initial shares is high, or ii) initial shares are endogenous but growth shocks occur randomly across regions. As argued in the main text, in our setting both initial language shares in a neighborhood and language growth shocks at the cantonal level are exogenous with respect to local rent and price dynamics. We support this claim with the robustness checks presented in Section 6.

[25] See, for example, and Borusyak et al. (2018), Adão et al. (2018), and Goldsmith-Pinkham et al. (2018).

C. Assessing Housing Supply Elasticity Estimates

In this section, we aggregate neighborhood-level housing supply elasticity estimates obtained from Equation 6 at the municipal, agglomeration, and cantonal level and provide a ranking of the most inelastic areas. In a next step, we compare these housing supply elasticity estimates to other estimates provided in the literature.

C.1 Ranking housing supply elasticities

Table C1 contains a ranking of different units, from most to least inelastic, according to their housing supply responsiveness with respect to rent and price changes, respectively. These units correspond to three levels of aggregation: cantons, 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 virtually the same with respect to rent and price changes, such that we do not distinguish between the two changes in the following discussion.

Columns 1-3 of Table C1 show the ranking for Cantons. Except for Basel City, all cantons feature a rental supply elasticity above one. Unsurprisingly, Basel City, Zurich, and Geneva appear in the top five most inelastic cantons. In fact, 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 Obwalden, Uri, 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 C1 illustrate the supply elasticity ranking of the 15 largest Swiss agglomerations. Note that all agglomerations feature a 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 rent

and price dynamics, as shown in Figure W-A1. 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.

Table C1: Ranking by supply elasticities

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Cantons			Agglomerations			Municipalities		
Rank	Rents	Prices	Rank	Rents	Prices	Rank	Rents	Prices
BS	.66	.25	Baden Brugg	1.04	.37	Geneva (GE)	.2	.11
ZH	1.54	.48	Lugano	1.32	.43	Basel (BS)	.24	.13
BL	1.62	.49	Zurich	1.44	.46	Brügg (BE)	.27	.14
GE	1.62	.49	Biel/Bienne	1.47	.46	Thalwil (ZH)	.33	.16
TI	1.65	.5	Neuchâtel	1.5	.46	Zurich (ZH)	.34	.17
AG	1.73	.52	Winterthur	1.51	.47	Bern (BE)	.35	.17
ZG	1.76	.52	Olten Zofingen	1.53	.48	Adliswil (ZH)	.36	.17
VS	1.81	.53	Basel	1.59	.49	Vevey (VD)	.4	.18
SO	1.82	.54	Geneva	1.69	.51	Pully (VD)	.42	.2
SH	1.86	.54	Lucerne	1.7	.5	Schlieren (ZH)	.42	.2
NE	1.89	.54	Bern	1.75	.52			
NW	1.89	.54	Zug	1.79	.53	.		
AR	1.89	.55	St. Gallen	1.8	.53	.		
BE	1.9	.55	Lausanne	1.92	.55	.		
SG	1.92	.55	Fribourg	2	.56			
GL	1.93	.55						
VD	1.94	.55				Villeret (BE)	2.45	.63
SZ	1.98	.56				Fieschertal (VS)	2.46	.63
TG	1.99	.57				Missy (VD)	2.46	.63
GR	2	.56				Lugnez (JU)	2.47	.63
LU	2.02	.57				Ependes (VD)	2.48	.64
OW	2.03	.57				Ergisch (VS)	2.49	.64
UR	2.06	.57				Frasco (TI)	2.49	.64
AI	2.11	.59				Isone (TI)	2.49	.64
FR	2.13	.59				Steinerberg (SZ)	2.49	.64
JU	2.17	.59				Zwischbergen (VS)	2.49	.64

Finally, columns 7-9 of Table C1 show the supply elasticity ranking of municipalities. To save space, we only report the 10 most inelastic and the 10 most elastic municipalities. Among the most-inelastic areas are major urban municipalities such as Geneva (GE), Basel (BS), Zurich

(ZH) and Bern (BE). Thalwil (ZH), Adliswil (ZH), and Schlieren (ZH) are suburban areas located within the proximity of the municipality of Zurich. Similarly, Pully (VD) is a suburban municipality near Lausanne. Finally, Vevey (VD) is a fairly urbanized town on Lake Geneva, and Brügg (BE) is a municipality that is highly constrained by regulatory constraints on the extensive margin. In contrast, the ten most elastic municipalities are mostly located in remote areas displaying large land availability and few geographic/regulatory constraints.

