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HOW RESPONSIVE ARE HOUSING MARKETS IN THE OECD? NATIONAL LEVEL ESTIMATES

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ABSTRACT/RÉSUME

How responsive are housing markets in the OECD? National level estimates

The trend rise of house prices in many OECD countries suggests weakness in the adjustment of supply to demand. This paper estimates long-term elasticities of housing supply to prices in OECD countries before exploring their drivers with a focus on policies. It finds a significant association between weaker supply responsiveness and a proxy measure for more restrictive land-use regulation. Besides, tighter rent controls are linked with lower supply elasticities. In turn, weak supply responsiveness implies that house prices rise more following stronger demand. The sensitivity of house prices to household income is also higher in countries that provide larger amounts of tax relief for homeowners.

JEL Classification codes: O18, R31

Keywords: Housing, house prices, residential construction, land use regulation, taxation

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Dans quelle mesure les marchés de l'immobilier sont-ils réactifs dans l'OCDE? Estimations au niveau national

La tendance à la hausse qui frappe les prix de l'immobilier résidentiel dans de nombreux pays de l'OCDE suggère que l'offre peine à s'y ajuster à la demande. Cette étude estime des élasticités-prix de long terme de l'offre avant d'en rechercher les déterminants avec un intérêt particulier pour le rôle des politiques publiques. Ce travail fait apparaître un lien significatif entre une plus faible réactivité de l'offre et une mesure indicative d'une orientation plus restrictive des politiques d'occupation des sols. Une réglementation plus stricte des loyers se révèle elle aussi associée à une plus faible élasticité de l'offre. À son tour, une plus faible réactivité de l'offre entraîne que les prix de l'immobilier résidentiel s'accroissent davantage pour une même augmentation de la demande. De plus, les prix de l'immobilier résidentiel sont plus sensibles aux variations de revenu des ménages dans les pays qui offrent de plus larges réductions fiscales aux propriétaires.

Classification JEL : O18, R31

Mots-clés : Logement, prix de l'immobilier résidentiel, construction résidentielle, politique foncière, taxation.

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HOW RESPONSIVE ARE HOUSING MARKETS IN THE OECD? NATIONAL LEVEL ESTIMATES

Maria Chiara Cavalleri, Boris Cournède and Ezgi Özsöğüt[1]

1. Introduction and main findings

1. The trend increase of house prices in many countries has undermined the affordability of housing. A recent OECD estimate suggests that it took 6.8 years of annual income in the mid-1980s to buy a house, while it now takes more than 10 years (OECD, 2019[1]). A sufficiently elastic supply ensures that the economy responds to housing needs in a timely manner without large price increases, thus underpinning housing affordability. The experience of the past three decades, during which housing has been a key channel of several economic crises including the global financial crisis as well as the decline in housing affordability, has revived interest in better understanding the dynamics of housing supply. Promoting affordable, good-quality housing is a policy priority for OECD governments.

2. This paper contributes to this debate with new analyses on the responsiveness of housing supply. A more elastic housing supply means that the economy provides additional dwellings more readily, when there is demand for them. A higher supply elasticity is therefore an indicator of greater economic efficiency as well as better inclusion by preventing price rises that would undermine access. The poor are the first to be crowded out in rigid markets (Grossmann et al., 2019[2]). An elastic housing supply allows a smooth adjustment of the dwelling stock to demand pressures and limits the adverse effects on consumption, mobility and employment that accompany rigid housing markets (Caldera Sánchez and Johansson, 2013[3]). Regulations that restrict housing supply can thus entail large economic costs: they have been found to impede worker movement to high-income areas, weakening convergence in human capital and per capita income (Ganong and Shoag, 2017[4]); a recent study estimates that misallocation resulting from overly tight land-use regulation has reduced US output by 36% over the period 1964-2009 (Hsieh and Moretti, 2019[5]). By facilitating geographic mobility, a more elastic supply of housing can also create incentives to provide local services more efficiently; there is empirical evidence that the local governments of areas where housing supply is more inelastic are more capable to hike taxes without providing additional services (Diamond, 2017[6]). Regulations that restrict housing supply have also been found to make homes more likely to be vacant, as these regulations exacerbate

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mismatches between supply and demand (Cheshire, Hilber and Koster, 2018[7]).[2] High house prices have even been seen as encouraging crime (Song, Yan and Jiang, 2019[8]).

3. Over the past decades, increases in real house prices have been positively correlated with population growth in a number of OECD countries (André, 2010[9]). Overall, the housing stock has adjusted in response to demand pressures, though more sluggishly in some countries than in others (Figure 1). Despite this, there remain today shortages of dwellings in a large number of OECD countries, where many households, especially poor ones, suffer from overcrowding (André and Chalaux, 2018[10]).

Figure 1. Population and housing stock growth

Note: The figure shows average annual population and housing stock growth between 1990 and 2018. Population growth includes the cohorts aged between 25 and 74 years. Housing stock growth is the average annual change in the number of residential dwellings in the country. The first observation is in 1990 for all countries except for Canada (1996). The last observation is in 2018 for all countries except for Canada and Ireland (2016), Australia and the United Kingdom (2015), Italy (2014), Switzerland, the United States, Portugal, Spain and Finland (2017).
Source: OECD Economic Outlook database and OECD Questionnaire on Affordable and Social Housing.

4. Cross-country research on the responsiveness of housing supply has been limited, predominantly because of data limitations. There is more research on regional supply responsiveness within a country (especially the United States) than across countries. Previous OECD research (Caldera Sánchez and Johansson, 2013[3]) has provided estimates of country-specific housing supply elasticities for 21 OECD countries using data from the early 1980s until the great financial crisis. Their results suggest that housing supply is more responsive to demand shocks in the United States followed by Sweden and Denmark. In all these countries, the housing supply elasticity is estimated to be above unity, implying that positive demand shocks would be absorbed predominantly by higher investment rather than by an increase in house prices. By contrast, lower elasticities are found in continental Europe (Austria, the Netherlands and Switzerland),

2. Restricting housing supply also increases the opportunity cost of vacancy, but empirically the mismatch effect dominates the opportunity-cost effect (Cheshire, Hilber and Koster, 2018[7]).

where investment reacts less to increased demand. The range of estimates lies between 0.15 and 2. More recently, Geng (2018[11]) using the same methodology as Caldera Sánchez and Johansson (2013[3]), has estimated country-specific supply elasticities for a sample of 20 OECD countries over the period 1989-2016, finding similar relative positions between countries and slightly less variation across estimates.

5. The present study contributes to the literature on the responsiveness of housing supply. It provides estimates of the price elasticity of residential investment for 25 economies using a multi-factor panel error correction model based on data from the 1980s to the end of 2017. It also investigates the impact of policies on these elasticities. In addition, the study estimates income elasticities of prices, which measure how prices respond to demand pressures, and relates them to supply elasticities while exploring the role of policies.

6. The main findings are:

- Confirming and extending previous research, housing supply responds differently to demand shocks across countries.
  - A group of countries exhibits strong responses to demand pressure, with supply elasticities that are estimated to be significantly above unity: Ireland, Norway, Sweden and the United States.
  - At the other end, supply elasticity estimates are significantly below one in Austria, Belgium, France, Germany, Israel, Italy, the Netherlands and Switzerland.
  - The supply elasticity is statistically equal to one in the other 13 countries in the sample.
- The cross-country variation in the estimated supply elasticities can be linked to differences in:
  - Geographical constraints and land-use regulations that limit further urban expansion or reduce incentives for new construction. Caveats are that, at the national level, geographical constraints are hard to summarise and proxies have to be used to gauge the average tightness of land-use regulations.
  - Tighter rent controls are linked with lower supply elasticities, presumably because they reduce the expected rental value of dwellings and hence the incentive to build them.
- Estimated income elasticities of house prices show that:
  - In countries with low supply elasticities, prices rise more in the face of greater demand.
  - Greater tax relief for home owners makes prices increase by more in the face of rising demand.

7. Housing markets are local rather than national, but the estimated national supply elasticities are in line with aggregating the results from region-level analysis reported in a companion paper (Bétin and Ziemann, 2019[12]). Furthermore, the regional evidence corroborates the findings from national-level analysis regarding the influence of land use restrictions on supply elasticities.

8. The next section presents the econometric framework. Section 3 reports estimated long-run price elasticities of housing supply, before policy and non-policy drivers are investigated in Section 4. The next section (5) discusses cyclical implications

of supply elasticities. The paper then turns to the long-term behaviour of prices (Section 6) before brief concluding remarks (7).

2. Econometric framework and specification

9. This study focuses on the long-run price elasticity of new housing supply akin to earlier work by the OECD (Caldera Sánchez and Johansson, 2013[3]). More in-depth analysis of how the housing market and policies influence crises and resilience can be found in a recent study (Cournède, Ziemann and Sakha, 2019[13]).

10. The data available at the national level allow the estimation of housing supply and price equations (see Table B.7. for a detailed description of the data). Early empirical studies of the housing market focussed on reduced-form estimations and formulating assumptions to derive supply or demand elasticities from the reduced-form coefficients (Muth, 1969[14]; Harter-Dreiman, 2004[15]). More recent studies generally estimate housing supply separately, usually as a function of several cost and price indicators. Alternatively, housing supply can be estimated as part of a system, often based on a stock-flow model, yielding a price equation together with an equation for new construction. Earliest examples of such models find their roots in conventional investment theory. Poterba (1984[16]) defines housing supply as net residential investment and estimates an asset-market model of the owner-occupied housing market. DiPasquale and Wheaton (1994[17]) use a stock adjustment model where the housing stock adjusts slowly to changes in demand and stock equilibrium is achieved only in the long run. Overall, while there is quite some variability in the theoretical foundations of empirical models of the housing markets, the estimated equations are not necessarily inconsistent and often quite similar (Annex A).

11. Following DiPasquale and Wheaton (1994[17]), the empirical approach in the present study builds on a stock-flow model of the housing market given by the following two equations:

$$S = I(X_2, P) + (1 - \delta)S_{t-1} \quad (1)$$

$$D(X_1, P) = S \quad (2)$$

12. On the supply side, equation (1) links changes in the housing stock (S) to new housing investment (I) such that, in the long run, the housing stock depreciates slowly at rate δ and expands gradually with new residential investment. Housing investment (I) in turn depends on house prices (P), as well as several cost shifters such as material and labour costs, summarised in the vector of variables X_2. Because of the durable nature of housing, the gradual adjustment of the stock of housing is driven primarily by the change in investment (DiPasquale and Wheaton, 1994[17]). For estimation, real residential investment is used as a proxy for the change in the housing stock and construction costs are used to gauge cost shifters, which yields the supply specification:

$$ln\, I = \beta_0 + \beta_1 lnP - \beta_2 lnCC \quad (3)$$

13. House prices are expected to raise residential investment, implying that when house prices are high there is an incentive for developers to invest, because of the chances of making large profits. Conversely, when construction costs are high, investment activity

is depressed since it is more expensive for investors to replace the existing stock of dwellings with new ones.[3]

14. On the demand side, equation (2) posits that the demand for housing is driven by a number of factors (captured in vector X_1) and that prices clear the market to bring demand in line with the available supply. Inverting the demand function (2) and log-linearising gives an empirical specification of the price equation of the form (4):

$$lnP = \alpha_0 + \alpha_1 lnY + \alpha_2 lnPOP + \alpha_3 lnS + \alpha_4 r \quad (4)$$

15. As in Meen (2002[18]), house prices (P) are related to real household disposable income (Y), population (POP), the stock of dwellings (S) and the real average mortgage interest rate (r). This specification of the price equation is akin to Muellbauer and Murphy's (2008[19]): real mortgage interest rates capture a key part of the user cost; population features on its own (in addition to driving the level of income) to capture the impact of changes in household size. The two equations (3) and (4), derived here from a stock-flow approach, also stem from life-cycle models (see Annex A).

