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The amplifying effect of capitalization rates on housing supply[☆]

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A B S T R A C T

We provide empirical evidence that increases in housing rental income lead to a larger supply response than price increases of the same percentage value. We rationalize this differential in supply responsiveness with an amplification mechanism arising from a downward revision of capitalization rates following a rental income increase. We document that the amplification of the housing supply price elasticity is less pronounced in geographically constrained and tightly regulated neighborhoods and areas having more sophisticated investors. Our findings hold valuable lessons for public policies affecting the housing rental income, such as rent control and housing subsidies.

1. Introduction

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

We start by developing a partial equilibrium framework featuring housing supply and demand as well as real estate investors. The theoretical framework serves two purposes. First, it guides our empirical analysis and, in particular, motivates the identification strategy used to estimate housing supply elasticities. Second, it allows us to rationalize differences in the estimated supply responsiveness to rent and price dynamics. We show that local changes in investors' expectations about rental income growth and risk premia are decisive to explain supply differences. Specifically, the housing supply response to changes in prices and rents is identical if capitalization rates do not adjust to changes in rents. If capitalization rates do adjust, housing supply price elasticities are either amplified or dampened by this adjustment.

Next, we bring the theoretical framework to the data and estimate the average responsiveness of housing supply with respect to price and rent changes at the neighborhood level. To do so, we use detailed georeferenced data on advertised residential properties and building stock for Switzerland covering the period 2005–2015. We find that an increase in rents leads to an about thrice as large supply increase than an increase of prices of the same percentage value: The supply response fol-

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

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lowing a ten percent increase in square meter rents (prices) is approximately 14 percent (four percent). According to our framework, these results suggest that, on average, real estate investors revise capitalization rates downward following a positive demand shock. This revision, in turn, amplifies the supply response to price changes. We document that the supply amplification, and the corresponding adjustment of expectations, are heterogeneous across space. Geographically constrained and tightly regulated markets – i.e., major urban areas and alpine tourist areas – and neighborhoods having more sophisticated buyers as proxied by landlords, institutional investors, or second-home investors display lower amplification values.

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

Our paper bridges two strands of the literature. The first strand focuses on the estimation of local housing supply price elasticities. Despite the importance of housing supply elasticity, papers quantifying it remain scarce. Gyourko and Molloy (2015) provide a comprehensive review of the literature investigating the estimation and determinants of housing supply. In his seminal article, Saiz (2010) estimates housing supply elasticities across U.S. Metropolitan Statistical Areas (MSAs) as a function of geographic and regulatory constraints. Using a Vector Error Correction Model, Wheaton et al. (2014) also estimate housing supply elasticities for U.S. MSA's, obtaining estimates in line with those of Saiz (2010). Baum-Snow and Han, 2021 adopt a structural approach to quantify cross- and within-city housing supply elasticities for U.S. metropolitan areas, showing that housing supply elasticities increase monotonically with the distance to city centers. While relying on Saiz (2010) empirical specification for estimating inverse housing supply elasticities, we follow a similar identification strategy as in Baum-Snow and Han, 2021. Specifically, we identify housing supply elasticities using local demand shocks triggered by the historic spatial distribution of sectoral employment shares and the connectivity of a neighborhood with local labor markets. As a complementary shift-share instrument, we use the historical distribution of language shares across Swiss neighborhoods combined with the growth of language groups at aggregate levels.

The second strand of the literature focuses on how investors' expectations impact market dynamics. Time variation in expectations – as captured by price to rent ratios dynamics – have been used by Case and Shiller (2003) to identify bubble-like behavior. By constructing a user cost model incorporating economic fundamentals, Himmelberg et al. (2005) show that expected house price appreciation plays an important role in explaining local U.S. price dynamics. Focusing on the U.S. housing boom in the early 2000s, Ben-David et al., 2019 show that agents invest in vacant homes if they expect further price increases. Kaplan et al. (2020) highlight the role of expectations for house price and rent movements around the Great Recession.

The importance of expectations for market dynamics has sparked interest in the way individuals form expectations. Mayer and Sinai (2007) investigate the effect of backward-looking expectations in house price booms. Sivitanides et al. (2010) find that capitalization rates behave similarly to price/earnings ratios, with economic agents forming price growth expectations based on past dynamics. Glaeser and Nathanson, 2017 construct a model where buyers are not entirely rational in predicting future price dynamics, which explains observed price correlation over time. Kuchler and Zafar (2019) show that individuals form expectations about house price dynamics from recent personal experiences. The fact that investors are myopic, or backward-looking, is in line with our findings, which suggest that investors expect further rent growth in locations that have experienced demand increases in the recent past. Using spatial variation, we show that part of the local housing supply response to demand shocks is affected by changes in investors' expectations.

We also relate to the literature on local geographic and regulatory constraints (e.g., Aura and Davidoff, 2008, Hilber and Vermeulen, 2016, and Lutz and Sand, 2019) and show that price supply elasticities are determined not only by regulation and geographic constraints but also by adjusting capitalization rates.[3] Hilber and Mense (2021) show that labor demand shocks in conjunction with supply constraints explain most of the increase in the price-to-rent ratio in Greater London over the last two decades.

Our contribution to the literature is threefold. First, we empirically establish a link between housing supply responsiveness and investors expectations. This link is essential, as public policies affecting rental income might lead to unanticipated consequences in the supply of housing due to changes in expectations. Second, our empirical analysis quantifies the spatial dynamics of local expectations. Specifically, we provide novel evidence that the adaptation of investors expectations occurs at the local level and that such adjustment is consistent with a path-dependent view of spatial development. Investors expect that places that have gained in attractiveness (i.e., experienced a positive demand shock) will continue to do so, as reflected by a decrease in capitalization rates, leading to additional housing development. Third, we show that the 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 cannot be observed when estimating the 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 explains our empirical identification strategy. Section 4 presents the data and provides descriptive statistics for the Swiss housing market. We discuss the results in Section 5 and provide several robustness checks in Section 6. Section 7 concludes.

2. Conceptual framework

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

2.1. Housing developers

As in Glaeser (2008), in each neighborhood n, housing developers choose the amount of housing space to develop. To build housing, developers must pay the price P_n^{land} to acquire land, and the local construction cost c_n to purchase building materials and remunerate labor.

[2] Similar homeownership rates are observed e.g., in Austria, Germany, and South Korea.

[3] Relatedly, Solé-Ollé and Viladecans-Marsal (2012) analyze the role of political competition for residential development. Lin and Wachter, 2020 document spillover effects of local regulatory constraints on neighboring localities, Cosman et al. (2018) analyze housing appreciation and marginal land supply in a dynamic framework.

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

Without loss of generality, we capture both local productivity of the construction sector, as well as the unit cost of inputs, in c_n. The developers profit optimization problem is given by

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

where P_n is the local price of housing per unit of living space, l denotes the amount of land and h the building height. We assume that the cost component $c_n h^{\delta_n^{int}+1} l$ is convex with respect to building height ($\delta_n^{int} > 0$), describing the fact that the construction of taller building becomes progressively costlier due to geographic and regulatory constraints limiting residential development on the intensive margin.[5]

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

$$Q_n^s = h_n^* L_n = \left(\frac{P_n}{(\delta_n^{int}+1)c_n} \right)^{\frac{1}{\delta_n^{int}}} \bar{L}_n P_n^{\frac{1}{\delta_n^{ext}} + \frac{1}{\delta_n^{int}\delta_n^{ext}}} = S_n P_n^{\epsilon_n^{Q,P}}, \tag{2}$$

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

2.2. Real estate investors

We build on the framework proposed by DiPasquale and Wheaton (1992) and assume that investors are willing to pay a square meter price P_n for a property generating a periodic rental income R_n in neighborhood n. Investors thus mediate between the property market - in which households consume housing *services* - and housing developers.[7] We assume that the elasticity of building tenure with regard to capitalization rate differences between owner-occupied and rental properties is infinite. Put differently, investors optimally choose whether to sell or rent out a property, which implies that the capitalization rate of rental and selling properties is the same. If it were not so, arbitrage opportunities would arise, leading investors to shift their demand from one real estate asset to the other.[8]