C.2 Comparison with estimates provided in the literature

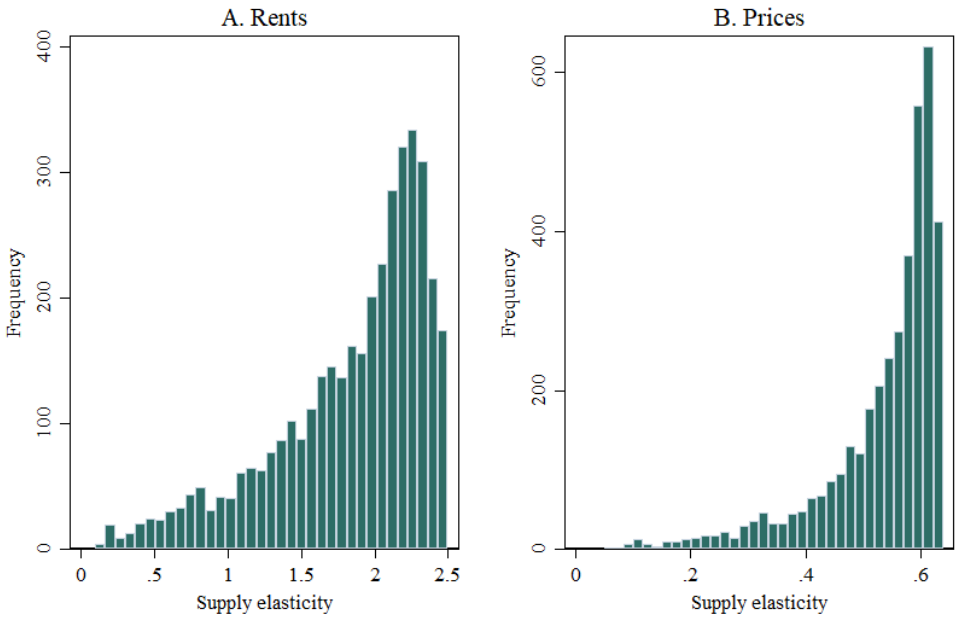
We compare our estimated price supply elasticities with those obtained by Saiz (2010) and Caldera and Johansson (2013).[26] We focus on these two papers for the following reasons. Because our methodological approach is mainly based on Saiz (2010), we can investigate how housing supply elasticities computed for major US 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.

Saiz (2010) finds an average supply elasticity of 1.54 (=1/0.65) for US metropolitan areas when heterogeneity is not considered, suggesting that US metropolitan areas are almost three times more elastic as Switzerland's 15 largest agglomerations, which have an average supply elasticity of 0.49 without heterogeneous effects.[27] Because we obtain a similar value of 0.47 for the average supply elasticity for the whole of Switzerland, which equals 0.47, the difference between the two elasticities does not hinge on the definition of Swiss agglomerations. 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 US Metropolitan Statistical Areas (MSAs) vary between 0.6 in Miami (FL) and 5.45 in Wichita (KS). As shown in Table C1, for Switzerland we obtain supply elasticities estimates ranging from 0.25 and 0.59 at the cantonal level, from 0.37 to 0.56 for major agglomerations, and from 0.11 to 0.64 at the municipal level.

[26] 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.
[27] We compute this value by averaging the elasticities of column 6 in Table C1.

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 US MSA is much larger in terms of area, population, and housing transactions than any 2x2 km cell in our country grid 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* US MSAs that is eliminated by aggregating data for these areas. As shown in Figure C1, in the case of Switzerland we do see that there is considerable dispersion in supply elasticity estimates across neighborhood, with a few places having extremely inelastic housing supply.

