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Study on behalf of the State Secretariat for Economic Affairs SECO and the Federal Office for Housing FOH

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Zusammenfassung

Die Miet- und Kaufpreise von Wohnimmobilien sind in den vergangenen zehn Jahren in der Schweiz deutlich angestiegen. Zwischen 2005 und 2015 erhöhten sich die Quadratmetermieten um 14,8 Prozent und die Quadratmeterpreise um 38,1 Prozent. Die Gründe für diesen signifikanten Anstieg der Miet- und Eigentumspreise sind vielfältig. Um diese Preissteigerungen zu erklären, betrachtete die Literatur bisher hauptsächlich nachfrageseitige Faktoren. Dazu gehören das Bevölkerungswachstum, das allgemeine Wachstum der Wirtschaft und der Einkommen, die niedrigen Hypothekarzinsen sowie die Verlagerung der Nachfrage von ländlichen Gebieten in städtische und vorstädtische Gebiete.

Gleichermassen entscheidend für die Preisentwicklung auf dem Markt für Wohnraum ist jedoch die Angebotsseite: Solange die steigende Nachfrage durch neue Kapazitäten an Wohnraum leicht ausgeglichen werden kann, kommt es nur zu einem geringen Preisanstieg. Wenn dagegen das Angebot starr ist, bewirkt auch ein relativ geringer Nachfrageanstieg eine ausgeprägte Preisreaktion. In diesem Zusammenhang ist die massgebliche ökonomische Messgrösse die sogenannte *Preiselastizität des Angebots*. Diese spiegelt die Steigung der Angebotskurve wider und misst, um wie viel Prozent sich der angebotene Wohnraum ändert, wenn der Preis um ein Prozent steigt. Die Preiselastizität des Angebots ist ein wichtiger Parameter, um zu beurteilen, ob zukünftige Nachfragesteigerungen vor allem zu höheren Miet- und Eigentumspreisen oder zu einer deutlichen Steigerung des Wohnangebots führen. Ausserdem ermöglicht sie Rückschlüsse auf die Wirkungen von Wohneigentumsförderung oder standortspezifischen Unterstützungsprogrammen. Beispielsweise können Förderungen des Wohneigentums mittels Steuerabzügen in Regionen mit unelastischem Angebot zu einem starken Anstieg der Preise führen und dabei die Wohneigentumsquote kaum steigern. Die Preiselastizität des Angebots erlaubt es zudem, die Verteilungseffekte von Förderprogrammen und das Ausmass von lokalen Miet- und Eigentumspreisanpassungen aufgrund öffentlicher Investitionen zu analysieren. Bisher gibt es jedoch sehr wenig empirische Evidenz zur Preiselastizität des Angebots in der Schweiz sowie den Faktoren, welche letztere beeinflussen.

In dieser Studie – des Center for Regional Economic Development (CRED) der Universität Bern – quantifizieren wir die Preiselastizität des Angebots auf dem Immobilienmarkt separat für Miet- und Eigentumspreise. Anhand von Preis- und Angebotsinformationen für Miet- und Kaufobjekte im Zeitraum 2005-2015 sowie Informationen über den gesamten Bestand an

Wohneinheiten erhalten wir die Preis- und Wohnungsbestandsänderung auf lokaler Ebene. Dabei definieren wir zwei Analyseebenen.

Die erste Analyseebene fokussiert mit Hilfe des *within agglomeration* Datensatzes auf die Wohnungsmärkte innerhalb der 15 grössten Schweizer Agglomerationen. Für diesen Datensatz definieren wir unsere Beobachtungseinheiten, indem wir progressiv grössere konzentrische Ringe um die Verwaltungszentren der Agglomerationen erstellen und diese anschliessend gemäss der Gemeindegrenzen unterteilen. Die zweite Analyseebene, *country grid* genannt, umfasst die gesamte Schweiz und unterteilt diese in quadratische Zellen von 2×2 km. Während uns der erste Datensatz ermöglicht, die Dynamik innerhalb der Agglomerationen zu analysieren, untersuchen wir anhand des *country grid* die Heterogenität lokaler Preiselastizitäten des Angebots und insbesondere die Determinanten der Heterogenität. Wir analysieren namentlich die Rolle geografischer sowie regulatorischer Einschränkungen. Geografische Einschränkungen werden zum Beispiel durch steile Hänge, Wasserflächen und felsige Gebiete spezifiziert, während regulatorische Einschränkungen beispielsweise durch Zonenvorschriften definiert sind. In unserer Analyse unterscheiden wir grundsätzlich zwischen zwei verschiedenen Arten von regulatorischen Massnahmen: Die sogenannten extensiven regulatorischen Grenzen, die das (horizontale) Ausmass der bebaubaren und geschützten Flächen bestimmen, und die sogenannten intensiven regulatorischen Grenzen, welche die Art und Intensität der Bebauung beeinflussen.

In unserer empirischen Analyse wenden wir einen Instrumentenvariablenansatz an, um die Preiselastizität des Angebots zu schätzen. Dieser ökonometrische Ansatz nutzt eine (oder mehrere) Variable(n), um exogene Nachfrageverschiebungen zu isolieren, welche die Angebotsseite des Marktes unberührt lassen. Die Literatur schlägt mehrere Variablen vor, die ein geeignetes Instrument für Nachfrageschocks auf dem Wohnungsmarkt darstellen können. Wir untersuchen die Gültigkeit dieser Variablen für die Schweizer Immobilienmärkte und stellen weitere geeignete Instrumente vor. Unsere Hauptergebnisse basieren auf Instrumenten, die die lokale Variation der Einwanderung, historische Geburtsraten und geografische Merkmale ausnutzen.

Unsere Ergebnisse zeigen, dass die durchschnittliche langfristige Mietpreiselastizität des Angebots innerhalb der 15 grössten Schweizer Agglomerationen bei ca. 1,9 liegt, während die Eigentumspreiselastizität des Angebots bei ca. 0,6 liegt. Das heisst, langfristig führt ein 10-prozentiger Anstieg der Mieten (Eigentumspreise) zu einem ungefähr 19 (6) -prozentigen

Anstieg des Gesamtangebots (sowohl Miet- wie auch Eigentumsobjekte zusammen) an Wohnobjekten. Wenn wir unsere Analyse auf das gesamte Land ausdehnen, erhalten wir eine durchschnittliche langfristige Mietpreiselastizität von ca. 1,6 und eine Eigentumspreiselastizität von ca. 0,5. Dies deutet darauf hin, dass die Schweizer Wohnungsmärkte stärker auf Miet- als auf Eigentumspreisänderungen reagieren. Im internationalen Vergleich liegt der Schweizer Immobilienmarkt damit im mittleren Bereich der Preiselastizität des Angebots.

Auf lokaler und regionaler Ebene bestehen jedoch erhebliche Unterschiede bei den Preiselastizitäten des Angebots. Betrachtet man die Kantone, so variiert die Mietpreiselastizität (Eigentumspreiselastizität) zwischen 0,66 (0,25) und 2,17 (0,59). Die Kantone Basel-Stadt und Zürich weisen die geringsten und die Kantone Fribourg und Jura die höchsten Preiselastizitäten auf. Auf der Ebene der Gemeinden liegt die Verteilung der Mietpreiselastizität (Eigentumspreiselastizität) zwischen 0,2 in Genf (GE) (0,11) und 2,49 in Zwischbergen (VS) (0,64). Im Allgemeinen beobachten wir die geringsten Preiselastizitäten in grossen städtischen und vorstädtischen Gebieten sowie in touristisch geprägten Orten. Kleinere Städte und ländliche Gebiete weisen dagegen ein deutlich elastischeres Wohnangebot auf.

Lokale Miet- und Eigentumspreiselastizitäten des Angebots werden durch verschiedene Faktoren beeinflusst. Zum Beispiel kann in dichtbesiedelten Gegenden kaum zusätzliches Bauland ausgewiesen werden, so dass eine Angebotsausweitung primär durch Verdichtung stattfinden muss. Dies geht mit vergleichsweise hohen Baukosten einher und führt damit zu einem unelastischen Angebot. Des Weiteren variieren die geografischen und regulatorischen Einschränkungen von Ort zu Ort. Eine Regressionsanalyse ermöglicht es, den Einfluss der Bestimmungsfaktoren Geografie und Regulierung auf die lokalen Preiselastizitäten des Angebots zu untersuchen. Um die Bedeutung der jeweiligen Dimension zu veranschaulichen, vergleichen wir jeweils die Preiselastizitäten des Angebots, die das Modell an einem Standort mit niedriger Ausprägung des jeweiligen Faktors (25-Perzentil) prognostiziert mit derjenigen, die sich bei einer hohen Ausprägung (75-Perzentil) einstellen würde. Erhöht man die regulatorischen Massnahmen, die das Ausmass der geschützten Flächen bestimmen, vom 25-Perzentil zum 75-Perzentil, so reduziert sich die Mietpreiselastizität des Angebots (Eigentumspreiselastizität) um ca. 22 (15) Prozent. Die Reduktion ist geringer und beträgt ungefähr 6-21 (1-11) Prozent bei regulatorischen Massnahmen, welche die Art und Intensität der Bebauung beeinflussen. Bemerkenswert ist, dass die intensiven sowie die extensiven regulatorischen Grenzen die Mietpreiselastizität stärker reduzieren als die Eigentumspreiselastizität. Bezüglich der geografischen Einschränkungen ergibt sich eine Reduktion von 4-11 (2-8) Prozent bei zunehmender Einschränkung.

Unsere Ergebnisse zeigen, dass die durchschnittliche Mietpreiselastizität des Angebots wesentlich höher ist als die Eigentumspreiselastizität. Beide Preiselastizitäten variieren jedoch regional deutlich. In einer prosperierenden Volkswirtschaft – gekennzeichnet durch starken Nachfragedruck aufgrund steigender Einkommen und wachsender Bevölkerung – besteht damit ein klarer Zielkonflikt zwischen restriktiver Raumentwicklung und Miet-/Preiswachstum. Da Massnahmen, welche die Freilandflächen schützen und die Bauhöhe einschränken, zu einem unelastischen Angebot führen, sind diese mit Kosten verbunden: Nachfrageschocks resultieren in höheren Mieten und Immobilienpreise, insbesondere in der Umgebung der grössten Agglomerationen.

Résumé

Le prix des logements, qu'ils soient en location ou en propriété, a fortement augmenté en Suisse ces dix dernières années. Entre 2005 et 2015, le prix des loyers au mètre carré a augmenté de 14,8 % et le prix de vente au mètre carré de 38,1 %. Les raisons de cette hausse marquée sont nombreuses. À ce jour, les chercheurs ont avant tout examiné les facteurs influençant la demande de logements, comme par exemple les effets de la croissance démographique et des revenus, des intérêts hypothécaires et du déplacement de la demande des zones rurales vers les zones urbaines et périurbaines.

L'offre est toutefois un facteur tout aussi déterminant dans l'évolution du prix du logement : tant que la croissance de la demande peut facilement être compensée par de nouveaux logements, la hausse des loyers et des prix restera modeste. Par contre, si l'offre est rigide, même un accroissement relativement modéré de la demande aura un effet notable sur les loyers et les prix. La mesure de référence utilisée en économie dans ce contexte est *l'élasticité-prix de l'offre de logements* ; elle reflète la pente de la courbe de l'offre et mesure la variation en pourcent de l'offre de logements lorsque le prix augmente de 1 %. L'élasticité-prix de l'offre est un paramètre important pour déterminer si les futures hausses de la demande de logements se traduiront principalement par une hausse des loyers et des prix de vente ou par une nette augmentation de l'offre de logements. La réactivité de l'offre de logements nous permet en outre de prédire les effets de politiques visant à favoriser l'accession à la propriété et de programmes de soutien géographiquement ciblés. Encourager l'accession à la propriété par des déductions fiscales peut, par exemple, entraîner une forte hausse des prix dans les régions ayant une offre inélastique, sans nécessairement induire une hausse du taux de propriété. De façon similaire, l'élasticité-prix de l'offre permet de déterminer les effets de répartition des programmes d'encouragement et le degré d'ajustement des prix de l'immobilier local à des investissements publics. Pourtant, il n'existe à ce jour que très peu d'études empiriques portant sur l'élasticité de l'offre en Suisse et les facteurs qui l'influencent.

Dans cette étude du *Center for Regional Economic Development (CRED)* de l'Université de Berne, nous quantifions l'élasticité de l'offre du marché immobilier en fonction des loyers et des prix de vente. À cette fin, nous utilisons les loyers et les prix de logements issus d'annonces immobilières parues entre 2005 et 2015, ainsi que des données sur le parc immobilier des logements résidentiels. Nous calculons le taux de croissance des loyers/prix et du nombre de

logements durant cette période au niveau local. Pour ce faire, nous définissons deux types de jeux de données.

Le premier jeu de données, dénommé *intérieur des agglomérations*, se concentre sur les marchés de l'immobilier au sein des 15 plus grandes agglomérations suisses. Nous définissons nos unités d'observation en créant des cercles concentriques progressivement plus grands autour des centres administratifs de ces agglomérations et en les intersectant avec les limites administratives des communes. Le deuxième jeu de données, que l'on nomme *grille nationale*, porte sur l'ensemble du territoire suisse, découpé en parcelles carrées de 2 km sur 2 km. Alors que le premier type de données nous permet d'analyser la dynamique qui se développe à l'intérieur des plus grandes agglomérations, on utilise le deuxième type de données afin d'étudier l'hétérogénéité locale de l'élasticité de l'offre et de ses déterminants. Nous analysons, en particulier, les effets engendrés par des restrictions topographiques et réglementaires. Par restrictions topographiques, on entend la présence de fortes pentes, de plans d'eau ou de terrains rocheux, tandis que les restrictions réglementaires prennent par exemple la forme de plans de zone. Dans notre analyse, nous distinguons les réglementations qui régissent l'expansion « horizontale » du milieu bâti – dites contraintes réglementaires extensives – de celles qui limitent l'intensité et le type de développement résidentiel, dites contraintes réglementaires intensives.

Dans notre analyse empirique, nous employons une méthode de variables instrumentales pour estimer l'élasticité de l'offre. Cette approche économétrique emploie une (ou plusieurs) variable(s) pour isoler les variations exogènes de la demande qui n'influent pas sur le côté offre du marché. On trouve, dans la littérature, plusieurs variables qui pourraient représenter un tel choc de la demande sur le marché immobilier. Nous examinons la validité de ces variables pour le marché immobilier suisse et proposons d'autres instruments appropriés. Nos résultats se basent principalement sur des variations de la demande causées par l'immigration, les taux de natalité historiques et les caractéristiques géographiques.

Nos résultats montrent que l'élasticité moyenne de l'offre en fonction des loyers dans les 15 plus grandes agglomérations suisses est d'environ 1,9, tandis que l'élasticité moyenne en fonction du prix de vente est d'environ 0,6. Cela signifie qu'à long terme, une augmentation des loyers (prix) de 10 % entraîne une hausse d'environ 19 % (6 %) de l'offre totale de logements (locatifs et en propriété). Lorsque nous étendons notre analyse à l'ensemble du pays, nous obtenons une élasticité moyenne de l'offre en fonction des loyers d'environ 1,6 et d'environ 0,5 en fonction du prix de vente. Cela indique que le marché du logement suisse réagit davantage aux variations des loyers qu'aux variations des prix de vente. En comparaison internationale, le marché immobilier suisse se situe dans la zone médiane par rapport à l'élasticité de l'offre.

Il existe toutefois des différences importantes dans l'élasticité de l'offre au niveau local et régional. Si l'on considère les cantons, l'élasticité de l'offre en fonction des loyers s'inscrit entre 0,66 et 2,17, tandis que pour l'élasticité de l'offre en fonction du prix de vente, la fourchette va de 0,25 à 0,59. Les cantons de Bâle-Ville et de Zurich affichent les plus faibles élasticités de l'offre, tandis que Fribourg et le Jura affichent les plus élevées. Au niveau des communes, l'élasticité de l'offre en fonction des loyers et en fonction des prix de vente va respectivement de 0,2 et 0,11 à Genève (GE) à 2,49 et 0,64 à Zwischbergen (VS). Dans l'ensemble, nous observons que l'élasticité de l'offre était plus basse dans les grandes zones urbaines et leur périphérie ainsi que dans les lieux touristiques. Les villes de plus petite taille et les zones rurales, en revanche, affichent une élasticité de l'offre de logements nettement plus élevée.

L'élasticité de l'offre locale par rapport aux loyers et aux prix de vente est tributaire de plusieurs facteurs. Dans les régions densément peuplées, par exemple, il n'y a plus guère de terrains constructibles, si bien que le développement de l'offre doit principalement passer par la densification du milieu bâti. Cela entraîne une augmentation des coûts de construction, ce qui à son tour mène à une offre plus inélastique. Les contraintes topographiques et réglementaires varient en outre d'un lieu à l'autre. Une analyse de régression permet d'examiner l'influence de ces deux types de contraintes sur l'élasticité de l'offre locale de logements. Pour illustrer l'impact de chaque contrainte séparément, on analyse comment l'élasticité de l'offre locale réagi lorsque l'on passe d'un niveau de contrainte faible – c'est-à-dire quand la valeur de la contrainte est égale au 25e percentile de la distribution – à un niveau plus élevé – c'est-à-dire au 75e percentile de la distribution. Si l'on augmente les mesures réglementaires qui déterminent l'étendue des zones protégées du 25e au 75e percentile, l'élasticité de l'offre en fonction des loyers (des prix de vente) diminue d'environ 22 % (15 %). La diminution de l'élasticité est un peu moindre, s'inscrivant dans une fourchette allant de 6 % à 21 % (1 % à 11 %), dans le cadre des mesures réglementaires influant sur le type et densité des bâtiments. Il apparaît donc que les contraintes réglementaires intensives et extensives réduisent davantage l'élasticité de l'offre en fonction des loyers qu'en fonction des prix de vente. Dans le cas des restrictions topographiques, la diminution de l'élasticité de l'offre varie entre 4 % et 11 % (2 % à 8 %) lorsque l'on passe d'un niveau de contrainte faible à un niveau plus élevé.

Nos résultats montrent que l'élasticité moyenne de l'offre en fonction des loyers est nettement plus élevée que l'élasticité moyenne de l'offre en fonction du prix de vente. Cela étant, l'élasticité de l'offre, quel que soit le marché considéré, varie fortement d'une région à l'autre. Dans une économie en prospère, caractérisée par une forte pression de la demande en raison de revenus et d'un développement démographique croissants, il y a des avantages et des inconvénients à contraindre le développement résidentiel. En diminuant l'élasticité de l'offre les réglementations visant à protéger les zones non construites et limitant la hauteur des bâtiments ont un coût : une hausse des loyers et des prix des logements engendrée par des chocs de la demande, en particulier aux abords des plus grandes agglomérations.

Executive Summary

The rents and prices of residential real estate have risen significantly in Switzerland over the past ten years. Between 2005 and 2015, the rent per square meter increased by 14.8 percent, whereas square meter prices increased by 38.1 percent. The reasons for this significant increase in rents and prices are manifold. To explain these increases, the literature has mainly focused on demand-side factors. These include population growth, overall growth in the economy and income, low mortgage rates, as well as the shift of housing demand from countryside areas to urban and suburban areas.

However, the supply side of housing markets is equally decisive for rent and price dynamics. As long as the quantity of supplied housing units can easily adjust to demand pressures, rents and prices will only increase moderately. In contrast, if the housing supply is rigid, even a relatively small increase in demand might lead to considerable rent and price increases. In this respect, the relevant economic measure is the so-called *housing supply elasticity*. This measure reflects the slope of the housing supply curve and measures the percentage by which the housing stock changes when rents or prices increase by one percent. Supply elasticity is an important parameter for assessing whether future demand increases will lead mainly to higher rents and prices or induce a significant increase in housing construction. Additionally, knowledge about housing supply elasticity allows inferences about the effectiveness of subsidies promoting homeownership or place-based policies. For example, subsidizing homeownership with tax deductions can result in higher prices in regions with inelastic housing supply, thus not increasing homeownership rates. Similarly, supply elasticities allow the prediction of distributional effects of support programs and the degree of capitalization of public investments in local rents and prices. Yet despite its importance, there is scarce empirical evidence about the supply elasticity of housing markets in Switzerland and its determinants.

In this study – conducted by the Center for Regional Economic Development (CRED) of the University of Bern – we estimate the supply elasticities of residential housing markets in Switzerland with respect to rent and price changes. To this end, we use advertisement data on rental and selling properties from 2005 to 2015 together with data on the stock of residential housing units. We compute corresponding changes in rents/prices and quantities over this period at the local level. More specifically, we define and analyze two types of samples.

The *within agglomeration sample* focuses on the dynamics of housing markets within the 15 major Swiss agglomerations. We define its units of observation by creating progressively larger concentric rings around the administrative centers of major agglomerations and intersecting them with municipality boundaries. The *country grid sample* partitions the whole territory of Switzerland into small square cells of 2 × 2 km. While the former sample allows us to zoom into the dynamics within agglomerations, we use the latter sample to investigate the heterogeneity of local housing supply elasticities and its determinants. In particular, we evaluate the role of geographic and regulatory constraints. Steep slopes, water bodies, and rocky areas define the former, whereas zoning regulations define the latter. Importantly, in our analysis, we distinguish regulatory measures preventing the 'horizontal' development of locations – the so-called extensive margin regulatory constraints – from regulatory measures restricting the intensity and type of development – the so-called intensive margin regulatory constraints.

Throughout our empirical analysis, we rely on an instrumental variable approach to recover the elasticity of housing supply. This econometric technique requires that we find one (or more) variable that isolates exogenous shifts of the housing demand while leaving the supply-side of the market unaffected. Several variables have been suggested in the literature to capture such demand shocks on the housing market. We investigate the pertinence of these variables for Swiss housing markets and suggest new ones. Our main results are based on exogenous demand shifts due to immigration, historic fertility rates, and land orientation.

We find that the average long-run supply elasticity of the housing market within the 15 major Swiss agglomerations is approximately 1.9 and 0.6 with respect to rent and price changes, respectively. This means that a 10 percent increase in rents (prices) will result in a 19 (6) percent increase in the total housing stock (i.e. both rental and selling properties) in the long-run. When expanding our analysis to the whole country, we find that the average long-run supply elasticity of the housing market is approximately 1.6 and 0.5 with respect to rent and price changes, respectively. This suggests that Swiss housing markets are more responsive to rent changes than to price changes. By international comparison, the Swiss housing market is thus in the middle range regarding housing supply elasticity.

There are, however, important differences in housing supply elasticities at the local and regional levels. At the cantonal level, the rental (price) supply elasticity varies between 0.66 (0.25) and 2.17 (0.59). The cantons of Basel-Stadt and Zurich feature the lowest supply elasticities, while the cantons of Fribourg and Jura feature the highest. At the municipal level, the rental (price) supply elasticity ranges from 0.2 (0.11) for Geneva (GE) to 2.49 (0.64) for Zwischbergen (VS). In general, we observe the lowest local supply elasticities in major urban and suburban areas and in highly touristic places. In contrast, smaller towns and rural areas display more elastic housing supplies.

Local rent and price elasticities are influenced by various factors. For example, hardly any developable land is available in densely populated areas. Thus, the expansion of supply must take place by further densification, leading to higher construction costs and more inelastic supply. Furthermore, geographic constraints and regulations vary locally. A regression analysis allows us to investigate the role of geographic and regulatory constraints in determining local supply elasticities. To separately investigate the importance of each dimension, we predict changes in local supply elasticities when a specific supply constraint is shifted from a low level – i.e., when the value of the considered constraint equals the 25th percentile of the distribution – to a more binding one – i.e., when the value of the considered constraint equals the 75th percentile of the distribution. Increasing all regulatory constraints on the extensive margin from the 25th percentile to the 75th percentile value, we find that the rental (price) supply elasticity decreases by approximately 22 (15) percent. The decrease is lower and amounts to approximately 6-21 (1-11) percent for regulatory constraints on the intensive margin. Notably, intensive and extensive margin regulatory constraints reduce the rental supply elasticities more than price supply elasticities. Regarding geographic constraints, there is a 4-11 (2-8) percent decrease in the supply elasticity when shifting from low to highly restricted places.

Our results show that the average housing supply elasticity with respect to rent changes is considerably more elastic than the average housing supply elasticity with respect to prices. However, both rental and price elasticities vary significantly across locations. There are clear tradeoffs in a growing economy – characterized by strong demand pressure due to rising incomes and population growth – between restricting residential development and rent/price dynamics. By making housing supply considerably more inelastic, policies that protect open land and restrict building height come at a cost: the capitalization of demand shocks into higher rent and price levels, especially within the proximity of major agglomerations.