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

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

$$\epsilon_n^{Q,R} = \frac{R_n}{Q_n^s}\frac{dQ_n^s}{dR_n} = \frac{P_n}{Q_n^s}\frac{dQ_n^s}{dP_n}\frac{R_n}{P_n}\frac{dP_n}{dR_n} = \epsilon_n^{Q,P}\epsilon_n^{P,R}, \tag{3}$$

where $\epsilon_n^{Q,P}$ is the standard housing supply price elasticity in Eq. (2), and $\epsilon_n^{P,R}$ is an *amplification coefficient* that corresponds to the price elasticity with respect to rent changes. This latter is determined by the responsiveness of the local capitalization rate to rent changes, i.e., $\epsilon_n^{P,R} = 1 - \epsilon_n^{i,R}$ (see Online Appendix A). Eq. (3) tells us that housing supply responses to rent and price changes differ when the elasticity of prices to rent changes is not unitary. If the valuation of local real estate assets is very sensitive to local rent changes, i.e., $\epsilon_n^{P,R} > 1$, the housing supply will respond more strongly to rent changes than to price changes. Investors adjustment of growth expectations and local risk captured by the capitalization rate determine the elasticity of local prices to local rents. If these factors were independent of rent dynamics, we should observe identical supply responses to rent and price changes, which is a central hypothesis we test empirically.[9]

A parametrization of local capitalization rates is instructive to provide an intuition about the way we differ from the literature and to understand the identification assumptions exposed in the next section. Let us assume that $i_n = i_0 R_n^{\gamma_n^R} P_n^{\gamma_n^P}$, where i_0 is the "standard" capitalization rate, which the literature usually assumes to be exogenously determined by capital markets.[10] The parameters γ_n^R and γ_n^P represent the local elasticity of capitalization rates with respect to rent and price shocks. It is easy to show that the amplification coefficient is pinned down by these two parameters via the equation $\epsilon_n^{P,R} = \frac{1-\gamma_n^R}{1+\gamma_n^P}$. This parametrization parsimoniously endogenizes capitalization rates while allowing for spatial differences in the investors' discount rate when evaluating real estate assets. If we set $\gamma_n^R = \gamma_n^P = 0$, we obtain the standard Gordon growth model. Empirically, we test whether this spatial generalization of the Gordon growth model is meaningful.[11]

2.3. Residents

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

$$U_{ni}^k(\omega) = b_{ni}^k(\omega)\frac{\tilde{W}_{ni}^k}{R_n^\alpha}, \tag{4}$$

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

[6] It is common in the literature to represent housing supply elasticity with a single structural parameter ϵ entering a housing supply function of the form $Q^s = SP^\epsilon$, see e.g., Hsieh and Moretti (2019), Baum-Snow and Han, 2021, and Lin and Wachter, 2020.

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

[8] We assume that rental and selling units are, on average, identical within a given neighborhood, such that investors' expectations are the same due to the no-arbitrage condition. In Section 3.1, we thus partial out potential quality differences from rent and price dynamics. The no-arbitrage assumption is at the core of the standard user cost approach employed by Hendershott and Slemrod (1983), Poterba (1984), and Mayer and Sinai (2007).

[9] Note that Eq. (3) is valid for any supply function whose price elasticity is described by a single parameter. The structure imposed by Eq. (2) only serves the purpose of illustrating the identification assumptions underlying the empirical estimation.

[10] Our results generalize to a parametrization that allows for *local* exogenous capitalization rates i_{0n}. In Section 6, we check the robustness of our results when i_{0n} includes local measures of liquidity risks and uncertainty in the revenue generated by the property.

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

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

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

We model $\tilde{W}_{ni}^{k}$ as wage per effective units of labor W_{ni}^{k} divided by commuting costs m_{ni}, implying that workers reduce labor supply when commuting from distant locations. Our focus being on housing markets, we do not explicitly model the demand side of labor markets, and consider wages W_{ni}^{k} as an exogenous variable.[12]

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

$$Q_n^d = \alpha \frac{\bar{W}_n}{R_n} N_n = \alpha \frac{1}{R_n^{\alpha(1+\epsilon^k)}} \frac{N}{\Phi} \sum_{i,k} B_{ni}^{k} \left(\frac{W_{ni}^{k}}{m_{ni}} \right)^{\epsilon^k+1}, \tag{5}$$

where $\bar{W}_n = \frac{1}{N_n} \sum_{i,k} \frac{W_{ni}^{k}}{m_{ni}} N_{ni}^{k}$ is the weighted average income earned in neighborhood n, $N_n = \sum_{i,k} N_{ni}^{k}$ is the total number of households living in n, and Φ is a composite term reflecting the attractiveness of all other possible pairs of residence r and employment s.[13] Eq. (5) provides two insights that prove useful when constructing housing demand shifters. Specifically, we should expect higher housing demand in neighborhoods that are i) better connected to productive areas, and ii) attractive along one of the dimensions captured by idiosyncratic tastes B_{ni}^{k}. In Section 3, we derive two instruments that capture shifts in housing demand triggered by these two dimensions while remaining exogenous with respect to housing supply changes.

2.4. Demand shocks, expectations, and housing supply

In this section, we outline comparative static results on how an exogenous demand shock informs us about changes in housing supply and adjustments of expectations. In interest of parsimony, let us denote by θ any local shock exclusively affecting the demand side of the housing market as described by Eq. (5), and assume that the periodic cost of housing services – equilibrium rents – increase following this demand shock, i.e. $\frac{\partial R_n}{\partial \theta_n} > 0$.

Using Eq. (2), the housing supply response to a demand shock is given by

$$\frac{\partial Q_n^s}{\partial \theta_n} = \frac{S_n \epsilon^{Q,P}}{i_n} P_n^{\epsilon^{Q,P}-1} \left(\frac{\partial R_n}{\partial \theta_n} - P_n \frac{\partial i_n}{\partial \theta_n} \right). \tag{6}$$

The term $P_n \frac{\partial i_n}{\partial \theta_n}$ is responsible for the amplification of housing supply via changes in capitalization rates following a positive demand shock.[14] We argue that the response of local capitalization rates to a positive demand shock is unequivocally negative, i.e. $\frac{\partial i_n}{\partial \theta_n} < 0$, thus increasing the supply of housing with respect to the standard Gordon Growth model in which capitalization rates are exogenously fixed and only the first term in parentheses remains.

This negative relationship arises because, following a positive demand shock, i) the perception of local risk likely decreases ($\frac{\partial r_n}{\partial \theta_n} < 0$), and/or ii) rent growth expectations increase ($\frac{\partial g_n}{\partial \theta_n} > 0$).[15] For example, an unexpected demand shock θ capturing improvements of local amenities, or a relocation of a sufficiently large company, leads to changes in local housing demand and thus alter investors' expectations.

Expectations are likely to be formed according to past dynamics (see e.g. DiPasquale and Wheaton, 1995). Our results are consistent with myopic expectation as documented for real estate markets by Kuchler and Zafar (2019). Begley et al. (2019) document that heterogeneous expectations about local population growth lead to differences in local price-rent ratios in the US. As long as the local demand increase has some unexpected element, myopic investors will adjust their expectations about the growth rates of rents upwards and thus decrease capitalization rates.

The equilibrium feature of rent growth rates makes it extremely difficult to predict them, even when investors have strong predictive capabilities regarding future demand changes. First, housing supply reacts endogenously at the local level to the demand shock. Second, even if a demand shock is initially localized to a given neighborhood, it will spread throughout the country due to the spatial equilibrium condition. This makes it very difficult to correctly predict the "final" effect of a demand change based on past dynamics, and it rationalizes the adjustment of expectations after the realization of a demand change.[16]

We note that the *extent* to which capitalization rates adjust following a positive demand shock arguably depends on the investors' idiosyncratic characteristic affecting their ability to build expectations. We investigate this matter in more detail in Section 5.3.

3. Empirical framework

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

3.1. Partialling out quality differences

The conceptual framework exposed in Section 2 implicitly assumes that the quality of housing goods is homogeneous within the same neighborhood and across rental and selling properties. The relatively small neighborhoods in our principal empirical analysis justify this assumption to a certain extent, as properties sharing similar housing characteristics tend to cluster together.