Figure C1: Distribution of local supply elasticity



As shown in Table C1, 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).[28]

The second factor is the difference in the magnitude of geographic and regulatory constraints of the two countries. As illustrated in Figure 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

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

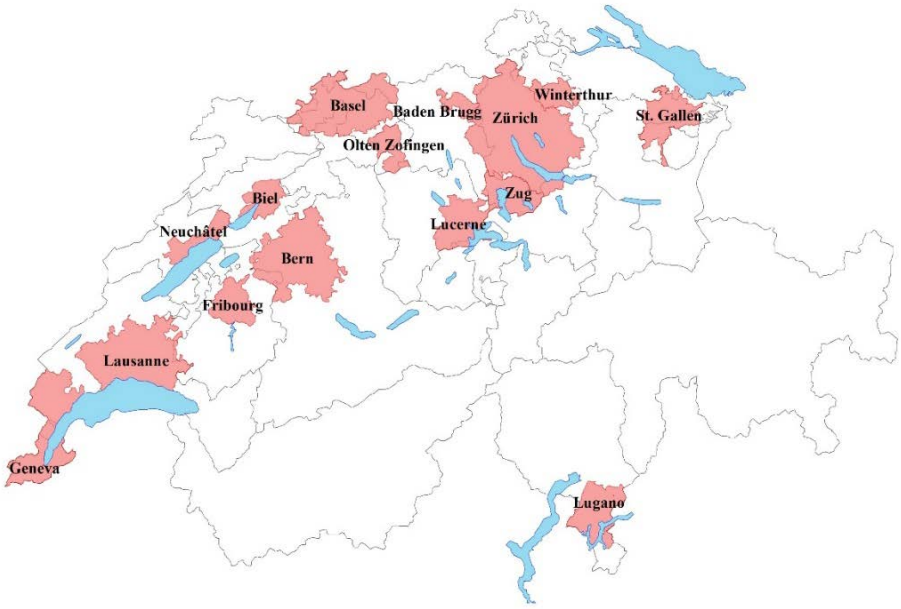
countryside areas. With the exception of a few extremely constrained MSAs, in the US there are ample quantities of open land are still available for residential development.

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. In fact, 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.

Web Appendix A. The Swiss Housing Market

In this section, we provide complementary information on the Swiss housing market. Figure W-A1 shows the country and cantonal boundaries, as well as the 15 major agglomerations in 2015 according to the Federal Statistical Office (FSO).

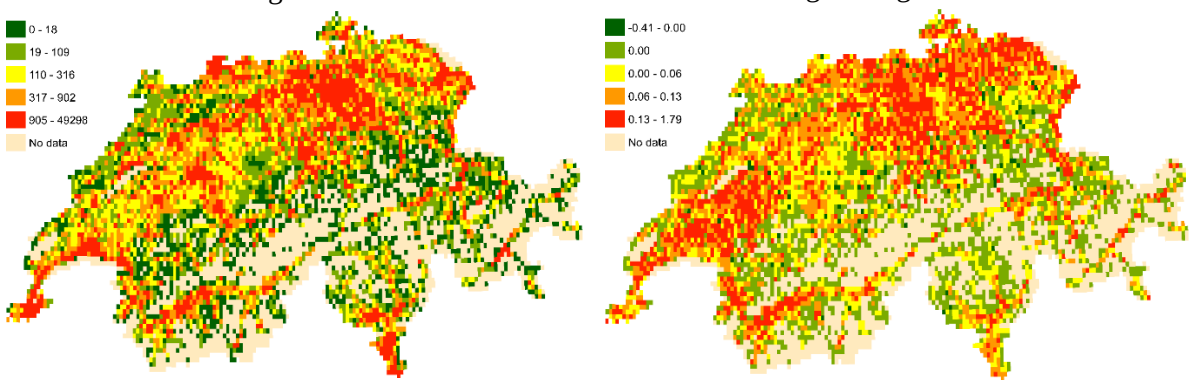
Figure W-A1: Major Swiss agglomerations in 2015



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. Neighborhoods (2x2km square cells) located within these urban areas display the highest housing stock density in 2015, as illustrated in Panel A of Figure W-A2.