16. Given the interest in estimating long-run supply elasticities, the investment equation (3) is estimated in an error correction (ECM) framework that links the variables in a composite model of short-run dynamics and fundamental conditions. A two-step procedure is applied. First, a cointegrating regression is estimated, representing the long-run equilibrium relationship. Standard panel unit root and cointegration tests are reported in Annex B. The second step involves the estimation of an equation representing the short-run dynamics augmented with the error correction component from the first stage to control for the adjustment process towards the long-term equilibrium. In the present study, this second step is essentially a validation step to verify that adjustment does indeed happen to the long-term equilibrium relationship estimated in the first step. The other estimated coefficients in the short-run equations are of lesser interest, given the focus on the long-run performance of the market (as opposed to where the emphasis would be if the objective were to produce short-term house price forecasts).

17. As part of the first stage, a long-run investment equation is estimated in a heterogeneous panel model with a general multi-factor error structure (Pesaran, 2006[20]). The long-run component of the ECM framework is hence an equation explaining residential investment as a function of real house prices and construction costs.

$$ln\, I_{c,t} = \beta_c^0 + \beta_c^1 ln\, P_{c,t} + \beta^2 ln\, CC_{c,t} + h' f_t + \varepsilon_{c,t} \quad (5)$$

18. In equation (5), *ln I* is the logarithm of real residential investment for country *c*, *ln P* is the logarithm of real house prices for the same country[4] and β^1 is the price elasticity of housing supply, measuring the extent of the supply adjustment to house prices. *lnCC* refers to construction costs, expressed in logarithmic terms, and f is a *n*-dimensional vector of unobserved exogenous factors common to all countries (Pesaran, 2006[20]). Common factors control for global variables or shocks that affect residential investment. In the framework of a housing supply equation, global unobserved factors would capture

3. This approach is similar to a Tobin's Q model of (residential) investment.

4. Alternative regressions experimented with real rent indices as a potential driver of construction, since rental units make up a substantial share of the housing stock in some OECD countries. However, no stable relationship could be identified, probably reflecting that house prices better capture the net present value from holding a house.

those elements of investment dynamics that are the result of technological progress in construction activity, globalisation effects, the synchronisation of housing cycles, trends in international capital flows, global demographic trends, secular changes in individual preferences and common trends in living standards.

19. The introduction of a factor structure helps when, as is the case in the present study, data constraints preclude expanding the model to a specification including many more control variables. In practice, the *n* factors are built as the cross-sectional averages of all the regressors (including instruments) and the endogenous variables that enter the model. These cross-sectional averages are assumed to influence residential investment across multiple countries at the same time, but each country reacts to them with a specific vector of factor loadings h'. The idiosyncratic error term ε is assumed to be independent of both explicit regressors in the equation as well as the factors f, but it allows for weak cross-sectional correlation.

20. The econometric framework detailed in equation (5) is likely to suffer from endogeneity between investment and house prices, and between investment and construction costs. The nature of endogeneity can be twofold:

- First, there could be a problem of omitted variable bias, if there exists a variable correlated with both investment and house prices that is not included in the regression. The use of factor variables helps to tackle this potential source of bias.
- Second, there could be reverse causality from investment to house prices, because a large increase in new construction could depress house prices. The analysis tackles this potential source of bias by instrumenting real house prices with their lags or demand factors (see Annex B for more details on the endogeneity challenges and the instrumental-variables strategy). Similarly, investment could affect construction costs in episodes of growing activity and constrained input provision: the specification hence uses lagged values of the construction cost variable.

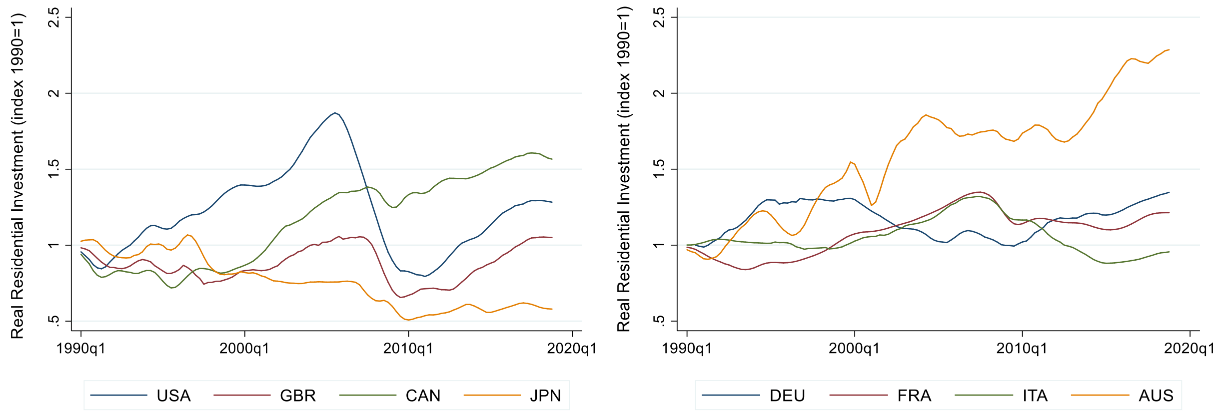
21. The second step looks at the short-run reaction of residential investment to house price changes and cost shifters, taking into account the presence of persistence effects. Annex B presents the estimation strategy and results for the short-run stage.

22. Equation (5) is estimated in a panel setting, which includes 25 countries using quarterly data from 1980Q1 to the end of 2017. The dependent variable is real residential investment, measured as the volume of gross fixed capital formation in housing. Figure 2 shows the profile of residential investment for a sample of OECD economies in the past 30 years. In Canada and Australia, residential investment has been on an upward trend since at least the early 2000s. The United States have experienced marked cyclical variations in housing investment around the mid-2000s, which have continued. In the United Kingdom, Italy and France, recent cycles in residential investment have been more modest in amplitude. Cournède, Sakha and Ziemann (2019[13]) provide more detailed indicators of housing dynamics in OECD countries.

23. Real residential property prices are inflation-adjusted nominal price indices sourced from the OECD database. For a majority of countries, these series are composed of the hedonic price of all types of dwellings (e.g. single-detached and semi-detached houses, multi-family apartments, condominiums and coops). Population series refer to the total population from the UN World Population Prospects database. Income is defined as real household disposable income per capita, the deflator being the private consumption deflator.

Figure 2. Residential investment

Selected OECD countries



Source: OECD Economic Outlook database.

24. The deflator of residential investment is used to measure the cost of construction. In OECD countries, after a long period of decline, real construction costs have been increasing rapidly from the early 2000s until the peak of the latest housing cycle. This cyclical pattern could reflect rising prices of construction material and rising marginal costs, possibly due to tensions on production capacity (André, 2010[9]). The behaviour of real construction costs has been highly heterogeneous across countries in the aftermath of the financial crisis.

25. In addition to the series already described, the explanatory variables in the price equation (4) include the housing stock and mortgage interest rates. Both are sourced from the European Mortgage Federation (EMF) Hypostat database. As this database has limited coverage prior to 2001, both series are extended to missing countries and years using previously available data taken from Caldera Sánchez and Johansson (2013[3]).

3. Empirical findings: the long-run price elasticity of housing supply

26. Table 1 presents the results of the estimation of the long-run supply equation detailed in equation (5), where real house prices are instrumented and construction costs enter with a lag. Four panel data estimators are tested and compared.

27. Columns 1 and 2 of Table 1 report results of panel models where the presence of cross-sectional dependence across countries has been taken into consideration and corrected with the addition of a vector of common shocks *f*. This specification corresponds to Pesaran's (2006[20]) Common Correlated Effects (CCE) model. Columns 3 and 4 report results of robustness tests where only country and quarterly time fixed effects are included in the panel model, thus representing a two-way fixed effect model (2WFE). Imposing homogeneity in the estimated coefficients ($\beta_c^1 = \beta^1$) allows to estimate pooled (P) panel regression models. When, instead, the model allows for country-specific slope coefficients, each cross-sectional unit will have its estimate of β^1 and the panel model is heterogeneous in nature. In the econometric setup of Table 1, which includes no geographical or policy variables to capture cross-country heterogeneity, the CCE MG model performs best from an econometric standpoint.

Table 1. Long-run price elasticity of housing supply

Panel results over a sample of 25 countries over the period 1980Q1-2017Q4

	(1)	(2)	(3)	(4)
Dependent variable: real residential investment (I)	CCE MG	CCE P	2WFE MG	2WFE P
Real house prices (P)	1.03***	0.96***	1.04***	0.80***
	(0.11)	(0.11)	(0.091)	(0.06)
Lag of construction costs (CC_{t-1})	-0.20	-0.23	-0.24*	-0.28*
	(0.15)	(0.16)	(0.14)	(0.15)
Observations	2 840	2 840	2 840	2 840
Countries	25	25	25	25
F Stat	239	103	479	90.1
Adjusted R^2	0.49	0.36	0.54	0.40
CD stat	5.01	3.00	-5.24	-2.53
Mean ρ	0.02	0.01		

Note: Standard errors (in parenthesis) are kernel-robust to arbitrary common correlated disturbances (Driscoll-Kraay). Statistical significance thresholds: *** p<0.01, ** p<0.05, * p<0.1. The CCE (Pesaran's (2006) Common Correlated Effects) models include country fixed effects and factor variables which are omitted from this table. The 2WFE models include country and time fixed effects which are not shown here. MG refers to the Mean Group estimator, i.e., the average of country-specific estimates. P refers to pooled estimation. CD stat is the result of the cross-sectional dependence test applied to the residuals of the model. Mean ρ is the estimated average pair-wise correlation across cross-sectional units, computed with the CD test.
Source: Authors' calculations.

28. Column 1 reports the results of the baseline specification, which allows for the presence of common factors (and, hence, it controls for spatial autocorrelation) and heterogeneous slope coefficients (β_c^1). The average elasticity of housing supply (Mean Group estimates) is slightly above unity, at 1.03, and results are statistically significant at standard threshold levels. Imposing coefficient homogeneity in the CCE model leads to the estimates shown in Column 2. In this case, the estimated elasticity is lower but still close to unity.[5] In addition, the average elasticity in the CCE MG estimator is very close also to comparable results when a model of housing demand and supply is estimated simultaneously (see Annex Table B.5).

29. Columns 3 and 4 show the results of simpler models with no common factors (*h'*=0), hence the models can possibly show correlated error terms across the cross-sectional dimension. Column 4 presents the results of a pooled estimation across the 25 countries using a two-way-fixed-effect pooled model (2WFE P), with country and time dummies. The estimated elasticity is below unity in a statistically significant way at 0.8. When the same panel model with country and time effects is estimated without imposing homogeneity (Column 3) the average elasticity of the cross-section (Mean Group estimator) is higher, close to unity and very similar to the baseline specification of Column 1. Overall, the results of the specification with and without common factors are similar, especially when not imposing a common slope. The similarity of results is

5. Both results are qualitatively similar, but there is a better performance in terms of R^2 of the mean group (CCE MG model) compared with the pooled specification. Post-estimation tests on the residuals allow detecting the presence of remaining cross-sectional dependence in the model. The CD test statistics run on the residuals point to the presence of some residual cross-sectional correlation, but this is close to zero ($\rho \approx 0$).

taken as an indication that the CCE MG model yields valid results while the CCE P and 2WFE MG models are sound approximations. By contrast, the two-way fixed effect pooled model does not have enough flexibility so that the pooled coefficient on real house prices is downward biased by the countries where it is very low.

