Housing prices, macro-prudential rules and the elasticity of housing supply: Evidence from Ireland*

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Abstract

The affordability and availability of housing has become one of the defining economic, political and social issues across many cities in high-income countries. We examine the determinants of housing supply in Ireland over recent decades, including prices, costs and non-price conditions in the mortgage credit market, the focus of many macro-prudential measures. We do this using data at the national and Dublin levels at annual frequency from 1970 and at quarterly frequency from 1995, as well as panels at county and micro-market level over more recent periods, and using error correction and SUR methods. We find consistent evidence that supply responds positively to prices and negatively to both construction costs and site costs, with the estimated responsiveness to prices no lower in recent periods than in earlier ones. We find no strong evidence that, independent of their role in determining housing demand, tighter credit conditions reduce housing supply.

Keywords: housing supply elasticity, Ireland, credit conditions.
JEL codes: E58, G21, R31

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1 Introduction

Housing has emerged as one of the most pressing economic, social and political issues across a range of high-income cities and countries in recent decades. Among OECD countries, inflation-adjusted housing prices went from being largely stable in trends to steadily increasing in the third quarter of the 20th century (Knoll et al., 2017). Construction rates have fallen in the same period with, for example, the peak of new homes built in New York since 2000 (26,400 in 2007) roughly half the annual *average* between 1961 and 1965, despite New York's population rising by one third in the same period. Land use restrictions and other policy-driven barriers to new supply may be at the heart of weak housing supply in many economies (Saiz, 2010).

In this paper, we examine the determinants of new supply in Ireland, in particular its responsiveness to prices and to mortgage market conditions, using complementary approaches and data from 1970. We build national annual and quarterly time series of capital formation, completions and permissions, as well as Dublin-focused equivalents, and employ error-correction methods to estimate the long-run supply equation, verifying that method with Seemingly Unrelated Regressions, to allow for reverse causality between supply and prices. We supplement these time series with two sets of quarterly panel analyses, one at county level from the mid-2000s – using three alternative measures of supply: completions, commencements and permissions — and the other exploiting rich spatial data on both property prices and planning permissions lodged at the level of 389 micro-markets from 2012.

In Ireland, as in other economies, there has been much public debate about the required volume of new housing and the low level of completions since the Great Recession. Just 23 homes were built per 1,000 residents during the 2010s, compared to 155 in the 2000s, and an average of 75 in the 1970s, 1980s and 1990s. The lack of new supply recently is matched by strong increases in prices: having fallen by just over 50% between 2007 and 2012, inflation-adjusted market prices rose by almost two thirds between 2012 and 2020. However, this unconditional correlation – comparing changes in supply and changes in prices – is distinct from the elasticity of housing supply to prices, a conditional correlation measuring how supply responds to prices, other things being equal.

Economic theory suggests the responsiveness, or elasticity, of housing supply in response to outward shifts in demand will be determined not by prices alone but instead by the ratio of prices to costs, i.e. new supply will be built when viable to do so. Further, the supply curve is likely to be kinked at the point of viability, below which housing supply is effectively inelastic. This reflects an important asymmetry that exists in housing supply: with the existing stock of housing immobile, downward shifts in demand will largely be met with a fall in prices, rather than a fall in quantities, although an increase in vacancy rates may substitute in part for the inability of housing quantities to adjust downwards. While housing prices (and land costs) vary substantially by location, build costs do not. This means that the location of the demand curve at regional level, relative to the kink in supply, will determine the supply response.

The key determinants of supply in our analysis are, therefore: (1) the capital value or market price of housing (at national, city, county or micro-market level); (2) the level of construction costs, allowing for relevant tax reliefs, which drove trends in net construction costs 1998-2008; and (3) the level of site or land costs. For simplicity, we refer to the elasticity of housing supply in response to price changes as the housing supply elasticity (HSE). We supplement these with a fourth potential determinant: non-price credit conditions in the mortgage market (hereafter mortgage market conditions, MMC). Following the Global Financial Crisis, macroprudential rules were introduced across a number of high-income economies. The most common form of these rules is loan-level limits on debt per household, usually some combination of debt-to-value and debt-to-income (or affordability) constraints. In Ireland, the Central Bank of Ireland (CBI) introduced macroprudential rules in late 2014. For owner-occupiers, these included a restriction that the gross mortgage debt be limited to 3.5 times gross household income (the LTI restriction) and, for first-time buyers, that the loan not exceed 90% of the value of the property (LTV); in other words, a deposit of 10% (for first-time buyers; 20% for others) was required. In the case of all four candidate regressors, we have an alternate measure, including the system-wide ratio of mortgage credit to household deposits as a measure of MMC prior to 2000, when CBI data on LTV and LTI begin.

We find strong evidence across all our specifications that housing prices, the cost of construction and, with some exceptions, the cost of land affect new housing supply, in line with the predictions of economic theory. The low level of new housing supply in Ireland during the 2010s is not anomalous, but rather explained well by the fundamentals included in the long-run equation, in particular the dramatic rise in construction costs. While housing prices in 2020 were roughly 20% below their 2007 level and land costs 40% lower, build costs after tax reliefs were between 70% and 90% higher in 2020 than 2007. Unlike in some other countries, we find little evidence that HSE is lower in the post-1995 period than before; similarly, we also find no evidence that, controlling for the cost of building and the cost of land, the HSE is lower in Dublin than in the country as a whole. This does not contradict the idea that land-use restrictions or other policy barriers limiting supply have grown in importance over time and are more relevant in Dublin than elsewhere; rather that, on balance, these barriers are reflected in higher costs, whether related to construction or sites, rather than in addition to those costs. We do not find any evidence that looser credit conditions are associated directly with higher housing supply, if anything the opposite; any effect is likely to be captured instead through the housing price channel.

We believe our contribution to the study of housing supply elasticity is three-fold. Firstly, we provide estimates of HSE in Ireland, at both national and regional level, allowing variation over a fifty-year period, for the first time.[1] Secondly, ours is the first paper in the literature that explicitly tests the role of macroprudential policy and mortgage market conditions more generally in determining supply. The lack of any consistent finding in relation to MMC means that our results are not sufficient to overturn the hypothesis that MMC measures affect supply but only indirectly, through the demand channel by pushing up prices. Lastly, and combining both these features, our analysis has significant implications for policymakers. As part of its *Housing for All* strategy, Ireland has targeted an increase in construction of more than 50% between 2020 and 2030. Our results imply that, absent other factors, net construction costs would need to fall by up to 40% or housing prices rise by one third for completions to increase from 20,000 per year (their level at the start of the 2020s) to 30,000 per year.

[1]While Caldera and Johansson (2013) include Ireland in their multi-country analysis, their supply equation is not based on economic theory. Specifically, it does not include the cost of land but does include population, a demand-side factor that should already be captured by prices. Further, they do not state the specific series used for their supply equation, which runs from 1980 to 2007 at quarterly frequency, despite quarterly data on investment (their outcome of interest) only being available from 1995. Consequently, it is not possible to replicate their results, which imply a very low HSE of 0.6, i.e. an increase in housing prices of 10% leads to an increase in investment of 6% in the long run.

In the next section, we review the related literature, highlighting four stylized facts that emerge from the growing body of research. In Section 3, we outline the construction of the dataset, including annual, quarterly and panel series used for supply, prices, costs and mortgage market conditions. Section 4 establishes our empirical strategy, while Section 5 presents the results for all the specifications outlined. The final section concludes by noting limitations as well as implications for both policymakers and the research community.

2 Literature Review

The body of research examining the elasticity of housing supply is both long-standing and, in recent years, rapidly growing. In general, estimated elasticities of housing supply with respect to prices are heterogeneous, varying substantially across locations (and time periods). This is a feature that has been shown for different levels of aggregation. Evidence ranges from perfectly elastic supply estimates (Follain, 1979; Malpezzi & Maclennan, 2001; Stover, 1986), to estimates ranging from 0.5 to 3 (DiPasquale & Wheaton, 1994; Harter-Dreiman, 2004; Mayo & Sheppard, 1996; Paixão, 2021; Poterba, 1984). Nonetheless, direct comparisons across studies are complicated, as studies differ by analytical framework and measurement of supply (such as new housing units built, building permits sought or issued, or the level of investment in construction from national accounts), as well as unit and period of coverage.

We highlight here four important stylized facts about HSE that emerge from a review of the literature. Firstly, a number of economic features are associated with responsive housing supply (high HSE). In particular, high housing supply elasticity can be explained by:

1. Low population density (Caldera & Johansson, 2013; Green et al., 2005)
2. Less restrictive building codes (Green et al., 2005; Ihlanfeldt & Mayock, 2014); and
3. Geographically less diverse regions, with mountainous terrain and water coverage associated with lower HSE (Meen & Nygaard, 2011; Saiz, 2010)

Further, recent studies using small geographic units show that HSE increases with distance from the urban center, a feature consistent with findings in relation to population density (Baum-Snow & Han, 2019). Due to the high correlation and intuitive reasoning, the literature focused on the U.S. often uses measures of geographic characteristics from Saiz (2010) or the Wharton Regulatory Land Use Index (Gyourko et al., 2008) as proxies for HSE (Davidoff, 2013; Glaeser et al., 2008). However, in the more recent literature these measures has been criticized since the Saiz instrument can be correlated with other city characteristics such as different industrial compositions (Davidoff, 2016). To overcome this issue, Guren et al. (2021) construct a sensitivity instrument by estimating the systematic historical sensitivity of local housing prices to regional housing cycles and then interacting these historical sensitivity estimates with today's shock to regional housing prices.

The second stylised fact from the literature is that the critical step is overcoming potential endogeneity problems arising from the well-known problem of separating housing demand from housing supply. As noted in Baum-Snow and Han (2019), unobserved productivity shocks could affect housing prices by increasing demand and supply by increasing construction costs, leading to a downward bias in the HES estimate. Aastveit et al. (2020) suggest that there is likely reverse causality between prices and supply. Both papers favor instrumental variable strategies, such as Bartik instruments (or at least instruments similar in spirit to or strongly correlated with Bartik shocks) or crime rates, which would isolate the demand-driven component in prices. An alternative approach is to use careful macroeconometric analysis, such as error-correction methods or seemingly unrelated regressions, to allow system-wide data to reveal underlying relationships.

Thirdly, HSE is plausibly related to the severity of housing market cycles. Glaeser et al. (2008) persuasively argue that the real estate cycle is affected by the HSE: regions with high HSE are less likely to experience bubbles and show less price appreciation compared to regions with low HSE levels. There may be some ambiguity in this relationship, however. On the one hand, it is plausible that a higher HSE led to greater overbuilding during the pre-2007 boom, resulting in greater excess inventory and thus larger price declines in the post-boom period; on the other hand, a higher HSE leads to smaller price increases during the boom, so there is a smaller price correction after the boom. Empirically, this has been supported by Huang and Tang (2012) and Ihlanfeldt and Mayock (2014). The former point to a significant relationship between HSE and price declines during the post-2007 bust, while the latter only find evidence that HSE played a role during the 2000 boom, but not during the subsequent bust. Davidoff (2013) finds no significant relationship between cycle intensity and HSE at the state level, albeit after accounting for state-level fixed effects. In a more recent study, Oikarinen et al. (2018) estimate mainly price and supply elasticities of income and contrast them with HSE represented by Saiz's measure. They confirm the finding of Glaeser et al. (2008) that cities with land constraints in particular have experienced drastic housing price overshoots and cycles around the fundamental price level.