Figure W-A2: Housing stock

A. Housing stock in 2015 B. Housing stock growth 2005-2015



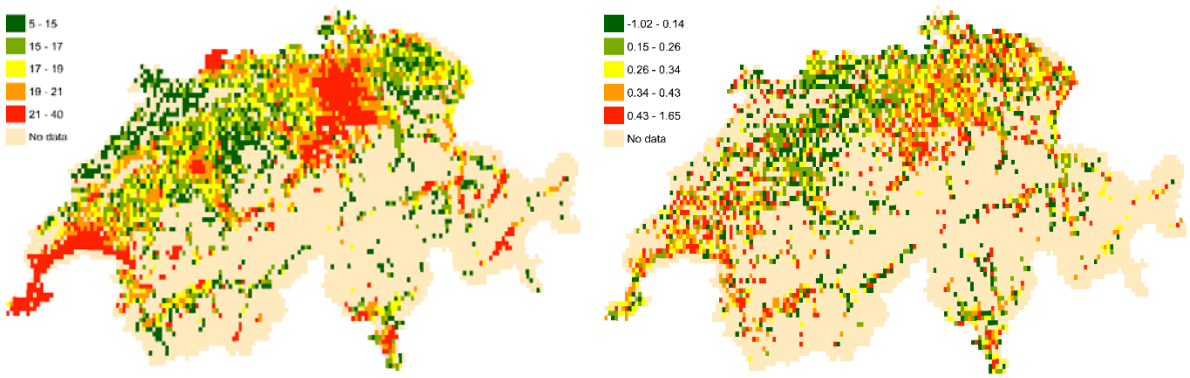
Notes: Data source: GWR. Number of residential buildings per grid cell. Range is according to quintiles. Grid cells are of size 2x2 km, which corresponds to 4 square km. The total number of grid cells is 10,332.

Areas without/ with a few buildings are typically located in the Alps, where residential development is hindered by steep slopes, terrain ruggedness, bad soil quality, and a lack of accessibility. Interestingly, as shown in Panel B of Figure W-A2 over the period of our analysis (2005-2015) the housing stock has markedly increased in suburban and countryside areas, growing at a lower rate within the proximity of the CBDs.[29] In more remote alpine areas, the stock remained unchanged or even decreased due to demolitions.

According to Panel A of Figure W-A3, rents per square meter are particularly high in major Swiss agglomerations, with Zurich-Zug and the Lemanic Arc – defined as the union of the agglomerations of Geneva and Lausanne – having the flattest rent gradient from their administrative centers. Smaller central business districts (CBDs) – such as Bern, Basel, or Lugano – display the steepest rent gradients, implying that more affordable rents can be found at a smaller distance from the city centers compared to larger agglomerations such as Zurich and Geneva. With the exception of a few sparse areas, rents have considerably increased throughout the Swiss territory, with higher increases within urban agglomerations than in rural areas, as shown in Panel B of Figure W-A3.

Figure W-A3: Asking rents

A. Rent in 2015 B. Rent growth 2005-2015



Notes: Data source: Meta-Sys. Asking rents and prices in CHF per square meter. The range is according to quintiles. Grid cells are of size 2x2 km, which corresponds to 4 square km. The total number of grid cells is 10’332.

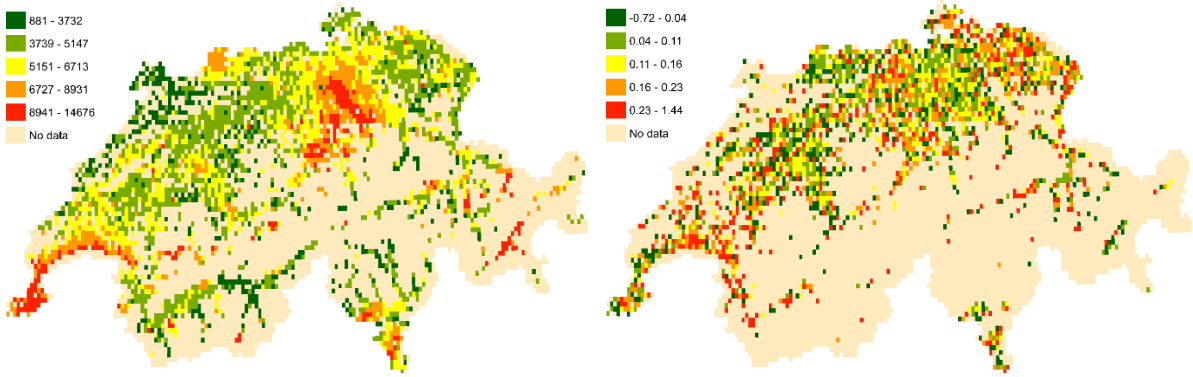
As illustrated in Panel A of Figure W-A4, the gradient of asking price per square meter is steeper than that for rents, with Zurich-Zug-Luzern and the Lemanic Arc representing the areas of the market with the highest prices. Similar to rents, prices have increased across the whole

