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 growth. 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 higher economic growth or more expensive houses. To address endogeneity of housing supply elasticity, we exploit a synthetic measure of terrain irregularities and 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 more than halved while the effects on house prices are larger.

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

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1. Introduction

Geographical and physical constraints heavily affect the urban shape, the extent of developable land and the elasticity of housing supply. These factors, in turn, determine the ability of a city to absorb the population growth due to a labor demand shock and whether the latter translates into higher economic growth or more expensive houses. The effects of local labor demand shocks on local population, economic growth and house prices have consequences not only in terms of spatial disparities in urban development (Saiz, 2010) but also on aggregate growth at country level (Hsieh and Moretti, 2015).

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 determine, on average, a rise of employment and housing prices by, respectively, 5.2% and 0.6%. 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 11% growth in employment and no increase on house prices. For cities at the 25th percentile (relatively inelastic supply) the effect on employment of the same labor demand shock is more limited (around 2%) while house prices increase by 3%. Results are robust to several checks made to take into account differential exposure to macroeconomic shocks across cities with a different size or located in different geographical areas. We also 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) or physical constraints (Saiz, 2010) on prices. Evidence on whether inelastic supply is likely to hamper local growth is more scant. The closest paper to ours is Glaeser et al. (2006). In their theoretical model they present a spatial general equilibrium model with heterogeneous housing supply elasticities across locations and show 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. However, physical constraints are arguably a more exogenous determinant of housing supply elasticity than land regulation, as the latter may be endogenously chosen by local actors in response to local economic conditions. Our paper presents some similarities in terms of identification with Harari (2016), 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.

The paper is organized as follows. Section 2 describes the empirical strategy and main identification issues. Section 3 describes the dataset and presents some descriptive evidence. Section 4 shows the results. Section 5 concludes.

2. 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 2.1). Second, we examine how the city's response to a demand shock varies depending on local housing supply elasticity (subsection 2.2). 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 2.3).

2.1 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):

$$\Delta ln(H)_{c,t} = \gamma_c \cdot \Delta ln(P)_{c,t} + \mu_{c,t} \tag{1a}$$

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:

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

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 going to be the predicted value of γ_c ($\widehat{\gamma_c}$) from either equation (1a) or (1b).

2.2 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:

$$output_{c,t} = \alpha + \beta shock_{c,t} + \delta\left(HSE_c \times shock_{c,t}\right) + \varphi_c + \tau_t + \mu_{c,t} \tag{2}$$

where $output_{c,t}$ 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, in the spirit of Bartik (1991), it is aimed at capturing the city-specific labor demand shock. More specifically, we first compute the employment share of each sector (two-digit NACE classification) 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 ($\delta > 0$).

2.3 Physical constraints to housing supply

There are two 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.[1] 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.

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 two main reasons. First, data on the strictness of urban planning and regulation on a long time horizon are not available.[2] 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 can lobby to lower the elasticity of house supply in response to economic shocks and capitalize part of the productivity boost (Fischel, 2001).

For these reasons 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

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

[2] 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.

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.

3. 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 3.1 for details on data sources and subsection 3.2 for some descriptive evidence on main variables.

3.1 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 up to the second order (i.e. neighboring municipalities plus the neighbors of the neighbors). As a robustness check we use a functional definition of a city as a Local Labor Market (LLM) for a shorter period of time.[3] Therefore all the variables of interest are computed at this 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

[3] 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). For the purposes of this paper, we use the LLMs map based on 2001 commuting patterns and we limit the analysis to the 2001-2011 decade.

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.[4]

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 city 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).

3.2 Descriptive evidence

In the 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 nearly 14%, respectively (Table 1). 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 1.4%; the corresponding figures for cities at the 25th and 75th percentile of housing stock growth distribution were 0.9% and 1.9%, respectively. Housing stock growth is

[4] This assumption is fairly supported by the evidence reported in Manzoli and Mocetti (2016).

relatively flatter 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 about 41 percent of the total variance of the underlying variables and it is the only component with an eigenvalue larger than one (Table 2); it is positively associated to land slope, to the fraction of land covered by water bodies and to the terrain fragmentation. As expected, cities with more physical and geographical constraints 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).

4. Results

In the following we first present the estimates of housing supply elasticity (subsection 4.1) and discuss some of the exogeneity conditions that are necessary for a causal interpretation of the parameters (subsection 4.2). Then we show how the impact of a demand shock on city growth (subsection 4.3) and house price growth (subsection 4.4) changes in cities with rigid and elastic housing supply. We also explore heterogeneity in the role of housing supply elasticity within cities (subsection 4.5). Finally, we replicate our analysis focusing on the first decade of the 2000s (thus with a shorter time horizon) but extending the analysis to the universe of Italian cities (subsection 4.6).

