The impacts of restricting housing supply on house prices and affordability

Final report

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The problem: The mounting housing affordability crisis

House values in England – particularly in London and the South East of England – are, especially relative to incomes, amongst the highest in the world. Price volatility is similarly extraordinary. During the last full real estate cycle, real house values in England as a whole were substantially more volatile than in the most volatile metro area – Los Angeles – in the United States. At the same time, houses are much smaller, on average, in England compared to Continental Europe. A new-build house is 38 per cent smaller in the UK than in densely populated Germany and 40 per cent smaller than in the even more densely populated Netherlands (Statistics Sweden, 2005). This is even though the average household size is larger in the UK than in the Netherlands or Germany (2.4 persons per household versus 2.3 and 2.2, respectively; UN Economic Commission for Europe, 2001). In other words: England is facing an extraordinary housing affordability crisis, especially in parts of the country and particularly during boom periods.

The housing affordability crisis has been slowly developing over decades. Real house prices have grown faster in England over the last 40 years than in any other European country. This implies that young households – in particular young families living in London or the South East of England – who want to get their feet on the owner-occupied housing ladder, are hardest hit by the crisis. Many older households who became home owners decades ago and have now accumulated – at least on paper – significant financial wealth in their property are the seeming beneficiaries of the long-standing British real house price growth. The gains for elderly home owners are in fact smaller than one might think; they cannot realise their gains unless they sell their house and move abroad, significantly downsize their housing consumption or give up owner-occupation and rent.

Report objectives and nature of empirical analysis

This report explores the *underlying causes* of the English housing affordability crisis. The main focus is on identifying the causal impact of spatial variation in *regulatory (planning) restrictiveness* on housing costs, housing affordability and house price dynamics. However, we also carefully control for physical supply constraints and disentangle and identify the separate causal impacts of the two types of constraints using standard econometric techniques, briefly explained below (under Key Finding 8) and explained in more detail in the body of the report.

The empirical analysis is based on a dataset that combines house price and income information – spanning 35 years and covering 353 local planning authorities in England – with rich and direct information on regulatory and physical supply constraints for these locations.

On the basis of this rich dataset, this report provides unambiguous *causal* evidence demonstrating that regulatory supply constraints and, to a lesser extent, physical supply constraints have had a serious negative long-run impact on housing affordability and have increased house price volatility. We summarise our key findings in more detail below:

Key findings

1. **House prices react more strongly to changes in demand in more supply constrained places. As a consequence, controlling for demand conditions, <u>house prices are significantly higher in more supply constrained places</u>.**
    - Both regulatory and physical supply constraints affect the response of house prices to changes in local earnings positively and in a statistically significant way.
    - Our central estimates imply that a one standard deviation increase in our measure of regulatory restrictiveness raises the house price-earnings elasticity of a local planning authority with average levels of constraints by 0.293. That is, a 10 per cent increase in local earnings raises house prices roughly 3 per cent more than it otherwise would.
    - A one standard deviation increase in our measure for local scarcity of (undeveloped) developable land has a very similar effect on the price-earnings elasticity. A 10 per cent increase in local earnings raises house prices by roughly 3 per cent more than it otherwise would.
    - Uneven topography also affects the responsiveness of prices to earnings shocks but the effect is relatively small quantitatively.

2. **<u>Regulatory constraints imposed by the British planning system</u> can to a large extent explain the high house prices in much of southern England. In most places <u>planning constraints have a larger impact on house prices than physical supply constraints</u>.**
    - Our simulations imply that the increase in real house prices between 1974 and 2008 can – to a large extent – be explained by the existence of tight planning constraints.
    - Although one standard deviation changes in the measures for regulatory restrictiveness and scarcity of developable land have roughly the same impact on the ‘price-earnings elasticity’ (see above), for the majority of local planning authorities the impact of regulatory constraints is much more severe than that of physical constraints. This is because – in contrast to our measure for regulatory restrictiveness – the distribution of our measure of local scarcity of undeveloped developable land is highly skewed; very few localities are actually constrained by physical constraints although those that are suffer badly in terms of housing supply elasticity.

3. **The extraordinarily high house prices in the Greater London Area (GLA) can to a large extent be explained by a combination of physical supply constraints due to local scarcity of undeveloped developable land and planning related constraints. Outside of the GLA, scarcity of undeveloped developable land has no meaningful impact on house prices.**

    - The findings of our base estimates imply that physical constraints due to scarcity of developable land are only binding in the most urbanized places. When we drop local planning authorities in the GLA – the most physically developed area in England – from our sample and re-estimate our base specification, the effect of physical constraints on the price-earnings elasticity disappears.
    - All our findings consistently imply that the effect of physical constraints on house prices is highly non-linear.
    - Even though our estimates suggest that physical constraints due to local scarcity of developable land are comparably more important than regulatory constraints in the GLA, this finding has to be interpreted with caution. Local scarcity of developable land itself reflects regulatory constraints – height restrictions that hinder ‘vertical development’. (In other large rich cities with less binding height restrictions – such as New York – it has been shown that regulatory restrictions have less impact on prices.)

4. **Physical supply constraints due to uneven topography (steep slopes, ruggedness) matter too, but the effect is relatively small in economic terms.**

    - We include uneven topography as a supply constraint-measure in our analysis because previous research for the US has demonstrated that steep slopes constrain residential development.
    - These results are robust to how exactly we define ‘uneven topography’ (i.e., whether we define it as elevation range or standard deviation of slope) and whether we measure linear or non-linear effects.
    - We also investigated whether other types of physical constraints may matter. Specifically, we examined whether ‘semi-developable’ land has any effect on the price-income elasticity. ‘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, technical constraints or viability considerations. We find that ‘semi-developable’ land has no discernible impact.

5. Regulatory and scarcity related physical supply constraints have a <u>larger effect on house prices during boom than during bust periods</u>.

- When we split our sample into time periods with positive and negative house price growth, we find – consistent with theory – that regulatory and physical supply constraints affect the price-earnings elasticity more strongly during boom periods.
- The estimated effects are highly statistically significantly different.

6. Regulatory and scarcity related physical supply constraints do not only explain high house prices but are the <u>key explanatory factors of housing affordability</u>.

- Housing affordability is essentially driven by three factors: house prices (negative effect), household earnings (positive effect) and the availability and cost of debt financing (higher mortgage interest rates reduce affordability).
- Our analysis implies that falling housing affordability has been driven in large parts by house prices and nominal interest rates. Housing affordability is low today despite very low nominal mortgage interest rates. This lack of affordability in large areas of the country is largely driven by regulatory constraints imposed by the British planning system.

7. The British planning system and physical supply constraints substantially <u>increase long-term and short-term house price volatility</u> but cannot fully explain it, suggesting that <u>macroeconomic factors also play a role</u>.

- The findings of our base specifications imply that a one standard deviation increase in regulatory restrictiveness raises the mean deviation of house prices by 6.6 percent and a one standard deviation increase in the share of land developed raises it by 7.1 per cent.
- Similarly, a one standard deviation increase in regulatory restrictiveness raises the mean deviation of house price growth by 1.4 per cent and a one standard deviation increase in the share of land developed raises it by 2.0 per cent.
- The year fixed effects – that capture time-specific macro-economic shocks – in our estimates account for a significant fraction of the cyclical behaviour of house prices, implying that macro factors that vary over time but not noticeably across local planning authorities (e.g., interest rate movements, overall GDP growth) may be quite important in explaining the cyclical behaviour of housing markets.

8. Our estimate of the <u>impact of the restrictiveness of the British planning system</u> on house prices can and should be interpreted as a <u>causal effect</u>.

- Our measure of regulatory restrictiveness is the refusal rate (= refused applications / total number of applications) of major residential projects in an local planning authority. The refusal rate (or: acceptance rate) of planning applications is a standard measure to capture regulatory restrictiveness. It is for example used in the seminal studies by Cheshire and Sheppard (1989), Preston et al. (1996) or Bramley (1998).
- Like many other indicators of planning restrictiveness, the refusal rate is potentially endogenous – that is, it may be both a cause and an effect:
  a) The refusal rate is influenced by demand conditions: it increases during boom periods and falls during bust periods.
  b) Developers may not submit planning applications in restrictive local planning authorities as they anticipate that their application is highly likely to be rejected. However, equally, a more restrictive local planning authority may encourage submissions because the payoff to developers increases with restrictiveness, other things equal.
  c) The refusal rate may also be influenced by other omitted factors that happen to be correlated with the price-earnings elasticity.
- The trouble with an endogenous explanatory variable is that its measured impact – when measured in an ordinary way – may be biased and cannot be interpreted as a causal effect. Fortunately, econometric techniques are available to take endogeneity issues into account and correct for them.
- The first endogeneity issue a) can easily be dealt with by using the average refusal rate over a long time period, in our case 1979 to 2008.
- Endogeneity issues b) and c) require a more advanced econometric technique. The standard econometric technique to correct for endogeneity and identify causal effects is the so called Instrumental Variable (IV) approach (the main IV-estimator – which we use in our analysis – is the Two-Stage-Least-Squares (TSLS)-estimator). The details of the approach – with respect to our analysis – are explained in Section 5.1.
- The IV-approach is a very widely used methodology in Statistics, Econometrics or Epidemiology to address the omitted variable problem (endogeneity issue c) and the classic errors-in variables problem (endogeneity issues a) and b)) (see e.g., Pearl (2000), Angrist and Krueger (2001) or Heckman (2008) for a more in depth discussion of the method and see e.g. Angrist and Krueger (1991) for a famous application of the IV-methodology.
- The basic idea of the IV-approach is to identify a variable or variables (the excluded instrumental variables or excluded instruments; often just abbreviated as instruments) that affect the key explanatory variable (in our case: the refusal rate) but only impact the outcome (the house price-earnings elasticity) through the key explanatory variable.

- In our empirical analysis we use two excluded instruments. The first instrument – the change in delay rate before and after 2002 is derived from a policy reform. As outlined in the report this instrument is strongly correlated with the refusal rate and can be expected to influence the price-earnings elasticity only through the refusal rate. Exploiting situations where the forces of nature or government policy have thrown up instruments is common practice in econometrics. See e.g. Angrist and Krueger (2001). See Angrist and Krueger (1991) for a famous study that uses a government policy to derive an instrument.
- The second instrument – the share of party votes – is frequently used in Applied Econometric work as an excluded instrument as it is often strongly correlated with a key explanatory variable but is only expected to be related to the outcome measure through the key explanatory variable. For example, Sadun (2008) uses the voting share as an excluded instrument to identify the restrictiveness of local planning policies in the context of retail development.
- A range of statistical tests suggest that our instruments are both valid and allow us to strongly identify the causal effect of the refusal rate on the house price-earnings elasticity. Our results are robust to using the combination of the two instruments or only one of the two instruments.
- Consistent with theoretical considerations we find that the unbiased causal impact of the refusal rate on house prices is much larger than biased estimates based on ordinary methods that do not take into account the endogeneity of the variable.
- One important contribution of this report – compared to previous studies on the impact of planning constraints on house prices – is that we deal with the endogeneity of refusal rates in a robust manner and therefore identify causal effects of the British planning system on house prices, rather than merely measuring correlations.

9. **Our estimate of the impact of physical constraints due to local scarcity of undeveloped developable land can and should be interpreted as a causal effect.**
    - Similar to the refusal rate, the share of undeveloped developable land is potentially endogenous (we explain the rationale in the body of the report). We deal with this endogeneity concern by using historic population density from about 100 years ago as an excluded instrument.
    - Tests suggest that the excluded instrument is both valid and allows us to strongly identify the causal effect of our key measure of physical constraints.

10. **Our estimated effects of the causal impact of the restrictiveness of the British planning system on house prices are <u>both cautious (lower bound) and robust</u> to a large number of sensitivity checks.**
    - The quantitative effects derived from our analysis are cautious as we assume that regulatory constraints were not binding in 1974 (despite research already claiming that they were having a significant impact, e.g., Hall et al., 1973, or Hall, 1974). To the extent that regulatory constraints were already binding in 1974, we underestimate their impact on house prices.
    - Our estimates are also cautious because they are based on estimates of the local impact of local constraints. Partial substitutability of locations implies that some of the impact of local constraints operates at the aggregate level, for which our analysis does not account.
    - The strong impact of land scarcity on house prices in the GLA is likely to be significant because local planning authorities in the GLA operate height restrictions. That is, part of the estimated impact of our key physical constraint measure may in fact be generated by regulatory constraints. This is another reason why the estimated impact of the restrictiveness of the planning system is a lower bound.
    - Our estimated effects are robust to a large number of sensitivity checks including using different geographical scales. The range of sensitivity or robustness checks undertaken is outlined in Sections 5.4-5.6 and 5.8. Our empirical findings are not significantly affected by any of these checks.

