Housing supply elasticity and growth: Evidence from Italian cities

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Abstract. The paper examines the impact of housing supply elasticity on urban development. Using data for a sample of about one hundred Italian main cities observed over 40 years, we first estimate housing supply elasticities at the city level. Second we show that differences in the elasticity of housing supply may determine the extent to which a demand shock translates into more intense employment growth, higher wages, or more expensive houses. To address endogeneity of housing supply elasticity, we exploit a synthetic measure of physical constraints as instrumental variable. We find that an exogenous increase in labor demand determine a rise of employment and housing prices; *however*, in cities with a less elastic housing supply the impact on economic growth is significantly lessened while the effects on house prices and wages are larger.

Keywords: housing supply elasticity; city growth; house prices; physical constraints.

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1. Introduction

The elasticity of housing supply plays a central role in understanding current disparities in the economic development of urban areas. Developable land and the relative rigidity of housing supply ultimately determine the ability of a city to absorb the population growth due to a labor demand shock; if the elasticity is particularly low, local productivity shocks may translate into more expensive housing rather than higher employment growth. The effects of local labor demand shocks on economic growth and house prices have consequences not only in terms of spatial disparities in urban development (Glaeser et al., 2006; Saiz, 2010; Glaeser and Gyourko, 2018) but also on aggregate growth at country level (Hsieh and Moretti, 2017).

In this paper we assess the impact of housing supply elasticity on urban growth and real estate prices using a sample of about one hundred Italian main cities observed over 40 years (i.e. census years from 1971 to 2011). The analysis is carried out in two steps. First, we compute the elasticity of housing supply in each city using a novel dataset on housing prices and stocks. Second, we analyze how a rigid housing supply may hamper city growth; more specifically, we examine whether the heterogeneous effects across cities of a labor demand shock – measured with the employment growth predicted by the sector composition of the local economy at the beginning of the period – can be due to differences in the housing supply elasticity. As housing supply is likely to be endogenous due to the presence of omitted variables that correlate with both housing prices and stocks and local economic performance, we exploit physical constraints as instrumental variable.

We find that a 10% increase in labor demand is associated to, on average, a rise of employment by about 5%. The effect is heterogeneous across cities: for cities at the 75th percentile of housing supply elasticity (relatively elastic supply) the 10% increase in labor demand generates a similar growth in employment while for cities at the 25th percentile (relatively inelastic supply) the effect on employment of the same labor demand shock is more limited (around 2%). The differential effect is likely mediated by the adjustment in the housing market. Indeed, while the labor demand shock is associated to an increase, on average, of the house price, the impact is largely concentrated on cities with less elastic housing supply. By using data on local wages for a shorter time span (1991-2011), we also find that the impact of labor demand shocks on local wages are qualitatively similar to that on house prices; this suggests that real wages in more rigid cities remain stable and labor demand shocks tend to benefit homeowners only. Finally, we looked at the different impact of the demand shock, within the same urban area, between the main city and its suburbs and we found that employment growth is lower and housing appreciation is higher in the former, likely due to the lower (higher) housing supply elasticity in the center (periphery) of the urban areas.

Previous literature on the topic has highlighted the role of land regulations (Glaeser et al., 2005; Libecap and Luek, 2011; Gyourko and Molloy, 2015) or physical constraints (Saiz, 2010) on prices. Evidence on whether inelastic supply is likely to hamper local growth is more scant. The closest papers to ours are those by Glaeser et al. (2006) and Saks (2008). The former includes a spatial general equilibrium model with heterogeneous housing supply elasticities across locations and shows that rigid supply implies lower population and income shocks, and larger housing appreciation; the empirical part of the paper studies the role of land regulation (proxied by the Wharton Index) on city growth for US metropolitan areas from 1980 to 2000. In the same vein, Saks (2008) find that land use restrictions and other government regulations have a substantial impact on housing and labor market dynamics in US metropolitan areas. Specifically, these regulations lower the elasticity of housing supply, consequently leading to larger housing appreciation and smaller employment growth.

We contribute to this literature along three main dimensions. First, we use physical constraints instead of land regulation as (exogenous) determinant of housing supply elasticity. Indeed, the dominant political economics view suggests that local land use regulations correspond to the wishes of a majority of local voters. Homeowners, in particular, have stronger incentives to protect their housing investments where land values are high initially (Fischel, 2001). Physical constraints, in contrast, are a credibly exogenous with respect to *current* economic conditions. Saiz (2010) highlights the endogeneity of land regulation while showing that supply elasticity in US cities is severely affected by geographical constraints (with land-constrained areas having more expensive houses).[1] Second, we provide evidence on the differential effects of the demand shock on the center and periphery of urban areas that are characterized by a different capacity to accommodate increase in housing demand. This might explain both the steepness of the house-price gradient and the extent of suburban sprawl. Third, we provide evidence on Italy that, differently from the US, is characterized by a lower housing supply elasticity and more rigid labor market; therefore our results are more informative about economies (such as European countries) where both the responsiveness of housing supply to changes in prices and labor mobility across locations are lower (Caldera and Johansson, 2013; Amior and Manning, 2018; Ciani et al., 2017).

The paper is organized as follows. Section 2 describes a simple model as guidance

[1] Our paper presents some similarities in terms of identification with Harari (2017), which studies the effect of city shape (i.e. compactness of an urban area) on wages and rents growth for Indian cities; city shape is instrumented by geographical constraints to the housing expansion. She finds that irregular shapes are negatively correlated with population, wage and housing prices growth. However, the paper is just loosely related to our research question since city shape is considered as an amenity rather than a determinant of housing supply.

for the interpretation of the empirical results. Section 3 describes the empirical strategy and main identification issues. Section 4 describes the dataset and presents some descriptive evidence. Section 5 shows the results. Section 6 concludes.

2. A simple theoretical model

We present a simple theoretical model that analyzes the role of house supply elasticity on the ability of a city to absorb local labor demand shocks. We use a simple Rosen-Roback framework characterized by inter-city labor mobility, decreasing returns to scale, and upward sloped housing supply curve. We analyze two different scenarios in terms of labor market institutions. We first study the case in which wages are set at local level; this implies that labor market adjustments are both on prices and quantities. The second case – probably much closer to the continental European realities – we consider instead the instance in which nominal wages are set at national level; in this case involuntary unemployment may rise and local labor markets adjustments are solely on quantities.

2.1 Model setup

The economy is made of a continuum of locations with mass M. Each location i produces a homogeneous good (Y_i) that is sold on an international market at price 1; production takes place by using only homogeneous labor (L_i), with the following production function:

$$Y_i = Z_i L_i^{\alpha} \tag{1}$$

where Z_i is a local productivity shifter and $\alpha < 1$ to ensure that labor demand is downward sloped.[2]

Workers/individuals have a Cobb-Douglas utility function based on the consumption of both the homogeneous good and housing services. This implies that indirect utility (V_i) for an individual living in location i is given by real income:

$$V_i = \frac{I_i}{r_i^{\gamma}} \tag{2}$$

[2] Labor is the only input of production. This modelling choice is motivated by the fact that, in the empirical part, we only consider the residential housing market, i.e. the one that is used by workers (and not by firms).

where I_i is the nominal expected income for an individual living in i, r_i represents local housing prices, and γ is the share of income devoted to the consumption of housing services. Each individual inelastically supply one unit of labor; this implies that labor market institutions play a role in determining I_i. In particular, if wages are set at local level, I_i is equal to local market-clearing wages. If wage-setting is centralized, there is involuntary unemployment and expected income is equal to national nominal wage times the probability to find an employment.[3]

Finally, the housing market is characterized by an upward sloping housing supply curve. Inverse supply curve is as follows:

$$r_i = P_i^{\theta_i} \tag{3}$$

where P_i is total population demanding housing services and θ_i is the inverse of the house supply elasticity (the larger θ_i the more rigid the housing market).