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

$$\ln \tau_{jnt} = \gamma_{nt}^{\tau} + \beta_t^{\tau} \mathbf{A}_{jnt} + \epsilon_{jnt}^{\tau}, \quad \tau = R,\ P \tag{7}$$

where τ_{jn} denotes either the price or rent of property j in neighborhood n at time t. The vector $\mathbf{A}_{jnt}$ includes a comprehensive set of attributes such as housing surface, the average number of rooms, age, age squared, and an indicator for single-family vs. multi-family houses. ϵ_{jnt}^{τ} denotes the error term.

[12] Indeed, the identification strategy exposed in Section 3 relies on exogenous changes in local labor demand. For this reason, we refrain to model labor demand endogenously.

[13] See Online Appendix A for a detailed derivation of Eq. (5).

[14] To keep the notation as simple and general as possible, here we refrain from explicitly formalizing the endogenous relationship between capitalization rates i_n and rents R_n – which are affected by the demand shock – and simply write $\frac{\partial i_n}{\partial \theta_n}$.

[15] Given that rent expectations enter capitalization rates negatively, an increase in expected rental growth decreases local capitalization rates.

[16] For the instruments used below, we find that past dynamics explain only very little of the variation such that demand changes cannot be perfectly anticipated based on past dynamics.

We use the estimated neighborhood-time fixed-effects γ_{nt}^{τ} as quality-adjusted log-prices (log-rents) $\ln P_{nt}$ ($\ln R_{nt}$).[17] Note that the coefficients β_t^{τ} are time-variant, such that the valuation of housing characteristics can flexibly change from period to period.

3.2. Model-informed identification of average supply elasticities

Log-linearizing supply Eq. (2), expressing prices as a function of quantities, and first differencing, in equilibrium[18] we obtain the following empirical specification

$$\Delta \ln P_n = \alpha^P + \frac{1}{\epsilon^{Q,P}} \Delta \ln Q_n + \Delta \ln S_n^P, \tag{8}$$

where $\frac{1}{\epsilon^{Q,P}}$ is the average *inverse* housing supply elasticity common to all neighborhoods and Δ denotes a time difference between 2005 and 2015. The term α^P denotes the average value of changes in observed supply shifters common to all neighborhoods and, in a slight abuse of notation, $\Delta \ln S_n^P$ represents the corresponding mean-centered variable. Time-invariant components are partialled out from $\Delta \ln S_n^P$ by first differencing, such that only *dynamic* supply shifters enter Eq. (8).

Estimating Eq. (8) by OLS likely leads to biased estimates of the parameter of interest due to the endogeneity of $\Delta \ln Q_n$ via the demand side. This is apparent from Eq. (5) when writing changes in housing demand as

$$\Delta \ln Q_n = \Delta \ln \bar{W}_n + \Delta \ln N_n - \Delta \ln R_n. \tag{9}$$

Therefore, estimates of $\frac{1}{\epsilon^{Q,P}}$ in Eq. (8) are potentially biased due to i) a correlation of the components of housing demand changes such as changes in average wages and number of residents with changes of unobserved supply shifters in $\Delta \ln S_n^P$ (omitted variable bias), and ii) the impact of housing prices via changes in rents on housing demand (reverse causality).

According to Eq. (2) (see Online Appendix A), $\Delta \ln S_n^P$ includes, in addition to exogenous supply shifters, changes in local construction cost. Changes in the price of construction materials and the cost to make land available for residential development are unlikely to differ across space, mostly due to the small country size. On the contrary, shifts in housing demand might affect construction costs via wages.

To partially address differences in construction costs across neighborhoods, we control, in a first step, for several supply shifters in Eq. (8). Let $\mathbf{X}_n$ denote the vector containing such controls.[19] In particular, $\mathbf{X}_n$ includes construction cost indices i.e., changes in labor and material costs defined for the main national construction markets, the intensity of historical development as measured by development density in 1980 and terrain ruggedness. According to Hilber and Robert-Nicoud (2013), the historic level of housing development proxies for the fact that high-amenity areas develop first and tend to adopt more stringent land-use regulations over time. Controlling for terrain ruggedness takes into account that plots of land featuring geographic characteristics favorable to development such as flat and non-rocky surfaces are likely developed before those showing adverse geographic characteristics. Therefore, we expect unfavorable geographic features to increase rents and prices over time, as developers face higher construction costs for providing additional housing units on the extensive margin of existing development. Similarly, we control for the elevation of the land. We further control for the distance to the nearest central business districts to capture potential time trend differentials in the labor supply (and demand) across space. These variables might also capture changes in transportation costs.[20]

Despite controlling for several supply shifters, omitted variables and reverse causality may still bias the estimation of Eq. (8). To solve this issue, we propose an instrumental variable approach that aims to exclusively shift housing demand while leaving housing supply unchanged. Specifically, we require an instrument, denoted $\Delta \ln Z_n$, which is relevant for housing demand changes while remaining exogenous to supply changes conditional on the set of controls in $\mathbf{X}_n$, i.e., $E(\Delta \ln Z_n \Delta \ln S_n^P | \mathbf{X}_n) = 0$.

As apparent from Eq. (9), we cannot use observed changes in the components of the housing demand, as in equilibrium they are affected by tension forces between housing demand and supply. Following the recent work by Baum-Snow and Han, 2021, we isolate exogenous changes in *labor demand* given the spatial linkages (commuting cost) of a neighborhood with employment centers. We define

$$\Delta \ln Z_n = \sum_{i,k} \frac{\mathbf{1}(m_{nit_0} < 1 \text{ hour})}{m_{nit_0}} f_{nt_0}^k \Delta \ln F_{C(n)}^k, \tag{10}$$

where the indicator function $\mathbf{1}(m_{nit_0} < 1 \text{ hour})$ equals one for neighborhoods i that are located at most at 60 minutes travel time from neighborhood n, and zero otherwise.[21] The quantity $f_{nt_0}^k$ represents the share of employment belonging to sector k in neighborhood n at time t_0. The term $\Delta \ln F_{C(n)}^k$ is the corresponding aggregate growth rate of employment in industry k over $[t, t_0]$ in region C in which neighborhood n is located.[22]

The intuition behind Eq. (10) is straightforward. We compute a weighted employment growth of the predetermined sectoral composition in the proximity of a given neighborhood by imposing a common industry growth equal to the one that occurred in the region C in which the neighborhood is located. Taking into account the proximity in terms of commuting time to other neighborhoods is of particular relevance in the case of small spatial units, e.g., neighborhoods, as most individuals likely do not work in the same neighborhood where they live. We use a one-hour radius for the maximum commuting distance in the benchmark analysis, as this leads to the strongest predictive power of the instrument.

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

The instrument defined by Eq. (10) is a shift-share instrument in line with Bartik (1991).[23] Recently, Adão et al., 2019, Borusyak et al., 2021, and Goldsmith-Pinkham et al., 2020 investigated the econometric assumptions necessary for the validity of shift-share instruments. These instruments are valid if either initial shares are independent and randomly assigned across observations or growth shocks occur randomly across regions. In our setting, we argue that initial sectoral shares are exogenous with respect to changes in unobserved supply shifters and local rent and price dynamics. The sectoral distribution of employment is highly persistent and largely determined by natural amenities and market access, such that the historic sectoral distribution is unlikely to be

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

[18] In equilibrium $Q_n^d = Q_n^s = Q_n$ holds, such that we omit supply and demand superscripts in what follows.

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

[20] Of course, these control variables also affect housing demand. In this case, including them in the supply function is even more important as they reduce endogeneity issues arising from changes in housing demand according to Eq. (9).

[21] We set travel time within the same municipality to 1 minute.

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

[23] Graham and Makridis, 2021 introduce a related identification strategy combining variation in the initial distribution of housing characteristics together with a national demand shift for these characteristics.

correlated with recent *changes* of local housing supply shifters $\Delta \ln S^P$. Following Goldsmith-Pinkham et al., 2020, in Section 6, we asses the validity of the identifying variation by computing the Rotemberg weights for each sector.