4.1 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 (1a). According to our estimates, the housing supply elasticity is around 0.13, suggesting that an increase of 10% of the (nominal) house prices over 10 years is associate to a 1.3% increase of the housing stock over the same time span (Table 1). Housing supply elasticity shows also a considerable heterogeneity across cities: the interquartile range over the median is nearly 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.

4.2 Exogeneity of demand shocks and physical constraints

The estimation of equation (2) 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 $(emp_{cst=1971}/emp_{st=1971})$ is small. This requirement is fulfilled in our data: the average 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. According to our evidence, the employment growth rate predicted by local demand shocks over the entire period (1971 to 2011) is almost uncorrelated with our proxy of physical constraints, thus suggesting 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 in the interval between 0.2 and 0.3. In Table 3 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).

4.3 Effects of housing supply elasticity on urban growth

We now analyze the impact of supply elasticity on economic growth. Table 4 reports the OLS and IV estimates of regression (2) 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). In column III we explore this heterogeneity with the reduced form (i.e. interacting the demand shock directly with our proxy of physical 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.

In Table 5 we replicate our baseline results using separately the geographical attributes that define our proxy of physical constraints. We consider both, again, the reduced form and the geographical attributes as instruments for housing supply elasticity. The results qualitatively confirm our baseline: the impact of a demand shock is lower in cities with steeper terrain, with a larger fraction of land covered by water bodies and in more fragmented lands.

In Table 6 we check our findings robustness looking at different model specifications. First, we examine whether results hold after including controls for differential trends across geographical areas (Centre-North vs. South of Italy) and city size (distinguishing cities below and above 250,000 inhabitants). Indeed physical constraints, as we have seen before, are more widespread in the Alpine region in the North and, therefore, one may argue that our results are driven by the exposure of the two areas to a differential 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 (1a), 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 (1b). Results are unaffected (column III).

4.4 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.

Table 7 reports OLS and IV estimates of regression (2) 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 modest increases 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 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).

4.5 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 (2) 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 8) 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). When looking at the interaction between the demand shock and housing elasticity, it 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 9 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 note of caution, 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 8 is channeled through housing (i.e. location) costs.

4.6 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. As above, 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.[5] Moreover, we also build a measure of physical constraints at the LLM level; details about the principal components analysis are reported in Table 10.

Table 11 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.

Table 12 presents the estimate by using housing prices as dependent variable. Labor demand shocks determine a relevant increase in housing prices. A 10% shock determine a rise in prices by 28%; as before the effect 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.

5. 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

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

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. Descriptive statistics

	mean	Standard deviation	25th percentile	50th percentile	75th percentile
Housing supply elasticity	0.127	0.040	0.101	0.131	0.150
Housing stock growth rate	0.146	0.077	0.091	0.138	0.185
House price growth rate	0.921	0.684	0.470	0.621	1.369

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

Table 2. Physical constraints: principal component analysis (province level)

	Eigenvalue	Proportion	Cumulative
1st component	1.241	0.414	0.414
2nd component	0.953	0.318	0.731
3rd component	0.806	0.269	1.000
	Land slope	% water bodies	Patch density
Coefficients of the 1st component	0.663	0.437	0.608

Results of the principal component analysis.

Table 3. Determinants of housing supply elasticity

Dependent variable:	Housing supply elasticity				
	I	II	III	IV	V
Principal component:					
Physical constraints	-0.008**				
	(0.003)				
Single components:					
Land slope		-0.018			-0.007
		(0.022)			(0.025)
% water bodies			-0.122**		-0.096
			(0.061)		(0.072)
Patch density				-0.188**	-0.182**
				(0.073)	(0.078)
Observations	103	103	103	103	103
R-squared	0.051	0.007	0.007	0.069	0.075

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 4. Housing supply elasticity and city growth: baseline

Dependent variable:	Log of employees			
	I	II	III	IV
Demand shock	0.523***	0.632***	0.570***	0.692***
	(0.172)	(0.157)	(0.163)	(0.179)
Demand shock × HSE		0.456***		0.708***
		(0.050)		(0.223)
Demand shock × physical constraints			-0.202***	
			(0.056)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	35.0
Observations	515	515	515	515
R-squared	0.705	0.780	0.720	0.757

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; 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 5. Housing supply elasticity and city growth: robustness to IVs