The final stylised fact from the HSE literature builds on the above and relates to its wider importance. Given the importance of housing in both household expenditure and household balance sheets, as well as the wider stock of assets, HSE has implications for wider macroeconomic and financial stability. Accetturo et al. (2020) show that demand shocks can have a positive impact on employment and growth in cities where the HSE is higher in Italy. Using a general equilibrium approach, Hsieh and Moretti (2019) have shown that a low HSE, due to restrictive land-use conditions, can lead to a welfare loss by preventing workers from accessing highly productive areas due to higher prices.

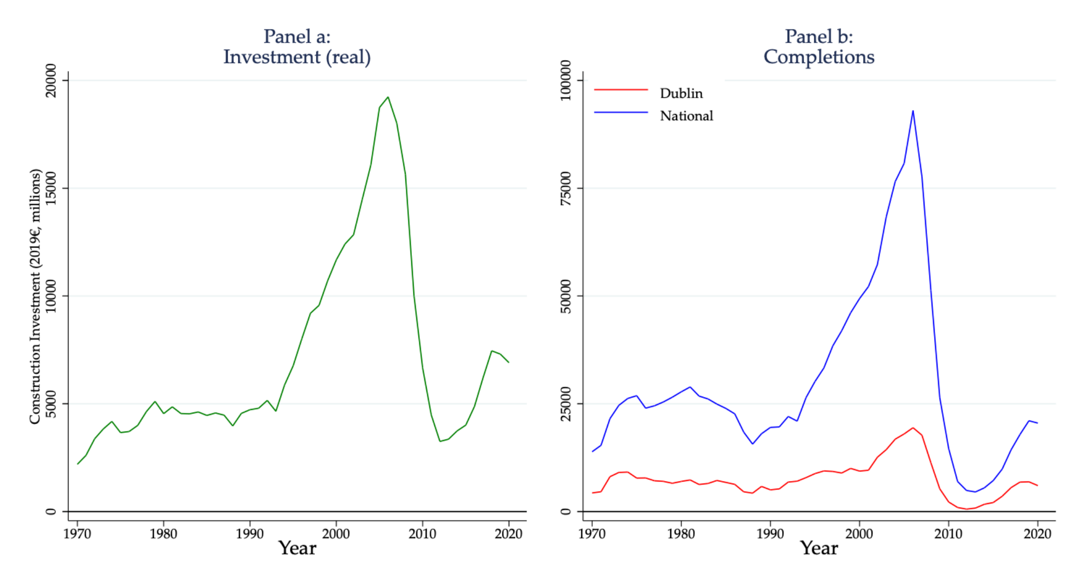
3 Data

In this section, we describe the dataset assembled for the subsequent analysis. We start by describing four related but distinct measures of new housing supply. We then describe price and cost series. We outline our data on mortgage market conditions, before describing other series used, including the deflators.

3.1 Housing Supply

Our core measure of housing supply at national level is the volume of **fixed capital formation** (FCF) in dwellings, including improvements, during a specified period (year or quarter). We take this from the PxStat database provided by Ireland's Central Statistics Office (CSO), specifically Table N2015, which gives gross fixed capital formation in millions of euro (current) from 1995 to 2020 at annual frequency, and Table NQQ40, which gives it quarterly frequency. Table NQQ40 distinguishes between FCF in the construction of new dwellings and in improvements to existing dwellings, allowing us to devise, for the period from 1995 at both annual and quarterly frequencies, series on FCF with and without improvements. For the period before 1995, only annual data are available. We use PxStat Table NAH15 for FCF in dwellings (in million of euro, current) for the period 1970-1995.[2] The left-hand panel of Figure 1 gives fixed capital formation, in millions of 2019 euro, at annual frequency.

Figure 1: Measures of new housing supply, since 1970



Our key alternative measure of housing supply, over longer periods, is the volume of dwellings completed in a particular period. From the first quarter of 2011, this is available from CSO Table NDQ06, at the level of the local authority and for three types of dwellings: estate or scheme houses; apartments; and one-off houses. For the period 1970-2011, we use connections to the electricity grid to measure completions of new homes.[3] This is available from CSO Table HSA11, again at the level of the local authority, by sector (public or private housing) and from 1994 by type (houses or apartments). We aggregate to national level or to the level of the 26 traditional counties from local authority. The number of local authorities has varied over time, most recently being reduced from 34 to 31 in 2014, but are consistently nested within the 26 traditional counties. The right-hand panel of Figure 1 gives the number of new dwellings completed, nationally and for Dublin, from 1970.

Our third measure of supply is commencements, i.e. the number of dwellings commenced in a particular period. This is available from January 2004, at monthly frequency and at the level of the local authority, using CSO Table HSM12 (to February

[2]Tables A.13 and B.13 of the 1977 edition of National Income and Expenditure provide series back to 1960 on investment in dwellings, nationally at annual frequency, but these are not used here, given the limitations on other data series.

[3]Some series for completions, aided by national grants or undertaken by local authorities, are available back to the 1920s, although their comprehensiveness cannot be ascertained.

2014) and Table HSM74 thereafter.[4] As with completions, we aggregate from local authority level (and here from monthly) to county and national level at quarterly frequency.

Our final measures of supply relate to planning permissions. Since 1964, the construction of new dwellings in Ireland has required permission to build from the relevant local authority. Statistics on the number of new homes for which planning permission has been granted are available from CSO Table BHQ05, at national level and quarterly frequency, from the start of 1975 (split by broad type: houses and apartments/flats). Quarterly figures by local authority are available from CSO Tables BHQ02 (2001Q1-2017Q4) and BHQ12 (from 2018Q1 respectively), for each of three housing types: estate housing, apartments, and one-off dwellings.

Lastly, we use rich spatial data on planning permissions lodged and granted, at the level of the individual site, using the National Planning Application Database (NPAD), which is operated by Ireland's Department of Housing, Local Government and Heritage. In addition to the location and outline of the relevant site, the dataset includes the dates of the receipt of the application and of the local authority's decision, and the outcome of decision, in particular whether (conditionally) accepted or rejected. There are over 410,000 applications from 2010 to mid-2021. These were then aggregated to the level of 'micro-markets', used as part of the Daft.ie Report (explained in more detail below). To link site-level planning data to micro-markets, based on named areas, all official Census 'Small Areas', created by the CSO, were assigned to a micro-market.[5] A spatial join was then used to connect planning permissions and micro-markets. This gives us the number of planning permissions lodged, for each of 389 micro-markets, at quarterly frequency from 2012Q1 to 2021Q2. It should be noted that the scaling is number of permissions, rather than the number of dwellings. For this reason, it is best considered as a measure of the responsiveness of one-off housing (where each permission relates to one and only one dwelling) rather than overall supply and is most comparable to county-level data on permissions for one-off dwellings, rather than all dwellings.

3.2 Housing Prices

We focus on the sale price of housing, as this reflects the capital value of real estate upon construction. National series on the sale price of housing are generated both for new dwellings and for the mix-adjusted price of all dwellings. For new dwellings, the median price of newly-built homes is available from 2010 at annual frequency, using CSO Table HPA05. This is extended back to 1970 using Department of Environment series on the average price of newly-built dwellings, by year. The data are similar to those underlying CSO Table HSA06 but, in their original published form, included separate averages for new and second-hand dwellings, nationally and for the five city boroughs, at both annual and quarterly frequency. The mix-adjusted price of all dwellings is taken from CSO HPA13 for 2005-2020, extended back to 1996 using the ESRI-PTSB average

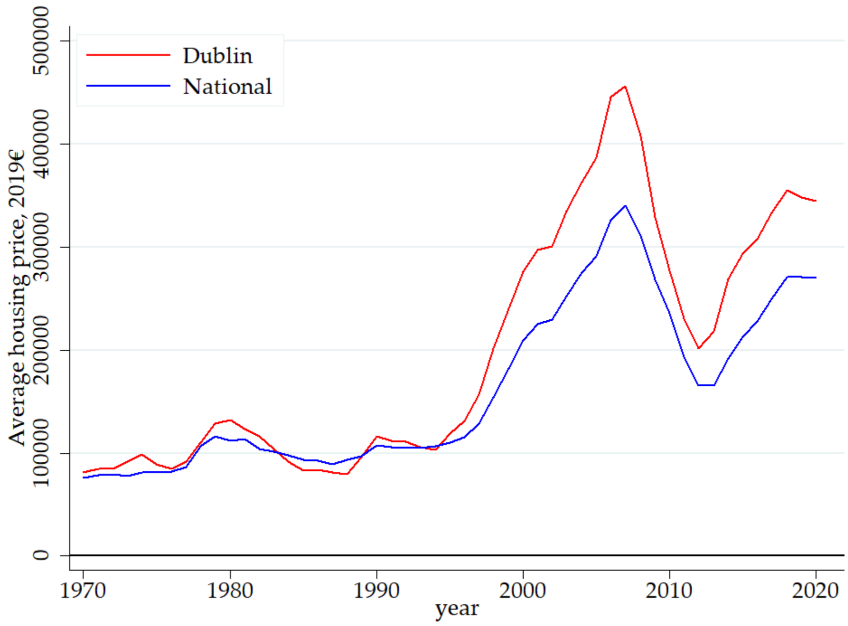
[4] At the time of writing (October 2021), this table had not been updated since February 2021. For that reason, we used the original source for the CSO, Table A5CB1 published by the Department of Housing, for the period March-June 2021.

[5] The coordinates of over 1 million listings on daft.ie, with assigned micro-market IDs, were projected over the Small Area shapefile. The most commonly occurring micro market, based on listings per small area, was used to assign a small area to a micro market. Once all small areas were assigned a micro market, the shapefiles were dissolved by micro market ID, resulting in a map of all micro-markets with well defined CSO based boundaries.

price, and extended back from 1996 to 1970 using the average of mean prices for both new and second-hand dwellings. For Dublin at annual frequency, and for both national and Dublin series at quarterly frequency (from 1995), the same sources are used.

Mix-adjusted average prices by county are available from 2006Q1 to 2021Q2, using averages calculated from the daft.ie report. While these are listed prices, their treatment – in particular the use of hedonics but also date of initial listings – means that they are very highly correlated with transaction prices, even during volatile market conditions (Lyons, 2019). An alternative is to use the mean price of transactions involving newly-built homes, by aggregating monthly data at the local authority level on the aggregate value of transactions and number of transactions, available from CSO Table HPM05. Daft.ie also provide average (mix-adjusted) price by micro-market, which facilitates the analysis of supply elasticity at quarterly frequency.