We further support exogeneity claims regarding $\Delta \ln Z_n$ by comparing our results with those obtained using an alternative shift-share instrument based on the distribution of language shares.[24] Specifically, for each neighborhood we compute the historical share of language shares and interact them with the cantonal growth of the respective language group.[25] Assuming that the idiosyncratic utility shifter can be decomposed as $B^k_{ni} = B_n B^k_i$ in Eq. (5), we can interpret this instrument as predicting demand changes via a shift in the idiosyncratic preferences B_n to live in a neighborhood n.

The no-arbitrage condition for investors purchasing real estate assets prevents that the demand shocks captured by our two instruments are tenure specific (see Section 2.2). Even if one of the demand shocks were more relevant to a specific part of the population that is more inclined to rent or own, it would propagate across tenures due to changes in attractiveness of investments. In the context of Switzerland, the close link between the rental and owner-occupied markets is reflected in a housing market that is approximately equally split between renters (56%) and owner-occupiers (44%). The close link between different housing market segments is supported by recent work of Mense (2020) for Germany, a country displaying similar housing market conditions as Switzerland. Specifically, the author shows that the local construction of high-quality housing units lowers rents throughout the rent distribution shortly after the new units are completed.

The estimation of the supply elasticity with respect to rent changes $\epsilon^{Q,R}_n$ follows the same logic as before. By substituting the relationship between prices and rents arising from the parametrization of capitalization rates into Eq. (8), and isolating R_n, we obtain

$$\Delta \ln R_n = \alpha^R + \frac{1}{\epsilon^{Q,R}} \Delta \ln Q_n + \Delta \ln S^R_n \tag{11}$$

where $\frac{1}{\epsilon^{Q,R}} = \frac{1}{\epsilon^{Q,P}\epsilon^{P,R}}$, and we assume that the vector $\mathbf{X}_n$ capturing the observable supply shifters discussed above is controlled for. The new error term is $\Delta \ln S^R_n = \frac{1}{\epsilon^{P,R}} \Delta \ln S^P_n$. Because this new error term equals the one of Eq. (8) times a constant structural parameter, the previous discussion of the identification assumptions still holds.[26]

We conclude this section by noting that average housing supply price and rent elasticity estimates can unambiguously be recovered from inverse supply equations (8) and (11) simply by taking the inverse of the estimated value for $\frac{1}{\epsilon^{Q,P}}$ and $\frac{1}{\epsilon^{Q,R}}$, respectively.[27]

Housing supply elasticity estimates allow us, in turn, to estimate elasticity parameters $\epsilon^{P,R}$ and $\epsilon^{i,R}$.[28]

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

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

Eqs. (8) and (11) assume that inverse supply elasticities with respect to prices and rents are constant across locations. However, our conceptual framework suggests that housing supply elasticity varies at the local level, both at the intensive and extensive margin of residential development. On the intensive margin, the empirical literature points out that supply elasticity might vary considerably according to regulatory restrictions – such as height restriction, floor to area ratios, etc. – adopted by local governments. According to Hilber and Robert-Nicoud (2013), attractive places are historically more developed and, as an outcome of the political game between land developers and owners of developed land, more regulated. On the extensive margin, Saiz (2010) points out that such constraints are empirically relevant only when there is enough development to make them binding.[29] To implement such considerations empirically, we thus follow Saiz (2010) and use the following approximation

$$\frac{1}{\epsilon^{Q,\tau}_n} \approx \beta^{avg,\tau} + \beta^{hist,\tau} \times Q^{1980}_n + \beta^{constr,\tau} \times \Lambda_n \times Q^{1980}_n, \quad \tau = R,\ P, \tag{12}$$

where the observed historic stock in 1980 Q^{1980}_n proxies for regulation constraints on the intensive margin, according to Hilber and Robert-Nicoud (2013). The variable Λ_n is a measure summarizing the most important geographic and regulatory constraints on the extensive margin. Inserting such approximation in Eqs. (8) and (11), we then estimate the following equation

$$\begin{aligned}\Delta\ln(\tau_n) = {} & \alpha^\tau + \beta^{avg,\tau}\Delta\ln(Q_n) + \beta^{hist,\tau}\Delta\ln(Q_n) \times Q^{1980}_n \\ & + \beta^{constr,\tau}\Delta\ln(Q_n) \times \Lambda_n \times Q^{1980}_n + \Delta \ln S^\tau_n, \quad \tau = R,\ P,\end{aligned} \tag{13}$$

where we control again for $\mathbf{X}_n$ (which includes historic development Q^{1980}_n) as well as for the main effect of extensive margin constraints Λ_n. Two remarks are worth noting. First, Λ_n is interacted with the historic stock level Q^{1980}_n, thus allowing the impact of regulatory constraints to become more binding in more-developed places. Having estimated the parameters $\beta^{avg,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$, we then recover $\epsilon^{Q,\tau}_n$ using Eq. (12). Second, the identification assumptions of the price and rent equation in Eq. (13) are the same as in Eqs. (8) and (11) provided Q^{1980}_n and Λ_n are exogenous with respect to $\Delta \ln S^\tau$.

4. Data and descriptive statistics

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

4.1. Data sources

Housing data We use 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

24 Saiz (2007) uses a similar approach by computing a shift-share instrument based on the number of immigrants moving into U.S. cities.

25 See Online Appendix C for a formal definition of the instrument.

26 The exogenous component of the capitalization rate i_0 is captured by the rent-specific constant α^R in Eq. (11). If we assume the parametrization of local capitalization rates exposed in Section 2 and allow for location-specific capitalization rates i_{0n}, the error term in Eq. (11) becomes $\Delta \ln S^R_n + \frac{1}{\epsilon^{P,R}} \frac{1}{1+\gamma^P_n} \Delta \ln i_{0n}$. Thus, the exogeneity of the instrument must also hold with respect to location-specific exogenous capitalization rates. In Section 6, we show that including several controls proxying for $\Delta \ln i_{0n}$ does not affect our results.

27 This relationship between inverse supply equations and housing supply elasticity parameter estimates is purely mechanical and does not hinge on additional identification assumptions. We obtain identical point estimates when estimating non-inverted supply equations.

28 Assuming that the identification assumptions underlying the 2SLS estimation of $\epsilon^{Q,P}$ and $\epsilon^{Q,R}$ hold, according to (3) we can estimate $\hat{\epsilon}^{P,R} = \frac{\hat{\epsilon}^{Q,R}}{\hat{\epsilon}^{Q,P}}$ and $\hat{\epsilon}^{i,R} = 1 - \hat{\epsilon}^{P,R}$.

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

of Buildings and Habitations published by the Swiss Federal Statistical Office (FSO) provides a census of the residential housing stock of the country. Changes in the housing stock are measured every five years, providing three time periods 2005, 2010, and 2015 that overlap with our advertisement data. Up to 2015, the register contains approximately 4.8 million housing units for the whole of Switzerland, 11.5 percent of which were built between 2005 and 2015. The 2000 Building Census (published by the FSO) provides information on whether a dwelling is a primary or secondary residence in that year.

Socio-demographic and economic data We use the Federal Population Census of 2000 (published by the FSO) as well as the Population and Households Survey from 2010 to 2015 (published by the 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, such as landlords and institutional investors. The FSO publishes a construction index tracking the cost evolution of material and labor in the construction sector for seven statistical areas. We obtained detailed information about the spatial distribution of employment and firms by sector from the Structural Business Statistics (STATENT). We use the NOGA 1 sector classification, which comprises 16 different sectors in the case of Switzerland.[30] We combine this information with data about road travel time provided by *www.search.ch* to construct a local measure labor market access.

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

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

4.2. Data structure and descriptive statistics

We structure the data by partitioning the whole territory of the country into small square neighborhoods of 2x2 km. We aggregate housing stock, socio-demographic and economic data, and geographic and regulatory constraints within these neighborhoods.[31] We assign each neighborhood to one of 2324 municipalities, which represent the lowest governmental tier in Switzerland and have an influence on land use regulation.

