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THE IMPACT OF SUPPLY CONSTRAINTS ON HOUSE PRICES IN ENGLAND *

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ABSTRACT: We explore the impact of different types of supply constraints on house prices in England by exploiting a unique panel dataset of 353 local planning authorities ranging from 1974 to 2008. Using exogenous variation from a policy reform, vote shares and historical density to identify the endogenous constraints-measures, we find that: i) Regulatory constraints have a substantive positive impact on the house price-earnings elasticity; ii) The effect of constraints due to scarcity of developable land is largely confined to highly urbanised areas; iii) Uneven topography has a quantitatively less meaningful impact; and iv) The effects of supply constraints are greater during boom than bust periods.

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1. Introduction

House values in England – particularly in London and the South East of the country – are amongst the highest in the world.[1] The average price of a single detached freehold house in Kensington and Chelsea in 2008 – the last year of our sample period – was £4.3M (8.6M in 2008 US dollars). Of course, the royal borough of Kensington and Chelsea is extraordinary in many respects. However, house values were also extremely high in less exceptional places. The mean price of an equivalent house in Richmond, a nice 'greenish' London suburb was £1.2M; in the rather distressed but maybe transforming London borough of Hackney it still fetched £767k. Perhaps most astonishingly, even in rural places (e.g., Cotswold in the West of England; £470k) and in struggling cities (e.g., Birmingham in the West Midlands; £353k) house prices are very high by international standards.[2] These statistics are even more astounding when housing size is taken into account. A new-build house is 38 percent smaller in the UK than in densely populated Germany and 40 percent smaller than in the even more densely populated Netherlands (Statistics Sweden, 2005).

Real house prices – but not real incomes – have grown faster in the UK over the last 40 years than in any other OECD country.[3] As a consequence of this, a genuine 'housing affordability crisis' has been developing. Young households are particularly strongly affected; they increasingly struggle to get their feet on the owner-occupied housing ladder. Although existing homeowners nominally benefit from higher asset prices, they are also in some sense adversely affected. They cannot realise the 'gains' unless they downsize housing consumption, give up owner-occupation and rent instead or sell their houses and move abroad. In the interim high house prices force them to live in comparably cramped spaces.

Price volatility is similarly extraordinary. During the last full real estate cycle *real* house values in the UK as a whole first rose by 83 percent during the upswing of the 1980s; they subsequently declined by 38 percent during the downturn of the first half of the 1990s. This swing is substantially larger than that of the most volatile metro area in the US during the same cycle period: real values in Los Angeles rose by 67 percent and declined by 33 percent.[4]

In this paper we set out to explore the causal impact of various types of long-run supply constraints on house prices in England. Our main focus is on how *regulatory constraints* affect the sensitivity of house prices to changes in demand. The proposition that the English

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[1] According to a comprehensive country comparison of the buying price per square metre for residential properties in 97 countries, provided by Globalpropertyguide.com (http://www.globalpropertyguide.com/most-expensive-cities; last accessed: 28 March 2013), the UK (London) is ranked *second*, only topped by the tiny city-state of Monaco, a famous tax heaven with no income tax. Ignoring this 'special case', the UK (London) tops the world ranking ahead of Hong Kong, France (Paris), Russia (Moscow), Singapore, Switzerland (Geneva), Japan (Tokyo) and the United States (New York).

[2] Average prices are based on actual transaction prices – provided by the Land Registry – of *all* single detached freehold houses sold during 2008.

[3] Measured between 1971q1 and 2011q1 (OECD Economic Outlook database, 2011). Nationwide house price data suggests that prices have grown faster in England since 1973q4 than in any other UK country.

[4] The calculations for the UK are based on the Nationwide house price index. The nominal index is deflated by the retail price index that excludes mortgage interest payments in order to obtain a real price index. The troughs of the cycle were in 1982 and 1995, the peak was in 1989. The figures for Los Angeles are taken from Glaeser *et al.* (2008) who investigate the cyclical behaviour of 79 metro areas in the US. Real prices in Los Angeles rose between 1984 and 1989 and declined between 1990 and 1994.

planning system impacts house prices is not far-fetched. The planning system is widely viewed as inflexible. Historically, it ignored market signals and has failed adequately to cope with changing socio-economic conditions. This rigid supply regime has been suggested – but not tested – to be an important cause of England's excessively high level and volatility of house prices.

An alternative proposition is that the high house prices are driven – at least in part – by strong demand for housing in conjunction with *physical (or geographical) constraints*. The *scarcity of developable land* and *uneven topography (steep slopes)* may both limit the long-run response of housing supply to demand induced price changes: whereas scarcity related constraints may be binding in highly developed locations such as the Greater London Area, slope related constraints may affect prices in rugged areas in the North and West of England. In this paper we carefully control for such physical supply constraints and disentangle and identify the separate impacts of the different types of constraints.

To do so, we compile a panel dataset that combines house price and earnings information – spanning 35 years and covering 353 English Local Planning Authorities (LPAs)[5] – with rich and direct information on regulatory and physical supply constraints for these locations. Exploiting this data and using exogenous variation from a policy reform, vote shares and historical density to identify the causal effects of the otherwise endogenous constraints-measures, we find that local regulatory constraints have a substantive positive impact on the response of local house prices to changes in local earnings. These results are robust to using a labour demand shock measure, derived from the local industry composition in 1971 and national employment growth in these industries, instead of using earnings. According to our baseline estimate, house prices would be around 35 percent lower if, hypothetically, all regulatory constraints were removed. More pragmatically: had the South East, the most regulated English region, the regulatory restrictiveness of the North East, still highly regulated in an international context, house prices in the South East would be roughly 25 percent lower. The effect of constraints due to local scarcity of developable land is largely confined to highly urbanised areas. The local impact of uneven topography is quantitatively less important. Hypothetically removing both types of physical supply constraints, again according to our baseline estimate, would reduce house prices by 15 percent. The effects of the various supply constraints on the price earnings elasticity are greater during boom than bust periods.

Our contribution to the literature is threefold: (i) We use a unique panel dataset to disentangle the impact of local regulatory supply constraints from two types of local physical constraints (the degree of residential development and ruggedness) on house prices in England; (ii) We identify – using an Instrumental Variables (IV) approach – causal impacts of these constraints by examining the extent to which they amplify the impact of earnings on house prices; and (iii) We provide a thorough quantitative interpretation of the estimated effects.

[5] LPAs are the local authorities or councils that are legally responsible for the execution of planning policy and hence, they are the natural geographical unit for our analysis of the impact of planning policy on house prices. The average number of households in a LPA in our sample is 53158, based on the 1991 Census. LPAs are thus larger than the typical American municipality but smaller than the typical metropolitan area.

2. Background

Various studies suggest that the extraordinarily high real house price growth in the UK over the last 40 years and in particular since the mid-1990s may be linked to the British planning system (e.g., Cheshire and Sheppard, 2002; Barker, 2004 and 2006; OECD, 2004; Evans and Hartwich, 2005). In fact early research on this topic indicates that the British planning system may have already imposed binding constraints as early as the beginning of the 1970s (Hall *et al.*, 1973). Cameron *et al.* (2006) investigate the proposition that regional house prices between 1972 and 2003 in Britain have deviated from fundamentals ('bubble hypothesis'). They find no evidence suggesting a 'bubble', instead their results are consistent with lack of house building in conjunction with strong demand growth as a major driver of house price appreciation during their sample period, consistent with the main findings in this paper.

A few recent studies investigate the economic impact of the British planning system empirically, including its effect on house prices. For example, Bramley (1998) explores the effect of various measures of planning restraint on various outcome measures including house prices in a cross-section of English locations. One important contribution of this study is that it provides an early discussion on (i) how planning constraints should be measured and (ii) endogeneity problems associated with different types of measures. Cheshire and Sheppard (2002) and Ball *et al.* (2009) convincingly illustrate the high gross and net costs of the planning system for a single LPA in England. Cheshire and Hilber (2008) find that the gross cost imposed by regulatory restrictions – measured as a 'regulatory tax' – varies substantially across British office markets and over time, with the highest cost being observed in the Greater London Area. The estimated regulatory tax for Westminster, perhaps one of *the* most regulated places in the world, exceeds 800% of marginal construction costs. The lowest costs are being observed in Newcastle; the estimated tax is negative during the mid/late 1980s. The time trend is positive in most markets, consistent with the proposition that land use regulation policies in England may have become more binding over time.

Outside of the UK, research on the impact of land use regulation on house prices has mainly focused on the US. A number of recent studies document that land use regulation reduces the housing supply price elasticity (e.g., Harter-Dreiman, 2004; Green *et al.*, 2005; Quigley and Raphael, 2005; Saiz, 2010) whilst raising price levels (e.g., Glaeser and Gyourko, 2003; Glaeser *et al.*, 2005*a,b*; Quigley and Raphael, 2005; Saks, 2008). Particularly relevant to our study, Saks (2008) shows that metro areas with few barriers to construction experience more residential construction and smaller increases in house prices in response to an increase in housing demand. Glaeser *et al.* (2005*a,b*) conjecture that tight land use controls may be largely to blame for the exorbitant rise in housing prices in parts of the US during the late 1990s and early 2000s. Glaeser *et al.* (2005*a*) uncover that the 'regulatory tax' exceeds 50 percent of condominium prices in places such as Manhattan or San Francisco but is negligible in places such as Pittsburgh or Houston.

Glaeser and Ward (2009), however, do not find a significant impact of local land use regulation on house prices across local municipalities in the Greater Boston area. They argue that since this area constitutes of many nearby and rather similar towns, households would not accept a regulation-induced rise in prices in one place, because they could easily substitute it for another nearby place. As a consequence, in their sample, local constraints on housing supply may only have an impact on prices at the level of the Greater Boston area. The same argument should not apply, however, to studies that consider locations that are less close substitutes such as metro areas in the US or, arguably, LPAs in England. Several theoretical models have been proposed that assume heterogeneity in tastes for locations inducing imperfect substitutability between locations (Aura and Davidoff, 2008; Gyourko *et al.*, forthcoming; Hilber and Robert-Nicoud, 2013). In such models supply constraints may raise prices because they constrain the number of households so that the marginal household has a higher willingness to pay for residing in a particular place.

A few studies suggest that *physical supply constraints* affect the supply price elasticity and that therefore demand shocks should have a stronger impact on house prices in places with more limited supply of developable land. Hilber and Mayer (2009) demonstrate that the more developed 50 percent of municipalities in Massachusetts (with comparably less open and developable land for new construction) have more inelastic supply of new housing and that in these places demand shocks are capitalised to a greater extent into house prices. (This finding also implies that the more and less developed places in Massachusetts are sufficiently imperfect substitutes to ensure a differential price response to demand shocks.) Saiz (2010) measures the amount of developable land based on the presence of water bodies and high elevation in the US, demonstrating that most metropolitan areas that are widely regarded as supply-inelastic are severely land-constrained by topography.

Saiz (2010) also documents that topographical constraints correlate positively and strongly with regulatory barriers to development and that both types of constraints negatively affect the elasticity of housing supply. Hilber and Robert-Nicoud (2013) provide a theoretical explanation and empirical evidence for the US consistent with this explanation for why more developed places tend to be more regulated. More desirable locations are more developed and hence owners of developed land will be relatively more politically influential than owners of undeveloped land. Land use constraints benefit the former group (via increasing property prices) but hurt the latter (via increasing development costs). Hence, as a consequence of political economy forces, more developed places will be more regulated. This theoretical insight has implications for our empirical work: local regulatory constraints may be endogenous to local land scarcity. It is thus important to control for both types of constraints and identify their causal effects using an IV approach.

A few recent studies explore the impact of the supply side on *house price volatility*. Glaeser *et al.* (2008) illustrate that during boom phases house prices in the US grow much more strongly in metro areas with inelastic supply. They also report that the level of mean reversion during bust phases is enormous; however, the price elasticity and price declines are hardly correlated. The implication is that metro areas with more inelastic supply will have higher price volatility but this is, consistent with our findings for England, mainly driven by stronger price reactions during upswings. Paciorek (2013) documents a strong positive relationship at the city-level in the US between the volatility of house prices and the stringency of regulation of new housing supply. His estimates and simulations suggest that supply constraints increase volatility through two channels: (i) Regulation lowers the elasticity of new housing supply by increasing lags in the permit process and by adding to the cost of supplying new houses on the margin and (ii) geographic limitations on the area available for building houses lead to less investment on average relative to the existing housing stock, leaving less scope for the supply response to attenuate the effects of a demand shock.

3. Theoretical Framework

In this section, we develop a theoretical framework, in which households sort according to their idiosyncratic preferences for heterogeneous locations, and, in which house prices are determined such that, in a spatial equilibrium, no household has an incentive to move – i.e. all opportunities for 'spatial arbitrage' are exhausted. This focus on arbitrage *between* places is consistent with our empirical analysis in that we control for the impact of all aggregate (macroeconomic) shocks through year fixed effects and therefore identify the house price-earnings elasticity on variation in housing demand and supply determinants *between* places.

Places may differ in many aspects, such as proximity to the sea, landscape features, the availability of cultural facilities or the quality of local public schools, and there is no reason why households should all value these amenities in the same way. Furthermore, some of these amenities are arguably unique to specific places. No other place in England, for example, reproduces the White Cliffs of Dover or London's choice of museums. Heterogeneity in preferences over places is likely reinforced by personal history. People may feel attached to the place where they grew up, because they acquired a taste for the regional culture or because they want to stay close to friends and family.

In such a setting with idiosyncratic preferences for heterogeneous locations, in spatial equilibrium, the household on the margin of purchasing a house in a certain location will determine the price of access to its amenities. For unique amenities that are not available in a more or less continuously varying quality throughout the country, this price will depend on both the supply of housing with access to these amenities and on the distribution of preferences – see for instance Bayer *et al*. (2007) for a discussion. As housing supply in the location that offers this access expands, households enter with ever lower willingness to pay for the amenity and the amenity-induced house price premium falls accordingly. As we show formally below, the impact of local earnings shocks on house prices then also depends on housing supply conditions for essentially the same reason. A positive shock to local productivity, which increases the earnings a household can obtain in the boosted location, attracts new households, who bid up the price of housing until the marginal household is indifferent to living elsewhere. A place where housing is supplied more elastically will draw more households, so that the marginal household's willingness to pay for its unique amenities is lower.