Figure 2: Inflation-adjusted sale price of housing, since 1970



3.3 Housing Costs

The principal series used to measure construction costs are CSO Table HSA09, for annual series, and its monthly equivalent Table HSM09. This was an official index, using a fixed output type (dwelling) and pricing the relevant labour and material inputs used accordingly, and ran at monthly frequency from 1975 to 2017. It is extended back to 1970 at annual frequency using the 'Capital Goods in Building & Construction' sub-component of the Wholesale Price Index and forward to 2021 using percentage changes in the estimate of the rebuilding cost of existing dwellings, per square metre, published by the Society of Chartered Surveyors (SCSI).

This official series suffers from the limitation that it is a fixed-quality basket, while housing quality is likely to have drifted substantially higher during the period being investigated (Lyons, 2014). The SCSI series provides an alternative from 1989, the first year in which it published estimates of the rebuilding cost of a home for insurance purposes. Throughout, a figure for Dublin was published, with additional estimates for

Cork (from 1992), Galway (from 1996), Waterford and Limerick (from 2004) and North-West and North-East regions (from 2013). While regional differences in level exist, the trends are very similar, which provides justification for the identifying assumption of an annual trend in construction cost and also similar levels of construction costs outside Dublin. While this series will reflect, for example, any additional costs of improved insulation standards over time, it also suffers from a fixed quantity, given that it is based on per-square-metre costs.

One important adjustment is needed to the series on gross construction costs. For much of the period, various forms of "Section 23" tax reliefs were available with respect to construction costs. In particular, in the decade to July 2008, when all schemes were closed, three principal schemes operated: rural renewal (from June 1998), integrated area urban renewal (from August 1998), and town renewal (from April 2000). As outlined in Revenue Commissioners (2020), these schemes were extremely broad and deep. In breadth, the urban schemes applied to 52 different areas in 23 counties, the rural scheme applied to the majority of five north-western counties (including two counties in full), while the town scheme applied to 100 further towns in 23 counties. It was deep, in the sense that all construction costs were eligible to full tax relief, provided the property was rented upon completion, with a minimum qualifying lease of three months. Crucially, the tax relief was not limited to the property itself and reliefs could be set off against any rental income from properties located in Ireland (whether covered by Section 23 or not) in that year or carried forward to future years. In effect, construction costs, net of tax reliefs, were dramatically reduced in almost all parts of the country during the period 1998-2008, even as gross costs rose dramatically.[6] Based on media coverage during the time of the reliefs, we parameterize these reliefs as a 60% discount on construction costs for the period 1998Q3 to 2008Q2; our results are not sensitive to increasing this relatively conservative estimate of the discount associated with Section 23.

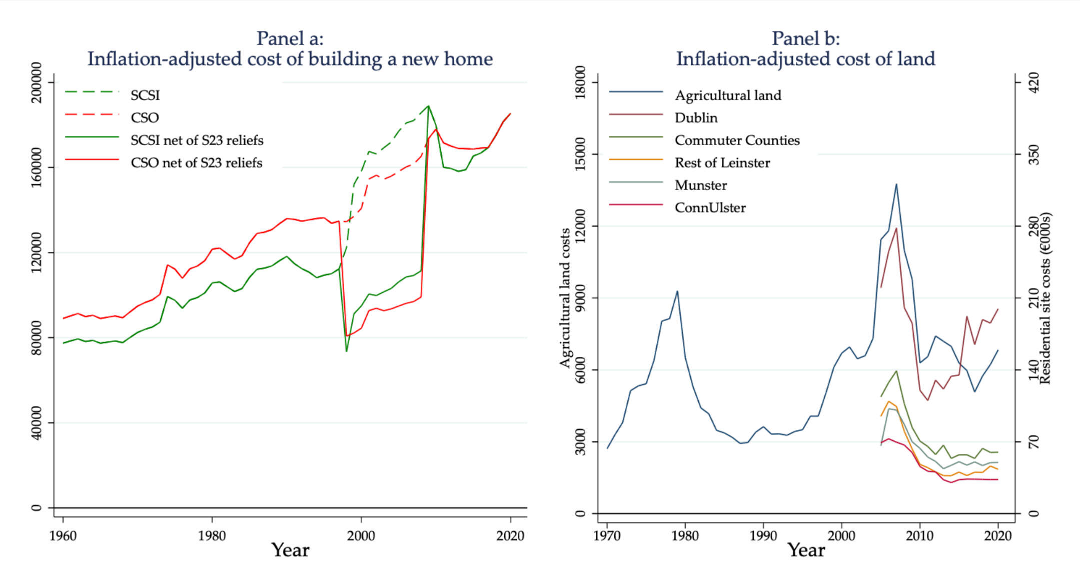
The second element of the cost of new homes relates to land (or site) costs. Economic theory predicts that land costs for any given site will be endogenous to the likely price (and build costs) and, in particular, where build costs are determined at a larger scale, such as the unit of the city or wider economy, and prices are determined locally, site values will, in equilibrium, be the difference between these two series. Given this endogeneity, we use lagged median residential site costs, at regional level, where available using micro-data assembled from the daft.ie archive. For five parts of the country – Dublin, its four commuter counties, the rest of the Leinster province, Munster, and the combination of Connacht and the three Ulster counties – annual median site costs were available for the period 2004-2021. For Leinster (outside the greater Dublin area), typical site costs rose from €100,000 in 2004 to €150,000 in 2007, before falling to €55,000 in 2013-2014 and rising to €65,000 by 2020. For the county-level quarterly panel analysis, counties were assigned to one of five regions and annual values were interpolated to quarterly. For the period before 2004, a national series for average agricultural land values, per acre, was used, as contained in Daly and Morgan (2022).

Figure 3 presents both elements of housing costs, since 1970. The left-hand panel

[6]Indeed, the two phenomenon are likely related. In June 1999, as the Section 23 scheme took full effect, the Chief Executive of the Society of Chartered Surveyors stated that "to get a builder at the moment is very difficult . . . There has obviously been an increase in building costs, as yet I couldn't put figures on it but there will be a substantial increase" (Tanney, 1999). The SCSI series of rebuilding costs for Dublin rose 43% between 1998 and 2000, from €90 per square foot to nearly €130, with the period 1997-2001 accounting for half of the €140 increase in per-square-foot rebuilding costs observed 1989-2021.

presents the overall estimate of the cost of building a three-bedroom semi-detached house, by year, using both cost series and accounting for tax reliefs 1998-2008. The right-hand panel presents two alternate measures of site costs: the typical residential site cost, by region, on the left-hand axis and the average per-acre cost of agricultural land, at national level, on the right-hand axis.

Figure 3: Measures of housing costs, since 1970

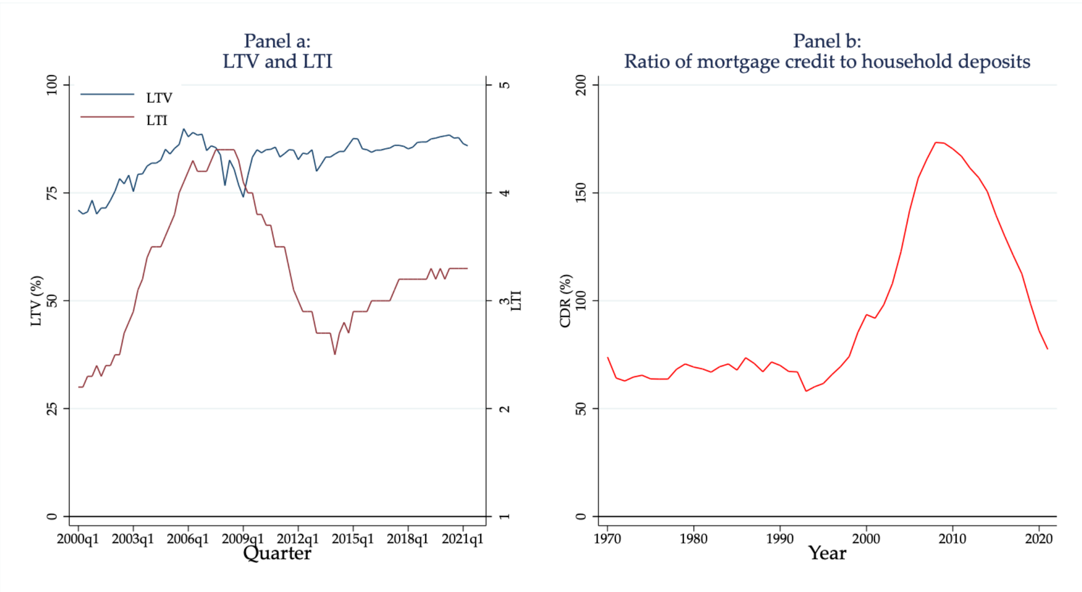


3.4 Mortgage Market Conditions

We measure mortgage market conditions in three complementary ways. Our preferred measure is the typical loan-to-value (LTV) of first-time buyers (FTBs). As described by Duca et al. (2011), this measure captures the injection of new credit into the housing market, as distinct from, for example, the release of existing equity enjoyed by those who already own housing. This is available at quarterly frequency from 2000Q1 and was provided by the Central Bank of Ireland for the country as a whole, for Dublin, and for the rest of the country, based on underlying loan-level data for financial institutions governed by its supervision rules from 2010, as per Lyons (2018). The same source also provided median loan-to-income (LTI) over the same span and for the same three spatial units. For the county-level panel, loan-to-income is preferred, as this better reflects higher price constraints in the capital: for example, in 2017, the typical deposit of a first-time buyer in Dublin was larger, rather than smaller, than those elsewhere in the country (16 percent rather than 13 percent), although the typical loan to income was also higher (3.5 vs 3.0). The greater deposit may reflect selection into the Dublin market of those with greater ability to rely on gifts or bequests, while the loan-to-income series better reflects the greater credit needed, given earning capacity (which may still be greater for those in the Dublin market).

These data are only available from 2000. Before this, we use data on the system-wide ratio of mortgage credit to household deposits, or credit-deposit ratio (CDR), following Lyons and Muellbauer (2015). This captures, at an aggregate level, the changes in non-price credit conditions in the mortgage market, relative to the domestic stock of savings. In particular, as shown in Figure 4, it captures the dramatic easing of credit conditions that took place in Ireland between the mid-1990s and the mid-2000s, when the ratio of mortgage credit to deposits rose from approximately 60% to 176%. This reflects the greater extent to which mortgage-issuing institutions increasingly relied on external sources of finance during the so-called "Great Moderation" that preceded the "Great Recession". This series becomes less reliable during the 2010s, as Irish-based mortgage-issuing institutions securitized large portions of their loan books, although these changes are, to the greatest extent possible, accounted for in the series used. More fundamentally, this is a stock measure and – following a dramatic increase in mortgage lending – further and more moderate easing of credit conditions may be less obvious than in the FTB series described above.

Figure 4: Credit conditions



3.5 Other series

Deflators All euro-denominated series – supply as measured by FCF, housing prices, and build and site costs – are converted into 2019 euro using the personal consumption expenditure deflator (PCE). Specifically, for the period 1995-2020, CSO Tables N2005 and N2006, corresponding to ESA Code P.3 (personal consumption of goods and services), were used to give nominal and real (2019) euro totals. These were extended back to 1970 using CSO Tables NAH05 and NAH06, giving an annual series for the PCE deflator, which increased from 7.42 in 1970 to 100.0 in 2019.[7] For quarterly analysis, the PCE deflator was interpolated from annual series.