From 2005 to 2015, rents have increased by approximately 14 percent while prices have increased by approximately 35 percent at the country level.[32] 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 Fig. 1. Specifically, Fig. 1 shows stock, rent, and price index growth in major 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. This suggests that in cities a lack of developable land in conjunction with geographic and regulatory constraints hinders further development. 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 rising at a faster pace - which implies that capitalization rates have been revised downward in these locations.

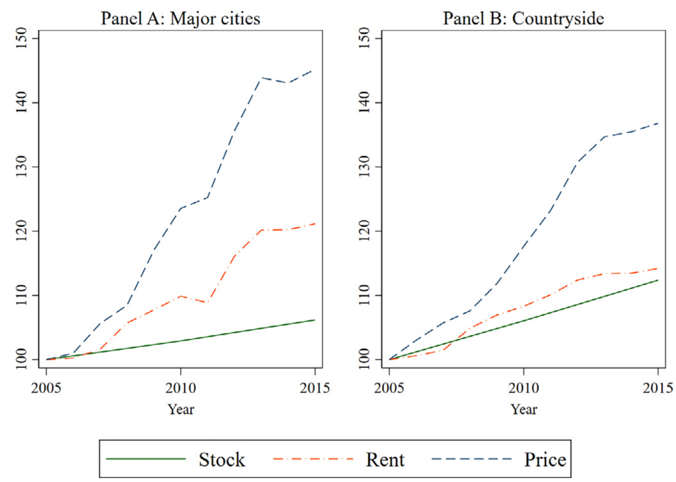

Fig. 1. Rent, price, and stock dynamics Notes: Cities include 2x2 km neighborhoods located in one of the 15 main municipalities of the corresponding biggest urban areas according to 2015 boundaries. The two panels show index growth from 2005 to 2015 of the considered variables, using 2005 as the base year (=100). Stock is measured as the total number of dwellings, and rents and prices are measured as advertised average rents and prices per square meter. See Online Appendix B.2 for a definition of major Swiss agglomerations.

In Fig. 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. Similarly to Saiz (2010) and Lutz and Sand (2019), we define *undevelopable land* as land that is located above 2000 m and whose land cover corresponds to unproductive vegetation, vegetation-free areas, or rocks, and glaciers.[33] 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.[34]

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[35], UNESCO cultural or natural heritage sites, parks, and other high-value natural amenity areas. These restrictions account for approximately 49.1 percent of the Swiss territory. Total restricted areas obtained by overlapping geographic and regulatory constraints at the extensive margin amount to approximately 67.3 percent of the country's surface. The remaining 32.7 percent of the country's surface (white area in Fig. 2) is available for development under different

[30] This classification corresponds to the major SIC industry groups in the U.S.

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

[32] 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.

[33] Our data allows us to compile this measure at even finer scale than previous literature.

[34] 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.

[35] In response to the 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.

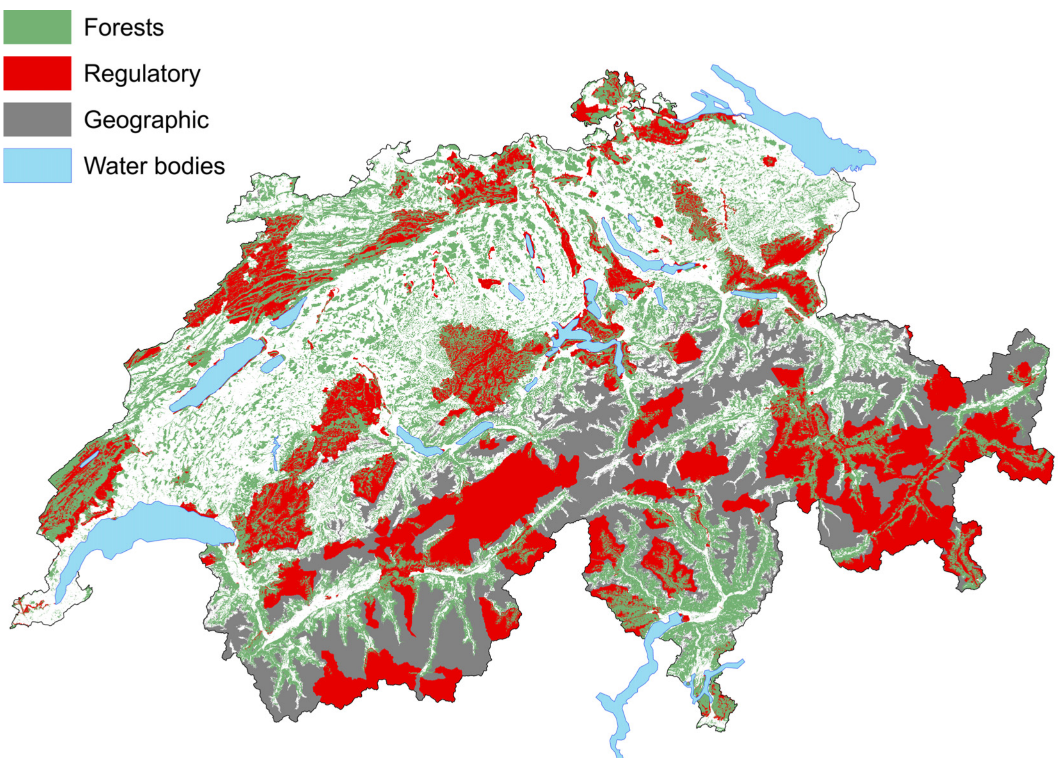

Fig. 2. Constraints to development Notes: We define geographic constraints as *undevelopable land*, which corresponds to a plot of land located above 2000 m, or whose land use classification corresponds to unproductive vegetation, vegetation-free areas, or rocks and glaciers. Except for forests, red areas summarize regulatory constraints on the extensive margin. Swiss forests are protected areas since 1876. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Inverse housing supply elasticity – average estimates.

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

Notes: Standard errors in parentheses $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors are clustered at the municipality level. The sample covers the period 2005–2015. The Adão et al., 2019 standard errors for columns (1), (2), (3), and (4) are 0.100, 0.048, 0.386, and 0.198, respectively. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Log rents and log prices are quality-adjusted with respect to the living surface, the number of rooms, age, age squared, and building type. All regressions control for supply shifters, which include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005–2015) in construction costs. See Online Appendix E for detailed estimation results and first stages. Changes in housing stock ΔLog Q, are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

regulatory measures determining the intensity and type of residential development.

5. Results

5.1. Supply elasticity estimates and amplification mechanism

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

Responsiveness estimates based on the industry instrument are equal to $\epsilon^{Q,R} = \frac{1}{0.694} = 1.44$ for rent and $\epsilon^{Q,P} = \frac{1}{2.367} = 0.42$ for price changes. These results show that, on average, the housing supply in Switzerland is relatively elastic to rent changes, but less so to price changes. The corresponding amplification effect is $\epsilon^{P,R} = \frac{\epsilon^{Q,R}}{\epsilon^{Q,P}} = 3.43$. The country's average response of local capitalization rates to rent changes is thus $\epsilon^{i,R} = 1 - \epsilon^{P,R} = -2.43$, suggesting that investors revise local rent

Table 2
Inverse housing supply elasticity – local estimates.

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

Notes: Standard errors in parentheses $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors are clustered at the municipality level. The sample covers the period 2005–2015. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Log rents and log prices are quality-adjusted with respect to the living surface, the number of rooms, age, age squared, and building type. All regressions control for supply shifters, which include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change in construction costs from 2005 to 2015. Total restricted area (Λ) is standardized and contains constraints on the extensive margin water bodies, undevelopable land, forest, and other protected areas. See Online Appendix E for detailed estimation results and first stages. Changes in housing stock ΔLog Q including interaction terms thereof are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

growth expectations (risk premium) upward (downward) following an exogenous positive demand shock.[36] These results remain mostly unchanged when using the instrument derived from historic language shares ($\epsilon^{P,R} = 2.68$) and when employing both instruments simultaneously ($\epsilon^{P,R} = 2.84$).