11. **The estimated effects of the impact of the British planning system on house prices are <u>very important in quantitative terms</u>**
    - Quantifying the 'economic impact' of regulatory constraints is tricky, not least because we identify our effects based on variation in regulatory restrictiveness across locations. Yet, the British planning system seems likely to impose constraints on residential development even in less restrictive places.
    - In an attempt to quantify the causal effects we have carried out a number of 'counterfactual' analyses for a local planning authority with average levels of regulatory restrictiveness.
    - The first such analysis assesses the overall impact of supply constraints by asking the question 'what would be the impact on house prices if – unrealistically – all supply constraints were removed?' This analysis suggests that house prices would be between 34 per cent (using the change in delay instrument) and 52 per cent (using the vote share instrument) lower, depending on the choice of instrumental variable strategy used to identify causal effects.
    - In a second counterfactual analysis we explore the effect of the various supply constraints measures using the regulatory restrictiveness at the 90th percentile, the average and the 10th percentile. The simulated effects are illustrated in Figure 5. These estimates imply an average house price for 2008 of £183,000 to £203,000 for the 10th percentile and £250,000 to £276,000 for

the 90th percentile depending on which model estimates are used.

- In a third counterfactual analysis we ask: What would be the effect on house prices if an local planning authority with average levels of constraints had instead the restrictiveness of the most restrictive English region (South East) or the least restrictive English region (North East). The results are illustrated in Figure 6. The simulated average house prices in 2008 would be £206,000 instead of £241,000 or £188,000 instead of £257,000 again depending on the model choice.
- We have also computed counterfactual analyses for a number of local planning authorities that are known to be comparably restrictive and unrestrictive, respectively. The results are illustrated in the Appendix Figures A5 to A8.

12. Our findings imply that if current trends continue and in the absence of major policy reforms, <u>future housing (affordability) crises will be increasingly severe</u>

- If current urbanisation trends continue and planning policies and incentive structures are unaltered, both regulatory and physical supply constraints will become even more binding, exacerbating future housing affordability crises and future house price volatility, implying an even larger impact of the housing market(s) on the macro-economy.

Conclusions: What can be done to make housing more affordable again?

Our empirical analysis has identified restrictive planning constraints – and to a lesser extent – physical constraints to be the main causal drivers of the housing affordability crisis in large parts of England. Reducing physical supply constraints – although not entirely impossible as the example of Hong Kong illustrates – is extremely difficult and costly and the scope for making more land available by removing physical constraints appears to be quite limited.

The more obvious solution therefore is to provide greater incentives to local planning authorities to permit more residential developments. However, how can such incentives be introduced? Three approaches seem sensible and deserve further consideration:

1. Use fiscal system to provide serious fiscal incentives to permit residential developments
2. Allow local planning authorities to benefit from land price uplifts for example via land auctions
3. Reform planning system so price signals become a material consideration

PROVIDE SERIOUS FISCAL INCENTIVES TO LOCAL PLANNING AUTHORITIES
(precedence: Switzerland, United States)

- Our empirical findings imply that local planning authorities have strong fiscal disincentives to permit new residential developments. This is due to a misalignment of costs (too much burden on local planning authorities) and benefits (too low long-term payback) associated with residential developments.
- The costs associated with residential development to the local planning authorities are substantial as they have to provide infrastructure, additional public services etc.; and there are real costs to residents in the immediate surroundings of proposed developments. An existing match-funding scheme (the Housing Planning Delivery Grant) provides some very partial compensation to local planning authorities for these costs. However, our findings imply that these funds are not effective in inducing local authorities to permit residential development.
- Impact fees to be paid by the developers to the local planning authorities in compensation for infrastructure costs and other burden have been shown in the US to make local communities more willing to accept developments and could induce local planning authorities to become less restrictive.
- The lions-share of future revenue streams associated with local residential development (all national taxes and fees with the exception of the council tax) is collected by the central government and redistributed to all local planning authorities via the central government grant system. As a consequence of this allocation mechanism, local planning authorities do not directly participate in a substantive way from the long-run benefits associated with any residential development they permit within their boundaries (e.g., through local tax increases), generating strong adverse incentives to permit residential developments.

- Experience from other countries with fiscal federalism (e.g., Switzerland or the United States) where benefits and costs of local development are more aligned (local residents can reap the benefits from local development via increased local tax revenue and do not merely bear the cost) suggest that genuine incentives at the local level to permit residential development can have a substantial soothing impact on housing affordability. For example, whereas according to the Bank for International Settlement real house prices more than quadrupled in the UK between 1970 and 2006, they increased by merely 12.7 percent in Switzerland during the same time period.

ALLOW LOCAL PLANNING AUTHORITIES TO BENEFIT FROM PLANNING GAIN
(precedence: The Netherlands)

- When land is first zoned for development it observes a massive uplift in values. One way to provide incentives to local planning authorities to permit development would be to let them capture all or at least parts of these planning gains. Various proposals have been suggested to achieve this objective (e.g., planning gain supplements, betterment taxes etc.) but one proposal appears to be particularly appealing: making use of a land auction mechanism (see, for example, Leunig, 2007, for a detailed proposal).

REFORM THE PLANNING SYSTEM SO PRICE SIGNALS BECOME A MATERIAL CONSIDERATION

- Cheshire and Sheppard (2005) propose the use of price signals in land use planning decision making. The idea is to exploit information embodied in price premiums of neighbouring parcels of land zoned for different purposes. The proposed mechanism envisages that if the price premium were above some threshold level, "this should provide a presumption of development unless maintaining the land in its current use could be shown to be in the public interest." The burden of proof would be allocated to the local planning authority so as to increase the likelihood of development. Such a mechanism arguably would make housing supply more elastic and the planning system more transparent. For a more in-depth discussion of the proposal see Cheshire and Sheppard (2005).

1 Research objective and outline of final report

House values in the United Kingdom – particularly in London and the South East of England – are, especially relative to incomes, amongst the highest in the world. The average price of a single detached (freehold) house in Kensington and Chelsea in 2008 was £4.3m ($8.6m using the relevant exchange rate). 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 £767,000. Perhaps most astonishingly, even in rural places (e.g., Cotswold in the West of England; £470,000) and in struggling cities (e.g., Birmingham in the West Midlands; £353,000) house prices are very high by international standards.[1]

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 per cent during the upswing of the 1980s; they subsequently declined by 38 per cent during the downturn of the first half of the 1990s. This price swing is substantially larger than that of the single most volatile metro area in the United States during the same cycle period: real values in Los Angeles rose by 67 per cent and declined by 33 per cent.[2]

In this report we set out to explore the causal long-term drivers of the high level and volatility of house prices in England, with the broader objective to better understand the long-run implications of various types of supply constraints on local housing market outcomes. Our main focus is on spatial variation in regulatory restrictiveness and its causal long-term impact on the level and volatility of house prices and housing affordability. However, we also carefully control for physical supply constraints and disentangle and identify the separate causal impacts of the two types of constraints.

The UK 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 Britain’s excessively high level and volatility of house prices (see e.g., Cheshire and Sheppard, 2002; Barker, 2004 and 2006; OECD, 2004; Evans and Hartwich, 2005a). The underlying economic rationale is straightforward: As long as land plots in different locations are not perfect substitutes, demand shifts should have a larger impact on

[1] Average prices are based on actual transaction prices – provided by the Land Registry – of *all* single detached (freehold) houses in the respective local planning authorities. It is worth noting that houses are much smaller, on average, in the UK compared to Continental Europe and the United States. For example, according to Statistics Sweden (2005) 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.

[2] The calculations for the UK are based on the Nationwide house price index. The price 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. Glaeser *et al.* (2008) investigate the cyclical behaviour of 79 metro areas in the United States, documenting that real prices in Los Angeles rose by 67 percent between 1984 and 1989 and declined by 33 percent between 1990 and 1994.

house prices and prices should be more volatile in places, in which space is more constrained by land use regulations or, more generally, in which housing supply is less price elastic.

An alternative proposition to the ‘regulation-hypothesis’ is that the high levels and volatility of house prices in England are driven by strong demand for housing in conjunction with physical space constraints. Two types of such constraints come to mind (and are suggested by the literature, see Section 2): local scarcity of (undeveloped) developable land and uneven topography (steep slopes). Numerous local housing markets in England are already quite developed and have little open land available for future development. To the extent that the remaining plots of developable land are not easily substitutable with open land in neighbouring markets (i.e., land in a particular location has some unique attributes) and to the extent that redevelopment is exceedingly costly, the local scarcity of developable land imposes a binding long-term supply constraint on a local land (housing) market. Consider for example Kensington and Chelsea, one of the most desirable boroughs in the heart of London; satellite imagery suggests that essentially the entire surface area of the borough is already covered by urban development, implying that future development can only be costly redevelopment on brown-field sites. The few open parcels of land may also have an extremely high real option value. However, the borough of Chelsea and Kensington is an extreme case. It is not per se clear how binding lack of open land is as a long-term constraint to housing supply in places where developable land is more readily available – over all local planning authorities, the average share of developable land already developed amounts to only about one quarter. Moreover, Chelsea and Kensington and similarly desirable and unique boroughs arguably also have very restrictive land use regulations (in particular: height restrictions). It is not self-evident to what extent the high price levels and volatility are driven by regulation or land scarcity or, in fact, demand side fluctuations in conjunction with other factors. Although large parts of England are not very mountainous, uneven topography (or steep slopes) is yet another constraint that potentially limits the long-term supply of housing, at least in the more rugged areas in the North and East of the country.

In theory, in a world without any long-term supply constraints (i.e., regulatory or physical constraints that have a persistent limiting effect on new construction of housing), sustained house price levels should not substantially exceed marginal production costs, even if demand fluctuates.[3] Price volatility, however, is not inconsistent with perfectly elastic long-term housing supply. For example, in a setting with building delivery lags (i.e., short-term supply is less than fully elastic—true in reality) and agents with imperfect foresight, fluctuating demand will generate price volatility.[4] Moreover, economic shocks can lead to endogenous oscillations of house prices. Wheaton (1999) demonstrates –

[3] Production costs include the opportunity costs of alternative land uses (e.g., for agricultural use), conversion costs, the value of expected future rent increases, the value of accessibility, an irreversibility premium and construction costs (see Capozza and Helsley, 1989 and 1990). In the absence of any supply constraints there would not be differential land rents and hence the value of accessibility would be zero.
[4] In a world with perfect foresight in which all demand shifts are fully anticipated, house prices should only grow with the interest (discount) rate. Such a setting is highly unrealistic, however.

using a stock-flow model – that myopic behaviour, more elastic supply than demand, long development lags, and low asset durability all may promote such oscillations.

In this report we compile a panel dataset that combines house price and income information, spanning 35 years and covering 353 local planning authorities in England, with rich and direct information on regulatory and physical supply constraints for these locations. Our regulatory data is quite unique; we obtained detailed information on the direct regulatory decisions (refusal rates and planning delays) for all local planning authorities in our sample on an annual basis between 1979 and 2008. Exploiting this data, we provide unambiguous evidence in favour of the proposition that regulatory supply constraints and, to a lesser extent, physical supply constraints causally affect the long-run impact of income on house prices in England, suggesting that these constraints have a negative long-run impact on housing affordability and increase house price volatility.

Our contribution to the literature is threefold. First, we disentangle the impact on house price dynamics of regulatory constraints from physical supply constraints. Recent empirical and theoretical work, mainly focusing on US housing markets, has pointed to a strong correlation between regulatory and physical barriers to new residential development (Hilber and Robert-Nicoud 2006 and 2009; Saiz, 2010). Notably, coastal cities such as Los Angeles, San Francisco, or Boston are not only more developed but also much more tightly regulated than say Midwestern metro areas. In order to disentangle regulatory from physical constraints we incorporate indicators of physical barriers to construction in our analysis, namely (i) the share of already developed developable land based on geo-coded, satellite based land cover data and (ii) measures of ruggedness based on elevation data. We interact all three measures of supply constraints (i.e., regulatory restrictiveness, land scarcity, and steep slopes) with annual earnings data (our measure of demand) and include the annual earnings figures as a separate control. This approach allows us to assess to what extent the three supply constraints amplify the impact of earnings on house prices.