30. The mean-group estimation (Column 1) allows looking at the country-specific estimates of the supply elasticities (detailed in Figure 3 and in Annex Table B.6). These estimates are highly (90%) correlated with the previous estimates by Caldera Sánchez and Johansson (2013[3]). They differ, however, by covering more countries and being often larger. The differences come from using up-dated data, which advance the end-point of the estimation from the first quarter of 2009 to the last one of 2017, and moving from single-country models to a panel specification with heterogeneous coefficients and common factors.

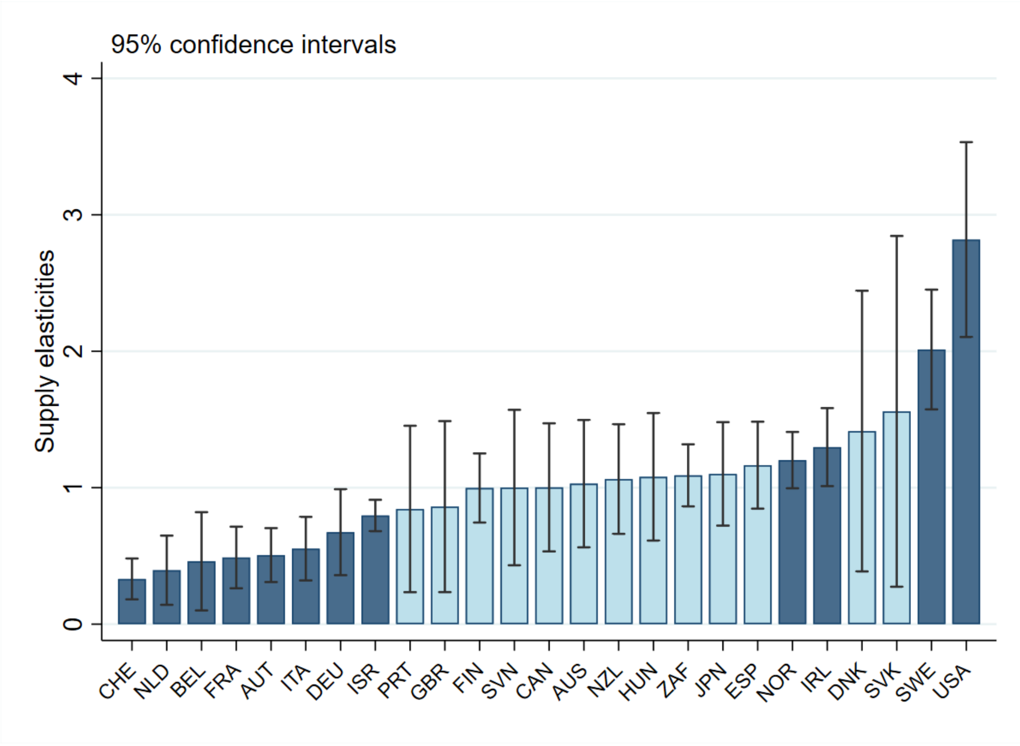
31. Three groups emerge with regards to the estimated supply elasticities:

- A central, large group of countries where the price elasticity of supply is statistically equal to one: Australia, Canada, Denmark, Finland, Hungary, Japan, New Zealand, Portugal, Spain, Slovakia, Slovenia, South Africa and the United Kingdom. For Denmark and Slovakia, this result occurs despite relatively large estimated coefficients as a result of substantial noise in the estimation of the country-specific coefficient.
- A group of countries where the elasticity is significantly above unity: Ireland, Norway, Sweden and the United States.[6]
- A group of countries where the elasticity is significantly lower than unity (yet greater than zero): Austria, France, Germany, Israel, the Netherlands, and Switzerland.

32. The coefficient on the lagged construction cost term is negative, as expected, yet slightly significant only in the 2WFE estimators. In a large part of the literature, construction costs, although always included in the regressions, are hardly ever significant. Most studies tend to agree on the presence of measurement errors and on the difficulty to proxy accurately for this variable in empirical investigations. The absence of a significant effect in the baseline model is also probably reflecting this difficulty.

6. The high level of the estimated price elasticity of supply in the United States is in line with earlier studies (Caldera Sánchez and Johansson, 2013[3]; Malpezzi and Maclennan, 2001[39]).

Figure 3. Estimated supply elasticities by country

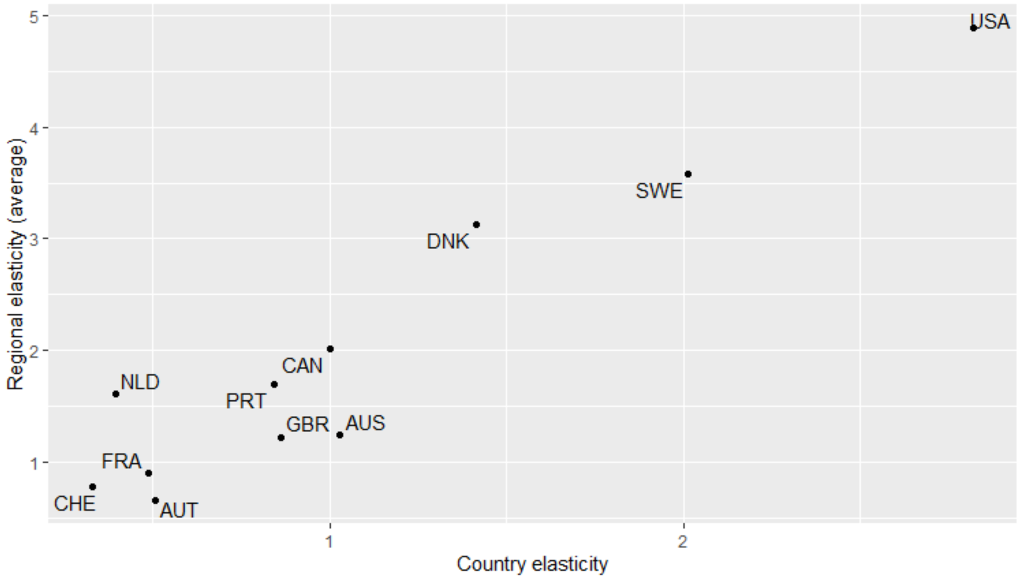


Note: The figure shows estimates of the long run supply elasticity (the β^1 in equation (5)) by country using the CCE MG approach in an unbalanced panel dataset of 25 countries from 1980Q1 to 2017Q4. Bars indicate the point estimate and the vertical lines show the corresponding confidence interval. Light blue bars indicate coefficients that are statistically equal to one.
Source: Authors' calculations.

33. Estimation of the short-run dynamics of the model confirms the presence of significant adjustment to the estimated long-run relationship, validating the approach (see the first section of Annex B, Table B.1 and Column 2 of Table B.6). Indeed, across the five estimation approaches, the convergence coefficient is always statistically and economically significant.

34. Housing markets are local rather than national, which raises a question as to whether supply elasticities estimated at the national level do indeed reflect an aggregate view of developments across each country. A companion paper estimates housing supply elasticities by region after controlling for natural constraints that are measured using geospatial data, matched to the urban areas in the covered regions (Bétin and Ziemann, 2019[12]). Overall, averaging the regional results by country yields estimates that are tightly correlated with the estimates from the country level analysis (Figure 4). This close link indicates that there is no aggregation bias at the national level, giving strength to the analysis conducted on national data.

Figure 4. Comparing regional to national estimates of housing supply elasticities

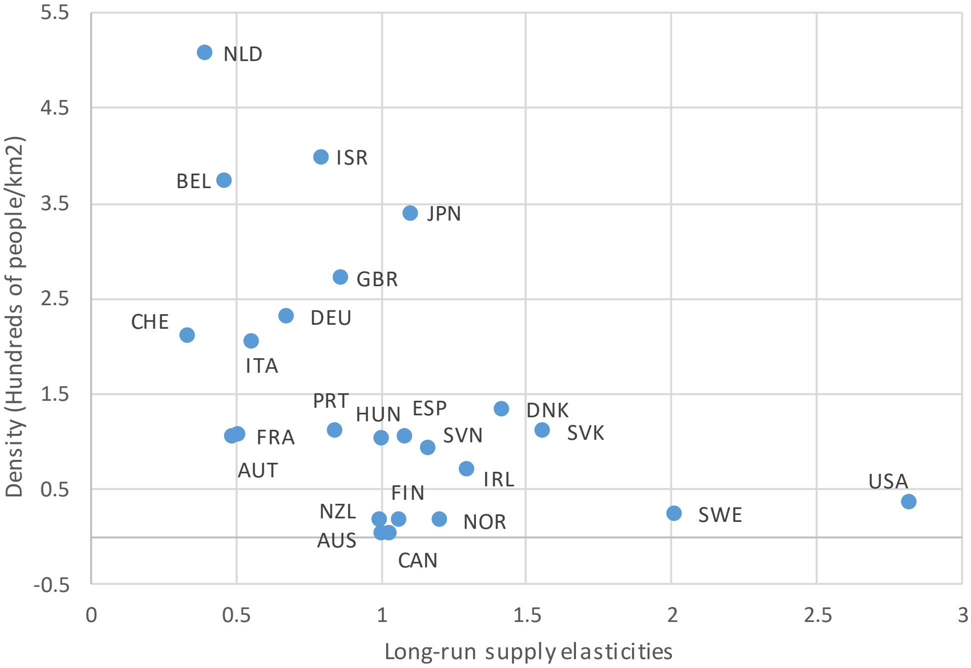


Note: Methodological differences resulting from the need to adapt to limitations of regional data imply a level difference between the national and regional estimates.
Source: Own calculations for the national estimates and Bétin and Ziemann (2019[12]) for the regional ones.

4. Determinants of long-run supply elasticities: The role of policies and geographic barriers

35. Cross-country differences in the supply responsiveness to prices are likely to stem at least in part from differences in demographic pressures and policies. As in previous research, this study finds that the cross-sectional variation of supply elasticities is negatively correlated with population density (Figure 5), a result that presumably captures the scarcity of developable land: areas with high population density are more likely to be more constrained to further urban expansion. This link is considerably tighter at the local level, as apparent in Bétin and Ziemann's (2019[12]) regional analysis.

Figure 5. Supply elasticities and population density



Note: Population density (hundreds of people per km^2) in 2017 or latest available date.
Source: Authors' calculations and OECD Regional Demography database.

36. There is limited analytical work on the factors explaining differences in housing supply responsiveness across countries. Such research is comparatively more abundant when explaining differences across regional and metropolitan areas, especially in the United States (Green, Malpezzi and Mayo, 2005[21]; Saiz, 2010[22]; Mayer and Somerville, 2000[23]). The regional literature generally agrees on the role played by constraints to land use and urban development originating from either regulatory or geographic barriers. The consideration of additional policy factors that could potentially affect supply decisions from the point of view of investors, such as fiscal and rental regulation, is less common.

37. At the aggregate level and across OECD countries, there is a lack of reliable and comparable data on barriers to new housing development, such as those due to land-use regulation. This is due to the intrinsic local nature of urban planning. Indeed, a majority of OECD countries has land use regulations set at the municipal or regional level, while the national government is predominantly involved with setting guidelines and general principles. How stringent and enforced the regulations for further expansion are varies greatly even across regions or municipalities within the same country. Similarly, the assessment of geographic constraints to urban development is hindered by the difficulty of an accurate assessment of technological limitations and the unpredictability of future urbanisation pressure. In addition, there is a possible risk of reverse causality, as, on the one hand, low elasticities could be the result of stringent regulation enforced over the years but, on the other hand, the enforcement of regulation over time could be the reaction to an otherwise highly elastic supply.