Our particular focus is on demonstrating the impact of long-term supply constraints on the relationship between earnings and house prices in a setting as outlined above. We consider the impact of an exogenous change in local earnings, which may be driven for instance by a shock to an industry that is well represented in the local area. While earnings may also be influenced by local housing market conditions, our empirical analysis below verifies the robustness of our results to potential endogeneity of earnings by identifying on such arguably exogenous labour demand shocks. Furthermore, we simplify the analysis by ignoring differences in labour participation and skills across households and by treating housing units as homogeneous.

We consider one particular location (in our empirical setting e.g. an LPA or a Travel to Work Area, TTWA) that is small relative to the rest of the country. Let the country be inhabited by H households, indexed by h. We assume that the utility V that household h derives from residing in the location we consider is given by:

$$V\left(Y,P,A,h\right)=Y-P+A+\varepsilon\left(h\right), \tag{1}$$

in which Y denotes local earnings, P is the price of a unit of housing in the location and A captures local amenities that households value similarly or that are available throughout the country. Crucially, $\varepsilon(h)$ is an idiosyncratic taste for the unique amenities of this specific location, which different households value differently. Alternatively, this term can be interpreted as representing attachment to the location through personal history, existing local social networks or other barriers to mobility, such as transaction taxes and other moving costs, that vary over households and affect a household's willingness-to-pay to live in this specific location.[6] We assume that households have to live in the location in order to earn Y, ignoring the possibility of commuting. We verify in the empirical analysis below that our results are not sensitive to this assumption; our findings hold at the geographical scale of TTWAs, which are designed to fully contain local labour markets and therefore encompass commutes.[7]

Through a sorting process, the location will be inhabited by the households with the strongest tastes for living there, while the marginal household h^* will receive the same utility as some reservation utility $\overline{V}$ on offer in the rest of the country. Given the small relative size of the location, we take this reservation utility to be exogenous. The idiosyncratic taste of the marginal household must then be given by:

$$\varepsilon\left(h^*\right)=\overline{V}-Y+P-A, \tag{2}$$

whereas only households with $\varepsilon\left(h\right)\geq\varepsilon\left(h^*\right)$ choose to reside in the location. Under the assumption that each household occupies one homogeneous unit of housing, the demand for housing units will therefore be given by:

$$Q_D\left(Y,P,A\right)=H\left[1-F\left(\overline{V}-Y+P-A\right)\right], \tag{3}$$

[6] Random utility theory treats the idiosyncratic taste as a random draw from some taste distribution. See Anderson *et al*. (1992) for an in-depth discussion of the foundations of this approach and Hilber and Robert-Nicoud (2013) for a recent application to location choice across cities. Our characterisation of preferences closely mimics this latter paper.

[7] Productivity shocks at this higher level of spatial aggregation, in our framework, may still have differential local house price effects across LPAs with varying supply conditions.

where F denotes the cumulative density function of the distribution of idiosyncratic tastes.[8] This distribution shapes the relationship between demand and prices – low taste dispersion implies that F is steep so that demand is highly elastic.

On the supply side, we assume that housing development costs (i.e., land and conversion costs plus construction costs) are a quadratic function of the number of units in the location and that supply constraints X make this cost function more convex:

$$C\left(Q_S, X\right) = \tfrac{1}{2} Q_S^2 X . \tag{4}$$

This simple specification ensures that marginal development costs $Q_S X$ rise more steeply and hence housing supply is less elastic in places in which supply constraints are more severe. Regulatory constraints are likely to reduce the sensitivity of new housing supply to demand shifts and the positive link between the availability of developable land and supply elasticity is also well documented in the theoretical literature – see Hilber and Mayer (2009) for a brief overview. We impose that $X > 0$, meaning that no place has infinitely elastic housing supply. A more realistic approximation of the true housing development cost function may be obtained by adding in a constant and linear terms in Q_S, X and $Q_S X$ without changing our main result.[9] Furthermore, by choosing an appropriate unit of measurement for X, we may arbitrarily scale the impact of $Q_S^2 X$ on development costs.

Competitive developers will supply new housing until the price equals marginal development costs, so $P = Q_S X$. Equating supply to demand by substituting (3) into this condition, we obtain:

$$P = XH\left[1 - F\left(\bar{V} - Y + P - A\right)\right]. \tag{5}$$

This condition implicitly defines the equilibrium price $P\left(Y, X\right)$ of a housing unit in the location. This price depends on all the variables defined so far and on the distribution of tastes, but we only denote local earnings and supply constraints as explicit arguments for the sake of simplicity.

The impact of a rise in local earnings on the equilibrium price is obtained by implicit differentiation of (5). If we assume that tastes are uniformly distributed over an interval with length $1/f$, we obtain after some manipulation that:

$$\frac{\partial P\left(Y, X\right)}{\partial Y} = \frac{XHf}{1 + XHf}. \tag{6}$$

The derivative of the house price with respect to earnings is clearly positive, as an increase in local earnings induces households from the rest of the country to move into the location that

[8] Treating $\varepsilon(h)$ as a random variable means that expression (3) should be interpreted as expected demand. We will abstract from the stochastic aspect for ease of exposition and assume that F is the cumulative density function of the realized distribution of tastes.

[9] The constant and the linear term in X do not affect marginal development costs. The linear terms in Q_S and $Q_S X$ do not affect the derivative of marginal development costs with respect to earnings.

we consider until the higher housing costs exactly offset the increased earnings potential. Importantly, the price response depends on supply constraints. By further differentiating equation (6) with respect to *X*, we obtain:

$$\frac{\partial^2 P(Y,X)}{\partial Y \partial X} = \frac{Hf}{(1+XHf)^2} . \tag{7}$$

As can easily be verified, the derivative in (7) is again positive. Hence, our main proposition can be formulated as:

> **Proposition:** *Local house prices respond more sensitively to local earnings shocks in more supply constrained locations*.

Although our focus in this paper is on the impact of earnings on house prices, the effect on house prices of a rise in *A* similarly depends on supply constraints.[10] This prediction is consistent with the empirical finding in Hilber and Mayer (2009) that exogenous shocks to public school spending have larger effects on house prices in places with little undeveloped land.

The second order derivative in expression (7) approaches zero when *f* gets large, implying that the severity of supply constraints does not influence the impact of earnings on house prices in this limiting case. The reason for this is that housing demand in equation (3) becomes perfectly elastic. A large *f* means that tastes are distributed on a small interval, so people have similar preferences for living in the location that we consider. This is the setting that Glaeser and Ward (2009) argue applies to local municipalities within the Greater Boston area and that could explain their empirical finding that their measure of local land use regulation does not affect local house prices.

At the other extreme, the dispersion in tastes gets so large that households cease to regard alternative places as potential substitutes and effectively become perfectly immobile. This case obtains when *f* approaches zero and it follows from expression (6) that the derivative of house prices to earnings then approaches zero as well, implying that there is no arbitrage between places and, as a result, the severity of supply constraints does not affect the house price response to shifts in earnings. However, even if there is no arbitrage between places, our Proposition should still hold if we consider that the demand for space per person rises with income (i.e., we relax our assumption that each household occupies one homogeneous unit of housing), so that richer households buy higher quality or larger houses and richer people are less likely to double-up with relatives and friends. In this setting, an earnings shock induced rise in demand for developed land increases its price in accord with the steepness of the developed land supply curve, which in turn depends on the severity of supply constraints. Moreover, by constraining housing improvements, regulation may also limit the supply of housing capital, thus further reinforcing the price response to an earnings-induced shift in demand for housing services. Although our empirical measure for the severity of regulatory

[10] As a result of the specification of utility in (1), the two variables are interchangeable in our model.

constraints refers to the refusal rate of new construction projects, we expect it to be closely correlated with the regulatory stance to improvements of the existing housing stock.

The above outlined framework is highly stylized and thus abstracts from a number of complicating factors. Importantly, our framework does not model the buy-rent decision as a possible margin of adjustment. We expect supply constraints to have similar effects on both the house price-earnings elasticity and the rent-earnings elasticity. This is, because under competitive conditions, profit-maximizing landlords will pass on any earnings shock-induced change in house prices to their tenants. After all, a rise in earnings benefits renters as well as homeowners and should thus also affect their willingness-to-pay. Nevertheless, it may be argued that in the short run, the demand for owner-occupied housing receives an additional push relative to the demand for renter-occupied housing, if the rise in earnings also eases financial constraints (see e.g., Ortalo-Magné and Rady, 2006). This additional demand push should generate larger price effects in more supply constrained places.[11]

Our theoretical framework also does not consider other demand factors – apart from earnings and amenities – that may affect local house prices. In our empirical analysis, we carefully control, however, for such factors by including in our estimating equation both year and LPA fixed effects. The year fixed effects absorb the impact of all factors that *do not vary across places*, such as mortgage interest rates and other macro-economic factors. The LPA fixed effects capture all *time-invariant local* demand factors. Another potential bias may arise from the omission of *time-varying local* demand shifters, other than earnings, that correlate systematically with the interaction of earnings and our instruments for supply constraints. We address this concern in a robustness check, discussed below, by identifying on exogenous earnings shocks.

4. Empirical Analysis

4.1. Data

We use LPA-level house price and income data from 1974 to 2008 and geographically match this data, using 2001 English district shape files, with regulatory data derived from public records, physical constraints data derived from satellite imagery and historical population density and employment by industry from the Census. The LPA-level share of votes for the Labour party in the 1983 General Election is derived from the British Election Studies Information System. We briefly describe the variables below. Details on the computation of all variables are given in Appendix A. Summary statistics for the baseline sample are provided in Table 1.

Our mix-adjusted *house price index* is derived from transaction price data from the Council of Mortgage Lenders (CML) (1974 to 1995) and the Land Registry (1995 to 2008). Our proxy for local housing demand, the *total weekly gross earnings for full-time male workers*, comes from the New Earnings Survey (NES) (1974 to 2004) and the Annual Survey of Hours and Earnings (ASHE) (2004 to 2008). The NES data is only available for the *workplace*. For

[11] In the longer run, discrepancies between local rents and the user cost of owner-occupied housing should be arbitraged away through conversions from rental to owner-occupied housing, although regulatory constraints may hamper this adjustment process as well.

consistency reasons, we collected the earnings data from the ASHE also at the workplace level. We discuss the implications of this in Section 4.2.3.

We obtained our measures of LPA-level regulatory restrictiveness from the Department of Communities and Local Government (DCLG). Our key measure – the *refusal rate of 'major' residential projects* – is defined by the DCLG as the share of residential projects consisting of 10 or more dwellings that was refused by an LPA in any particular year. The refusal rate of planning applications is a standard measure to capture regulatory restrictiveness. It is for example used in Cheshire and Sheppard (1989), Preston *et al.* (1996) or Bramley (1998). Figure B1 in Appendix B illustrates the average refusal rate by LPA, measured between 1979 and 2008. Refusal rates over the last 30 years have been clearly highest in the Greater London Area and in the South and lowest in the North of the country. The second variable – the delay rate for major residential projects – is defined as the number of decisions that are delayed over 13 weeks in any particular LPA and year relative to all decisions made in that LPA and year. The 13 weeks-threshold is a 'performance' target introduced by the Labour government in 2002 with the intent to speed up the planning process. We use the *change in the delay rate pre- and post- the policy reform* as an instrumental variable to identify the potentially endogenous refusal rate. We discuss the rationale for this in Section 4.2.1.

The literature broadly suggests two types of physical supply constraints measures. The first measure, the *share developed land* – the share of all developable land that is already developed – is derived from the 1990 Land Cover Map of Great Britain (LCMGB). As Figure B2 illustrates, local scarcity of open developable land is greatest in the Greater London Area and in and around the larger cities in the West Midlands (Birmingham) and the Northwest (Manchester), yet developable land seems amply available in most other areas – the share developed land does not exceed 15 percent in the median LPA.

The second measure is derived from Ordinance Survey Panorama Digital Elevation data. Burchfield *et al.* (2005) and Saiz (2010) suggest that ruggedness and steep slopes impose barriers to new residential development. Following Burchfield *et al.* (2005), we use the *range in elevation*, defined as the difference between the minimum and the maximum elevation in an LPA, as a proxy for whether an LPA is in a mountainous area. Mountains at the fringe of development may hamper urban expansion. Figure B3 illustrates spatial variation in the elevation ranges across England, suggesting that steepness induced constraints may be greatest in the North and the West. The correlation between our elevation range indicator and the 'share developed land' is negative and fairly strong (-0.48), consistent with the proposition that uneven topography hampers residential development.

4.2. Endogeneity Concerns and Identification Strategy

Two of our supply constraints measures – the *refusal rate* and the *share developed land* – are subject to endogeneity concerns. Moreover, local earnings may also be influenced by house prices and supply conditions. Below we discuss how we address these concerns.

4.2.1. Identifying the refusal rate

The post-1947 British planning system has been characterised by LPAs deriving very limited fiscal benefits from permitting development but facing most or all of the development related infrastructure and congestion costs. As a consequence, LPAs often side with NIMBYs ('not in my backyard' residents) and hinder or refuse altogether new development projects within their borders – especially larger projects that require costly new infrastructure provisions. In this context, we would expect that LPAs that are comparably more restrictive refuse a greater share of major development projects.[12] Our preferred measure of regulatory restrictiveness is then the *refusal rate for major residential projects*. Alas this measure, like all other direct measures of regulatory restrictiveness, is endogenous. One concern is that refusal rates are higher during boom periods when housing demand and hence house prices are high. 'Ambitious' projects may only be put forward during boom periods and bureaucrats may be overwhelmed with large piles of applications and so unable to deal with all of them. NIMBYs may also try harder to block new developments during boom times. We address these particular endogeneity concerns by using the *average refusal rate* over the entire period for which we have data; 1979 to 2008. However, at least one endogeneity concern remains, even when employing the average refusal rate and location fixed effects: developers may be less likely to submit a planning application in the first instance, when they know that the relevant LPA is very restrictive and the chance of refusal high. So in restrictive LPAs the observed refusal rate may underestimate the 'true' tightness of the local planning regime. In order to address this and other potential endogeneity concerns related to our refusal rate measure, we use two separate identification strategies.