Other Despite the nature of the error-correction method, including its one-step formulation, the potential exists for either reverse causality or omitted variable bias, with

[7] In further robustness checks, not shown below, four alternative deflators were used: GDP, GNI*, GFCF and the headline CPI measure. These did not materially affect the results, nor did they improve the model fit.

inter alia supply (including new supply) a determinant of price, as well as price determining new supply. To examine this, further data series are needed, in particular to verify the validity of the results from ECM, using Seemingly Unrelated Regressions (SUR) and Instrumental Variable (IV) methods. This includes estimates of population and number of households, which are interpolated from Census frequency where necessary, as well as county-level estimates of household income. These, and the mortgage rate, are sourced from the CSO.

4 Empirical Strategy

To analyse the determinants of HSE in Ireland, we use five complementary sets of specifications.

1. Firstly, we examine the responsiveness of housing supply, nationally at annual frequency, using investment, completions and planning permissions, from the 1970s to the present day.
2. Secondly, we examine the responsive of housing supply in Dublin, Ireland's largest city, using completions data over the same period.
3. Thirdly, we use national data at quarterly frequency, for both FCF, which are available in Ireland since 1995, and completions (over the same time period), to examine more closely the relationship between supply and its determinants.
4. Fourthly, we construct a county-level panel, for each of the 26 traditional counties in Ireland and examine how supply – measured by completions, commencements and permits – responds to prices and costs.
5. Finally, we examine whether this relationship holds at the sub-county level, using a panel dataset of prices and planning permissions granted, at quarterly frequency from 2012Q1, across 389 micro-markets.

In all sets of specifications, we have as our core long-run equation the following:

$$ln(supply)_{it} = \alpha + \beta ln(hp)_{i,t-v} + \gamma_1 ln(c^B)_{i,t-v} + \gamma_2 ln(c^L)_{i,t-v} + \delta ln(MMC)_{i,t-v} \quad (1)$$

where hp refers to housing prices, c^B to build costs, c^L to land costs, and MMC to mortgage market conditions, and v to the appopriate lag for each regressor. The coefficient β gives the estimate of HSE, i.e. how housing supply responds to changes in prices, other factors being equal. As described in Section 3, identifying assumptions include that, to the first order, neither build cost nor mortgage market conditions vary substantially outside Dublin at any given point in time. Given more recent data by region on build costs, and given that the mortgage market comprises only national lenders and no local ones, these are unlikely to be problematic.

Our standard empirical set-up is an error-correction framework, where changes in supply in this period reflect the extent to which the long-run equation in the last period was out of equilibrium: for example the larger a positive error (or residual) in the last period, the more supply should correct down in this period. We estimate our equations using both two-step and one-step error correction frameworks. Given the number of specifications, for ease of exposition we report the coefficients from the long-run equation as estimated in the first of two steps, unless otherwise stated. However, given the potential for correlation between long-run determinants and short-run dynamics, we report results from the one-step set-up at regular intervals. As is to be expected, given the range of measures of supply, as well as regressors, short-run dynamics can vary by exact specification.

Across the first four sets of specifications, we also examine whether estimated HSE varies over time, using rolling windows and growing windows methods. The rolling windows method takes the smallest viable window (for example 25 years in an annual setting or 8 years, i.e. 24 quarters, in a quarterly setting) and estimates the core equation for each window, moving the start and end periods forward by one each time. This is particularly helpful in examining whether the coefficient is different in one period (e.g. 1970-1995) than another (e.g. 1996-2020). The growing windows method supplements this approach, by starting with a minimum viable window and adding one extra period at a time. Together with the rolling windows approach, this can aid the identification of periods where parameter values change substantially.

5 Results

This section reports results from estimating Equation 4 for the different measures of supply and using the different time series and panels, as outlined in the previous section. To start, we analyse investment, completions and permissions, at annual frequency and at national level, with completions also available for Dublin. We then develop a national quarterly time series model that includes LTV/LTI measures of MMC. In our remaining sets of specifications, we exploit county and micro-market variation in prices and price trends.

As described in Section 3, in addition to four different measures of outcome (capital formation, completions, permissions and commencements), we have baseline and alternative measures of our four regressors. For all geographic levels apart from micro-markets, we have mix-adjusted average prices as our preferred measure but also average (usually median) price of new homes. Build costs are measured through the official CSO measure but, for robustness, SCSI data can be used for the period from 1989. Land costs are measured using agricultural land values from 1970 and direct measures of site costs from 2004. Lastly, our principal measure of credit conditions (MMC) is median first-time buyer LTV (at national level) and LTI (at county level) from 2000; prior to 2000, the analysis relies on the credit to deposit ratio.

In all specifications, we use a log-log model, allowing the coefficients estimated to be interpreted indirectly (one-step ECM) or directly (two-step) as elasticities. The lag structure is such that costs, for both construction and site, enter with a longer lag (in years or quarters) than prices and MMC, reflecting the theoretical and empirical understanding on the relative speed of demand compared to supply.

5.1 Annual time-series

Detailed regression results for the determinants of housing supply over the long-run in Ireland are given in Table 1, for the all-in-one error correction set-up; results for a two-stage error-correction set-up, where a long-run equation is estimated in levels and then inserted into a short-run dynamic equation, are given in Appendix Table A.1. In what follows, an overview is given for each of the four regressors. We turn first to results for HSE, i.e. the responsiveness of housing supply to changes in prices. Figure

5 presents an overview of the estimates of long-run HSE, across all three measures of housing supply from 1970.

Price elasticity of supply For investment in new dwellings, the estimated long-run responsiveness of housing supply to a change in prices is 1.5 – in other words, a 10% increase in prices is associated with, everything else being equal, a 15% increase in investment in residential construction. Figure 5 presents the implied long-run HSE for 25-year samples, using the same specification. Samples where the overall relationship does not hold, defined here as where the t-statistic on the speed-of-adjustment (lagged level) takes a value of less than one, are omitted; this results in seven successive 25-year samples, ending between 2006 and 2012 being dropped from the graph.[8] What is striking is how the earliest and latest samples – which run 1970-1994 and 1996-2020 respectively – produce estimates of the long-run HSE that are very similar (1.42 and 1.51 respectively) and also in line with the overall 1970-2020 sample (1.50).

For completions, the same parsimonious model produces sensible results, with the sign on coefficients in line with economic theory and all variables statistically significant.[9] The model also has solid explanatory power, with an R^2 of 80%, as with investment, and a root mean square error of 0.11 (versus 0.077 for investment). The specifics, however, are somewhat different in two key respects. Firstly, the overall estimate of HSE is higher: 2.07 compared to 1.5 for investment. Secondly, the rolling windows results suggest if anything greater responsiveness over time of housing supply to changes in prices, when measured by completions rather than investment. The long-run elasticity effectively doubles from 1.7 in the 1970-1994 sample to 3.3 in the 1996-2020 sample.

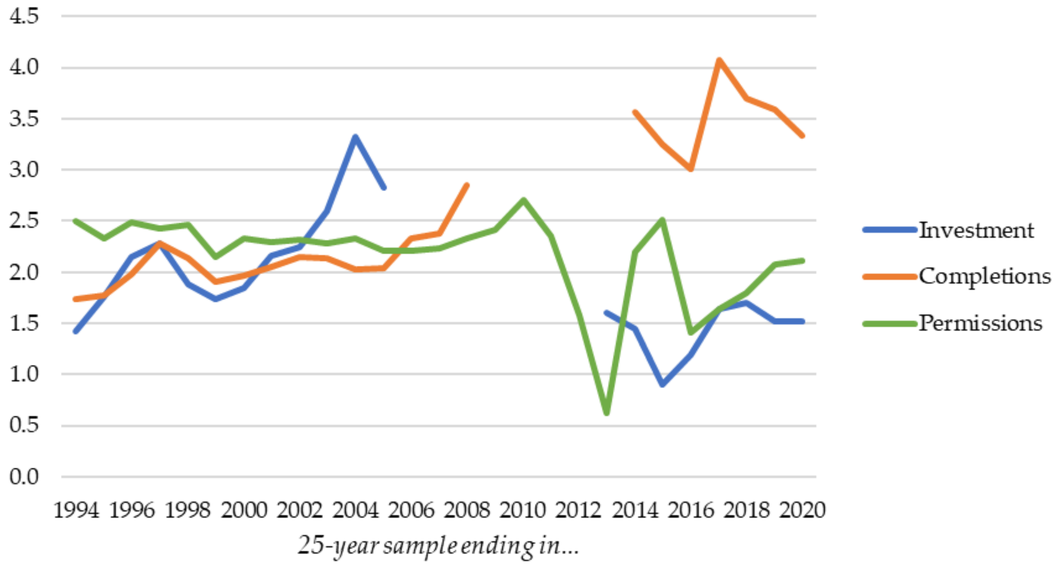
For permissions, we use the same parsimonious model with similar results, including for R^2 and most regressors, although the coefficient on land costs is not statistically significant. The overall estimate of the responsiveness of permissions to changes in housing prices is 2.1, in line with the estimate for completions (and above that for investment: 1.5). In rolling windows analysis, the estimated elasticity is largely stable, averaging 2.3, until the 25-year samples ending in the early 2010s. After some volatility, the measure in the final sample (1996-2020) has a value of 2.1, in line with estimate HSE for the overall period.

Supply & Costs For the period as a whole, there is a clear negative relationship between construction costs, whether measured by the CSO series or by the SCSI measure, and housing supply. This is in line with economic theory: for a given price level, higher costs will reduce viability and thus shift in supply. For investment, the estimated long-run elasticity of supply with respect to construction costs is -0.84, while for the two other unit-based measures – completions and permissions – the response is greater than unit-elastic. With private completions as the outcome of interest, the estimated elasticity is -1.27 while for permissions it is -1.85. Rolling windows analysis highlights the break involved with Section 23 reliefs: in all three series, once 25-year samples extend beyond 1998 there is a clear break in parameter estimates, with the implied elasticity even turning positive until 2008 for investment and completions. For permissions, the elasticity remains negative throughout but reduces in size during this decade, im-

[8] The implied long-run elasticities in these samples vary from +6 to -100.

[9] The outcome used is the total number of private-sector completions. If all completions are used instead, the model still holds, although the coefficient on land costs becomes insignificant, perhaps reflecting the lack of land costs for public housing in the Irish system.

Figure 5: Estimates of long-run HSE, from 25-year annual samples by rolling window and measure of supply



plying a reduced importance to costs when widespread reliefs were available. In all three set-ups, the elasticity with respect to costs in the 25-year sample ending in 2020 is smaller than in the sample overall: -0.72, -1.27 and -1.36 for investment, completions and permissions, respectively.