38. In terms of geographic barriers, the analysis of the impact of land restrictions on construction activity is limited by the fact that these barriers are more likely to exert their impact at the regional or metropolitan level. Aggregate analysis is likely to show aggregation bias, especially as more constrained, high-density areas are being averaged with areas with sparse population and smaller demand pressures.

39. Bearing these caveats in mind, it is still worth investigating how the variation of housing supply elasticities is affected by the combination of land use and urban development constraints, originating from either regulatory or geographic barriers in a way similar to that of Green, Malpezzi and Mayo (2005[21]) and Saiz (2010[22]) in relation to US local markets. Even imperfectly captured, the cross-country heterogeneity in the estimated supply elasticities could still reflect largely the distinct institutional characteristics of each national housing market, as well as the geographic constraints to further development that are typical of each region. This section presents results from this analysis. However, the empirical results presented in this section should be interpreted with caution, because of the lack of not only adequate data on regulatory restrictions to new housing development but also a precise assessment of the extent and stringency of geographic barriers. The precise assessment of these barriers is also prone to mismeasurement and to revisions over time as regulation can change and because rapid technological developments in housing construction could make it possible to build in areas previously considered as impracticable.

40. Building on an analysis similar to Saiz (2010[22]), the estimates of the supply elasticities turn out to be negatively affected by the presence of geographic or policy barriers. Where such barriers exist, housing supply cannot easily respond to price increases, even in competitive construction markets. The extent of geographic barriers is gauged by an indicator of available or developable land based on aggregate data on land cover. Available land is measured as the share of non-water surfaces in a country that is not (yet) occupied by buildings.[7] Figure 6 shows the share of developed land over total available land. Countries with currently limited artificial surfaces compared with the total available land could face low geographic constraints to expand further the share of urban land, and hence show a high elasticity of supply. Conversely, in countries, such as the Netherlands and Belgium, where the share of artificial land is already high, there can be relatively little room for further urban expansion of available land should population pressures rise. The inverse of the developed land indicator is a proxy that measures the extent of geographic barriers to further urban and artificial developments.[8]

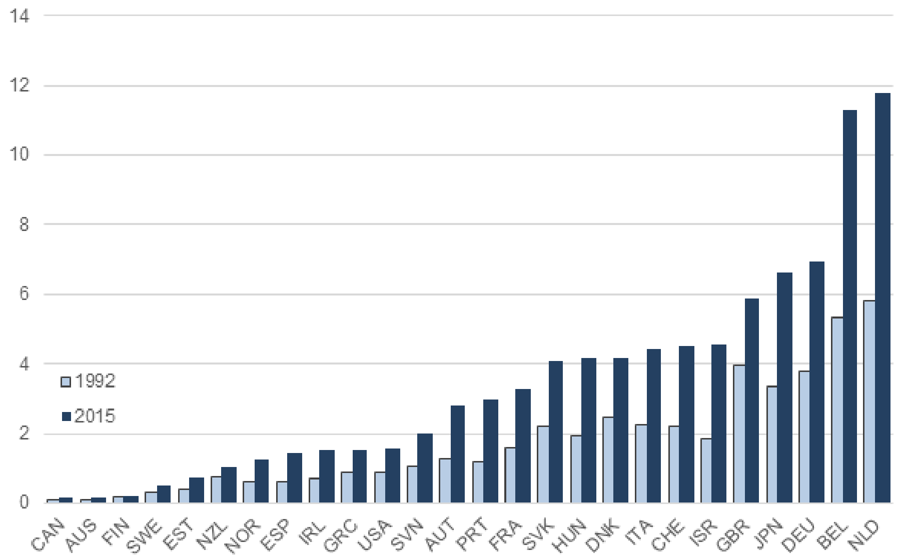
41. As a gauge of land-use regulatory restrictions across a country, two indicators are considered. The first one (introduced immediately below) is based on the distribution of land-use regulation powers across government levels. The second one (discussed further below) is the change in built-up area per capita observed over the period 1975-1990.

7. In Saiz's (2010[22]) analysis, available land is also identified by excluding steep surfaces. As this information is not available on a country-aggregate measure, such a correction is not included.

8. A drawback of the indicator of available land is that it does not control for the possibility of further compact development, that is, urban expansion that does not consume additional land, such as the case of vertical expansion and densification.

Figure 6. Developed relative to developable land

Percentage of total developable land, 1992 and 2015



Note: The indicator represents the share of a country's total artificial surfaces over total developable land. Developable land is land that could potentially be used for the development of urban and artificial surfaces. It is a rough proxy since it covers current artificial surfaces and all natural and semi-natural areas in a country, excluding surfaces occupied by oceans and inland waters.
Source: OECD Land cover database and OECD computations.

42. A novel cross-country proxy indicator inspired by the Wharton Residential Land Use Regulatory Index has been built for this study to gauge the restrictiveness of land use regulation. This new indicator uses the replies to the 2019 OECD Questionnaire on Affordable and Social Housing. It comprises two components:

- *Decentralisation:* Countries with more decentralised land-use and planning regulation can be anticipated, overall, to enforce tighter planning regulation: the reason stems from political-economy considerations. Indeed, the more planning decisions are made locally, the more effectively local owners can push for restrictions that will preserve or increase the value of their house (Fischel, 2004[24]). As a result, local authorities have typically been more restrictive than higher level governments in controlling and shaping land development due to the dominance of local obstructive stakeholders (Glaeser and Ward, 2009[25]; Hilber and Robert-Nicoud, 2013[26]). Ahrend, Gamper and Schumann (2014[27]) found that coordination across municipal governments facilitates construction to densify cities.[9] This component of the indicator captures the possibility of such effects by assigning a higher value (reflecting a more stringent environment) to more decentralised land-use regulatory settings. There are also empirical indications that assigning zoning and project-approval powers to local authorities implies higher levels of income segregation (Lens and Monkkonen, 2015[28]).

9. The restrictions typically resulting from high degrees of municipal-level authority over land often take the form of height restrictions or minimum-lot-size requirements, both of which translate into greater sprawl when developable land is available in neighbouring areas (Blöchliger et al., 2017[37]; Ehrlich, Hilber and Schöni, 2018[38]).

- *Overlap:* Countries where multiple government levels are involved in land planning decisions can emerge as comparatively more stringent than those where fewer groups are involved. The reason is that each group can potentially exercise a veto, objection or delaying rights on projects. The same logic underpins core components of the Wharton Residential Land Use Regulatory Index (Gyourko, Saiz and Summers, 2008[29]).[10] Points for this dimension are assigned on the basis of the number of administrative actors involved in land planning.

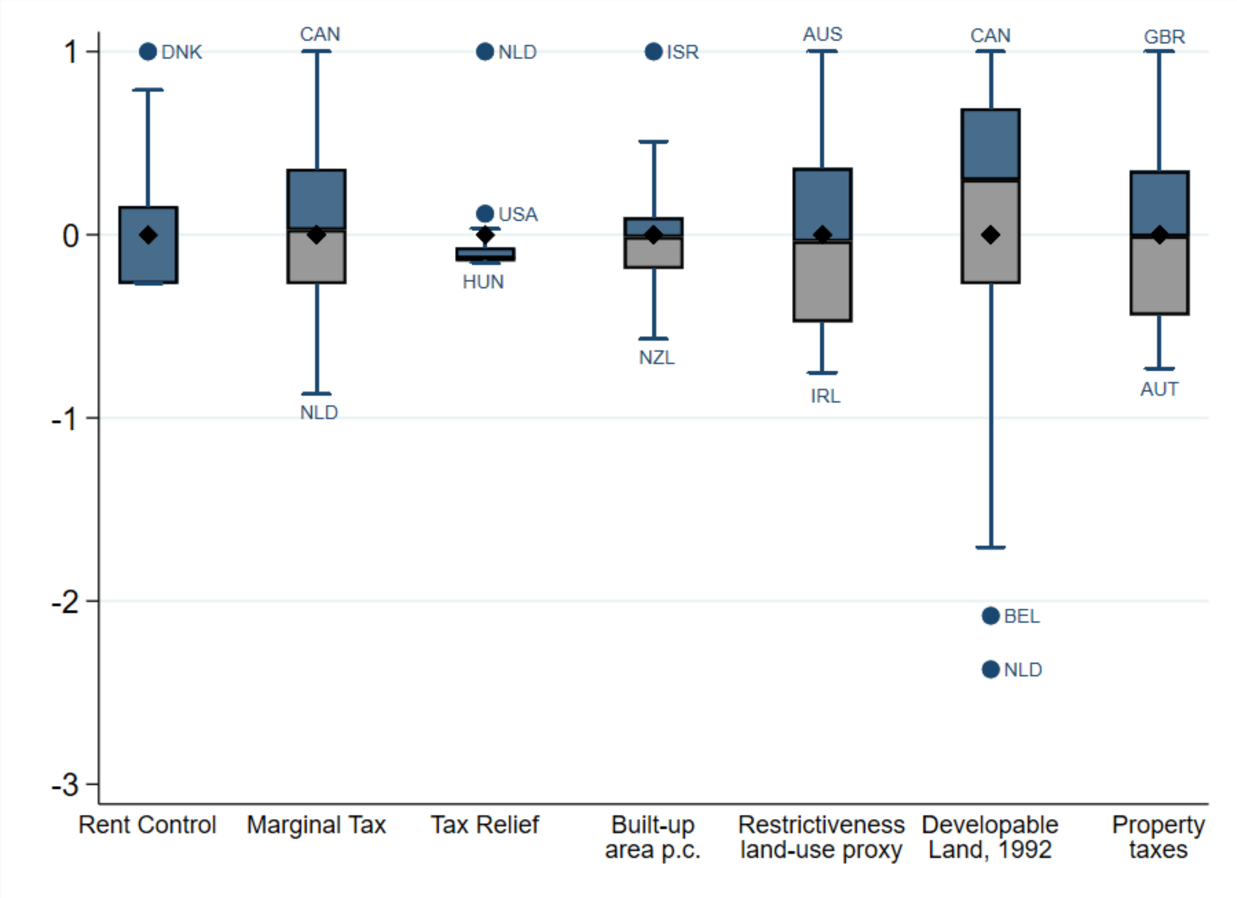
43. This proxy indicator of land-use restrictiveness varies a lot across countries (see the width between the 25th and 75th percentile in Figure 7).This variation reflects that the governance of land use differs markedly across OECD countries (OECD, 2017[30]).

44. Nevertheless, this indicator of land-use restrictiveness is linked to regulation today, while the baseline horizon for the elasticity estimates is a long horizon from the 1980s. It could be that stringent regulation today is the result of a historically high elasticity of supply that the legislator is currently trying to counteract. To overcome this possible reverse causality bias between the elasticity and the stringency of the regulation, another indirect indicator of regulatory barriers is tested that is kept exogenous from the estimation sample: the change in built-up area per capita over the period 1975-1990. In the vast majority of OECD economies, this growth rate is positive, meaning that the area of developed land grew more than population in this period. This indicator has the advantage of considering the change in construction activity controlling for population pressures. Countries where the (positive) growth of built-up area per capita has been higher in the past are probably those where regulation has historically allowed construction activity to react strongly to population pressures. The indicator should therefore be linked with greater supply responsiveness.