The *first identification strategy* exploits exogenous variation derived from a 2002 policy reform. On the 1st of April 2002 the Labour government introduced three new targets with the intention of speeding up the planning process. The main effect of the reform was that after 2002 an explicit target for *major development projects* was in place, so LPAs could no longer significantly delay those projects and still meet their target by approving smaller projects more speedily. Of course not meeting targets is an option for LPAs. In fact, to our knowledge there are no explicit formal sanctions if an LPA does not meet a particular target. However, in practice the central government has powerful 'tools' of withholding financial resources to LPAs and of removing their leeway in decision-making such that LPAs *de facto* do have significant incentives to fulfil the government targets at least in the medium term; being on the 'watch list' for a short period of time may have less severe consequences. However, as is often the case, the policy reform had some perverse impacts such as major applications being turned down more quickly to meet the deadline, fewer pre-application discussions or longer delays in considering conditions (Barker, 2006).

Our identification strategy exploits the fact that LPAs did have the option to substitute one form of 'penalised' restrictiveness (not meeting the delay target) with other 'non-penalised' forms (e.g., rejecting major applications in order to meet the key target). The observable

[12] The restrictiveness may differ across LPAs for example because of differences in the vested interests and ideology of the constituency or because the benefits associated with certain development projects are greater for certain LPAs than others. For instance, LPAs with high unemployment rates may have greater incentives to permit development because of short-term job creation during the construction process. See Cheshire and Hilber (2008) for evidence in favor of this proposition.

implication is that *changes* in the refusal rate and *changes* in the delay rate should be uncorrelated before it became clear that the targets are introduced (all planning parameters are optimised in pre-reform equilibrium) but should become negatively correlated afterwards, as the restrictive LPAs can be expected to have altered their behaviour to reject more major residential applications (an *increase* in the refusal rate) in order to meet their delay target (a *reduction* in the delay rate). After the adjustment process induced by the policy reform is completed, the two variables can be expected to become uncorrelated again in the new equilibrium. The solid line in Figure 1 illustrates this point by plotting the regression coefficient of the two measures, *change* in refusal rate and *change* in delay rate, over time. The coefficient is relatively close to zero and not statistically different from zero for most years until about two years prior to the introduction of the new targets. Then it turns strongly negative post-reform, before returning again to close to zero, consistent with our proposition.

Our identifying assumption is that the policy reform had a differential impact on more and less restrictive LPAs. The most restrictive LPAs should have had the strongest incentives to delay major residential projects pre-reform, so were most likely not to meet the new key target. They also should have had the strongest incentives post-reform to reduce their delay rate for major projects by refusing a greater share of them in order to meet the key target. For less restrictive LPAs, with low refusal rates to begin with, there was no or less need to alter their behaviour to accommodate the target. Hence, rather than looking at the delay rate of an LPA, our instrument is the *change in the delay rate pre- and post-reform*; the most restrictive LPAs should have had the greatest decrease in the delay rate. In our empirical work we use the average of the delay rates between 1994 and 1996 as our measure of the delay rate *prior* to the reform. This time window is clearly before the involved agents started to anticipate the reform.[13] Figure 1 suggests that during this time period the correlation between the change in the refusal rate and the change in the delay rate was indeed reasonably close to zero. As post reform window we use the period between 2004 and 2006, since most of the adjustment process had taken place during this time period: as Figure 1 illustrates, the negative correlation between the change in refusal rate and the change in delay rate during this period was quite strong.

Our *second identification strategy* exploits exogenous variation arising from spatial variation in the share of votes to the Labour party at the General Election of 1983. Political party composition has been used for example by Bertrand and Kramarz (2002) and Sadun (2011) as an instrument for the restrictiveness of the local planning system.[14] The rationale for this is as follows: low and middle income Labour voters have traditionally cared more about housing affordability and less about protection of house values; fewer low income residents own homes. Hence, we would expect the local share of votes to the Labour party to be negatively associated with the restrictiveness of the local planning system. Our identifying assumption is that, controlling for location fixed effects, the share of votes to Labour in 1983 affects the

[13] Our choice of the pre-reform window is influenced by the fact that the Labour Government, which eventually introduced the delay rate targets, took office in May 1997. When taking office, it was making a lot of political noise, about the ‘scandal’ of planning delays and had announced they were going to act to reduce delays. It seems reasonable to assume that no LPA could have anticipated the 2002-reform prior to 1997.

[14] Sadun (2011) explores whether planning regulation in Britain protects independent retailers. She argues that Conservatives have traditionally been associated with a strong opposition towards big-box retailing.

impact of earnings on house prices only through planning restrictiveness. We chose a General Election rather than a local election as the latter may be significantly affected by *local* housing market conditions or opposition to large scale local development projects. We chose the General Election of 1983 as it is the earliest year for which we could obtain General Election data that can be geographically matched to the LPA-level.

4.2.2. Identifying the share developed land

Whilst one of our physical constraints measures – the elevation range – is clearly exogenous, the share developed land in 1990 is arguably endogenous as well. How developed a particular location is, is an equilibrium outcome; the result of demand and supply side pressures. For example, more desirable places will attract more inhabitants and will consequently be more developed. Similarly, more restrictive LPAs should have more open land for future development, all else equal. Hence, contemporaneous land scarcity could be in part explained by the tightness of the planning system during our sample period (e.g., through allocation of Greenbelts) or in fact by many other contemporaneous factors that may also affect house prices. In order to address this endogeneity concern we use historic population density in 1911 as an instrument to identify the share developed land in 1990. This instrument pre-dates the 'birth' of the modern British planning system – the Town and Country Planning Act of 1947 – by several decades. Our identifying assumption is that the population density almost 100 years ago will be indicative of early forms of agglomeration (and local amenities), so we expect the variable to be strongly correlated with the share of developed land almost 100 years later but, controlling for LPA fixed effects that capture local amenities, we would not expect historic density to directly (other than through land scarcity) explain *changes* in contemporaneous house prices.

4.2.3. Identifying shifts in housing demand

In our empirical analysis we use male weekly earnings at the LPA-level as a shifter of the local housing demand curve. Our earnings measure refers to earnings by place of work and not by place of residence. While a residence based measure of earnings may be a better proxy for local housing demand (i.e., not all local workers demand housing locally but all residents do), the workplace-based measure relates more directly to shocks to local labour demand. Such shocks may be caused by a shock to an industry that is well represented in the area. The mining industry provides an obvious example. Access to coal used to be an important determinant of productivity in the era of manufacturing, but in today's service based economy it is barely relevant. Depending on their industry composition, some locations have suffered considerably more from this change than others.

Local earnings, however, also depend on the responsiveness of labour supply to shocks in demand. In turn, the responsiveness of local labour supply depends on how easily the housing stock can be extended to accommodate new workers. Glaeser *et al*. (2006) and Saks (2008) have documented the impact of housing supply conditions on local labour market outcomes in the US.

In order to address this endogeneity concern, we consider the robustness of our main results to identifying variation in earnings on shocks to labour demand due to the local industry composition of employment in 1971 and changes in employment by industry at the national level. Our shock measure is the level of employment in each LPA that would have resulted given its industry composition in 1971, had employment in each industry developed in the same way as at the national level. So for instance, this measure predicts a large drop in employment in areas that were specialized in mining. We discuss details of the construction of the labour demand shock measure in Appendix C. This measure is exogenous to the extent that local labour supply shocks have a negligible impact on industry employment at the national level, which seems plausible in view of the large number of geographical units in our analysis and the small number of industries to which we disaggregate employment.[15] Similar shock measures have been used in for instance Bartik (1991), Blanchard and Katz (1992) and Saks (2008).

4.3. Empirical Baseline IV-Specification

In line with our theoretical prediction that local house prices respond more sensitively to local earnings shocks in more supply constrained locations, we interact all three measures of local supply constraints – regulatory restrictiveness, land scarcity and uneven topography – with local annual earnings and include annual earnings as a separate control. We instrument the refusal rate and the share developed land by employing the identification strategies discussed above. This approach allows us to assess to what extent the three supply constraints amplify the impact of earnings on house prices. Our baseline specification is:

$$\begin{aligned}\log\left(house\ price_{j,t}\right) &= \beta_0 + \beta_1 \log\left(earnings_{j,t}\right) + \beta_2 \log\left(earnings_{j,t}\right) \times \overline{\boldsymbol{refusal\ rate}}_{\boldsymbol{j}} \\ &+ \beta_3 \log\left(earnings_{j,t}\right) \times \boldsymbol{\%developed}_{\boldsymbol{j}} + \beta_4 \log\left(earnings_{j,t}\right) \times elevation_j \\ &+ \sum_{i=1}^{34} \beta_{4+i} D_t + \sum_{i=1}^{352} \beta_{38+i} D_j + \varepsilon_{j,t} .\end{aligned} \tag{8}$$

The **bold** variables are instrumented to identify causal effects. The upper bar indicates an average over all years, for which we have planning application data. The specification includes year-fixed effects D_t and LPA-fixed effects D_j to capture all unobserved characteristics that do not vary across space or over time.

We standardise all three supply constraint measures to ease interpretation of the coefficients. We subtract the sample mean of each supply constraint measure from the measure itself and divide this difference by the standard deviation of the measure. This transformation allows us to interpret the estimated coefficients as *an increase in the house price-earnings elasticity due to a one standard deviation increase in the respective constraint measure*. By implication, the coefficient on the earnings variable can be interpreted as the house price-earnings elasticity for an LPA with average levels of supply constraints.

4.4. Main Results

Table 2 summarises our main findings. In column (1) of Panel A we report the results of estimating equation (8) with naïve OLS, so we don't instrument the supply constraint

[15] The seven industries are: agriculture; mining; manufacturing; construction; utilities and transport; distribution and services; national and local government services and defense.

measures. All observations are clustered by pre-1996 counties as the earnings and house price data for earlier years had to be partly inferred from county-level information (see Appendix A for details). The coefficient on the price-earnings elasticity is highly statistically significant and positive, taking a value of 0.32, implying that in an LPA with average levels of constraints, a (permanent) 10 percent increase in earnings raises house prices by 3.2 percent. The coefficients on the earnings × supply constraints interactions point to modest but statistically significant heterogeneity of this elasticity across LPAs: the house price-earnings elasticity rises to 0.38 in an LPA in which the refusal rate is one standard deviation above the English average and to 0.41 in an LPA in which the share developed land is one standard deviation above the English average. The elevation range does not appear to affect the house price-earnings elasticity in a statistically significant manner.

Results for our baseline IV specification in equation (8) are reported in columns (2) to (4) of Panel A. The specification in column (2) uses all available instruments to identify the endogenous variables, columns (3) and (4) drop, respectively, the *share votes to Labour* and the *change in delay rate*. The corresponding first-stage results are shown in columns (1) to (6) of Panel B.

The IV results of our preferred specification with *all* instruments, reported in column (2) of Panel A, indicate that a one standard deviation increase in the refusal rate raises the house price-earnings elasticity by 0.29 and a one standard deviation increase in the share of developed land raises the elasticity by 0.30. The coefficients on the two interaction terms are more than four times and more than three times, respectively, larger than the corresponding naïve OLS-coefficients. Furthermore, the estimates now point to the elevation range as a statistically significant barrier to construction as well: a one standard deviation increase in this variable raises the house price-earnings elasticity by 0.095. Conditional on the validity of our exclusion restrictions, these may be interpreted as causal effects. The coefficient on earnings is smaller than in the previous specification yet it is imprecisely estimated.

While the estimated coefficients suggest that average refusal rates and the share of developable land developed have similar effects, in reality regulatory constraints are much more severe than local land scarcity induced constraints in most LPAs. The distribution of the latter variable is much more skewed (skewness=1.18) than the former (skewness=0.33). Only in the most urbanised areas, physical supply constraints are genuinely binding *in a quantitative sense*. We further explore the quantitative significance of our findings in a counterfactual analysis in Section 5.

The remaining TSLS-specifications reported in columns (3) and (4) of Panel A test the sensitivity of our results to the strategy employed to identify the refusal rate. In column (3) we only use the change in delay rate to identify the impact of the refusal rate. In column (4) we only use the share of votes to Labour. Given the different nature of the two identification strategies, it is reassuring that the effect of regulatory constraints on the house price-earnings elasticity is highly significant in both cases. Estimates of both regulatory and physical constraints are higher when we use the share of votes to Labour as an instrument. Our preferred specification in column (2) yields effects that are in between the two estimates.

Corresponding first-stage results in Panel B suggest that our instruments for the refusal rate and the share developed land all have the predicted signs and are highly statistically significant. The Kleibergen-Paap F-statistic suggests that weak identification may not be a concern, even when we only use the change in delay rate or the share votes to Labour as single instruments to identify the refusal rate.

The year fixed effects in our various estimates in Table 2 – illustrated in Figure 2 – imply cyclical behaviour at the aggregate level. Our counterfactual analysis in Section 5 explores to what extent cyclical behaviour can be explained by local supply constraints.

4.5. Results for Boom and Bust Periods

Barriers to construction ought to matter less during periods with weak local housing demand. Since the existing housing stock is durable, when local demand is falling, the relevant part of the supply curve is almost perfectly inelastic, irrespective of the presence of any man-made or physical supply constraints – the supply curve is 'kinked' (Glaeser and Gyourko, 2005).

Table 3 tests the conjecture that supply constraints are more binding during boom than bust periods. We define 'bust periods' as years when average real house price growth in England was negative: from 1974 to 1977, in 1981 and 1982, from 1990 to 1996 and in 2008.[16] The remaining years are, somewhat casually, labelled 'boom periods'. Results from separately estimating our preferred specification, which uses all available instruments, on the sub-samples of boom and bust years are shown in columns (1) and (2). Consistent with theory, we find that the impact of a one standard deviation increase in the refusal rate is almost twice as large during 'booms' than 'busts', raising the house price-earnings elasticity by 0.27 and 0.15, respectively. A one standard deviation increase in the share of developed land raises the house price-earnings elasticity by 0.29 during 'booms' and by 0.20 during 'busts'. The difference between these effects – tested either separately or jointly – is statistically significant.