Reassuringly, the above results support our exogeneity claims about the instruments. This is for two reasons. First, despite having the expected positive impact on $\Delta \ln Q$, the two instruments capture different variations while leading to very similar estimates.[37] In this case, it seems unlikely that if one or both instruments were endogenous, they would converge toward similar estimates. Second, the overidentification tests reported at the bottom of columns 5 and 6 do not point toward endogeneity issues. In Section 6, we further investigate the exogeneity of the instrument with respect to the inclusion of potential confounders.

5.2. Housing supply and amplification heterogeneity

We now turn to the analysis of housing supply heterogeneity at the local level. Table 2 summarizes the results when all relevant constraints on the extensive margin - including water bodies, undevelopable land, forest, and other protected areas - are considered together in the total restricted area Λ_n. We follow the same structure as in Table 1 and report the results using the instruments based on industry shares (columns 1 and 2), language shares (columns 3 and 4), and the two instruments simultaneously (columns 5 and 6). In addition to the extensive margin restrictions, we account for the historic level of building development Q_n^{1980}, thus allowing the impact of regulatory constraints to become more binding in more-developed places.

The coefficients of the double and triple interaction terms, which capture local supply heterogeneity, are all highly significant for rental and selling properties. These estimates suggest that i) historically developed places have more inelastic housing markets both with respect to rent and price changes, and ii) geographic and regulatory constraints on the extensive margin are more binding in more-developed places.[38] Relative to the main effect, $\Delta \log Q$, the double interaction coefficients are systematically lower for selling than for rental properties. This implies that previous development patterns decrease the average supply elasticity of rental properties to a larger extent than that of selling properties.

Having estimated the coefficients $\beta^{avg,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ for rental and selling properties, we compute supply elasticities coefficients at the neighborhood level according to Eq. (12). To facilitate the visual representation of these parameters, we aggregate these local supply elasticities at the municipality level by using the mean values. In Fig. 3 we show the spatial distribution of local housing supply price elasticity $\epsilon_n^{Q,P}$ (Panel A) and of the corresponding amplification coefficient $\epsilon_n^{i,R}$ (Panel B).[39]

As apparent from Fig. 3 (Panel A), housing supply price elasticity varies considerably across space. Major agglomerations - and even more so areas near major CBDs – are particularly inelastic, with the municipality of Zurich and its neighboring agglomerations accounting for the largest area displaying inelastic housing supply.[40] In contrast, countryside areas generally display comparatively higher elasticity values. However, this is not always true for alpine regions. Some alpine regions, especially touristic ones, have low price elasticity values, likely due to the importance of geographic constraints in conjunction with high levels of historical development.[41]

Compared to the housing supply elasticities estimated by Saiz (2010) for the major U.S. metropolitan areas, the supply side of the Swiss housing market is significantly less elastic to price changes. This is not surprising as Gyourko and Molloy (2015) point out that among OECD countries, the U.S. is among the countries displaying

[36] These spatial results are in line with recent findings investigating aggregate time dynamics. By simulating a dynamic model, Begley et al. (2019) find that a positive demand shock – as captured by higher population growth – leads to lower capitalization rates. It also aligns with the findings of Kaplan et al. (2020), who finds that a change in expectations drives the dynamics of price-rent ratios.

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

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

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

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

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

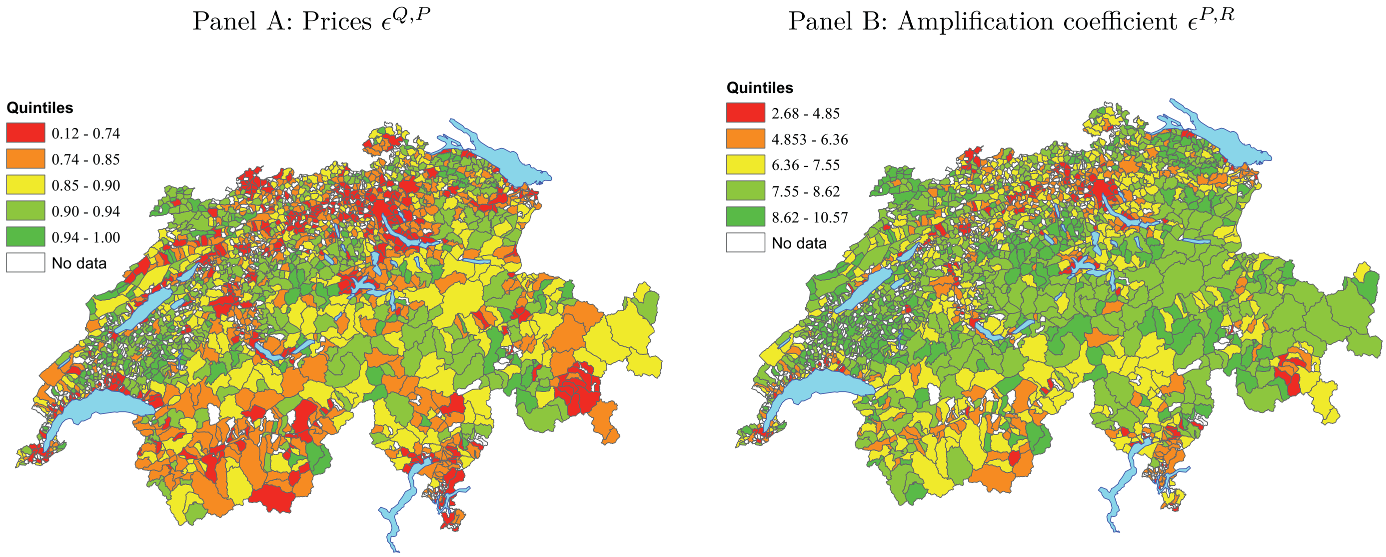

Fig. 3. Local housing supply elasticities and amplification coefficient Notes: Supply elasticity interval defined according to quintiles of the distribution. Local estimates are computed using Eq. (13) for 2km side country grid data. Heterogeneity is due to the sum of relevant geographic and regulatory 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 Eq. (13) 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.

the most elastic housing supply. The unresponsiveness in Switzerland can be explained by the intensive and extensive margin constraints to development. On the intensive margin, housing development in Switzerland is constrained to low density. Even major cities, such as Zurich and Geneva, high-rise buildings (i.e., buildings counting more than seven stories) are the exception rather than the rule. On the extensive margin, widespread geographic and regulatory constraints hinder new development even in the countryside.[42]

As shown in Fig. 3 (Panel B), the amplification mechanism displays considerable spatial heterogeneity, with values ranging from 2.68 to 10.57. These results suggest that central places display the lowest value of $\epsilon_n^{P,R}$, whereas countryside areas the highest. Following a shock to the periodic rental income, investors thus revise their expectations and risk premia more in remote areas than in central ones. This heterogeneous adaptation across space might be explained by the fact that attractive, and typically heavily restricted and regulated, central places already command high rent growth expectations and low risk premia. In such places, a positive demand shock is unlikely to modify investors' expectations strongly. On the contrary, it is more likely that investors revise their expectations substantially following a demand shock in elastic countryside areas where previous demand has been scarce. This is in line with the hypothesis of a path-dependent view of spatial development. Investors myopically anticipate that places having experienced low (high) demand in the past will continue to do so in the future, thus (not) updating their beliefs when such places are indeed subject to a positive demand shock.

To investigate the role played by specific supply constraints in determining the breadth of heterogeneity of local supply responses, we estimate Eqs. (8) and (11) by including interactions between ΔQ_n and specific supply constraints. We then compute average supply elasticities when the considered constraints are set to their 25th and 75th percentile value of the distribution of these constraints across all neighborhoods of the country. We classify supply constraints into three main categories. Geographic constraints, which arise from natural features of the landscape, are proxied by the share of undevelopable land, i.e., water bodies or rocky areas. Regulatory constraints on the *extensive* margin, which represent barriers to development on new plots of land, are given by protected areas, i.e. forests, cultural or natural heritage sites, and areas exclusively reserved for agriculture purposes according to federal law.[43] Finally, regulatory constraints on the *intensive* margin, which capture any other regulation, are proxied by the level of the housing stock in 1980.