10. These components of the Wharton index are: LPPI, SPII and LZAI.

Figure 7. Policy settings vary markedly across countries

Distribution of policy indicators across 25 countries, latest observation



Note: Diamonds indicate the mean; a thick solid black line shows the median. Each indicator is cross-sectionally de-meaned and expressed relative to its maximum value. Data refer to 2017 or the latest available date except for developable land and the change in built-up area per capita that refer to 1992 and 1990, respectively. The cross-sectional sample consists of the 25 countries shown in Figure 3, except for the land-use restrictiveness proxy and the built-up area per capita index (covering 24 countries), the tax relief (15 countries), and rent control indicator (19 countries). The marginal tax is the average of the marginal effective tax rate (METR) for home-owners with a mortgage and the METR for home-owners without one (OECD, 2018[31]). Tax relief is the forgone tax revenue due to the existence of a tax relief or credit for access to home ownership; it is expressed as percentage points of GDP. The index of rent control is sourced from Kholodilin (2018[32]). The change in built-up area per capita is computed between 1975 and 1990. Developable land is the share of non-built-up, non-water land in each country in 1992. The land-use restrictiveness proxy is an indicator capturing the presence and importance of land-use regulations at lower levels of government. The higher the indicator, the more land-use planning decisions are decentralised, which has been found to result in tighter building restrictions (Ahrend, Gamper and Schumann, 2014[27]). Property taxes is the share of property taxes over total tax revenues.
Source: See note above.

45. Table 2 reports empirical results of the likely impact of geographic barriers and land-use regulation restrictiveness on the estimated supply elasticities. The supply equation (equation 5) is estimated using the pooled CCE model but including policy interactions to capture cross-country heterogeneity (Columns 2-4); the pooled model without interactions is reported for information but considered as inferior as it does not capture cross-country heterogeneity (Column 1). The barrier indicators (denoted *R* for

the above-defined regulation proxy and the change in built-up area and L for land unavailability) enter as interaction factors with prices. This specification is equivalent to assuming a decomposition of the unique supply elasticity, β, estimated in Table 1 into multiple components according to the following formula:

$$ln\, I_{c,t} = \beta_c^0 + \beta_c^1 ln\, P_{c,t} + \beta^2 ln\, CC_{c,t} + h' f_t + \varepsilon_{c,t} =$$

$$\beta_c^0 + (\beta^a - \beta^r R_c - \beta^l L_c) lnP_{c,t} + \beta^2 lnCC_{c,t} + h' f_t + \varepsilon_{c,t} \quad (6)$$

The estimation is carried out over a shorter sample, 1991Q1-2017Q4, in order to ensure the exogeneity of the built-up area per capita indicator. In addition, available land is measured in 1991, in order to express geographic barriers at the beginning of the estimation sample and remove endogeneity concerns.

Table 2. The role of land-use barriers in housing supply

Dependent variable: real residential investment	(1)	(2)	(3)	(4)
Real house prices	0.83***	1.04***	0.96***	0.81***
	(0.09)	(0.09)	(0.08)	(0.03)
Real house prices x Available land (L)		0.20***	0.19***	0.11***
		(0.022)	(0.024)	(0.007)
Real house prices x Change in built-up area per capita (R)			0.19**	
			(0.09)	
Real house prices x Land-use restrictiveness proxy (R)				-0.012***
				(0.003)
Observations	2 438	2 438	2 367	2 367
Countries	25	25	24	24
F Stat	117	54.7	191	228
Adjusted R^2	0.14	0.20	0.39	0.57

Note: The estimates are obtained from a model of equations (5) and (6) using pooled estimators (CCE P) as policy interactions capture cross-country heterogeneity. The sample runs from 1991Q1 to 2017Q4. The model without policy interactions is shown in Column 1 for reference but is not considered valid as it does not capture cross-country heterogeneity. All of the estimated equations include lagged construction costs and factor variables, which are omitted from this table for simplicity. The policy variables and the available land indicator have been de-meaned before entering the estimation. Model 4 is the only specification that used – for the same horizon - country and quarterly dummies (2WFE model) instead of factor variables, because of the presence of collinearity across variables and better stability of the estimates. Standard errors (in parenthesis) are kernel-robust to arbitrary common correlated disturbances (Driscoll-Kraay). Statistical significance thresholds: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

46. The regression results are consistent with the view that more land availability, greater ease of construction and more limited land-use restrictiveness all boost the price elasticity of housing supply. Column 1 in the table reports the pooled coefficients for comparison with the other estimates, which account for heterogeneity. Column 2 adds to the baseline specification the role of available land, equivalent to (1-L) in equation (6). Available land has a positive impact on the elasticity, meaning that countries that have fewer geographic constraints usually have more elastic supply. The indicator for the ease of construction based on the pre-estimation-sample growth of the built-up area per capita also shows the expected sign (positive) and is statistically significant (Column 3). On the contrary, the restrictiveness of the regulation today has a negative (though small) impact on the supply response (Column 4). In the companion paper, Bétin and Ziemann (2019[12]) have evaluated the impact of the national proxy indicator for restrictive regulation with regional data. They find that tighter land use restrictions, as measured by the proxy indicator, are associated with weaker supply, corroborating the result obtained by the present study with national data.

47. Housing investment can also be affected by a number of policies not directly aimed at regulating supply, but that can indirectly affect the supply adjustment. This is the case, for example, of rental controls, which can result in lower supply by reducing the expected net present value of housing investment. An interaction with Kholodilin's (2018[32]) indicator of rent control allows testing the presence of such an effect (Table 3). It turns out that, indeed, tighter rent controls reduce the responsiveness of housing supply to demand pressures, although the effect is small.[11]

Table 3. The role of rent regulation in housing supply

Dependent variable: real residential investment	(1)	(2)
Real house prices	0.96***	1.36***
	(0.13)	(0.12)
Real house prices x Rent control		-0.054***
		(0.016)
Observations	2,840	2,160
Countries	25	19
F Stat	50.4	109
Adjusted R^2	0.14	0.22

Note: The estimates are obtained from a model of equation (5) using pooled estimators (CCE P). All of the estimated equations include lagged construction costs and factor variables, which are omitted from this table for simplicity. All models are estimated over the period 1980Q1 to 2017Q4. The index of rent control is sourced from Kholodilin (2018[32]) and enters the estimation in de-meaned form. Standard errors (in parenthesis) are kernel-robust to arbitrary common correlated disturbances (Driscoll-Kraay). Statistical significance thresholds: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.

11. Bétin and Ziemann's (2019[12]) regional analysis finds no significant effect of rent control at the regional level, presumably because their sample, which starts in 2000, covers a period during which there is relatively limited cross-country variation in rent regulation. By contrast, the national analysis for many countries covers the 1980s and 1990s, during which there was more cross-country contrast in rent regulation.

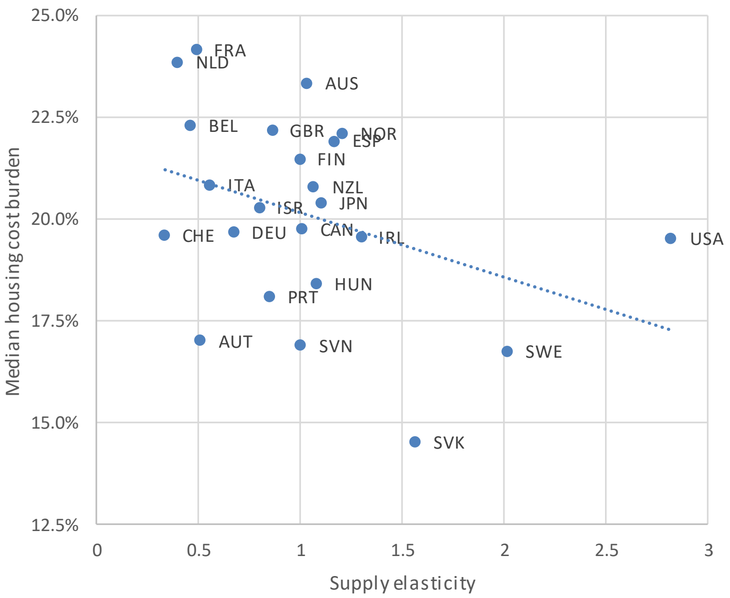
5. Consequences of housing supply elasticities for affordability and cycles

5.1. Housing supply elasticities and affordability

48. More inelastic supply means that prices will have to go higher to generate the same level of construction. Meeting housing needs is therefore by definition more difficult in countries where supply is more inelastic. There turns out to be some link between supply elasticities and median housing costs: in countries where supply is more inelastic such as France or the Netherlands, median households tend to spend more of their income on rent or mortgage servicing than in countries where supply is more elastic such as Sweden or the United States (Figure 8).

Figure 8. There is some link between supply elasticities and median housing costs

Median of the 2014 housing cost burden from mortgages or rents vs. estimated supply elasticity



Note: The trend line is statistically significant at the 10% confidence level.
Source: OECD Affordable Housing database and elasticity estimates from Figure 3.

5.2. Supply elasticities and housing cycles

49. Differences in construction responsiveness should influence the dynamics of housing cycles. Homebuilding will thus exhibit larger cycles where the supply elasticity is larger. The country estimates of housing supply elasticities and the observed record of housing cycles bear this hypothesis out (Table 4). Construction cycles are considerably larger in countries where supply is more elastic. Furthermore, housing markets where supply takes longer to adjust back to equilibrium typically experience more protracted housing booms (Figure 9).

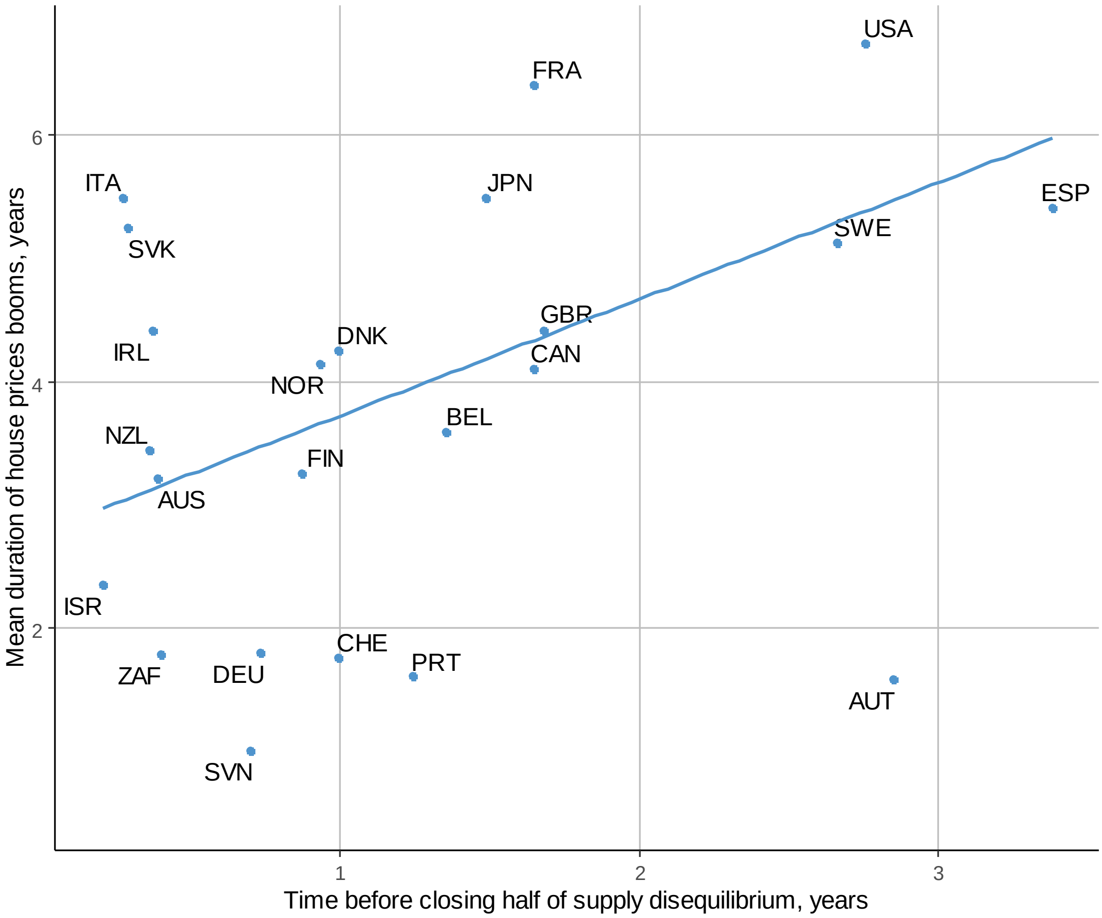
Table 4. Investment cycles are more pronounced where supply is more elastic

Percentages and percentage points

	Low-elasticity countries	High-elasticity countries
Average real homebuilding growth	0.3	0.6
Volatility of real homebuilding growth	3.4	4.9
Average homebuilding expansion during booms	50.6	80.7
Average drop during busts	22.5	30.4

Note: High-elasticity countries are the economies where the estimated supply elasticities reported in Figure 3 are above the median value. Low-elasticity countries are the remainder.
Source: Authors' calculations.