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ACRONYMS

ARE	Federal Office for Spatial Development (Bundesamt für Raumentwicklung)
BLN	Federal inventory of landscapes and natural monuments (Bundesinventar der Landschaften und Naturdenkmäler)
BWO	Federal Office of Housing (Bundesamt für Wohnungswesen)
CBD	Central business district
CRED	Center for Regional Economic Development
ESOP	Statistics of the annual population (Statistik des jährlichen Bevölkerungsstandes)
FFF	Crop rotation areas (Fruchtfolgeflächen)
FINMA	Swiss Financial Market Supervisory Authority (Eidgenössische Finanzmarktaufsicht)
FOEN	Federal Office for the Environment (Bundesamt für Umwelt, BAFU)
FPC	Federal Population Census
FSO	Swiss Federal Statistical Office
GWR	Federal Register of Buildings and Habitations (Eidgenössisches Gebäude- und Wohnungsregister)
MSA	US Metropolitan Statistical Areas
SECO	State Secretariat for Economic Affairs (Staatssekretariat für Wirtschaft)
SNB	Swiss National Bank
STATPOP	Population and Households Survey (Statistik der Bevölkerung und der Haushalte)
Swisstopo	Federal Office of Topography (Bundesamt für Landestopografie)
RPG	Spatial Planning Act (Revision des Raumplanungsgesetzes)
UNESCO	United Nations Educational, Scientific and Cultural Organization
WSL	Swiss Federal Research Institute for Forest, Snow and Landscape (Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft)

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1. Introduction

We analyze the supply responsiveness – also called housing supply elasticity – of Swiss housing markets with respect to rent and price changes. The supply responsiveness of housing markets is of major importance, since it determines how markets react to demand shocks. In areas having a responsive housing supply, higher demand leads to a greater quantity of supplied housing, whereas in less-responsive places, demand shocks yield substantial rent and price increases (inelastic supply). As such, our analysis helps us to understand why some regions in Switzerland have experienced major rent and price increases in the last decade, and it helps us predict future rent and price developments. For policy makers, the analysis of supply elasticities at the local level provides valuable information about i) the indirect costs – in terms of higher rent and price levels – of various forms of regulation restricting housing development and ii) the degree of capitalization of policies affecting the demand-side of the housing market.

We start our analysis by aggregating housing stock data on residential buildings (single family, multifamily, and ancillary use buildings) and corresponding asking rents and prices, as advertised by major online portals, within small municipality neighborhoods belonging to one of the 15 largest Swiss agglomerations.[1] Our empirical results indicate that the average long-run (2005-2015) supply responsiveness within these agglomerations is approximately 1.9 and 0.6 with respect to rent and price changes, respectively. A 10 percent increase in rents thus translates into a 19 percent increase in total supplied housing units (i.e. both rental and selling properties), whereas a 10 percent increase in prices causes a 6 percent increase in the total supplied quantity. These results imply that on average, the total housing supply in major agglomerations reacts more strongly to rent changes than to price fluctuations. When housing supply is investigated separately for rental and owner-occupied housing units, we find that the supply responsiveness of rental units to rent changes increases to 2.43, and the responsiveness of owner-occupied properties to price changes decreases to 0.4. These differences from the previous results are not statistically significant.

In a next step, we analyze fine-scale housing supply elasticity patterns for the whole of Switzerland. To do this, we redefine our spatial units of observation in order to include areas outside major agglomerations. More specifically, we aggregate the Swiss housing stock and advertisement data within 2x2 km grid cells partitioning the country’s territory. We find that

[1] We rely on the 2012 definition of agglomerations by the Swiss Federal Statistical Office (FSO).

the average long-run supply elasticity of the housing market for the whole of Switzerland is approximately 1.6 and 0.5 with respect to rent and price changes, respectively. However, the results reveal considerable heterogeneity of supply responsiveness across space due both to geographic and regulatory constraints. In our analysis, we distinguish two types of regulatory constraints: those on the *extensive* margin – i.e., designated areas where residential development is not allowed, such as forests and parks – and those on the *intensive* margin – capturing the effect of the restrictiveness of zoning regulations on the intensity of residential development.

When considering the impact of each type of constraint on local supply responsiveness individually, we find that regulatory constraints – both on the extensive and intensive margins – seem to reduce the supply responsiveness more than geographic constraints. The joint impact of all regulatory constraints on the extensive margin seems to hinder supply elasticities more than regulations on the intensive margin. Importantly, both geographic and regulatory constraints seem to be binding only in areas characterized by historically high development levels, such as city centers and suburban areas.

The computation of fine-scale supply elasticities – which depend on local geographic and regulatory constraints – allows us to derive housing supply responsiveness at more aggregate levels. At the municipal level, Geneva (GE) and Basel (BS) have the lowest rental supply elasticities, while Steinerberg (SZ) and Zwischbergen (VS) have the highest ones. At the agglomeration level, Baden-Brugg and Lugano display the lowest supply elasticities, whereas Lausanne and Fribourg have the highest. At the cantonal level, Basel Stadt and Zurich have the lowest rental supply elasticities, while Fribourg and Jura have the highest. The ranking for the different levels of aggregation remains virtually unchanged for price supply elasticities.

In the last two decades, researchers have investigated the supply responsiveness of housing markets in several countries and its consequences for market outcomes. The empirical literature provides convincing evidence that the extent to which demand shocks are capitalized into higher house prices critically depends on variations in the responsiveness of housing supply (Mayer and Sommerville, 2000; Malpezzi and Maclennan, 2001; and Glaeser, Gyourko, and Saks, 2006). Saks (2008) finds that places in the United States with fewer regulatory constraints to new development experience more construction of residential units and smaller price increases due to positive shocks in housing demand. Hilber and Mayer (2009) analyze data from Massachusetts and provide evidence that locations with less developable land have a less responsive housing supply and a higher degree of house price capitalization compared to those with less-developed locations and, accordingly, more capacity for supply adjustments. Saiz (2010) characterizes housing supply elasticity in the US as a function of both geographic and regulatory constraints. He obtains values ranging from 0.6 for Miami (FL) to 5.45 for Wichita (KS). Importantly, the analysis suggests that geographic constraints are one of the main factors driving spatial heterogeneity in supply responsiveness. Caldera and Johansson (2013) estimate housing supply elasticities with respect to prices for 21 OECD countries. With a supply elasticity of 0.15 from 1980 to 2004, the authors rank Switzerland as the country with the least responsive housing supply. The highest housing supply elasticity is observed in the United States at a value of 2.01, and the mean supply elasticity across these 21 OECD countries is 0.63. However, they adopt a different approach, making their results not directly comparable to ours.

In a recent study, Hilber and Vermeulen (2016) estimate the house price-earnings elasticity for the UK, finding that prices react more strongly to earnings changes – which are expected to raise the demand for housing space – in more-regulated areas. In contrast to Saiz (2010), the authors identify regulatory constraints as the main element affecting price-earnings elasticities, while geographic features of the landscape play only a minor role. For Switzerland, there is scarce empirical evidence about the elasticity of housing supply to price and rent changes.

We contribute to the existing literature in several ways. First, by creating a unique data set combining geo-referenced housing advertisements and housing stock information, we estimate the supply responsiveness based on micro-level variation in rents, prices and quantities. In contrast to previous research, the micro approach entails several benefits, as it allows one to i) estimate supply responsiveness at the local level, thus allowing us to compute aggregate supply elasticities at different institutional levels, which is particularly relevant in a highly decentralized country such as Switzerland; ii) partial out unobserved factors at the highly local level and thereby improve the consistency and precision of the estimated elasticities compared to the more aggregated approaches in the literature; and iii) exploit localized housing demand shifts to recover supply elasticities. Second, we investigate the responsiveness of total stock changes with respect to rents as well as prices. Previous literature focused only on the responsiveness with regard to prices and did not take into account the interrelations between the rental and selling markets. Third, we investigate the impact of land use regulation on the extensive and intensive margins on the supply responsiveness. We show that such regulations predominantly matter in more-developed places where they are binding. Fourth, we quantify the effects of geographic and regulatory constraints on local supply elasticities and evaluate the relative importance of the two dimensions for the rent and price responses observed in Switzerland. This provides valuable information about the extent to which the rent and price responsiveness is determined by exogenous natural factors versus potentially endogenous policy variables. Fifth, we analyze a comprehensive set of instruments used in previous studies and compare the validity of these instruments with respect to alternative sources of exogenous variation.

The remainder of the report is structured as follows. Section 2 provides descriptive statistics of the Swiss housing market, elaborating on the most important factors that affect the demand and supply sides of the market. Section 3 contains a brief data description and a non-technical overview of the methodology used to estimate the responsiveness of housing supply. Section 4 presents the empirical results. Section 5 describes the conducted robustness checks. Section 6 summarizes the results and draws conclusions about the potential effects of policy instruments on the housing market.

2. Swiss housing market

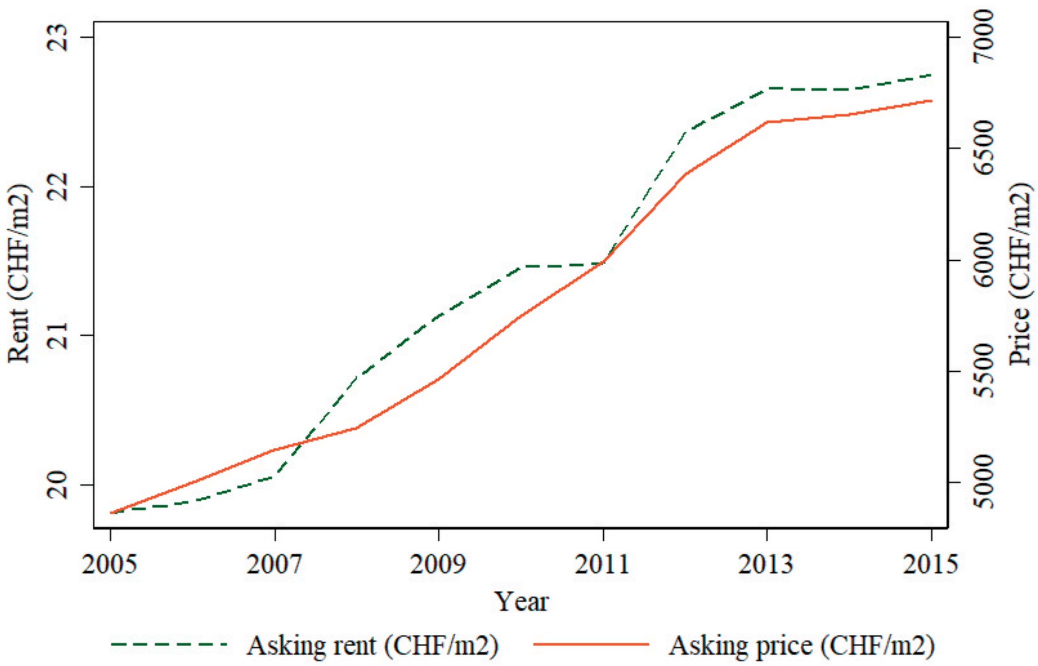
2.1. Rents, prices, and demand-side drivers

In the last decade, rents and prices have considerably increased in Switzerland, as shown in Figure 1. Rents, despite being subject to a mild form of rent control, have increased by 14.8 percent over the last decade, rising from 19.8 CHF per square meter in 2005 to more than 22.7 CHF per square meter in 2015.[2] Similarly, housing prices have grown by 38.1 percent over the last ten years, increasing form 4,900 CHF per square meter in 2005 to more than 6,700 CHF per square meter in 2015.

Despite a general positive trend at the country level, rents and prices – and their dynamics – are extremely heterogeneous across space, as illustrated in Figure 2 to 5.

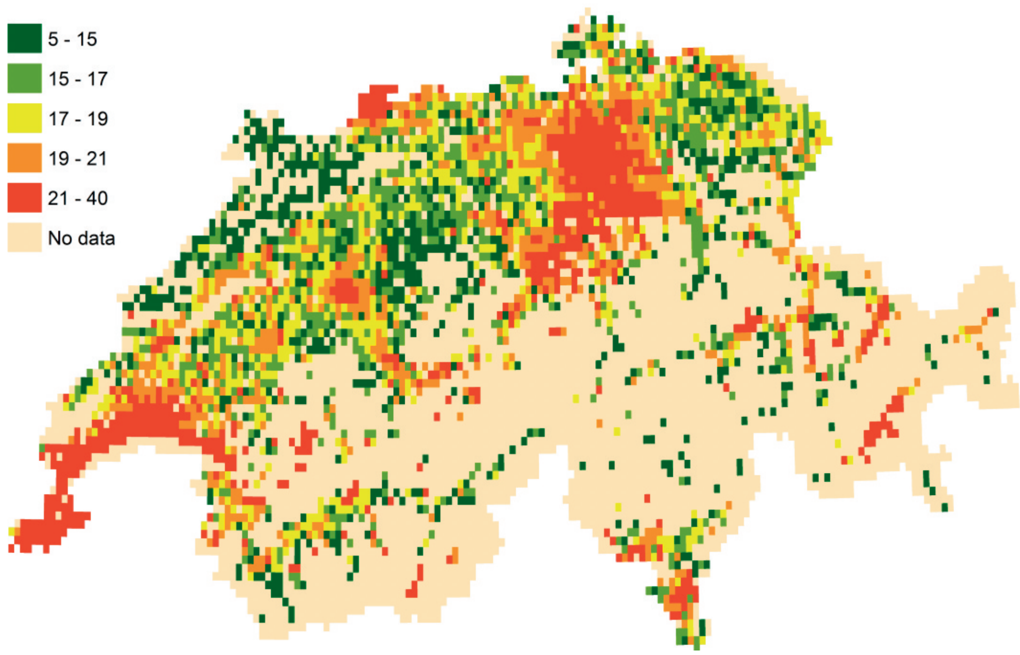
[2] To prevent abusive increases, property owners can adjust rents only if some formal criteria are met. For example, rents can be increased if the reference interest rate for mortgages and/or the consumer price index increases. In the long run, however, several exceptions in the regulation make rent control mildly binding. For example, rents can be increased to market levels when tenants change or after major renovations.

Figure 1: Asking rents and prices in 2015



Notes: Data source: Meta-Sys. Own computations and figure.

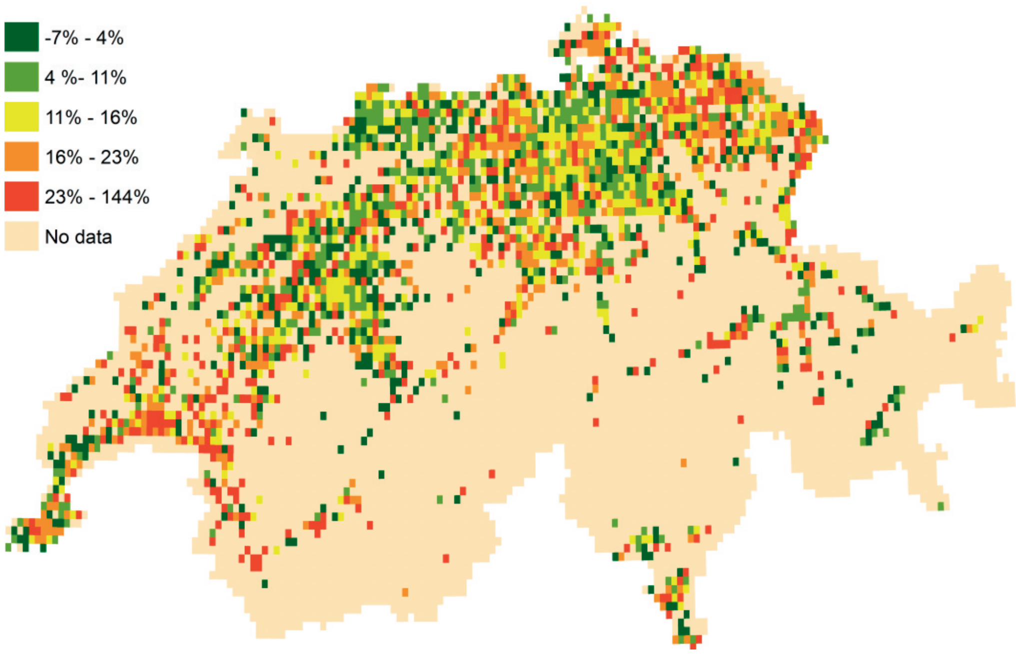
Figure 2: Asking rents in 2015



Notes: Data source: Meta-Sys. Asking rents in CHF per square meter. Range is according to quintiles. Grid cells are of size 0.026 times 0.026 degrees, which corresponds to approximately 5.725 square Kilometers. The total number of grid cells is 7,212.

According to Figure 2, rents per square meter are particularly high in major Swiss agglomerations, with Zurich-Zug and the Lemanic Arc – defined as the union of the agglomerations of Geneva and Lausanne – having the flattest rent gradient[3] form their administrative centers. Smaller central business districts (CBDs) – such as Bern, Basel, or Lugano – display the steepest rent gradients, implying that more-affordable rents can be found at a smaller distance from the city centers compared to larger agglomerations such as Zurich and Geneva. With the exception of a few sparse areas, rents have considerably increased throughout the Swiss territory, with higher increases within agglomerations than in the rural areas, as shown in Figure 3.

Figure 3: Asking rents growth 2005-2015

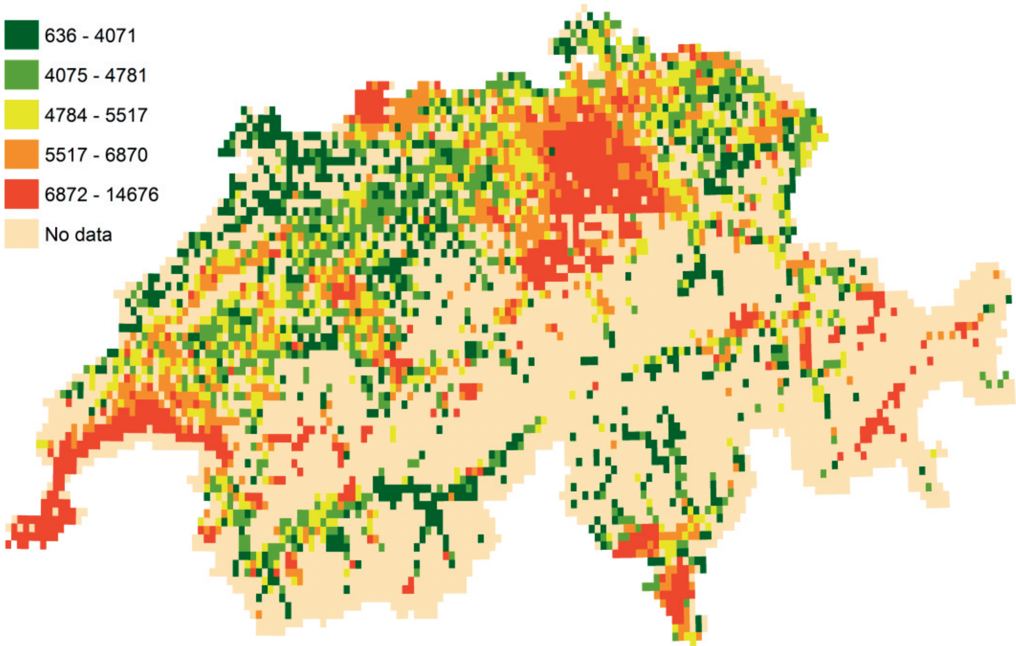


Notes: Data source: Meta-Sys. Growth in percentage of asking rents per square meter between 2005 and 2015. Range is according to quintiles. Grid cells are of size 0.026 times 0.026 degrees, which corresponds to approximately 5.725 square Kilometers. The total number of grid cells is 7,212.

As illustrated in Figure 4, the gradient of asking price per square meter is less steep than that for rents, with Zurich-Zug-Luzern and the Lemanic Arc representing the areas of the market with the highest prices. Similar to rents, prices have increased across the whole country, with only a few locations displaying a negative price growth (see Figure 5).

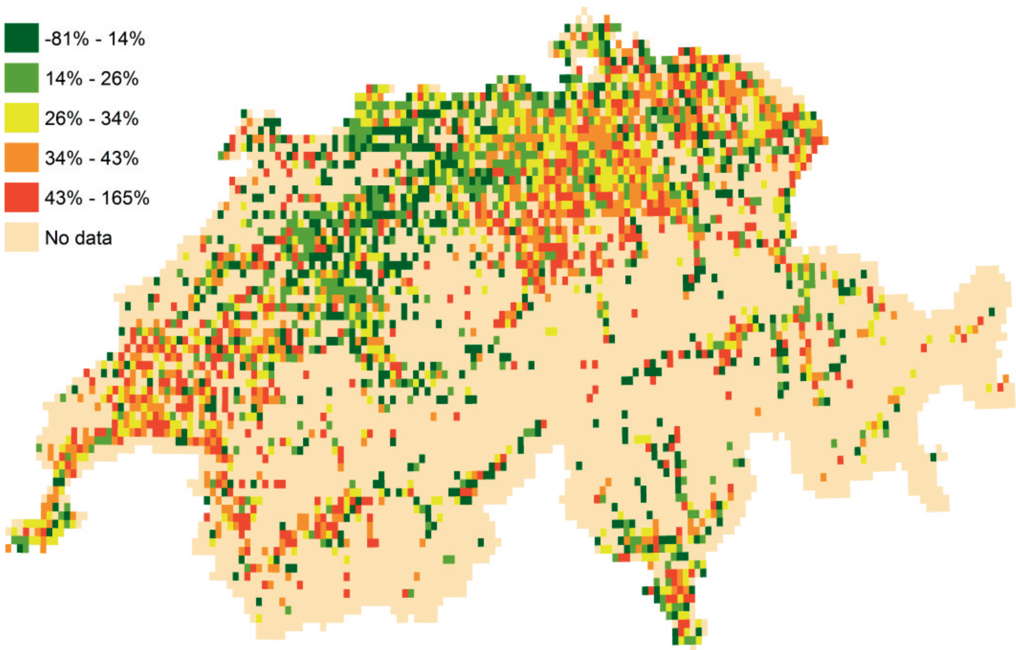
[3] The so-called rent gradient reflects the slope of the bid-rent curve. The latter displays how rents change with distance to the CBD.

Figure 4: Asking prices 2015



Notes: Data source: Meta-Sys. Asking prices in CHF per square meter. Range is according to quintiles. Grid cells are of size 0.026 times 0.026 degrees, which corresponds to approximately 5.725 square Kilometers. The total number of grid cells is 7,212.

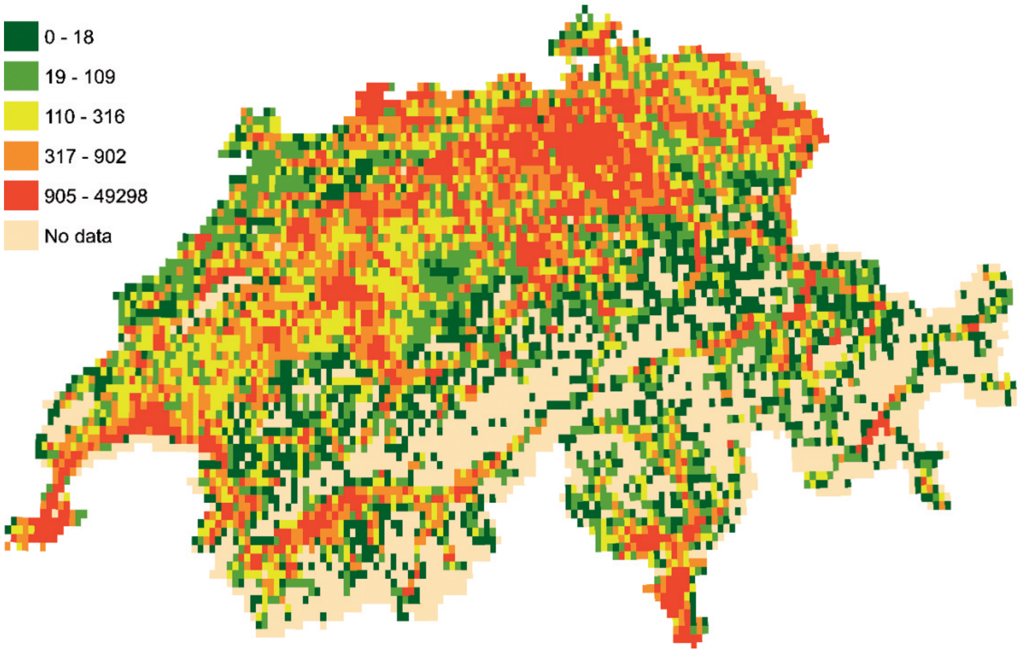
Figure 5: Asking prices growth 2005-2015



Notes: Data source: Meta-Sys. Growth in percentage of asking prices per square meter between 2005 and 2015. Range is according to quintiles. Grid cells are of size 0.026 times 0.026 degrees, which corresponds to approximately 5.725 square Kilometers. The total number of grid cells is 7,212.

It is interesting to relate rent/price levels and their dynamics to the level and dynamics of the housing stock, as measured by the number of housing units. Figure 6 and 7 illustrate the level of the Swiss housing stock in 2015 and its growth between 2005 and 2015, respectively. Not surprisingly, in 2015, the larger part of the housing stock was concentrated in major agglomerations: approximately 46 percent of the country's housing stock was located within 10 km of one of the 15 largest CBDs. However, over the last decade, the stock has increased more markedly in suburban and countryside areas, growing at a lower rate within the proximity of the CBDs.[4] In more-remote alpine areas, the stock remained unchanged or even decreased.