We assume that labor is mobile across locations; when indirect utility rises in one location, workers immediately migrate. This creates an upward pressure on local housing services that, as a consequence, re-equilibrates utility levels across locations. This implies that in all locations $V_i = V$.

2.2 Local wage flexibility

We first analyze the case in which local wages are flexible, that is they can adjust to local labor market conditions without frictions. Since both workers and firms are atomistic, local wages are equal to the marginal product of labor:

$$w_i = \alpha Z_i L_i^{\alpha-1} \tag{4}$$

Using (4), (2), and (3) and recalling that when local wages are flexible there is no involuntary unemployment ($P_i = L_i$), we are able to derive equilibrium employment levels, wages, and housing prices:

$$L_i^F = \left(\frac{\alpha Z_i}{V}\right)^{\frac{1}{1-\alpha+\gamma\theta_i}} \tag{5}$$

$$r_i^F = \left(\frac{\alpha Z_i}{V}\right)^{\frac{\theta_i}{1-\alpha+\gamma\theta_i}} \tag{6}$$

[3] This implies that workers are risk neutral.

$$w_i^F = \left[\frac{(\alpha Z_i)^{\gamma\theta_i}}{V^{\alpha-1}}\right]^{\frac{1}{1-\alpha+\gamma\theta_i}} \tag{7}$$

where F denotes equilibrium levels in the case of wage flexibility.

2.3 Local wage rigidity

We now analyze the case in which wages are set at national level ($w_i = w$); we assume that each location is too small to influence nation-wide wage bargaining and, therefore, firms and workers take the salary as given. The main difference between this setting and the previous one is that we now allow for the existence of involuntary unemployment; in other words there is a wedge between local labor demand and supply. Local demand is now equal to:

$$L_i^R = \left(\frac{\alpha Z_i}{w}\right)^{\frac{1}{1-\alpha}} \tag{8}$$

where R denotes now the local wage rigidity case.

Expected income is equal to the nation-wide wage (w) times the probability to find an employment; since labor is homogeneous, this is equal to the local employment rate ($\rho_i = L_i/P_i$). Using (8), (2), and (3), we are able to derive equilibrium housing prices, population and employment rates for the case of wage rigidity.

$$r_i^R = \left(\frac{\alpha^{\frac{1}{1-\alpha}} w^{-\frac{\alpha}{1-\alpha}}}{V}\right)^{\frac{\theta_i}{1+\gamma\theta_i}} Z_i^{\frac{\theta_i}{(1-\alpha)(1+\gamma\theta_i)}} \tag{9}$$

$$P_i^R = \left(\frac{\alpha^{\frac{1}{1-\alpha}} w^{-\frac{\alpha}{1-\alpha}}}{V}\right)^{\frac{1}{1+\gamma\theta_i}} Z_i^{\frac{1}{(1-\alpha)(1+\gamma\theta_i)}} \tag{10}$$

$$\rho_i^R = \Omega Z_i^{\frac{\gamma\theta_i}{(1-\alpha)(1+\gamma\theta_i)}} \tag{11}$$

where Ω is the employment rate shifter. More formally, $\Omega = \left(\frac{\alpha}{w}\right)^{\frac{1}{1-\alpha}} \Big/ \left(\frac{\alpha^{\frac{1}{1-\alpha}} w^{-\frac{\alpha}{1-\alpha}}}{V}\right)^{\frac{1}{1+\gamma\theta_i}}$.

2.4 Comparative statics

We are now ready to analyze the role of house supply elasticity on the way cities absorb local labor demand shocks. Comparative statics is made by studying what happens to employment, housing prices, and (depending on the institutional setting) wages or employment rates when local labor demand (Z_i) increases and by analyzing the role of house supply elasticity (θ_i) in determining possible heterogeneous effects.

More practically, we take consider equations (5), (6), and (7) for the wage flexibility case and equations (8), (9), and (11) for the wage rigidity case.

For these equations we first take logs and compute the derivative with respect to local labor demand ($\partial lnx/\partial lnZ_i$, where x are left-hand side variables of each equation); this is equivalent to study the direct effect of local labor demand shocks to local economic variables.

Then we study the mediating role of house supply elasticity, by calculating the cross-derivatives ($\partial^2 lnx/\partial lnZ_i \partial\theta_i$); these derivatives are able to show possible heterogeneities in the direct effects.

Results are displayed in Table 1. In all institutional frameworks, a rise in the local labor demand determines an increase in employment and housing prices; demand shocks also may increase local wages or employment rates depending on the features of the wage-setting procedure. This is not surprising; if local demand increases, firms raise their employment levels. This put an upward pressure on either wages or employment rates and, as a consequence, it determines a rise in local utility levels. Migration acts like a re-equilibrating mechanism; the arrival of new workers raises housing prices due to the upward sloping housing supply curve.

The role of housing supply elasticity is apparent when we analyze the cross-derivatives ($\partial^2 lnx/\partial lnZ_i \partial\theta_i$). The increase in equilibrium employment is attenuated when housing supply is particularly rigid.[4] This is due to the fact that, in rigid housing markets, migration flows determine a more pronounced rise in prices; as a consequence, inter-city migration slows down and the local labor market becomes tighter. As a result, wages or employment rates increase at a faster pace.

3. Empirical strategy

We adopt a two-steps empirical approach. First, we estimate housing supply elasticity at the city level, looking at the responsiveness of the changes in the housing stock to the changes of house prices (subsection 3.1). Second, we examine how the city's

[4] This is not true when wages are rigid because land is not considered as production function and, therefore, housing supply rigidity affect utility levels but not labor demand by firms.

response to a demand shock varies depending on local housing supply elasticity (subsection 3.2). In order to address endogeneity concerns about housing supply elasticity (as housing stock and prices are both correlated with city growth), we exploit physical constraints as instrumental variable (subsection 3.3).

3.1 Estimation of housing supply elasticity

In the first step supply elasticities are calculated for each city by running the following regression, in the spirit of Green et al. (2005):

$$\Delta ln(H)_{c,t} = \gamma_c \cdot \Delta ln(P)_{c,t} + \mu_{c,t} \tag{12a}$$

where $\Delta ln(H)_{c,t}$ and $\Delta ln(P)_{c,t}$ are, respectively, the housing stock and the price growth rates for city c at time t, and γ_c is the city-specific elasticity (our key parameter).

A possible drawback in the estimation of equation (1a) is that housing is durable and, therefore, it is not downsized in the event of the city experiencing a negative population shock. This implies that the adjustment on the extensive margin (construction of new houses) may depend also on the intensity of the use of the existing housing stock; in order to account for this source of heterogeneity we also estimate housing supply elasticity through the following specification:

$$\Delta ln(H)_{c,t} = \gamma_c \cdot \Delta ln(P)_{c,t} + \theta I_{c,t-1} + \tau_t + \mu_{c,t} \tag{12b}$$

where $I_{c,t-1}$ is the fraction of occupied houses in the city c at time $t-1$; we also include year fixed effects (τ_t) to take into account common shocks (e.g. housing market cycle or new environmental regulations, at the national level, that may tilt consumers' decisions).

Our time-invariant measure of housing supply elasticity (HSE_c) for the rest of the paper is the predicted value of γ_c ($\widehat{\gamma_c}$) from either equation (12a) or (12b).