Figure 9. Housing booms last longer where supply adjusts more slowly



Note: The time before closing half of supply disequilibrium is the estimated half-life of convergence: t=log(0.5)/log(1-α) where α is the estimated speed of adjustment, that is the opposite of the coefficient shown in Table B.6.
Source: authors' calculations.

6. Price responsiveness: Cross-country differences and their drivers

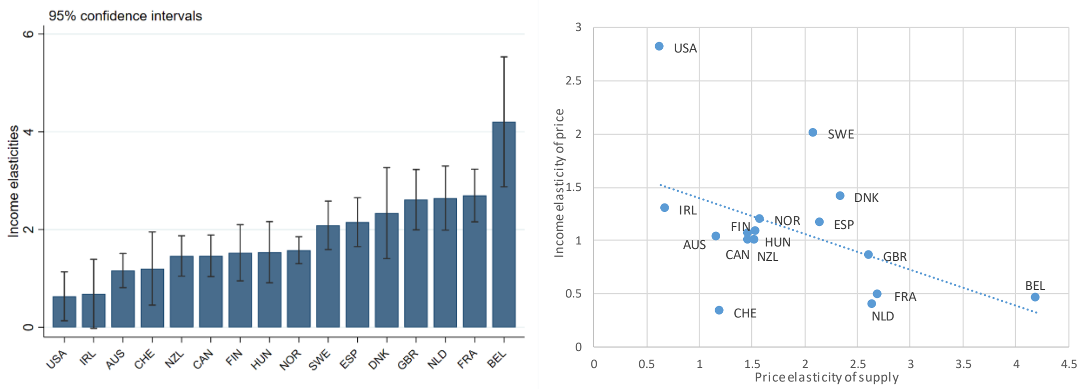
50. This section presents estimates of how house prices respond to variations in demand before discussing which drivers explain these differences. The price equation of the stock-flow model is estimated as:[12]

$$lnP_{c,t} = a_c^0 + a_c^1 lnY_{c,t} + a^2 lnPOP_{c,t} + a^3 lnS_{c,t-1} + a^4 r_{c,t} + \eta_{c,t} \qquad (7)$$

51. Most of the adjustment to income shocks is expected to occur through prices in countries where supply is more rigid (see last section of Annex B for a conceptual derivation). The results of estimating equation (7) are broadly in line with this view (Figure 10, Panel B). Many countries with relatively low supply elasticities (e.g. Belgium and France) are found to have high income elasticities of prices, while countries with elastic supply exhibit relatively high income elasticities of prices (e.g. United States and Ireland). There are, however, deviations from this correspondence, to which housing taxation policies are likely contribute by influencing how attractive households find it to invest in housing when their income expands (or divest from when income shrinks).

Figure 10. Estimated income elasticities by country

A. Income elasticities by country B. Income elasticities vs supply elasticities



Note: The table shows estimates of the long-run income elasticity of house prices (the a^1in Equation 7) by country using the 2WFE mean group approach in a balanced panel dataset of 21 countries estimated from 1995Q1 to 2015Q4. Estimates for Italy, Austria, Germany, Japan and Portugal are not reported in the chart, because they are not statistically significant.
Source: Authors' calculations.

52. Empirical investigations can shed light on how tax policies influence price elasticities in addition to the effect of supply responsiveness. For this purpose, equation (7) is rewritten as (8) so as to document how differences in supply elasticities β_c^1 (shown on Figure 3) and tax policies shape the response of house prices to income changes:

$$lnP_{c,t} = a_c^0 + a^1 lnY_{c,t} + a^2 lnPOP_{c,t} + a^3 lnS_{c,t-1} + a^4 r_{c,t} + a^5 \beta_c^1 lnY_{c,t} + a^6 P_c lnY_{c,t} + \eta_{c,t} \qquad (8)$$

12. There is no need to instrument the housing stock for its response to house prices. First, this response occurs only through home building, which is sensitive to prices but in each quarter only has a very small impact on the size of the total dwelling stock (Meen, 2002[18]; Ball, Meen and Nygaard, 2010[33]). Second, the use of the lagged stock in (7) further reduces the scope for feedback of prices to the housing stock in the estimated equation.

53. The resulting estimates (Table 5) confirm that prices are more sensitive to incomes where supply responds more weakly to demand. Indeed, higher supply elasticities are linked with lower income elasticities of prices: the coefficient in front of the interaction between income and the supply elasticity is always negative and strongly significant.

54. House prices respond less vigorously to income shocks in countries that have a higher marginal effective rate of property taxation or that rely more on property taxes (measured by the share of property taxes in the tax mix averaged over time to avoid cyclical effects). Finally, house prices move more following demand shocks in countries that offer greater tax relief for homeownership.

Table 5. The influence of selected policies on the income elasticity of house prices

Dependent variable: Real house price	(1)	(2)	(4)	(5)	(6)
Net household disposable income (Y)	1.32***	1.45***	2.21***	1.60***	1.38***
	(0.13)	(0.11)	(0.21)	(0.16)	(0.14)
Total dwelling stock (S)	-1.22***	-1.29***	-1.04***	-1.27***	-1.36***
	(0.23)	(0.25)	(0.31)	(0.24)	(0.28)
Real average mortgage interest rate (r)	-0.59***	-0.61***	-0.55***	-0.64***	-0.62***
	(0.17)	(0.17)	(0.15)	(0.18)	(0.17)
Total population (POP)	1.42***	1.39***	0.65	1.78***	1.77***
	(0.35)	(0.34)	(0.46)	(0.35)	(0.45)
Y x Price elasticity of housing investment (β^1)		-0.31***	-0.67***	-0.35***	-0.30***
		(0.056)	(0.075)	(0.049)	(0.056)
Y x Tax relief for access to homeownership			0.59***		
			(0.16)		
Y x Marginal effective property tax rate				-1.07**	
				(0.45)	
Y x Taxes on property (% of total tax revenue)					-0.027*
					(0.015)
Observations	1 750	1 750	1 248	1 750	1 750
Countries	21	21	15	21	21
F Stat	287	463	526	475	376
Adjusted R^2	0.42	0.44	0.54	0.48	0.44

Note: The estimates are obtained from a model of equation (8) using pooled estimators. All models are estimated over the period 1995Q1 to 2015Q4. Each indicator enters the estimation in demeaned form. Standard errors (in parenthesis) are kernel-robust to arbitrary common correlated disturbances (Driscoll-Kraay). Statistical significance thresholds: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculations.
Source: Own calculations.

7. Concluding remarks

55. The above analyses have shown that housing supply and price adjustment mechanisms exhibit differences across OECD countries and that policies shape these differences besides geographical constraints. In particular, greater land-use restrictiveness (which is approximated using an indicator of decentralisation and overlap in planning responsibilities based on political economy considerations) is linked with significantly weaker responses of supply to demand changes. Tight rent control also appears to impair supply responses. Low supply responsiveness in turn means that house prices rise more strongly when household income grows. In addition, for a given level of supply responsiveness, more tax relief for homeowners makes house prices more sensitive to income.

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Annex A. Life-cycle housing models

56. An early theory of the housing market drew predominantly on life-cycle models (Meen (2002[18]) and Ball, Meen and Nygaard (2010[33])). In these models, equilibrium conditions dictate that the marginal rate of substitution between housing (h) and a composite consumption good (c) is related to the selling price and the user cost of residential capital:

$$\frac{\mu_h}{\mu_c} = P(t)\left[(1-\theta)i(t) - \pi + \delta - \frac{\dot{g}^e}{g(t)}\right] \quad (A.1)$$

57. In equation (A.1), P(t) is the real purchase price of dwellings; θ is the household marginal tax rate; $i(t)$ is the market interest rate; δ is the depreciation rate of the housing stock; π is a general inflation rate; $\frac{\dot{g}^e}{g(t)}$ is the expected real capital gain from housing and $(.)$ indicates the time derivative. Market efficiency also requires an arbitrage relationship to hold, such that:

$$P(t) = \frac{R(t)}{\left[(1-\theta)i(t)-\pi+\delta-\frac{\dot{g}^e}{g(t)}\right]} \quad (A.2)$$

58. Where R(t) is the real imputed rental price of housing services. With equation (A.2), the value of a house can be expressed as the present discounted value of housing services. An important feature of the life-cycle approach is that it considers the consumption of housing services (imputed rents) and the investment role of housing simultaneously. The market in housing services is assumed to clear in each time period so that, in a reduced form, the rent reflects all the factors determining housing demand and supply. This is why it is often empirically difficult to distinguish between life-cycle models and reduced-form models.

59. Equation (A.2) has been used as the basis for structural models of the housing market. Starting with Poterba (1984[16]) and then Meen (2002[18]), the imputed rental price is related to the housing stock (H), the number of households (HH) and real per capita disposable income (RY):

$$R(t) = f(RY_t, HH_t, H_t) \quad (A.3)$$

Inserting (A.3) into (A.2) yields

$$ln(g) = \psi(ln(RY_t), ln(HH_t), ln(H_t)) / \left[(1-\theta)i(t) - \pi + \delta - \frac{\dot{p}^e}{p(t)}\right] \quad (A.4)$$

A log-linear approximation of (A.4) gives the following equation to estimate:

$$p_t = \alpha_1 + \alpha_2(hh_t) + \alpha_3(ry_t) - \alpha_4(h_t) - \alpha_6(rr_t) + \epsilon_{1,t} \quad (A.5)$$

Where *rr* is the term in the denominator of equation A.4. In equation (A.5) house prices (p) are related to the housing stock (h), the number of households (hh), real income (ry) and the real interest rate (rr). It is also possible to invert the relationship in order to estimate the equilibrium housing stock.

60. The second part of the model by Poterba (1984[16]) focuses on the determinants of the housing stock. The housing stock depends on the profitability of new construction (driven by real house prices and construction costs) and the size of the pre-existing stock.

$$h_t = \beta_1 + \beta_2(p_t) - \beta_3(cc_t) + \beta_4(h_{t-1}) + \epsilon_{2,t} \qquad (A.6)$$

61. The demand and supply equations to estimate are:

$$p_t = \alpha_1 + \alpha_2(hh_t) + \alpha_3(ry_t) - \alpha_4(h_t) - \alpha_6(rr_t) + \epsilon_{1,t} \qquad (A.5)$$

$$h_t = \beta_1 + \beta_2(p_t) - \beta_3(cc_t) + \beta_4(h_{t-1}) + \epsilon_{2,t} \qquad (A.6)$$

62. When (A.6) is inserted into (A.5), thanks to the presence of the term h in Equation (A. 5), a reduced-form price equation can be defined which includes construction costs (cc). However, as noted in Meen (2002[18]), construction costs and house prices may not appear empirically linked by any relationship in the long run since the emergence of such an effect would be the result of the full adjustment of the housing stock, a correction that generally happens very slowly. Furthermore, a strong degree of collinearity between construction costs and interest rates can make estimation difficult.