Our second contribution is that we infer causality, that is, we address endogeneity concerns related to the measure of regulatory restrictiveness by using a novel instrument derived from a policy reform enacted in 2002 – introduced by the Labour government shortly after re-election, as well as by using an instrument based on vote shares (political preferences). Historic records on population density (in conjunction with location fixed effects) are used to identify contemporaneous land scarcity.

Our third contribution is that we provide a thorough quantitative interpretation of our findings. House prices are predicted in counterfactual scenarios in which supply constraints are hypothetically set at different levels (10th versus 90th percentile, North East versus South East) or removed one by one. Although ‘removing’ supply constraints entirely is unrealistic in practice, the corresponding counterfactual scenarios allow us to get a sense of how important quantitatively the constraints are for house price levels and housing affordability. Averaging over all local planning authorities, we find that house prices in 2008 would be between 21.4 (lowest bound estimate) and 38.1 percent (lower upper bound estimate) lower in 2008 if no planning applications were rejected. The ‘lowest bound’ estimate is based on an identification that uses the instrument from the 2002 policy reform (change in delay instrument), whereas the ‘lower upper bound estimate’ is based on an identification that uses the vote share instrument. The former identification strategy yields a smaller estimated causal effect of regulatory restrictiveness than the latter. We label the former estimate ‘lowest bound’ because (a) the estimated effect is comparably smaller and (b) our estimates are generally cautious in nature. For example, we assume that regulatory constraints were not binding in 1974 despite research already claiming that they were having a significant impact (see e.g., Hall *et al.*, 1973 or Hall 1974). We label the latter estimate ‘lower upper bound’ because the estimated effect is comparably larger, yet apart from using the ‘upper bound instrument’ the effect is still cautious in nature.

Based on the same counterfactual scenarios (removing supply constraints one by one), the standard deviation of house prices during the sample period would be between 29.7 (lower bound) and 51.6 per cent lower (lower upper bound) absent of regulatory constraints.[5] In addition, house prices (volatility) would be between 9.9 and 13.1 (between 12.6 and 13.1) per cent lower absent of scarcity constraints and between 2.8 and 3.1 (between 3.3 and 3.6) per cent lower in the absence of elevation-induced barriers. These estimates of the overall impacts of constraints are cautious in the sense that they assume no binding constraints in 1974 but also in the sense that they are based on estimates of the local impact of local constraints. Partial substitutability of locations implies that some of the impact of local constraints operates at the aggregate level, for which our analysis does not account. The effect of topography is comparably small; however, this should be seen in the light of the fact that the average English local authority is comparably flat. England consists of relatively few local planning authorities that are severely constrained by steep slopes that hinder or prevent residential construction. Finally, in line with theoretical considerations, we find that the impacts of regulatory and land scarcity related supply constraints on the price-earnings-elasticity are greater during boom than during bust periods.

It is important to note here 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 (internalisation of negative externalities; provision of local public goods; reduction of uncertainty[6]) 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 a prosperous community in southern England, Reading. Their estimates imply that the restrictions had a net welfare cost equivalent to nearly 4 percent as an annual income tax.[7] To the extent that Cheshire and Sheppard’s findings

[5] The impact of regulation on house price volatility should neither be under- nor over-estimated since the value for 1974 simply drops out in computations of the standard deviation.
[6] For example, strict planning controls reduce the uncertainty that a neighbour may add an extra story to the house and remove one’s own views on a beautiful lake. However, as for example Mayo and Sheppard (2001) or Ball *et al.* (2008) point out, lengthy and costly planning applications with uncertain outcomes also generate uncertainty on the side of developers and/or future occupants.
[7] Net welfare cost is meant here in the strict sense that benefits were also quantified and so the measure was the excess value of total costs over benefits expressed in terms of equivalent income variation.

apply for the whole of England this would suggest that our estimated positive impact of regulatory supply constraints on house values (and volatility) is to a large extent due to pure costs imposed by the constraints rather than due to benefits derived from correction of market failure. However, since our report 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 of the planning system. Nevertheless, our findings have important and worrying policy implications, which we outline in the conclusion.

In the next section we discuss how our report fits into the broader literature, providing a background for our analysis. The underlying theoretical framework for our empirical analysis and derived empirical specifications are discussed in Section 3. Section 4 provides an overview over the relevant data sources. The subsequent Section 5 discusses empirical issues and how we address them methodologically and summarises our main empirical findings. Section 6 discusses the quantitative significance of our findings. We draw conclusions and briefly discuss policy implications in the final Section 7.

2 Background

The main focus of our empirical analysis is on the impact of land use planning policies on housing costs and price volatility. A few recent studies conducted in the United States document that land use regulation reduces the housing supply elasticity (e.g., Green *et al.*, 2005; Quigley and Raphael, 2005; Saiz, 2010) whilst raising price levels (e.g., Glaeser and Gyourko, 2003; Glaeser *et al.*, 2005a and b; Quigley and Raphael, 2005). Glaeser *et al.* (2005 a and b) suggest that tight land use controls may be largely to blame for the exorbitant rise in housing prices in the US during the late 1990s and early 2000s. On the other hand, Glaeser and Ward (2009) do not find a significant impact of land use regulation on prices across jurisdictions 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 jurisdiction, because they could easily substitute it for another nearby place. As a consequence, local constraints on housing supply can only have an impact on prices at the level of the entire area. The same argument would not apply to the previously mentioned studies on the relationship between land use regulation and prices since these consider much larger areas that are less close substitutes.[8]

The impact of the housing supply elasticity on price volatility is somewhat less straightforward. Glaeser *et al.* (2008) illustrate that during boom phases house prices in the US grow much more strongly in metro areas with inelastic supply (i.e., locations with tight regulation). They also document that the level of mean reversion during the bust phases is enormous; however, there is very little correlation between the price elasticity and price declines.[9] The implication is that metro areas with more inelastic supply will have higher price volatility but this is almost exclusively driven by the stronger price reaction during upswings.

A larger number of studies investigate the response of house prices to demand fundamentals and the adjustment process to long-run equilibrium using panel data. Two studies are particularly noteworthy as they investigate the impact of measures of regulatory constraints on the response of house prices to demand fundamentals. That is, they explore to what extent regulatory constraints may affect the long-term and short-term response of house prices to income, Harter-Dreiman (2004) explores the link between the price of single-family housing and personal income in the US for the period between 1980 and 1998 employing a two-equation vector error correction system. Her

[8] Theoretical models with imperfect substitutability between locations generally assume heterogeneity in tastes for location, see e.g. Gyourko *et al.* (2006), Aura and Davidoff (2008) or Hilber and Robert-Nicoud (2006, 2009). 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 the place.

[9] One potential explanation for this finding is that the housing supply curve is kinked (Glaeser and Gyourko, 2005), that is, the supply curve is (more or less) elastic when demand is strong but – due to the durability of the housing stock – highly inelastic during severe downturns (negative shifts of the demand curve). An alternative proposition is that in less regulated places (such as Phoenix or Las Vegas in the US) adaptive expectations and construction lags may generate ‘speculative over-construction’ during upswings and subsequent strong price declines during bust periods. ‘Speculative over-building’ is, however, quite unlikely across England given the severity of the planning constraints.

findings imply an elastic long-run supply function but a relatively slow pace of adjustment to long-run equilibrium, suggesting that a major demand shock can be expected to impact housing prices for several years following the shock (70 per cent of the adjustment occurs within the first five years and 90 per cent within the first 10 years). Interestingly, Harter-Dreiman finds substantial differences in the co-integrating relationship between house prices and income. That is, the long-run house price-income elasticity is roughly twice as high in more constrained places (consistent with the findings in this report). It is worth noting that Harter-Dreiman finds only minor – largely counterintuitive – differences in the short-term responsiveness of house prices to income between more and less regulated places.

Capozza *et al.* (2004) estimate an error correction model where the long-run equilibrium value is estimated as a function of a number of economic factors and where serial correlation and mean reversion coefficients characterise the adjustment process of house prices to the fundamental value. They include a crude proxy of supply restrictions in their analysis (they also experimented with regulatory indices but did not find any effects and discarded those measures). In their initial steady-state regression, they find – consistent with our results – that supply constraints increase house prices. Capozza and his co-authors subsequently examine the determinants of serial correlation and mean reversion coefficients. Their results imply that supply constraints cannot explain the deviation of house prices from the fundamental value.

In a similar vein, Cameron *et al.* (2006) – using a dynamic equilibrium correction model that takes into account spatial interactions – investigate the proposition that regional house prices between 1972 and 2003 in Britain have deviated from fundamentals ('bubble hypothesis'). Their results are consistent, with plausible long-run solutions, rejecting the hypothesis of a price bubble during their sample period. However, 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. That is, their results are consistent with the main findings of this report.

Our study has some similarities with Harter-Dreiman (2004) and Capozza *et al.* (2004) in that we infer supply conditions from the long-run relationship between house prices and income. In contrast to these studies, however, we focus on the role of supply constraints with the main objective being to disentangle much more carefully the causal long-run impact of regulatory from physical constraints.

Recent empirical studies that examine the impact of land use controls measure regulatory restrictiveness in either of two ways. The first measure, pioneered by Glaeser *et al.* (2005a), is the so-called regulatory tax, which is the gap between prices and marginal construction costs. The second measure is an aggregate index of regulatory restrictiveness based on survey data (see e.g., Saks, 2008; Saiz, 2010).

Consider the studies that use the regulatory tax measure first. Glaeser *et al.* (2005a) define the regulatory tax as the difference between the price of a condominium and its marginal construction costs, interpreting it as the increase in costs imposed by regulatory restrictions. They find that the regulatory tax exceeds 50 per cent of condominium prices in places such as Manhattan or San Francisco. This suggests that the regulatory tax in these places is the second most important ‘tax’, only topped by the income tax. At the same time, the authors estimate the regulatory tax on housing to be negligible in places such as Detroit, Pittsburgh, Philadelphia, or Houston. Using the same methodology but applying it to various British office markets, Cheshire and Hilber (2008) find that the regulatory costs differ vastly across markets and over time, with the highest regulatory costs being observed in the (most developed) Greater London Area (the estimated regulatory tax for London Westminster, perhaps one of the most regulated places in the world, exceeds 800 percent of marginal construction costs) and the lowest costs being observed in Newcastle (the estimated tax was slightly negative during the mid/late 1980s). Cheshire and Hilber also document that the time trend is positive in most markets, consistent with the proposition that land use regulation policies in Britain may have become more binding over time.

In theory, as long as regulatory constraints are absent, the price of an additional story to an existing high-rise building should equal marginal construction costs independent of demand. More practically, absent of height restrictions, developers will keep on adding additional stories to the building as long as the obtainable price for the additional story exceeds the cost of adding that last story. The regulatory tax should be zero. However, in a world with supply constraints (e.g., height restrictions), the regulatory tax may not only be driven by the extent of inhibitions on housing supply, but also by demand factors. This is most easily seen by interpreting it as a shadow price of direct land use restrictions.[10] For example, a rural local planning authority that is in an economic downturn may impose regulations that render tall buildings and new construction virtually impossible, yet the shadow price of these restrictions is zero if there is no demand for tall buildings and new construction. If the restrictiveness of planning were interpreted as the extent to which it reduces the sensitivity of housing supply to demand conditions, the same local planning authority should be regarded as highly restrictive. Put differently, the local planning authority may not alter its stance on residential development over time, and hence remains in some sense equally restrictive in this second interpretation, but the shadow price of planning-induced constraints will become positive and will increase during the upturn of the business cycle (when the restrictions become effectively binding). That is, spatial and temporal differences in the regulatory tax may not only reflect differences in regulatory attitude but also demand conditions.

Another drawback of the regulatory tax approach is that it is a ‘black box’ in the sense that in general equilibrium, it reflects a shadow price of the aggregate of all types of constraints that bind residential development, ranging from density zoning to building height restrictions and arguably even geological supply constraints.[11] To the extent that geological constraints are binding (and not regulated – very unlikely in practice) the

[10] These could be thought of as height restrictions as in Glaeser et al. (2005a) and Cheshire and Hilber (2008), but the same logic also applies for example to greenbelts around various cities in England.
[11] For instance, the regulatory tax in Manhattan estimated by Glaeser *et al.* (2005a) plausibly relates predominantly to height restrictions, but it might be perceivable that geological constraints in some areas of Manhattan prevent high-rises from being built any higher for practical or safety reasons. Of course, in reality, there are likely regulations in place that prevent construction of high-rise buildings on unstable ground.

regulatory tax measure may potentially be an upper bound estimate of the gross cost of regulation. In a similar vein, Guthrie (2010) argues that price mark-ups over construction costs do not necessarily imply regulation-induced barriers to new construction but could in part reflect the value of a delay option.