Table 3 shows the results. We observe that places with a low share of undevelopable land (25th percentile) display a supply elasticity for rent changes of 0.61, whereas those at the upper end (75th percentile) display a 2.8% lower supply elasticity of 0.59. In the case of price elasticities, this heterogeneity is more pronounced. Places with a relatively high share of undevelopable land display a 5.7% lower price elasticity of housing supply than those with a low share of undevelopable land. We interpret the results when considering extensive and intensive margin regulatory constraints analogously. The most pronounced inter-quartile heterogeneity is observed when geographic and extensive margin regulatory constraints are considered together, as supply elasticity differences amount to 16.6% for rents and 34.6% for prices.

5.3. *Investors' sophistication and the revision of local expectations*

Our explanation for observed spatial differences in the revision of investors' expectations is that investors differ in their ability to anticipate demand shocks. To empirically test this proposition, let us assume that some investors are more sophisticated than others. In particular, more sophisticated investors have access to a better information set, which allows them to predict future demand growth more precisely. Given these assumptions, we expect that in places where more sophisticated investors buy properties, the amplification mechanism (capitalization rate update) is lower (less negative).

We proxy the presence of sophisticated investors in a given neighborhood with the share of landlords, institutional investors, and second-home buyers. The 2000 Federal Population Census contains detailed in-

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

[43] Given that the nature of the considered geographic constraints is similar to the one of extensive margin regulation, we analyze the latter in conjunction with the former.

Table 3
Contributions of geographic and regulatory constraints to supply heterogeneity.

	25th	75th	% change	25th	75th	% change
	(1)	(2)	(3)	(4)	(5)	(6)
	Rents			Prices		
Geographic constraints: Undevelopable	0.61	0.59	-2.80***	2.63	2.48	-5.70**
Total geographic & regulatory extensive margin constraints: Total restricted	1.67	0.56	-16.60***	3.53	2.31	-34.56**
Regulatory constraints - intensive margin: Stock 1980	0.69	0.58	-15.40***	3.21	2.40	-25.10***

Notes: Standard errors in parentheses $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors are clustered at the municipality level. Columns (1) and (4) show the 25th quintiles of elasticities. Columns (2) and (5) show the 75th quintiles of elasticities. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Note that the historic stock serves as a proxy for the intensity of regulation. Total restricted includes all geographic constraints and all regulatory constraints on the extensive margin.

Table 4
Investors' sophistication and expectations.

	(1)	(2)	(3)	(4)	(5)	(6)
	Amplification effect					
Share of landlords	-6.178***	-4.408***				
	(0.328)	(0.342)				
Share of institutional investors			-11.046***	-13.830***		
			(1.292)	(1.376)		
Share of 2nd homes					-5.620***	-5.292***
					(0.717)	(0.410)
Observations	1,851	3,829	1,851	3,733	1,851	3,829
R-squared	0.24	0.17	0.27	0.26	0.14	0.18

Notes: Standard errors in parentheses $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors are clustered at the municipality level. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Controls include elevation, elevation standard deviation, log-distance to the nearest CBD, city dummy, total restricted areas, and change (2005–2015) in construction costs.

formation on the type of owner of a building. The label 'institutional investors' encompasses large firms investing in real estate, such as pension funds, banks, and insurance companies. Therefore, institutional investors include owners that *do not* live in the neighborhood or that, at the very least, do not consume residential housing in that location. By measuring the local presence of landlords and institutional investors, we can abstract from idiosyncratic consumption preferences related to residential housing that might drive purchasing decisions of owner-occupiers. In the case of second-home buyers, Bernstein et al. (2019) have documented that these type of buyers tends to exhibit fewer biases in their investment decisions.

We estimate the following cross-sectional relationship

$$\epsilon_n^{P,R} = \alpha + \beta\omega_n + \mathbf{\Theta}_n\gamma + \upsilon_n, \tag{14}$$

where $\epsilon_n^{P,R}$ represents the amplification coefficient in neighborhood n (computed relying on the industry share instrument), and ω_n is the predetermined share of either landlords, institutional investors, or second homeowners in 2000. As in Table 2, The vector $\mathbf{\Theta}_n$ contains time-invariant controls such as elevation, elevation standard deviation, log-distance to the nearest CBD, construction costs, log-housing stock in 1980, total restricted areas, and change (2005–2015) in construction costs. The variable υ_n is a stochastic error term.

Table 4 shows the estimation results. In columns 1, 3, and 5, we report results based on the same sample as in Table 2, whereas in columns 2, 4 and, 6, we perform out-of-sample predictions based on the elasticity estimates of Table 2.[44] We perform such out-of-sample predictions to include a larger number of neighborhoods containing shares of sophisticated investors, which provides a greater variation in the observed investor types that we can exploit empirically.

The results in Table 4 shows that a higher share of landlords, institutional investors, and second homes is indeed associated with a lower amplification effect. The relationship between the amplification effect and landlords, institutional investors, and second-home investors is robust across samples. The effect of the share of institutional investors is bigger in magnitude than the ones for landlords and second-home investors, which suggests that the former anticipate future demand shocks at least as good or better than landlords and second-home investors. This seems reasonable, given that institutional investors are professional buyers investing in real estate, mainly to realize capital gains or benefit from rental income, and typically devote considerable resources to conduct market studies to optimize their investment strategies. Overall, our results point to heterogeneous expectation adjustment similar to Makridis (2020).[45]

6. Robustness checks

6.1. Modifiable areal unit problem

One may question the stability of our results for different definitions or areal units. More specifically, according to Briant et al. (2010), our point estimates of (inverse) supply elasticities in Table 1 might vary depending on the aggregation level. We thus verify the robustness of our estimates by both decreasing (down to 1 km) and increasing (up to 3 km) the sides of square the neighborhoods. Additionally, because they represent the lowest-tier political units in Switzerland, we estimate our specifications also at the municipality level.

Panels A to C of Table 5 illustrate the results. As before, we report estimates based on the industry instrument (columns 1 and 2), language

[44] More precisely, we use the estimates of $\beta^{avg,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ reported in Table 2 together with observed values of Q_n^{1980} and Λ_n to predict local housing supply elasticities according to Eq. (12) in places where there was not a sufficient number of advertised rental or selling properties in the years 2005 and 2015.

[45] While our framework exclusively focuses on real estate markets, Makridis (2020) relates changes of homeowners' expectations about the current and future state of the national economy to property capital gains realized at the local level.

Table 5
Robustness – local market size.

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

Notes: Standard errors in parentheses $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors are clustered at the municipality level. The sample covers the period 2005–2015. For Panels A, B, and, D the units of observations are obtained by partitioning Switzerland in 1x1, 3x3, and 2x2 km neighborhoods, respectively. The units of observations for Panel C are the Swiss municipalities. For Panel D we restrict the sample to units that have at least 20 selling and rental advertisements. All regressions control for supply shifters, which include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005–2015) in construction costs. Changes in housing stock ΔLog Q, are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

instrument in (columns 3 and 4), and both instruments simultaneously (columns 5 and 6). The average supply elasticity estimates for rents and prices are stable for 1 km, 3 km side cells, as well as at the municipality level. The magnitude of the elasticities increases somewhat for the 1 km side neighborhoods while they decrease somewhat at the municipality level. Importantly, for all levels of aggregation, we find evidence of stronger supply response to rent than price changes, with amplification coefficients stable across specifications and similar to those of Table 1.

6.2. Frequency of rent and price observations

We investigate whether grid-cells containing a small number of rental and selling properties, typically located remote areas, are driving our main results. In Panel D of Table 5, we thus report estimation results when restricting the sample of our main analysis to 2x2km grid cells containing at least 20 observations for *both* rental and selling properties. The estimated coefficients remain almost identical to those in the benchmark Table 1.

6.3. Local risk

A further concern might be that local factors influence the fundamental capitalization rate i_0 introduced above. In this case, local changes Δi_{0n} are captured by the error term in Eq. (11), and, if correlated with the instrument, they might bias our results. Even though there are no obvious factors that determine local fundamental capitalization rates that correlate with initial industry shares, we may analyze this concern by controlling for potential local determinants of $\Delta \ln i_{0n}$. This includes, most likely, factors describing local risk perceptions of investors.