Even aside from the parameterized treatment of tax reliefs, there are reasons to believe that the path of construction costs over time is imperfectly measured by both CSO and SCSI measures, as quality and quantity of housing changed over time in ways not captured by one or both series. This will, of course, affect the accuracy and precision of estimates of the elasticity of supply to construction costs. The same issue characterizes the estimated response of housing supply to land costs. For the full 50-year sample, the estimated long-run elasticity is -0.42 for investment and -0.49 for (private) completions, and statistically significant in the one-step error-correction set-up. In the permissions specification, however, the coefficient is not statistically significant and its inclusion or omission does not affect parameters for other regressors. In principle, this may reflect a difference in the supply measure: while completions and investment reflect effort already undertaken (including sites secured), planning permissions are a more immediate supply response but without any on-the-ground commitment. However, varying the lag structure for the permissions specification does not improve the diagnostics for this regressor. More accurate data on land costs are available from 2004 and we use these in panel settings.

Table 1: Annual national long-run house price relationship (one-step error correction)

	1970-2020			1970-1995			1996-2020		
	Investment	Completions	Permissions	Investment	Completions	Permissions	Investment	Completions	Permissions
Prices	0.446***	0.523***	1.127***	0.757***	0.952***	2.107	0.415*	0.481*	1.167***
	0.077	0.107	0.164	0.172	0.177	1.046	0.144	0.187	0.214
epsilon	1.497	2.067	2.103	1.756	1.773	2.331	1.515	3.34	2.106
Build costs	-0.249**	-0.321*	-0.989***	-0.133	-0.287	-2.223	-0.197	-0.095	-0.754**
	0.083	0.137	0.226	0.226	0.2	1.892	0.178	0.224	0.249
epsilon	-0.836	-1.269	-1.845	-0.309	-0.534	-2.459	-0.719	-0.66	-1.361
Land costs	-0.125**	-0.125*	0.103	-0.169**	-0.108	0.033	-0.074	-0.372	0.267
	0.042	0.06	0.086	0.048	0.059	0.299	0.18	0.218	0.235
epsilon	-0.419	-0.494	0.192	-0.392	-0.201	0.037	-0.27	-2.583	0.482
MMC	-0.194**	-0.497***	-0.947***	-0.473	-0.959**	-1.291	-0.179	-0.069	-1.1**
	0.068	0.111	0.17	0.243	0.285	0.832	0.216	0.3	0.327
epsilon	-0.651	-1.964	-1.767	-1.097	-1.786	-1.428	-0.653	-0.479	-1.986
SOA	-0.298***	-0.253***	-0.536***	-0.431**	-0.537***	-0.904**	-0.274*	-0.144	-0.554***
	0.05	0.053	0.083	0.113	0.114	0.279	0.121	0.098	0.107
r2	0.76	0.766	0.763	0.748	0.784	0.409	0.752	0.838	0.846
rmse	0.077	0.11	0.136	0.054	0.056	0.149	0.098	0.121	0.133
N	50	50	45	25	25	20	25	25	25

Notes: This table shows the results of an all-in-one single-step error correction regression, where the dependent variable is the log of investment, completions or supply, as denoted by the column heading. The sample is given by the supercolumn heading. Prices, build costs and land costs are as described in the text, as is MMC (mortgage market conditions). SOA refers to the speed of adjustment, i.e. the coefficient on the lagged level of the relevant supply measure, while the coefficients are those on the relevant lagged level of the regressors. To calculate the long-run equilibrium coefficient, the coefficient shown above for any regressor is divided by the speed of adjustment (multiplied by minus 1) and given by *epsilon*.

Mortgage market conditions Our final regressor relates to mortgage market conditions. In the 50-year sample, these are captured by the ratio of mortgage credit to household deposits (Lyons & Muellbauer, 2015). As discussed above, theory would suggest that the loosening of credit conditions is a housing demand-side factor, rather than a supply side one and that a positive impact of credit conditions on housing supply would be indirect, through pushing up prices, rather than direct. Our national annual sample confirms – across all three supply measures – the absence of a separate direct channel from credit conditions to supply. Indeed, for all three measures, the estimated long-run elasticity of housing supply to the credit-deposit ratio is negative, rather than positive: from -0.65 for investment to -1.96 for completions. The negative relationship – it should be noted controlling for the level of prices and costs – is not statistically significant for the second half of the sample. The all-in-one error-correction specification includes a dynamic term for this ratio, which is positive and (for the full sample) statistically significant. This suggests a ceiling to the supply effect: a given loosening of credit conditions (the change in cdr) has a smaller impact on supply, where those credit conditions are already looser to begin with (the level of cdr).

Robustness Table 1 summarizes the regression results and diagnostics for the overall 50-year sample and the earlier and later 25-year samples, based on the one-step error-correction set-up. Results from a two-step error correction set-up are similar, in particular for the estimate of HSE: estimated HSE coefficients for investment, completions and permissions in the full sample are 1.48, 1.85 and 1.95, compared to 1.50, 2.07 and 2.10 in the one-step set-up. The effect is similar for build costs, but with the coefficients in the two-step set-up larger in magnitude, while the negative coefficient on MMC and the weaker significance of land costs also carries over. This provides confidence for using the two-set set-up where necessary. As noted above, the potential remains for reverse causality or omitted variables. We further estimate the long run relationship employing a seemingly unrelated regression (SUR) framework using a demand equation with prices as the dependent variable and on the right hand side population, disposable income and the net mortgage market rate in order to account for contemporaneous correlation between the errors of demand and supply equation. Results, which are given in the Appendix (Section A.3), support the single-equation set-up adopted here.

Dublin completions We supplement our national time-series analysis with an analysis of dwellings completed in Dublin, Ireland's largest city, at annual frequency from 1970. Table 2 summarizes the results. Overall, the responsiveness of completions in Dublin to changes in Dublin housing prices is estimated at just below 2 (1.99), compared to 2.07 nationally for completions. There are significant differences between earlier and later periods, however. Completions in Dublin responded more modestly to price changes 1971-1996 with an estimated HSE close to 0.8 (compared to 1.77 nationally for the same period). In the later period (1996-2020), the responsiveness of completions was far greater: 3.25, effectively in line with the national average for this later sample (3.34). As with the national 50-year sample, build costs, land costs and MMC (as captured by the credit-deposit ratio) were negatively linked with housing supply and with coefficients that were, by and large, similar to the estimates for the national sample. For the post-1995 period, however, no statistically significant relationship exists between the ratio of credit to deposits and dwellings completed in Dublin.

Table 2: Annual Dublin long run house price relationship (one-step error correction)

	Completions		
	1970-2020	1970-1995	1996-2020
Prices	0.671***	0.551*	1.12**
	0.16	0.257	0.329
epsilon	1.991	0.825	3.246
Build costs	-0.561	-0.42	-0.217
	0.25	0.377	0.458
epsilon	-1.665	-0.629	-0.629
Land costs	-0.238	-0.236	-0.199
	0.118	0.086	0.419
epsilon	-0.706	-0.353	-0.577
MMC	-0.7**	-1.895*	-0.694
	0.243	0.669	0.639
epsilon	-2.077	-2.837	-2.012
SOA	-0.337***	-0.668***	-0.345*
	0.078	0.157	0.131
r2	0.482	0.57	0.607
rmse	0.221	0.121	0.248
N	50	25	25

Overall, across national and Dublin annual samples from 1970, there is strong evidence that supply responds positively to increases in housing prices, and negatively to build and land costs, in line with the predictions of basic economic theory. Moreover, there is no evidence to suggest a positive direct link between mortgage market conditions and housing supply; a negative link is driven by the pre-1995 period. These results are largely confirmed by our SUR framework in Section A.3. The determinants of housing supply in Dublin over the last half-century have been similar to those for the country as a whole. Both nationally and in Dublin, the responsiveness of supply to changes in price – other factors being equal – increased in the post-1995 period, with Dublin's HSE converging to the national average.

5.2 Quarterly time-series

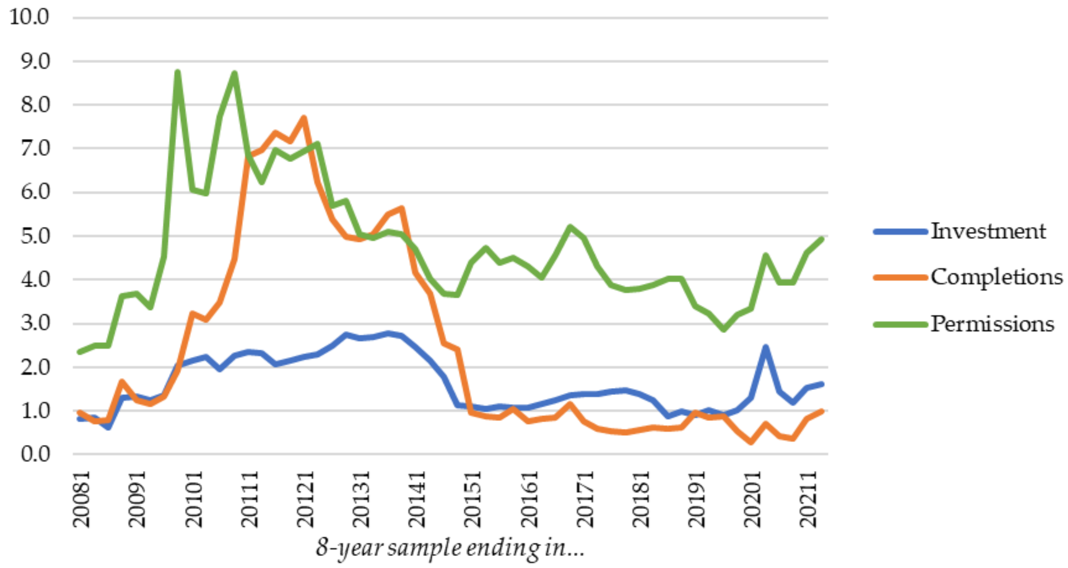
From 1995, quarterly national accounts are available for Ireland, allowing an analysis at higher levels of frequency. We include two additional measures of MMC, to better understand whether any relationship exists between credit supply and housing supply. As described above, in addition to the ratio of credit to deposits (a system-wide measure), we also have from 2001 median loan-to-income (LTI) and loan-to-value (LTV) for first-time buyers, at quarterly frequency. Table 3 reports regression results for three national measures of supply – investment (FCF), completions and permissions – and three measures of MMC, using the one-step error correction method. In all nine cases, the speed of adjustment to the equilibrium relationship is rapid, indicating the specification implied by theory explains the observed outcomes well. As with the annual data set, we also employ rolling window methods, in this case 32 quarters (rather than 25 years). These analyses are supplemented in robustness checks with growing windows and in Appendix A.3, using a seemingly unrelated regression (SUR) set-up, to rule out mismeasurement through reverse causality.