4.6. Alternative Geographical Scales

Our main analysis is conducted at the LPA-level, because this corresponds with the geographical scale at which planning decisions are made. However, housing markets of proximate LPAs may be strongly integrated. As a robustness check, in Table 4 we therefore report specifications for three alternative geographical scales at a higher level of spatial aggregation: Travel to Work Areas (TTWAs), Functional Urban Regions (FURs) and Pre-1996 counties. TTWAs, of which there are 150 in England, are designed to capture local labour markets. TTWAs are subdivided into urban and rural areas; as a further robustness check we also estimate our main specification on the subset of 71 urban TTWAs. FURs constitute an alternative definition of integrated urban housing markets, which is based on commuting patterns in 1990. The analysis at Pre-1996 county level also verifies robustness of our results for imputing LPA-level earnings data from county and London borough-level data prior to 1997. Our sample consists of 55 FURs and 46 Pre-1996 counties.

[16] We could not infer an average growth rate for the first year in our sample, but national house price data leave little doubt that 1974 was a bust year (see e.g., Muellbauer and Murphy, 1997).

Table 4 reports results at different geographical scales for our preferred specification (column 2 of Table 2). LPA-level results are reproduced in column (1) for ease of comparison. Columns (2) to (5) report results for alternative geographical scales. All observations are weighted with the number of households in the 1990 Census, since the different geographical units vary enormously in their household size. For instance, the smallest TTWA, Berwick, contains hardly more than 10,000 households, whereas the number of households exceeds three million in London. In order to make coefficients comparable across specifications, we standardise supply constraints to their standard deviation at LPA level, so that at each geographical scale, coefficients correspond to a one LPA-level standard deviation change.

Results turn out to be remarkably homogeneous across different geographical scales, indicating that our results are largely unaffected by spatial correlation between LPAs. The estimated impact of a one LPA-level standard deviation increase in refusal rates on the house price-earnings elasticity ranges from 0.23 for urban TTWAs to 0.33 for pre-1996 counties, while the estimated impact of a one LPA-level standard deviation increase in the share of developed land ranges from 0.22 for pre-1996 counties to 0.30 at the LPA level. The coefficients are always highly statistically significant. Results for the elevation range are similarly homogeneous. The Kleibergen-Paap F-statistic suggests that at higher spatial levels of aggregation, identification tends to become stronger.

4.7. Potential Endogeneity of Earnings

Our empirical analysis so far has ignored any possible influence that house prices and supply conditions may have on earnings, our housing demand shifter. In order to address this endogeneity concern, the first column in Panel A of Table 5 replicates our baseline specification – column (2) of Table 2 – but replaces earnings with the labour demand shock measure described in Section 4.2.3. Consistent with our baseline results, reassuringly, we find that the impact of this shock on house prices depends on both regulatory and physical supply constraints, with all three interaction effects being highly statistically significant.

One drawback of the estimated effects is that we cannot directly compare their quantitative significance with the baseline results. To get a better idea of how these findings compare, we first predict earnings on the basis of our shock measure and then replace earnings in our base specification with the predicted earnings measure. The first column in Panel B reveals that our labour demand shock has the expected impact on earnings and is highly statistically significant. Using the predicted earnings from this regression, the second column of Panel A then uncovers that the impact of this shock on house prices through earnings also depends on both regulatory and physical supply constraints in a statistically highly significant way. The implied quantitative effects of the interaction effects are substantially larger than in our baseline results. However, the Kleibergen-Paap F statistic points to a weak identification issue in either of the first two columns of Table 5, so that coefficient estimates may suffer from bias and should be interpreted with some caution.

Table 4 indicates that our identification becomes considerably stronger at higher levels of spatial aggregation; hence, we replicate the above specifications at the level of TTWAs. These areas are designed to correspond with the local labour market area level, so they may also be more appropriate for analysing the impact of labour demand shocks. Results are reported again in Table 5, in the last two columns of Panel A and column (2) of Panel B. Supply constraints – especially regulatory constraints – turn out to be highly significant determinants of the sensitivity of house prices to shifts in demand, while weak identification is no longer an issue. Moreover, the magnitudes of the effects in column (4) of Table 5 – especially the coefficient on the interaction term for regulatory constraints (0.30 vs. 0.27) – are now similar to the TTWA-level results in Table 4. Overall, these results are reassuring that our main findings are robust to endogeneity concerns related to our earnings measure.

4.8. Additional Robustness Checks

We carried out a large number of additional robustness checks. The main results are reported in Appendix D, while the interested reader is referred to Hilber and Vermeulen (2010) for more extensive checks.

To begin with, demand for housing may have increased faster in places closer to London in a way that is not fully captured by existing controls in our baseline specifications. To address this, Table D1 adds to our baseline specifications a term that interacts a linear time trend with the distance between the centroid of the LPA and Charing Cross/Trafalgar Square in the heart of London.[17] It turns out that this interaction effect is statistically significant only in the OLS specification, whereas it is completely statistically insignificant in the TSLS specifications. Moreover, except in the OLS case, the impacts of the various supply constraints measures on the house price-earnings elasticity are very similar compared to the baseline specifications reported in Table 2.

Table D2 reproduces our baseline results for a sample from which all LPAs in the Greater London Area (GLA) are removed. We do this to explore to what extent our results are driven by the country's dominant city and capital.[18] Interestingly, while the results for the regulatory constraints interactions remain statistically significant and quantitatively meaningful, the positive coefficient on the share developed land × earnings interaction term becomes much smaller and statistically insignificant suggesting that the impact of the share developed land on the price-earnings elasticity may be largely confined to the highly urbanised GLA. This finding is consistent with the fact, discussed in Section 4.4 and illustrated in Figure B2, that the share developed land measure is highly skewed with only few LPAs – mainly concentrated in the GLA – facing genuine scarcity of open developable land and most LPAs having open developable space in abundance.

In an additional set of tests, we explore the robustness of our findings to alternative definitions of our instruments. With regard to the change-in-delay-rate instrument, Table D3 reports both first and second-stage results, using 2003-2008 as post reform window and either 1979-2001 (using all pre-reform years) or 1996-2001 (using a symmetric 6 year window) as

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[17] Charing Cross is the 'official' centre of London (see http://www.bbc.co.uk/london/content/articles/2005/08/15/charingcross_feature.shtml). Nevertheless we experimented with alternative definitions of 'centre of London'. Specifically, we chose the centroid of the 'City of London' and King's Cross as alternative central points. Results are, not surprisingly, nearly identical.

[18] Removing only the City of London (the city's central business district) from our sample as an alternative robustness check leaves results virtually unchanged.

pre-reform windows. We report specifications where we use the change in delay-rate instrument (but not the Labour share one) – as in column (3) of Table 2 – so as not to confound the robustness check with the second instrument used to identify the refusal rate. In Hilber and Vermeulen (2010), we carried out a number of additional, related, robustness checks. We altered the pre- and post-reform time window of our change-in-delay-rate instrument by one year in each direction. We also used the share of votes to Labour in alternative General Election years: 1997 (a Labour landslide unlike 1983, which was a Conservative landslide), 2005 (a comparably close Labour victory) and the average of the three years 1983, 1997 and 2005. Results are very similar in all cases.

In a set of further tests, reported in Hilber and Vermeulen (2010), we replicated our analysis but used alternative measures for our supply constraint proxies. To begin with, we utilised a measure for share developed land that treats semi-developable land as non-developable (in our main specifications we treated semi-developable land as developable). 'Semi-developable' land includes land cover categories that are common in *flood risk areas*. It also includes land cover categories that are at the margin of being developable because of e.g. geological constraints. Next, we used alternative measures to proxy for slope related physical constraints. Specifically we used two measures that are based on the range between highest and lowest altitude (dummy variables that take the value of one if the elevation range in metres is in the top 75th / in the top 90th percentile). The two measures take into account that the effect of ruggedness may be highly non-linear. Finally, we repeated this exercise but used an altogether different measure for slope related constraints: the standard deviation of slopes in degrees. Results were virtually unaltered in all cases.

5. Counterfactual Analysis

In this section, we carry out a counterfactual analysis in order to develop a better understanding of the quantitative implications of our empirical findings. Before turning to a discussion of the results, we should stress that they ought to be interpreted with some caution. Our counterfactual scenarios are based on the estimated impact of *local* supply constraints on *local* house prices. Since the substitutability of housing across LPAs is likely to be considerable, some of the effects of *local* supply constraints may operate at the *aggregate level*. In the unrealistic extreme case of perfect substitutability, constraints on local supply would not affect local prices at all relative to prices in other places, but they would push up the aggregate price level. Incorporating such repercussions at the aggregate level would require a full general equilibrium analysis of all local housing markets in England, which is beyond the scope of this paper. By implication, our counterfactuals represent a potentially significant underestimation of the aggregate implications of supply constraints and, in particular, of the planning system. We underestimate the effect of regulatory constraints even further to the extent that they were already binding in 1974. This is a real possibility given that the British Town and Country Planning Act was already introduced in 1947. In fact, evidence provided by Hall *et al.* (1973) suggests that this was likely the case.

We conduct our counterfactual analysis on the basis of the three TSLS specifications reported in Table 2. Our preferred specification with all instruments provides a 'baseline estimate'. The two distinct identification strategies for the refusal rate measure provide a bandwidth of plausible quantitative effects: in the context of the caveats discussed above, they offer a 'lowest bound' and 'lower upper bound' estimate, respectively. Each specification yields a prediction of local house prices conditional on local earnings, local supply constraints and LPA and period fixed effects. Counterfactual scenarios are then obtained by predicting house prices with supply constraints set to zero one by one, which allows us to get a sense of how important quantitatively the separate constraints are for house price levels. However, since removing supply constraints entirely may be unrealistic in practice, we create alternative scenarios by removing only one standard deviation of each supply constraints measure. In order to quantify the impact of local income dynamics in the absence of supply constraints, we also subtract the 'independent' earnings term. This is done for each LPA separately first, and then we take the averages of the predicted house prices and counterfactual scenarios over all locations to derive a counterfactual scenario for the *'average' English LPA*.

The results of this exercise are summarised in Table 6. The complementary Figures 3 and 4 illustrate the impact of the various local supply constraints and the independent effect of local earnings fluctuations graphically and over the entire sample period. Figure B4 illustrates the scenarios for a few distinctive LPAs that are known to be comparably restrictive or unrestrictive: Westminster and Newcastle upon Tyne were the most and least restrictive markets with respect to regulating office space in Cheshire and Hilber (2008). Reading and Darlington represent a relatively restrictive and a relatively relaxed local authority in Cheshire and Sheppard (1995). House prices are in logarithms and their value in 1974 is subtracted in all four LPAs in order to improve comparability. Finally, we vary the regulatory restrictiveness of the 'average' LPA to several alternative levels: the 10th and the 90th percentile of the restrictiveness distribution and the level of the least and most restrictive English region, that is, the North East and the South East. Figure 5 illustrates the predicted real house prices over the sample period for the 'average' English LPA and these counterfactual scenarios, as well as for scenarios in which restrictiveness is either increased or reduced by one standard deviation.

Bearing the various caveats in mind, the scenarios point to a substantial impact of regulatory supply constraints: house prices in the 'average' LPA in England in 2008 would be 21.5 (lowest bound) to 38.1 percent (lower upper bound) lower if the planning system were completely relaxed. The baseline estimate yields a reduction of 35 percent. The standard deviation of prices during the sample period would be between 29.7 and 51.6 percent lower, with the baseline being 47.6 percent. Removing all regulatory barriers is not very realistic, but even reducing the restrictiveness by one standard deviation leads to a 14 percent reduction in house prices using the baseline estimate, and a 19 percent reduction in the standard deviation. Figure 5 illustrates that setting the restrictiveness level to the 10th percentile of the distribution or to the level measured in the North East also yields substantial reductions in house prices. House prices would be roughly 25 percent lower in the South East, had it the restrictiveness level of the North East, which is arguably still highly restrictive in an international context.

Consistent with the observation that physical supply constraints are genuinely binding in a quantitative sense only in few highly urbanized areas (Sections 4.4 and 4.8), our counterfactual analysis points to a modest average impact relative to that of regulatory constraints: house prices (their standard deviation) would be 9.9 to 10.5 (12.6 to 13.1) percent lower absent of scarcity constraints and 2.8 to 3.1 (3.3 to 3.6) percent lower in the absence of elevation differentials. As expected, local earnings have little impact on house prices once supply constraints are removed.

As Figure B4 illustrates, the impact of the different types of constraints varies significantly across locations. In the densely developed borough of Westminster, physical constraints matter most, regulatory constraints are most important in the prosperous provincial town of Reading and in Newcastle and Darlington house prices are comparably little influenced by supply constraints.

Finally, not all of the house price dynamics is explained by local earnings dynamics and the differential effects it has depending on local supply constraints. Even when holding local earnings and their interactions with local supply constraints constant, average house prices in England, as illustrated in Figure 3, would have increased between 1974 and 2008 in real terms. We speculate that this residual price dynamics reflects, at least in part, the *aggregate* impact of local supply constraints in conjunction with local earnings fluctuations, as discussed above. It may also be the result of macro-economic factors such as fluctuations in interest rates, financial liberalization or aggregate income shocks. However, in line with life-cycle macro-models that assume that the supply of land is inelastic (e.g., Ortalo-Magne and Rady, 2006; Kiyotaki *et al.*, 2011), the impacts of these aggregate demand factors still depend on supply constraints such as those introduced by the rigid English land use planning system.[19] We also cannot rule out that the residual effects are due to adaptive expectations in conjunction with construction lags, although, as already discussed in Section 2, Cameron *et al.* (2006) provide evidence against the 'bubble hypothesis' for UK regions, at least for the period between 1972 and 2003.

6. Conclusions

Housing affordability has been a vital policy concern in Britain for the larger part of the past one and a half decades, leading many to speak of an 'affordability crisis'. Especially young households increasingly struggle to get 'their feet on the property ladder' and to afford a 'decent home', particularly in the Greater London Area and the South of England but also elsewhere. Our findings point to the English planning system as an important causal factor behind this 'affordability crisis'. Moreover, recent studies have suggested that regulatory constraints have become more binding over the last few decades (in the US: Glaeser *et al.* 2005*b*; in the UK: Cheshire and Hilber, 2008) and may become even more binding – across the globe – in the future (Hilber and Robert-Nicoud, 2013). To the extent the latter is true; our findings imply that affordability problems may become even worse during future upswings, especially in highly urbanised areas, where the house price to income ratio may rise even more dramatically than elsewhere.