On the other hand, Cheshire and Hilber (2008) note that the regulatory tax does not differentiate between costs that are imposed by different aspects of regulation and may miss certain types of costs that regulation imposes. They point out that the regulatory tax does not capture costs imposed by compliance complexity or delays in decision making. So the regulatory tax estimates may be a lower bound estimate of a gross cost of land use regulation in any location. Moreover, the regulatory tax does not provide an answer on how other types of supply constraints affect housing costs and volatility.

Compared to the shadow price methodology, our study sets out to causally identify a much more direct relationship between outcomes of the planning system and housing market dynamics. By relating house prices to demand factors and interaction effects with supply constraints, we disentangle the two sides of the market. Refusal rates of major residential projects, our empirical measure for planning restrictiveness, are an equilibrium outcome as well: local planning authorities with inflexible housing production targets will decline more projects in periods of high demand. Therefore, the causal effect of this measure is identified using a policy reform, as will be explained in Section 5.1. This yields an estimate of the impact of regulation on housing costs using an entirely different approach, which does not rely on the ‘black box’ of regulatory taxes.

A number of empirical studies conducted in the US rely on regulatory indices (i.e., measures of the overall regulatory stringency of metropolitan areas or municipalities) to study the determinants and the economic impact of land use regulation (Saks, 2008; Hilber and Robert-Nicoud, 2009; Saiz, 2010). Particularly relevant for our report, Saks (2008) assembles a regulatory index based on various surveys from the late 1970s and early 1980s to show that metro areas with relatively few barriers to construction experience more residential construction and smaller increases in house prices in response to an increase in housing demand. Moreover, Saks shows that regulatory supply constraints alter local employment and wage dynamics in places where regulation is comparably tight.

One drawback of aggregate regulatory indices based on survey questionnaires is that they are based on the perception of local officials – who may have an incentive to misrepresent the true extent of regulatory restrictiveness or may under- or overestimate it – it is not as direct a measure of restrictiveness as actual decisions of local planning bodies (although direct measures of regulatory stringency can also be biased; see section 5.1). A further drawback of regulatory indices is that they are typically only available for one particular point in time (and different surveys are typically not directly comparable). This feature of the data prevents a panel analysis, which allows researchers to control for location and year fixed effects and thereby to control for many time-invariant and location-invariant unobserved characteristics that hamper the interpretation of cross-sectional regression results. It also prevents researchers from exploiting exogenous inter-temporal variation generated by policy reforms that can be used to infer causal effects.

A few studies suggest that physical supply constraints may affect the supply price elasticity (Hilber and Mayer, 2009; Saiz, 2010) and that therefore demand shocks should have a stronger impact on house prices in places with more limited supply of developable space. Hilber and Mayer (2009) demonstrate that municipalities in Massachusetts with less open 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. Saiz (2010) measures the amount of developable land based on the presence of water bodies and high elevation (slopes above 15 per cent), demonstrating that most metropolitan areas that are widely regarded as supply-inelastic are, in fact, severely land-constrained by topography. He also documents that topographical constraints correlate positively and strongly with regulatory barriers to development. His estimates imply that both regulatory and physical constraints negatively affect the elasticity of housing supply. Our findings for England are consistent with the implication that both types of constraints reduce the long-term responsiveness of new construction to prices. In a related study, Hilber and Robert-Nicoud (2009) provide a theoretical foundation for the proposition that more desirable places will be more physically developed and hence more regulated. Their empirical analysis suggests that the share of developed land has a causal effect on the tightness of land use regulation. The implications for the empirical work that follows in Section 5 are that the 'share of developed land' may not only proxy for physical constraints but also for land use regulation. Hence, it is important to identify the casual effects of the two types of supply constraints measures using an instrumental variable technique.

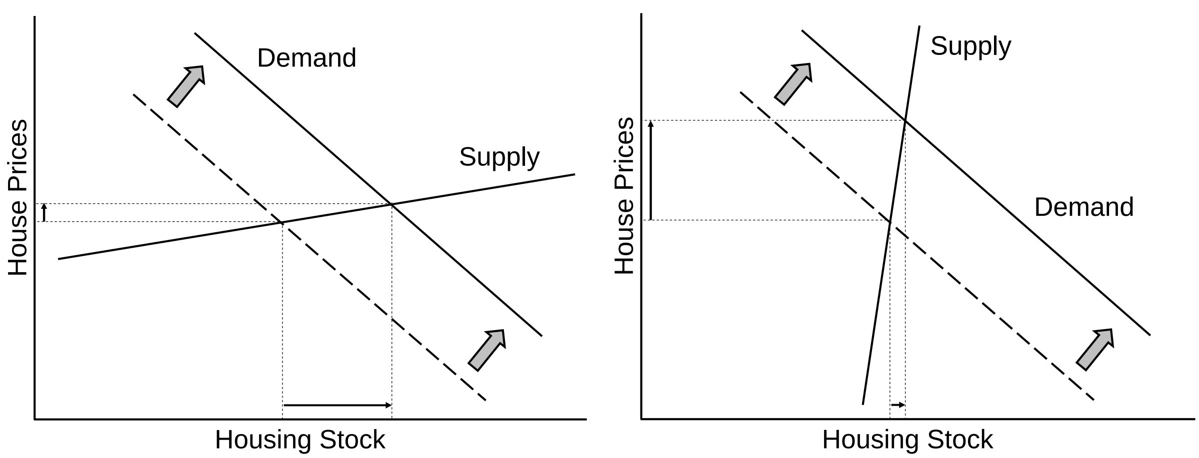
A number of studies have investigated the economic impact of the British planning system (e.g., Bramley, 1998; Cheshire and Sheppard, 2002; Ball *et al.*, 2008). Bramley (1998) explores the effect of various quantitative and qualitative measures of planning restraint on various outcome measures including house prices in a cross-section of English locations. One important contribution of this study is that it provides an early discussion on how planning constraints should be measured and problems involved with different types of measures. The study also discusses (but does not address) issues of endogeneity and reversed causation. Cheshire and Sheppard (2002) and Ball *et al.* (2008) convincingly illustrate the high net and/or gross cost of the planning system for a single local planning authority in England. These studies do not answer the question however to what extent spatial differences in the regulatory restrictiveness can explain differences in the responsiveness of house prices to income. Cheshire and Hilber (2008) document that the regulatory tax varies very substantially across British (and Continental European) office markets. However, it is not per se clear to what extent these findings for office markets apply to housing markets as well. In fact, some observers have argued that the British Town and Country Planning Act of 1947 led to an inflexible planning system that similarly constrains housing supply everywhere in Britain. In this line of reasoning, a recent article in The Economist (2008) suggested that the negative impact of the inflexible British planning system may not be confined to urban areas but may also strongly apply to rural areas. The article suggested that the planning system may be to a significant extent to blame for urban/rural disparities and concluded that a *“more liberal planning system would allow towns and villages to accommodate new arrivals more easily, thus spurring development in rural areas.”* The empirical analysis that follows below will shed light on the question to what extent regulatory restrictiveness varies across space and how that impacts house price levels and volatility.

3 Theoretical considerations and derived empirical specification

In a world where locations are perfect substitutes for each other and where all households are perfectly mobile and have the same tastes for amenities and local public services, the demand curve for local housing is perfectly elastic (horizontal). Perfectly mobile households would simply not accept any difference in the price of housing in perfectly substitutable places, unless they were perfectly compensated by a difference in for instance amenities or public services. In such a setting, any positive (negative) demand shock should be fully capitalised into higher (lower) house prices, independent of the price elasticity of housing supply.

However, in reality locations can hardly be considered to be perfect substitutes. Households are less than perfectly mobile (and some are perfectly immobile). Moreover, households differ in their preferences for local amenities and public services. Some people care mainly about the outdoors and public parks, others have strong preferences for good primary or secondary schools and yet others have strong tastes for good services for the elderly (e.g., proximity to retail facilities and public transport). In such a setting, where the local housing demand curve is less than perfectly elastic (i.e., is downward sloping), a principal mechanism linking supply constraints to housing market dynamics is that shifts in demand should have a larger impact on prices in markets in which new construction is less responsive to prices. This mechanism is illustrated in **Figure 1**.

Figure 1: Supply conditions and housing market dynamics



The left panel characterises a location in which there exist few geographical or man-made constraints on new housing supply. The supply curve is nearly horizontal, indicating that a small rise in prices will bring forth a large quantity of new houses. Hence, a shift in housing demand from the dashed to the solid line will lead to a small rise in prices and a large increase in the housing stock. The right panel, in contrast, corresponds to a severely constrained location. The supply curve is nearly vertical, indicating that prices have to rise by a lot in order to bring forth a small amount of new construction. In this location, the same shift in housing demand will lead to a much larger rise in prices.

Earnings are a major – probably *the* major – determinant of local housing demand. Following the logic of **Figure 1**, we can formulate our main hypothesis:

> **House prices are more sensitive to earnings in more supply constrained locations. Consequently, given increases in earnings will cause house prices to be higher in more supply constrained locations.**

We can derive this – empirically testable – hypothesis formally. Assume that housing demand $Q_{j,t}^{D}$ in location *j* and period *t* is a function of prices and income, as well as of *time-invariant* local conditions such as amenities and *time-variant national* developments like the mortgage interest rate. Assume further that the functional relationship is log-linear; the following demand equation is obtained:

$$\log\left(Q_{j,t}^{D}\right) = \varepsilon^{D}\log\left(P_{j,t}\right) + \varepsilon^{Y}\log\left(Y_{j,t}\right) + \alpha_{j}^{D} + \beta_{t}^{D} + \nu_{j,t}^{D}, \qquad (1)$$

where $\nu_{j,t}^{D}$ reflects idiosyncratic unobserved heterogeneity. The price and income elasticities of local housing demand, denoted ε^{D} and ε^{Y}, depend on the degree of substitutability between locations: demand is less elastic if particular households are more strongly attached to particular places.

Supply is a function of prices, time-invariant local conditions like soil conditions and national developments such as the price of construction inputs:

$$\log\left(Q_{j,t}^{S}\right) = \varepsilon_{j}^{S}\log\left(P_{j,t}\right) + \alpha_{j}^{S} + \beta_{t}^{S} + \nu_{j,t}^{S}. \qquad (2)$$

The price elasticity of housing supply ε_{r}^{S} is allowed to vary over locations, as it may depend on local land use regulations, the amount of developable land or other local conditions. Which factors exactly affect local supply elasticity and in what way are key issues in our research.

With prices equating demand to supply, we should observe the following long-run relationship between house prices and income:

$$\log\left(P_{j,t}\right) = \varepsilon_{j}^{PY}\log\left(Y_{j,t}\right) + \alpha_{j} + \beta_{t} + \nu_{j,t}, \qquad (3)$$

where $\varepsilon_{j}^{PY} = \varepsilon^{Y} \Big/ \left(\varepsilon_{j}^{S} - \varepsilon^{D}\right)$ is the long-run elasticity of house prices with respect to income, the fixed effects α_t and β_t are linear combinations of the demand and supply-specific fixed effects and $\nu_{j,t}$ is a linear combination of demand and supply-specific unobserved heterogeneity. As long as locations are not perfect substitutes and demand elasticities are finite, the variation in ε_j^{PY} is driven by variation in supply elasticity.[12] We have the following comparative static property:

$$\frac{\partial}{\partial \varepsilon_j^S} \varepsilon_j^{PY} < 0, \tag{4}$$

that is, the more elastic local housing supply, the smaller the long-run impact of income on prices. As a consequence, factors that hamper elastic housing supply, such as restrictive land use regulation or lack of developable land, should induce a more elastic response of house prices to income in the long run.

In our empirical work, we estimate a modified version of Equation (3), in which variation in ε_j^{PY} is captured by interaction effects of income with several supply constraints:

$$\log\left(P_{j,t}\right) = \left(\gamma + \sum_k \delta_k X_j^k\right) \times \log\left(Y_{j,t}\right) + \alpha_j + \beta_t + \nu_{j,t}, \tag{5}$$

where X_j^k, k = 1, ..., K, consists of indicators for regulatory and physical constraints, which will be discussed in greater detail below.