Dependent variable:	Log of employees					
	I	II	III	IV	V	VI
Demand shock	0.535***	2.659	0.555***	1.124*	0.930***	0.674***
	(0.170)	(27.65)	(0.174)	(0.655)	(0.177)	(0.178)
Demand shock × HSE		8.976		2.522*		0.633***
		(115.9)		(1.406)		(0.134)
Demand shock × land slope	-0.220					
	(0.336)					
Demand shock × % water bodies			-5.130***			
			(1.580)			
Demand shock × land fragmentation					-2.729***	
					(0.836)	
City FEs	YES	YES	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES	YES	YES
Model	RF	IV	RF	IV	RF	IV
Physical attribute:	Land slope		% water bodies		Land fragmentation	
First stage F-statistics		0.0		1.3		51.1
Observations	515	515	515	515	515	515
R-squared	0.706	0.736	0.713	0.756	0.722	0.769

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; 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 variables are the interaction between (estimated) housing supply elasticity and the demand shock; the corresponding instrumental variables has been built accordingly (i.e. interacting the proxy of physical constraints with the demand shock). We consider separately the different components of physical constraints, i.e. land slope, % land covered of water bodies and land fragmentation (as measured by patch density). Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Housing supply elasticity and city growth: robustness to model specification

Dependent variable:	Log of employees		
Model	(1)	(2)	(3)
Demand shock	0.691***	0.880***	0.723***
	(0.237)	(0.185)	(0.209)
Demand shock × HSE	0.735	0.669***	0.939**
	(0.450)	(0.159)	(0.384)
City FEs	YES	YES	YES
Year FEs	YES	YES	YES
First stage F-statistics	11.4	53.5	19.1
Observations	515	515	515
R-squared	0.752	0.785	0.695

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; 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 (1) include controls for differential geographical areas and city size trends; in model (2) the observations are weighted by the t-student of housing supply elasticity estimates; in model (3) 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. Housing supply elasticity and house prices

Dependent variable:	Log of house prices			
	I	II	III	IV
Demand shock	0.059	0.046	0.020	-0.080
	(0.160)	(0.162)	(0.151)	(0.191)
Demand shock × HSE		-0.056		-0.584**
		(0.056)		(0.296)
Demand shock × physical constraints			0.167***	
			(0.063)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	35.0
Observations	515	515	515	515
R-squared	0.991	0.991	0.991	0.989

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; 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. Housing supply elasticity and city growth within a city

	Panel A			
Dependent variable:	Log of employees in the main municipality			
	I	II	III	IV
Demand shock	0.381**	0.504***	0.456***	0.648***
	(0.167)	(0.160)	(0.154)	(0.234)
Demand shock × HSE		0.515***		1.121***
		(0.053)		(0.326)
Demand shock × physical constraints			-0.320***	
			(0.057)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	35.0
Observations	515	515	515	515
R-squared	0.521	0.640	0.566	0.476
	Panel B			
Dependent variable:	Log of employees in the suburbs			
	I	II	III	IV
Demand shock	0.842***	0.925***	0.856***	0.892***
	(0.230)	(0.226)	(0.229)	(0.232)
Demand shock × HSE		0.346***		0.209
		(0.067)		(0.263)
Demand shock × physical constraints			-0.060	
			(0.077)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	35.0
Observations	515	515	515	515
R-squared	0.720	0.746	0.720	0.742

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 9. Housing supply elasticity and house prices within a city

	Panel A			
Dependent variable:	Log of house prices in the main municipality			
	I	II	III	IV
Demand shock	0.094	0.083	0.049	-0.068
	(0.164)	(0.167)	(0.155)	(0.211)
Demand shock × HSE		-0.049		-0.683**
		(0.056)		(0.325)
Demand shock × physical constraints			0.195***	
			(0.064)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	35.0
Observations	515	515	515	515
R-squared	0.991	0.991	0.991	0.988
	Panel B			
Dependent variable:	Log of house prices in the suburbs			
	I	II	III	IV
Demand shock	-0.025	-0.036	-0.062	-0.157
	(0.180)	(0.181)	(0.171)	(0.204)
Demand shock × HSE		-0.049		-0.556*
		(0.060)		(0.309)
Demand shock × physical constraints			0.159**	
			(0.066)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	35.0
Observations	515	515	515	515
R-squared	0.990	0.990	0.990	0.988

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 10. 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.