Our empirical analysis suggests that the English planning system has also made house prices substantially more volatile. Most owner-occupiers have to 'overinvest' in housing due to an

[19] To the extent that the price effect of such macro-economic factors has been reinforced by supply constraints, our counterfactual analysis again underestimates the impact of these constraints on aggregate house prices.

investment constraint induced by owner-occupied housing (Henderson and Ioannides, 1983). Hence, in contrast to corporate and institutional investors, constrained owner-occupier households cannot adequately diversify their portfolios. An increase in house price volatility increases this distortion and therefore reduces the likelihood of owning, all else equal (Turner, 2003; Hilber, 2005). Existing homeowners may be to some extent protected from price fluctuations. If they move within the same market, then if they buy high they should be able to sell high (and vice versa). Even if households move between markets they will be protected to the extent that the covariance in house prices between the two markets is high (Sinai and Souleles, 2013). However, this argument does not apply to first-time buyers who typically face severe credit constraints (having low levels of accumulated wealth and relatively junior salaries), are in need of high leverage and are fully exposed to market conditions.[20] These are also the households that are most affected by the ‘affordability crisis’.

An increase in house price volatility, through the consumption channel, also has important negative consequences for the macro-economy. A higher degree of house price volatility may lead to increased volatility of consumption and reduced macro-economic stability. It was these types of considerations that lead the UK government to scrutinise the planning system and its relationship with the wider economy in the first instance (Barker, 2004, 2006).

Finally, we note that our findings do not *necessarily* suggest that the British planning system as a whole is welfare decreasing. There are considerable potential benefits from some aspects of regulation (internalization of negative externalities; provision of local public goods; reduction of uncertainty[21]) that will be positively capitalised into land values, so are not due to pure costs imposed by regulatory supply constraints. Cheshire and Sheppard (2002) did estimate the net welfare effects of restrictions on land supply in Reading. Their estimates imply that the restrictions had a small effect on benefits relative to costs, resulting in a net welfare cost equivalent to nearly 4 percent as an annual income tax. However, since our study merely quantifies the *total impact* of regulatory supply constraints on house prices, we are not able to take a conclusive stand on the net welfare impact. Nevertheless, our findings have important and worrying policy implications, at least for certain groups of the population.

[20] In England most first-time buyers are almost fully exposed to the interest rate risk. Mortgage lenders often offer a two year fixed rate – the so called ‘teaser rate’ – but this subsequently becomes a flexible rate, determined by market conditions. Hence housing affordability is strongly adversely affected if interest rates increase unexpectedly.

[21] Strict planning controls reduce, for example, the uncertainty that a neighbour may add an extra story to an existing house, thereby destroying a nice view into a public park. However, as for example Mayo and Sheppard (2001) or Ball *et al.* (2009) point out, lengthy and costly planning applications with uncertain outcomes also generate uncertainty on the side of developers and/or future occupants.

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TABLES

Table 1
Summary Statistics: Regression Sample

	Obs.	Mean	Std. Dev. overall	Std. Dev. between	Std. Dev. within	Min.	Max.
Panel data							
Real house price index (1974 = 100)	12355	142.9	71.1	14.7	69.6	35.8	711.2
Real male weekly earnings (2008 GBP)	12355	485.4	117.6	68.1	95.9	223.9	1394.1
Refusal rate of major residential projects (%), 1979-2008	10539	25.4	17.3	8.7	15.0	0	100.0
Share of major residential decisions over 13 weeks (%), 1979-2008 (delay rate)	10539	43.4	22.4	8.6	20.7	0	100.0
Predicted employment based on 1971 local industry composition and national employment growth	12355	57403	47561	47462	3946	3455	501427
Cross-sectional data							
Average refusal rate over period 1979 - 2008 (%) *	353	25.4	8.7			0	50.9
Share of developable land developed in 1990 (%) †	353	25.7	23.3			0.9	97.6
Range between highest and lowest altitude (m)	353	208.8	171.2			5.0	975.0
Change in delays between 1994-1996 and 2004-2006	353	-3.1	22.0			-63.5	53.1
Change in delays between 1979-2001 and 2003-2008	353	-1.0	15.4			-61.9	47.7
Change in delays between 1996-2001 and 2003-2008	353	-14.4	17.7			-71.1	31.1
Share of votes for Labour, 1983 General Election (%)	353	16.3	9.1			0.1	41.0
Population density in 1911 (persons per km2)	353	733.3	2561.6			3.3	22028.8
Range between highest and lowest altitude (m)	353	208.8	171.2			5.0	975.0
Distance to Trafalgar square (km)	353	164.3	115.0			2.6	478.8
Number of households in 1991	353	53158	37086			2169	374079

Notes: * Skewness = 0.33; median = 0.25. † Skewness = 1.18; median = 0.15.

Table 2
Baseline Specifications: OLS and TSLS (N=12355, LPAs=353)

	PANEL A – Dependent variable: Log (real house price index)			
	(1)	(2)	(3)	(4)
		TSLS: *Second stage*		
	OLS	All three instruments	All but share Labour	All but change in delay rate
Log(real male weekly earnings)	0.317***	0.0887	0.200**	0.0436
	(0.0494)	(0.0859)	(0.0811)	(0.103)
Av. refusal rate of major residential projects × log(real male weekly earnings)	0.0669***	**0.293*** **	**0.164*** **	**0.339*** **
	(0.0157)	**(0.0566)**	**(0.0627)**	**(0.0635)**
Share of developable land developed in 1990 × log(real male weekly earnings)	0.0935**	**0.295*** **	**0.234*** **	**0.331*** **
	(0.0399)	**(0.0493)**	**(0.0437)**	**(0.0498)**
Range between highest and lowest altitude × log(real male weekly earnings)	-0.000473	0.0951**	0.0714**	0.112***
	(0.0214)	(0.0388)	(0.0322)	(0.0427)
LPA and year fixed effects (and constant)	Yes	Yes	Yes	Yes
R-squared overall / within / between	0.327 / 0.957 / 0.0877			
Kleibergen-Paap F		11.75	10.70	10.54

	PANEL B – TSLS: *First stage*					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Refusal × Earnings	Developed × Earnings	Refusal × Earnings	Developed × Earnings	Refusal × Earnings	Developed × Earnings
Log(real male weekly earnings)	0.523**	-0.0486	0.926***	-0.266**	0.562**	-0.0383
	(0.215)	(0.105)	(0.310)	(0.126)	(0.236)	(0.107)
Change in delay rate b/w 1994-1996 and 2004-2006 × log(real male weekly earnings)	-0.139***	-0.0364	-0.241***	0.0188		
	(0.0410)	(0.0306)	(0.0556)	(0.0326)		
Share votes for Labour in 1983 × log(real male weekly earnings)	-0.516***	0.278***			-0.549***	0.269***
	(0.0746)	(0.0505)			(0.0789)	(0.0486)
Population density in 1911 (persons per km2) × log(real male weekly earnings)	-0.154***	0.429***	-0.250***	0.480***	-0.159***	0.428***
	(0.0211)	(0.0379)	(0.0312)	(0.0405)	(0.0225)	(0.0386)
Range between highest and lowest altitude × log(real male weekly earnings)	-0.00296	-0.400***	0.0361	-0.421***	-0.0226	-0.405***
	(0.0550)	(0.0842)	(0.0616)	(0.0901)	(0.0564)	(0.0858)
LPA and year fixed effects (and constant)	Yes	Yes	Yes	Yes	Yes	Yes
R-squared overall model	0.363	0.560	0.106	0.495	0.345	0.559
R-squared within model	0.376	0.655	0.205	0.609	0.361	0.654
R-squared between model	0.363	0.560	0.106	0.495	0.345	0.559

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. **Bold** variables are endogenously determined. All supply constraints measures are standardised. Observations are clustered by pre-1996 counties.

Table 3
Impact of Supply Constraints during Boom and Bust (TSLS, 2nd Stage)

	(1)	(2)
	Boom	Bust
Log(real male weekly earnings)	0.115	0.0651
	(0.0792)	(0.104)
Refusal rate × log(real male weekly earnings) *	**0.267*** **	**0.152** **
	(0.0549)	**(0.0605)**
Share developed in 1990 × log(real male weekly earnings) *	**0.290*** **	**0.200*** **
	(0.0447)	**(0.0508)**
Range in altitude × log(real male weekly earnings)	0.0967**	0.0938***
	(0.0415)	(0.0337)
LPA fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	7766	4589
Number of LPAs	353	353
Kleibergen-Paap F	11.37	11.52

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. **Bold** variables are endogenously determined. Instruments include: Change in delay rate b/w 1994-1996 and 2004-2006, share votes for Labour in 1983 and population density in 1911. All supply constraints measures are standardised. Observations are clustered by pre-1996 counties. Boom is defined as: national real HP growth > 0%. Bust is defined as: national real HP growth < 0%. * Test of equality of the coefficient rejects with p=0.02. Joint test of equality of all three interaction effect-coefficients rejects with p=0.01.

Table 4
Robustness Check: Baseline Specification for Different Geographical Scales
(TSLS, 2^{nd} Stage)

	Dependent variable: Log(real house price index)				
	(1)	(2)	(3)	(4)	(5)
Geographical unit:	Local Planning Authority	Travel to Work Area	*Urban* Travel to Work Area	Functional Urban Region	Pre-1996 County
Log(real male weekly earnings)	0.0887	0.217	0.341**	0.395**	0.0746
	(0.0859)	(0.132)	(0.172)	(0.173)	(0.241)
Av. refusal rate of major residential projects × log(real male weekly earnings)	**0.293*** **	**0.267*** **	**0.228*** **	**0.263*** **	**0.326*** **
	(0.0566)	**(0.0362)**	**(0.0386)**	**(0.0638)**	**(0.0630)**
Share of developable land developed in 1990 × log(real male weekly earnings)	**0.295*** **	**0.217*** **	**0.236*** **	**0.236*** **	**0.216*** **
	(0.0493)	**(0.0339)**	**(0.0401)**	**(0.0789)**	**(0.0317)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.0951**	0.0580**	0.0846***	0.0744*	0.0705**
	(0.0388)	(0.0251)	(0.0323)	(0.0393)	(0.0308)
Geographical unit fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	12355	5250	2485	1925	1610
Number of geographical units	353	150	71	55	46
Kleibergen-Paap F	11.75	64.90	44.66	26.90	31.87

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. **Bold** variables are endogenously determined. Instruments include: Change in delay rate b/w 1994-1996 and 2004-2006, share votes for Labour in 1983 and population density in 1911. All supply constraints measures are standardised. The coefficients can be interpreted as an increase in the house price-earnings elasticity due to a one standard deviation increase (based on the LPA-sample) in one of the constraint measures. Observations are clustered by pre-1996 counties.

Table 5
Baseline Specification but Using Labour Demand Shock as Demand Shifter

	PANEL A – Dependent variable: Log(real house price index)			
Geographical unit:	Local Planning Authority		Travel to Work Area	
	(1)	(2)	(3)	(4)
Demand shifter:	Labour demand shock	Predicted earnings	Labour demand shock	Predicted earnings
Log(labour demand shock) *	0.306**		0.244**	
	(0.122)		(0.118)	
Log(predicted earnings based on labour demand shock)		-2.683		-0.530
		(1.661)		(0.529)
Av. refusal rate of major residential projects × labour demand shock	**0.656*** **		**0.587*** **	
	(0.123)		**(0.115)**	
Av. refusal rate of major residential projects × predicted log(earnings)		**0.643*** **		**0.304*** **
		(0.222)		**(0.0506)**
Share of developable land developed in 1990 × labour demand shock	**0.916*** **		**0.389*** **	
	(0.107)		**(0.0412)**	
Share of developable land developed in 1990 × predicted log(earnings)		**0.533*** **		**0.130*** **
		(0.180)		**(0.0192)**
Range between highest and lowest altitude × × labour demand shock	0.331***		0.122	
	(0.108)		(0.0744)	
Range between highest and lowest altitude × × predicted log(earnings)		0.190*		0.0672**
		(0.107)		(0.0300)
Geographical unit (LPA or TTWA) FEs	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	5250	5250
Number of geographical units	353	353	150	150
Kleibergen-Paap F	5.18	3.17	65.71	17.69

	PANEL B – Dependent variable: Log(real male weekly earnings)	
	(1)	(2)
Log (labour demand shock)	0.343***	0.445***
	(0.110)	(0.132)
Geographical unit (LPA or TTWA) FEs	Yes	Yes
Year fixed effects	Yes	Yes
Observations	12355	5250
Number of geographical units	353	150
R-squared overall / within / between	0.40/0.91/0.091	0.29/0.96/0.22

Notes: * Labour demand shock is defined as the employment in each LPA that would have resulted given its industry composition in 1971, had employment in each industry developed in the same way as at the national level. Robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. **Bold** variables are endogenously determined. All supply constraints measures are standardised. Observations are clustered by pre-1996 counties.