[29] The share of housing stock within 5 km of the CBDs decreased from 30 percent in 2005 to 29.6 percent in 2015 despite the efforts to contain urban sprawl.

country, with only a few locations displaying a negative price growth, as shown in Panel B of Figure W-A4.

Figure W-A4: Asking prices

A. Price in 2015 B. Price growth 2005-2015

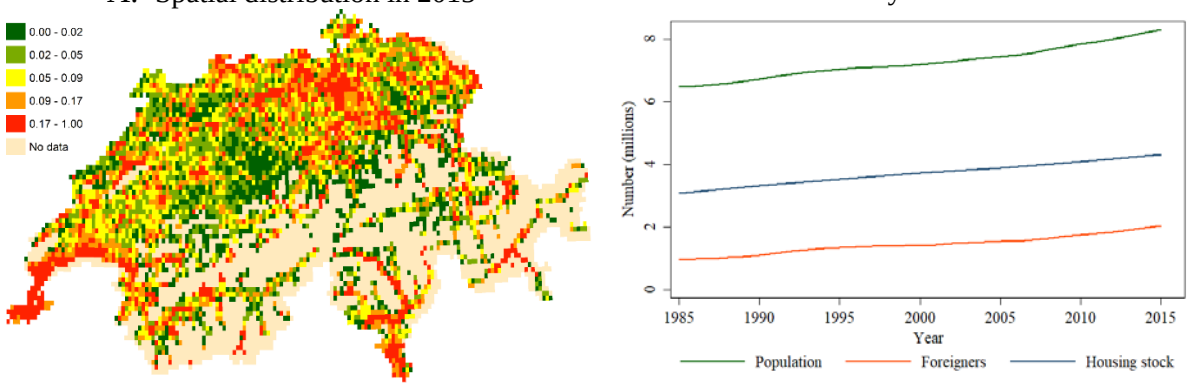


Notes: Data source: Meta-Sys. Asking rents and prices in CHF per square meter. The range is according to quintiles. Grid cells are of size 2x2 km, which corresponds to 4 square km. The total number of grid cells is 10'332.

Observed differences in rents, price, and stock dynamics are due, in part, to a mix of demand-side shocks varying at the national and local levels. At the national level, for example, mortgage interest rates have persistently decreased over the last ten years, with 10-year fixed rates falling below 1.5 percent.

Figure W-A5: Foreign residents

A. Spatial distribution in 2015 B. Country time trend



Notes: Data source Panel A: STATPOP. Range is according to quintiles. Grid cells are of size 2x2 km. The total number of grid cells is 10,332. Data source Panel B: GWR and Statistik des jährlichen Bevölkerungsstandes (ESOP). Own computations and figure.

The Swiss population has grown at a sustained rate in the last few decades, going from fewer than 6.5 million inhabitants at the beginning of the 1980s to approximately 8.3 million in 2015. However, as illustrated in Panel A of Figure W-A5, the important immigration inflow is unevenly distributed across space. Foreign shares tend to be particularly high in neighborhoods

within/near major urban areas and in high-amenity places within the proximity of lakes or ski resorts. In contrast, countryside areas usually have low foreign shares. As shown in Panel B of Figure W-A5 the population growth of the country is mostly driven by immigration, as the total population and number of foreign residents follow parallel trends. As expected, the housing stock grew parallel to the population growth.

Web Appendix B. Detailed Estimation Results

Table W-B1 is structured in the same way as Table 1 in the main text and shows the results of the corresponding OLS estimates. As expected, due to the simultaneity of changes in local prices/rents and changes in the local stock of housing the point estimates of the OLS specifications display a substantial downward bias compared to the IV estimates in Table 1. This results in overestimating the local supply elasticities with respect to price and rent changes.