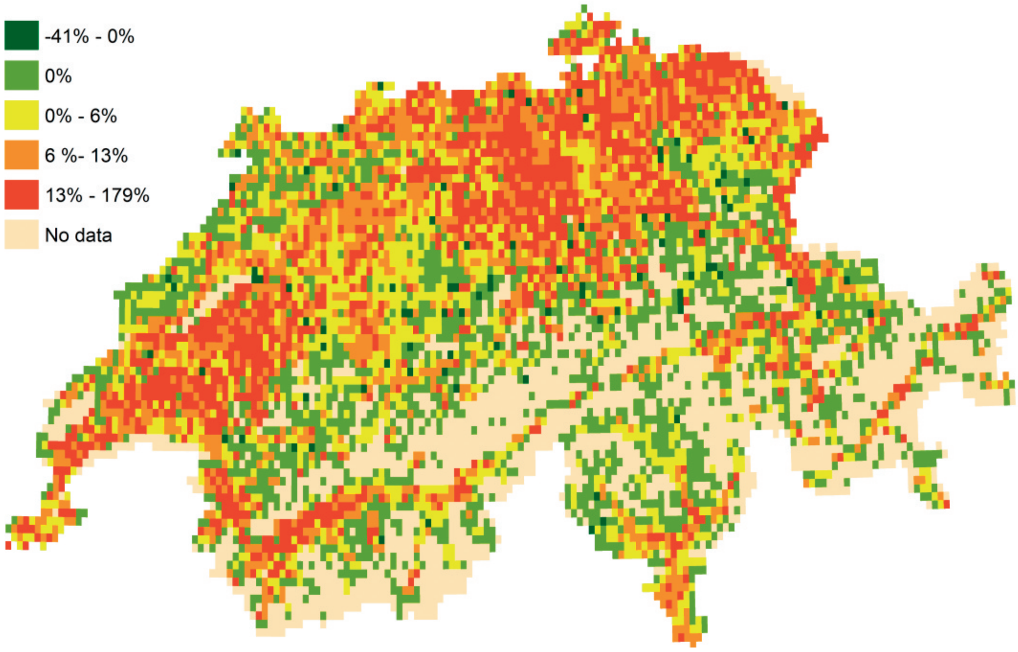
Figure 6: Housing stock spatial distribution in 2015



Notes: Data source: GWR. Number of residential buildings per grid cell. Range is according to quintiles. Grid cells are of size 0.026 times 0.026 degrees, which corresponds to approximately 5.725 square Kilometers. The total number of grid cells is 7,212.

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

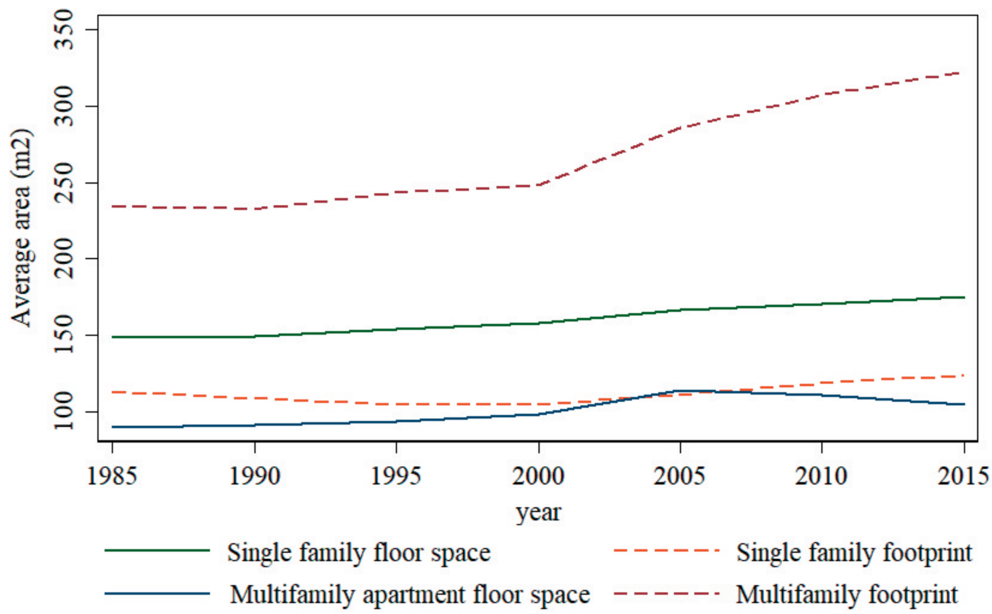
Figure 7: Stock growth 2005-2015



Notes: Data source: GWR. Growth in percentage in residential building between 2005 and 2015. Range is according to quintiles. Grid cells are of size 0.026 times 0.026 degrees, which corresponds to approximately 5.725 square Kilometers. The total number of grid cells is 7,212.

Since the previous figures show rents and prices per square meter, they also reflect changes in the market characteristics of housing units. As shown in Figure 8, for example, the average living surface of newly built single-family and multi-family housing units displays different aggregate trends. The former shows a slight but persistently positive growth in living surface, which is accompanied by a corresponding increase in the building footprint from 2000 onwards. This is not true for multi-family housing units. From 2000 onwards, the footprint of multi-family buildings has increased significantly, but after 2005, the living surface of housing units in these buildings started to reverse its growth, decreasing from 120 square meters in 2005 to 110 square meters in 2015. The decrease in residential floor space for multi-family houses is likely to reflect an increase in rents and prices that outpaced nominal wage growth, thus leading people to live in smaller apartments.

Figure 8: Areas of newly built flats and buildings

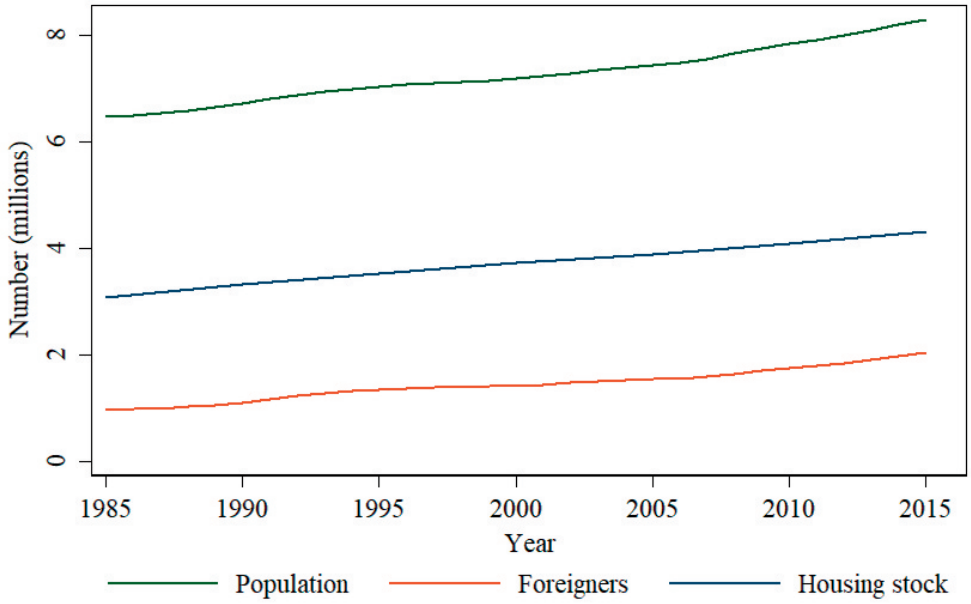


Notes: Data source: GWR. Own computations and figure.

The observed differences in the dynamics of prices, rents, housing stock, and housing characteristics are partly due to a mix of demand-side drivers varying at the national and local levels. At the national level, mortgage interest rates have persistently decreased over the last ten years, with 10-year fixed rates falling below 1.5 percent. Because mortgage debts have progressively become less costly, demand pressure on the owner-occupied housing market has considerably increased. To prevent excessive increases in house prices, in 2012, the Swiss financial sector introduced self-regulation, approved by the Swiss Financial Market Supervisory Authority (FINMA, Eidgenössische Finanzmarktaufsicht), with several measures tightening the access to mortgage credit. One of these measures, for example, requires that at least half of the usual down payment of 20% that is necessary to purchase a residential property must consist in capital – i.e., savings, in most cases – held by households, preventing households from completely relying on their pension funds for the down payment. Moreover, since 2012 a countercyclical capital buffer – a preventative capital measure within the Basel III framework – is available in Switzerland. The countercyclical capital buffer has been activated by the Federal Council upon the proposal of the Swiss National Bank (SNB) for the first time in February 2013. Since January 2014, the countercyclical capital buffer amounts to 2 percent of risk-weighted positions secured by residential property situated in Switzerland.

Second, nominal wages have increased by approximately 12 percent from 2005 to 2015 at the country level. However, important disparities exist at the regional and local levels. Regional and local wage dynamics affect how households bid in the housing market, thus affecting rent and price growth.

Figure 9: Population, foreign and stock dynamics



Notes: Data source: GWR and Statistik des jährlichen Bevölkerungsstandes (ESOP). Own computations and figure.

Third, and arguably most importantly, the Swiss population has grown at a sustained rate in the last few decades, mostly due to immigration. In 2016, Switzerland was ranked at 4th place according to the OECD's Better Life Index, with particularly high sub-index values in categories such as income, jobs, health, safety, and life satisfaction. Arguably, the high quality of life of the country, together with the economic crisis in many European countries, has spurred a significant inflow of immigrants.[5] Switzerland's population went from less than 6.5 million inhabitants at the beginning of the 1980s to approximately 8.3 million in 2015. As illustrated in Figure 9, this population increase is largely driven by immigration, as the total population and number of foreign residents follow parallel trends. As expected, the housing stock grew parallel to the population growth.

Finally, the federal government provides Cantons with wide autonomy regarding tax policies, public good provision, and land use policies. In turn, municipalities – which are the lowest-tier

[5] Economic geography models (e.g., Blouri and Ehrlich, 2017, in a European context) consider three main factors affecting residential location choices of individuals: person-specific valuation of the place, migration costs, and real income. This latter, in particular, is a function of wage levels and prices (including housing costs).

political units – must comply with cantonal laws, while still enjoying considerable autonomy.[6] Therefore, the demand side of the market is affected not only by the proximity to major labor markets and natural amenities but also by fiscal incentives households have at the municipality/cantonal level.

2.2. Geographic and regulatory constraints

Housing supply in Switzerland is influenced by several geographic and institutional factors at both the national and local levels. Switzerland's federalist structure encourages housing development, as cantons and municipalities retain fiscal advantages in expanding their tax base. These incentives have arguably contributed to a rapid development of suburban and countryside areas. At the more local level, geographic and regulatory constraints limit housing development. We start by discussing geographic constraints, and we subsequently describe regulatory constraints on the extensive and intensive margins, respectively. The data sources, definitions, and importance of geographic and regulatory constraints are summarized in Table 1.

Geographic features preventing any form of development are an important component of the Swiss landscape. Panel A of Table 1 summarizes those considered in the present study. Unproductive surfaces – comprising the Alps – and water bodies represent the two most obvious geographic features. In what follows, we define *undevelopable land* as land that is located above 2000 meters and whose land-cover corresponds to unproductive vegetation, vegetation-free areas, rocks and glaciers. Figure 10 shows the spatial distribution of undevelopable land and water bodies – given by lakes and rivers – across the Swiss territory. As is evident from the figure, undevelopable land considerably reduces developable land availability in the countryside, mostly in alpine regions. In contrast, water bodies significantly

[6] This is true for the time period considered in our empirical analysis. In 2014, the autonomy of cantons and municipalities regarding land use policies was restricted. With the adoption of the revised Spatial Planning Act (RPG, Revision des Raumplanungsgesetzes) of 2014, cantons are now obliged to submit detailed zoning plans for approval by the federal government. The amount and distribution of zoned land across municipalities belonging to the canton must be defined according to the predicted cantonal population growth.

reduce the amount of developable land within a major agglomerations, as virtually all major CBDs are adjacent to a lake or river.[7]

Other topographical features of the landscape might make development costlier, without completely preventing it. Land ruggedness is arguably the most important of these topographical features. For this reason, we also measure the standard deviation of elevation within a small area. The higher the standard deviation of elevation in these areas, the higher the development costs, thus making housing supply less responsive to demand shocks.

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 the development of locations as regulations on the extensive margin. In contrast, measures that do not restrict whether a place can be developed or not but rather determine the intensity and type of residential development are referred to as regulations on the intensive margin.

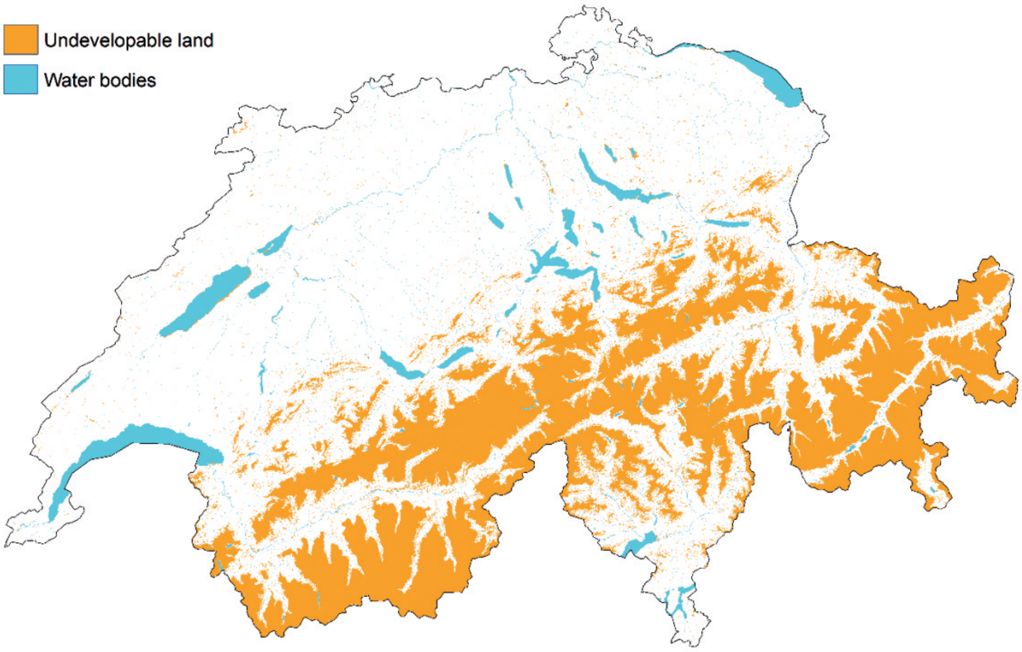
Regulations on the extensive margin include crop rotation areas, forests, UNESCO cultural or natural heritage sites, and high amenity value areas, as illustrated in Panel B of Table 1. Figure 11 and 12 illustrate the spatial extent of these restrictions. Note that in general, regulations on the extensive margin are not mutually exclusive. For example, the UNESCO classification of an area of particular natural value might partly overlap with the boundary of a regional park.

[7] 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. These advantages include, for example, comparatively lower costs in the production of electric and hydro mechanical energy.

Table 1: Supply constraints

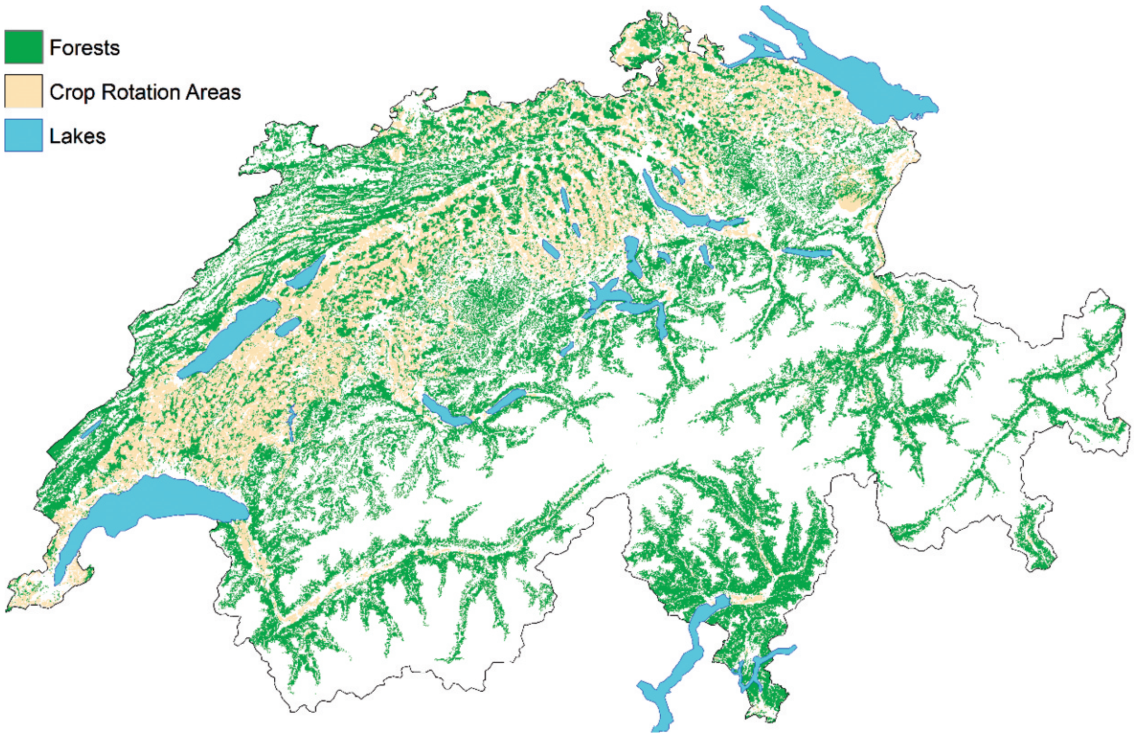
Type of heterogeneity	Label	Description	Area share of Switzerland	Source
		Panel A: Geographic constraints		
Water and undevelopable land	Undevelopable	Water bodies + rocks, and glaciers above 2000	31.2%	Arealstatistik der Schweiz
Standard deviation of elevation (land ruggedness)	Elevation SD	Within grid cells of 2 km	-	Arealstatistik der Schweiz
		Panel B: Regulatory constraints - extensive margin		
Forests	Forest	Protected forest	27.7%	Arealstatistik der Schweiz
Crop rotation areas (Fruchtfolgeflächen)	FFF	Areas best suited for agriculture	12.3%	Cantonal offices for spatial development
Federal inventory of landscapes and natural monuments (Bundesinventar der Landschaften und Naturdenkmäler)	BLN	Most valuable landscapes of Switzerland	18.9%	Federal Office for the Environment (FOEN)
Regional and national parks (Pärke von nationaler Bedeutung)	Parks	Parks of national importance	12.7%	Federal Office for the Environment (FOEN)
UNESCO cultural heritage	UNESCO cultural	Buildings of particular architectural merit, entire towns, and sites created by the emergence of industrialisation	2.8%	Federal Office for the Environment (FOEN)
UNESCO natural heritage sites	UNESCO natural	Natural sites with outstanding universal value	2.8%	Federal Office for the Environment (FOEN)
		Panel C: Regulatory constraints - intensive margin		
Intensity of regulation	Stock1980	Proxy for the intensity of regulation (cf. Saiz, 2010)		Federal Register of Buildings and Habitations (GWR)
Newly zoned industrial areas (Unüberbaute Arbeitszonen)	Zoned industrial		-	ARE Bauzonenstatistik, 2012
Number of zoning instruments	WSL1	Survey data; number of zoning instruments available at the municipality level	-	Forschungsanstalt für Wald, Schnee und Landschaft, 2016
Zoning restrictiveness index	WSL2	Survey data; questions about restriction of residential zones and compact settlement development	-	Forschungsanstalt für Wald, Schnee und Landschaft, 2016
Building permit refusal rate	Refusal rate	Share of building permits that were rejected	-	Meta-Sys
		Panel D: Total restricted area		
Geographic + regulatory constraints - extensive margin	Total restricted		78.2%	

Figure 10: Geographic constraints



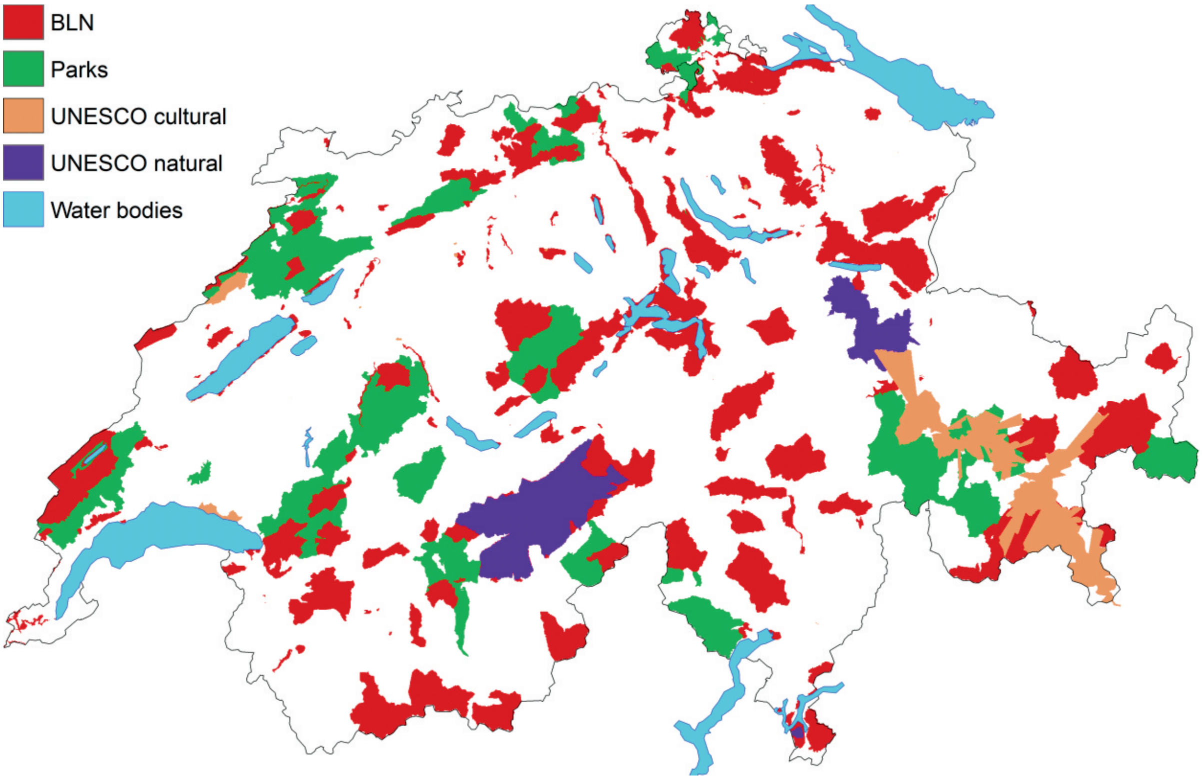
Notes: We use information from Swisstopo and Arealstatistik jointly with the data about the elevation from COPERNICUS to compute undevelopable land. We define 100x100 meter raster cells as *undevelopable land* if they are located above 2000 meter and their land cover classification according to the Arealstatistik (2004-2009) corresponds to unproductive vegetation (class 15), vegetation-free areas (class 16), rocks and glaciers (class 17).

Figure 11: Forests and crop rotation areas



Notes: Data source: Arealstatistik and cantonal offices of topography. Own graph. Forests and crop rotation areas may overlap due to imprecision of the FFF data. In total only 1.2% of the forest area overlaps with the FFF.

Figure 12: UNESCO, BLN, and Parks



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

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

In response to industrialization in Europe and in Switzerland, in 1876, Switzerland passed a law prohibiting further deforestation, de facto freezing forest areas to the level observed at that time. The law has remained mainly unchanged to the present day.[8] As a result of these laws, the forest area in the highly populated regions has remained practically unchanged since 1876.

One of the objectives of the United Nations Educational, Scientific and Cultural Organization (UNESCO) is to protect cultural and natural heritage of outstanding universal value. Currently, UNESCO recognizes 981 cultural or natural heritage sites worldwide, 11 of which are located in Switzerland. These areas mostly consist of buildings of particular architectural interest, historic towns, and areas with valuable natural amenities.

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

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

Overall, areas protected by FFF, forest, UNESCO, regional and national parks or BLN regulations cover approximately 60 percent of the Swiss territory (see Figure 11 to 12). Areas that are non-developable according to our definition of geographic constraints make up approximately 31.2 percent of the Swiss territory. The total restricted area (geographic and regulatory constraints at the extensive margin) amount to approximately 78.2 percent of surface, since many regulatory constraints at the extensive margin overlap with geographic constraints.

The intensity of residential development is also regulated in Switzerland. In particular, Cantons define zoning plans – which typically regulate the intensity of residential development – according to general guidelines dictated by the federal government. Municipalities have to

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

comply with cantonal plans and adapt their zoning policies accordingly. Since there is no source of comprehensive information about the type of zoning policies implemented across cantons and municipalities, we rely on several proxies that capture regional differences in the intensive margin regulation. Panel C of Table 1 contains the five main measures that we use in the analysis.

We use the historical housing stock in 1980 to capture the relevance of geographic and regulatory constraints. In fact, according to Saiz (2010) geographic constraints are binding only in more developed places. On the other hand, Hilber and Robert-Nicoud (2013) argue that attractive places are developed first and become more regulated to cater to the interests of local residents.

We derive the second measure – newly zoned industrial area – from 2012 official zoning data, harmonized for the whole of Switzerland, on the land use attributed to undeveloped plots of land. More specifically, we measure the local level of the quantity of land made available for commercial and industrial development (Arbeitszonen). The motivation for this measure is the following. For fiscal reasons, some municipalities might favor commercial and industrial development over residential development. If this is the case, we expect municipalities that zone large quantities of commercial and industrial land at the local level to be more restrictive with respect to residential development in that area, thus making housing supply more inelastic.[9]

Given the lack of information about the type and restrictiveness of instruments used to regulate development intensity, we rely on survey data for our third and fourth proxy. Note that a similar approach – which relies on the Wharton index proposed by Gyourko, Saiz, and Summers (2008) – is usually adopted in the literature investigating housing supply in the US.