Table 3: Quarterly national long run house price relationship (one-step error correction)

	CDR			LTI			LTV		
	Investement	Completions	Permissions	Investement	Completions	Permissions	Investement	Completions	Permissions
Prices	0.542***	0.502*	1.596***	0.657***	0.512*	2.077***	0.909***	0.657**	2.782***
	0.15	0.223	0.43	0.167	0.215	0.48	0.185	0.223	0.524
$epsilon$	1.522	2.39	3.874	1.95	2.547	4.626	2.029	2.869	4.583
Build costs	-0.472***	-0.97***	-0.957***	-0.448***	-0.952***	-0.986***	-0.488***	-0.972***	-1.02***
	0.107	0.27	0.24	0.108	0.277	0.234	0.105	0.272	0.222
$epsilon$	-1.326	-4.619	-2.323	-1.329	-4.736	-2.196	-1.089	-4.245	-1.68
Land costs	0.113	-0.027	-0.435	0.009	-0.128	-0.309	-0.018	-0.084	-0.77**
	0.124	0.236	0.34	0.105	0.199	0.286	0.083	0.167	0.239
$epsilon$	0.317	-0.129	-1.056	0.027	-0.637	-0.688	-0.04	-0.367	-1.269
MMC	-0.117	-0.06	-0.119	-0.085	0.049	-0.672	-0.723*	-0.581	-2.823**
	0.074	0.134	0.222	0.131	0.24	0.409	0.274	0.476	0.885
$epsilon$	-0.329	-0.286	-0.289	-0.252	0.244	-1.497	-1.614	-2.537	-4.651
SOA	-0.356***	-0.21***	-0.412***	-0.337***	-0.201***	-0.449	-0.448***	-0.229***	-0.607***
	0.073	0.058	0.088	0.073	0.058	0.088	0.082	0.062	0.102
r2	0.316	0.188	0.229	0.299	0.185	0.254	0.353	0.2	0.32
rmse	0.102	0.192	0.279	0.104	0.193	0.275	0.1	0.191	0.262
N	86	86	81	85	85	81	85	85	81

HSE For each of three measures of supply, and across all three measures of MMC, the positive relationship between prices and supply observed in the annual data is also seen in the quarterly data. Quarterly data suggest that permissions are most responsive. The estimated HSE from the long-term equation in a one-stage ECM setup is shown in Figure 6 for each of the three measures of supply, for different eight-year rolling windows. Quarterly data suggest very responsive supply when transitioning from increasing to falling prices. For all three measures, an eight-year sample that includes the 2008-2012 period produces an estimate of HSE that is significantly larger than a sample that finishes in 2008Q1: an elasticity of 6-7 for completions and permissions (rather than 1-2) and between 2 and 3 for investment (rather than 1). Results from using planning permissions as the measure of supply suggest this more responsive supply persists throughout the later rolling windows, with an estimated HSE of 5 in the final eight-year sample, which ends in 2021Q3. For investment and completions, however, estimated HSE had fallen back significantly: unitary elasticity for completions (similar to the earliest sample ending in 2008Q1) and 1.6 for investment (roughly twice the estimated HSE for the earliest sample).

Figure 6: Estimates of long-run HSE, from 8-year quarterly samples by rolling window and measure of supply



MMC Across all three measures of supply, there is no evidence to suggest that – controlling for other factors, in particular housing demand as reflected in prices – that looser lending conditions are associated with higher level of housing supply. As with annual data, in all nine cases shown in Table 3, the coefficient is negative. In seven of those cases, it is not statistically significant; in the other two, a higher loan-to-value is associated with lower housing supply, when measured by investment or permissions and other things being equal. Together with the national results, this presents strong *prima facie* evidence that macro-prudential rules, introduced in 2014, have not adversely affected housing supply in Ireland.[10]

[10]This is based on the premise that, had those rules not been introduced, mortgage-lending institutions would have been more generous in their lending than was observed. It should be noted that the typical

Costs Across all nine quarterly specifications, build costs have a negative effect on housing supply, in line with basic economic theory. Likely due to the imprecise nature of the build cost series, as well as the different nature of the three measures of supply, the estimates vary significantly. Taking as the baseline investment as the measure of housing supply, and loan-to-value as the measure of MMC (as it is associated with the smallest RMSE in quarterly specifications), the implied long-run elasticity of housing supply to costs is just above unitary (-1.09), compared an estimated HSE of just above 2 in the same specification. In only one of the nine specifications is there a statistically significant negative relationship between supply and estimated land costs, again perhaps reflecting the imprecision in its measurement.

Dublin Table 4 presents the core regression results for Dublin supply, measured at quarterly frequency using both completions and permissions for the period for which quarterly data are available. The results, from a two-step error correction set-up and supported by rapid adjustment to equilibrium (shown in the SOA term), largely confirm the earlier analyses. Again, supply increases in response to a rise in housing prices or a fall in costs; any relationship with mortgage market conditions is negative.

Table 4: Quarterly Dublin long run supply equation (one-step)

	Permissions			Completions		
	CDR	LTV	LTI	CDR	LTV	LTI
Prices	1.053 *	1.053 *	1.182 *	0.799 **	0.799 **	0.836 ***
	0.432	0.432	0.449	0.241	0.241	0.244
epsilon	2.077	2.077	2.239	3.05	3.05	3.167
MMC	-0.034	-0.034	-0.164	-0.001	-0.001	-0.077
	0.023	0.023	0.207	0.011	0.011	0.099
epsilon	-0.067	-0.067	-0.311	-0.004	-0.004	-0.292
Build costs	-0.764 *	-0.764*	-0.839 *	-0.717**	-0.717**	-0.706**
	0.352	0.352	0.35	0.224	0.224	0.222
epsilon	-1.507	-1.507	-1.589	-2.737	-2.737	-2.674
Land costs	-0.091	-0.091	-0.029	-0.015	-0.015	0.142
	0.428	0.428	0.588	0.201	0.201	0.282
epsilon	-0.179	-0.179	-0.055	-0.057	-0.057	0.538
SOA	-0.507***	-0.507***	-0.528***	-0.262 ***	-0.262 ***	-0.264 ***
	0.105	0.105	0.107	0.062	0.062	0.062
r2	0.219	0.219	0.203	0.231	0.231	0.237
rmse	0.556	0.556	0.562	0.271	0.271	0.27
N	85	85	85	85	85	85

5.3 County-level quarterly panel

We supplement our national and Dublin analyses with two forms of panel analysis, the first using the 26 traditional counties of Ireland and three measures of housing supply:

loan-to-income of first-time buyers did increase from roughly 2.5 in 2014 to 3.3 in 2021, as the rules applied.

completions, commencements and permissions. All specifications include county fixed effects. The first four columns of Table 5 shows the five principal coefficients from estimating the county-level panel at quarterly frequency from 2004 to 2021 (66 quarters for each of 26 counties). As with the national quarterly analysis, we use the same SUR framework to ensure the validity of our error-correction set-up; we use LTI as our principal measure of MMC, as this is likely to better reflect the more binding nature of spatially invariant macro-prudential mortgage rules (as discussed above).

Dwelling completions Where the outcome of interest is completions by county and quarter, the price and cost variables are very consistent with national and Dublin datasets but with, if anything, slightly larger magnitudes. The estimated HSE for completions from the two-step error-correction set-up is 3.1, while costs enter with a negative coefficient of 1.6 (construction) and 1.3 (land). The coefficient on LTI is, in this instance, positive and statistically significant, at 0.45 – the only instance across all specifications where there is any evidence of an independent positive link between credit supply and housing supply.[11]

Dwelling commencements As with completions, using the number of dwellings commenced in a quarter yields coefficients on price and costs in line with earlier analyses: a statistically significant positive estimated HSE (but larger, at 4.4) and negative for costs (1.4 for construction and 1.9 for land). The coefficient on MMC is not statistically significant. Using the SUR framework, the estimate of HSE reduces to 3.4, while the effect of MMC is indistinguishable from zero (-0.004) and statistically insignificant.

Dwelling permissions The findings where the outcome of interest is the number of dwellings for which planning permission was granted are consistent with other measures of supply and other datasets above. Once again, HSE is positive – and slightly larger, at over 5.1, or 4.4 in the SUR framework – while higher costs, both construction and land, lower supply. In this setting, again there is no positive link between credit supply and housing supply: the coefficient is negative and statistically significant (in both ECM and SUR frameworks).

Permissions for one-offs The fourth column in Table 5 shows the results where the outcome of interest is the number of 'one-off' units for which planning permission was granted. We view this as the most comparable to the measure of supply available at micro-market level (see below). Compared to overall permissions, the coefficient is noticeably smaller, 2.2 vs. 5.2, implying greater responsiveness from the professional (for-profit) development sector to market price signals. Again, there is no systematic link between MMC and supply, in either ECM or SUR set-ups. (The estimate of HSE is similar across both set-ups.)

5.4 Micro-market quarterly panel

We close our analysis with an analysis at the sub-county level, a panel of 389 micro-markets from 2012Q1. The unit of supply available in this instance is the number of planning permissions submitted (not the number of units for which planning was

[11] Using LTV, rather than LTI, as the measure of MMC, results in a slightly smaller estimated HSE (2.7 vs. 3.1) and an estimate of MMC elasticity of 0.8.

Table 5: Long run housing supply equation - county and micromarkets (two-step)

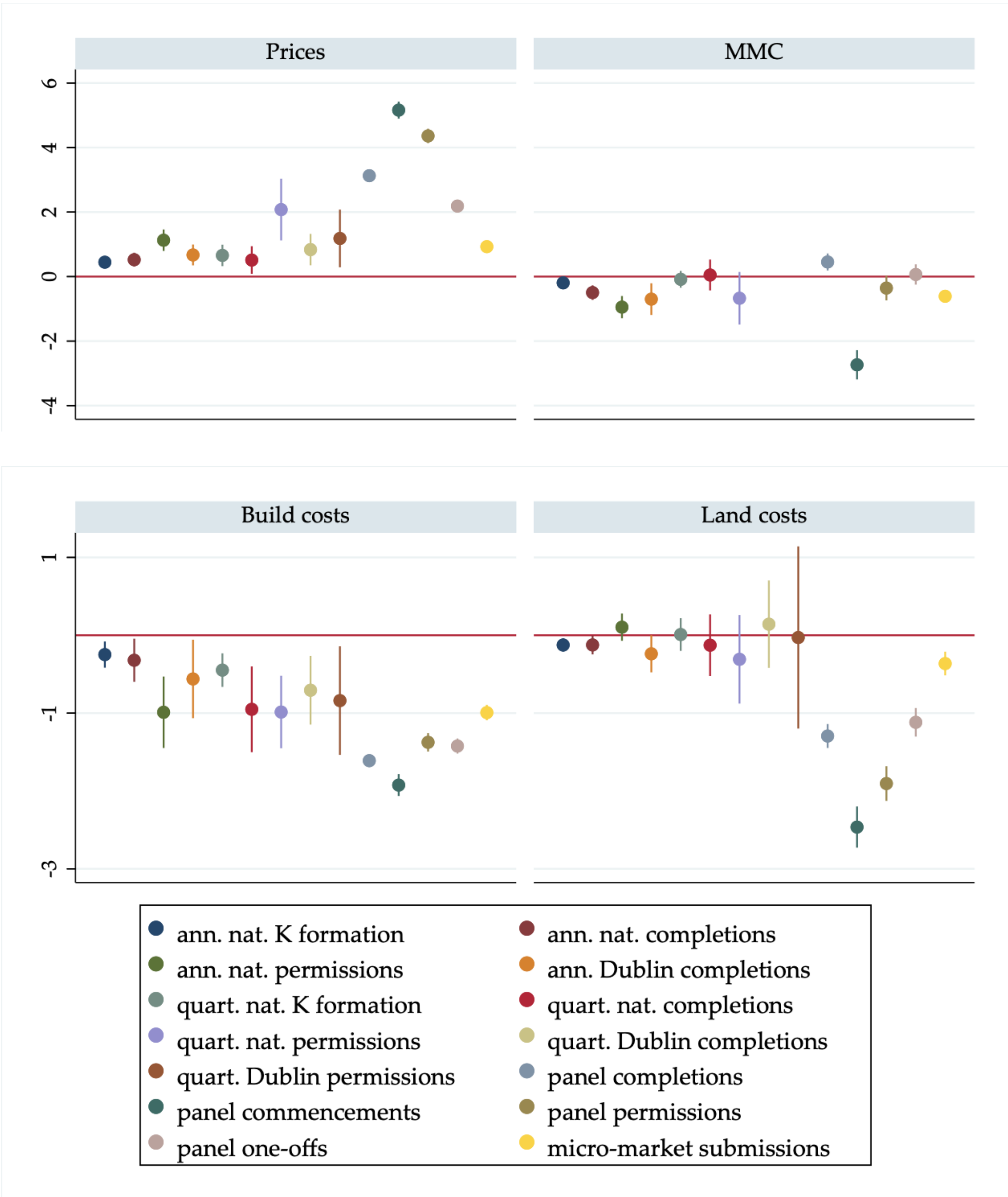
	County panel				micro markets
	Completions	Commencements	Permissions	Permissions: One-offs	Permissions: Submitted
Prices	3.128***	5.161***	4.361***	2.185***	0.928***
	(0.08)	(0.14)	(0.11)	(0.09)	(0.04)
Build costs	-1.611***	-1.924***	-1.375***	-1.423***	-0.994***
	(0.04)	(0.07)	(0.06)	(0.05)	(0.05)
Land costs	-1.294***	-2.464***	-1.905***	-1.118***	-0.364***
	(0.08)	(0.13)	(0.11)	(0.09)	(0.08)
MMC	0.453***	-2.736***	-0.356	0.065	-0.610***
	(0.13)	(0.23)	(0.19)	(0.16)	(0.08)
SOA	-0.082***	-0.168***	-0.226***	-0.151***	-0.209**
	(0.01)	(0.01)	(0.02)	(0.01)	(0.07)
N	1,716	1,716	1,716	1,716	14,961
r2	0.932	0.800	0.873	0.821	0.116
rmse	0.288	0.495	0.417	0.344	0.489
p	0.000	0.000	0.000	0.000	0.000