Table 11. Housing supply elasticity and city growth: LLMs

Dependent variable:	Log of employees			
	I	II	III	IV
Demand shock	0.813***	0.832***	0.845***	0.970***
	(0.101)	(0.0977)	(0.0937)	(0.142)
Demand shock × HSE		0.132		1.070*
		(0.0820)		(0.598)
Demand shock × physical constraints			-0.132*	
			(0.0703)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	10.1
Observations	1,168	1,168	1,168	1,168
R-squared	0.227	0.232	0.239	0.235

Panel regression where the units of analysis are LLMs, observed in census years 2001 and 2011. The dependent variable is the log of employment; 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 12. Housing supply elasticity and house prices: LLMs

Dependent variable:	Log of house prices			
	I	II	III	IV
Demand shock	2.817***	2.488***	2.774***	2.604***
	(0.310)	(0.287)	(0.313)	(0.345)
Demand shock × HSE		-2.246***		-1.458
		(0.283)		(1.118)
Demand shock × physical constraints			0.180	
			(0.152)	
City FEs	YES	YES	YES	YES
Year FEs	YES	YES	YES	YES
Model	OLS	OLS	RF	IV
First stage F-statistics	-	-	-	22.7
Observations	1,168	1,168	1,168	1,168
R-squared	0.754	0.786	0.755	0.782

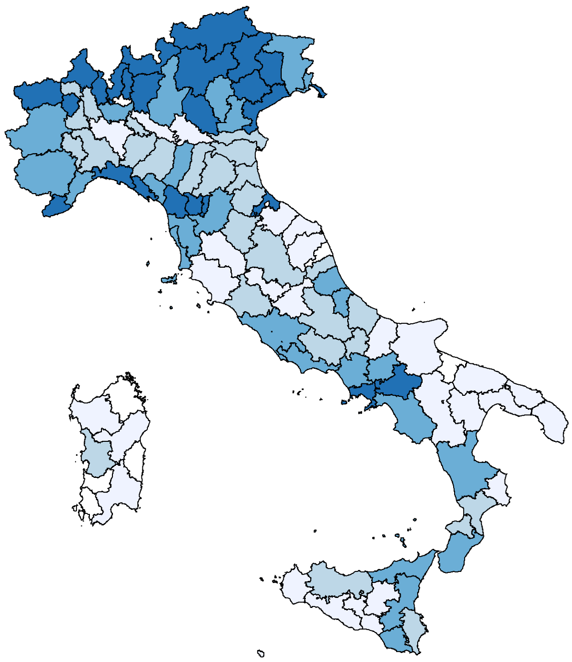
Panel regression where the units of analysis are LLMs, observed in census years 2001 and 2011. The dependent variable is the log of house prices; the demand shock is the log of employment predicted on the basis of the initial sector composition of the local economy and the national sector dynamics. The 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.

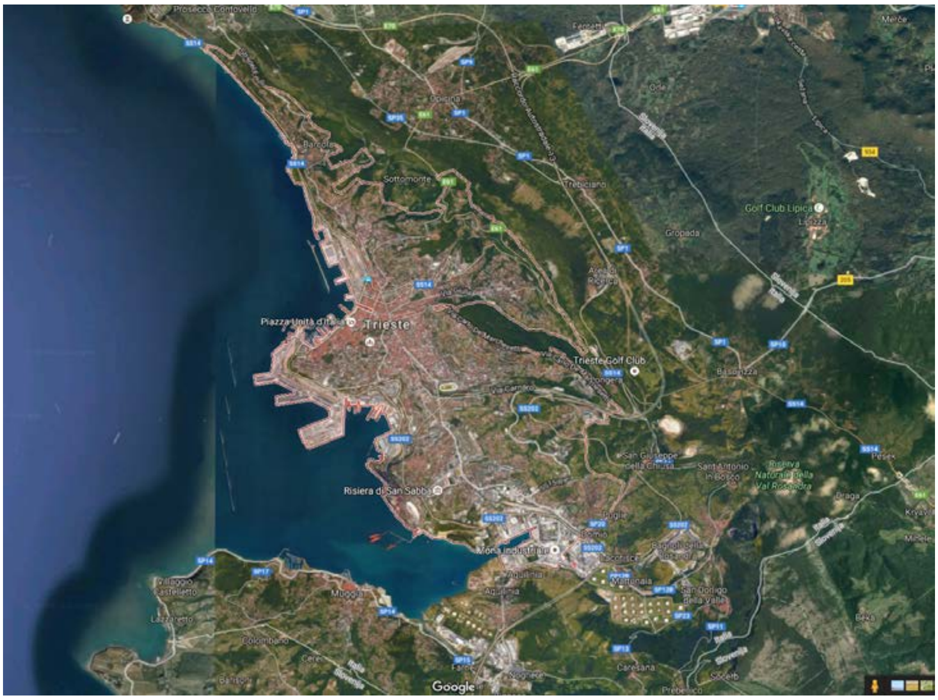
Figure 2. Physical constraints across provinces