In 2014, the Swiss Federal Research Institute for Forest, Snow and Landscape (WSL, Eidgenössische Forschungsanstalt für Wald, Schnee und Landschaft) surveyed Swiss municipalities, asking them to provide information about their administrative structures, the instruments they use to regulate spatial planning, and the year when the respective instruments

[9] In our empirical analysis, we have also considered the role played by other types of land use, such as the amount of new land zoned for residential development. However, the results were not meaningful and are thus not reported in what follows.

were introduced (Kaiser et al., 2016).[10] Using the results of the survey, we construct two measures of regulatory restrictiveness on the intensive margin. We define WSL1 as the number of planning instruments used by a given municipality. More specifically, a municipality might implement up to four instruments. The two main instruments are the re-zoning of developable plots of land into protected areas and restricting further development of areas with low density. The second instrument is a measure to decrease the expansion of low-density residential housing, especially single family houses. Two additional instruments we consider, aim to optimize the spatial distribution of developable land (i.e. residential zones are newly arranged) and to define preservation areas to contain urban development.[11] We complement WSL1 with an index WSL2 based on the answer regarding the main planning instruments listed above.[12]

Finally, as a fifth proxy for regulation at the intensive margin, we compute building refusal rates – i.e., the number of refused buildings and renovation permits divided by their total number – at the municipality level from 2001 to 2004. The refusal rate reflects the effective restrictiveness of local governments regarding residential development.

3. Empirical framework

3.1. Data sources and units of observation

The empirical analysis relies on several data sources. The interested reader can refer to Appendix A3 for more-detailed information about these data sources. First, we use geo-referenced data on advertised rents and housing prices provided by Meta-Sys. Covering the period 2004 to 2016, the data set contains approximately 2.1 million postings of rental properties and approximately 0.8 million postings of selling residences for the whole of Switzerland. In addition to asking rents and prices, the data set includes detailed information

[10] The survey, which had a response rate of 69 percent, was created as part of two projects funded by the Swiss National Science Foundation: the project "Controlling urban sprawl – limiting soil consumption" and the project "What are the determinants of local growth management regulations at the municipal level and how do they affect urban sprawl? A spatial econometric analysis".

[11] The two main instruments are given by questions 4c3 and 4c5 of the WSL report. The additional instruments are given by questions 5b2 and 5b8.

[12] We use principal component analysis to recover a variable (WSL2) capturing the largest relative share of variation from the two main regulatory measures. The index proportion considers 56.11 percent of the question regarding the re-zoning of developable plots of land into protected areas and 43.89 percent of the question regarding the restriction of further development of areas with low density.

on housing characteristics. The median residence offered for rent has 3.5 rooms and 80 square meters of floor space, whereas the median residence offered for sale has 5 rooms and 140 square meters of floor space. Regarding geographical distribution, the data resemble the distribution of inhabitants in Switzerland. The agglomerations of the 15 main cities in Switzerland, as defined by the Swiss Federal Statistical Office (FSO) in 2012, count for 66.6 percent of the rental postings and 44.5 percent of the sale postings.

Second, the Federal Register of Buildings and Habitations (GWR, Eidgenössisches Gebäude- und Wohnungsregister) administers a census of the residential housing stock of the country. In particular, changes in the stock are precisely measured every 5 years, providing three time periods – 2005, 2010, and 2015 – that overlap with the advertisement data. The register contains approximately 4.8 million residential habitations for the whole of Switzerland, 550,000 of which were built between 2005 and 2015.

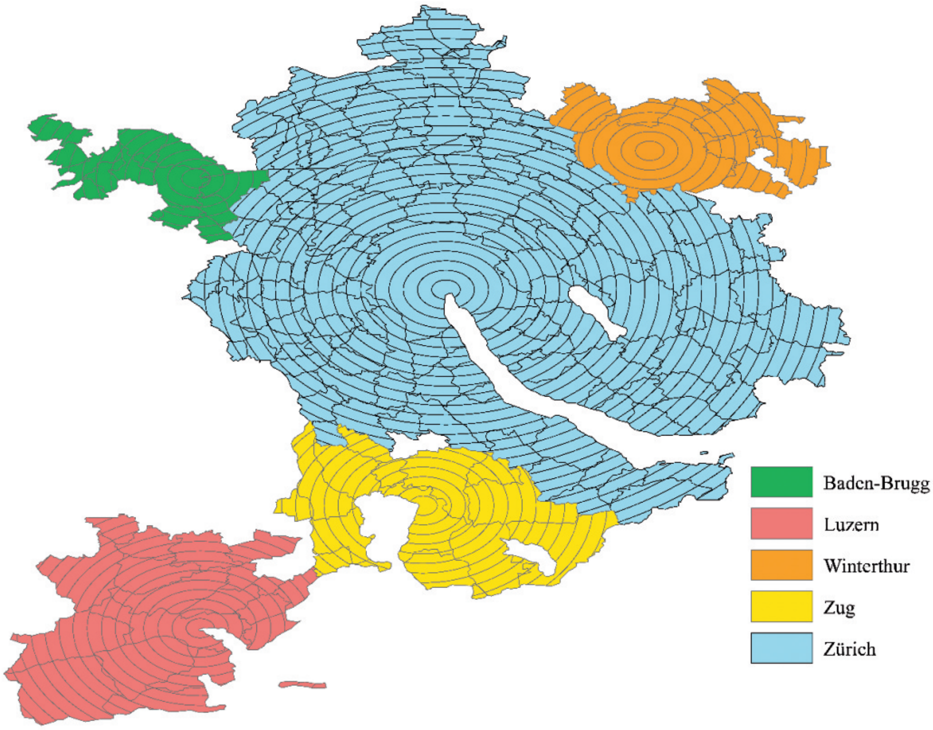
Third, we use the Federal Population Census of 2000 as well as the Population and Households Survey (STATPOP) from 2010 to 2015 to infer geo-referenced homeownership rates and to obtain information on predetermined levels and changes of the local socio-demographic composition – i.e., nationality, language, and religion, and fertility rates – of residents living in a given area.

Fourth, the *Arealstatistik der Schweiz* provides satellite-based land cover classifications, allowing us to identify geographic constraints, such as lakes, rocks, and glaciers, and areas subject to particular regulations, such as forests.

Fifth, information about regulations on the extensive margin – and protected areas in particular – is obtained from Cantonal offices of spatial planning and from the Federal Office for the Environment (FOEN). Data on regulatory constraints on the intensive margin are provided by the Federal Office for Spatial Development (ARE, Bundesamt für Raumentwicklung), which provided harmonized zoning data for the whole of Switzerland in 2012, the Swiss Federal Research Institute for Forest, Snow and Landscape (WSL), which provided survey data on regulatory instruments, and Meta-Sys, which provided municipality-level statistics on refusal rates.

Finally, we complement these data with a variety of GIS data on Swiss administrative units and metropolitan areas (FSO), climate (MeteoSwiss), and elevation (European Environment Agency).

Figure 13: Within agglomeration data – Zurich and neighbouring areas



Notes: Within agglomeration data structure for Zurich and neighboring agglomerations. Concentric rings around the administrative center of each agglomeration are created by step of 1km. Units of observations are given by the intersection of concentric rings with municipality boundaries.

We structure the above data using two different approaches. In the first approach, we restrict our sample to those areas belonging to one of the 15 major Swiss agglomerations according to the 2012 classification of the FSO, which contained approximately 55 percent of the Swiss population in 2015. The considered agglomerations are Baden-Brugg, Basel, Bern, Biel/Bienne, Fribourg, Geneva, Lausanne, Lugano, Luzern, Neuchâtel, Olten-Zofingen, St. Gallen, Winterthur, Zug, and Zurich. In a next step, we define our units of observation by creating concentric rings around the administrative centers of major agglomerations and intersecting them with municipality boundaries. In our empirical analysis, we create concentric rings by progressively increasing the radius by 1 km. We refer to these spatial units as the *within agglomeration* sample. Figure 13 shows the units of observation that we obtain for Zurich and the surrounding agglomerations. In every period, we aggregate geo-referenced data on advertisements, housing stock, location, and socio-demographic characteristics within these areas.

The second approach, which we refer to as *country grid*, consists in partitioning the whole territory of the country into small square cells of approximately 5.725 square kilometers.[13] We then aggregate housing transactions, stock and socio-demographic data within these cells. We complement these data with the geographic and regulatory restrictions discussed in the previous section. More precisely, we structure geographic and regulatory restrictions into raster data having a 100x100 meter resolution and aggregated them within the 2x2 km country grid cells. Descriptive maps of the previous section are based on this data structure. This approach is particularly useful when analyzing supply elasticities across space for the whole country, as we do not have to arbitrarily associate grid cells located in the countryside with a specific agglomeration. In fact, extending the within agglomeration data structure to the whole of the country would have led to overlapping concentric rings, making a definition of the units of observation somewhat subjective.

Both the within agglomeration and country grid approaches entail several advantages compared to using municipality aggregates. First, because municipalities independently decide the amount, intensity, and location of new housing development, each observational unit captures the heterogeneity in the changes of the housing stock and rents/prices both across and within municipalities belonging to a given agglomeration. Second, we can measure supply and demand shifters at a fine spatial scale. For example, terrain ruggedness and social composition may vary considerably within the same municipality, which in turn affects local housing supply and demand. Third, the fine scale structure of the data allows us to partial out local unobserved time-invariant determinants of the housing supply. Finally, once fine-scale supply elasticities are estimated locally, we can easily aggregate them at different levels, including municipalities.

Table 2 and 3 contain summary statistics of the considered variables for the within agglomeration and country grid samples, respectively. Note that we restrict the samples to units of observation for which rents and prices per square meter are available in both 2005 and 2015. We use information about geographic and regulatory constraints only for the country grid sample.[14] A few points are worth noting: The rent and price dynamics from 2005 to 2015 are extremely similar in both samples, although prices display stronger increases than rents. Rents

[13] This corresponds to grids with a side length of 2 km times 2 km at the equator, or 0.026 times 0.026 degrees. The corresponding size in Switzerland is approximately 5.725 due to the distortion of the coordinate system.

[14] The limited variation of many of the considered geographic and regulatory restrictions within major agglomerations prevented us from investigating their impact on these areas.

have increased by approximately 11.4 percent within agglomerations and by 14.1 percent countrywide. Similarly, prices have increased by approximately 35 percent in both samples. Total stock changes are also similar, with a growth of 9.7 percent and 11.4 percent in the within agglomeration and country grid samples, respectively. Although surprising on first sight, we attribute the trend similarities to the fact that agglomerations cover a sizable share of the country, as illustrated in Figure A2 - 2 in the Appendix.

Table 2: Descriptive statistics – within agglomeration (n=1,167)

	2005				2015			
	mean	min	max	sd	mean	min	max	sd
Dependent variables								
Rent (CHF/m2)	19.24	9.00	41.80	3.90	21.62	11.64	39.92	4.22
Price (CHF/m2)	5,069	2,072	11,679	1,379	6,820	2,022	13,017	1,936
Independent variable								
Stock[a] (no.)	1,644	3	65,076	4,419	1,804	3	66,966	4,621

	Time invariant			
	mean	min	max	sd
Instruments				
Bartik foreign[b]	0.08	0.00	0.42	0.05
Bartik language[b]	0.10	-0.07	0.26	0.06
N-W orientation (%)	0.25	0	0.93	0.16
Fertility rates[c]	0.07	0.04	0.15	0.02
Controls				
Elevation (m)	528	254	1,160	131
Elevation SD[d] (m)	48	2	303	40
Distance from nearest CBD (km)	9.56	0.33	30.85	5.43
Stock1980[a] (number of units)	1,254	3	57,297	3,962

Notes: [a] Measured as the number of individual housing units. [b] Because Bartik instruments are weighted growth rates, they do not have physical units. [c] Share of children up to five years old in the year 1990 at the municipality level. [d] SD=standard deviation. Only the 15 biggest Swiss agglomerations are considered, namely Baden-Brugg, Basel, Bern, Biel-Bienne, Fribourg, Geneva, Lausanne, Lugano, Luzern, Neuchâtel, Olten-Zofingen, St. Gallen, Winterthur, Zug, and Zurich. The sample is restricted to units of observations for which rents and prices per square meter are available both in 2005 and 2015.

The remaining variables presented in Table 2 and 3 – instruments, controls, and geographic and regulatory constraints – are time invariant. We postpone the discussion of the instruments to section 3.4 where we discuss the validity of each instrument. The controls we employ are common to both the within agglomeration sample and the country grid sample.[15] Not surprisingly, units of observation located within major agglomerations display a shorter distance to major CBDs, are located at a lower altitude and have smoother surfaces than the

[15] For ease of exposition, we exclusively classify the standard deviation of elevation and the housing stock in 1980 as controls. However, in our analysis of local supply elasticities based on country grid data, we use these variables to proxy for geographic and regulatory constraints.

observations in the country grid sample, which does not constrain agglomerations. The average amount of historic housing stock cannot be directly compared between the two data sets, due to differences in the size of the units of observation.

Table 3: Descriptive statistics – country grid (n=2,022)

	2005				2015			
	Mean	Min	max	sd	mean	min	max	sd
Dependent variables								
Rent (CHF/m2)	17.05	5.60	42.03	3.94	19.46	8.25	40.20	3.98
Price (CHF/m2)	4,377	870	11,679	1,283	5,931	1,384	14,676	1,867
Dependent variables								
Stock[a] (number of units)	1,655	1	48,622	3040	1,844	1	49,298	3,221

	Time invariant			
	mean	min	max	sd
Instruments				
Bartik foreign[b]	0.07	0.00	0.40	0.05
Bartik language[b]	0.09	-0.28	0.29	0.07
N-W orientation (%)	0.25	0	0.82	0.15
Fertility rates[c]	0.08	0.04	0.16	0.02
Controls				
Elevation (m)	623	193	2,397	265
Elevation SD[d] (m)	73	2	410	70
Distance from nearest CBD (km)	19.68	0.57	102.01	16.64
Stock1980[a] (number of units)	1,214	1	43,739	2,643
Geographic constraints				
Undevelopable[e] (%)	0.06	0	1	0.14
Regulatory constraints – extensive				
Forest (%)	0.26	0	0.94	0.18
FFF (%)	0.27	0	0.93	0.23
BLN (%)	0.17	0	1	0.31
UNESCO cultural (%)	0.02	0	1	0.12
UNESCO natural (%)	0	0	0.65	0.02
Total restricted (%)[f]	0.41	0	1	0.28
Regulatory constraints – intensive				
Zoned industrial (%)	0.01	0	0.24	0.02
WSL1	1.24	0	4	1.10
WSL2	0.29	-0.66	3.02	1.21
Refusal rate	0.13	0	1	0.07

Notes: [a] Measured as the number of individual housing units. Note that the historic stock also serves as a proxy for the intensity of regulation. [b] Because Bartik instruments are weighted growth rates, they do not have physical units. [c] Share of children up to five years old in the year 1990 at the municipality level. [d] SD=standard deviation. [e] Share of water bodies and undevelopable land within the cell. [f] Computed as the sum of geographic and regulatory constraints on the extensive margin, excluding FFF (covers 67.5 percent of Switzerland). The sample is restricted to units of observations for which rents and prices per square meter are available both in 2005 and 2015. The number of observations for variables representing extensive margin regulatory constraints is lower due to missing values: Zoned industrial (1062 obs.), WSL1 (1512 obs.), WSL2 (1424 obs.), refusal rate (1971 obs.).

Let us now turn to the geographic and regulatory constraints for the country grid sample. As is evident from Table 3, among the constraints preventing development, forests and FFF are, on average, the most important, followed by BLN, undevelopable, and UNESCO areas. The total amount of restricted areas, which is given by the union (without FFF) of these areas, is important in magnitude, as it represents, on average, approximately 41 percent of the total grid cell area.[16]

Concerning regulatory measures on the intensive margin, the average share of newly zoned land in 2012 for industrial or commercial development is low across the country. The number of zoning instruments implemented by municipality to regulate development is also low: on average, municipalities tend to use one instrument, although there is considerable variation in this variable. Some municipalities do not use any instrument, whereas others use the full set. Finally, on average, municipalities refuse 13 percent of submitted building/renovation projects.

3.2. Introducing the concept of housing supply elasticities

Equilibrium rents and prices are determined by the interaction of demand and supply forces. On the demand side, households bid for rental and selling properties according to the utility they expect to derive from the consumption of housing services in a given location. Factors influencing the bidding price, the so-called *demand shifters*, are various and include households' attributes, such as age, income, and wealth; municipality characteristics, mainly public expenditure vs. fiscal burden; and local features, such as socio-demographic composition of the neighborhood, access to transportation infrastructure, and value of natural amenities.

On the supply side, housing developers and property owners rent and sell properties at a given asking price. Factors affecting the asking price, the so-called *supply shifters*, include variables affecting construction and trading costs. According to standard production theory, the cost of capital, price of construction materials, and labor costs are the main shifters of asking prices.

From the above examples, it is clear that demand and supply might share some shifters. For example, labor costs in the construction industry strongly affect asking prices. However, because the construction industry also represents an important share of the economy of the country, it also influences a share of the housing demand through wages. Another example is provided by the distance from city centers. According to the standard monocentric city model,

[16] The FFFs are not included in the total restricted area, because they do not have an effect on the heterogeneity and are thus redundant.

a greater distance from major labor markets shifts housing demand downward, as commuting costs increase. On the other hand, areas that are closer to city centers are historically more developed, and binding regulatory constraints – in the form of zoning restrictions – might be in place, thus affecting the supply side of the market.

The intersection of the demand curve with the supply curve leads to equilibrium housing prices and quantities. The tradeoff between equilibrium housing costs and the benefits of living in a given area determines where people live. The literature highlights that, other things equal, households with similar tastes and socio-economic characteristics sort in the same areas, creating local clusters of homogeneous households (e.g., Bayer et al., 2004; and Basten et al., 2017).

The price elasticity of supply is defined as the ratio of percentage changes in the quantity of supplied housing and percentage price changes, which, in what follows, we refer to as *supply elasticity*:

$$\text{Supply elasticity} = \frac{\%\Delta\text{Quantity supplied}}{\%\Delta\text{Price}}. \tag{1}$$

We define an analogous measure with regard to rent changes. The supply elasticity tells us how the supply of housing units changes in response to rent or price changes. If the percentage change in supplied quantity is greater than that in prices (or rents) – leading to a supply elasticity greater than 1 – this implies that housing supply can adapt well to price signals. In this case, the market is *elastic*. For example, a supply elasticity of 1.2 means that a price growth of 10 percent is followed by a 1.2x10 percent=12 percent increase in supplied housing units. Markets with a supply elasticity below 1 are considered *inelastic.*

3.3. Estimating long-run housing supply elasticities

In this section, we provide a discussion of the methodology employed to compute supply elasticities. To identify the supply elasticities, we proceed as follows:[17] We start by averaging asking rents/prices within a given unit of observation, computing the total number of housing units, and calculating the corresponding growth of these aggregate variables from 2005 to 2015.

[17] Please refer to Appendix A4 for further details underlying the empirical identification of supply elasticities.

We then separately regress the growth of rents/housing prices on housing stock growth, controlling for several supply shifters:

$$\Delta \ln(y_{it}^{\tau}) = \beta^{\tau} \Delta \ln(q_{it}) + \boldsymbol{\alpha^{\tau} s_i} + \epsilon_{it}^{\tau}, \quad (1)$$

where y_{it}^{τ} represents average asking rents ($\tau = R$) or asking prices ($\tau = P$) per square meter in the i-th unit of observation at time t , and q_{it} is the *total* housing stock.[18] We denote by Δ the time difference between 2005 and 2015. The error term ϵ_{it} contains unobserved dynamic components affecting the housing supply. The parameters β^R and β^P represent inverse housing supply elasticities. Taking the inverse of these two coefficients, we obtain the supply elasticities. We estimate the inverse supply elasticities following Saiz (2010) – instead of regressing quantity changes on price changes – because available exogenous demand shifters turn out to be more relevant for quantity changes.

The vector s_i contains a number of time-invariant supply shifters, which we assume as exogenous throughout the empirical analysis. To account for the impact of previous development on rent and price dynamics, we control for the log of the housing stock in the 1980s. According to Hilber and Robert-Nicoud (2013), the level of historic housing development proxies for the contemporaneous restrictiveness of land use regulations implemented in a given area. High-amenity areas develop first and, because of the political game played between land developers and owners of developed land, tend to adopt more-stringent land use regulations. These stringent regulations likely have a direct impact on supply price dynamics. Furthermore, Saiz (2010) argues that in more developed places geographic constraints are more binding due to a lack of developable land.

To further control for spatial patterns in the regulatory restrictiveness of housing supply not captured by the historic housing stock, we partial out the distance of the i-th unit of observation from the administrative center of one of the 15 major agglomerations. We do this because many suburban areas that were largely undeveloped in the 1980s have progressively become better connected with the CBD and have started to zone low-density residential land to attract wealthy taxpayers, thus imposing regulatory constraints on land developers. Of course, according to standard urban theory, distance from CBDs represents a demand shifter. However, as noted by

[18] By computing rents and prices per square meter, we partial out the effect of one of the main determinants of the quality of the housing stock, namely, the living floor space. This adjustment is particularly important at the local level, as the surface of housing goods may vary considerably from one unit of observation to another.

Saiz (2010), the fact that an exogenous control variable in Equation 1 correlates with $\Delta\ln(q_{it})$ via the demand side does not affect the validity of the identification strategy presented below.

Finally, we control for geography-based supply shifters, such as elevation and terrain ruggedness. Within a given area, a plot of land featuring– in terms of low construction costs, such as flat and not rocky terrain – geographic features favorable to development are likely developed before those characterized by adverse geographic characteristics. Therefore, we expect unfavorable geographic features to increase asking rents/prices over time, as developers face higher construction costs for providing additional housing units on the extensive margin of existing development.

Figure 14: Supply elasticities: Fribourg vs. Zurich

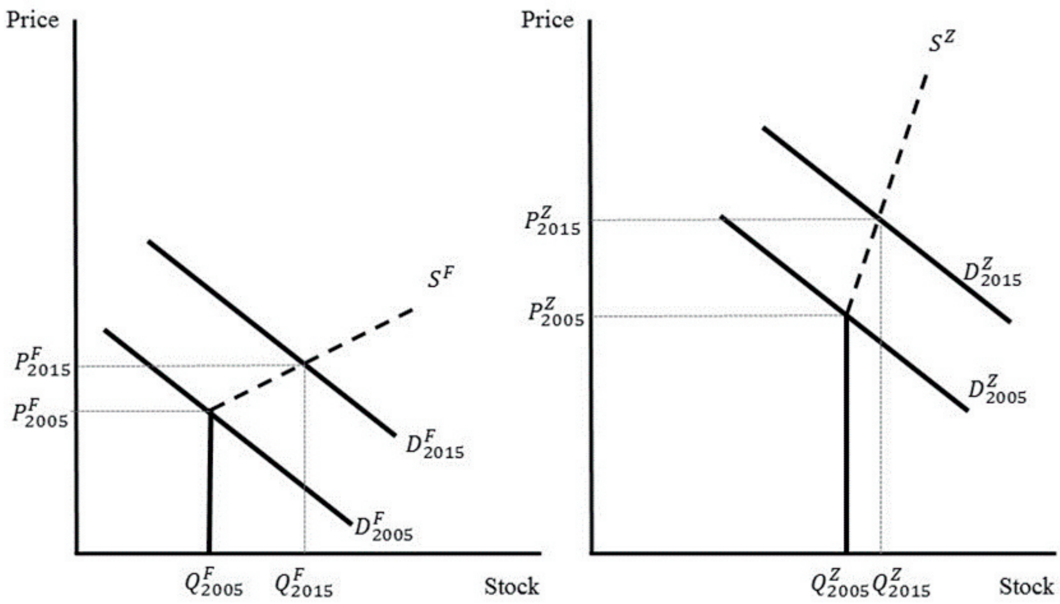


Figure 14 is a stylized graph showing the variation in quantities and prices that we exploit to recover the average supply elasticity. For illustration purposes, we focus on the agglomerations of Fribourg and Zurich. Similar graphs can be produced for rents and other agglomerations. The agglomeration of Zurich is generally more urbanized, and new land for residential development is scarcer than in the agglomeration of Fribourg. The initial (fixed) housing stock in 2005 is greater in Zurich than in Fribourg, and the scarcity (in relative terms) of developable land makes the supply curve for the Zurich agglomeration S^Z steeper than the supply curve S^F of Fribourg. Because the inverse supply elasticity – i.e., 1/Supply elasticity – is the slope of the supply function between 2005 and 2015, the Zurich agglomeration is more inelastic than the agglomeration of Fribourg. The average supply elasticity for major Swiss agglomerations represents the average response of supplied housing quantities in agglomerations to price signals.

3.4. Instrumenting changes in the housing stock

Estimating Equation 1 presents several econometric challenges. The most important arises from the fact that we would like to estimate the responsiveness of the supply curve, but we only observe equilibrium prices and quantities, which are given by the intersection of the demand and supply curves. However, Figure 14 suggests an approach to solve this problem. As explained in the early work of Wright (1928), any variable that shifts housing demand while leaving housing supply unaffected can be used to trace out the supply function. The statistical method allowing the implementation this idea is called the instrumental variable approach, which we adopt throughout our statistical analysis.

Econometric theory provides two main conditions that a candidate demand shifter must satisfy in order to act as an instrument for demand shocks. First, it must be a strong predictor of demand changes (instrument relevance). This requirement can be visualized in Figure 14 as follows: we can infer the slope of the supply function only if the instrument shifts the demand curve enough. Second, the instrument must not have a direct effect on asking rents/prices (instrument exogeneity). Put differently, the only channel through which the instrument can affect prices is the shift in the demand.

In Figure 14, this condition translates into the fact that the instrument only affects the demand curve, leaving the supply curve unchanged. If the instrument were to shift both curves, we would not be able to recover the slope of the supply curve and, thus, could not isolate the supply elasticity.