3.2 Housing supply elasticity and city growth

In the second step, we assess how the impact of a demand shock in a city is mediated by the local housing supply elasticity. In practice we want to test whether an exogenous labor demand shock affects urban outcomes – in terms of employment and real estate prices – according to the elasticity of housing supply in the city. We implement this empirical design by running the following regression:

$$y_{c,t} = \alpha + \beta shock_{c,t} + \delta\left(HSE_c \times shock_{c,t}\right) + \varphi_c + \tau_t + \mu_{c,t} \tag{13}$$

where $y_{c,t}$ is the main outcome variable (i.e. log of employment or log of house prices), for city c at time t. The variable $shock_{c,t}$ is the log employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics and it is aimed at capturing the city-specific labor demand shock.[5] More specifically, we first compute the employment share of each sector (two-digit NACE classification) at the beginning of the period and then we multiply it by the employment in the sector at the national level over the subsequent decades; in formulas: $shock_{c,t} = \sum_s \omega_{c,s,t=1971} \times emp_{s,t}$ where $\omega_{c,s,t=0}$ measure the weight of sector s in city c at the beginning of the period (i.e. $t = 1971$) and $emp_{s,t}$ is the employment of sector s at time t at the national level. Finally, $HSE_c = \widehat{\gamma_c}$ is the housing supply elasticity previously estimated and φ_c and τ_t are city and year fixed effects, respectively.

We expect that a demand shock impacts positively on city growth ($\beta > 0$) and that the impact is higher in cities with a more elastic housing supply ($\delta > 0$).

3.3 Physical constraints to housing supply

There are three main concerns in estimating equation (2) by OLS. The first is measurement error: HSE_c is estimated for each city over four points in time and this implies that outliers or mis-measurements for few years may severely affect the estimates of city level elasticities.[6] A second concern relates to the omitted variable bias: both prices and quantities are equilibrium values; this implies that they are influenced by local economic conditions that, in turn, may affect local growth. Finally, there might be reverse causality as the dependent variable can affect the estimate of housing supply elasticity.

To address these issues we instrument HSE_c. Potential candidates are both physical and administrative constraints that may hamper urban development and residential market adjustment to a demand shock. We have decided to use physical constraints for both operative and identification reasons. First, data on the strictness of urban planning and regulation on a long time horizon are not available for Italy.[7] Second, urban regulation and its actual enforcement are not truly exogenous as may reflect city-specific factors correlated with the outcome variable. For example, the need to intercept a demand shock may induce local government to relax the regulatory framework or its enforcement; from a political economy point of view, if homeowners care about the value of their housing, they may lobby to lower the elasticity of house supply in response to

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[5] This shift-and-share demand shock was initially used by Bartik (1991) and popularized by Blanchard and Katz (1992).

[6] The periods are 1981-1971, 1991-1981, 2001-1991 and 2011-2001.

[7] The report on *Doing Business in Italy 2013* contains measures of regulations, including those dealing with construction permits. However, they refer to a regulatory framework holding in more recent years (i.e. outside our sample's temporal window) and to a small set of cities, thus being useless for our goals.

economic shocks and capitalize part of the productivity boost (Fischel, 2001).[8]

Therefore we use physical constraints (Saiz, 2010). We exploit a proxy of terrain irregularities and ruggedness; the physical constraints represent (time-invariant) city-specific characteristics that limit land use and residential development and they are a *natural* source of exogenous variation. More specifically, we build a summary measure of physical constraints as the first principal component of three different variables: land slope, fraction of surface covered by water bodies, and land fragmentation. Land slope captures the fact that steeper terrains make more difficult residential development. Fraction of surface covered by water bodies also represents an obvious limitation to developable land. Finally, urban shape and residential development may be affected also by land fragmentation (e.g. how mountains and water bodies are distributed); this heterogeneity is captured by patch density, a measure describing the uneven distribution of different land types over the territory.

4. Data and variables

We consider the 103 province capitals ($c = 1,2,\dots,103$) observed in census years ($t = 1971, 1981, 1991, 2001, 2011$). Our key variables are house prices, housing stock and employment in the private sector (our proxy of economic outcome). See subsection 4.1 for details on data sources and subsection 4.2 for some descriptive evidence on main variables.

4.1 Definitions and data sources

A first challenge when we analyze long-term patterns in urban economics is the choice of the unit of observation. As Cuberes (2011) sets out, both administrative and functional definitions of cities have advantages and drawbacks. On the one hand, administrative boundaries are sometimes arbitrary and lack of economic content but are generally more stable over time. On the other hand, functional definitions of metropolitan areas have more economic meaning but they are endogenous with respect to local economic conditions and they change over time; this makes them less suitable for long run comparisons.

For this reason, we use a mixed approach; for baseline estimates we define a urban area as the cluster of municipalities including the province capital and all contiguous municipalities. As a robustness check we use a functional definition of a city as the one

[8] See also Hilber and Robert-Nicoud (2013) who model residential land use constraints as the outcome of a political economy game between owners of developed and owners of undeveloped land.

provided by the national institute of statistics with the Local Labor Markets (LLMs).[9] All the variables of interest are computed at the corresponding aggregate level.

House prices are calculated using data from *Il Consulente Immobiliare*, a semiannual survey conducted for a review published by Il Sole 24 Ore media group (Muzzicato et al., 2008). The data are divided into two property categories (new and existing) and three locations for each city (center, semi-center and outskirts). The main advantages of this survey are its long time range (from mid 60s) and broad territorial reach, as it comprises data on all provincial capitals. Unfortunately, those data are available only for the province capitals and, therefore, we do not observe house prices in the contiguous municipalities. To overcome this data limitation we assume that house prices in the contiguous municipalities are similar to those of the peripheral neighborhoods of the main cities.[10]

Housing stocks (i.e. number of housing units) are drawn from Istat and they are available at the municipality level for census years (from 1971); census data also distinguish between occupied and empty housing units.

Employment is drawn from Istat and it is available at the municipality (and sector) level for census years (from 1971). Sector data are used to compute, for each municipality, the employment share of each sector (two-digit NACE classification) at the beginning of the period and the growth rate of each sector at the national level; these variables are then used to build a time-varying city-specific measure of exposure to demand shocks.

Exogenous sources of variability for housing supply elasticity come from indicators of terrain irregularities and physical constraints: land slope, fraction of surface covered by water bodies and land fragmentation. Land slope is drawn from Istat and it is measured as the difference between the maximum and the minimum altitude of the city over the land surface. The fraction of surface covered by water (e.g. lakes, rivers, wetlands and other internal water bodies) is drawn from ISPRA (*Istituto Superiore per la Protezione e la Ricerca Ambientale*). Finally, land fragmentation is captured by patch density – a measure describing the uneven distribution of different land types over the province territory – and is drawn again from ISPRA (see the appendix for further details on this indicator).

4.2 Descriptive evidence

[9] Starting from 1981, Istat started surveying the commuting patterns across municipalities by Italian workers. This allowed constructing commuting matrixes among municipalities. The Istat LLM is a set of at least two contiguous municipalities characterized by self-contained commuting patterns (at least 75% of local population lives and works in the LLM).

[10] This assumption is fairly supported by the evidence on the house price gradient from the center to the periphery shown in Manzoli and Mocetti (2016).