granted). As noted above, given this measure is skewed towards low-quantity applications, we include for comparability results for planning permissions for one-off units. We use micro market fixed effects for account for unobserved market-level heterogeneity. Results are displayed in the final column of Table 5. The estimated HSE is smaller than in other panel settings (0.9 compared to 2.2-5.2) but remains strongly statistically significant. Again, costs reduce housing supply – in the case of construction costs, the elasticity is effectively unitary. The coefficient for MMC is negative, as in a number of other settings, while the speed of adjustment (at 20% per quarter) is quite fast.

5.5 Summary of results

Figure 7 summarizes all of the above results, presenting the estimated elasticity of housing supply to changes in prices, costs and mortgage market conditions. The top two panels show the variables for which the expected coefficient is positive, prices and mortgage market conditions, while the bottom two show coefficients for the cost measures, where theory suggests a negative coefficient. The most striking feature is that the elasticity of supply to prices and to costs is remarkably consistent and in line with theoretical predictions, across all specifications. The housing supply elasticity to prices is statistically significant in all cases; there were only few exceptions for costs where this was not the case. In contrast, the estimated elasticity of supply to MMC exhibit a strong degree of heterogeneity. Not only there is no clear pattern with effects ranging from -3 to .5, additionally there seems to be no pattern in significance levels. These results are not driven by the choice of price measure or the choice of credit conditions series. Moreover, when estimating demand and supply equations jointly in national quarterly and county panel data sets, credit conditions drop close to zero and turn insignificant. A similar result is obtained when splitting up the quarterly and Dublin sample in different time periods. In particular, the more recent period from the mid-1990s to the present yields consistently insignificant estimates for MMC.

Figure 7: Graphical summary of estimated coefficients



6 Conclusion

The responsiveness of housing supply to demand is a topic of key concern for policymakers in many high-income economies. In this paper, we examined the determinants of housing supply in Ireland over the last five decades, using a variety of methods, data series and geographic and temporal scales. Throughout, we found clear evidence not only that housing supply responded to price increases but also that the responsiveness of supply persists to the present. Using annual and national data, the estimated responsiveness of completions to a 1% increase in prices was twice as high 1996-2020 (at 3.5%) than 1970-1995 (1.75%). Estimated HSE for investment and for permissions were similar in both periods, while quarterly data also indicate no fall-off in elasticity 2015-2021 compared to 2001-2008.

What, then, explains the overall lack of new housing supply in Ireland in recent years? The results above reflect conditional elasticities, as is conventional in economics – how supply responds to prices, other factors being equal. The extraordinary tax reliefs on construction costs, however, that applied 1998-2008 appear to have had both short-run and long-run consequences. In the short run, they did indeed have their intended effect, improving viability of new construction and facilitating large increases in housing supply. Almost immediately after their introduction, however, gross construction costs appear to have dramatically increased. Despite a small fall during the 2008-2012 crash, build costs – net of any reliefs – were almost twice as high in 2021 as in 2007, while prices (and land costs) were lower.

Our analysis also investigated the role of credit conditions, within the context of mortgage market rules introduced in 2014. We find no evidence that tighter lending conditions reduces housing supply directly; instead, any impact of macro-prudential rules on housing supply is likely indirect, by affecting demand and thus prices. To our knowledge, ours is the first study to attempt to examine this issue directly and thus our results have wider relevance than just the Irish case.

It is important to note the limitations to our analysis. We rely on macroeconometric techniques, in particular error-correction methods, to reveal determinants of housing supply. While we verify our results both within the method itself, assessing RMSE and the speed of adjustment, and using other methods, in particular SUR, it remains for future research to embed supply within the broader Irish housing system of equations. National and Dublin time-series results are supported by panel analyses at county and market levels. An analysis that exploits these spatial differences more explicitly – especially considering site-level permissions data – would shed further light on the determinants of Irish housing supply. A further limitation of this study relates to data: while measures of supply and prices are likely reliable, series capturing build costs, land costs and MMC are less precise. CBI data on mortgage market conditions since 2000 help but a detailed investigation of build and site costs, the latter varying hugely across space within the Irish market, would aid future investigations of supply responses.

Lastly, our findings have implications for public policy. It is the stated goal of Irish housing policy, in the 2021 *Housing for All* strategy, to increase completions from roughly 20,000 per year to over 30,000. The analysis here suggests that, for a 50% increase in supply to happen, prices would need to increase or costs to fall. Taking the 50-year analysis of national completions, the estimated HSE of 2.07 implies a 24% increase in prices would be needed to generate a 50% increase in supply. The same specification gives an elasticity of supply with respect to costs of -1.3, meaning a fall in construction costs of nearly 40% would be needed to achieve the same effect.

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A Appendix

A.1 Appendix A

Figure A.1: Yearly adding window using CDR

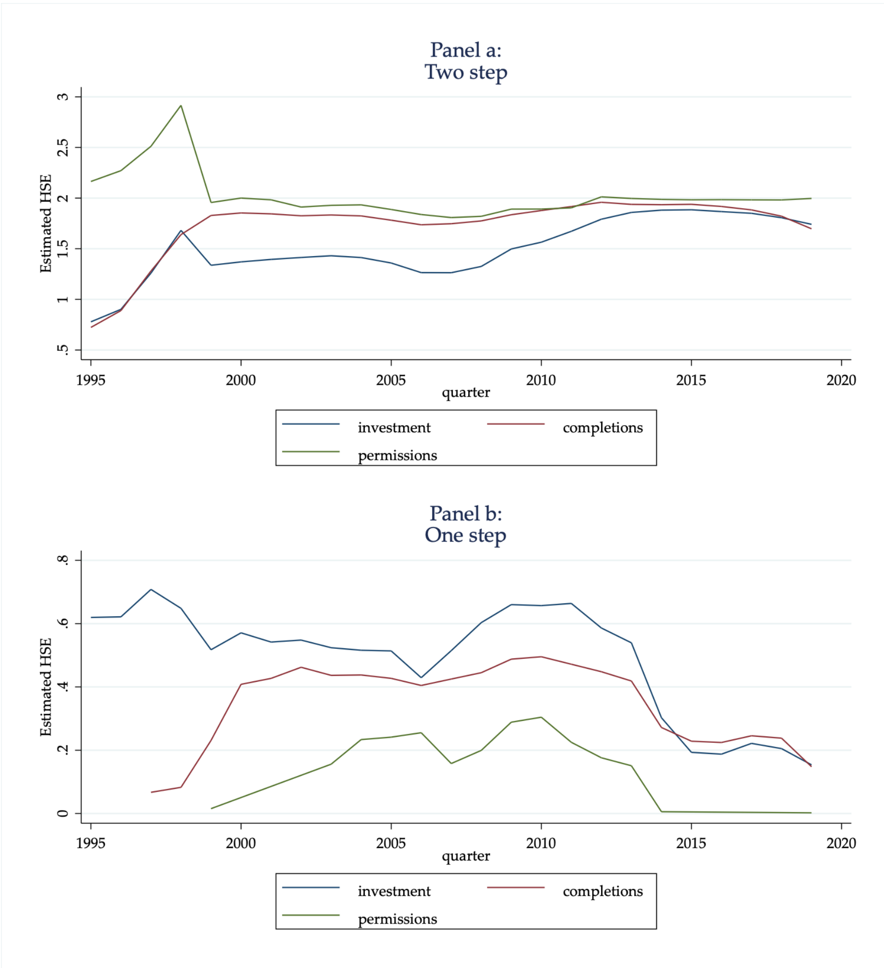
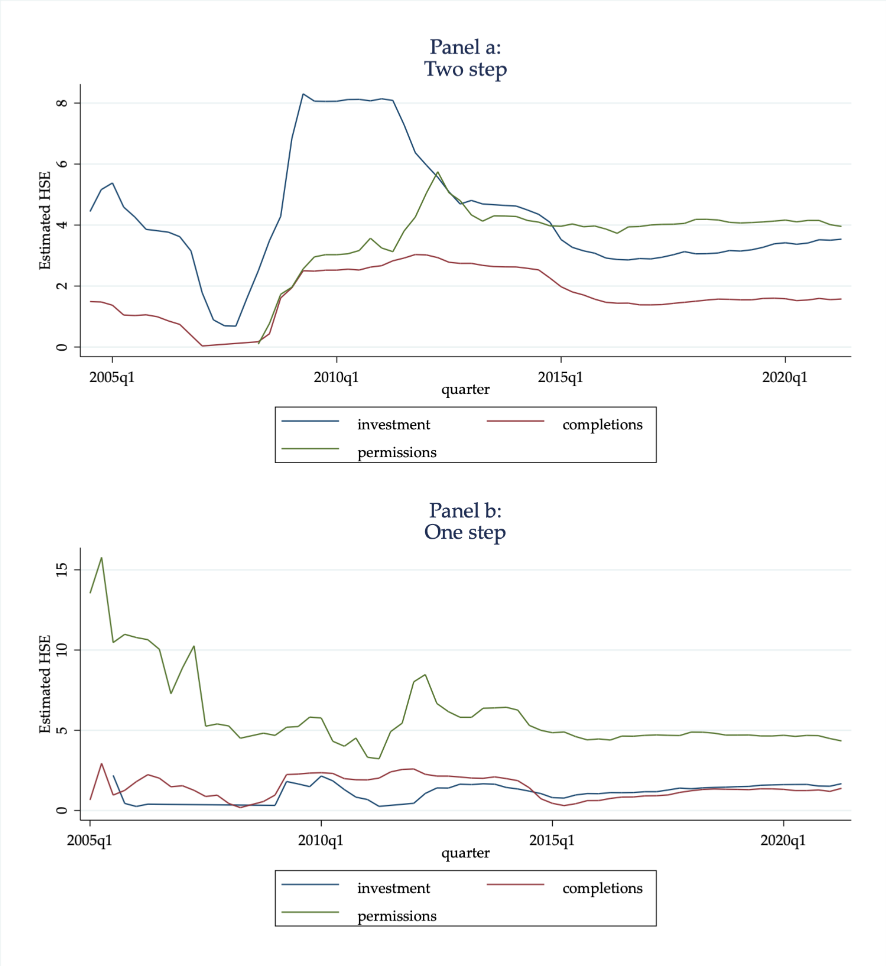