[12] We assume that the price elasticity of housing supply ε_j^S varies by location but not the price elasticity ε^D and income elasticity ε^Y of local housing demand. To the extent that the local housing demand elasticities vary by locations as well, this generates heterogeneity and a so called attenuation bias. Our instrumental variable approach allows us to "correct" for this attenuation bias. Using instruments that are highly correlated with our supply constraints measures but not directly related to the house price-earnings elasticity allows us to identify the causal unbiased impact of our supply constraints measures.

4 Overview of data sources

We use house price and income data from 1974 to 2008 and geographically match this data at the local planning authority-level (based on 2001 English district shape files) with regulatory data derived from public records, physical constraints data derived from satellite imagery and historical population density and composition controls derived from the Census. We describe the variables and sources below.[13] Summary statistics of all variables used in our empirical analysis are provided in **Table 1**.

4.1 House price data (real mix adjusted house price index)

We obtained the house price data from the Land Registry (1995 to 2008) and from the Council of Mortgage Lenders (CML) (1974 to 1995).[14] A first look at the data reveals that house prices differ vastly across locations in England. Averaged over the period between 2006 and 2008, house prices were more than ten times higher in Kensington and Chelsea in the heart of London than in Burnley in the Northwest of England. (This compares to a factor of two for the difference in the earnings figures between these two places, suggesting that housing is much more affordable in Burnley than in Kensington and Chelsea.) House prices are not only much higher in Kensington and Chelsea; they are also much more volatile. Over the period between 1974 and 2008 the standard deviation in prices was about twice as high.

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. For the CML and the Land Registry data separately, we have first determined local planning authority-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. The type 'other' has been discarded in the CML 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 form 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 continued index for the period between 1974 and 2008

[13] For further details on the construction of the variables see Hilber and Vermeulen (2009).

[14] 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. Data for 1978 are missing, so we interpolated the final house price index using values for 1977 and 1979. 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 local planning authorities 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 local planning authorities in the same CML-location 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.)

was then created by multiplying the Land Registry index 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)[15], and by setting values for 1974 to 100 in all local planning authorities.

One issue encountered in this approach is that for some housing type$\times$local planning authority$\times$year combinations, no transactions were observed so that we could not compute a mean price. This occurred more frequently in the sparser CML data (9 per cent of all housing type$\times$local planning authority$\times$year cells). Of these cases, 89 per cent could be imputed with mean prices at the county level, 11 per cent 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 local planning authority. In the Registry data, less than 0.7 per cent 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.

4.2 **Income data** (real weekly earnings of full-time working men)

The arguably most important proxy for housing demand is household income. In order to capture housing demand we therefore obtained data on total weekly gross earnings for full-time male workers from 1974 onward. Specifically, for the period between 1997 and 2008 we obtained local planning authority-level earnings data from the Annual Survey of Hours and Earnings (ASHE)/New Earnings Survey (NES).[16] 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 local planning authority-level. For some local planning authorities 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 local planning authority-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 local planning authority-level time-series for earlier years. A few local planning authorities in our panel have some gaps in earnings information (1.7 per cent 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 local planning authority-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

[15] 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.

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

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 a Retail Price Index. A quick glance at the data suggests that volatility in earnings varies substantially across local planning authorities and over time; clearly income has risen much faster during the sample period say in the City of London compared to some less desirable places such as Darlington in the Northeast of England.

4.3 Measures of planning induced supply constraints

We obtained our measures of regulatory restrictiveness from the Planning Statistics group at the Department for Communities and Local Government. Our key measure of regulatory restrictiveness – the refusal rate of major residential projects – is defined as the share of residential projects consisting of 10 or more dwellings that was refused by an local planning authority in any particular year. **Appendix Figure A1** illustrates the average refusal rate by local planning authority, 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 local planning authority and year relative to all decisions made in that local planning authority 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 subsequently use the delay rates pre- and post- the policy reform to identify the potentially endogenous refusal rate variable. We outline the identification strategy in Section 5.1.

In compiling the panel data for the refusal and delay rates at local planning authority-level from 1979 to 2008 (on an annual basis), we kept track of changes in local planning authority boundaries (mainly mergers) over time, matching all the data to the 2001 local planning authority boundaries.[17] Both variables; the refusal rate and the delay rate should capture the restrictiveness of the regulatory system. All else equal more restrictive local planning authorities will be more likely to refuse and delay planning applications. Both variables, however, are also subject to endogeneity concerns: If developers know that a particular local planning authority is likely to reject an application, they may be less likely to apply in the first place. (Conversely, a more restrictive local planning authority may encourage applications because the payoff to developers increases with restrictiveness, other things equal.) In a similar vein, in order to meet delay targets and thereby improve their ‘performance’, local planning authorities may become more restrictive by refusing more applications in the first place (Ball *et al.*, 2008). So delay rates (in isolation) may not be a good proxy measure for regulatory

[17] 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 local planning authorities. The number of applications considered by UDCs and NPAs is typically small compared to the number of applications considered by local planning authorities.

restrictiveness. We discuss these endogeneity issues and our strategy to identify the causal impact of the refusal rate in greater depth in Section 5.1.

4.4 Measures of physical constraints (derived from land cover and elevation data)

a) Land-cover data

Land cover data are an essential input to our research, as they are needed to compute the share of developable land in urban use. Our proposition is that the higher the share in urban use already, the more expensive it will be to convert additional plots of land to residential use. There are various reasons to expect that housing supply is less elastic in locations in which less open developable land is available. See Hilber and Mayer (2009) for a detailed discussion of the relevant arguments.

The first Land Cover Map of Great Britain (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 meter 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) or Hilber and Robert-Nicoud (2009). See **Appendix Table A1** for details on the classification used. Semi-developable land was added as a separate category for the purpose of robustness checks (see Section 5.8). 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. We report our regressions using the measure that includes semi-developable land as developable; however, all our results are virtually unchanged if we use the alternative measure that classifies semi-developable land as non-developable. See **Appendix Figure A2** for an illustration of the spatial variation in local land scarcity across England. Not surprisingly, land scarcity is greatest in the Greater London Area and in and around the larger cities in the West Midlands (Birmingham) and the Northwest (Manchester).

b) Elevation data

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 Land-Form PANORAMA DTM. Each file provides a 20 km by 20 km tile which is equally divided by a 50 m grid and the heights are represented as values at the intersections of this grid. The literature suggests that steepness of land may impose significant barriers to new residential development (Burchfield *et al.*, 2005; Saiz, 2010). Essentially following Burchfield *et al.* (2005), we consider two measures for barriers to new construction. The range in elevation, defined as the difference between the minimum and the maximum elevation in a local planning authority, proxies whether an local planning authority is in a mountainous area. Mountains at the fringe of development may hamper urban expansion. The standard deviation of the slope at local planning authority level indicates ruggedness, where in each grid point slope is computed in the steepest direction. Construction costs are likely to increase with ruggedness and density of development should be expected to be lower (Saiz, 2010). We estimate our base specifications using the range-in-elevation measure but carry out robustness checks with the standard-deviation-of-the-slope measure as well (see Section 5.8). **Appendix Figure A3** illustrates spatial variation in the elevation ranges across England, suggesting that steepness induced constraints may be greatest in the North and the West of the country. The correlation between our elevation range indicator and the share of developable land already developed is negative and fairly strong (-0.48), consistent with the proposition that steepness is hampering residential development.

4.5 Measure of 'shadow price of regulation'

A concept that measures the cost of regulation – reflecting both demand and supply conditions – is the shadow price of regulatory restrictions. This shadow price may be measured in different ways. Cheshire and Hilber (2008) estimate costs of planning constraints (such as height restrictions) in British office markets by comparing the price of an additional floor to the cost of constructing it. They find that regulatory costs differ vastly across markets and over time, with the highest regulatory costs being observed in the (most developed) Greater London Area and with the time trend being positive in most markets. Whilst these findings provide important insights and are indicative, the study does not consider the regulatory cost imposed on housing and the sample does not include more rural local planning authorities.

Another way to estimate the shadow price of land use restrictions is to consider the price of land with planning permission at the urban fringe. In the absence of restrictions on land conversion, the price of converted land should approximately equal the price of agricultural land plus conversion costs.[18] Land use regulation creates a gap between these prices that rises with the extent to which restrictions are binding, as a result of inflexible planning and high demand (see Section 3.1 of Cheshire and Vermeulen (2009) for a graphical exposition of this argument).

From the Valuation Office, we have obtained estimates of the price of bulk land in excess of two hectares at local planning authority level in 2007. These estimates assume the land to be situated in a typical location for the area, have planning permission, services to the edge of the site and be ripe for development. To that extent if the market for the majority of residential land in the locality is made up of 'brownfield sites' this fact will be reflected in the valuations. Likewise if planning permissions in the location generally include an element of affordable housing that will also be reflected in the land values to the same extent as the market would do so.

Bulk land is likely to be located at the urban fringe, in particular in local planning authorities with a high share of developable land. So if we are willing to assume that the regional variation in agricultural land prices and conversion costs is limited, then the

[18] It may also contain an option value that reflects uncertainty about future urban housing demand, as in Capozza and Helsley (1990).

regional variation in bulk land prices may be regarded as an indicator for regulatory costs. We use the price of bulk land as an alternative measure to capture the restrictiveness of regulatory constraints in our empirical analysis below. The estimates that use the price of bulk land instead of our more direct measures of regulatory restrictiveness (the refusal rate) provide a robustness check of our main results.[19]

More urbanised local planning authorities tend to have higher bulk land prices implying more restrictive planning policies. As outlined in the Interim Report, the correlation between our main measure of regulatory restrictiveness (the refusal rate of major residential applications) and the price of bulk land is quite high, supporting our interpretation of the measure as a shadow price.

4.6 Other instrumental and control variables

Our analysis includes a number of additional so called **excluded instrumental variables**. These 'instruments' are used to identify the causal effects of our supply constraints measures. (We outline this instrumental variable approach in more detail in Section 5.1.) In addition to the change-in-delay rate instrument (already mentioned in Section 4.3), we use the share of votes for the Labour party in the 1983, 1997 and 2005 General Elections at local planning authority-level as instruments to identify the local refusal rate – our measure of regulatory restrictiveness. The source of the underlying Constituency level raw data is the British Election Studies Information System.[20] We geographically matched the election results at Constituency level to the local planning authority-level using GIS. More specifically, we used the Constituency-level boundaries for the relevant years to match the raw data to the 2001 local planning authority-level boundaries. As instrument for the 'share developable land that is already developed we use historical population density for 1911, derived from the British Census. We geographically matched the available town-level data from 1911 to 2001 local planning authority boundaries using GIS.[21]

In order to control for so called 'composition effects' we include a number of **control variables** derived from the Census 1981, 1991 and 2001. (See Section 5.1 for a discussion of the rationale of including these composition controls.) Specifically, we include the share of population aged between 45 and 64 years, the share of the workforce employed in manufacturing and the share higher educated. We also derive the total number of households in a local planning authority from the Census. We use the latter variable for weighting purposes (see Section 5.5 below). Finally, in order to compute our housing affordability index (see **Appendix 1** for the methodology and

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[19] Since the shadow price interpretation is only valid at the fringe of cities, we will carry out this robustness check at the higher level of spatial aggregation of Travel to Work Areas (TTWAs). We weight the price of bulk land at the LPA-level by the amount of developable land that is undeveloped to obtain a price of bulk land at TTWA-level. See Section 5.6 for further discussion.

[20] We thank Richard Topf for kindly providing the elections data at Constituency level in Excel format to us.

[21] The town-level data were derived from the UK data archive. We thank Tim Leunig who added latitude and longitude information using the OS Gazetteer and generously provided this augmented data to us.

details) we have used the Standard Variable Rate as reported in the Economic Fact book from Lloyds Banking Group, which is based on Halifax and the Bank of England.