In the last 40 years there has been a sharp increase in house prices, though patterns have been geographically differentiated: the median urban area in our sample recorded an annual (nominal) growth rate slightly larger than 6%; the corresponding figures for cities at the 25th and 75th percentile of house price growth distribution were less than 5% and 14%, respectively (Table 2). Housing stock also recorded an increase across decades, though with smaller growth rates: the housing stock in the median urban area recorded an annual growth rate equal to 1.3%; the corresponding figures for cities at the 25th and 75th percentile of housing stock growth distribution were 0.9% and 1.5%, respectively. Housing stock growth has been lower than house price growth, even after deflating house prices with the consumer price index (Figure 1). In particular, house prices increased significantly during the 1970s, exhibited a smaller variation in the 1980s and the 1990s and reverted to a new phase of steeper progression during the 2000s.

Concerning a multidimensional concept like irregular terrain and physical constraints, we propose a summary indicator obtained from a principal component analysis and extracting information from the three geographical attributes discussed above. The first principal component explains nearly 40 percent of the total variance of the underlying variables and it is the only component with an eigenvalue larger than one (Table 3); it is positively associated to land slope, to the fraction of land covered by water bodies and to the terrain fragmentation. As expected, the most physically costrained cities are localized in the Alpine region, in the provinces of Liguria, that are delimited by the sea shore on the south and surrounded by mountains on the north, and in some of the provinces of Campania (Figure 2).

5. Results

In the following we first present our estimates of housing supply elasticity (subsection 5.1) and discuss some of the exogeneity conditions that are necessary for a causal interpretation of the parameters (subsection 5.2). Then we show how the impact of a demand shock on city growth (subsection 5.3) and house price growth (subsection 5.4) changes in cities with rigid and elastic housing supply. We also explore heterogeneity in the role of housing supply elasticity within cities (subsection 5.5). Finally, we examine the impact on wages and employment rate (subsection 5.6).

5.1 The estimation of housing supply elasticity

In this section we perform the first step of the analysis by estimating city level house price elasticity, as shown in equation (12a). According to our estimates, the housing supply elasticity is around 0.12, suggesting that an increase of 10% of the (nominal) house prices over 10 years is associated to a 1.2% increase of the housing stock over the same time span (Table 2). Housing supply elasticity shows also a considerable heterogeneity across cities: the interquartile range over the median is above 40%.

The cities with the lowest housing supply elasticity include main metropolitan areas (e.g. Milan, Turin, Genoa, Naples, etc.) and cities hemmed in geographically (e.g. Genoa, La Spezia, Trieste, etc.). This is rather reassuring since housing supply elasticity is expected to be lower for cities with a high land use (i.e. that almost reached their city limits) and whose urban shape is heavily constrained by geographical features (such as mountains, rivers, lakes, etc.). On the contrary, most of the cities with the highest housing supply elasticity are surrounded by cultivated and flat fields, thus suggesting the existence of (a buffer of) developable land in response to a demand shock.

Figure 3 provides visual evidence of the relationship between housing supply elasticities and physical attributes: Trieste and Oristano are two polar cases in the joint distribution of the two variables. Trieste is characterized by low housing supply elasticity and strong geographical constraints to residential development; indeed, the city is located in the North-East of Italy, towards the end of a narrow strip of territory lying between the Adriatic Sea and Slovenia. The urban territory lies at the foot of an imposing escarpment that comes down abruptly from the Karst Plateau towards the sea. According to our physical attributes, the land slope is well above the average and the level of land fragmentation is among the highest across Italian provinces. On the contrary, Oristano is located in Sardinia, in the Campidano plain. The urban territory is surrounded by cultivated fields and the proximity to the sea does not appear to have affected the urban shape that is fairly compact and regular. According to our physical attributes, the land slope is well below the average and the provincial landscape is highly homogenous according to the patch density indicator.

5.2 Exogeneity of demand shocks and physical constraints

The estimation of equation (13) with two stage least squares is based on the assumption that labor demand shocks are exogenous to local economic conditions and that physical constraints are uncorrelated with such shocks.

The Bartik-style shocks can be considered exogenous if local labor markets are small enough not to influence national trends; indeed, if complete specialization prevails at the start of the period, we would not be able to disentangle national shocks from local (endogenous) trend. This means that, for each sector, the share that each city has on national aggregate ($emp_{cst=1971}/emp_{st=1971}$) must be small. This requirement is fulfilled in our data: the mean and median shares are, respectively, 0.5% and 0.1%. The 99th percentile is 6.7%.

We also empirically check whether exogenous shocks are correlated with physical features of the city; this basically corresponds to test whether labor demand shocks are as good as randomly assigned to cities with respect to their physical features. According to our evidence, the correlation between employment growth rate predicted by local demand shocks over the entire period (1971 to 2011) and physical constraints is quite low (-0.15); when we consider decennial changes in demand shocks and subtract city-level fixed effects this correlation is basically zero. This corroborates the idea that geographical features are orthogonal with respect to our labor demand shock, which can then be considered as good as random.

Physical constraints are instead correlated with housing supply elasticity as shown in Figure 4, where we plot the estimated housing supply elasticity and our proxy of physical constraints for all province capitals; in this case the correlation is negative and above 0.3. In Table 4 we corroborate more formally this visual evidence. Specifically, we perform a cross-sectional regression where the city-specific estimated elasticities are the dependent variable and our indicator of physical constraints is the explanatory variables. The two variables are strongly and significantly correlated and with the expected sign (column I). The impact is also significant in economic terms: a variation of 1 standard deviation in the proxy of physical constraints leads to a variation of about 0.3 standard deviation in the estimated housing supply elasticity.

Then we replicate the partial correlations between the housing supply elasticity and the three geographical attributes taken as determinants of physical constraints. Results are qualitatively confirmed as land slope, the fraction of land covered by water bodies and the land fragmentation indicator are negatively and correlated with housing supply elasticity; these results hold both when each indicator is considered separately (columns II to IV) and when they are jointly included (column V).

5.3 Effects of housing supply elasticity on urban growth

We now analyze the impact of supply elasticity on economic growth. The upper panel of table 5 reports the OLS and IV estimates of regression (13) using specifications in levels with fixed effects. The demand shock is, as expected, positively correlated with city employment. According to these estimates, a 10% increase in the predicted demand leads to a 5% increase in the employment at the city level (column I). The impact is heterogeneous across cities and, in particular, is stronger in cities with a more elastic housing supply elasticity (column II)[11]. In column III we explore this heterogeneity with the reduced form (i.e. interacting the demand shock directly with our proxy of physical

[11] In its interaction with demand shock, HSE has been taken as difference from its average value. This implies that estimates on coefficients for demand shock without interaction refers to the location with average HSE.

constraints) and in column IV we rely on IV strategy. The first stage F-statistics of the excluded instrument is, as expected, well above the threshold of 10, commonly used to detect weak instruments (Bound et al., 1995). According to the IV estimates, the impact of a labor demand shock is 2% for a city at the 25th percentile of housing supply elasticity and increases to 11% for a city at the 75th of the same distribution. The IV results qualitatively confirm the OLS ones, though they are upwardly revised probably due to the measurement error in the estimation of housing elasticity (attenuation bias).

In upper panel of Table 6 we check our findings robustness looking at different model specifications. First, we test whether results hold after including controls for differential trends across city size (distinguishing cities below and above 250,000 inhabitants) in order to account for potential exposure of cities to different macroeconomic shock. However, our results are robust to the inclusion of such controls (column I). Second, one may have concerns on the measure of housing supply elasticity as it is not observed but it has been estimated and in some (few) cases it is not statistically significant. Therefore, we replicate our baseline regressions weighting observations with the t-student of $\widehat{\gamma_c}$ estimated in equation (12a), in order to give less weight to provinces with less precise estimates of housing supply elasticity. Our results are substantially unchanged (column II). Finally, we propose a refined estimation of housing supply elasticity, using parameters estimated after having controlled for the intensity of use of the existing housing stock, as shown in equation (12b). Results are unaffected (column III).[12]

5.4 Effects of housing supply elasticity on house prices

The evidence discussed so far support the hypothesis that the impact of a demand shock on city growth is higher where the housing supply curve is more elastic. In this subsection we complement this evidence showing whether the house price growth is smaller in cities with higher housing supply elasticity.