Table W-B1: Inverse supply elasticities – OLS estimates of Table 1

Panel A: Average supply elasticities				
	(1)	(2)	(3)	(4)
Outcome	ΔLog Rent/m2		ΔLog Price/m2	
$\Delta \text{Log} Q$	0.1523***	0.1189***	0.2749***	0.2879***
	(0.0329)	(0.0397)	(0.0503)	(0.0589)
Observations	2261	1419	2261	1419
Panel B: Heterogeneous supply elasticities				
$\Delta \text{Log} Q$	0.1408***	0.1168**	0.2227***	0.2712***
	(0.0407)	(0.0522)	(0.0550)	(0.0594)
Stock 1980 × $\Delta \text{Log} Q$	0.0224	0.0006	0.1225*	0.0123
	(0.0386)	(0.0350)	(0.0678)	(0.0581)
Total restricted ×	-0.0055	-0.0227	-0.0071	-0.0714
Stock 1980× $\Delta \text{Log} Q$	(0.0299)	(0.0260)	(0.0608)	(0.0522)
Observations	2261	1419	2261	1419
Controls				
Supply shifters	Yes	Yes	Yes	Yes
ΔHousing characteristics	No	Yes	No	Yes

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. In columns 1-4 supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, and total restricted areas. Total restricted area is standardized and contains constraints on the extensive margin – water bodies, undevelopable land, forest, and other protected areas. In columns 2 and 4 housing characteristics include share of single-family housing and for the housing characteristics age and number of rooms.

Table W-B2 and W-B3 replicate the IV results of Table 1 in the main text and show the coefficients for all controls which are not reported in Table 1. Table W-B2 corresponds to the average supply elasticities (Panel A of Table 1), including first stage results. Table W-B3A reports second stage estimates of heterogeneous supply responses (Panel B of Table 1), whereas in Table W-B3B we report the corresponding first stages.

Table WB - 2: Average supply elasticity (2005-2015) – Panel A of Table 1

Panel A: Average supply elasticities				
	Second stage IV			
	(1)	(2)	(3)	(4)
Outcome	ΔLog Rent/m2		ΔLog Price/m2	
Instrument	Bartik languages			
ΔLog$Q$	0.7454***	0.4750**	2.1257***	2.7845***
	(0.2881)	(0.2202)	(0.3592)	(0.4780)
Elevation	0.0498*	0.0384	0.1826***	0.2692***
	(0.0295)	(0.0296)	(0.0395)	(0.0683)
Elevation SD	0.0806	0.1460*	0.2963**	0.6760***
	(0.0969)	(0.0855)	(0.1466)	(0.2113)
Log-distance CBD	-0.0030	0.0000	-0.0274***	-0.0311***
	(0.0057)	(0.0045)	(0.0091)	(0.0098)
Log-housing stock 1980	0.0169***	0.0177***	0.0261***	0.0626***
	(0.0040)	(0.0045)	(0.0060)	(0.0119)
ΔShare of single family housing		0.0130***		0.0414*
		(0.0049)		(0.0222)
ΔNr. of rooms		-0.2026***		0.0960
		(0.0445)		(0.0725)
ΔAge		-0.0081		0.0159
		(0.0064)		(0.0123)
Constant	-0.0908	-0.0646	-0.1904**	-0.5765***
	(0.0640)	(0.0632)	(0.0813)	(0.1571)
Kleibergen-Paap F	69.49	61.07	69.49	50.18
Observations	2261	1419	2261	1419
	First stage			
Outcome	ΔLog$Q$		ΔLog$Q$	
Bartik Languages	0.2457***	0.2962***	0.2457***	0.2589***
	(0.0295)	(0.0379)	(0.0295)	(0.0365)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 2x2 km.