The question remains as to which demand shifters we should use as an instrument. Table 4 lists the potential candidates investigated in the present study. Two variables – reported in Panel A of Table 4 – were found to be strong predictors of long-run demand growth: the Bartik (or shift-share) instrument of Swiss vs. foreign households living in a given region and the Bartik instrument of the main spoken languages of local residents (independently of nationality).[19]

[19] This approach to constructing instruments was proposed by Bartik (1991). See Appendix A4 for further details.

Table 4: Instruments for changes in local housing demand in Switzerland

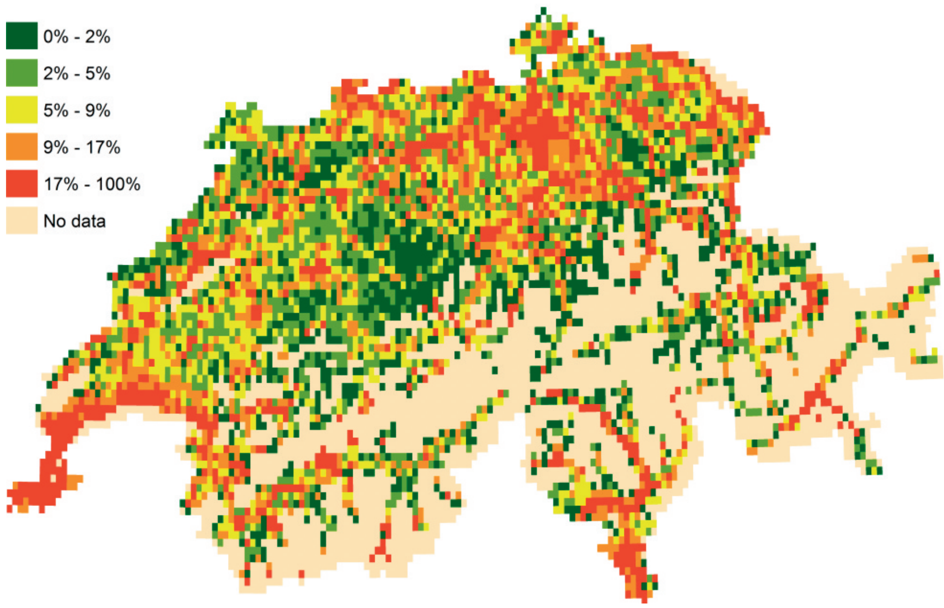
Instrument	**Literature**
Panel A: Valid instruments	
Bartik foreign	Related to Saiz (2010)
Bartik main spoken languages	Not used before
N-W orientation	Related to Ehrlich, Hilber, and Schöni (2017a)
Fertility Rates	Chapelle and Eyméoud (2017)
Panel B: Weak or irrelevant instruments	
Historic housing stock	
Historical housing stock/ density	Poterba (1984)
Historical housing stock growth	Hilber and Mayer (2009)
Amenities	
Temperature	Saiz (2010)
Sun hours	Not used before
Rainfall	Not used before
Distance to lakes	Not used before
Open view on lakes	Not used before
Labor	
Soil composition	Combes et al. (2010)
Bartik industrial composition	Saiz (2010); Hilber and Vermeulen (2016)

Notes: The instruments' relevance is determined according to a first-stage regression in which relative changes in the housing stock from 2005 to 2015 are regressed on the considered instrument and time-invariant supply shifters s_i. Our baseline results rely on Bartik instruments for foreign vs. Swiss households and main spoken languages of immigrants. Results using orientation and fertility rates instruments are presented in the robustness check section. Results for weak and irrelevant instruments are not reported.

More specifically, the Bartik foreign instrument is computed at the grid cell level as follows: First, we derive the shares of foreign and Swiss residents within each cell in 2000 using census data that provide detailed information about the place of residence and about nationality. Second, we use these shares as weights to compute weighted average growth rates of the numbers of foreign and Swiss residents. In particular, the cantonal level growth rates of the numbers of foreign and Swiss residents between 2000 and 2015 are multiplied by the corresponding cell-specific shares of foreign and Swiss residents within the cell in 2000. Similarly, cantonal growth rates of the number of individuals speaking one of the eight most spoken languages in Switzerland – which in decreasing order of importance are German, French, Italian, Portuguese, English, Serbian, Albanian, and Spanish – between 2000 and 2015 are multiplied with the corresponding language shares measured in 2000 for a given local area. The idea of these instruments is that aggregate population dynamics at the cantonal level dissipate according to predetermined shares and thus generate a local demand shift that is independent of local price dynamics.

As illustrated in Figure 15, there is considerable heterogeneity in the distribution of foreign households across space. Foreign shares tend to be particularly high within/near major urban areas and in high-amenity places within the proximity of lakes or ski resorts. In contrast, countryside areas usually have low foreign shares. When constructing the Bartik instrument for foreign households, we exploit this predetermined heterogeneity of the share of foreigners in the year 2000 together with the observed foreign/Swiss households' growth at the cantonal level from 2000 to 2015.

Figure 15: Foreign distribution in 2000



Notes: Data source: STATPOP. Range is according to quintiles. Grid cells are of size 0.026 times 0.026 degree which corresponds to approximately 5.725 square Kilometers. The total number of grid cells is 7,212.

Concerning exclusion restrictions – i.e., the fact that our instrument should affect rents/prices only through changes in the stock – we reason as follows: Because we compute supply elasticities using discrete changes (growth over time) in rents/prices and the quantity of housing stock, time-invariant factors affecting supply and prices at the local level do not matter. Therefore, the exogeneity of the instruments must occur only with respect to dynamic changes in the housing supply not controlled for in our analysis. Supply dynamics not controlled for in our base specification include changes in the factors of production of the housing sector. Changes in the factors of production, however, are unlikely to be correlated with our instruments exploiting the changes in local immigration that is predicted by predetermined shares of foreigners in the local population.

Predetermined shares of foreigners serve as a predictor of the distribution of future immigration patterns within a country. This is because individuals tend to migrate into areas where people sharing the same cultural values live. The fact that migration networks play a crucial role in the location choice of immigrants has been documented, for example, by Altonji and Card (1989), Carrington et al. (1996) and Winters et al. (2001). Saiz (2010) exploits this argument to instrument changes in the housing demand across US Metropolitan Statistical Areas (MSAs) with the share of new immigrants relative to the initial population. Due to the fine-scale nature of our data structures, however, migration patterns *within* agglomerations are likely endogenous. In fact, immigrants may choose a given agglomeration according to existing communities but may decide where to live depending on rent and price dynamics. This sorting behavior seems even more likely in the case of Switzerland: due to the limited size of Swiss agglomerations, individuals can easily interact with each other even when they do not live in the same local area. To take into account this endogenous sorting behavior, our shift-share instruments build on migration networks by interacting local shares of foreign (resp. Swiss) households with their corresponding growth rates at the *cantonal* (or even national) level, as these aggregate immigration trends are unaffected by local price dynamics. The same reasoning applies for the Bartik instrument exploiting local changes in the share of the most common languages.

Supply shifters include the cost of capital and construction materials, which are likely to be determined at the national level. Combined with the small size of Switzerland, the competition in the construction sector makes wage dynamics homogeneous across locations. In section 5, we further investigate the potentially endogenous link between immigration and labor supply in the housing sector by explicitly controlling for long-run construction cost changes and initial price levels.

Besides our preferred Bartik instruments – which measure (weighted) growth rates in the shares of foreign vs. Swiss households and main spoken languages – we have identified two other variables that predict changes in the housing demand, although less strongly. First, using the

Federal Population Census, we compute the share of children up to five years old in the year 1990 and at the municipality level.[20] The basic reasoning is that areas characterized by historically high fertility rates – which are arguably exogenous to future rent and price dynamics – experience a stronger demand growth from 2005 to 2015. In fact, during this period, children who were aged between zero and five in 1990 reached the legal age, with the oldest of them 30 years old, in 2015. The relevance of the instrument hinges on the fact that those born in a given municipality will decide to live in that area when they grow up. However, this is not always the case, which explains the weaker predictive power of the instrument with respect to the Bartik instruments.

In addition to fertility rates, we compute the share of North-West-oriented surface within a country grid cell to use the orientation of a location as a demand instrument.[21] This measure is a good candidate, as it is clearly exogenous to rent and price dynamics. The instrument relates to the work of Ehrlich, Hilber, and Schöni (2017a), which empirically find that places with more-attractive natural amenities – such as areas that are southward oriented, thus receiving more sun during the day – historically tend to be more developed. Since the period of our analysis is extremely recent, we expect that in that period, housing demand would grow more in northward-oriented areas, as southward-oriented areas cannot accommodate the demand.

For completeness, in Panel B of Table 4 we report variables used in the literature to instrument housing demand, which we found are not a good predictor in the case of local Swiss housing markets. Instruments based on the historic housing stock (e.g., Poterba, 1984; and Hilber and Mayer 2009) – given by the residential housing stock in 1980 and its growth from 1980 to 1990 – do not seem to be good predictors of changes in the housing stock from 2005 to 2015. Despite a strong path dependency of stock *levels* across time periods, the stock growth from 2005 to 2015 is basically unrelated to historic levels (with the exception of one case, which we discuss below). As illustrated in Figure 7, city centers – characterized by high historic stock levels – and countryside areas – characterized by low historic stock levels – are the regions where the contemporaneous stock growth is lower. This suggests that important nonlinearities might link historic stocks to present stock growth, but they are difficult to uncover. A similar reasoning applies to historic growth rates of the residential housing stock, which seem unrelated to the

[20] In contrast with the 2000 population census, data are only available at the municipality level.

[21] This share is computed as the number of 100x100 meter pixels that are north-west oriented within a given 2x2 km country grid cell divided by the total number of pixels in the grid cell.

2005-2015 growth. Historic stocks as well as historic growth rates are, of course, market outcomes themselves, and it is unclear whether such instruments exclusively isolate supply or demand shifts. Arguments can be made in favor of one or the other shift. Therefore, when instrumenting contemporaneous stock changes – which depend on both demand and supply dynamics – with historic stock growth, we hardly isolate pure demand shocks.

We also investigated climate instruments (including temperature, sun hours, rainfall) and soil composition. These instruments seem to be irrelevant to predicting contemporaneous residential stock changes. This lack of predictive power is mainly due to the small size of Switzerland. In fact, the climate and soil quality instruments are largely homogeneous over the country's territory, varying only in specific areas.

Due to the small variation in climate and soil instruments, we have constructed other instruments to capture the amenity value of a plot of land at the micro level. In particular, we computed the distance to lakes and the amount of open view on them. The motivation for using these instruments is that places that are more attractive should positively correlate with demand growth. However, these instruments are weakly correlated with contemporaneous stock growth. The reason for this lack of correlation is likely because from 2005 to 2015, the most-attractive places were mostly fully developed. As such, increased demand for these places is not reflected in local stock changes.

Bartik industrial composition turns out insignificant for the disaggregated data set used because pronounced commuting detaches employment location from housing demand. Accordingly, local employment shocks do not necessarily reflect in local changes of housing demand.

3.5. The role of geographic and regulatory constraints

Equation 1 assumes that inverse supply elasticities are, on average, constant across locations. This assumption seems too restrictive for two reasons. First, supply elasticity in a given area might vary considerably according to regulatory restrictions adopted by local governments. According to Hilber and Robert-Nicoud (2013), attractive places are more developed and, as an outcome of the political game between land developers and owners of developed land, more regulated. To proxy for this regulation effect, we interact the housing stock level in the 1980s with contemporaneous stock growth:

$$\Delta \ln(y_{it}^{\tau}) = \beta^{s,\tau} \Delta \ln(q_{it}) + \beta^{hist,\tau} \Delta \ln(q_{it}) \times q_{i1980} + \alpha^{\tau} s_i + \epsilon_{it}^{\tau}. \quad (2)$$

Second, in addition to regulatory restrictions, recent research shows that land availability influences housing supply elasticities. By investigating supply elasticities across metropolitan areas in the US, Saiz (2010) was the first to provide compelling evidence that geographic and regulatory constraints strongly reduce supply responsiveness at the aggregate level. Hilber and Vermeulen (2016) find that housing prices react more strongly to earnings changes in local jurisdictions where regulation is more stringent and/or less land is available for development. However, as argued by Saiz (2010), geographic constraints are binding only in places where development levels are high enough. To investigate these propositions, we thus estimate the following equation

$$\Delta \ln(y_{it}^{\tau}) = \beta^{s,\tau} \Delta \ln(q_{it}) + \beta^{hist,\tau} \Delta \ln(q_{it}) \times q_{i1980} + \beta^{constr,\tau} \Delta \ln(q_{it}) \times \Lambda_{\mathrm{i}} \times q_{i1980} + \alpha^{\tau} s_i + \epsilon_{it}^{\tau}, \tag{3}$$

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

Having estimated $\beta^{s,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ for rental and selling properties, we can compute local supply elasticities (within grid cell i) as

$$SE_i^{\tau} = \frac{1}{\beta^{s,\tau} + \beta^{hist,\tau} q_{i1980} + \beta^{constr,\tau} \Lambda_{\mathrm{i}} \times q_{i1980}}, \tau = R, P. \tag{4}$$

Accordingly, the estimated coefficients together with the spatial distribution of the historic stock $\ln(q_{i1980})$ and the distribution of geographic and regulatory constraints collected in Λ_{i} determine the local value of supply elasticity SE_i^{τ}.

4. Results

In this section, we start by discussing point estimates of average and local supply elasticities with respect to rent and price changes. In a next step, we use the estimated supply elasticities at the local level to i) provide a ranking of cantons, major agglomerations, and municipalities according to their supply elasticity and ii) quantify the extent to which geographic and regulatory constraints decrease local supply elasticities. Finally, we compare our results to those presented in the literature. Detailed result tables are available in Appendix A1.

4.1. Supply elasticities of rental and selling properties

Table 5 summarizes baseline supply elasticity estimates for rental and selling properties. Column 1 shows the inverse average supply elasticities β^R and β^P estimated using Equation 1 for rents (Panel A) and prices (Panel B) within major agglomerations. The estimates are equal to 1.91 (=1/0.5225) and 0.57 (=1/1.7489), respectively. A 10 percent increase in rents in the long-run leads to a 19.1 percent in total supplied housing units, whereas a 10 percent increase in prices causes only a 5.7 percent increase in total supplied housing units.

The above estimates suggest that housing markets in major Swiss agglomerations are relatively elastic to rent changes but are much less elastic to price changes. We attribute this difference to the market segmentation of rental and selling properties, for which different housing demand and supply functions likely exist. In fact, housing units belonging to the rental market are usually supplied in multifamily buildings well connected with the city center. In contrast, many selling properties are located in low-density suburban and countryside areas having notable natural amenities. Because zoning regulations within major agglomerations are aimed toward high-intensity development – in these high-demand areas, housing developers build until these regulations are binding[22] – rent increases lead to a stronger increase in supplied units than rising prices. Put differently, the supply of selling properties cannot adjust as easily as that of rental properties due to the more binding regulatory restrictions in these areas.

To further investigate the link between the rental and selling markets, we decompose total stock growth into growth of rental and owner-occupied units (relative to the initial level of the total housing stock; see Appendix A3 for more details), and we estimate the corresponding inverse supply cross-elasticities. Column 2 of Table 5 shows the estimation results within major

[22] For example, housing developers build a building until they reach the maximal floor to area ratio allowed by zoning regulation.

agglomerations. The supply elasticity of rental properties with respect to rent changes equals 2.42 (=1/0.4125), whereas the supply elasticity of selling properties with respect to price changes is equal to 0.40 (=1/2.5294). The estimated inverse supply elasticities for rents and prices in Column 2 are within one standard deviation of the estimates presented in Column 1, and the difference is not significant, as the confidence bounds of the estimates overlap at conventional levels.

The cross-elasticity of the rental market is not statistically significant, while that of the selling market is significant at the 1 percent level and equal to 0.73 (=1/1.3615). These results imply that a 10 percent price growth causes 7.3 percent more properties to be rented out. For the cross-elasticity of the rental market, the point estimate would suggest that a 10 percent rent increase leads to 31.3 percent more properties being sold in the long-run. However, the latter cross-elasticity is estimated at a very low precision, as is evident from the large standard error, and we cannot reject a zero cross-elasticity of the rental market.

Table 5: Long run inverse supply elasticities – Rental and selling market

	Within agglomeration		Country grid	
	(1)	(2)	(3)	(4)
Panel A: IV-second stage estimates for rental properties				
Dependent variable	ΔLog Rent/m2			
$\Delta \text{Log} Q$	0.5225***		0.6417***	0.3997**
	(0.1557)		(0.1852)	(0.1745)
$\Delta \text{Log} Q_{\text{Rent}}$		0.4125***		
		(0.1210)		
$\Delta \text{Log} Q_{\text{Own}}$		0.3194		
		(0.4371)		
Stock 1980 × $\Delta \text{Log} Q$				0.3972***
				(0.0897)
Total restricted ×				0.1754***
Stock 1980 ×$\Delta \text{Log} Q$				(0.0492)
Panel B: IV-second stage estimates for selling properties				
Dependent variable	ΔLog Price/m2			
$\Delta \text{Log} Q$	1.7489***		1.9567***	1.5655***
	(0.2976)		(0.2650)	(0.2419)
$\Delta \text{Log} Q_{\text{Rent}}$		1.3615***		
		(0.2877)		
$\Delta \text{Log} Q_{\text{Own}}$		2.5294**		
		(1.1380)		
Stock 1980 × $\Delta \text{Log} Q$				0.7044***
				(0.1389)
Total restricted ×				0.3405***
Stock 1980 ×$\Delta \text{Log} Q$				(0.0808)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. All the point estimates are estimated controlling for elevation, elevation standard deviation, log-distance to the nearest CBD, and log-housing stock in 1980. In column 4, we also control for the main effect of the total restricted area on rents/prices. Changes in the housing stock are instrumented with Bartik foreign and Bartik language. Total restricted area is standardized.

We interpret the magnitude of the estimated cross-elasticities cautiously, as the relevance of the instruments is much weaker than for the results of Column 1. We have argued that the rental and selling markets are characterized by different demand and supply functions. If the two markets were perfectly separated, the rent/price signal in one segment should not affect the quantity of housing units supplied in the other segment, implying a cross-elasticity equal to zero. Of course, this is not the case. Despite homeownership rates being exceptionally low within Swiss cities, many dwellings in multifamily buildings – which could have been rented out – are sold each year. To the extent that rental and owner-occupied units are substitutes for housing developers – i.e., developers can decide whether to rent or sell a property – we expect positive cross-elasticities, which is confirmed by our estimates.

The (inverse) cross-elasticity of the rental market 3.13 (=1/0.3194) is statistically insignificant but similar in magnitude to the supply elasticity of rental properties 2.42 (=1/0.4125). This means that rent increases affect the quantity of supplied selling properties roughly as much as the quantity of supplied rental properties. The situation is slightly different for the selling market, where the magnitude of the inverse cross-elasticity estimate is smaller than the main one, implying that price changes affect more the quantity of supplied rental units than that of selling properties. This difference in magnitude is, however, only weakly statistically significant due to the imprecision of the main elasticity estimate. Therefore, our analysis of cross-elasticities seems to suggest that rent (price) changes affect the quantity of supplied rental and selling properties in approximately equal measure. However, note that – in line with the results of Column 1 – the magnitude of the estimates in Column 2 for rental properties in Panel A is consistently smaller than that of the estimates in Column 2 for the selling properties in Panel B. These results suggest that developers can indeed substitute the supply of rental units with selling ones (and vice versa), but zoning restrictions make the selling market more inelastic to both rent and price signals.

4.2. Heterogeneity of supply elasticities

We now turn to the analysis of the heterogeneity of housing supply at the local level. To this end, we rely on country grid data. We start by estimating average supply elasticities for the whole of the country. The supply estimates are equal to 1.56 (=1/0.6417) for rents and 0.51 (=1/1.9567) for prices (see column 3 of Table 5). Counterintuitively, both elasticities are slightly lower than those we obtain for major agglomerations. We attribute this to two factors. First, due to the definition of agglomerations, several agglomerations such as Geneva, Lausanne, and Bern include elastic countryside areas. On the other hand, the country grid data include areas that are particularly inelastic due to geographic and regulatory constraints, as illustrated in Figure 10 to 12. Note also that the difference in magnitude is not statistically significant: the estimates of Columns 1 and 3 are within one standard deviation from each other.

To investigate the role played by geographic and regulatory constraints, we then estimate Equation 3, where we include a double interaction term $\Delta \ln(q_{it}) \times q_{i1980}$ and a triple interaction term $\Delta \ln(q_{it}) \times \Lambda_{\mathrm{i}} \times q_{i1980}$. These interactions are based on contemporaneous changes in the housing stock, historic development, and geographic/regulatory constraints. Column 4 of Table *5* summarizes the results when all relevant constraints on the extensive margin – including water bodies, undevelopable land, forest, BLN, regional and national parks, and UNESCO sites – are added in Λ_{i} (we designate this term as "Total restricted area").[23]

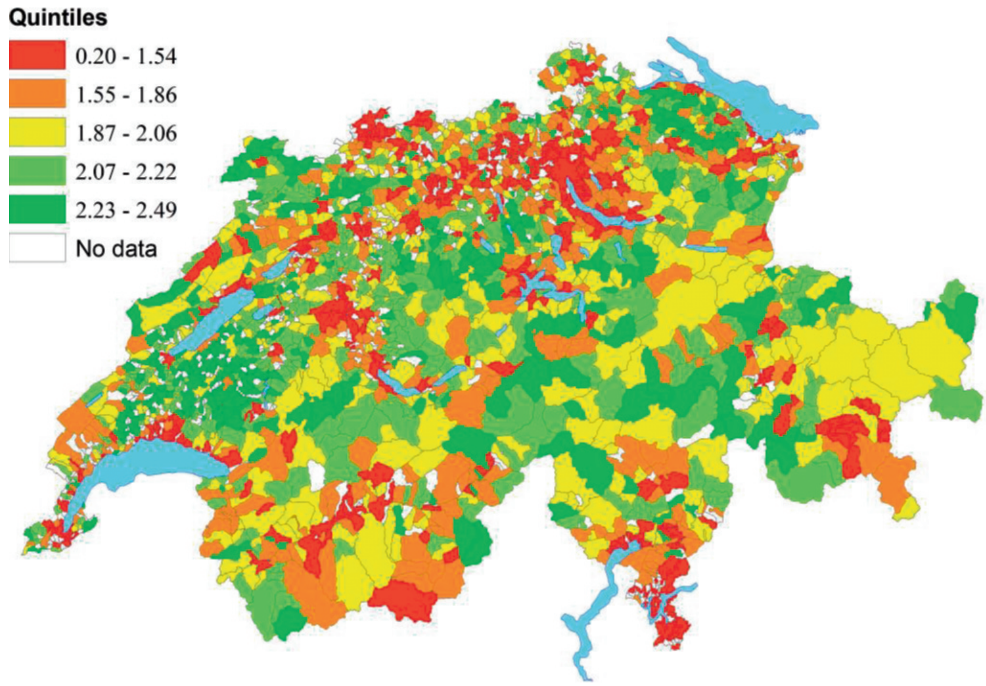
A few remarks are worth noting. First, the average supply elasticities in column 4 that come from changes in the housing stock alone are similar to those in column 1, with elasticity values of 2.50 (=1/0.3997) for rents and 0.64 (=1/1.5655) for prices. Second, the coefficients of the double and triple interaction terms are highly significant for rental and selling properties. These estimates suggest that i) historically developed places have more-inelastic housing markets both with respect to rent and price changes, and ii) geographic and regulatory constraints are more binding in more-developed places.[24] In the next section, we illustrate how we can use the estimated coefficients to infer the impact of geographic and regulatory constraints on housing supply elasticities. Third, the two estimated coefficients are systematically lower for rental than selling properties, suggesting that previous development patterns and geographic/regulatory constraints seem to decrease the supply elasticity of selling properties to a larger extent than that of rental properties.

[23] The FFFs are not included in the total restricted area because they do not have an effect on the heterogeneity and are thus redundant.

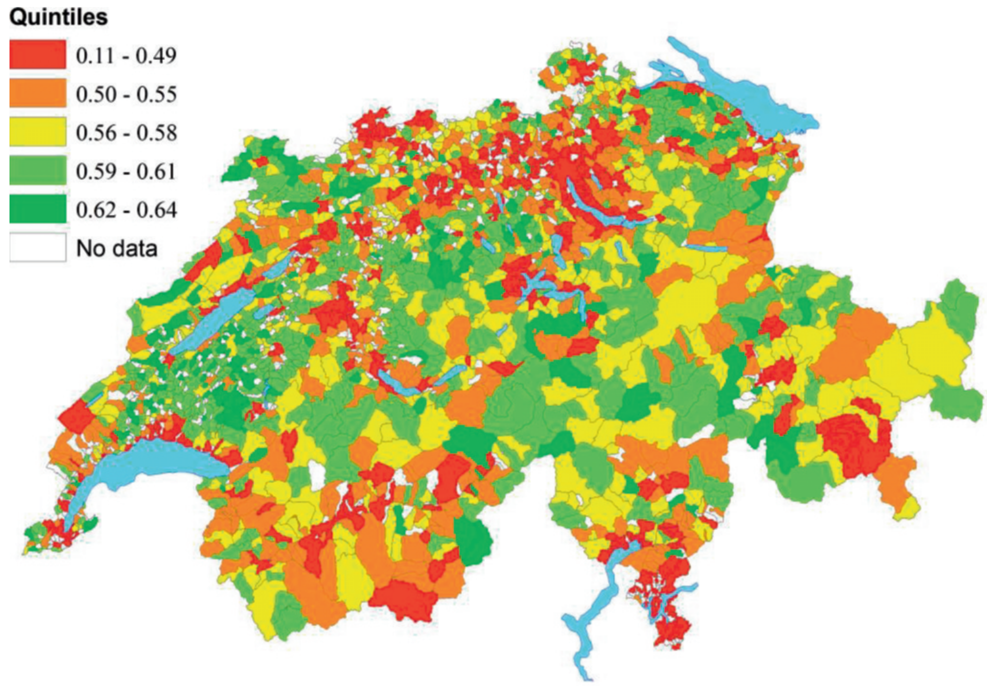
[24] In Table A1 - 3, we show that the heterogeneity arising from geographic and regulatory constraints alone is never significant. Note that to compute our estimates, we always include geographic/regulatory constraints as a control, thus partialling out a direct effect of this variable on rent and price dynamics.