The lower panel of table 5 reports OLS and IV estimates of regression (13) using the log of house price as dependent variable. Since we use city fixed effects as controls, this amounts to estimate the effect of the labor demand shock on house price dynamics. As expected, the demand shock is positively correlated with house price growth (column I). According to these estimates, a 10% increase in the predicted demand leads to an

[12] In Table A1 we replicate the analysis using the valued added instead of employment as indicator of the economic activity. Results are qualitatively similar, thus confirming our main findings on the heterogeneous effect of the demand shock across cities, depending on housing supply elasticity. Nevertheless we don't use value added as main outcome variable for two main reasons: first, the value added is estimated at the province level while our definition of the city includes only the province capital and its neighboring municipalities; second, value added are based on estimates elaborated by the Istituto Tagliacarne while we prefer to work with (more reliable) census data.

increase in house prices at the city level (column I), though the coefficient is not statistically significant at the conventional levels. The impact is heterogeneous across cities and, in particular, it is lower in cities with more elastic housing supply elasticity (column II). The impact of the demand shock is higher in cities with more physical constraints (column III) and when using the latter as instrumental variable, we find that IV estimates upwardly revise the OLS ones (columns IV). According to the latter (our preferred specification), the impact is nearly 3% for a city at the 25th percentile of housing supply elasticity (while, in contrast, there is no increase in house prices for a city at the 75th of the same distribution).

In lower panel of Table 6 we check our findings robustness looking at different model specifications. Results are substantially confirmed.

5.5 Effects on the distribution of economic activities within a city

In a spatial equilibrium framework, firms decide to locate away from a central business district (that, in Italy, usually correspond to the historical downtown of the main city) when location costs in central locations exceed benefits (Fujita and Thisse, 2002). This implies that fluctuations in location costs (housing prices), driven by the interaction between labor demand shocks and housing supply elasticities, may reshape the distribution of economic activities within a city.

To check this hypothesis, we run a regression in which we estimate the effects of the same (urban area-wide) labor demand shock on different portions of the city (i.e. different municipalities within the same urban area). In practice, we re-estimate equation (13) by using, as dependent variables, the (log) employment and (log) prices separately for the main city (i.e. the center of the urban area) and the suburbs (i.e. the periphery); labor demand shocks and house supply elasticities are, instead, computed at the wider (urban area) level.

Results for employment (Table 7) show that the labor demand shock lead to a higher employment growth in the suburbs with respect to the main city of the urban area. This might reflect the lower capability of the centers to absorb the employment growth and confirm the idea that demand shocks determine a relocation of economic activities away from the main city (i.e. where housing supply is presumably more rigid). The interaction between the demand shock and housing elasticity, according to our IV estimates (column IV), is positive either in the center or the periphery but it is significant and particularly sizable only in the main city. Therefore housing elasticity matters for the main cities, as they are more constrained in terms of housing supply while is less relevant for the suburbs.

Table 8 reports regression results using the log of house prices as dependent variable. The impact of a labor demand shock leads to a relatively higher appreciation in the main cities with respect to their corresponding suburbs. Moreover, the impact of the demand shock on prices continues to be lower in areas characterized by a higher supply elasticity, though this is less evident for the peripheries of the urban areas. Admittedly, in this case the confidence intervals of the estimates of the two panels largely overlap; however, this is likely due to the fact that prices in peripheral areas are imputed, thus leading to an attenuation bias. Even with this caveat, these findings confirm that housing supply conditions are relatively more important for the central areas with respect to suburbs and that the relocation mechanism described in Table 7 is channeled through housing (i.e. location) costs.

5.6 The impact on wages and employment rate

In Table 9 we replicate the analysis of regression (13) using private sector wages as dependent variable (equation 13). Due to the lack of reliable wage data before 1991, sample size is smaller respect to the previous estimates. Nevertheless, results on housing and employment hold even within such smaller time span, therefore they can be compared to the ones of Table 9.

Overall, the impact of demand shocks on wages is negligible, being not statistically significant in the OLS (column II) and basically zero in IV estimates (column IV).[13] This is consistent with a framework where national wage setting hampers wage response to local shocks (see Table 1). Nonetheless we find a modest negative coefficient for the interaction between demand shock and physical constraint (column III), having a p-value below 5 per cent. This suggests that there is still some scope for local wage adjustment when housing supply is particularly rigid. In Table 10 we examine the impact on the employment rate. Also in this case, findings are in line with a rather sticky wage setting, since a positive demand shock increases participation in labour market. According to IV estimates, this effect is mildly stronger where housing supply is less elastic. Indeed, the larger housing elasticity, the higher the extent to which demand shocks could generate migration, which could attenuate employment growth relatively to the number of residents.

Overall, results on wages and employment rate seem to suggest that we are in an intermediate setting between flexible and rigid wages, being nevertheless closer to the latter. This is consistent with our prior knowledge about Italian labour markets. Interestingly, we find a further confirmation about the mediating role of housing supply elasticity on local labour markets. Indeed, national wage setting is expected to yield spatial divergence in terms of employment and unemployment rate, to the extent to which demand shocks are asymmetric across areas; whithin this framework higher

[13] Data were kindly shared by Emanuele Ciani. See Ciani et al. (2017) for more details.

housing elasticity could mitigate such imbalances by allowing for greater workers mobility towards areas which benefit from positive shocks.

6. Concluding remarks

Cities are the physical infrastructure in which most of modern economic exchanges take place. Their characteristics are likely to have relevant consequences in terms of local and aggregate growth. In particular, real estate plays a crucial role due to the fact that local labor demand shocks generally determine an inflow of workers (from other areas) needing to use housing services. As theory has pointed out, cities characterized by a rigid housing supply generally grow less and the benefits of productivity shocks are more often capitalized by real estate owners.

In this paper we investigate this issue using a novel dataset for main Italian cities over a period of 40 years. We have shown that local demand shocks in rigid cities end up in a slower employment growth and a larger increase in housing prices.

As city are at center stage for aggregate economic growth (Glaeser, 2011), this result has relevant policy implications. If productivity shocks happen to be more frequent in rigid cities, local disparities in wages and rents would rise, with relevant aggregate effects on national growth. Although this paper has focused on physical constraints to gain identification, rather than land regulations, there is a wide range of options to rise the housing supply elasticity in rigid cities. Urban mobility from other municipalities (i.e. reducing commuting costs from nearby areas), for example, might mitigate the problem; investments in infrastructure would induce suburbanization (Baum-Snow, 2007) and, hence, reduce pressure on the real estate markets in city centers. Even public transportations may play a major role, along with improvements in the governance of wide metropolitan areas as suggested by World Bank (2009).

A final cautionary note is necessary for the interpretation of these results in a European context. Most of the current rigidities in housing supply in European (and, especially, Italian) cities derive from the presence of historical landmarks; their presence is obviously a cost in terms of housing supply rigidities. However, cultural amenities are also able to attract skilled individuals with positive effects on local productivity and on the stability of the local business cycle (Brueckner et al., 1999). This implies that the policy management for those cities is definitely more complex than in other contexts.