Table WB - 3A: Heterogeneous supply elasticities (2005-2015)

Second stage of Panel B of Table 1

Panel B: Heterogeneous supply elasticities				
	Second stage IV			
	(1)	(2)	(3)	(4)
Outcome	ΔLog Rent/m2		ΔLog Price/m2	
Instrument	Bartik languages			
$\Delta\text{Log}Q$	0.4481*	0.0058	1.4627***	1.5412***
	(0.2674)	(0.2236)	(0.3631)	(0.4285)
Stock 1980 × $\Delta\text{Log}Q$	0.5656***	0.5153**	1.2609***	1.2697***
	(0.1665)	(0.2036)	(0.3175)	(0.4825)
Total restricted × Stock 1980× $\Delta\text{Log}Q$	0.2208**	0.1651*	0.4879***	0.4264**
	(0.0867)	(0.0918)	(0.1738)	(0.2011)
Elevation	0.0380	0.0305	0.1552***	0.2429***
	(0.0294)	(0.0291)	(0.0389)	(0.0626)
Elevation SD	0.0245	0.0528	0.0902	0.3420**
	(0.0989)	(0.0834)	(0.1400)	(0.1681)
Log-distance CBD	0.0061	0.0081*	-0.0059	-0.0095
	(0.0056)	(0.0048)	(0.0097)	(0.0108)
Log-housing stock 1980	-0.0210*	-0.0301*	-0.0567***	-0.0553
	(0.0111)	(0.0182)	(0.0219)	(0.0431)
Total restricted	-0.0301	-0.0324	-0.0296	-0.0512
	(0.0244)	(0.0306)	(0.0470)	(0.0648)
ΔShare of single family housing		0.0086*		0.0403*
		(0.0046)		(0.0229)
ΔNr. of rooms		-0.1901***		0.0690
		(0.0428)		(0.0654)
ΔAge		-0.0080		0.0134
		(0.0064)		(0.0107)
Constant	0.1287*	0.2484**	0.2759**	0.2043
	(0.0781)	(0.1254)	(0.1400)	(0.2756)
Kleibergen-Paap F	19.05	11.14	19.05	13.74
Observations	2261	1419	2261	1419

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 2x2 km. Total restricted area is standardized and contains all relevant constraints on the extensive margin – including water bodies, undevelopable land, forest, and other protected areas.

Table WB - 3B: Heterogeneous supply elasticities (2005-2015) - First stage of Panel B of Table 1

	First stage											
	(1)			(2)			(3)			(4)		
Outcome	ΔLog$Q$	Stock 1980 × ΔLog$Q$	Total Restricted Stock× 1980 × ΔLog$Q$	ΔLog$Q$	Stock 1980 × ΔLog$Q$	Total Restricted Stock× 1980 × ΔLog$Q$	ΔLog$Q$	Stock 1980 × ΔLog$Q$	Total Restricted Stock× 1980 × ΔLog$Q$	ΔLog$Q$	Stock 1980 × ΔLog$Q$	Total Restricted Stock× 1980 × ΔLog$Q$
Language	0.3118***	0.0763	-0.1458***	0.3878***	0.2547***	-0.3010***	0.3118***	0.0763	-0.1458***	0.3522***	0.2375**	0.3522***
	(0.0327)	(0.0558)	(0.0470)	(0.0426)	(0.0941)	(0.0750)	(0.0327)	(0.0558)	(0.0470)	(0.0410)	(0.0924)	(0.0410)
Stock 1980 × Language	-0.1074***	0.0707	0.2543***	-0.0829***	-0.0385	0.4026***	-0.1074***	0.0707	0.2543***	-0.0812***	-0.0380	-0.0812***
	(0.0189)	(0.0785)	(0.0712)	(0.0190)	(0.0883)	(0.0608)	(0.0189)	(0.0785)	(0.0712)	(0.0190)	(0.0876)	(0.0190)
Total restricted × Stock 1980 × Language	-0.0554***	-0.1423***	0.5399***	-0.0387***	-0.1838***	0.6151***	-0.0554***	-0.1423***	0.5399***	-0.0338**	-0.1809***	-0.0338**
	(0.0144)	(0.0506)	(0.0651)	(0.0125)	(0.0586)	(0.0659)	(0.0144)	(0.0506)	(0.0651)	(0.0134)	(0.0595)	(0.0134)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 2x2 km. Total restricted area is standardized and contains all relevant constraints on the extensive margin – including water bodies, undevelopable land, forest, and other protected areas.

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