Annex B. Additional information on the empirical strategy

Tackling endogeneity in the supply equations

63. The endogeneity bias is the result of the adjustment mechanism linking housing demand and supply in equilibrium. The use of an IV approach to correct this situation is widespread in the housing literature. However, there is some disagreement among authors about what supply variable is endogenous to price adjustment. In a standard demand-supply model, the simultaneous adjustment should involve prices and quantity. Hence, in equilibrium, it is prices and the housing stock – not the level of construction – that are simultaneously determined (Ihlanfeldt and Mayock, 2014[34]). This is the endogeneity bias considered in Saiz (2010[22]) and the regional analysis performed below. However, other authors (Topel and Rosen, 1988[35]) extend this assumption by observing that endogeneity is also likely to affect investment dynamics and prices, since the adjustment of the housing stock from one equilibrium to another is driven primarily by investment.

64. The presence of endogeneity is tested in the model using the Durbin-Wu-Hausmann test, which confirms the existence of possible bias. Hence, to control for the endogeneity between investment and prices, the model is estimated using an instrumental variable (IV) approach, where real house prices are instrumented using their lags or demand factors. A first stage regression is estimated between house prices and some demand factors. Then, the fitted values from the first stage regression are used instead of prices in the estimation of equation (5). Total population and real disposable income per capita are used as instruments for prices where they are feasible and strong, which corresponds to 10 countries. The first and second lag of real house prices are used for the remaining 15 economies, where they better meet availability and validity criteria than population and income.

65. Total population and disposable income per capita are the chosen instruments for Austria, Canada, Switzerland, Denmark, Finland, Italy, Japan, Norway, Slovakia, and Sweden. In the remaining economies, lagged prices are used instead. In some cases (Portugal, Israel, Hungary and South Africa), the use of population and income as instruments is not possible because data are either not available or too short. In other cases (Australia, Germany, France, the United Kingdom, New Zealand and Slovenia), population and income are not valid instruments over extended time horizons, but they could be used over shorter horizons yielding comparable results. In the remaining economies (Belgium, Spain, Ireland and the United States), estimates using population and income tend to be implausibly high and very volatile across different time horizons, probably reflecting robustness issues.

66. The possible reverse causality between investment and construction costs is controlled for by using lags of the construction cost variable instead of assuming a contemporaneous relationship.

Estimation of short-run adjustment equations

67. The change in house prices is often an important driver of construction activity since it tends to generate short-run incentives which are more frequent than shocks to the cost of production. However, the presence and magnitude of adjustment costs and persistence effects may prevent a rapid adjustment of the housing stock to a new level

equilibrium following a demand shock. This stickiness of investment can be an additional factor explaining sustained deviations from equilibrium in some countries. The second stage involves the estimation of the following short-run dynamic differenced equation, where the variables in equation (5) are turned into first differenced terms and $\varepsilon_{c,t}$ is the error term estimated from equation (5).

$$\Delta lnI_{c,t} = \kappa_c + \omega_c \Delta lnP_{c,t} + \varphi \Delta lnCC_{c,t} + \varrho_c \varepsilon_{c,t-1} + \psi \sum_{j=1}^{N} \psi_j \, \Delta lnI_{c,t-j} + \epsilon_{c,t} \quad \text{(B.1)}$$

68. In equation (B.1), $\varepsilon_{c,t}$ is the cointegrating vector, representing the departure of the current level of investment from its long-run equilibrium value. The corresponding estimated coefficient ϱ measures the speed of the adjustment to the long-term equilibrium relationship. κ_c are a series of country dummies, $\sum_{j=1}^{N} \psi_j \, \Delta lnI_{c,t-j}$ control for the Nth-order serial autocorrelation of investment and $\epsilon_{c,t}$ is an unobserved transitory disturbance term. $\Delta lnI_{c,t}$ and $\Delta lnP_{c,t}$ are first differenced terms of investment and prices, respectively and both terms are tested to be I(0). Price changes are instrumented to deal with their likely endogeneity to changes in investment.

69. Equation (B.1) is estimated in a panel setting, which includes 25 countries using quarterly data from 1980Q1 to the end of 2017. The dependent variable is the log change in real residential investment, measured as the volume of gross fixed capital formation in housing.

70. Table B.1 reports the estimated results of the second stage of the econometric model and hence the estimates of equation (B.1) using five different estimation approaches. As in the long-term equation (5), house price variables have been instrumented using the first difference of population and real disposable income per capita, or lags of the dynamic term on house prices. These instruments are applied mostly for precautionary reasons since, theoretically, the inclusion of lags of the dependent variable should already capture past dynamics of the explanatory variables. The number of lags is selected on the basis of the observed degree of serial autocorrelation in the residuals of the equation without dynamic terms[13] and on the assumption that residential investment dynamics may have a certain degree of persistence.

71. Column 1 of Table B.1 shows the estimated coefficients of equation (B.1) in the baseline specification where coefficients of the error correction term (ECT) and of prices are heterogeneous across countries. The reported results are then the cross-sectional average of the individual estimates. Similarly, Column 4 reports results of a heterogeneous coefficient panel model that includes time and country fixed effects instead of lagged terms of the dependent variable (an estimation in line with Column 3 in Table 1 for the long-run equation). Column 2 reports results from a Pooled Mean Group estimator (Pesaran, 2006[20]) where the ECT term is the one from a first stage estimation imposing homogeneous long-run coefficients across the panel units, while the short-run parameters (ECT terms and short-run price elasticities) are assumed heterogeneous. The remaining Columns, 3 and 5, show results from pooled estimation models using either the baseline specification with lagged dependent variables (Column 3) or time dummies (Column 5).

72. Although very different in nature, all estimators tend to agree on the main features of the model. The coefficient of the error correction term (ε) is negative and statistically significant in each approach, validating the error-correcting behaviour

13. Using standard tests on the residuals of the equation, it appears that two lags of the dependent variables are sufficient to remove residual autocorrelation from the model.

assumed in this study. Significant convergence holds even when the convergence coefficient is allowed to vary across countries (Table B.6). Growth in real house prices tends to have a positive effect on investment in each model, but this effect (i.e. estimates of ω) is typically smaller compared to the long-run estimate (β^1), thus confirming the hypothesis of stickiness in the adjustment behaviour of investment to price shocks in the short run. Changes in construction costs tend to have a puzzling positive effect on investment.

Table B.1. Estimated parameters of the short-run dynamic equation

Panel results over a sample of 25 countries over the period 1980Q1-2017Q4

	(1)	(2)	(3)	(4)	(5)
Dep. Variable: Δ Real residential investment	Baseline MG	Baseline PMG	Baseline P	2WFE MG	2WFE P
Δ Real house price	0.51***	0.44***	0.86***	0.79***	1.15***
	(0.12)	(0.13)	(0.14)	(0.18)	(0.19)
Error correction term (ε)	-0.2***	-0.2***	-0.1***	-0.08***	-0.02***
	(0.030)	(0.32)	(0.014)	(0.014)	(0.0042)
Δ Lag of construction costs	0.14**	0.18**	0.10*	0.11*	0.12*
	(0.069)	(0.075)	(0.057)	(0.065)	(0.066)
Observations	2 777	2 777	2 777	2 815	2 815
Countries	25	25	25	25	25
F stat	2605	19.9	33.4	23.4	32.5
Adjusted R^2	0.25	0.015	0.048	-0.25	-0.13

Note: The results are based on quarter-on-quarter differenced variables. The error correction term included in the short-run dynamic equations is, for each column, the residual from the estimation of the long-run equation (equation 5) using the matching approach, except for the PMG that uses the error structure from the CCE P long-run estimation. The regressions include two lagged terms of the dependent variable, country and time fixed effects as appropriate. These terms are not reported in this table. Standard errors (in parenthesis) are kernel-robust to arbitrary common correlated disturbances (Driscoll-Kraay). Statistical significance thresholds: *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' calculations.

Cross-sectional dependence, panel unit root and co-integration tests

73. Cross-sectional dependence tests are conducted to verify the presence of cross-sectional dependence in the data and across the panel units. Table B.2 reports results from Pesaran's (2004[36]) test statistics, which clearly show the presence of dependence, especially high in the level variables (mean ρ estimates). These estimates are significantly different from zero and the null hypothesis of independence is strongly rejected. These results justify the use of an estimator and a model corrected for the presence of spatial dependence, affecting both the estimation of the parameters and, especially, the calculation of standard errors. The inclusion of a multi-factor error structure in Equation (5) is the chosen solution to take into account the latent components of spatial autocorrelation.

Table B.2. Cross-sectional dependence test results

Variable	CD Statistic	Mean ρ
Residential investment	58.97***	0.28
Real house prices	68.37***	0.34
Construction costs	64.27***	0.32
Total population	164.34***	0.77
Disposable income per capita	153.94***	0.77
Disposable income	162.29***	0.81
Dwelling stock	163.92***	0.78
Real mortgage rate	83.23***	0.40
Δ Residential investment	16.10***	0.08
Δ Real house prices	25.85***	0.13
Δ Construction costs	10.87***	0.06
Δ Total population	9.22***	0.04
Δ Disposable income per capita	13.08***	0.07
Δ Disposable Income	13.08***	0.07
Δ Dwelling stock	14.65***	0.07
Δ Real mortgage rate	14.06***	0.07

Note: The test measures the mean correlation between panel units in individual variables. The panel dimension is 25 countries and the sample for the variables is 1980Q1 to 2017Q4. The null hypothesis is CS independence. The cross-sectional dependence measure (ρ) is the mean of the pair-wise correlation between the cross-section units of the variable. Pesaran (2004[36]) CD test for cross-sectional dependence in individual variables.
Source: Authors' calculations.

74. In order to apply an ECM approach and consider a cointegrating relationship between the variables, a necessary but not sufficient condition is that the variables contain unit roots and are integrated of the same order. In a panel setting as in the present study, the presence of a unit root and of the order of integration can be assessed using a number of panel unit root tests. However, because of the presence of cross-sectional dependence, not all of the unit root and cointegration tests can be applied. Standard ADF test statistics must be adjusted in order to consider the presence of spatial autocorrelation. Test statistics that are too restrictive on the error structure would likely yield wrong results for the cointegrating relationships. The CIPS procedure is used to test for the presence of unit roots in the variables of the supply-demand model. CIPS statistics are calculated as the simple average of the individual CADF statistics.

Table B.3. Panel unit root tests

Pesaran panel unit root test in the presence of cross-section dependence (CIPS test statistics)

Variable	Only intercept	With intercept and trend
Residential investment	-1.74	-2.87
Real house prices	-1.31	-1.87
Construction costs	-1.98	-1.95
Total population	-2.39	-2.33
Disposable income per capita	-2.01	-2.85
Dwelling stock	-2.04	-2.93
Real mortgage rate	-5.62	-6.06
Δ Residential investment	-5.58	-5.71
Δ Real house prices	-4.38	-4.98
Δ Construction costs	-5.81	-6.03
Δ Total population	-0.69	-2.15
Δ Disposable income per capita	-6.10	-6.30
Δ Dwelling stock	-2.29	-2.60
Δ Real mortgage rate	-6.19	-6.42

Note: Panel unit root tests for each variable, conducted over 25 countries and a horizon from 1980Q1 to 2017Q4. CIPS statistics are computed as the simple average of the individual specific CADF(2) tests, where two time lags are used in each regression. The null hypothesis is homogeneous non-stationarity, i.e., that all series have a unit root. The alternative hypothesis is that some series are stationary. Critical values for the CIPS statistics are -2.3, -2.16 and -2.08 for 1%, 5% and 10% significance, respectively, for the model with intercept only; -2.77, -2.65 and -2.59 for 1%, 5% and 10% significance, respectively, for the model with intercept and time trend.
Source: Authors' calculations.