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Tables

Table 1. Predictions of the theoretical model

	$\frac{\partial lnx}{\partial lnZ_i}$	$\frac{\partial^2 lnx}{\partial lnZ_i \partial \theta_i}$
Institutional framework:	wage flexibility	
$x =$ labor (L_i)	$\frac{1}{1-\alpha+\gamma\theta_i} > 0$	$-\frac{\gamma}{(1-\alpha+\gamma\theta_i)^2} < 0$
$x =$ housing prices (r_i)	$\frac{\theta_i}{1-\alpha+\gamma\theta_i} > 0$	$\frac{1-\alpha}{(1-\alpha+\gamma\theta_i)^2} > 0$
$x =$ wages (w_i)	$\frac{\gamma\theta_i}{1-\alpha+\gamma\theta_i} > 0$	$\gamma\frac{1-\alpha}{(1-\alpha+\gamma\theta_i)^2} > 0$
$x =$ employment rate (ρ_i)	0	0
Institutional framework:	wage rigidity	
$x =$ labor (L_i)	$\frac{1}{1-\alpha} > 0$	0
$x =$ housing prices (r_i)	$\frac{\gamma\theta_i^2}{(1-\alpha)(1+\gamma\theta_i)} > 0$	$2\gamma\theta_i\frac{1+\gamma\theta_i}{(1-\alpha)(1+\gamma\theta_i)^2} > 0$
$x =$ wages (w_i)	0	0
$x =$ employment rate (ρ_i)	$\frac{\gamma\theta_i}{(1-\alpha)(1+\gamma\theta_i)} > 0$	$\frac{\gamma}{(1-\alpha)(1+\gamma\theta_i)^2} > 0$

Own calculations based on equations (5), (6), (7), (8), (9), and (11).

Table 2. Descriptive statistics

	mean	standard deviation	25th percentile	50th percentile	75th percentile
Housing supply elasticity	0.121	0.044	0.094	0.129	0.147
Housing stock growth rate	0.140	0.080	0.087	0.131	0.183
House price growth rate	0.951	0.680	0.487	0.664	1.432

Sources: authors elaborations on data from Consulente Immobiliare and Istat.

Table 3. Physical constraints: principal component analysis

	eigenvalue	proportion	cumulative
1st component	1.173	0.391	0.391
2nd component	0.974	0.325	0.716
3rd component	0.853	0.284	1.000
	land slope	% water bodies	patch density
Coefficients of the 1st component	0.674	0.409	0.615

Results of the principal component analysis at the capital province level.

Table 4. Determinants of housing supply elasticity

Dependent variable:	housing supply elasticity				
	I	II	III	IV	V
Principal component:					
Physical constraints	-0.013***				
	(0.004)				
Single components:					
Land slope		-0.030*			-0.017
		(0.018)			(0.019)
% water bodies			-0.133**		-0.115**
			(0.051)		(0.049)
Patch density				-0.255***	-0.244***
				(0.072)	(0.074)
Observations	103	103	103	103	103
R-squared	0.094	0.016	0.013	0.105	0.122

Cross-section regression where the units of analysis are province capitals and the dependent variable is housing supply elasticity. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Effects on city growth and house prices: baseline

Dependent variable:	Log of employees			
	I	II	III	IV
Demand shock	0.528***	0.630***	0.542***	0.667***
	(0.174)	(0.154)	(0.156)	(0.166)
Demand shock × HSE		0.565***		0.770***
		(0.048)		(0.155)
Demand shock × physical constraints			-0.270***	
			(0.053)	
R-squared	0.656	0.772	0.682	0.757
Dependent variable:	Log of house prices			
Demand shock	0.116	0.100	0.109	0.052
	(0.148)	(0.150)	(0.143)	(0.156)
Demand shock × HSE		-0.085		-0.353*
		(0.052)		(0.192)
Demand shock × physical constraints			0.124**	
			(0.063)	
R-squared	0.992	0.992	0.992	0.991
First stage F-statistics	-	-	-	57.2
Observations	515	515	515	515
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV

Panel regression where the units of analysis are province capitals, observed in census years 1971, 1981, 1991, 2001 and 2011. The dependent variables are the log of employment (top panel) and of house prices (bottom panel); the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Effects on city growth and house prices: robustness to model specification

Dependent variable:	Log of employees		
	I	II	III
Demand shock	0.631***	0.747***	0.638***
	(0.170)	(0.192)	(0.175)
Demand shock × HSE	0. 784***	0.729***	0.868***
	(0.172)	(0.128)	(0.192)
R-squared	0.755	0.769	0.743
Dependent variable:	Log of house prices		
Demand shock	0.086	0.152	0.066
	(0.182)	(0.172)	(0.165)
Demand shock × HSE	-0.367*	-0.381**	-0.398*
	(0.220)	(0.162)	(0.237)
R-squared	0.991	0.992	0.991
First stage F-statistics	51.3	80.4	43.9
City FEs	YES	YES	YES
Year FEs	YES	YES	YES
Observations	515	515	515

Panel regression where the units of analysis are province capitals, observed in census years 1971, 1981, 1991, 2001 and 2011. The dependent variables are the log of employment (top panel) and of house prices (bottom panel); the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Model (I) include controls for differential trends by city size; in model (II) the observations are weighted by the t-student of housing supply elasticity estimates; in model (III) housing supply elasticity is estimated accounting for shock common to all cities and the fraction of empty houses (i.e. intensity of housing stock use). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Effects on growth within the city

	Panel A			
Dependent variable:	Log of employees in the main municipality			
	I	II	III	IV
Demand shock	0.419**	0.529***	0.436***	0.592***
	(0.171)	(0.158)	(0.150)	(0.190)
Demand shock × HSE		0.610***		0.963***
		(0.048)		(0.178)
Demand shock × physical constraints			-0.338***	
			(0.053)	
R-squared	0.523	0.693	0.575	0.636
	Panel B			
Dependent variable:	Log of employees in the suburbs			
	I	II	III	IV
Demand shock	0.807***	0.878***	0.811***	0.842***
	(0.255)	(0.245)	(0.252)	(0.252)
Demand shock × HSE		0.396***		0.195
		(0.084)		(0.255)
Demand shock × physical constraints			-0.069	
			(0.092)	
R-squared	0.690	0.716	0.691	0.710
First stage F-statistics	-	-	-	57.2
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
Observations	515	515	515	515

Panel regression where the units of analysis are province capitals, observed in census years 1971, 1981, 1991, 2001 and 2011. The dependent variable is the log of employment in the main municipality (top panel) and in the neighboring municipalities (bottom panel); the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 8. Effects on house prices within the city

	Panel A			
Dependent variable:	Log of house prices in the main municipality			
	I	II	III	IV
Demand shock	0.173	0.160	0.166	0.102
	(0.147)	(0.150)	(0.143)	(0.161)
Demand shock × HSE		-0.071		-0.397**
		(0.054)		(0.199)
Demand shock × physical constraints			0.139**	
			(0.063)	
R-squared	0.992	0.992	0.992	0.991
	Panel B			
Dependent variable:	Log of house prices in the suburbs			
	I	II	III	IV
Demand shock	-0.020	-0.033	-0.025	-0.075
	(0.167)	(0.168)	(0.163)	(0.173)
Demand shock × HSE		-0.076		-0.308
		(0.056)		(0.204)
Demand shock × physical constraints			0.108	
			(0.067)	
R-squared	0.991	0.991	0.991	0.990
First stage F-statistics	-	-	-	58.2
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
Observations	515	515	515	515

Panel regression where the units of analysis are province capitals, observed in census years 1971, 1981, 1991, 2001 and 2011. The dependent variable is the log of house prices in the main municipality (top panel) and in the neighboring municipalities (bottom panel); the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 9. Effects on wages