5 Empirical strategy and empirical findings

5.1 Empirical issues, derived empirical strategy and estimating equations

The empirical implications of the theoretical considerations in Section 3 are straightforward: A given increase in earnings should raise house prices more in locations that have more stringent regulatory and physical supply constraints. Or in empirical terms: The coefficients on the interaction terms between earnings and the respective supply constraints measure should all be positive. Following the empirical specification formulated in equation (5) we can estimate the following equation:

$$\begin{aligned}
&\log\left(house\ price_{j,t}\right) = \beta_0 + \beta_1 \log\left(earnings_{j,t}\right) \\
&+\beta_2 \log\left(earnings_{j,t}\right) \times measure\ of\ regulatory\ constraints_j \\
&+\beta_3 \log\left(earnings_{j,t}\right) \times measure\ of\ land\ scarcity\ related\ constraints_j \\
&+\beta_4 \log\left(earnings_{j,t}\right) \times measure\ of\ topography\ related\ constraints_j \\
&+\sum_{i=1}^{34} \beta_{4+i}\, D_t + \sum_{i=1}^{352} \beta_{38+i}\, D_j + \varepsilon_{j,t}\ ,
\end{aligned} \tag{6}$$

where D_t and D_j denote the year-specific and location-specific fixed effects that capture macro-economic shocks and time-invariant unobservable characteristics at the local level, respectively.

The main empirical concern with the above equation is the **potential endogeneity of some of the supply constraints measures**. Such endogeneity may arise for instance when housing market dynamics influence planning decisions rather than the other way around (issue of reverse causation), when housing market dynamics and the share of developed land in urban use are jointly determined by unobserved factors like the attractiveness of some location (omitted variable problem), or when regulatory restrictiveness is measured with error (attenuation bias). In all of these cases, causal interpretation of estimated effects is impossible and the estimated coefficients may be biased. Causal inference is then only possible – through the so called Instrumental Variable (IV)-approach. The IV-approach is a very widely used methodology in Statistics, Econometrics or Epidemiology to address endogeneity issues. See e.g., Pearl (2000), Angrist and Krueger (2001) or Heckman (2008) for a more in depth discussion of the method and see e.g. Angrist and Krueger (1991) for a famous application of the IV-methodology. The main IV-estimator is the so called Two-Stage Least Squares (TSLS)-estimator. The method requires valid and sufficiently strong 'excluded instrumental variables': variables that only affect housing market conditions through their impact on the supply constraints measures.

Identifying valid instruments and inferring causal and unbiased effects of the various supply constraints measures on house prices is an important contribution of this Final Report. We describe concrete endogeneity concerns and discuss our so called 'identification strategies', that is, how exactly we identify (or infer) causal and unbiased effects of supply constraints on house prices below.

a) *Endogeneity concerns related to regulatory constraints measure and identification strategies*

The centralised British planning system is rather unusual in the sense that local planning authorities essentially have no (or only very limited) benefits from allowing development but face most or all of the cost. This is in contrast to many other countries, where local municipalities can reap (most of) the benefits from development. Hence, in the absence of any targets or fiscal incentives, local planning authorities supposedly have generally little interest in approving future development within their boundaries. Moreover, we would expect that comparably more restrictive[22] local planning authorities would refuse a greater share of development projects – particularly, major development projects as those projects are most likely to require costly new infrastructure provisions. For these reasons, our preferred measure of regulatory restrictiveness is 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 will be higher during boom times because housing demand and hence house prices are high (argument of reverse causation). This may be in part because bureaucrats are overwhelmed and so unable to deal with all the applications that are submitted (i.e., a capacity constraints problem is present) or it could be because more 'ambitious' projects are put forward only during boom periods. For instance: when local house prices are very high, developers might propose to convert Greenbelt land even if they know that the odds are high that such proposals are turned down. We address this endogeneity concern by using the **average refusal rate over the entire period for which we have data (1979 to 2008)**. However, at least one endogeneity issue remains even when we use the average refusal rate and location fixed effects, namely, the possibility that developers may be less likely (or more likely) to submit a planning application in the first instance if they know that the relevant local planning authority is very restrictive and the chance of rejection is very high. So in restrictive local planning authorities the refusal rate may underestimate (or overestimate) the 'true' tightness of the planning system.

In order to address this and other potential endogeneity concerns related to our refusal rate measure, we use two separate independent identification strategies:

(1) Exploit exogenous variation derived from 2002 policy reform

On the 1 April 2002 the then freshly re-elected Labour-government introduced three new targets with the intention of speeding up the planning process. The three targets were as follows: (i) at least 60 per cent of major applications should be determined within 13 weeks; (ii) at least 65 per cent of minor applications should be determined within 8

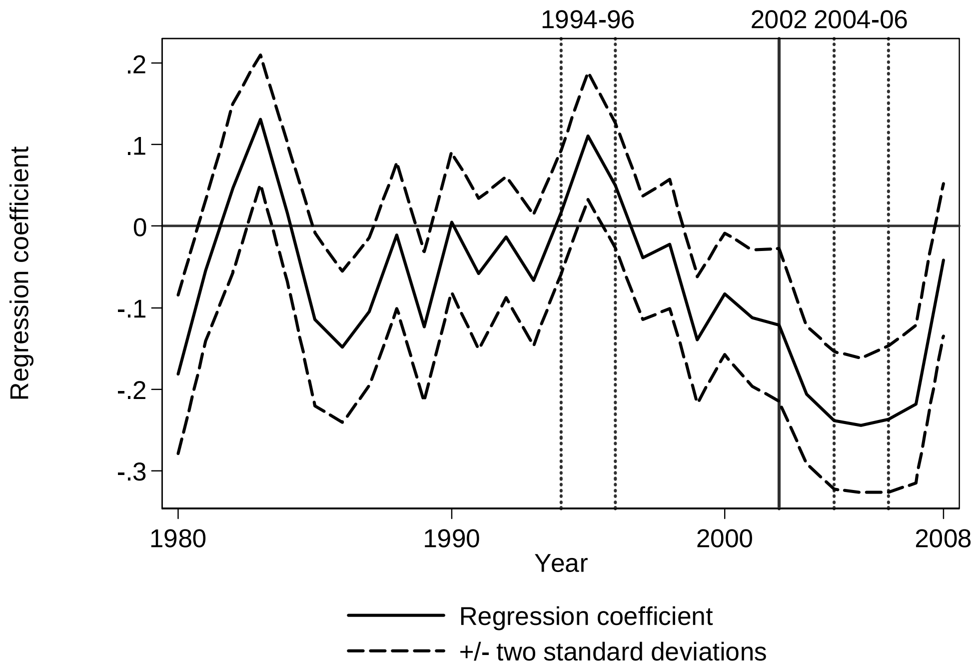
[22] The restrictiveness can differ across local planning authorities for example because of spatial differences in the vested interests and ideology of the constituency or because the benefits associated with certain development projects may be greater for certain local planning authorities than others. For instance, local planning authorities in high unemployment areas may have a greater incentive to allow residential (or industrial/commercial) development because of short-term job creation during the construction process. Industrial or commercial development may also generate long-term benefits in the form of sustained job creation that is particularly valuable for local planning authorities with high unemployment. See Cheshire and Hilber (2008) for evidence in favor of the latter proposition and Hilber and Robert-Nicoud (2009) for a more general analysis of the origins of land use regulation.

weeks; and (iii) at least 80 per cent of all other applications should be determined within eight weeks. These three targets replaced an older target that did not differentiate between major and minor applications.

The main effect of the reform was that after 2002 an explicit target for major development projects was in place, so local planning authorities could no longer significantly delay those projects and still meet the targets by approving the smaller projects more speedily. Of course not meeting the targets is an option for a local planning authority. In fact, to our knowledge there are no explicit (i.e., precisely formulated) sanctions if a local planning authority does not meet the targets. However, in practice the central government has powerful ‘tools’ of withholding financial resources to local planning authorities and of removing their leeway in decision-making such that local planning authorities 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 above established fact that local planning authorities did have the option to substitute one form of “penalised” restrictiveness (not meeting the delay targets) with another form of “non-penalised” restrictiveness (i.e., rejecting major applications in order to meet the key target that at least 60 per cent of major applications should be determined within 13 weeks or other forms of “non-penalised” behaviour that hinders development). To the extent that this is true, the observable implication is that changes in refusal rates and changes in delay rates should be uncorrelated before it became clear that the targets are introduced (all planning parameters are optimised in the pre-reform equilibrium) but should become negatively correlated afterwards as (the restrictive) local planning authorities 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 targets (a reduction in the delay rate). After finalising the adjustment process induced by the policy reform the two variables should become uncorrelated again (new equilibrium). **Figure 2** illustrates this point by plotting the regression coefficient of the two measures (change in refusal rate and change in delay rate) over time (solid line). (The dotted lines in **Figure 2** illustrate the confidence intervals (+/- two standard deviations) of the coefficients 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 but turns strongly negative post-reform (before returning to the new equilibrium), consistent with our proposition.

Figure 2: Relationship between change in refusal rate and change in planning delay rate for major residential applications



Our identifying assumption is that the policy reform had a differential impact on more and less restrictive local planning authorities. That is, the most ‘restrictive’ local planning authorities 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 local planning authorities with low refusal rates there was no (or less) need to alter their behaviour to accommodate the target.) Hence, rather than looking at the delay rate of an local planning authority, our instrument is the **change in the delay rate pre- and post-reform**; the most restrictive local planning authorities should have observed the greatest decrease in the delay rate. In our empirical work we chose as our time window to capture the change in delay rate prior to the reform as the average of the delay rates between 1994 and 1996. This time window is clearly before the time, the involved agents may have started to anticipate the reform. **Figure 2** 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 (and not statistically different from zero for most periods). As post reform window we chose the period between 2004 and 2006 as we would expect that most of the adjustment process takes place during this time window. Again, **Figure 2** suggests that this time window is sensible as the negative correlation between the change in refusal rate and the change in delay rate was quite strong. As a robustness check we also carried out our analysis with alternative time windows. Our findings are essentially unchanged if we shift the time windows one year in either direction (see the next section for a discussion of results). The left panel of **Appendix Figure A4** provides a map of English local planning authorities along with the predicted average refusal rate based on the exogenous variation derived from our change-in-delay rate instrument.

(2) Exploit exogenous variation derived from spatial differences in political party composition

As an alternative instrument to the change-in-delay-rate we propose the **share of votes to the Labour party at the General Election of 1983**. Political party composition has been used for example by Sadun (2008) as an instrument for the restrictiveness of the local planning system.[23] The rationale for using political party composition as an instrument 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 the share of votes to Labour in 1983 affects the impact of earnings on house prices only through planning restrictiveness. We choose the vote in general elections as they are presumably less affected by local housing market conditions. (Local-authority level elections may be influenced, for example, by opposition to larger scale local development projects.) We choose 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 local planning authority-level (for earlier election years, electronic boundary files are not available at Constituency-level). (The General Election of 1983 was a landslide victory for the Conservatives. However, as we document in Section 5.2, our empirical findings are not sensitive to the choice of the general election year.)

b) Endogeneity concerns related to physical constraints measure 'share developed that is already developed' and identification strategy

While one of our physical constraints measures – the elevation range – is clearly exogenous, the share of developable land that is already developed in 1990 (roughly the middle of our sample period) is subject to endogeneity concerns. Specifically, how developed a particular location is, is an equilibrium outcome; the result of demand and supply side pressures. On the demand side, more desirable places will have greater demand for housing and will consequently be more developed. On the supply side, more restrictive local planning authorities should have more open land for future development. 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 could too explain house price levels and price dynamics. In order to address this endogeneity concern we use historic population density in 1911 as an instrument to identify the share of the developable land that is already developed. This instrument pre-dates the 'birth' of the modern British planning system (i.e., 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

[23] Sadun (2008) 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.

later but, controlling for local planning authority 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.

c) Endogeneity concerns related to earnings measure and identification strategy

In our empirical analysis below we use male weekly earnings at local planning authority-level as a shifter of the housing demand curve. The predicted effect of an increase in earnings – a shift of the housing demand curve to the right in our theoretical framework – is illustrated in **Figure 1**. We implicitly assume that earnings are an exogenous shifter of housing demand. That is, we in interpret a change in earnings as an exogenous housing demand shock.

However, changes in earnings may be endogenously determined; they may be driven by shocks to labour demand or by changes in the composition of the local labour force. That is, local wages may change as a consequence of shocks to an industry that is well represented in the area, but a change in average earnings in a particular local planning authority may also be in part the result of an influx of highly skilled workers (replacing less highly skilled workers) due to, for instance, changing preferences for good state schools. While both – labour demand shocks or composition effects – should be expected to affect house prices through increasing housing demand, a labour demand-driven increase in the local wage level will affect the demand for housing in a different way than sorting of say higher educated workers into certain areas (for instance because of changing preferences for certain local amenities or public services). While a labour demand shock that increases local wages attracts households from other areas (so generates a pressure to add new housing units), a composition effect may not alter the total number of units demanded at a given price but may instead exert an impact on the quality of housing (e.g., how well maintained they are), which also affects house prices. Hence, while we would expect that the effect of a labour demand shock on house prices depends on the intensity of supply constraints, changes in the local household composition could affect prices independent of supply constraints. That is, more highly skilled may invest more money into new kitchens or bathrooms that would increase the price of the respective housing unit independent of housing supply conditions.