Panels A and B of Table 6 report estimation results when we proxy local risk by using local vacancy rates (VR, columns 1 and 2 of Panel A), local time on the market of advertised rental units ($TOMR$, columns 3 and 4 of Panel A) and selling units ($TOMP$, columns 5 and 6 of Panel A), and local unemployment rates (Unem, columns 5 and 6 of Panel B).

Vacancy rates and unemployment rates proxy for the uncertainty associated with the rental income of a property located in a given area, whereas time on market captures its liquidity.[46] Note that here we control for the initial levels and not contemporary changes of these variable since the latter would represent mediator i.e., endogenous variables. As is evident from Table 6, we can confirm significantly higher responsiveness of housing supply to rent changes than to price changes when we individually control for the above variables. The corresponding amplification effects are very similar to those of our benchmark results.

6.4. Local variation in the type of housing units

As discussed in Section 3.1, we partial out differences in the attributes of renting and selling units across regions. However, one might worry that the observed housing characteristics that we use for adjusting quality differences might not fully capture dissimilarities between rental and selling properties. Note that this problem only matters to the extent that unobserved quality differences correlate with our benchmark instrument based on industrial composition, which seems unlikely. Nevertheless, we address this potential concern by controlling for i) the pre-

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

Table 6
Robustness - confounders.

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

Notes: Standard errors in parentheses $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors are clustered at the municipality level. The sample covers the period 2005–2015. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. All regressions control for supply shifters. Supply shifters include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, total restricted areas, and change (2005–2015) in construction costs. Changes in housing stock ΔLog Q, are instrumented using a shift-share instrument for industries I in all columns. Panel A columns (1) and (2) control for the vacancy rate in 2000 VR, columns (3) and (4) control for the time on market for rental properties TOMR, and columns (5) and (6) control for the time on market for selling properties TOMP. Panel B columns (1) and (2) control for the ownership rate in 2000 Own00, columns (3) and (4) control for the growth in ownership (2005–2015) GOwn, and columns (5) and (6) control for the share of unemployment in 2000 Unem.

Table 7
Inverse housing supply elasticity – shorter term estimates.

	(1) ΔLog P	(2) ΔLog R	(3) ΔLog P	(4) ΔLog R	(5) ΔLog P	(6) ΔLog R
ΔLog Q	2.697***	0.590**	2.222***	0.477**	2.367***	0.514**
	(0.418)	(0.287)	(0.381)	(0.232)	(0.341)	(0.204)
ΔLog Q × D_{10--15}	-0.226	0.102	-0.127	0.575**	-0.140	0.453**
	(0.345)	(0.273)	(0.306)	(0.227)	(0.288)	(0.218)
Instruments	I	I	L	L	I & L	I & L
Observations	4,836	4,836	4,836	4,836	4,836	4,836
Kleibergen-Paap F	14.69	14.69	37.08	37.08	26.78	26.78
Overidentification	–	–	–	–	0.54	0.11

Notes: Standard errors in parentheses $^{*}p < .10$, $^{**}p < .05$, $^{***}p < .01$. Standard errors are clustered at the municipality level. The sample covers the period 2005–2015. The units of observations are obtained by partitioning Switzerland in 2x2 km neighborhoods. Log rents and log prices are quality-adjusted with respect to the living surface, the number of rooms, age, age squared, and building type. All regressions control for supply shifters, which include elevation, elevation standard deviation, log-distance to the nearest CBD, log-housing stock in 1980, and change in construction costs from 2005 to 2010 and from 2010 to 2015. Changes in housing stock ΔLog Q including interaction terms thereof are instrumented using a shift-share instrument for industries I in columns (1) and (2), a shift-share instrument for main spoken languages L in columns (3) and (4), and both these instruments I & L in columns (5) and (6).

determined level of homeownership rates in 2000 ($Own00$), and ii) the change in ownership rates between 2005 and 2015 ($GOwn$). Controlling for these two variables allows us to take explicitly into account variations in the composition of housing goods across neighborhoods. Panel B of Table 6 documents that the results remain mostly unchanged.

6.5. *Rotemberg weights*

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

To test this assumption in our framework, we follow Goldsmith-Pinkham et al., 2020 and compute the Rotemberg weights for the different industries and languages.[47] These weights indicate which industries/languages entering the instruments are driving the results. In our case, the five most important sectors are information and communication, wholesale and retail trade, administrative and support service activities, accommodation and food service activities, and financial and insurance activities. The three most important languages are German, Italian, and Portuguese. In the interest of brevity, we report the results in Online Appendix E.

As suggested by Goldsmith-Pinkham et al., 2020, we test the exclusion restriction by checking the correlation of the five most important initial share and possible confounders. As confounders, we use the change (2005–2015) in vacancy rate, the change (2005–2015) in time on market for rental properties, the change (2005–2015) in time on market for selling properties, the ownership rate in 2000, the growth (2005–2015) in ownership rate, and the share of unemployment in 2000. Re-

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

assuringly, this analysis shows that the initial shares are not related to possible confounders.

6.6. Shorter term supply responses

We also investigate how our results change when shortening the horizon of our analysis. Specifically, we compute rent, price, and stock growth over 2005–2010 and 2010–2015. We then estimate the usual inverse supply elasticities using the pooled data set comprising these two time intervals. To investigate whether inverse supply elasticity estimates differ between 2005–2010 and 2010–2015, we introduce an interaction between $\Delta \log Q$ and a time dummy D_{10-15}, which equals one over the 2010–2015 period, and zero otherwise.

Table 7 shows the results. The interaction term capturing different inverse elasticities between 2005–2010 and 2010–2015 is significant only for the rent regressions in columns (4) and (6).[48] In general, the findings in Table 1 are confirmed for all specifications, as the coefficients of the price equations are still greater than those of the rent equations in both periods and, although lower in magnitude due to the interaction term, the amplification coefficient $\epsilon^{P,R}$ is equal or greater than 2 also in 2010–2015.

7. Conclusion

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

Our empirical analysis indicates that residential housing supply in Switzerland reacts more than thrice as strongly to rent changes than to price variations of the same magnitude. Rent and price elasticities equal, on average, 1.44 and 0.42, respectively. Our conceptual framework attributes this "amplification effect" to an adjustment of capitalization rates – which reflect investors expectations concerning future rent growth and risk premia – following an exogenous demand shock. This adjustment is consistent with a myopic path-dependent view of residential development in the sense that investors believe that the places that grew more (less) in the past will continue to do so also in the future. An unexpected positive demand shock to a historically less attractive area thus triggers a considerable downward revision of investor's capitalization rates, which further increases prices and, in the end, boosts the amount of supplied housing.

When zooming in at the neighborhood level, we document considerable spatial heterogeneity in the local supply elasticities due to geographic and regulatory constraints. The supply responsiveness with respect to both rent and price changes is very inelastic in major urban centers and alpine tourist areas and more elastic in the countryside. A comparison of the two elasticities at the local level reveals that the resulting amplification effect is much lower in urban and tourist areas and considerably higher in the countryside.

This spatial variation of the supply amplification holds interesting insights about the way investors perceive and influence residential development at the local level. First, investors seem to form expectations regarding future rent growth and risk heterogeneously across space and at a fine-scale level. Second, following a positive demand shock, investors seem to revise their expectations only to a limited extent in tightly regulated and geographically constrained places. In contrast, in less constrained areas, they revise their expectations significantly.

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

We conduct our analysis over a period of growing demand in the Swiss housing market. Whether the estimated supply amplification effect is symmetric, thus dampening housing supply during a downturn of the real estate market remains an open question. Because housing is durable, we do not expect an amplification mechanism to be present shortly after a negative demand shock, as the supply elasticity with respect to both rent and price changes will be zero. In the longer run, we argue that a negative demand shock, symmetric to the one we investigated, might lead to a larger decrease in housing prices through higher capitalization rates and, subsequently, lower housing supply. However, testing this hypothesis remains a task for future research covering a different phase of the housing cycle.

[48] Note that Saiz (2010) also does not find major differences when scaling down the estimation of long-run housing supply price elasticity from 30 to 10-year intervals.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jue.2021.103370

CRediT authorship contribution statement

Simon Büchler: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Maximilian v. Ehrlich:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Olivier Schöni:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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