Dependent variable:	Log of wages			
	I	II	III	IV
Demand shock	0.059	0.030	0.022	-0.026
	(0.068)	(0.074)	(0.062)	(0.090)
Demand shock × HSE		-0.084***		-0.250**
		(0.028)		(0.111)
Demand shock × physical constraints			0.106***	
			(0.035)	
R-squared	0.991	0.992	0.992	0.990
First stage F-statistics	-	-	-	39.3
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
Observations	309	309	309	309

Panel regression where the units of analysis are province capitals, observed in census years 1991, 2001 and 2011. The dependent variable is the log of wages in the private sector; the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

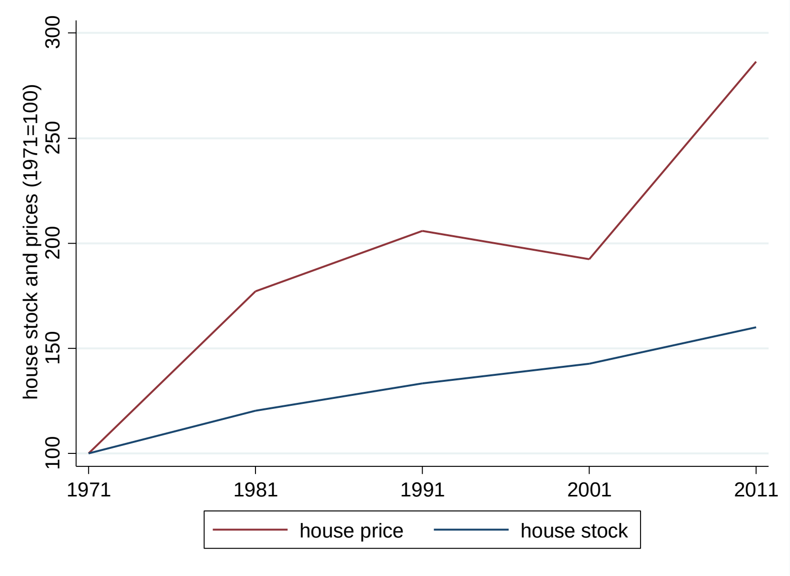
Table 10. Effects on employment rate

Dependent variable:	Log of employment rate			
	I	II	III	IV
Demand shock	0.201***	0.200***	0.198***	0.176***
	(0.045)	(0.046)	(0.046)	(0.055)
Demand shock × HSE		-0.005		-0.136**
		(0.020)		(0.066)
Demand shock × physical constraints			0.048**	
			(0.020)	
R-squared	0.651	0.651	0.658	0.593
First stage F-statistics	-	-	-	57.2
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
Observations	515	515	515	515

Panel regression where the units of analysis are province capitals, observed in census years 1971, 1981, 1991, 2001 and 2011. The dependent variable is the log of employment rate; the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

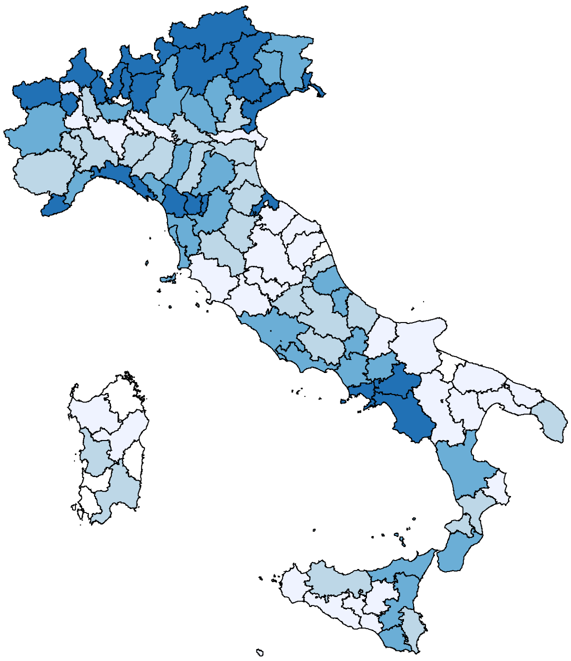
Figures

Figure 1. Housing prices and stock



House prices have been deflated by the consumer price index. Source: authors' elaborations on data from Il Consulente Immobiliare, Istat.

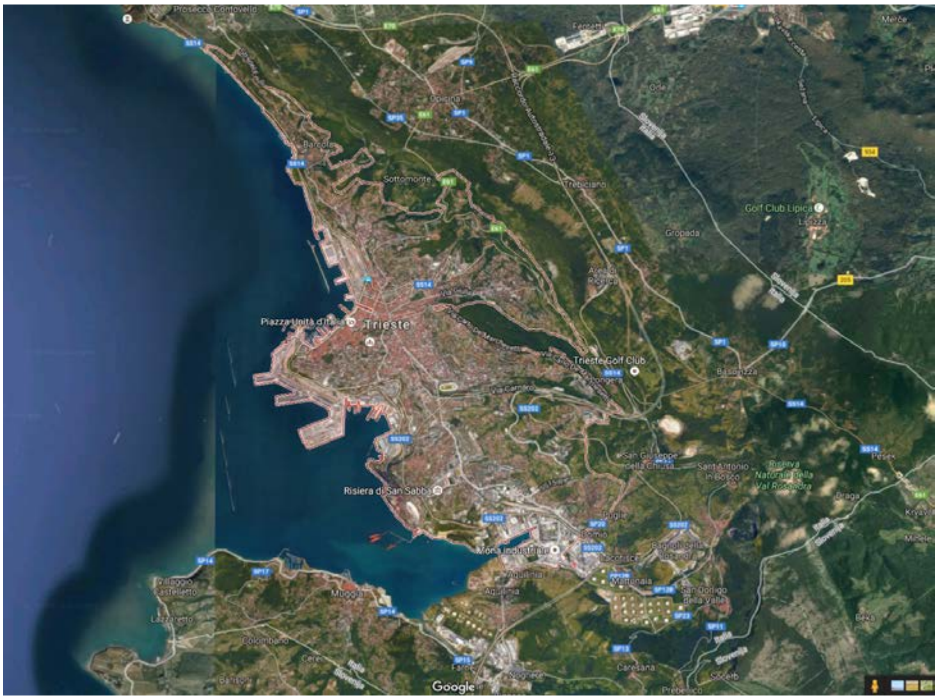
Figure 2. Physical constraints across provinces



Source: authors' elaborations on data from Istat and ISPRA.

Figure 3. Physical constraints and housing supply elasticity

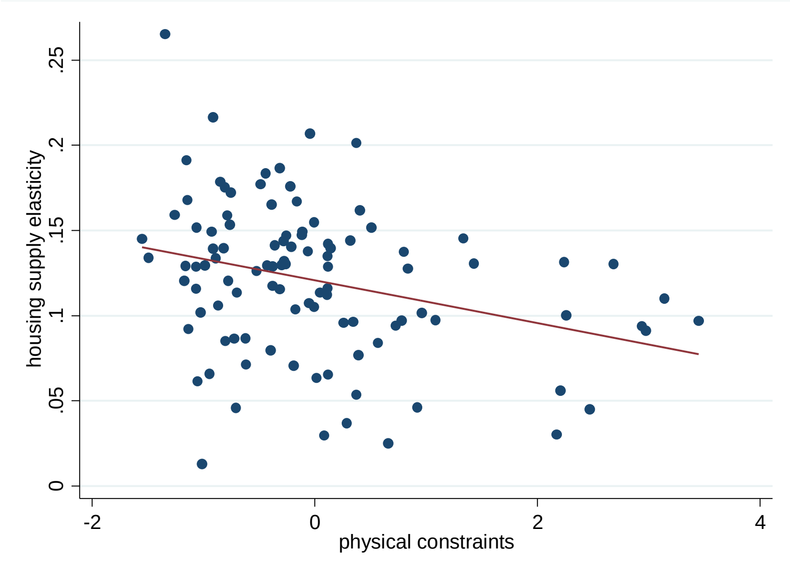
Trieste: high physical constraints and low housing supply elasticity