Figure 16: Local supply elasticities

A. Rents



B. Prices

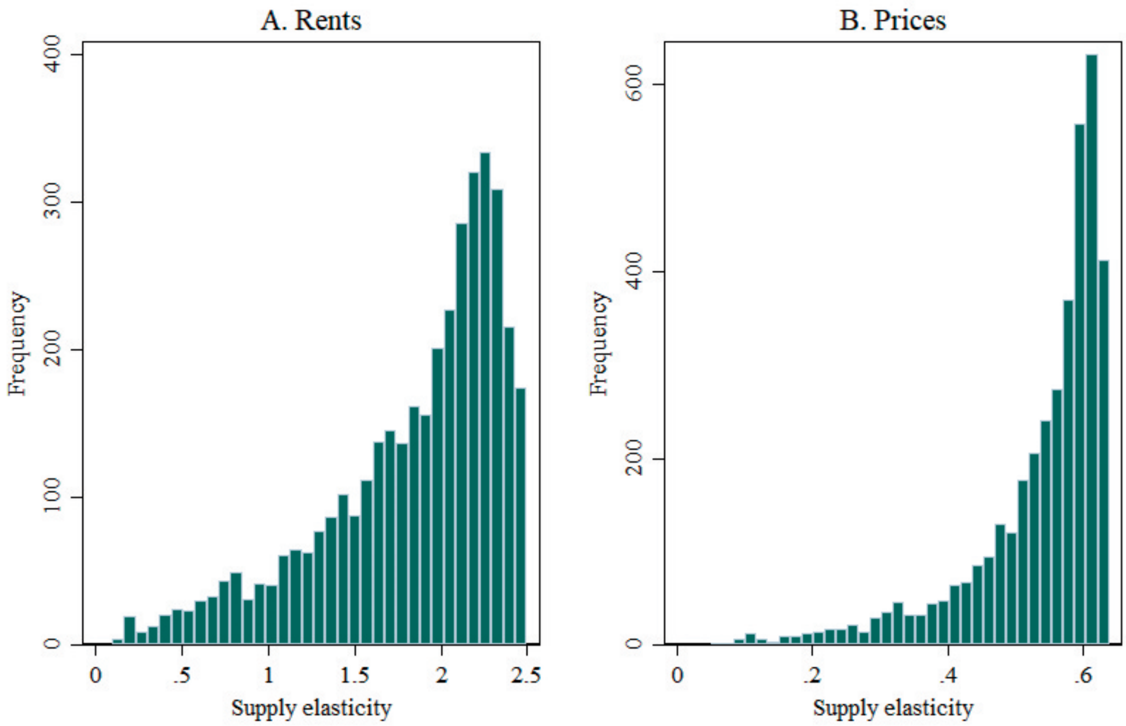


Notes: Supply elasticity interval defined according to quintiles of the distribution. Local estimates are computed using Equation 4 for 2km side country grid data. Heterogeneity is due to the sum of relevant geographic and regulatory constraints on the extensive margin (FFF are excluded) and due to the historic housing stock. Elasticities for cells in which transactions occurred only in 2005 or 2015 – which are thus not included in Equation 3 due to first differencing – are imputed according to their value of geographic and regulatory constraints. No data corresponds to municipalities whose area is not the largest relative share of a grid cell.

Having estimated the coefficients $\beta^{s,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ for rental and selling properties, we can use Equation 4 to compute supply elasticities at the grid cell level. We do this by exploiting the local value of the historic housing stock and geographic/regulatory constraints. For illustration purposes, in a next step, we aggregate these local supply elasticities at the municipality level. See Figure 16A and B. The corresponding distributions are illustrated in Figure 17A and B.

As apparent from Figure 16A and B, housing supply elasticity varies considerably across space. Major agglomerations – and even more so, areas near major CBDs – are particularly inelastic. In contrast, countryside areas generally display comparatively higher elasticity values. However, this is not always true for Alpine regions. Some areas in the cantons of Wallis, Ticino, and Graubünden have low elasticity values – both for rent and price changes – likely due to the importance of geographic constraints in conjunction with historic development. The municipalities of Zermatt (VS) and St. Moritz (GR), for example, count among the 10 percent most-inelastic Swiss municipalities.

Figure 17: Distribution of local supply elasticity



Concerning the spatial distribution of supply elasticities, Zurich and its neighboring agglomerations account for the largest area displaying inelastic housing supply. Even farther away from CBDs, housing supply remains fairly inelastic.

Figure 17A and B provide insight into the distribution of local supply elasticities. The distribution of both rent and price elasticities is skewed to the left. This implies that when computing average supply elasticities at a given aggregation level, the resulting elasticity will be affected by a few extremely inelastic places. This is even truer for supply responsiveness with respect to price dynamics.

We use the estimated local supply elasticities to rank the responsiveness of housing markets at three different aggregation levels: cantons, agglomerations, and municipalities. The ranking – from least- to most-elastic places – is provided in Table 6. Note that the ranking with respect to the three levels of aggregation is virtually the same for rental and selling properties, such that we do not distinguish between the two market segments in the following discussion.

Columns 1-3 of Table 6 show the ranking for Cantons. Except for Basel City, all cantons feature a rental supply elasticity above one. Not surprisingly, Basel City, Zurich, and Geneva appear in the top five most inelastic cantons. In fact, these cantons are among the most urbanized ones in Switzerland, and additionally, housing markets of Geneva and Basel City are constrained by country boundaries. More surprising at first sight is the presence of Ticino and Basel-Landschaft. As we show in the next section, however, terrain ruggedness – as measured by the standard deviation of elevation – and forests play a major role in constraining housing supply, thus explaining the low elasticity we measure for Ticino. In Basel-Landschaft the inelastic supply is manly driven by urbanization and regulation, especially the protected forests.

The most-elastic cantons are Obwalden, Uri, Appenzell Innerrhoden, Fribourg, and Jura. In contrast to the most-inelastic cantons, these five cantons are characterized by a lower degree of urbanization and a comparatively lower degree of regulatory constraints.

Columns 4-6 of Table 6 illustrate the ranking of the 15 largest Swiss agglomerations. Note that all agglomerations feature a rental supply elasticity above one. Surprisingly, the agglomeration of Baden-Brugg is the most inelastic, whereas the agglomerations of Basel and Geneva rank only eighth and ninth, respectively. Lugano is the second most inelastic major agglomeration in Switzerland. This is hardly surprising, as its agglomeration area is constrained by the Lugano Lake and the surrounding hills. Zurich also counts among the most-inelastic agglomerations.

Table 6: Ranking by predicted supply elasticities

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

Notes: Main municipalities have the following rent/price elasticity values: Geneva (0.20/0.11), Basel (0.24/0.13), Zürich (0.34/0.17), Bern (0.35/0.17), Fribourg (0.53/0.24) Biel/Bienne (0.55/0.22), Olten (0.58/0.25), Baden (0.61/0.26), Neuchâtel (0.73/0.26), St. Gallen (0.86/0.32), Lausanne (0.91/0.30), Lucerne (0.94/0.32), Winterthur (1.11/0.38), Lugano (1.20/0.40), Zug (1.43/0.45).

We interpret this ranking with due caution, because the definition of the boundaries of a given agglomeration is arbitrary with respect to rent and price dynamics, as shown in the appendix Figure A2 - 2. For example, the FSO defines the agglomeration of Baden-Brugg by a relatively small surface that closely surrounds the respective city centers. Therefore, it is not surprising that this agglomeration displays lower supply elasticities than that of Zurich, which has a considerably larger surface. Similarly, the agglomeration of Geneva and Lausanne incorporates countryside areas that make the aggregate supply elasticity considerably more elastic.

Finally, columns 7-9 of Table 6 show the supply elasticity ranking of municipalities. To save space, in Table 6, we only report the 10 most inelastic and the 10 most elastic municipalities. Among the most-inelastic areas are major urban municipalities such as Geneva (GE), Basel (BS), Zurich (ZH) and Bern (BE). Thalwil (ZH), Adliswil (ZH), and Schlieren (ZH) are suburban areas located within the proximity of the municipality of Zurich. Similarly, Pully (VD) is a suburban municipality near Lausanne. Finally, Vevey (VD) is a fairly urbanized town on Lake Geneva, and Brügg (BE) is a municipality that is highly constrained by regulatory constraints on the extensive margin. In contrast, the ten most elastic municipalities are mostly located in remote areas displaying large land availability and few geographic/regulatory constraints.

4.3. Quantifying the importance of geographic and regulatory constraints

We now turn to the importance of geographic and regulatory constraints in hindering housing development. In the previous section, we saw that such constraints do reduce local housing supply elasticity. In this section, we quantify the importance of specific geographic/regulatory constraints.

We proceed as follows. In Equation 4, we set $\beta^{s,\tau}$, $\beta^{hist,\tau}$, and $\beta^{constr,\tau}$ equal to the estimated values in Column 4 of Table 5 for rental and selling properties, and we set historic within-grid cell development q_{i1980} equal to the average value (1,214). To isolate the impact of a specific geographic/regulatory constraint, we then set the value of the constraint variable Λ_i equal to the 25th and 75th quantiles and compute the corresponding supply elasticities. Comparing these two elasticities allows us to infer the impact of the constraint for an average developed cell. In the case of supply heterogeneity arising only due to historic development, we estimate Equation 3 and set the housing stock in the 1980s equal to the 25th and 75th quantile values. Table 7 contains the results of these computations.

As is evident from the table, geographic constraints preventing development, although highly significant, decrease supply elasticities only to a relatively small extent. On the other hand, the standard deviation of elevation decreases housing supply elasticities in a more important way, with a -11.4 percent and -7.7 percent reduction in rent and price elasticities. Terrain ruggedness is more important than undevelopable area, likely because in those areas where land availability is strongly restricted by geographic constraints, development is scarcer and few/no advertisements are available in our data.

Table 7: Contributions of geographic and regulatory constraints to supply heterogeneity

	25th quantile	75th quantile	% change	25th quantile	75th quantile	% change
		Rents			Prices	
Geographic constraints						
Undevelopable	1.50	1.44	-3.70***	0.50	0.49	-1.70**
Elevation SD	1.52	1.34	-11.40*	0.51	0.47	-7.70*
Regulatory constraints-extensive margin						
Forests	1.36	1.19	-12.10	0.49	0.45	-7.90*
FFF	1.73	1.85	6.50	0.39	0.40	2.70
Other protected areas: Sum of BLN, Parks, and UNESCO	1.44	1.27	-12.10*	0.50	0.44	-11.30***
All regulatory constraints-extensive margin (except FFF) [a]	1.39	1.08	-22.10***	0.48	0.41	-15.00***
Regulatory constraints-intensive margin						
Stock1980 [b]	1.83	1.45	-21.00***	0.55	0.49	-11.00***
WSL1	1.69	1.42	-15.70**	0.50	0.49	-0.90
WSL2	1.60	1.35	-15.60**	0.54	0.51	-4.30
Refusal rate	1.63	1.47	-9.60***	0.47	0.47	-1.50
Zoned Industrial	1.92	1.82	-5.80	0.57	0.53	-5.60**
Total						
Total restricted (except FFF) [c]	1.40	1.00	-28.50***	0.48	0.38	-20.80***

Notes: *** p<0.01, ** p<0.05, * p<0.1. [a] Individually FFF has an insignificant effect on the heterogeneity of supply elasticities (both prices and rents). Accordingly, we neglect it when estimating the total effect of regulatory constraints. [b] Note that the historic stock serves as a proxy for the intensity of regulation. [c] Total restricted includes all geographic constraints and all regulatory constraints on the extensive margin excluding FFF (covers 67.5 percent of Switzerland). Including FFF does not qualitatively affect the results; the quantile ranges for total geographic and regulatory constraints when accounting for FFF are 1.24, 1.03 and 0.43, 0.37 for rents and prices, respectively.

Regulatory constraints on the extensive margin seem to have, in general, a greater impact on supply elasticities. Except for FFF and forests for the rental properties, all regulatory constraints have a meaningful and significant effect. The regulations for BLN, parks, and UNESCO sites have the largest negative impact on supply elasticities, followed by forests. The FFF seems not to have an impact on supply elasticity. This may be because Cantons chose their FFF in a sensible way by limiting them to areas where they would not hinder development. When all significant restrictions are considered together – i.e., we compute the total amount of areas protected by all extensive margin regulations except FFF[25] – we obtain an important and highly significant decrease in supply elasticities. More precisely, more-regulated places (whose total regulated area belongs to the 75th quantile of the distribution) have a supply rent (price)

[25] In our computations, we take into account that regulated areas overlap. A restricted area is only counted once.

elasticity that is 22.1 percent (15 percent) lower than that of areas that are less regulated (whose total regulated area belongs to the 25th quantile of the distribution).

Intensive margin regulations also play a significant role, the most important of which is the level of historic development, which proxies for the intensity of current regulations. Places that are historically more developed display a 21 percent and 11 percent lower supply elasticity with respect to rent and price changes, respectively. Other intensity restrictions based on zoning data and refusal rates seem to matter only for rent changes. In particular, WSL1, WSL2, and refusal rates have an important and significant impact on rental supply elasticities. For price elasticities, their impact is insignificant and comparatively close to zero. In contrast with these three measures, the amount of land zoned for industrial and commercial purposes only matters for price elasticities. Areas zoning a larger amount of industrial and commercial land have approximately 5.6 percent lower price elasticities. The impact for rent elasticities is similar in magnitude but is statistically insignificant.

Finally, we consider the joint impact of geographic and extensive margin regulatory constraints (without FFF). It makes sense to consider these two categories together, as they both prevent new development on the extensive margin. The combined effect is highly statistically significant and has the largest magnitude among all the restrictions we have investigated. Areas with more total restricted areas have rent (price) supply elasticities that are 28.5 percent (20.8 percent) lower than that of less-restricted areas.

A word of caution is in order concerning the impacts of WSL1, WSL2, refusal rates, and the amount of land zoned for industrial/commercial purposes. Throughout our analysis, we have assumed that the variable Λ_i is exogenous to contemporaneous rent and price dynamics. This assumption is likely valid for geographic constraints, regulatory constraints on the extensive margin, and historic housing stock. Geographic constraints are clearly intrinsically exogenous, as they do not depend on any economic activity. The regulatory constraints on the extensive margin we consider in the present study are largely predetermined: they were implemented, at the very least, fifteen years before our period of analysis, thus ruling out reverse causality issues; they are regulated at the federal level, thus avoiding endogeneity issues linked to welfare-optimizing local governments; and their practical implementation is unrelated to persistent rent/price dynamics, ruling out omitted variable bias.

This exogeneity of regulatory instruments is likely not the case for WSL1, WSL2, refusal rates, and the amount of land zoned for industrial/commercial purposes. In fact, WSL1 and WSL2 are based on 2014 data, and the industrial zoned data are from 2012. Reverse causality might pose an issue here, and the corresponding estimates should be interpreted as correlations rather than causations. For example, municipalities might decide which zoning restrictions to implement, and to what extent, according to the observed price dynamics up to 2014. Refusal rates are built based on predetermined data from 2001 to 2004, but they may still correlate with unobserved determinants of rent and price growth.

4.4. Comparison with other estimates in the literature

We compare our estimated rent and price supply elasticities with those obtained by Saiz (2010) and Caldera and Johansson (2013). We focus on these two papers for the following reasons. Our methodological approach is mainly based on Saiz (2010). Therefore, from the empirical point of view, we can verify how the supply elasticities computed for major US metropolitan areas generalize to the case of Switzerland. On the other hand, despite adopting a completely different approach that relies on country-level time series data to estimate a system of simultaneous demand-supply equations, Caldera and Johansson (2013) provide an average supply elasticity for Switzerland. Because the literature has analyzed supply elasticity relative to price changes, in what follows, we do not discuss our supply elasticity estimates for rent dynamics.

Saiz (2010) finds an average supply elasticity of 1.54 (=1/0.65) for US metropolitan areas when heterogeneity is not considered, suggesting that US metropolitan areas are almost three times as elastic as Switzerland's 15 largest agglomerations, which have an average supply elasticity of 0.57 (=1/1.75) without heterogeneous effects. Because we obtain a similar value for the average supply elasticity for the whole of Switzerland when using country grid data, the difference between the two elasticities does not hinge on the definition of Swiss agglomerations. When considering housing supply heterogeneity with respect to prices, we also observe important differences from Saiz (2010). Taking into account geographic and regulatory constraints, the housing supply elasticities of US Metropolitan Statistical Areas (MSAs) vary between 0.6 in Miami (FL) and 5.45 in Wichita (KS). For Switzerland, we obtain supply elasticities with respect to prices ranging from 0.11 and 0.64 at the municipal level and between 0.25 and 0.59 at the cantonal level (see Table 6).

We impute this difference to two factors. The first factor is the vast difference in the aggregation level of the units of observation used in the two empirical analyses. Saiz (2010) works at a more aggregate level: the smallest US MSA is much larger in terms of area, population, and housing transactions than any 2x2 km cell in our country grid data. The aggregation level, in turn, strongly affects the variation across units of observations. It is reasonable to assume that there is vast supply heterogeneity *within* US MSAs that is eliminated by aggregating data for these areas. Indeed, as shown in Table 6, the distribution of supply price elasticities changes according to the aggregation level, with lower and higher values becoming more uncommon at a higher level of aggregation (i.e., the variance of the estimates decreases).[26]

The second factor is the difference in the importance of the geographic and regulatory constraints of the two countries. As illustrated in Figure 10 to 12, Switzerland's geographic and regulatory constraints hindering extensive margin development are extremely widespread across the country's territory, making housing supply inelastic by international comparison even in countryside areas. It is difficult to imagine that a similar setting is present in the U.S., where – with the exception of a few extremely constrained MSAs – ample quantities of open land are still available for residential development.

Interestingly, Caldera and Johansson (2013) find that Switzerland has the lowest supply price elasticity among a panel of 21 OECD countries. With an average supply elasticity of 0.15 with respect to price changes, their estimate is even lower than those we obtain in Table 5. Besides differences in magnitude due to the methodological approach, we argue that this lower value is strongly influenced by Swiss cities. In fact, Caldera and Johansson (2013) use countrywide price indices whose dynamics are driven by core cities – such as Geneva, Zurich, Lausanne, Basel and Bern – as these are the places where most properties are transacted. Indeed, as illustrated in Table 6, if we consider the housing supply elasticities of these cities aggregated within their municipal boundaries, we obtain values extremely similar to that found by Caldera and Johansson (2013).

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

Our analysis of heterogeneous supply elasticity at a fine scale allows us to reconcile the findings of Caldera and Johansson (2013) with the recent work of Hilber et al. (2017a, b). By international comparison, the Swiss housing market is in the middle range regarding the housing supply elasticity. Whereas the housing market in Switzerland is relatively elastic to rent changes, it is much less elastic to price changes. However, there is considerable heterogeneity in supply responsiveness at the local level, with countryside areas typically displaying higher supply elasticities than areas within major agglomerations. In fact, the most-elastic Swiss municipalities – with a rent (price) supply elasticity value of approximately 2.5 (0.6) – are approximately 12.5 (5.8) times more elastic than highly urbanized municipalities. This elasticity differential is arguably one of the main factors causing rent/price and stock growth differentials between core agglomerations and the countryside areas in the last few decades. In the former areas, housing markets have reacted to increases in housing demand with higher rents and prices. In the latter areas, rents and prices have grown less, but residential development has occurred at a higher rate.

5. Robustness checks

We verify the robustness of our baseline results presented in Table 5. Detailed estimation results discussed in this section are contained in Appendix A1.

5.1. Shorter-term dynamics

The results of Section 4 are obtained by investigating long-run supply elasticities (2005-2015). Here, we briefly analyze whether shorter-run supply elasticities display different dynamics using within agglomeration data. More specifically, we estimate i) the average five-year supply elasticity of major Swiss agglomerations during the periods 2005-2010 and 2010-2015 and ii) the response of housing prices/rents to lagged supply changes.

To do so, we adapt the shift-share foreign and language instruments as follows. First, we impute the growth in the share of foreign households and the shares of main spoken language at the cantonal level between 2005 and 2010 and between 2010 and 2015. Due to limited data availability, we must restrict the number of main spoken languages to German, French, Italian, English, Iberian (sum of Portuguese and Spanish), Serbian, and all other languages.[27] Second,

[27] Precise data on these initial shares is available only in the Federal Population Census of 2000. We impute 2005 and 2010 values using the Population and Households Survey (STATPOP) from 2010 to 2015. However, since

we multiply these growth rates by their corresponding shares measured in 2000. This provides us with two time-varying instruments for short-term demand shocks. By pooling the rent/price and stock growth of the two time periods together, we can estimate shorter-run supply elasticities following the methodology of the previous section.

Shorter-term supply elasticities are similar to long-run ones, with 1.32 (=1/0.7565) for rents and 0.56 (=1/1.7771) for prices, although the supply elasticity to rent changes is somewhat lower (see Table A1 - 4). These results suggest that periods of five years are long enough for the housing supply to adjust to demand pressures. Note that our preferred shorter-term estimates are obtained using only the foreign shift-share instrument. This is for two reasons. First, it is not possible to precisely compute the five-year growth of the main spoken languages, because the limited sample size of the STATPOP between 2010 and 2015 does not allow us to observe every language in the considered areas. Since it is less demanding, the distinction between Swiss vs. foreign households still works. Second, the language instrument does not pass the redundancy test. The short-term Kleibergen-Paap F statistics of the shift-share foreign instrument are lower than the long-run ones, hinting at the fact that shorter-term fluctuations in the housing demand are more difficult to capture with nationality dynamics. As explained in the previous point, however, this might also be due to data limitations.

In the case of lagged supply elasticity, we relate the growth of the housing stock between 2005 and 2015 to price changes over the period 2005-2017. We then instrument using foreign and language shift-share instruments over 2005-2015, as in our baseline results. In this case, the inverse supply elasticity estimates are similar to those reported in Table 5, likely because the rent and price changes between 2005 and 2017 largely correlate with the corresponding 2005-2015 dynamics (see Table A1 - 5).

5.2. Construction costs and mean reversing rents and prices

As pointed out in Section 3, our instrumental variable approach hinges on the assumption that foreign immigration – which affects both foreign vs. Swiss households and language growth – does not relate to unobserved rent and price dynamics. This assumption is violated if local shifts in foreign labor supply lead to changes in construction costs. We thus verify the robustness of our results when including a construction cost index as a control. More precisely,

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STATPOP consists in a *sample* of the Swiss population, it is not possible to determine precise short-term growth rates for every main spoken language. To solve this problem, we further group together main spoken languages.

the construction cost index we use is published by the FSO and measures changes in development costs for seven Swiss greater regions.[28] Following Saiz (2010), we divide the cost growth observed in these regions between 2005 and 2015 by the 2005 level of rents/prices at the local level, which corresponds to changes in construction costs as a share of initial rents/prices. Despite being potentially endogenous, including initial rents/prices allow us to proxy for unobservable supply shifter in the rental and selling markets, respectively. The dynamic changes in construction costs relative to initial rents/prices is highly significant for the two markets, but it does not seem to affect our results (see Table A1 - *6*).[29] The robustness of our results to this inclusion seem to support the hypothesis that the labor market of the construction industry in Switzerland is fairly homogeneous and its dynamics are virtually the same across different areas.

5.3. Modifiable Areal Unit Problem

We investigate the robustness of our results in relation to the Modifiable Areal Unit Problem. More specifically, according to Briant et al. (2010), our point estimates of (inverse) supply elasticities might vary depending on the aggregation level. We thus change the surface covered by our units of observation for both within agglomeration and country grid data.

Table 8: Inverse supply elasticities estimates using within agglomeration data

	IV-second stage long-run estimates			
	3km	5km	3km	5km
Dependent variable	ΔLog Rent/m2		ΔLog Price/m2	
$\Delta \text{Log} Q$	0.6264***	0.5711***	2.0156***	1.7829***
	(0.1880)	(0.1826)	(0.3444)	(0.3312)
Observations	834	746	834	746

Note: All the point estimates are estimated controlling for elevation, elevation standard deviation, log-distance to the nearest CBD, and log-housing stock in 1980. ΔLogQ is instrumented with Bartik foreign and Bartik language.

In the case of within agglomeration data, we progressively increase the distance between concentric rings intersected with municipality boundaries by up to 5 km.[30] The results are

[28] The seven regions are the Lake of Genva (VD, VS, GE), Espace Mittelland (BE, FR, SO, NE, JU), Northwestern Switzerland (BS, BL, AG), Zurich (ZH), East Switzerland (GL, SH, AR, AI, SG, GR, TG), Central Switzerland (LU, UR, SZ, OW, NW, ZG), and Ticino (TI).

[29] Note that we also tried to include the construction cost index and initial rent/prices in the model additively. In this case too, our main results did not change.