Figure A.2: Quarterly adding window using LTI



A.2 Appendix B

Table A.1: Annual national long-run house price relationship (2step)

	1970-2020			1970-1995			1996-2020		
	Investment	Completions	Permissions	Investment	Completions	Permissions	Investment	Completions	Permissions
Prices	1.757***	2.249***	2.420***	0.572*	1.153***	1.933**	1.237* **	1.956***	2.366***
	(0.12)	(0.16)	(0.19)	(0.22)	(0.25)	(0.57)	(0.18)	(0.27)	(0.25)
Build costs	-0.556***	-1.160***	-0.955***	0.695**	-0.217	-1.793*	-1.028* **	-1.566***	-1.036***
	(0.14)	(0.18)	(0.22)	(0.19)	(0.22)	(0.64)	(0.16)	(0.23)	(0.22)
Land costs	-0.353**	-0.458**	-0.171	0.009	0.005	0.200	-1.178* **	-1.882***	-1.457***
	(0.10)	(0.14)	(0.17)	(0.05)	(0.06)	(0.16)	(0.24)	(0.35)	(0.32)
MMC	-1.147***	-2.337***	-2.598***	-1.246***	-1.998***	-3.002***	-0.106	-0.679	-1.242**
	(0.18)	(0.24)	(0.29)	(0.26)	(0.29)	(0.74)	(0.31)	(0.45)	(0.42)
SOA	-0.329*	-0.397***	-0.459***	-1.183***	-1.049***	-0.794***	-0.575* *	-0.621**	-0.691***
	(0.13)	(0.11)	(0.09)	(0.19)	(0.16)	(0.19)	(0.17)	(0.19)	(0.10)
N	50.000	50.000	46.000	25.000	25.000	21.000	25.000	25.000	25.000
r2	0.854	0.845	0.833	0.864	0.828	0.725	0.902	0.926	0.928
rmse	0.210	0.279	0.304	0.074	0.083	0.187	0.191	0.278	0.261
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A.2: Annual Dublin long run house price relationship (2step)

	Completions		
	1970-2020	1970-1995	1996-2020
Prices	1.702***	0.480*	2.130***
	(0.16)	(0.18)	(0.29)
MCC	-2.268***	-2.423***	-1.108
	(0.29)	(0.38)	(0.61)
Build costs	-0.784***	0.184	-0.865**
	(0.22)	(0.18)	(0.29)
Land costs	-0.712***	-0.289***	-1.836***
	(0.17)	(0.07)	(0.46)
SOA	-0.276*	-1.069***	-0.368*
	(0.11)	(0.21)	(0.18)
N	50.000	25.000	25.000
r2	0.791	0.781	0.888
rmse	0.337	0.109	0.362
p	0.000	0.000	0.000

Table A.3: Quarterly national long run house price relationship (2step)

	CDR			LTI			LTV		
	Investment	Completions	Permissions	Investment	Completions	Permissions	Investment	Completions	Permissions
Prices	1.490***	1.573***	1.608***	1.486***	3.530***	3.279***	3.269***	3.960***	3.844***
	(0.06)	(0.12)	(0.13)	(0.10)	(0.24)	(0.25)	(0.32)	(0.25)	(0.26)
MMC	-0.569***	0.134	0.047	-1.665***	-0.301	0.912	-0.367	-1.017**	-1.135
	(0.08)	(0.17)	(0.36)	(0.12)	(0.33)	(0.70)	(0.20)	(0.35)	(0.78)
Build costs	-0.886***	-1.199***	-1.182***	-1.917***	-2.299***	-2.503***	-2.215***	-2.118***	-2.100***
	(0.07)	(0.06)	(0.08)	(0.10)	(0.11)	(0.15)	(0.11)	(0.12)	(0.16)
Land costs	-0.282***	-0.294*	-0.218*	-0.008	-1.273***	-1.448***	-1.155***	-1.062***	-1.629***
	(0.06)	(0.14)	(0.10)	(0.09)	(0.27)	(0.19)	(0.33)	(0.28)	(0.21)
SOA	-0.166***	-0.237	-0.248	-0.151**	-0.128	-0.145	0.017	-0.054	-0.034
	(0.05)	(0.14)	(0.14)	(0.05)	(0.12)	(0.12)	(0.21)	(0.22)	(0.21)
N	202.000	85.000	85.000	202.000	85.000	85.000	82.000	82.0 ¿ 00	82.000
r2	0.842	0.951	0.950	0.798	0.944	0.944	0.939	0.9 ¿ 42	0.938
rmse	0.214	0.128	0.128	0.320	0.251	0.250	0.264	0.2 ¿ 56	0.265
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0 ¿ 00	0.000

Table A.4: Quarterly Dublin long run supply equation (2step)

	Completions			Permissions		
	CDR	LTI	LTV	CDR	LTI	LTV
Prices	1.601***	5.438***	5.087***	2.661***	4.737***	4.327***
	(0.38)	(0.27)	(0.27)	(0.48)	(0.45)	(0.43)
Build costs	-1.692***	-1.680***	-1.855***	-0.831***	-0.818***	-0.993***
	(0.18)	(0.12)	(0.12)	(0.18)	(0.21)	(0.20)
Land costs	0.287	-1.616***	-2.166***	-0.902	-1.963***	-2.506***
	(0.51)	(0.29)	(0.26)	(0.54)	(0.49)	(0.42)
MMC	-2.276***	-1.448***	-1.989	-1.524***	-1.731**	-3.499*
	(0.26)	(0.36)	(1.08)	(0.31)	(0.62)	(1.75)
SOA	-0.236***	-0.726***	-0.620***	-0.956***	-0.865***	-0.790***
	(0.06)	(0.11)	(0.11)	(0.11)	(0.12)	(0.11)
N	110.000	85.000	85.000	90.000	85.000	85.000
r2	0.795	0.935	0.925	0.727	0.697	0.683
rmse	0.455	0.285	0.305	0.451	0.485	0.496
p	0.000	0.000	0.000	0.000	0.000	0.000

A.3 Appendix C

Table A.5: Seemingly unrelated regression - annual national results (2step)

Panel A: Demand

	investment	completions	permissions
Income	1.285***	1.292***	1.284***
	(0.36)	(0.36)	(0.36)
PHHR	6.187***	6.194***	6.211***
	(1.55)	(1.54)	(1.55)
SOA	-0.008	0.022	0.043
	(0.19)	(0.19)	(0.19)

Panel B: Supply

Prices	1.569***	2.428***	2.653***
	(0.23)	(0.35)	(0.31)
MMC	-0.331	-1.004*	-1.467***
	(0.30)	(0.46)	(0.41)
Build costs	-0.818***	-1.397***	-0.847***
	(0.16)	(0.24)	(0.22)
Land costs	-0.871***	-1.442***	-1.090***
	(0.21)	(0.32)	(0.29)
SOA	-0.728**	-0.766***	-0.685***
	(0.23)	(0.20)	(0.14)
N	19.000	19.000	19.000
r2	0.478	0.478	0.478
rmse	0.146	0.146	0.146
p	0.000	0.000	0.000

Table A.6: Seemingly unrelated regression - quarterly national results (2step)

Panel A: Demand

	CDR			LTI			LTV		
	investment	completions	permissions	investment	completions	permissions	investment	completions	permissions
Income	1.989***	1.995***	1.964***	1.974***	1.977***	1.963***	1.976***	1.968***	1.963***
	(0.13)	(0.13)	(0.15)	(0.13)	(0.13)	(0.15)	(0.13)	(0.13)	(0.15)
PHHR	8.026***	8.103***	8.023***	7.987***	7.998***	8.024***	7.996***	8.006***	8.031***
	(0.52)	(0.52)	(0.54)	(0.52)	(0.52)	(0.54)	(0.52)	(0.52)	(0.54)
SOA	-0.096**	-0.112**	-0.118***	-0.094*	-0.112**	-0.116**	-0.096**	-0.111**	-0.116**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Panel B: Supply									
Prices	1.366***	2.344***	3.044***	1.508***	2.967***	4.195***	1.573***	2.738***	3.912***
	(0.14)	(0.26)	(0.33)	(0.16)	(0.31)	(0.32)	(0.15)	(0.30)	(0.33)
MMC	-0.345*	-1.029***	-1.231***	0.096	-0.198	-1.127**	-0.113	1.170	-1.116
	(0.14)	(0.26)	(0.29)	(0.16)	(0.33)	(0.36)	(0.34)	(0.66)	(0.75)
Build costs	-1.021***	-2.046***	-1.766***	-1.203***	-2.457***	-2.023***	-1.157***	-2.723***	-2.085***
	(0.08)	(0.16)	(0.17)	(0.07)	(0.14)	(0.15)	(0.08)	(0.16)	(0.18)
Land costs	0.172	-0.083	-0.427	-0.228	-1.026***	-1.111***	-0.182	-1.161***	-1.666***
	(0.16)	(0.31)	(0.34)	(0.13)	(0.25)	(0.27)	(0.10)	(0.20)	(0.22)
SOA	0.072	0.302**	-0.203	0.093	0.211*	-0.160	0.076	0.255*	-0.105
	(0.09)	(0.10)	(0.15)	(0.09)	(0.10)	(0.15)	(0.09)	(0.10)	(0.14)
N	73.000	73.000	70.000	73.000	73.000	70.000	73.000	73.0 ¿ 00	70.000
r2	0.787	0.787	0.784	0.787	0.787	0.784	0.787	0.7 ¿ 87	0.784
rmse	0.096	0.096	0.098	0.096	0.096	0.098	0.096	0.0 ¿ 96	0.098
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0 ¿ 00	0.000