Oristano: low physical constraints and high housing supply elasticity

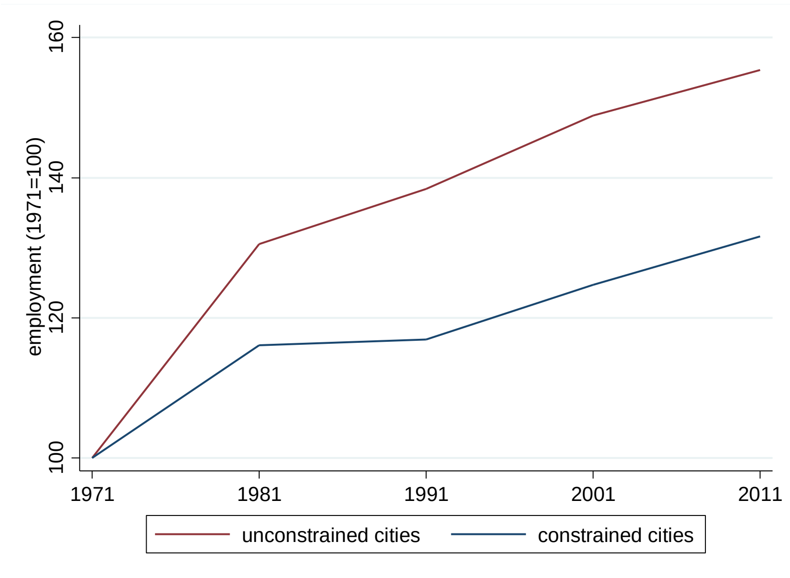
Source: Google earth view.

Figure 4. Physical constraints and housing supply elasticity



Source: authors' elaborations on data from Il Consulente Immobiliare, Istat and ISPRA.

Figure 5. Employment growth by physical constraints



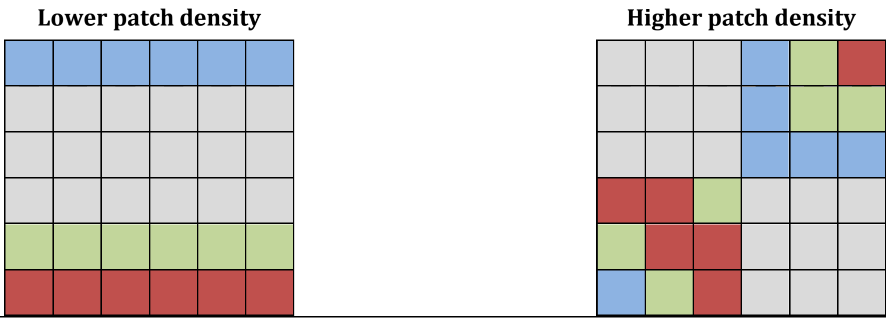
Constrained (unconstrained) cities are those with the physical constraint index above (below) the median. Source: authors' elaborations on data from Istat and ISPRA.

Appendix

A.1 Patch density

Patch density increases with a greater number of patches within a reference area. In the figure reported below two different "landscapes" are presented, both composed of four different land types, covering the same area; let's define them as the urban area (grey), the mountains (maroon), the surface covered by water bodies (blue) and the flat developable land (green). The difference between the two landscapes concerns the extent to which land is fragmented; this heterogeneity can be expressed by the number of patches. The landscape on the left is more homogenous since there are 4 patches corresponding to the four different land types. The landscape on the right, on the contrary, is more fragmented and there are 10 patches: even though the land types are present in the same proportion, they are more unevenly distributed.

Figure A1. Patch density



Source: authors' example.

A.2 Value added as measure of economic growth

Table A1. Effects on growth: value added (province level)

Dependent variable:	Log of value added			
	I	II	III	IV
Demand shock	0.174	0.232	0.180	0.239
	(0.174)	(0.180)	(0.166)	(0.180)
Demand shock × HSE		0.325***		0.362**
		(0.052)		(0.144)
Demand shock × physical constraints			-0.127**	
			(0.054)	
R-squared	0.959	0.964	0.959	0.964
First stage F-statistics	-	-	-	57.2
Observations	515	515	515	515
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV

Panel regression where the units of analysis are province capitals, observed in census years 1971, 1981, 1991, 2001 and 2011. The dependent variable is the log of value added (at the province level); the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

A.3 Robustness using a larger sample of cities (and a shorter time horizon)

In order to assess robustness of our results we also replicate the analysis on a different sample: we consider the universe of Italian cities – defined as Local Labor Markets (LLMs) – and we restrict the temporal window (because of data availability) to the census years 2001 and 2011. We first build a measure of housing supply elasticity that is given by the ratio of the percentage change in the housing stock between 2001 and 2011 to the percentage change of house prices in the same temporal window.[14] Moreover, we also build a measure of physical constraints at the LLM level; details about the principal components analysis are reported in Table A2.

The upper panel of table A3 reports the results for employment. We restrict the analysis to the 584 LLMs with at least 10,000 inhabitants. According to these estimates, a 10% increase in the predicted demand leads to 8% increase in the employment (column I). The impact is again heterogeneous across cities, being higher in more elastic cities (column II). Reduced form and IV estimates (columns III and IV, respectively) confirm the OLS results. More specifically, according to IV estimates, the actual impact of the demand shock ranges from less than 2% in cities with less elastic housing supply (i.e. 25th percentile of housing supply elasticity) to 18% for a city at the 75th of the same distribution.

The lower panel of table A3 presents the estimate by using housing prices as dependent variable. Labor demand shocks determine a relevant increase in housing prices that, again, is larger in less elastic LLMs. This is confirmed also in the reduced form and IV regressions even if the effects are quite imprecisely estimated.

Table A2. Physical constraints: principal component analysis (LLM level)

	Eigenvalue	Proportion	Cumulative
1st component	1.430	0.477	0.477
2nd component	0.978	0.326	0.803
3rd component	0.592	0.197	1.000
	Land slope	% water bodies	Patch density
Coefficients of the 1st component	0.695	0.245	0.676

Results of the principal component analysis.

[14] Data on house price at the more disaggregate level are drawn from OMI.

Table A3. Effects on city growth and house prices (LLM level)

Dependent variable:	Log of employees			
	I	II	III	IV
Demand shock	0.813***	0.829***	0.845***	0.995***
	(0.101)	(0.0970)	(0.0937)	(0.149)
Demand shock × HSE		0.0968		1.110*
		(0.0815)		(0.597)
Demand shock × physical constraints			-0.132*	
			(0.0703)	
R-squared	0.227	0.230	0.239	0.235
Dependent variable:	Log of house prices			
Demand shock	2.523***	2.149***	2.474***	2.250***
	(0.296)	(0.290)	(0.298)	(0.358)
Demand shock × HSE		-2.280***		-1.668
		(0.240)		(1.033)
Demand shock × physical constraints			0.198	
			(0.141)	
R-squared	0.826	0.854	0.826	0.852
First stage F-statistics	-	-	-	20.2
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
Observations	1,168	1,168	1,168	1,168

Panel regression where the units of analysis are LLMs, observed in census years 2001 and 2011. The dependent variable are the log of employment (top panel) and of house price (bottom panel); the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The main explanatory variable is the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variable has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.