Another empirical issue is that changes in the local household composition could affect our estimates of the impact of supply constraints on the house price-earnings elasticity if changes in the composition of the local labour force correlate with our supply constraints measures. For instance, if young households would increasingly sort into highly developed places, our estimate of the impact of the share of developable land that is developed could be biased downwards, because it might pick up the effect that changes in these areas are more likely to be composition-induced and hence exert a smaller impact on house prices. However, note that in our empirical analysis below we instrument for scarcity related and regulatory supply constraints. Hence, arguably those measures should not be subject to omitted variable bias and our empirical findings should not be altered in a meaningful way if we add composition controls. Indeed, our findings reported in Section 5.4 suggest that adding composition controls does not alter the estimated price-earnings elasticity in a meaningful way.[24]

d) Estimating equation

Following the empirical specification in equation (5) and the discussion above, we can formulate our base estimating equation as follows:

$$\begin{aligned}\log\left(house\ price_{j,t}\right) &= \beta_0 + \beta_1 \log\left(earnings_{j,t}\right) + \beta_2 \log\left(earnings_{j,t}\right) \times \overline{\boldsymbol{refusal\ rate}}_{\boldsymbol{j}} \\ &+ \beta_3 \log\left(earnings_{j,t}\right) \times \boldsymbol{\%developed}_{\boldsymbol{j}} + \beta_4 \log\left(earnings_{j,t}\right) \times elevation_j \\ &+ \sum_{i=1}^{34} \beta_{4+i} D_t + \sum_{i=1}^{352} \beta_{38+i} D_j + \varepsilon_{j,t} \ . \end{aligned} \tag{7}$$

The **bold** variables indicate that they are endogenously determined and need to be instrumented to identify causal effects as outlined above. The upper bar indicates an average over all years, for which we have planning application data.

We standardize all three supply constraint measures to ease the interpretation of the coefficients. That is, we subtract the sample mean of each supply constraint measure from the supply constraint measure itself and divide this difference by the standard deviation of the measure; using the notation from Section 3 we can formulate this as follow: $\left(X_j^k - \overline{X}^k\right)/\sigma$, where the upper bar indicates the average over all local planning authorities. This allows us to interpret the estimated coefficients as an increase in the house price-earnings elasticity due to a one standard deviation increase in one of the constraint measures. By implication, the coefficient on the earnings variable can be interpreted as the house price-earnings elasticity for a local planning authority with average levels of supply constraints.

5.2 Estimating the base specification using OLS and TSLS: Main Results

Table 2a summarises our main findings. Column (1) of Panel A shows results for our naïve OLS specification that does not take into account endogeneity issues. Results for the IV strategy that uses both the change in delays *and* the share of votes to Labour as instruments to identify the average refusal rate are shown in the second column of this panel, while corresponding first-stage results are shown in Panel B. Both specifications include local planning authority- and year-fixed effects to capture all unobserved characteristics that are either time-invariant or do not vary across space. Moreover, 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. The coefficient

[24] Of course, in an ideal world, we would identify the causal effect of earnings by employing the same instrumental variable technique that we use to identify our supply constraints measures. However, apart from the lack of a valid and strong instrument to identify earnings, we face the problem that instrumenting for earnings would mean that we would instrument both terms of the interaction effects (earnings *and* the respective supply constraints-measure). This would make weak identification (and hence significant bias towards OLS) extremely likely.

on the price-earnings elasticity in column (1) is highly statistically significant and positive, taking a value of 0.32. This implies that in a local planning authority with average constraints, i.e. an local planning authority in which all supply constraints take their average value, a (permanent) 10 per cent increase in earnings would raise house prices by 3.2 per cent. Coefficients for the earnings $\times$ supply-constraints point to modest but statistically significant heterogeneity of this elasticity across local planning authorities: the house price-earnings elasticity rises to 0.38 in an local planning authority in which the refusal rate is one standard deviation above the English average and it rises to 0.41 in an local planning authority in which the share of developable land that is developed is one standard deviation above the English average. The interaction between the elevation range and earnings does not seem to affect the house price-earnings elasticity in a statistically significant manner.

Consistent with our conjecture that OLS estimates are biased, the IV results in column (2) of Panel A indicate that the house price-earnings elasticity is to a much greater extent determined by supply conditions. Whereas there is no statistically discernible impact of earnings on house prices in a local planning authority with average constraints, a one standard deviation increase in refusal rates raises the house price-earnings elasticity by 0.29 and a one standard deviation increase in the share of developable land developed raises the house price-earnings elasticity by 0.30. Interestingly the coefficients on both interaction terms are much larger (more than twice as large) in the TSLS than in the OLS suggesting that the endogeneity bias on the land scarcity variable also led us to underestimate the true impact of local land scarcity induced supply constraints on the responsiveness of house prices to earnings. Furthermore, the estimates now point to elevation range as a significant barrier to construction too: 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.

Corresponding first-stage results in Panel B, column (1), suggest that our proposed instruments for the refusal rate, the change in delay rates pre- and post-reform and the share of votes to Labour, both have the predicted negative effect on the interaction term refusal rate $\times$ earnings. That is, the greater the decrease in the delay rate, the higher the refusal rate, consistent with the proposition that the most restrictive local planning authorities had the strongest incentives to reduce the delay rate and increase the refusal rate at the same time. Furthermore, local planning authorities in which a larger share of votes went to Labour in the 1983 General Elections refused less major residential projects, consistent with the proposition that Labour-voters care more about affordability and less about protection of house values. Both instruments are highly statistically significant, a necessary condition for strong identification. Column (2) of Panel B indicates a positive and highly significant impact of population density in 1911 on the share of developable land that was developed in 1990, whereas this share appears to be unaffected by our instruments for the refusal rate. The Kleibergen-Paap F-statistic of 11.8 suggests that the bias of the TSLS-estimates towards the OLS is minimal and that weak identification of the endogenous variables is not an issue.

Table 2b shows IV results for alternative identification strategies, in which either one of our two instruments for refusal rates is dropped. In column (1) of Panel A, the impact of refusal rates is identified on change in delays, whereas in column (2) it is identified on the share of votes to Labour. Corresponding first-stage results are contained in Panel B. Both instruments separately are statistically significant predictors of refusal rates and Kleibergen-Paap F-statistics of 10.7 and 10.5 respectively suggest that using only changes in delay or the share of votes to Labour yields an identification that is sufficiently strong. Given the inherently different nature of these two identification strategies, it is reassuring to find that each of them separately reveals highly significant effects of regulatory constraints. A one standard deviation increase in refusal rates is estimated to raise the house price-earnings elasticity by 0.16 if identified on changes in delay and by 0.34 if identified on share of votes to Labour. A one standard deviation increase in the share of developable land developed is estimated to raise the house price-earnings elasticity by 0.23 or 0.33 respectively. Estimates of both regulatory and physical constraints are somewhat higher when we use the share of votes to Labour as an instrument. Our preferred specification that uses both instruments, column (2) of Panel A in **Table 2a**, yields effects that are in between these two estimates, but they are closer to the specification that uses the share of votes to Labour only.

Appendix Tables A3 and A4 investigate robustness of these findings for alternative definitions of the instruments. In **Appendix Table A3** we alter the pre- and post-reform time window of our change-in-delay-rate instrument by one year in each direction. Both, the first-stage and second-stage results are very reassuring that our results are not altered in any meaningful way by the precise choice of the time windows. The Kleibergen-Paap F-statistics again suggest that weak identification is not a problem in these specifications. In **Appendix Table A4**, we consider the share of votes to Labour in the 1997 and the 2005 General Elections or the mean of the three election years to test whether our results are sensitive to the choice of the election year. While the 1983 General Election – which was the basis for deriving our instrumental variable – brought a landslide victory for the Conservative party, 1997 brought a landslide victory for the Labour party and 2005 was a relatively close election. Again, both, the first and second-stage results are very reassuring that our results are not altered noticeably by the choice of the election year. Weak identification is again not a problem.

The estimated effects in **Table 2a/b** are sizeable as our counterfactual analysis discussed in Section 6 further reveals. It is worth noting in this context that these results give the impression that physical supply constraints may be at least as important in economic terms as planning induced constraints in affecting the price-earnings elasticity. However, the estimated coefficients do not take into account the fact that in most local planning authorities regulatory constraints are more severe than local land scarcity induced constraints (the distribution of the latter variable is much more skewed than the former). See Section 6 for an in-depth discussion of this argument. **Appendix Table A2** reports the year fixed effects for all specifications shown in **Table 2a/b**. The year fixed effects capture a significant fraction of the cyclical behaviour of the markets, implying that macro factors that vary over time but not noticeably across local planning authorities (e.g., interest rate movements, overall GDP growth) may be quite important in explaining the cyclical behaviour of housing markets in England.[25]

5.3 Asymmetry of effects during boom and bust periods

Barriers to construction ought to matter less in periods when demand for new housing is low. Theoretically, we would expect supply constraints to be binding only when house prices exceed the costs of construction. If they are below this threshold, durability of structures should render supply almost fully inelastic irrespective of the presence of any man-made or physical constraints (Glaeser and Gyourko, 2005). **Table 3** tests the conjecture that supply constraints are more binding during boom periods than during busts. Bust periods have been defined 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.[26] Results from estimating our preferred specification on the subsample of boom or bust years are shown in columns (1) and (2) respectively. Consistent with what theory would predict, we find that the impact of a one standard deviation increase in the refusal rate is almost twice as large in boom periods than during busts, raising the house price-earnings elasticity by 0.27 or 0.15 respectively. A one standard deviation increase in the share of developable land developed raises the house price-earnings elasticity from 0.20 during bust periods to 0.29 during boom periods. The difference between these effects – tested either separately or jointly – is highly statistically significant.

Subsequent columns contain results for similar IV regressions in which the impact of refusal rates is identified on either changes in delay (columns 3 and 4) or the share of votes to Labour (columns 5 and 6). These results are fully consistent with what we find for our preferred specification: irrespective of the employed identification strategy, both man-made and physical supply constraints have a substantially larger impact on the house price-earnings elasticity during boom periods than during bust phases. Furthermore, the Kleibergen-Paap F-statistics suggest the identification is sufficiently strong in all specifications.

5.4 Controlling for possible composition effects

As discussed in Section 5.1, changes in earnings may be driven by labour demand shocks or by composition effects, which can be expected to affect housing demand differentially. This may introduce an omitted variables bias if changes in composition of the workforce correlate with supply constraints. While we do instrument for scarcity related and regulatory supply constraints – and omitted variable bias should therefore not affect the estimated impact of supply constraints on the price-earnings-elasticity – an additional robustness check is to directly control for composition effects. To the extent that our identification strategies for the supply constraints measures help us to identify

[25] We note that the average house price-earnings elasticity in this specification is close to zero, whereas the elasticity in aggregate house price models often exceeds 1, consistent with the notion that the year-dummies may be picking up the effects of general income growth in England. Our empirical specification only explains the causal effects of local income movements.

[26] Obviously, we could not infer an average growth rage 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).

the true impact of the supply constraint measures on the house price-earnings elasticity, adding composition controls should affect our results very little.

We construct local planning authority-level information about the composition of the local labour force from the Census. In particular, we consider the share of the population aged between 45-64, the share of local employment in manufacturing and the share of the population that is highly educated.[27] As a consequence of using Census data, our sample is restricted to the Census years 1981, 1991 and 2001. **Table 4** documents regression results on this restricted sample, in which the three composition controls are entered in different combinations. Columns (1) to (6) identify the impact of refusal rates on both instruments. The baseline regression without composition controls in column (1) indicates well-identified and statistically significant impacts of regulatory and physical supply constraints on the house price-earnings elasticity, which are larger than the effects reported in **Table 2a/b**. In the next three columns, which enter the demographic, industry and educational controls separately, only the share of population aged between 45 and 64 has a significant positive impact on house prices, while the Kleibergen-Paap F-statistic points to a possible weak identification issue in the other two regressions. The specification in column (5) that enters the demographic and the industry control, which is well-identified, also indicates that only the share of population aged between 45 and 64 raises house prices. The specification that includes all controls in column (6) is weakly identified. Nevertheless, the estimated impact of supply constraints on the house price-earnings elasticity is remarkably consistent. In no specification do the coefficients on refusal rates and the share of developed land deviate from their baseline estimate in column (1) in a statistically significant sense.