[30] Reducing the distance between concentric rings being intersected with municipality boundaries would lead to areas that are too small, i.e., we would lose too many observations due to a lack of advertisements in the areas.

shown in Table 8. As can be seen, the average inverse supply elasticities for both rents and prices are slightly higher than our baseline results. Interestingly, the difference is higher with 3 km rings than with 5 km rings. However, this increase is not statistically significant.

Table 9: Inverse supply elasticities estimates using country grid data

	(1)	(2)	(3)	(4)
	Panel A: IV-second stage – country grid 1km side			
Dependent variable	ΔLog Rent/m2		ΔLog Price/m2	
$\Delta \text{Log}Q$	0.4594**	0.1002	2.2999***	1.5320***
	(0.2188)	(0.1981)	(0.4050)	(0.3438)
Stock 1980 × $\Delta \text{Log}Q$		0.9539***		2.1801***
		(0.3680)		(0.8253)
Total restricted ×		0.4100*		1.1226**
Stock 1980 × $\Delta \text{Log}Q$		(0.2235)		(0.5018)
Observations	3,210	3,210	3,210	3,210
	Panel B: IV-second stage – country grid 3km side			
$\Delta \text{Log}Q$	0.9290***	0.7334***	2.2501***	1.8993***
	(0.2574)	(0.2465)	(0.3428)	(0.3367)
Stock 1980 × $\Delta \text{Log}Q$		0.2435***		0.4637***
		(0.0601)		(0.0923)
Total restricted ×		0.0917***		0.2060***
Stock 1980 × $\Delta \text{Log}Q$		(0.0338)		(0.0530)
Observations	1,329	1,329	1,329	1,329

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. All the point estimates are estimated controlling for elevation, elevation standard deviation, log-distance to the nearest CBD, and log-housing stock in 1980. ΔLogQ is instrumented with Bartik foreign and Bartik language.

In the case of country grid data, we verify the robustness of our estimates for heterogeneous supply elasticities by both decreasing (down to 1 km) and increasing (up to 3 km) the sides of the cells. Table 9 illustrates the results. Although moving in the right direction, the average and heterogeneous supply estimates for rents become unstable and less significant for both 1 km and 3 km side cells. For prices, the average estimates are quite stable. Overall, the heterogeneous supply estimates for both rents and prices are more stable for the 3 km side cells than for the 1 km side cells. This instability is probably fueled by the irrelevance of extensive margin constraints at the very fine scale. Put differently, 1 km side cells in which geographic or protected areas are important probably drop out of our sample, as no housing transactions occur in these areas. On the other hand, aggregating at a higher level (3 km side) does not seem to affect the direction, magnitude, and statistical significance of our inverse supply elasticities much.

5.4. Other robustness checks

We implement several additional robustness checks. First, we investigate how our baseline results change when we use alternative instruments, namely, the share of north-west-oriented plots of land in a given area and fertility rates in 1990 at the municipality level (see Table 4 for a summary of relevant instruments). More specifically, we investigate the robustness of average rent and price elasticities within major agglomerations for two sets of instruments: Bartik foreign and north-west orientation, and Bartik language and fertility rates. The estimated parameters remain extremely similar to those of Table 5 and remain highly significant (see Table A1 - 6).[31]

Second, we control for the main effect of total restricted constraints (geographic and regulatory restrictions at the extensive margin) when estimating the heterogeneity of supply elasticities with country grid data. This allows us to partial out the direct effect of all extensive margin regulations (except FFF) on rent and price dynamics while focusing on a specific heterogeneity channel. The estimated coefficient for the inverse supply elasticity does not change, which confirms our benchmark results. Interestingly, the included main effect for total extensive margin regulation (except FFF) is never significant and is close to zero, confirming that regulations only matter in places where development is important (i.e., they only matter when interacted).

Third, we increase the cluster areas within which we allow standard errors to be auto correlated. Up to the district level – which usually includes several municipalities – our baseline results remain highly significant.

6. Conclusions

In the last few years, the public discussion about house price dynamics has primarily focused on the demand side of markets, investigating the role played by growing incomes, immigration, low interest rates, housing subsidies, and increased mobility of individuals due to better transportation infrastructure and technology. In the case of Swiss housing markets, in particular, researchers have investigated specific demand-side drivers such as immigration and mortgage interest rates. For example, Häcki (2016) finds that positive migration inflows are

[31] We also tested further combinations of the instruments Bartik foreign, Bartik language, north-west orientation, and fertility rates. The estimated parameters remain stable. The results are available upon request.

associated with higher price growth of owner-occupied housing. Similarly, Degen and Fischer (2017) investigate the link between Swiss house prices and immigration flows, finding that growing immigration drives up prices, especially for single-family houses. Drechsel and Funk (2017) investigate how mortgage rate shocks affect house prices.

Yet, housing supply is the other main determinant of observed rent and price dynamics. Our report aims to fill the gap present in the literature by investigating how housing supply reacts to rent and price changes in Switzerland. Our results indicate that within major agglomerations, Swiss housing supply adapts more easily to rent than to price signals. When extending the analysis to the whole of the country, we observe important heterogeneity in local supply responsiveness. Major urban centers and touristic areas display very inelastic housing supply, whereas countryside areas usually have a relatively more responsive housing supply. The more pronounced elasticity of housing supply with respect to rent changes than price changes persists at the local level. By international comparison, the Swiss housing market is in the middle range regarding housing supply elasticity for prices.

We investigate two main factors determining local supply elasticity: geographic and regulatory constraints. We find that both have a considerable effect in reducing the responsiveness of local supply elasticities, with the latter being more important than the former. In particular, regulatory constraints preventing residential development on the extensive margin have the strongest individual impacts on supply elasticities. Regulatory constraints that limit the intensity of residential development also matter, but to a lesser extent.

Our results hold important lessons for policy makers. First, there are clear trade-offs in a growing economy – characterized by strong demand pressure due to rising incomes and population growth – between restricting residential development and rent/price dynamics. By making housing supply considerably more inelastic, policies that protect open land and restrict building height come at a cost: the capitalization of demand shocks into higher rent and price levels, especially within the proximity of major agglomerations.

Second, the impact of policies aiming to affect housing demand – such as housing subsidies – will vary across space depending on the local supply elasticity. In particular, most-inelastic places will capitalize shifts in the housing demand to a large extent, thus mainly benefitting existing property owners and landowners and hurting renters. A similar capitalization effect is expected for fiscal incentives and public good provision.

Our analysis opens the way to new questions that we think deserve to be investigated in the future. Constraints to residential development – especially in major agglomerations – might prevent many people from living near their place of work, possibly leading to a misallocation of individuals across space. This might lead to negative externalities such as lower matching quality on labor markets.

Another important question is to what extent local housing supply differentials are due to the Swiss federalist setting, and fiscal competition in particular. Ehrlich, Hilber, and Schöni (2017b) argue that – in addition to local tax rates – the zoning of residential land might be implemented strategically to attract wealthy taxpayers: low-density restrictions – which usually lead to the construction of single-family houses – attract higher-income taxpayers. Additionally, local homeowners might vote for to implementation of restrictive regulations to capitalize demand pressure into higher rents/prices, ultimately increasing their property value. These incentives are likely to make housing supply more inelastic at the local level, but their empirical relevance has not been investigated yet.

Finally, it would be very valuable for future academic and policy-oriented research to develop a homogeneous database about the local regulatory environment of the Swiss housing market. In the present study, we relied on a set of valuable sources that could represent a starting point for future data collection and analysis of regulation impacts.

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A1. Appendix Tables

Table A1 - 1: Long run supply elasticity (2005-2015) – within agglomeration sample

Panel A: OLS and IV-second stage estimates						
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
Δ Log Q	0.0859***	0.3444**	0.5225***	0.2280***	1.5830***	1.7489***
	(0.0319)	(0.1469)	(0.1557)	(0.0456)	(0.2812)	(0.2976)
Elevation	0.0791**		0.1081***	0.1012**		0.2019***
	(0.0329)		(0.0366)	(0.0468)		(0.0691)
Elevation SD	-0.2745***		-0.1890	-0.2995**		-0.0017
	(0.1044)		(0.1239)	(0.1513)		(0.1899)
Log-distance CBD	-0.0203***		-0.0233***	0.0012		-0.0089
	(0.0051)		(0.0055)	(0.0088)		(0.0116)
Log-housing stock 1980	0.0127***		0.0200***	0.0211***		0.0468***
	(0.0032)		(0.0044)	(0.0047)		(0.0077)
Observations	1,167	1,167	1,167	1,167	1,167	1,167
R-squared	0.0540			0.0384		
Kleibergen-Paap F		36.52	31.96		36.52	31.96
Critical values (IV)		19.93/11.59/8.75/7.25			19.93/11.59/8.75/7.25	
Hansen J statistic		0	0.611		0.0216	0.350
Panel B: IV-first stage estimates						
Dependent variable		Δ Log Q	Δ Log Q		Δ Log Q	Δ Log Q
Foreign		0.0288	0.2234**		0.0288	0.2234**
		(0.0700)	(0.0923)		(0.0700)	(0.0923)
Language		0.4184***	0.2917***		0.4184***	0.2917***
		(0.0553)	(0.0603)		(0.0553)	(0.0603)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by intersecting increasing rings by step of 1km with boundaries of municipalities located within major urban areas.

Table A1 - 2: Heterogeneity in long-run supply elasticities (2005-2015) – country grid with 2km side

Panel A: OLS and IV-second stage estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable		ΔLog Rent/m2			ΔLog Price/m2	
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
$\Delta \mathrm{Log}Q$	0.1288***	0.3736**	0.5015***	0.3387***	1.3251***	1.7412***
	(0.0421)	(0.1662)	(0.1774)	(0.0535)	(0.2025)	(0.2458)
Stock 1980 × $\Delta \mathrm{Log}Q$	0.0477**	0.1093***	0.1746***	0.0645***	0.2296***	0.2683***
	(0.0203)	(0.0179)	(0.0315)	(0.0244)	(0.0282)	(0.0462)
Elevation	0.0176		0.0404*	0.0252		0.1100***
	(0.0221)		(0.0236)	(0.0217)		(0.0293)
Elevation SD	0.0276		0.0782	0.1499*		0.3344***
	(0.0766)		(0.0805)	(0.0888)		(0.1120)
Log-distance CBD	0.0057		0.0033	-0.0001		-0.0146*
	(0.0048)		(0.0055)	(0.0062)		(0.0083)
Log-housing stock 1980	0.0035		-0.0063	0.0110**		0.0015
	(0.0048)		(0.0056)	(0.0051)		(0.0071)
Observations	2,022	2,022	2,022	2,022	2,022	2,022
R-squared	0.0137			0.0397		
Kleibergen-Paap F		61.35	48.99		61.35	48.99
Critical values (IV)		7.03/4.58/3.95/ 3.63			7.03/4.58/3.95/ 3.63	

Panel B: IV-first stage estimates

Dependent variable	$\Delta \mathrm{Log}Q$	Stock 1980 × $\Delta \mathrm{Log}Q$	$\Delta \mathrm{Log}Q$	Stock 1980 × $\Delta \mathrm{Log}Q$	$\Delta \mathrm{Log}Q$	Stock 1980 × $\Delta \mathrm{Log}Q$	$\Delta \mathrm{Log}Q$	Stock 1980 × $\Delta \mathrm{Log}Q$
Language	0.3651***	-0.2574***	0.3306***	-0.0393	0.3651***	-0.2574***	0.3306***	-0.0393
	(0.0315)	(0.0559)	(0.0325)	(0.0503)	(0.0315)	(0.0559)	(0.0325)	(0.0503)
Stock 1980 × Language	-0.0440***	0.4829***	-0.0366***	0.3065***	-0.0440***	0.4829***	-0.0366***	0.3065***
	(0.0050)	(0.0645)	(0.0069)	(0.0506)	(0.0050)	(0.0645)	(0.0069)	(0.0506)

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

Table A1 - 3: Heterogeneity in long-run supply elasticities with triple interaction (2005-2015) – country grid with 2 km side sample

Panel A: OLS and IV-second stage estimates						
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable		ΔLog Rent/m2			ΔLog Price/m2	
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
$\Delta \text{Log}Q$	0.1241***	0.3897**	0.3997**	0.3177***	1.3752***	1.5655***
	(0.0440)	(0.1713)	(0.1745)	(0.0572)	(0.2122)	(0.2419)
Stock 1980 × $\Delta \text{Log}Q$	0.0453	0.1856***	0.3972***	0.0967**	0.4674***	0.7044***
	(0.0339)	(0.0452)	(0.0897)	(0.0466)	(0.0674)	(0.1389)
Total restricted × Stock 1980 × $\Delta \text{Log}Q$	-0.0009	0.0783***	0.1754***	0.0319	0.2438***	0.3405***
	(0.0223)	(0.0297)	(0.0492)	(0.0308)	(0.0462)	(0.0808)
Elevation	0.0173		0.0391	0.0249		0.1087***
	(0.0220)		(0.0246)	(0.0217)		(0.0305)
Elevation SD	0.0488		0.0389	0.1792*		0.1942
	(0.0833)		(0.0868)	(0.0951)		(0.1182)
Log-distance CBD	0.0054		0.0050	-0.0005		-0.0106
	(0.0048)		(0.0056)	(0.0062)		(0.0086)
Log-housing stock 1980	0.0030		-0.0198**	0.0081		-0.0226*
	(0.0053)		(0.0086)	(0.0058)		(0.0116)
Total restricted	-0.0130		-0.0319	-0.0282		-0.0214
	(0.0188)		(0.0226)	(0.0238)		(0.0331)
Observations	2,022	2,022	2,022	2,022	2,022	2,022
R-squared	0.0141			0.0407		
Kleibergen-Paap F		35.65	33.53		35.65	33.53

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

Panel B: IV-first stage estimates												
	(2)			(3)			(5)			(6)		
Dependent variable	$\Delta LogQ$	Stock 1980 × $\Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$	$\Delta LogQ$	Stock 1980 × $\Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$	$\Delta LogQ$	Stock 1980 × $\Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$	$\Delta LogQ$	Stock 1980 × $\Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$
Language	0.3934***	-0.2482***	-0.0557	0.3529***	0.0449	-0.1159*	0.3934***	-0.2482***	-0.0557	0.3529***	0.0449	-0.1159*
	(0.0315)	(0.0571)	(0.0480)	(0.0330)	(0.0622)	(0.0622)	(0.0315)	(0.0571)	(0.0480)	(0.0330)	(0.0622)	(0.0622)
Stock 1980 × Language	-0.1095***	0.4614***	0.0734*	-0.0856***	0.1596**	0.1857***	-0.1095***	0.4614***	0.0734*	-0.0856***	0.1596**	0.1857***
	(0.0114)	(0.0698)	(0.0417)	(0.0140)	(0.0687)	(0.0686)	(0.0114)	(0.0698)	(0.0417)	(0.0140)	(0.0687)	(0.0686)
Total restricted × Stock 1980 × Language	-0.0696***	-0.0228	0.5687***	-0.0449***	-0.1353***	0.5498***	-0.0696***	-0.0228	0.5687***	-0.0449***	-0.1353***	0.5498***
	(0.0102)	(0.0370)	(0.0451)	(0.0091)	(0.0363)	(0.0446)	(0.0102)	(0.0370)	(0.0451)	(0.0091)	(0.0363)	(0.0446)

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

Table A1 - 4: Short run supply elasticity (2005-2010, 2010-2015 pooled) – within agglomeration sample

Panel A: OLS and IV-second stage estimates						
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
ΔLog$Q$	0.1512***	2.0153**	0.7565***	0.1129**	3.6872***	1.7771***
	(0.0334)	(0.8339)	(0.2558)	(0.0499)	(1.3579)	(0.4312)
Elevation	0.0412**		0.0584***	0.0778***		0.1251***
	(0.0183)		(0.0210)	(0.0251)		(0.0347)
Elevation SD	-0.1221*		-0.0589	-0.1623**		0.0114
	(0.0667)		(0.0730)	(0.0713)		(0.1025)
Log-distance CBD	-0.0109***		-0.0141***	0.0055		-0.0035
	(0.0028)		(0.0034)	(0.0047)		(0.0062)
Log-housing stock 1980	0.0060***		0.0104***	0.0132***		0.0253***
	(0.0017)		(0.0026)	(0.0026)		(0.0046)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,511	2,511	2,511	2,511	2,511	2,511
R-squared	0.0316			0.0101		
Kleibergen-Paap F		7.282	22.09		7.282	22.09
Critical values (IV)		16.38/8.96/6.66/5.53			16.38/8.96/6.66/5.53	

Panel B: IV-first stage estimates						
Dependent variable		ΔLog$Q$	ΔLog$Q$		ΔLog$Q$	ΔLog$Q$
Foreign (time-varying)		0.2311***	0.4745***		0.2311***	0.4745***
		(0.0856)	(0.1010)		(0.0856)	(0.1010)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by intersecting increasing rings by step of 1km with boundaries of municipalities located within major urban areas.

Table A1 - 5: Lagged supply elasticity – within agglomeration sample

	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: OLS and IV-second stage estimates					
Dependent variable	ΔLog Rent/m2 (2005-2017)			ΔLog Price/m2 (2005-2017)		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
ΔLog$Q$ (2005-2015)	0.0989***	0.2746*	0.4583***	0.2431***	1.4062***	1.5763***
	(0.0330)	(0.1601)	(0.1641)	(0.0464)	(0.2728)	(0.2901)
Elevation	0.0803**		0.1039***	0.1644***		0.2522***
	(0.0332)		(0.0359)	(0.0424)		(0.0631)
Elevation SD	-0.3464***		-0.2750**	-0.3568**		-0.0918
	(0.1153)		(0.1291)	(0.1552)		(0.1804)
Log-distance CBD	-0.0195***		-0.0223***	0.0016		-0.0090
	(0.0052)		(0.0055)	(0.0093)		(0.0111)
Log-housing stock 1980	0.0108***		0.0163***	0.0223***		0.0426***
	(0.0034)		(0.0044)	(0.0047)		(0.0072)
Observations	1,200	1,200	1,200	1,200	1,200	1,200
R-squared	0.0476			0.0442		
Kleibergen-Paap F		37.15	32.75		37.15	32.75
Critical values (IV)		19.93/11.59/8.75/7.25			19.93/11.59/8.75/7.25	
	Panel B: IV-first stage estimates					
Dependent variable		ΔLog$Q$	ΔLog$Q$		ΔLog$Q$	ΔLog$Q$
Foreign		0.0287	0.2091**		0.0287	0.2091**
		(0.0679)	(0.0889)		(0.0679)	(0.0889)
Language		0.4120***	0.2987***		0.4120***	0.2987***
		(0.0538)	(0.0582)		(0.0538)	(0.0582)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by intersecting increasing rings by step of 1km with boundaries of municipalities located within major urban areas.

Table A1 - 6: Share of construction costs and alternative instruments – within agglomeration sample

Panel A: IV-second stage estimates						
	Construction costs	Orientation	Fertility rate	Construction costs	Orientation	Fertility rate
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Δ Log$Q$ (2005-2015)	0.7418***	0.6087***	0.5287***	1.8363***	1.2573***	1.7361***
	(0.1531)	(0.1844)	(0.1730)	(0.2934)	(0.3144)	(0.3073)
Elevation	0.0937**	0.1138***	0.1085***	0.1754**	0.1694***	0.2011***
	(0.0373)	(0.0386)	(0.0370)	(0.0730)	(0.0579)	(0.0701)
Elevation SD	-0.0937	-0.1721	-0.1878	0.1106	-0.0980	-0.0042
	(0.1310)	(0.1264)	(0.1261)	(0.1957)	(0.1787)	(0.1897)
Log-distance CBD	-0.0323***	-0.0238***	-0.0233***	-0.0140	-0.0057	-0.0089
	(0.0063)	(0.0058)	(0.0056)	(0.0120)	(0.0100)	(0.0116)
Log-housing stock 1980	0.0271***	0.0215***	0.0202***	0.0511***	0.0385***	0.0466***
	(0.0045)	(0.0045)	(0.0047)	(0.0076)	(0.0074)	(0.0080)
ΔShare of construction cost rents	25.5551***					
	(3.5841)					
ΔShare of construction costs prices				3,950,7838***		
				(1,269.5243)		
Observations	1,167	1,167	1,167	1,167	1,167	1,167
Overidentification (Hansen J statistic)	0.170	0.854	0.480	0.304	0.128	0.157
Kleibergen-Paap F	34.97	12.08	32.37	35.75	12.08	32.37
Critical values (IV)		19.93/11.59/8.75/7.25			19.93/11.59/8.75/7.25	
Panel B: IV-first stage estimates						
Dependent variable	ΔLog$Q$	ΔLog$Q$	ΔLog$Q$	ΔLog$Q$	ΔLog$Q$	ΔLog$Q$
Foreign (2005-2010)	0.2536***	0.3619***		0.2220**	0.3619***	
	(0.0939)	(0.0806)		(0.0916)	(0.0806)	
Language	0.2929***		0.3563***	0.3098***		0.3563***
	(0.0602)		(0.0488)	(0.0590)		(0.0488)
Orientation		0.0497**			0.0497**	
		(0.0214)			(0.0214)	
Fertility rate			0.5299**			0.5299**
			(0.2583)			(0.2583)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by intersecting increasing rings by step of 1km with boundaries of municipalities located within major urban areas.

Table A1 - 7: Short run supply elasticity including redundant instrument (2005-2010, 2010-2015 pooled) – within agglomeration sample

Panel A: OLS and IV-second stage estimates						
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
Δ$\text{Log}Q$	0.1511***	3.5949*	1.1628***	0.0886*	4.3351**	1.9554***
	(0.0334)	(2.1736)	(0.4336)	(0.0498)	(1.7463)	(0.4834)
Elevation	0.0410**		0.0696***	0.0470*		0.1297***
	(0.0183)		(0.0251)	(0.0240)		(0.0367)
Elevation SD	-0.1227*		-0.0163	-0.1208*		0.0324
	(0.0667)		(0.0862)	(0.0721)		(0.1096)
Log-distance CBD	-0.0109***		-0.0163***	-0.0046		-0.0044
	(0.0028)		(0.0045)	(0.0042)		(0.0066)
Log-housing stock 1980	0.0060***		0.0133***			0.0265***
	(0.0017)		(0.0036)			(0.0049)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,511	2,511	2,511	2,511	2,511	2,511
R-squared	0.0316			0.0036		
Kleibergen-Paap F		3.651	11.09		3.651	11.09
Critical values (LIML)		8.68/5.33/4.42/3.92			8.68/5.33/4.42/3.92	
J statistic		0.157	0.0103		0.331	0.143
Panel B: IV-first stage estimates						
Dependent variable		Δ$\text{Log}Q$	Δ$\text{Log}Q$		Δ$\text{Log}Q$	Δ$\text{Log}Q$
Foreign (time-varying)		0.2537**	0.5099***		0.2537**	0.5099***
		(0.1080)	(0.1190)		(0.1080)	(0.1190)
Language (time-varying)		-0.0079	-0.0125		-0.0079	-0.0125
		(0.0215)	(0.0211)		(0.0215)	(0.0211)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by intersecting increasing rings by step of 1km with boundaries of municipalities located within major urban areas.

Table A1 - 8: Long run supply elasticity (2005-2015) – country grid 2 km side restricted to major agglomerations

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: OLS and IV-second stage estimates						
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
$\Delta \text{Log} Q$	0.2059***	0.1960	0.3606**	0.3115***	1.4029***	1.7877***
	(0.0507)	(0.1411)	(0.1557)	(0.0811)	(0.2598)	(0.3076)
Elevation	0.0524		0.0629*	0.0969**		0.1969***
	(0.0348)		(0.0360)	(0.0455)		(0.0613)
Elevation SD	-0.1483		-0.0966	-0.1904		0.3035
	(0.1723)		(0.1767)	(0.2213)		(0.2667)
Log-distance CBD	-0.0165***		-0.0172***	0.0001		-0.0066
	(0.0057)		(0.0059)	(0.0107)		(0.0151)
Log-housing stock 1980	0.0187***		0.0210***	0.0262***		0.0483***
	(0.0038)		(0.0044)	(0.0070)		(0.0108)
Observations	791	791	791	791	791	791
R-squared	0.0919			0.0560		
Kleibergen-Paap F		100.5	81.02		100.5	81.02
Critical values (IV)		16.38/8.96/6.66/5.53			16.38/8.96/6.66/5.53	
Panel B: IV-first stage estimates						
Dependent variable		$\Delta \text{Log} Q$	$\Delta \text{Log} Q$		$\Delta \text{Log} Q$	$\Delta \text{Log} Q$
Language		0.4815***	0.4174***		0.4815***	0.4174***
		(0.0480)	(0.0464)		(0.0480)	(0.0464)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 2x2 km. The sample is restricted to the 15 biggest agglomerations.