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

Figure 3. Physical constraints and housing supply elasticity

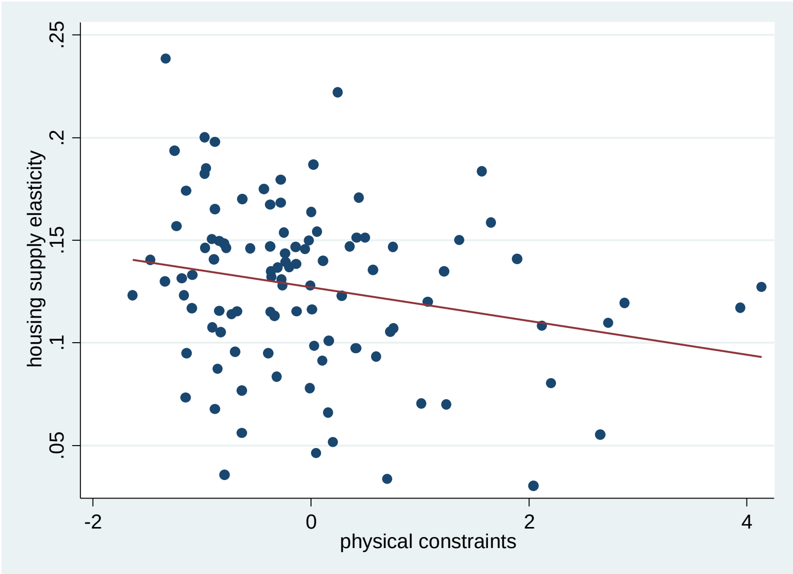
Trieste: high physical constraints and low housing supply elasticity



Oristano: low physical constraints and high housing supply elasticity

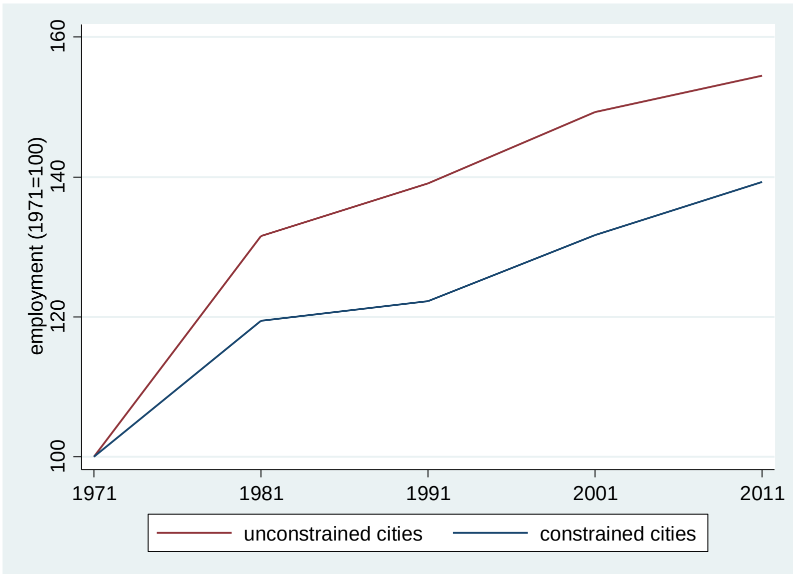
Source: Google earth view.

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

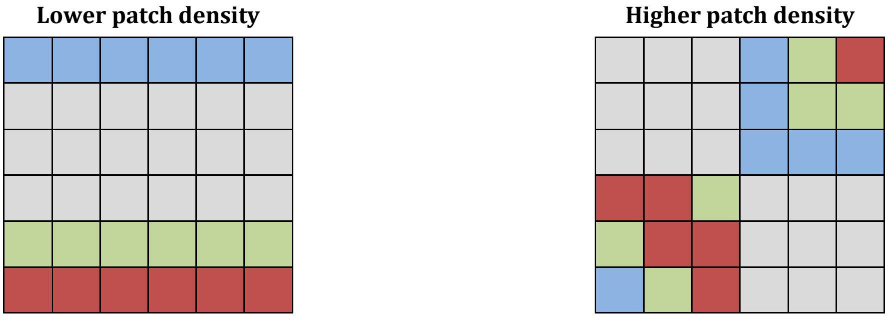


Constrained (unconstrained) cities are those with the physical constraint index above (below) the median. Source: authors' elaborations on data from Istat and ISPRA.

Appendix

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.