Table 6
Counterfactual Analysis for Average English Local Planning Authority

PANEL A
Counterfactual real house prices in average English LPA (in 2008 GBP), N=35
Baseline Estimates

Variable	Value in 1974	Value in 2008	Std. Dev.	Min	Max
Predicted	79184	225820	53265	57660	234176
Predicted without planning	79184	146851	27922	58371	151896
- and share developed set to zero	79184	123891	21247	56410	128060
- and elevation range set to zero	79184	117295	19468	54064	121269
- and independent effect of earnings removed	79184	112201	18138	52254	115973
Predicted with refusal rate lowered by one std. dev.	79184	195294	43240	57966	202351
- and share developed lowered by one std. dev.	79184	168671	34709	58276	174619
- and elevation range lowered by one std. dev.	79184	160905	32274	58376	166535
- and independent effect of earnings removed	79184	153917	30110	58471	159261

PANEL B
Counterfactual real house prices in average English LPA (in 2008 GBP), N=35
Lowest Bound Estimates

Variable	Value in 1974	Value in 2008	Std. Dev.	Min	Max
Predicted	79184	225820	53265	57660	234176
Predicted without planning	79184	177378	37448	58184	183678
- and share developed set to zero	79184	155026	30450	58451	160446
- and elevation range set to zero	79184	148765	28547	58492	153991
- and independent effect of earnings removed	79184	134690	24348	57466	139342
Predicted with refusal rate lowered by one std. dev.	79184	208147	47436	57831	215749
- and share developed lowered by one std. dev.	79184	185331	40019	58076	191971
- and elevation range lowered by one std. dev.	79184	178864	37945	58151	185234
- and independent effect of earnings removed	79184	161941	32597	58362	167613

PANEL C
Counterfactual real house prices in average English LPA (in 2008 GBP), N=35
Lower Upper Bound Estimates

Variable	Value in 1974	Value in 2008	Std. Dev.	Min	Max
Predicted	79184	225820	53265	57660	234176
Predicted without planning	79184	139699	25776	57854	144456
- and share developed set to zero	79184	115885	19077	53592	119741
- and elevation range set to zero	79184	108848	17297	51048	112499
- and independent effect of earnings removed	79184	105891	16578	49981	109424
Predicted with refusal rate lowered by one std. dev.	79184	192031	42182	58001	198951
- and share developed lowered by one std. dev.	79184	163457	33070	58343	169191
- and elevation range lowered by one std. dev.	79184	154869	30403	58457	160252
- and independent effect of earnings removed	79184	150661	29112	58516	155873

FIGURES

Fig. 1
Relationship between Change in Refusal Rate and Change in Planning Delay Rate

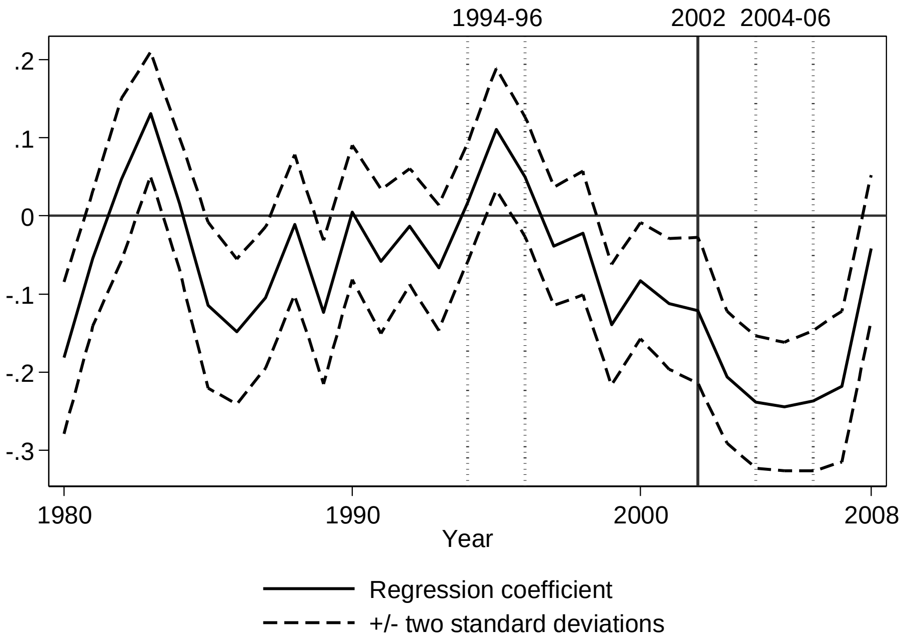


Fig. 2
Year Fixed Effects:
Impact of Unobserved Characteristics at Aggregate Level

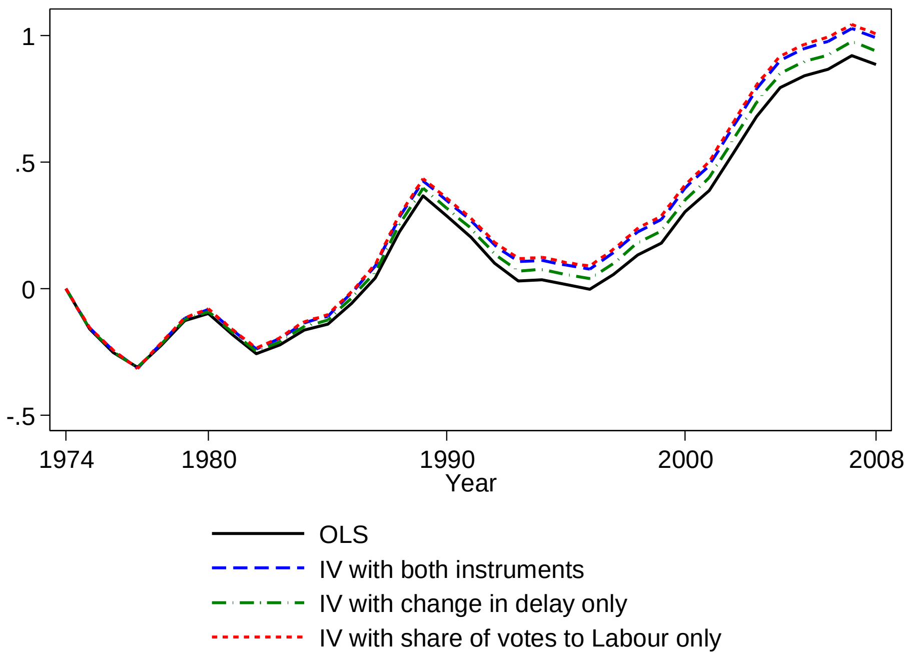


Fig. 3
Impact of Removing Supply Constraints on House Prices in Average English LPA: Baseline Estimate (TSLS)

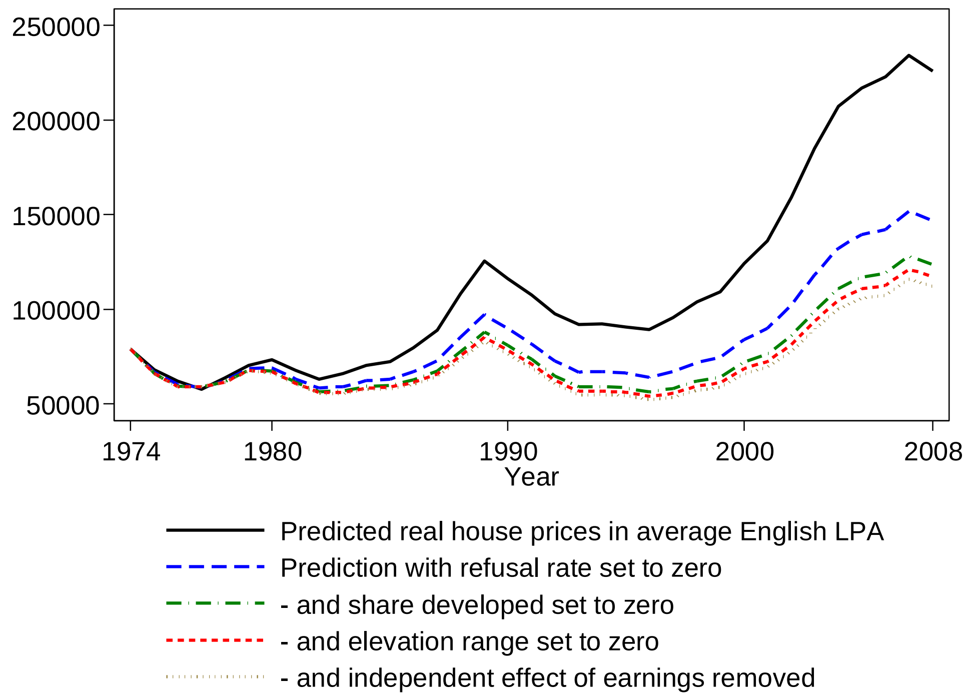


Fig. 4
Impact of Reducing Supply Constraints on House Prices in Average English LPA: Baseline Estimate (TSLS)

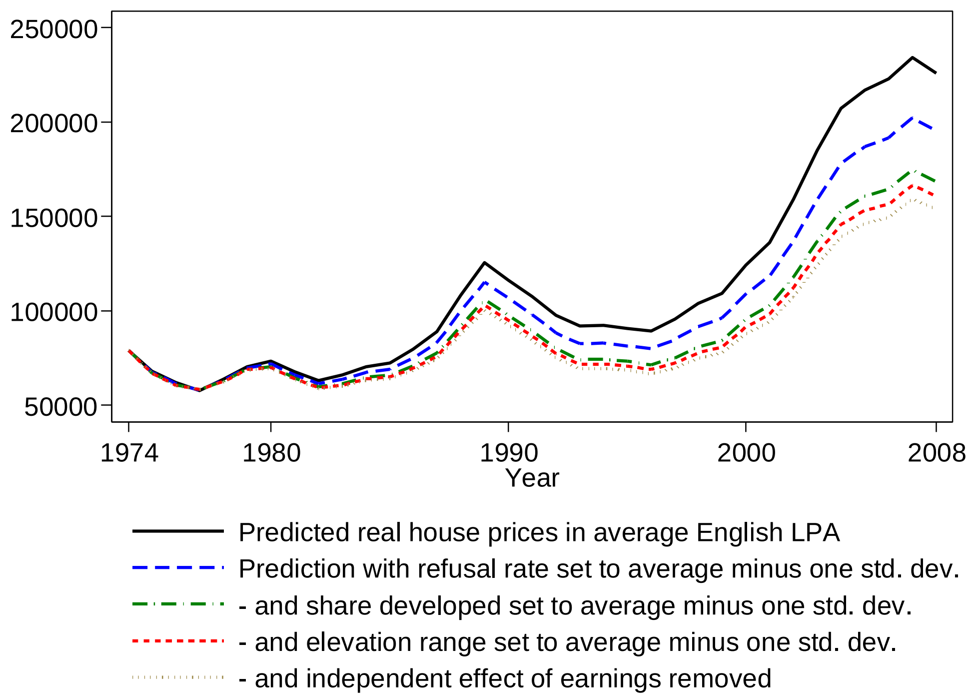
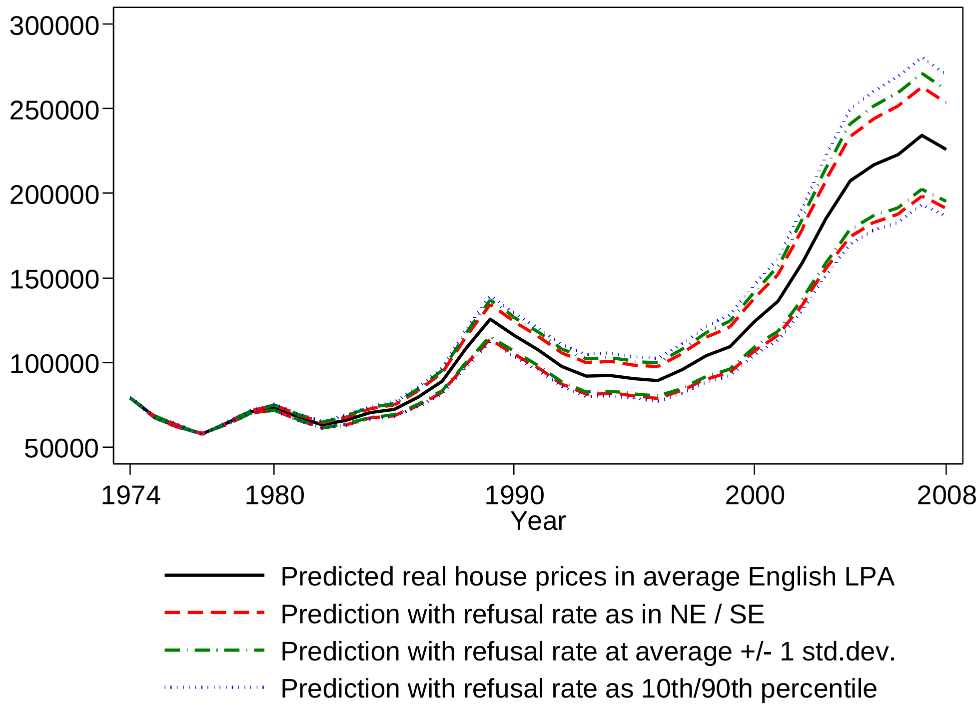


Fig. 5
Regulatory Restrictiveness and House Prices: Northeast vs. Southeast, +/- one Standard Deviation and 10th vs. 90th Percentile



APPENDICES

Appendix A: Detailed Description of Data and Sources

This appendix provides details on the various sources and computation of variables used in our empirical analysis.

Real house price index

We obtained the house price data from the Council of Mortgage Lenders (CML) (1974 to 1995) and from the Land Registry (1995 to 2008).[22] For the purpose of our analysis we need to construct a house price index. We do so by taking account of the composition of sales in terms of housing types by adopting a *mix-adjustment* approach (see e.g., Wall, 1998). Essentially, this index holds constant the share of each housing type, analogous to consumer price indices that measure the cost of a fixed basket of goods and services. Housing types distinguished in the CML data (1974 to 1995) are 'bungalow', 'detached house', 'semi-detached house', 'terraced house', 'flat / maisonette in converted house', 'purpose-built flat or maisonette' and 'other'. The type 'other' has been discarded in these data, leaving six different types. In the registry data (1995 to 2008), four housing types are distinguished: 'detached', 'semi-detached', 'flat / maisonette' and 'terraced'.

For the CML and the Land Registry data separately, we first determined LPA-specific weights by averaging the share of sales of each type over the period of observation: 1974 to 1995 for the CML data and 1995 to 2008 for the Land Registry data. These weights were subsequently used for computing weighted average house prices, by multiplying weights with mean house prices for each type and summing over all types. Weighted prices from the CML data were divided by weighted prices in 1974 and weighted prices from the Land Registry data were divided by weighted prices in 1995. A continuous index for the period between 1974 and 2008 was then created by first setting the Land Registry index to 1 for 1995 and then multiply it with the CML index value for 1995. The real price index was obtained by deflating the nominal series with a Retail Price Index for all items excluding mortgage interest payments obtained from the Office of National Statistics (ONS)[23], and by setting values for 1974 to 100 in all LPAs.