75. The results of the CIPS test on panel unit root are presented in Table B.3. The tests from models with an intercept only suggest that the hypothesis of a unit root cannot be rejected for any of the variables expressed in levels, except for the mortgage rate, which is stationary. Conversely, the differentiated variables all tend to be stationary, except for the population variable. The model with a time trend indicates that most variables are trend stationary. The results point to evidence that supply and demand variables are predominantly I(1) and can hence be linked by a cointegrating relationship. This is confirmed by direct cointegration tests (Table B.4).

Table B.4. Panel co-integration tests

	Price equation	Investment equation
Stat	-1.38	-1.41
P-value	0.08	0.07

Note:
1. The null hypothesis is no cointegration. The alternative hypothesis is that some panels are cointegrated. The price equation is a test for a cointegrating relationship between house prices, income and population. The investment equation is a test for a cointegrating relationship between residential investment and house prices. Both equations are tested with the inclusion of an intercept and are estimated over the sample 1980Q1 to 2017Q4.
2. Westerlund (2007) test for panel cointegration in the presence of possible cross-sectional dependence.
Source: Authors' calculations.

System estimation

76. The stock-flow model, by assuming a clearing mechanism in the housing market via the slow adjustment of the housing stock to demand shocks, postulates an equilibrium relationship between house prices and housing demand and supply. Some of the recent housing literature has relied on simultaneous equation models to jointly estimate the parameters of this equilibrium relationship. In Caldera Sánchez and Johansson (2013[3]), housing demand (i.e., the price equation) and supply (i.e., the investment equation) are included in a system of equations estimated simultaneously using seemingly unrelated regressions (SUR). As a robustness check to the baseline estimation (CCE MG), a system of simultaneous equations representing the long-run equilibrium between housing demand and supply is estimated. The long-run demand and supply equations are, respectively:

$$lnP_{c,t} = \alpha_0 + \alpha_1 \ln Y\_pc_{c,t} + \alpha_2 lnPOP_{c,t} + \alpha_3 lnS_{c,t} + \alpha_4 r_{c,t} + \epsilon_{c,t} \quad \text{(B.2)}$$

$$ln\, I_{c,t} = \beta_1 + \beta_2 lnP_{c,t} - \beta_3 lnCC_{c,t-1} + \varepsilon_{c,t} \quad \text{(B.3)}$$

77. The systems of structural equations is estimated using three-stage least square methods (3SLS), which allow to estimate a demand equation containing an endogenous variable (real house price) among the explanatory variables. This model is estimated in an unbalanced panel setting of 23 countries[14] over the same estimation horizon as the baseline model. Results are reported in Table B.5 for both a pooled estimation across the panel units (Columns 1 and 2), and a mean estimate of country-specific systems of equations (Column 3 and 4), as in Caldera Sánchez and Johansson (2013[3]). Overall, the results for the supply equation are aligned with the baseline model and point to a mean supply elasticity of 1. This confirms the robustness of the estimates that, even with very different estimation methods, yield consistent results.

14. South Africa and Israel are excluded for lack of data.

Table B.5. Estimation results from a model of simultaneous equations

Estimation horizon from 1980Q1 to 2017Q4

	(1) Pooled		(2) Mean Group	
	Demand equation	Supply equation	Demand equation	Supply equation
Dependent variable:	*Real house prices*	*Residential investment*	*Real house prices*	*Residential investment*
Income per capita	1.58*** (0.05)		1.80*** (0.22)	
Mortgage rate	-0.82*** (0.14)		-0.30** (0.13)	
Population	1.26*** (0.13)		4.85 (3.34)	
Housing stock	-0.41*** (0.087)		-1.77 (1.75)	
Real house prices		0.97*** (0.047)		0.97*** (0.14)
Lag of constr. Costs		-0.27*** (0.067)		-0.74** (0.39)
R^2	0.83	0.99	0.83	0.63
Observations	2 434		2 647	
Countries	23		23	

Note: The table shows estimation results from a system of simultaneous equations of housing demand and supply using quarterly data from the early 1980s until the end of 2017. Pooled estimates are the results of a panel estimation with imposed coefficient homogeneity. Mean Group estimates are the results of country-specific estimates of the simultaneous model, which have then been averaged across panel units. Robust standard errors are in parentheses. Statistical significance is denoted following standard threshold levels: *** p<0.01, ** p<0.05, * p<0.1
Source: Authors' calculations.

Detailed heterogeneous-coefficient estimation results

Table B.6. Estimated coefficients of the supply equation by country

	(1)	(3)
Country	Long-run supply elasticities (β)	Speed of adjustment (ϱ)
AUS	1.03***	-0.36***
	(0.24)	(0.11)
AUT	0.51***	-0.059***
	(0.10)	(0.017)
BEL	0.46**	-0.12***
	(0.18)	(0.031)
CAN	1.00***	-0.10**
	(0.24)	(0.048)
CHE	0.33***	-0.16***
	(0.076)	(0.042)
DEU	0.67***	-0.21***
	(0.16)	(0.070)
DNK	1.41***	-0.16**
	(0.52)	(0.071)
ESP	1.17***	-0.050***
	(0.16)	(0.017)
FIN	1.00***	-0.18***
	(0.13)	(0.052)
FRA	0.49***	-0.10**
	(0.11)	(0.041)
GBR	0.86***	-0.098***
	(0.32)	(0.037)
HUN	1.08***	-0.050***
	(0.24)	(0.017)
IRL	1.30***	-0.37***
	(0.14)	(0.13)
ISR	0.80***	-0.57***
	(0.058)	(0.21)
ITA	0.55***	-0.47***
	(0.12)	(0.090)
JPN	1.10***	-0.11**
	(0.19)	(0.044)
NLD	0.40***	-0.20***
	(0.13)	(0.071)
NOR	1.20***	-0.17**
	(0.10)	(0.077)
NZL	1.06***	-0.38***
	(0.20)	(0.11)
PRT	0.84***	-0.13***
	(0.31)	(0.047)
SVK	1.56**	-0.45***
	(0.65)	(0.13)
SVN	1.00***	-0.22
	(0.29)	(0.14)
SWE	2.01***	-0.063***
	(0.22)	(0.014)
USA	2.82***	-0.061**
	(0.36)	(0.026)
ZAF	1.09***	-0.35***
	(0.12)	(0.081)

Note: The long-run supply elasticities in column 1 are the country estimates of β^1 in equation (5). The speed of adjustment is the coefficient ϱ in equation (B.1) using Model 1 in Table B.1. Standard errors (in parenthesis) are kernel-robust to arbitrary common correlated disturbances (Driscoll-Kraay). Statistical significance thresholds: *** p<0.01, ** p<0.05, * p<0.1.

Link between supply elasticities and the estimated income elasticity of prices

78. The stock-flow model outlined at the beginning of the paper can be written as the following equations for demand (in log price form) and the investment rate:

$$lnP = \alpha_0 + \alpha_1 lnY + \alpha_2 lnPOP - \alpha_3 lnS + \alpha_4 r \qquad \text{(B.4)}$$

$$\frac{I}{S_{t-1}} = \beta_0 + \beta_1 lnP - \beta_2 lnCC \qquad \text{(B.5)}$$

The stock of housing evolves with net investment:

$$S = S_{t-1} + I$$

It follows that:

$$\ln S = \ln\left(S_{t-1}\frac{S}{S_{t-1}}\right) = \ln S_{t-1} + ln\left(1 + \frac{I}{S_{t-1}}\right) \sim \ln(S_{t-1}) + \frac{I}{S_{t-1}} \qquad \text{(B.6)}$$

Substituting (B5) into (B6) and the result into (B4) allows rewriting (B4) as the reduced form price equation:

$$lnP = \frac{\alpha_0}{1+\beta_1\alpha_3} + \frac{\alpha_1}{1+\beta_1\alpha_3}lnY + \frac{\alpha_2}{1+\beta_1\alpha_3}lnPOP + \frac{\alpha_3}{1+\beta_1\alpha_3}lnS_{t-1} + \frac{\alpha_4}{1+\beta_1\alpha_3}r + \frac{\alpha_3}{1+\beta_1\alpha_3}lnCC \qquad \text{(B.7)}$$

$$lnP = \eta_0 + \eta_1 lnY + \eta_2 lnPOP + \eta_3 lnS_{t-1} + \eta_3 r + \eta_4 lnCC \qquad \text{(B.8)}$$

where η_j represents the reduced form (i.e. observed) demand coefficients, which will depend on the structural parameters of demand and β_1 is the price elasticity of housing supply.

Consequently, the observed responsiveness of prices to changes in income η_1 is expected to be higher in countries with inelastic supply (which have a lower β_1) since $\eta_1 = \frac{\alpha_1}{1+\beta_1\alpha_3}$.

79. The price equation estimates reported in the main text use a specification analogous to (B.8), with the difference that construction costs are not included. They are excluded for two empirical reasons: first, residential construction costs in practice turn out to be quite collinear with real interest rates; second, the available statistics for housing construction costs, that is the residential investment deflators, involve substantial noise. Robustness checks however indicate that including them does not qualitatively alter the results (though deteriorates estimation quality for the aforementioned reasons). Besides, the empirical estimates use gross investment for lack of data on net investment. As the estimation is conducted in log form, the regression fixed effects will absorb the depreciation rate.

Data sources

Table B.7. Description and sources of variables

Variable	Description	Source
House Prices	Real house price (index)	OECD Economic Outlook database
Real construction costs	Residential fixed capital formation deflator	OECD Economic Outlook database
Residential investment	Gross fixed capital formation, housing, volume	OECD Economic Outlook database
Income	Real net household disposable income	OECD Economic Outlook database
Mortgage interest rate	Real mortgage interest rate sourced from EMF Hypostat extended to missing countries and years using a second measure of average interest rates defined by Caldera Sánchez and Johansson (2013[3])	European Mortgage Federation (EMF), OECD calculations*
Housing stock	Total dwelling stock from EMF Hypostat extended backwards using the growth rates of now discontinued series from the UN Economic Commission for Europe used by Caldera Sánchez and Johansson (2013[3])	European Mortgage Federation (EMF), Authors' calculations*
Population	Total population	United Nations
Rent control	Index reflecting on the number of regulations that restrict rent increases including real rent freezes, nominal rent freezes, rent level control, limits of decontrolling (e.g. change of tenant, new or vacant dwelling) as well as restrictions on subletting	DIW (Kholodilin, 2018[32])
Marginal effective property tax rate (owner-occupied)	Marginal effective tax rates (METR) on owner-occupied homes are derived as the differences between the pre- and post-tax rates of return of a marginal investment divided by the pre-tax rate of return of that investment where post-tax real rate is the minimum rate of return necessary to make the investment worthwhile.	OECD Tax Policy Studies: Taxation of Household Savings (OECD, 2018[31])
Tax relief	Foregone tax revenue due to tax relief for access to home ownership	OECD Affordable Housing Database
Property tax	Taxes on property, % of taxation	OECD Revenue Statistics database