Table A1 - 9: Heterogeneity in long-run supply elasticities (2005-2015) – country grid with 1km side

Panel A: OLS and IV-second stage estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
$\Delta\text{Log}Q$	0.0627**	0.2165	0.2160	0.1702***	1.4431***	1.8446***
	(0.0255)	(0.1665)	(0.2007)	(0.0391)	(0.2642)	(0.3408)
Stock 1980 × $\Delta\text{Log}Q$	0.0442*	0.3489***	0.5089***	0.1092**	0.8413***	0.9520***
	(0.0261)	(0.0782)	(0.1314)	(0.0545)	(0.1578)	(0.2821)
Elevation	0.0132		0.0249	0.0455**		0.1381***
	(0.0181)		(0.0203)	(0.0217)		(0.0316)
Elevation SD	0.0634		0.2116	0.1997		1.0211***
	(0.1219)		(0.1602)	(0.1403)		(0.2370)
Log-distance CBD	-0.0016		-0.0015	-0.0110**		-0.0231***
	(0.0033)		(0.0040)	(0.0053)		(0.0080)
Log-housing stock 1980	0.0069**		-0.0088	0.0066		0.0021
	(0.0032)		(0.0067)	(0.0040)		(0.0133)
Observations	3,210	3,210	3,210	3,210	3,210	3,210
R-squared	0.0080			0.0205		
Kleibergen-Paap F		36.10	25.89		36.10	25.89
Critical values (IV)		7.03/4.58/3.95/ 3.63			7.03/4.58/3.95/ 3.63	

Panel B: IV-first stage estimates

Dependent variable	$\Delta\text{Log}Q$	Stock 1980 × $\Delta\text{Log}Q$	$\Delta\text{Log}Q$	Stock 1980 × $\Delta\text{Log}Q$	$\Delta\text{Log}Q$	Stock 1980 × $\Delta\text{Log}Q$	$\Delta\text{Log}Q$	Stock 1980 × $\Delta\text{Log}Q$
Language	0.3676***	-0.1674***	0.2786***	-0.0001	0.3676***	-0.1674***	0.2786***	-0.0001
	(0.0362)	(0.0325)	(0.0378)	(0.0311)	(0.0362)	(0.0325)	(0.0378)	(0.0311)
Stock 1980 × Language	-0.1534***	0.3911***	-0.0845***	0.1952***	-0.1534***	0.3911***	-0.0845***	0.1952***
	(0.0197)	(0.0689)	(0.0221)	(0.0525)	(0.0197)	(0.0689)	(0.0221)	(0.0525)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 1x1 km.

Table A1 - 10: Heterogeneity in long-run supply elasticities including total restrictions as main effect (2005-2015) – country grid with 1km side

Panel A: OLS and IV-second stage estimates						
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
$\Delta \text{Log}Q$	0.0668**	0.2374	0.1002	0.1633***	1.5265***	1.5320***
	(0.0269)	(0.1758)	(0.1981)	(0.0374)	(0.2999)	(0.3438)
Stock 1980 × $\Delta \text{Log}Q$	0.0262	0.5339***	0.9539***	0.1406*	1.5801***	2.1801***
	(0.0485)	(0.1650)	(0.3680)	(0.0788)	(0.3290)	(0.8253)
Total restricted × Stock 1980 × $\Delta \text{Log}Q$	-0.0229	0.2119*	0.4100*	0.0397	0.8464***	1.1226**
	(0.0498)	(0.1094)	(0.2235)	(0.0852)	(0.2170)	(0.5018)
Elevation	0.0134		0.0187	0.0451**		0.1211***
	(0.0181)		(0.0210)	(0.0217)		(0.0335)
Elevation SD	0.0532		0.1495	0.2124		0.7567***
	(0.1288)		(0.1520)	(0.1494)		(0.2263)
Log-distance CBD	-0.0016		-0.0009	-0.0111**		-0.0213**
	(0.0033)		(0.0042)	(0.0053)		(0.0086)
Log-housing stock 1980	0.0074**		-0.0200*	0.0057		-0.0273
	(0.0034)		(0.0121)	(0.0044)		(0.0267)
Total restricted	0.0059		-0.0298	-0.0086		-0.0521
	(0.0155)		(0.0289)	(0.0203)		(0.0601)
Observations	3,210	3,210	3,210	3,210	3,210	3,210
R-squared	0.0081			0.0206		
Kleibergen-Paap F		15.71	14.88		15.71	14.88

Notes: Standard errors in parentheses*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 1x1 km.

Panel B: IV-first stage estimates												
	(2)			(3)			(5)			(6)		
Dependent variable	$\Delta LogQ$	Stock 1980 $\times \Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$	$\Delta LogQ$	Stock 1980 $\times \Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$	$\Delta LogQ$	Stock 1980 $\times \Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$	$\Delta LogQ$	Stock 1980 $\times \Delta LogQ$	Total Restricted Stock× 1980 × $\Delta LogQ$
Language	0.4078***	-0.1527***	0.0024	0.3100***	0.0549	-0.0667***	0.4078***	-0.1527***	0.0024	0.3100***	0.0549	-0.0667***
	(0.0367)	(0.0332)	(0.0285)	(0.0406)	(0.0347)	(0.0258)	(0.0367)	(0.0332)	(0.0285)	(0.0406)	(0.0347)	(0.0258)
Stock 1980 × Language	-0.3246***	0.3284***	0.1313***	-0.1824***	0.0320	0.1969***	-0.3246***	0.3284***	0.1313***	-0.1824***	0.0320	0.1969***
	(0.0344)	(0.0750)	(0.0444)	(0.0432)	(0.0706)	(0.0495)	(0.0344)	(0.0750)	(0.0444)	(0.0432)	(0.0706)	(0.0495)
Total restricted × Stock 1980 × Language	-0.2216***	-0.0812**	0.5924***	-0.1106***	-0.1869***	0.4952***	-0.2216***	-0.0812**	0.5924***	-0.1106***	-0.1869***	0.4952***
	(0.0282)	(0.0347)	(0.0514)	(0.0301)	(0.0464)	(0.0483)	(0.0282)	(0.0347)	(0.0514)	(0.0301)	(0.0464)	(0.0483)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 1x1 km.

Table A1 - 11: Heterogeneity in long-run supply elasticities (2005-2015) – country grid with 3km side

Panel A: OLS and IV-second stage estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
ΔLog$Q$	0.1619***	0.6042***	0.8055***	0.4507***	1.5510***	2.0605***
	(0.0596)	(0.2180)	(0.2506)	(0.0798)	(0.2555)	(0.3367)
Stock 1980 × ΔLog$Q$	0.0325*	0.0615***	0.1188***	0.0561**	0.1208***	0.1824***
	(0.0185)	(0.0114)	(0.0242)	(0.0281)	(0.0225)	(0.0465)
Elevation	0.0055		0.0520*	0.0352		0.1531***
	(0.0231)		(0.0297)	(0.0236)		(0.0380)
Elevation SD	-0.0049		0.0180	0.0185		0.0718
	(0.0682)		(0.0706)	(0.0791)		(0.0869)
Log-distance CBD	0.0096*		0.0042	-0.0010		-0.0179*
	(0.0055)		(0.0072)	(0.0067)		(0.0094)
Log-housing stock 1980	0.0015		-0.0110	0.0054		-0.0094
	(0.0069)		(0.0075)	(0.0093)		(0.0117)
Observations	1,339	1,339	1,339	1,339	1,339	1,339
R-squared	0.0155			0.0500		
Kleibergen-Paap F		46.39	32		46.39	32
Critical values (IV)		7.03/4.58/3.95/ 3.63			7.03/4.58/3.95/ 3.63	

Panel B: IV-first stage estimates

Dependent variable	ΔLog$Q$	Stock 1980 × ΔLog$Q$	ΔLog$Q$	Stock 1980 × ΔLog$Q$	ΔLog$Q$	Stock 1980 × ΔLog$Q$	ΔLog$Q$	Stock 1980 × ΔLog$Q$
Language	0.3173***	-0.3748***	0.2788***	-0.1635***	0.3173***	-0.3748***	0.2788***	-0.1635***
	(0.0318)	(0.0763)	(0.0332)	(0.0539)	(0.0318)	(0.0763)	(0.0332)	(0.0539)
Stock 1980 × Language	-0.0206***	0.5432***	-0.0224***	0.3618***	-0.0206***	0.5432***	-0.0224***	0.3618***
	(0.0025)	(0.0599)	(0.0039)	(0.0378)	(0.0025)	(0.0599)	(0.0039)	(0.0378)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 3x3 km.

Table A1 - 12: Heterogeneity in long-run supply elasticities (2005-2015) – country grid with 3km side

	Panel A: OLS and IV-second stage estimates					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ΔLog Rent/m2			ΔLog Price/m2		
	OLS	2SLS	2SLS	OLS	2SLS	2SLS
$\Delta \text{Log} Q$	0.1513**	0.6125***	0.7334***	0.4099***	1.5809***	1.8993***
	(0.0651)	(0.2222)	(0.2465)	(0.0879)	(0.2630)	(0.3367)
Stock 1980 × $\Delta \text{Log} Q$	0.0276	0.0962***	0.2435***	0.0954**	0.2459***	0.4637***
	(0.0286)	(0.0275)	(0.0601)	(0.0432)	(0.0398)	(0.0923)
Total restricted × Stock 1980 × $\Delta \text{Log} Q$	-0.0034	0.0352*	0.0917***	0.0363*	0.1267***	0.2060***
	(0.0147)	(0.0186)	(0.0338)	(0.0207)	(0.0261)	(0.0530)
Elevation	0.0055		0.0536*	0.0367		0.1550***
	(0.0230)		(0.0300)	(0.0237)		(0.0382)
Elevation SD	0.0193		-0.0202	0.0391		-0.0477
	(0.0747)		(0.0782)	(0.0860)		(0.0970)
Log-distance CBD	0.0087		0.0069	-0.0016		-0.0105
	(0.0057)		(0.0072)	(0.0067)		(0.0098)
Log-housing stock 1980	0.0008		-0.0239**	0.0002		-0.0368**
	(0.0077)		(0.0106)	(0.0105)		(0.0156)
Total restricted	-0.0202		-0.0159	-0.0391		-0.0054
	(0.0224)		(0.0275)	(0.0274)		(0.0379)
Observations	1,339	1,339	1,339	1,339	1,339	1,339
R-squared	0.0168			0.0522		
Kleibergen-Paap F		29.73	23.96		29.72	24.11

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 3x3 km.

Panel B: IV-first stage estimates												
	(2)			(3)			(5)			(6)		
Dependent variable	$\Delta \text{Log}Q$	Stock 1980 $\times \Delta \text{Log}Q$	Total Restricted Stock× 1980 × $\Delta \text{Log}Q$	$\Delta \text{Log}Q$	Stock 1980 $\times \Delta \text{Log}Q$	Total Restricted Stock× 1980 × $\Delta \text{Log}Q$	$\Delta \text{Log}Q$	Stock 1980 $\times \Delta \text{Log}Q$	Total Restricted Stock× 1980 × $\Delta \text{Log}Q$	$\Delta \text{Log}Q$	Stock 1980 $\times \Delta \text{Log}Q$	Total Restricted Stock× 1980 × $\Delta \text{Log}Q$
Language	0.3370***	-0.3598***	-0.0807	0.2945***	-0.0568	-0.0889	0.3370***	-0.3598***	-0.0807	0.2945***	-0.0568	-0.0889
	(0.0322)	(0.0954)	(0.0643)	(0.0326)	(0.0859)	(0.0674)	(0.0322)	(0.0954)	(0.0643)	(0.0326)	(0.0859)	(0.0674)
Stock 1980 × Language	-0.0506***	0.5204***	0.0403	-0.0419***	0.2350***	0.1207**	-0.0506***	0.5204***	0.0403	-0.0419***	0.2350***	0.1207**
	(0.0061)	(0.1021)	(0.0485)	(0.0081)	(0.0844)	(0.0612)	(0.0061)	(0.1021)	(0.0485)	(0.0081)	(0.0844)	(0.0612)
Total restricted × Stock 1980 × Language	-0.0312***	-0.0237	0.5950***	-0.0169***	-0.1137*	0.5656***	-0.0312***	-0.0237	0.5950***	-0.0169***	-0.1137*	0.5656***
	(0.0070)	(0.0663)	(0.0737)	(0.0056)	(0.0619)	(0.0701)	(0.0070)	(0.0663)	(0.0737)	(0.0056)	(0.0619)	(0.0701)

Notes: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the municipality level. The unit of observations are obtained by partitioning the whole territory of the country in small square cells of 3x3 km.

A2. Appendix Figures

Figure A2 - 1: Housing stock in 1980

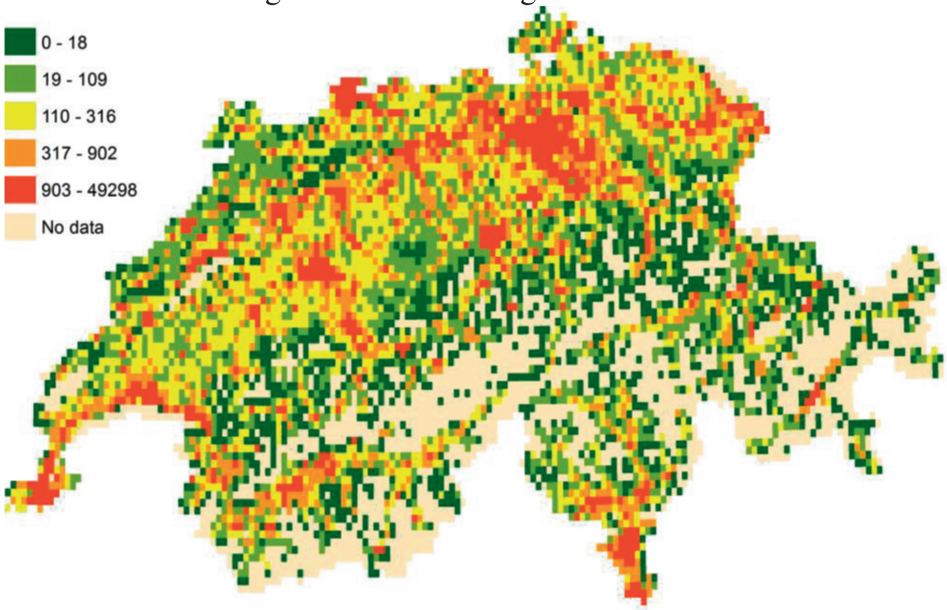
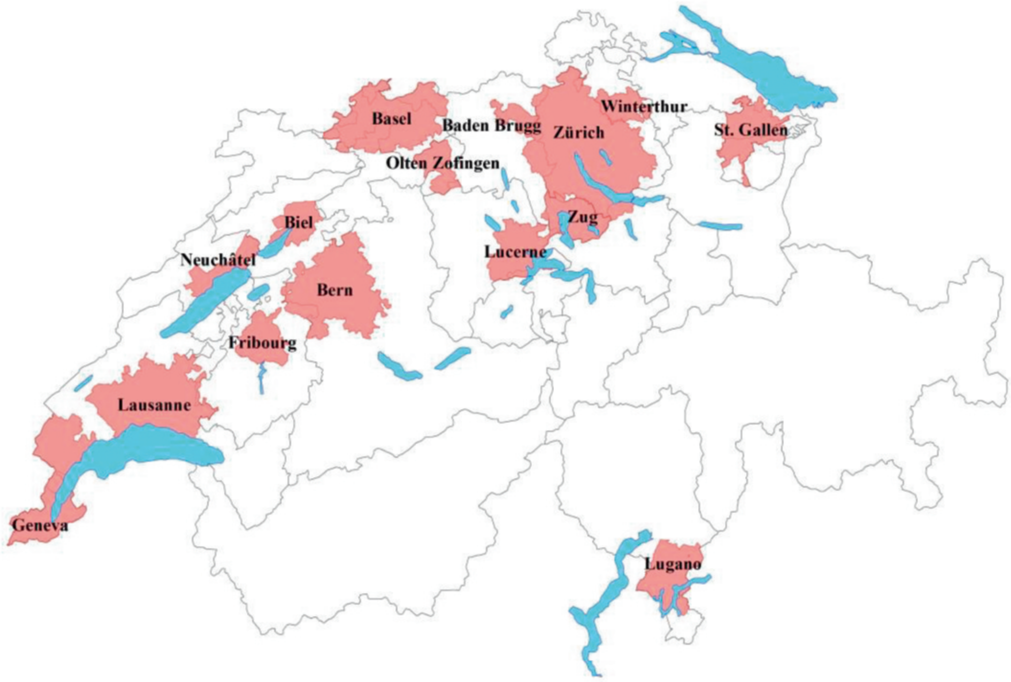


Figure A2 - 2: Major Swiss agglomerations in 2015



A3. Data Appendix

Housing advertisements

Advertisement data for rental and selling properties were provided by *Meta-Sys*, an information provider. By gathering daily advertisements from the most popular real estate platforms in Switzerland, the proprietary data set consists of approximately 2.1 million postings of rental housing units and 0.8 million postings of selling properties from 2004 to 2016. Importantly, *Meta-Sys* cleans the data from cross-platform duplicates such that each advertised housing unit is counted only once in the data. Table A3 - 1 illustrates the main variables contained in the data set.

Table A3 - 1: Housing advertisements

Variable	Units	Description
x-coordinate	WGS-1984	x-coordinate of the residence
y-coordinate	WGS-1984	y-coordinate of the residence
Rent	CHF	Asking rent per month including additional costs. Used to compute the rent per square meter.
House price	CHF	Asking price. Used to compute the house prices per square meter.
Floor space	m2	Floor space of residence. Used to compute the rents/house prices per square meter.
Rent per square meter	CHF/m2	Monthly asking rent per square meter of floor space.
House price per square meter	CHF/m2	Asking price per square meter of floor space.
Building period	Year	Year the residence was built. This variable is missing for about 50 percent of the observations.

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

Additionally, we lose observations when computing rents or house prices per square meter, since not all advertisements contain information on the floor space of the housing unit. Our final data set comprises approximately 1.6 million postings of rental properties and approximately 0.65 million postings of selling properties. These postings are aggregated over our within agglomeration sample, each country grid cell, and municipalities in 2004-2005, 2009-2010, and 2014-2015.

Federal Register of Buildings and Habitations (GWR)

The Federal Register of Buildings and Habitations takes a census of the entire residential housing stock of Switzerland. Two features of the data set are worth noting. First, each building is georeferenced. Second, the register contains information on the housing stock spanning the last century. The precise construction year is missing for many buildings, but the FSO attributes a specific construction period to all of them. These time intervals are large for early periods (1919 or older, 1919-1945, and 1945-1960, 1960-1970, and 1970-1980). From the 1980s, the building period is recorded every five years. We aggregate data on the housing stock for our within agglomeration sample, country grid cells, and municipalities in the periods 1980, 2005, 2010, and 2015. Table A3 - 2 describes the variables used from the building register.

Table A3 - 2: Federal register of buildings and habitations

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

Federal Population Census and the Population and Households Survey

Table A3 - 3: Households characteristics

Variable	Units	Description
x-coordinate	WGS-1984	x-coordinate of residence
y-coordinate	WGS-1984	y-coordinate of residence
Nationality	Country code	Nationality of individuals. Each country has a different country code. Used to compute the development in foreigners.
Language	Language code	Main language spoken at home. Each language has a different language code. Used to compute the development in languages spoken.
Homeownership	Dummy	Dummy variable. 1 if an individual is a home owner, 0 if not. Used to compute the home ownership rate in 2000 and to impute the homeownership rate in 2005, 2010, and 2015.

Information on households' socio-demographic characteristics is provided by the Federal Population Census (FPC) and the Population and Households Survey (STATPOP). The FPC is a census of the Swiss population that was conducted with decadal frequency until 2000. From

2010 onward, STATPOP replaced the census. Each year, STATPOP consists of a representative sample of at least 200,000 households. Both data sources share common information on household characteristics such as housing expenditure and tenure mode, employment, mobility, education, language and religion. Table A3 - 3 describes the variables used in this study.

Because the FPC provides geo-coded information for the entire Swiss population, we can compute precise homeownership rates in 2000 for our within agglomeration sample, for each country grid cell, and for municipalities. Due to the limited sample size of STATPOP, this is not possible in the following years. Therefore, we impute homeownership rates as follows. First, STATPOP allows us to compute reliable homeownership rates at the district level in 2015 (districts are composed of several municipalities). Using the FSO 2015 definition of districts, we compute the corresponding homeownership rates in 2000 at the district level. Second, we compute the growth rate in homeownership at the district level between 2000 and 2015. Using a linear interpolation, we then impute homeownership growth rates for the periods 2000-2005 and 2000-2010. Finally, we multiply the initial homeownership rates in 2000 at a given level (within agglomeration, country grid, or municipality) with the computed growth rates, thus obtaining the imputed homeownership rates in 2005, 2010, and 2015 at each of the considered levels.

A4. Econometric Details

A4.1 Instrumenting changes in the housing stock

The equilibrium changes of the housing stock $\Delta \ln(q_{it})$ are endogenous via changes in the housing demand. Because housing demand negatively correlates with rents and price growths, we expect OLS estimates to be downwardly biased, thus implying overestimated supply elasticities. To overcome this problem, we instrument for $\Delta \ln(q_{it})$ using two shift-share instruments based on nationality (Swiss vs. foreign) and culture, as measured by the eight most spoken languages in Switzerland.[32] More specifically, the foreign shift-share instrument is defined as the weighted average of cantonal growth rates in foreign vs. Swiss residents, where the weights are the predetermined local shares of foreign and Swiss residents in 2000. Similarly, the cantonal growth rates of the main spoken languages are averaged using the

[32] The eight most spoken languages in Switzerland in decreasing order are German, French, Italian, Portuguese, English, Serbian, Albanian, and Spanish. The other languages are pooled as “rest”.

distribution in 2000 of these languages at the local level. The explicit formulae to compute the instruments are

$$z_{it} = \sum_{j=1}^{J} \frac{f_{ijt_0}}{f_{it_0}} \frac{f_{cjt}-f_{cjt_0}}{f_{cjt_0}} = \sum_{j=1}^{J} s_{ijt_0}\, g_{cjt}, \qquad \text{(A4.1.1)}$$

where i = units of observation (local area), j = Swiss/foreign status or main spoken language, f_{ijt_0}, f_{cjt_0} = the number of residents of a given nationality or spoken language within unit i and canton c at time t_0; f_{it_0} = the total number of residents within unit i at time t_0; and t is a time period defining the growth of nationality type/ spoken language since t_0. Thus, s_{ijt_0} is the share of Swiss/foreign status or main spoken language at time t_0 and $g_{cjt}$is the growth rate of number of residents of a given nationality or spoken language at the cantonal level.

The two standard conditions allowing identification of the parameter β in Equations 1, 2 and 3 are $E(\Delta \ln(q_{it})\, z_{it}) \neq 0$ (instrument relevance) and $E(z_{it}\epsilon_{it}) = 0$ (instrument exogeneity). Because foreign immigration has consistently and persistently affected resident population patterns in the last few decades in Switzerland, observed changes in the local distribution of nationalities and the main spoken languages provide a strong predictor of changes in the housing demand.

To claim exogeneity for our instruments, local foreign/language shares and cantonal growth rates must not correlate with the error term of the supply equation. Because time-invariant unobservables affecting supply prices at the local level are eliminated by first differencing, the instruments must be exogenous only with respect to the long-run unobservable supply dynamics contained in ϵ_{it}. Supply dynamics not controlled for in our base specification include changes in the factors of production of the housing sector. Changes in the factors of production, however, are unlikely to be correlated with our instruments for three reasons.

First, the cost of capital and construction materials is determined at the national level.

Second, the construction sector is extremely competitive. Combined with the small size of Switzerland, this competition makes wage dynamics homogeneous across locations. Therefore, the predetermined foreign and language distributions s_{ijt_0} in 2000 are unlikely to affect the long-run labor dynamics of the housing sector.

Third, according to Altonji and Card 1989, immigration is mostly determined by the pre-existing distribution of communities across space. However, since our units of observation consist of small areas, immigrants may decide to move to a given agglomeration for cultural reasons but might sort within the area according to the cost of housing. In fact, the limited size of Swiss agglomerations might still allow new immigrants to interact with the same cultural group even if households do not live in the same area. In this respect, the sorting of new immigrants is endogenous to local price dynamics. For this reason, and in line with the philosophy of shift-share instruments, we use the growth rates of foreign status and languages g_{cjt_0} at the *cantonal* level.

In section 5, we further investigate the endogenous link between immigration and labor supply in the housing sector by explicitly controlling for long-run construction cost changes and initial price levels.

A4.2 Cross-elasticities and endogeneity issues

We discuss some endogeneity issues when trying to disentangle market-specific – i.e., rental or selling – supply elasticities from Equation 1. The first step is to decompose total stock changes as follows

$$\Delta \ln q_{it} \cong \frac{n_{own}(t_2)+n_{rent}(t_2)-n_{own}(t_1)-n_{rent}(t_1)}{n_{own}(t_1)+n_{rent}(t_1)} = \frac{n_{own}(t_2)-n_{own}(t_1)}{n_{own}(t_1)+n_{rent}(t_1)} + \frac{n_{rent}(t_2)-n_{rent}(t_1)}{n_{own}(t_1)+n_{rent}(t_1)} \cong \Delta \ln q_{it}^R + \Delta \ln q_{it}^P,$$

where $\Delta\ln(q_{it}^R)$ and $\Delta\ln(q_{it}^P)$ are changes in the rental and selling stock relative to the total stock. It is tempting to estimate 2SLS supply equations using market-specific stock growths separately (where we omit supply shifters to simplify the notation)

$$\Delta \ln(y_{it}^{\tau}) = \beta^{\tau}\Delta \ln(q_{it}^{\tau}) + \alpha^{\tau} s_i + \epsilon_{it}^{\tau}. \qquad \text{(A4.2.1)}$$

However, the estimates relying on the set of instruments used to estimate Equation 1 are inconsistent. In fact, the exogeneity assumption is likely violated. This is because the market-specific error terms in Equation 1 contain the terms $\Delta\log(q_{it}^R)$ and $\Delta\log(q_{it}^P)$ of the *other* market segment. Since our set of (relevant) instruments is common to the two markets, the exogeneity assumption is likely not valid. It is valid only if the omitted variables actually do not have any impact on the dependent variable, which is a strong assumption. We thus have to control for both $\Delta\log(q_{it}^R)$ and $\Delta\log(q_{it}^P)$, and we assume that our set of instruments $z_1, \dots, z_k$ $(k \geq 2)$ contains sufficient variation to disentangle the two components.

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