One issue encountered in this approach is that for some housing type×LPA×year combinations, no transactions were observed so that we could not compute a mean price. This

[22] The CML data are derived from two successive surveys. The Survey of Mortgage Lenders (SML) consists of house price data for the period from 1992 to 2004, while the Local Authority Mortgages Survey, 5% Sample Survey of Building Society Mortgages (SSBSM) consists of data from 1974 to 1991. In contrast to the Land Registry data, which contain all housing transactions in England, the SML and SSBSM are samples, in which the geographical scale is less fine; slightly more than 100 areas for most years. The CML data contain more housing characteristics, but for reasons of consistency, we construct a mix-adjusted index using information on the housing type only. The data are geographically matched in such a way that LPAs in the same CML-area have the same price index for the period from 1974 to 1995. (For the years with an overlap of CML and Land Registry data we prefer the latter as the much larger sample size ensures greater reliability.)

[23] The RPI for all items excluding mortgage interest payments was available only from 1978 onwards, so for the period 1974 – 1977 it was imputed with the general RPI. Note that deflation does not affect our estimation results, because of the period fixed effects.

occurred more frequently in the sparser CML data (9 percent of all housing type × LPA × year cells). Of these cases, 89 percent could be imputed with mean prices at the county level, 11 percent were imputed with mean prices at the level of Government Office regions, and the remaining 5 cells had to be imputed with national averages. The potential bias due to imputation is limited, as empty cells are more likely to occur for types with a low weight: the average weight of missing cells was 0.02 and for cells in which the county mean was missing as well it was 0.01. So these imputations hardly affect the weighted average house price in an LPA. In the Land Registry data, less than 0.7 percent of cells were missing and the average weight was 0.05. All of these cases could be imputed with mean prices at the county level.

Real weekly earnings of full-time working men

We obtained data on total weekly gross earnings for full-time male workers at the workplace level from 1974 onward. Specifically, for the period between 1997 and 2008 we obtained LPA-level earnings data from the Annual Survey of Hours and Earnings (ASHE)/New Earnings Survey (NES).[24] For the period between 1974 and 1996 we obtained the earnings data at the county- and London borough level from the NES. We geographically matched this data to the LPA-level. For some LPAs there is a sizeable gap in earnings between 1996 and 1997. These gaps are caused by the fact that the pre-1997 data is measured at the county (or borough) level, while the post-1996 data is measured at the LPA-level. The gap has been bridged by using county-level earnings information for 1997 and by using the growth rates from the county-level data to generate an imputed LPA-level time-series for earlier years.[25]

A few LPAs in our panel have some gaps in earnings information (1.7 percent of all cells are missing). For missing observations at the tails of the time-series we use growth rates from the county-level/region-level earnings indices to impute the earnings figures. For all other gaps we use the 'pattern' of growth at the country/region-level. For a handful of cases the earnings trends at the LPA-level and the county-level go in different directions. Here we use alternative sensible imputation strategies. We carried out a number of robustness checks, which confirm that our findings are not sensitive to the particularities of the imputation strategy. In fact our findings are virtually unchanged if we do not impute the missing earnings figures at all. Real earnings, finally, are obtained by deflating the nominal series with the Retail Price Index.

Planning induced supply constraints

We obtained detailed information on the direct regulatory decisions (refusal rates and planning delays) for all English LPAs on an annual basis between 1979 and 2008 from the Planning Statistics Group at the Department for Communities and Local Government (DCLG). In compiling the panel data for the refusal and delay rates at LPA-level from 1979

[24] The ASHE was developed to replace the NES in 2004. This change included improvements to the coverage of employees, imputation for the item non-response and the weighting of earnings estimates.

[25] On the post-1996 sample, the correlation between the logarithm of earnings at the LPA and the county level is 0.77. Regressing the logarithm of LPA-level earnings on the logarithm of county-level earnings and LPA and period fixed effects for the same sample, yields a coefficient of 0.96, with a standard error of 0.023. These figures indicate that LPA-level movements in earnings within each county tend to be rather similar. Reported standard errors are robust to this correlation as they are clustered at the county level. Note also that column (5) of Table 4 uses as the geographical unit the pre-1996 county, so these results do not rely on any imputation of earnings from the county to the LPA level, yet results are qualitatively and quantitatively similar.

to 2008 (on an annual basis), we kept track of changes in LPA boundaries (mainly mergers) over time, matching all the data to 2001 LPA boundaries.[26]

Physical constraints derived from land cover and elevation data

Our *share developed land* measure is derived from the Land Cover Map of Great Britain (LCMGB). The first LCMGB was developed in 1990 as part of the long-running series of UK Countryside Surveys. The LCMGB provides data, derived from satellite images, allocating land to 25 cover types on a 25 metre grid. We obtained the 1990 LCMGB from the Centre for Ecology and Hydrology.

In order to get an operational measure of the *share developed land* (i.e., the share of all developable land that is already developed) we categorised different land use classes into non-developable land, developable yet undeveloped land and developed land, in a way similar to Hilber and Mayer (2009), Hilber (2010) or Hilber and Robert-Nicoud (2013). Specifically, we classified the following land uses as *'developed'*: 'suburban/rural developed' and 'urban development'. We classified as *'non-developable'*: 'sea/estuary', 'inland water', 'costal bare ground', 'saltmarsh', 'ruderal weed' and 'felled forest'. We classified as '*developable*': 'grass heath', 'mown/grazed turf', 'meadow/verge/semi-natural swards', 'bracken', 'dense shrub heath', 'scrub/orchard', 'deciduous woodland', 'coniferous/evergreen woodland', 'tilled land', 'inland bare ground' and 'open shrub heath'. Finally, we classified as *'semi-developable'*: 'rough/marsh grass', 'moorland grass', 'open shrub moor', 'dense shrub moor', 'upland bog' and 'lowland bog'. Semi-developable land was added as a separate category for the purpose of robustness checks. About one percent of all land cover in 1990 was unclassified. We have discarded this category from our computations. From these classes, we compute the share of developed land (either inclusive or exclusive of semi-developable land in the denominator of the formula) as an indicator for physical supply constraints.

As a second set of measures for physical constraints we assembled elevation data for England by merging 525 separate elevation raster/grid files from the 1:50,000-scale Ordnance Survey Panorama Digital Elevation data. Each file provides a 20 kilometre by 20 kilometre tile which is equally divided by a 50 metre grid and the heights are represented as values at the intersections of this grid.

Other instrumental and control variables

We use the *share of votes for the Labour party in the 1983, 1997 and 2005 General Elections* at LPA-level as instruments to identify the local refusal rate (the latter two are used only in robustness checks). The source of the underlying Constituency level raw data is the British Election Studies Information System. We geographically matched the election results at Constituency level to the LPA-level using GIS. More specifically, we used the Constituency-level boundaries for the relevant years to match the raw data to the 2001 LPA-level boundaries. As instrument for the *share developed land* we use *historical population density*

[26] Observations on National Park Authorities (NPAs) have been discarded. Observations on Urban Development Corporations (UDCs) have been added to LPA observations if their boundaries were confined within a single LPA, and they were discarded if they dealt with developments in multiple LPAs. The number of applications considered by UDCs and NPAs is typically small compared to the number of applications considered by LPAs.

for 1911, derived from the British Census. We geographically matched the available town-level data from 1911 to 2001 LPA boundaries using GIS.[27]

Aggregation to alternative geographical scales

We aggregated our data from the LPA level to three alternative geographical housing market definitions (TTWAs, FURs and Pre-1996 counties) in the following way. Averages of LPA-level house prices and earnings were weighted by the number of households in the 1991 Census. Regulation data were created by first aggregating all applications, refusals and delays and then computing the relevant rates. Similarly, land cover and population data were first scaled to the different area definitions before computing the relevant rates. Elevation variables were weighted by area. Election outcomes were again weighted by the number of households in the 1991 Census.

[27] The town-level data were derived from the UK data archive. Latitude and longitude information was added using the OS Gazetteer.

Appendix B: Appendix Figures

Fig. B1
Average Refusal Rate – Major Residential Projects over 1979-2008

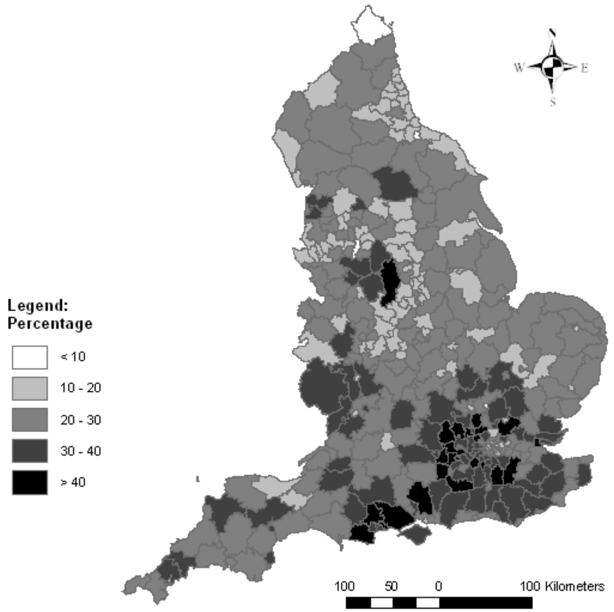


Fig. B2
Share Developable Land Developed in 1990

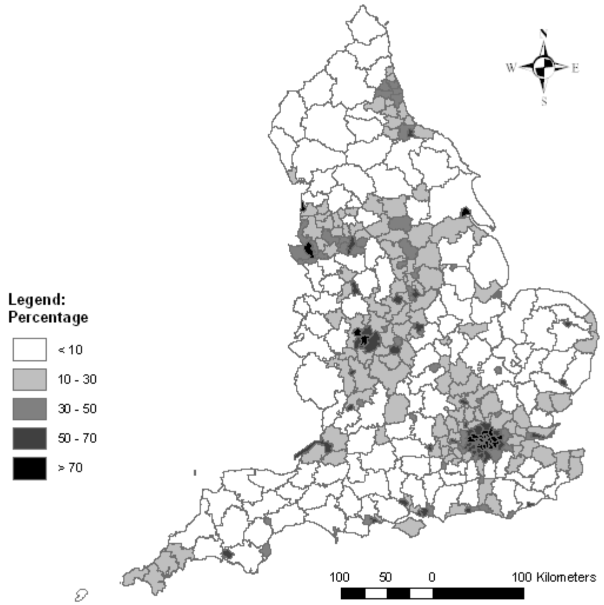
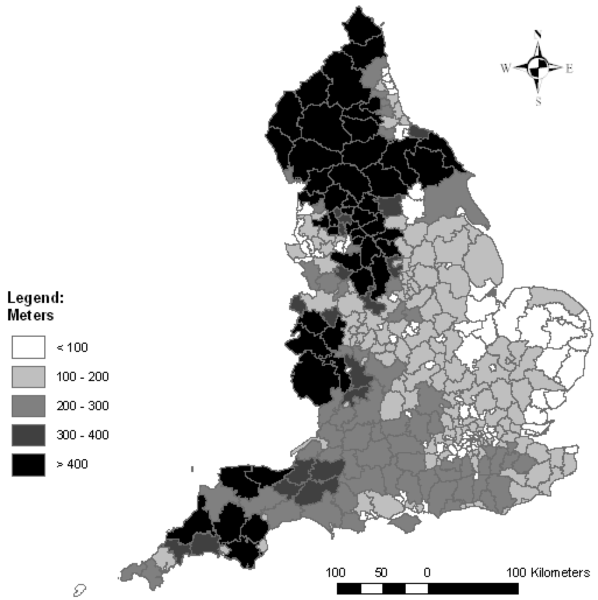


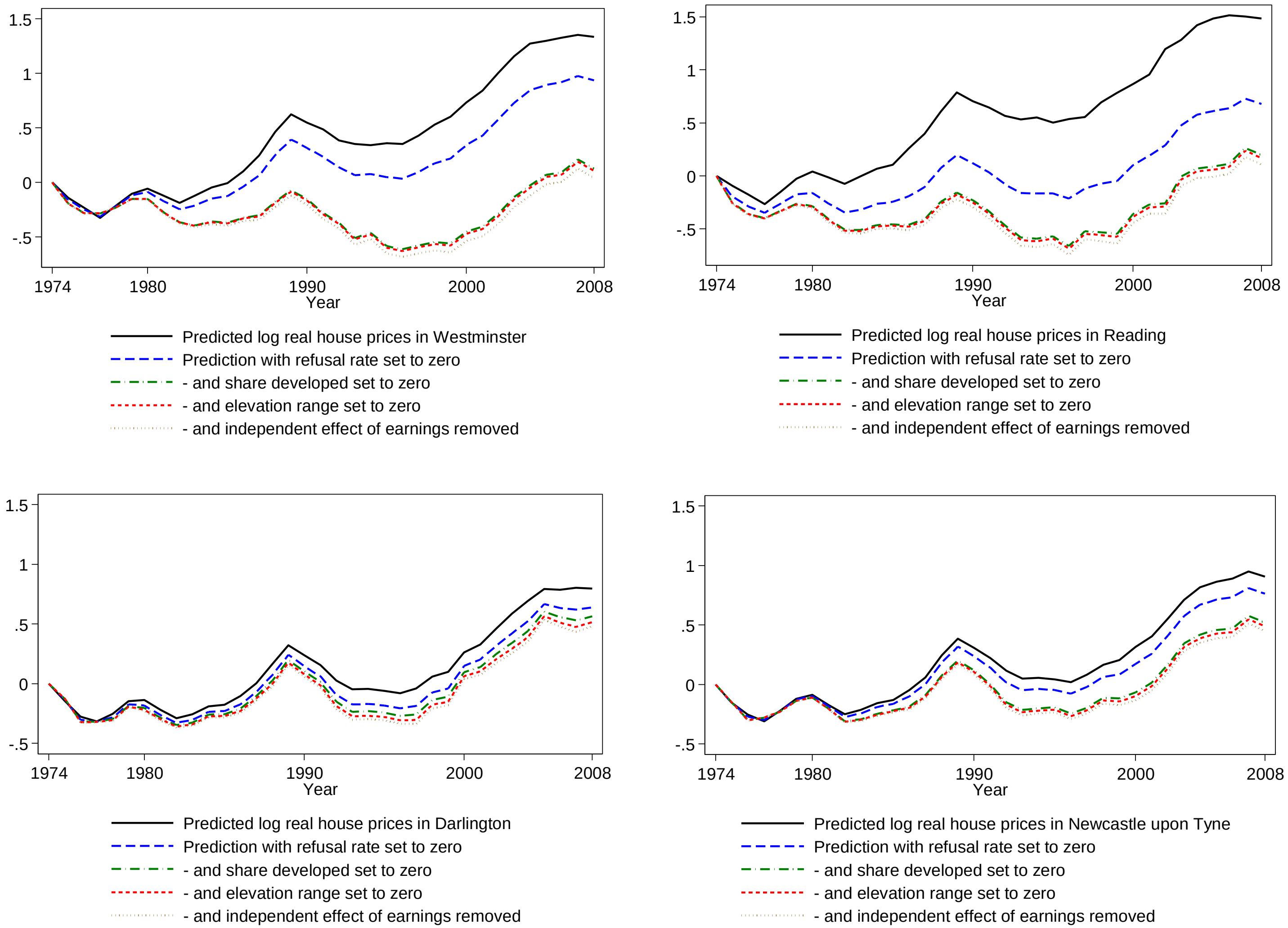
Fig. B3
Elevation Range



Note: Missing value for Council of the Isles of Scilly

Fig. B4

Predicted Log of Real House Prices in Selected LPAs under Alternative Supply Constraints-Scenarios: Baseline Estimates



Appendix C: Construction of Labour Demand Shock Measure

The 1971 UK Census of Population provides employment by industry for a 10% sample of residents in each Enumeration District, which we aggregated to 2001 LPA and TTWA geographies. Industries are classified into 7 broad categories on the basis of the 1 digit SIC of 1968. The data neither distinguish a fulltime/part-time breakdown nor a male/female split, so this is all adult employment. Table C1 documents employment shares in column (1).

Table C1
Industry Composition of Employment, 1971

	Share of total employment in %, England 1971	
	(1)	(2)
Industry	Census of Population	Employer Surveys
Agriculture	2%	2%
Mining	1%	3%
Manufacturing	35%	43%
Construction	7%	8%
Utilities; Transport	8%	12%
Distribution; Services	39%	24%
National and Local Government Service; Defence	7%	7%
Total	100%	100%

A national time series of employment growth by industry from 1971 to 2008 was obtained by combining two sources of information. For the period from 1971 until 1978, we used the Census of Employment – Employee Analysis, which disaggregates employment of male fulltime employees in England into 3 digits of SIC 1968. Table C1, column (2), shows the disaggregation of employment for 1971 using this source. Differences between columns (1) and (2) of Table C1 are attributable to the fact that unlike the Census of Population, the Census of Employment excludes women, part-time workers and the self-employed. For the period from 1978 until 2008, we use employment by all fulltime workers in the UK, disaggregated to broad industries (on the basis of 1 digit) of the 2007 SIC. The Office of National Statistics provides these data in the Workforce Jobs by Industry, drawing on employment and labour force surveys. Consistent with the 1971 Census of Population, this data includes the self-employed and women, but it excludes part-time workers. Moreover, unlike the other two sources it includes Scotland, Wales and Northern Ireland. While such inconsistencies could potentially reduce the strength of our instrument, they are mitigated by the fact that we only use growth rates of employment by industry, which can always be computed in an internally consistent way because the datasets have one overlapping year.

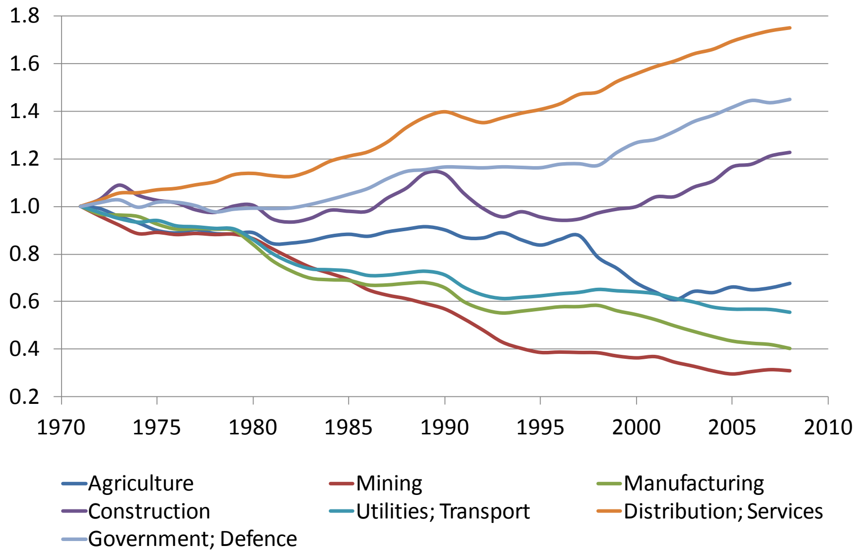
A number of changes in industrial classification occurred between the 1968 and 2007 classifications. The Office of National Statistics provides mappings between old and new industry classifications at a broad level. Furthermore, for each year in which the classification changed, we have employment in both the old and the new classification from the Census of

Employment – Employee Analysis. This allows us to back out the percentage of employment in each new industry class that came from different old industry classes. We use these weights to create a consistent time series of industry employment in the 1968 classification that can be matched to the LPA industry composition in the 1971 Census of Population.

For two years (1978 and 1981), the Census of Employment – Employee Analysis was available in the industry classifications of both 1968 and 2007. This allows us to perform a rudimentary validation on the mapping. Simulating SIC 1968 employment for both years from employment in the 2007 classification gave correlation coefficients of 0.96 and 0.97 respectively, while the correlation coefficient of the change between these two years for the actual and simulated employment by industry data was 0.86.

In order to create the labour demand shock, we produced indices of the resulting employment by industry series, where the 1971 level has been set to 1, as shown in Figure C1. For each LPA and industry, employment was multiplied with the corresponding index and the result was aggregated over industries. This yields the employment in each LPA that would have resulted given its industry composition in 1971, had employment in each industry developed in the same way as at the national level. Figure C1 highlights the significant rise of employment in Distribution and Services as well as in the public sector, set against the decline of mining and manufacturing. In view of the spatial pattern of employment in these industries, one would certainly expect these developments to leave their marks on local labour market dynamics – as confirmed in Panel B of Table 5.

Fig. C1
Indices of Employment by Industry



Appendix D: Appendix Tables

Table D1
Baseline Results but with Additional Control: Distance to Centre of London (Charing Cross/Trafalgar Square) × Time-Trend (OLS and TSLS, 2nd Stage)

	(1)	(2)	(3)	(4)
		TSLS: *Second stage*		
	OLS	All three instruments	All but share Labour	All but change in delay rate
Log(real male weekly earnings)	0.258***	0.112	0.183***	0.0530
	(0.0456)	(0.0831)	(0.0619)	(0.123)
Refusal rate ×	0.0300**	**0.318*** **	**0.143***	**0.442*** **
log(real male weekly earnings)	(0.0138)	**(0.110)**	**(0.0864)**	**(0.166)**
Share developed in 1990 ×	0.0752**	**0.308*** **	**0.219*** **	**0.395*** **
log(real male weekly earnings)	(0.0313)	**(0.0854)**	**(0.0601)**	**(0.116)**
Range in altitude ×	0.0457*	0.0735**	0.0868***	0.0781*
log(real male weekly earnings)	(0.0238)	(0.0353)	(0.0298)	(0.0431)
Distance to Trafalgar Square ×	-1.68e-05***	8.38e-06	-6.79e-06	1.92e-05
linear time trend	(4.84e-06)	(1.31e-05)	(9.76e-06)	(1.93e-05)
LPA and year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355
Number of LPAs	353	353	353	353
R-squared overall model	0.498			
R-squared within model	0.958			
R-squared between model	0.0541			
Kleibergen-Paap F		4.55	5.97	2.50

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. **Bold** variables are endogenously determined. All supply constraints measures are standardised. Observations are clustered by pre-1996 counties.

Table D2
Baseline Results but Only for LPAs outside Greater London Area – OLS and TSLS (2nd Stage)

	(1)	(2)	(3)	(4)
		TSLS: *Second stage*		
	OLS	All three instruments	All but share Labour	All but change in delay rate
Log(real male weekly	0.219***	0.112**	0.173***	0.101*
earnings)	(0.0483)	(0.0535)	(0.0592)	(0.0571)
Refusal rate × log(real male weekly	0.0651***	0.158***	0.0996**	0.174***
earnings)	(0.0154)	(0.0337)	(0.0405)	(0.0371)
Share developed in 1990 ×log(real	-0.0270	-0.0142	-0.0364	0.00550
male weekly earnings)	(0.0210)	(0.0404)	(0.0387)	(0.0438)
Range in altitude ×	-0.0231	-0.0191	-0.0267	-0.0122
log(real male weekly earnings)	(0.0203)	(0.0223)	(0.0219)	(0.0233)
LPA and year fixed effects	Yes	Yes	Yes	Yes
Observations	11200	11200	11200	11200
Number of LPAs	320	320	320	320
R-squared overall model	0.463			
R-squared within model	0.963			
R-squared between model	0.163			
Kleibergen-Paap F		13.60	10.10	17.27

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. **Bold** variables are endogenously determined. All supply constraints measures are standardised. Observations are clustered by pre-1996 counties.

Table D3
Alternative Pre- and Post-Reform Time Windows

	PANEL A – Dependent: Log(real house price index) TSLS: *Second stage*		
	(1)	(2)	(3)
	Baseline: Table 2 Column (3)	Use change in delay rate b/w 79-01 & 03-08	Use change in delay rate b/w 96-01 & 03-08
Log(real male weekly earnings)	0.200**	0.264***	0.168**
	(0.0811)	(0.0600)	(0.0679)
Refusal rate × log(real male weekly earnings)	0.164***	0.0921**	0.200***
	(0.0627)	(0.0392)	(0.0629)
Share developed in 1990 ×log(real male weekly earnings)	0.234***	0.193***	0.254***
	(0.0437)	(0.0265)	(0.0351)
Range in altitude × log(real male weekly earnings)	0.0714**	0.0550*	0.0797***
	(0.0322)	(0.0284)	(0.0298)
LPA and year fixed effects	Yes	Yes	Yes
Observations	12355	12355	12355
Number of LPAs	353	353	353
Kleibergen-Paap F	10.70	21.40	11.58
	PANEL B – TSLS: *First stage for refusal × earnings*		
Log(real male weekly earnings)	0.926***	0.879***	0.913***
	(0.310)	(0.313)	(0.337)
Change in delay rate *(alternative time windows as defined above)*	-0.241***	-0.301***	-0.236***
	(0.0556)	(0.0498)	(0.0437)
Population density in 1911 (persons per km2) × log(real male weekly earnings)	-0.250***	-0.268***	-0.248***
	(0.0312)	(0.0338)	(0.0342)
Range between highest and lowest altitude × log(real male weekly earnings)	0.0361	0.0464	0.0471
	(0.0616)	(0.0618)	(0.0617)
LPA and year fixed effects	Yes	Yes	Yes
Observations	12355	12355	12355
Number of LPAs	353	353	353
R-squared overall model	0.106	0.132	0.103
R-squared within model	0.205	0.229	0.203
R-squared between model	0.106	0.132	0.103

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. **Bold** variables are endogenously determined. All supply constraints measures are standardised. Observations are clustered by pre-1996 counties.

2011

2011/1, Oppedisano, V; Turati, G.: "What are the causes of educational inequalities and of their evolution over time in Europe? Evidence from PISA"
2011/2, Dahlberg, M; Edmark, K; Lundqvist, H.: "Ethnic diversity and preferences for redistribution "
2011/3, Canova, L.; Vaglio, A.: "Why do educated mothers matter? A model of parental help"
2011/4, Delgado, F.J.; Lago-Peñas, S.; Mayor, M.: "On the determinants of local tax rates: new evidence from Spain"
2011/5, Piolatto, A.; Schuett, F.: "A model of music piracy with popularity-dependent copying costs"
2011/6, Duch, N.; García-Estévez, J.; Parellada, M.: "Universities and regional economic growth in Spanish regions"
2011/7, Duch, N.; García-Estévez, J.: "Do universities affect firms' location decisions? Evidence from Spain"
2011/8, Dahlberg, M.; Mörk, E.: "Is there an election cycle in public employment? Separating time effects from election year effects"
2011/9, Costas-Pérez, E.; Solé-Ollé, A.; Sorribas-Navarro, P.: "Corruption scandals, press reporting, and accountability. Evidence from Spanish mayors"
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2011/11, Mira Godinho, M.; Cartaxo, R.: "University patenting, licensing and technology transfer: how organizational context and available resources determine performance"
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2011/21, Tonello, M.: "Mechanisms of peer interactions between native and non-native students: rejection or integration?"
2011/22, García-Quevedo, J.; Mas-Verdú, F.; Montolio, D.: "What type of innovative firms acquire knowledge intensive services and from which suppliers?"
2011/23, Banal-Estañol, A.; Macho-Stadler, I.; Pérez-Castrillo, D.: "Research output from university-industry collaborative projects"
2011/24, Ligthart, J.E.; Van Oudheusden, P.: "In government we trust: the role of fiscal decentralization"
2011/25, Mongrain, S.; Wilson, J.D.: "Tax competition with heterogeneous capital mobility"
2011/26, Caruso, R.; Costa, J.; Ricciuti, R.: "The probability of military rule in Africa, 1970-2007"
2011/27, Solé-Ollé, A.; Viladecans-Marsal, E.: "Local spending and the housing boom"
2011/28, Simón, H.; Ramos, R.; Sanromá, E.: "Occupational mobility of immigrants in a low skilled economy. The Spanish case"
2011/29, Piolatto, A.; Trotin, G.: "Optimal tax enforcement under prospect theory"
2011/30, Montolio, D; Piolatto, A.: "Financing public education when altruistic agents have retirement concerns"
2011/31, García-Quevedo, J.; Pellegrino, G.; Vivarelli, M.: "The determinants of YICs' R&D activity"
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2011/43, Cortés, D.: "Decentralization of government and contracting with the private sector"
2011/44, Turati, G.; Montolio, D.; Piacenza, M.: "Fiscal decentralisation, private school funding, and students' achievements. A tale from two Roman catholic countries"

2012

2012/1, Montolio, D.; Trujillo, E.: "What drives investment in telecommunications? The role of regulation, firms' internationalization and market knowledge"
2012/2, Giesen, K.; Suedekum, J.: "The size distribution across all "cities": a unifying approach"
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