Columns (7) and (8) report specifications that include all three composition controls, in which the impact of refusal rates is identified on the change in delay or the share of votes to Labour respectively. Again, the Kleibergen-Paap F-statistics indicate weak identification problems. As in **Table 2a/b**, we find that compared to the specification that is identified on both instruments, estimates of the impact of supply constraints are smaller in the former and larger in the latter specification, but they remain in the same ballpark. Overall, the evidence gathered in **Table 4** does not suggest that our estimate of the impact of supply constraints is driven by changes in household composition.

5.5 Robustness check: Use alternative geographical definitions of 'housing markets'

Housing markets of proximate local planning authorities may be strongly integrated, so that carrying out the analysis at a higher level of spatial aggregation may be more appropriate. Furthermore, not all of our data could be collected at local planning

[27] The Census definition for highly educated varies between years: in 1981 it is the share of persons over 18 with a degree, professional or vocational education, in 1991 it is the share persons over 18 with at least a degree and in 2001 it is the share people over 16 with at least a degree. The slight changes in definitions in the variable over the three Census years are unlikely to bias our results because we control for year fixed effects, which capture potential differences in levels. The cross-sectional variation should not be notably affected whether the sample universe is defined as over 16 or over 18.

authority level at all points in time. A robustness check at higher levels of aggregation also indicates the extent to which this data imperfection affects our results.

We consider three alternative geographical definitions. Travel to Work Areas (TTWAs), of which there are 150 in England, are designed to capture local labour markets. It seems sensible to define local housing market areas as coinciding with local labour market areas, because households can change their house within these areas without changing jobs. TTWAs are subdivided into urban and rural areas so as a further robustness check, we also estimate our main specification on the subset of the 71 urban TTWAs. Functional Urban Regions (FURs) constitute an alternative definition of integrated urban housing markets, which is based on commuting patterns in 1990. Our sample consists of 55 FURs. Finally, we consider the pre-1996 county classification, which is the highest level of spatial aggregation for which we use data. Our dataset consists of 46 such pre-1996 counties.[28]

Table 5 documents estimation results at all different geographical scales for our preferred specification, where local planning authority-level results have been reproduced in column (1) for ease of comparison. The impact of regulatory constraints is identified on both the change in delays and the share of votes to Labour. Furthermore, in columns (2) to (5), all observations are weighted with the number of households in the 1990 Census, because of extreme variations in magnitudes. For instance, the smallest TTWA, Berwick, contained hardly more than 10,000 households, whereas this number exceeded 3 million in London. In order to make coefficients comparable across specifications, we have standardised supply constraints to their standard deviation at local planning authority level, so that at each geographical scale, coefficients correspond to a one local planning authority-level standard deviation change in restrictiveness.

Results turn out to be remarkably homogeneous across different geographical scales. The estimated impact of a one local planning authority-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 local planning authority-level standard deviation increase in the share of developable land developed ranges from 0.22 for pre-1996 counties to 0.30 at the local planning authority level. These coefficients are always highly statistically significant. Results for elevation range are similarly homogeneous. The Kleibergen-Paap F-statistic suggests that at higher spatial levels of aggregation, the identification becomes stronger rather than weaker.

Appendix Table A5 replicates these analyses using either the change in delay (Panel A) or the share of votes to Labour (Panel B) as single instruments. Again, results are highly homogeneous across geographical scales. However, a weak identification issue

[28] We have aggregated our data from the LPA level to these alternative geographical housing market definitions in the following way. Averages of LPA-level house prices and earnings are weighted by the number of households in the 1990 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 are weighted by area. Election outcomes are weighted again by the number of households in the 1990 Census.

is present at higher levels of aggregation if only the change in delay rate is used as instrument. This suggests that identification in **Table 5** is driven more strongly by the share of votes to Labour instrument.

5.6 Robustness check: Use ‘shadow price’ as alternative regulatory measure

As argued in section 4.5, the price of bulk land may be considered as an alternative proxy for regulatory restrictiveness. Hence, as a further robustness check, in **Table 6a/b** we estimate the same specifications as in **Table 2a/b**, but we replace the refusal rate with the bulk land price (shadow-price)-variable. Furthermore, since the price of bulk land can only be meaningfully interpreted as a shadow price on developable land with planning permission if this land is situated at the fringe of the city, we carry out the analysis at the TTWA level. Bulk land prices are weighted by the amount of (undeveloped) developable land, of which there will generally be most at peripheral local planning authorities within a TTWA. As with the analyses at higher spatial levels of aggregation in **Table 5**, we weight observations with the number of households in the 1990 Census.

The OLS results in column (1), Panel A, of **Table 6a** indicate an average house price-earnings elasticity of 0.47 which rises by 0.097 if the shadow price rises by one TTWA-level standard deviation. Physical supply constraints do not appear to affect this elasticity in a statistically significant manner. Again, these results may be biased because of endogeneity of the supply constraints measures. In particular, as the shadow price measure reflects the price of bulk land in 2007, there is a substantial risk of omitted variables correlating with both, this measure and house prices. Moreover, our shadow price measure may contain an option value that reflects uncertainty about future urban housing demand (Capozza and Helsley, 1990). In order to deal with these endogeneity concerns, we use the same instruments as before: estimates in column (2), Panel A, of **Table 6a** identify the impact of the shadow price on both change in delay and share of votes to Labour. We now find a much larger impact of a one standard deviation increase in the shadow price on the house price-earnings elasticity of 0.20, which is highly statistically significant. However, the impact of physical supply constraints is again not statistically significant. First stage results in Panel B indicate that both instruments predict the shadow price well and the Kleibergen-Paap F-statistic confirms sufficient strength of our identification. In columns (1) and (2), Panel A, of **Table 6b**, results are identified on either the change in delay or the share of votes to Labour separately. Results appear to be consistent across these specifications, although a weak identification issue may be present if we identify on changes in delay only.

5.7 Effects of supply constraints on house price volatility

Our results so far indicate that regulatory and physical supply constraints render housing markets more volatile in the sense that they raise the sensitivity of prices to demand conditions. Markets in which prices are more sensitive to demand fluctuations should be expected to be more volatile. In this section we investigate the relationship between supply constraints and more conventional measures of housing market volatility. In particular, we define long-term volatility as the standard deviation of the logarithm of real house prices within each local planning authority and we define short-term volatility as the standard deviation of the growth rate of real house prices within each local planning authority. In order to facilitate interpretation, both measures are multiplied by a factor of 100.

Table 7 reports cross-sectional regressions of long and short-term price volatility on our (standardised) supply constraints measures in Panels A and B respectively. Column (1) of Panel A contains naïve OLS results for the long-term volatility measure. The constant may be roughly interpreted as indicating that in an average local planning authority, house prices deviate from their mean by about 43 per cent on average. A one standard deviation increase in refusal rates is found to raise this mean deviation by 1.8 per cent and a one standard deviation increase in the share of developable land developed raises it by 2.0 per cent. The elevation range appears to affect long-term volatility negatively. However, only the impact of refusal rates is statistically significant. As these estimates are likely to be troubled by endogeneity issues for essentially the same reasons as in our preceding analysis, we report IV results in columns (2) to (4). In column (2) we instrument the refusal rate with both the change in delay and the share of votes to Labour, whereas in columns (3) and (4) we use each instrument separately, and in all three columns we instrument the share developed with population density in 1911. Results in all three columns point to a much larger and statistically significant impact of both regulatory and physical supply constraints. For instance, in column (2), a one standard deviation increase in refusal rates raises the mean deviation from mean house prices by 6.6 per cent and a one standard deviation increase in the share of developable land developed raises it by 7.1 per cent. These effects are similar across the IV specifications and they are well identified.

Column (1) of Panel B contains naïve OLS results for the short-term volatility measure. The constant may be roughly interpreted as indicating that in an average local planning authority, house price growth deviates from its mean by about 10 per cent on average. A one standard deviation increase in refusal rates is found to raise this mean deviation by 0.2 per cent and a one standard deviation increase in the share of developable land developed raises it by 0.6 per cent. Again we find a negative impact of elevation range, but now the physical supply constraint measure appears to be statistically significant rather than the refusal rate. Nevertheless, the IV-results in columns (2) to (4) indicate that for short-term volatility, there is a much larger and statistically significant impact of both regulatory and physical supply constraints. In column (2), a one standard deviation increase in refusal rates raises the mean deviation from mean house price growth by 1.4 per cent and a one standard deviation increase in the share of developable land developed raises it by 2.0 per cent. These effects are well identified and quite similar across the IV specifications, although the impact of regulatory constraints is estimated to be significantly smaller when this effect is identified on changes in delay only. Overall, a substantial causal impact of supply constraints on both short and long-term volatility appears to be present, as should be expected from the results reported in previous sections.

5.8 Other robustness checks

Results of a number of additional robustness checks are reported in **Appendix Tables A6 to A8**. **Appendix Table A6** replicates the second-stage results of the specifications reported in **Table 2a/b** on sub-samples that drop either the City of London or local planning authorities located in the Greater London Area Government Office Region from our regression sample. The City of London is a special case as planning applications are 'negotiated'. Planning applications for any major development in the City of London are extremely costly and developers will only formally submit a planning application if the pre-application negotiation process was successful. Hence, the 'official' refusal rate in the City of London was zero (or missing) throughout the period with available information. One might be concerned that the inclusion or exclusion of the City of London may significantly alter our results. However, the various specifications reported in **Appendix Table A6** clearly reveal that irrespective of the identification strategy employed, our results are virtually unchanged independent on whether we treat the City of London as a special case (and drop it) or not. Since the Greater London Area may be regarded as exceptional too, we also consider robustness to dropping the 33 local planning authorities in this region. Now the estimated impact of refusal rates is lower, whereas the impact of physical supply constraints disappears. This suggests that the Greater London Area local planning authorities do play an important role in identifying our results or, put differently, that these effects appear to be relatively strong in the Greater London Area. However, **Appendix Table A6** also indicates that the impact of regulatory constraints is not confined to this area.

Appendix Table A7 shows second stage results of the specifications reported in **Table 2a/b** but this time we replace the share of developable land that is developed with a similar measure, in which semi-developable land is treated as non-developable rather than 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, technical constraints or viability considerations. We find that the treatment of 'semi-developable' land as either 'developable' or 'non-developable' has no discernible impact on our findings.

Appendix Table A8 reports results for our preferred specification, except that we use alternative measures to proxy for slope related physical constraints. Specifically we use three alternative measures that are based on the range between highest and lowest altitude. The first measure is our base measure; the other two measures are dummy variables that take the value of one if the elevation range in meters is in the top 75th / in the top 90th percentile. The latter two measures take account of the possibility that the effect may be highly non-linear; elevation related supply constraints may only be present in the very top local planning authorities in terms of elevation range. As columns (1) to (3) of **Appendix Table A8** reveal, results are rather similar across specifications and our key results are essentially unaltered. Columns (4) to (6) of **Appendix Table A8** repeat this exercise but this time we use an alternative measure for slope related physical constraints: the standard deviation of slopes (in degrees). Again, the positive coefficient on all three measures is quite similar across specifications, although the coefficient is not quite statistically significant in column (4). Our main results are again essentially unaltered. Overall, these findings suggest that our key results are not sensitive to the precise choice of a measure for slope related supply constraints. Also, the coefficients on the various elevation/slope $\times$ earnings interaction effects are not dramatically different (and not very large) across specifications implying that slope related constraints may have a rather second order impact overall on the responsiveness of house prices to earnings independent of how exactly we measure the constraint.

6 Counterfactual analysis

In the previous chapter we report house price-earnings elasticities and document how the various supply constraint measures affect this elasticity. From a policy perspective, the more relevant question is of course what the quantitative impact of the various supply constraints is on house prices and on housing affordability. To what extent is the England housing affordability crisis driven by supply constraints and what would be the consequence of relaxing regulatory barriers to residential development? In this chapter, we carry out a counterfactual analysis in order to shed light on these questions and to develop an understanding of the quantitative implications of our empirical results.

6.1 Quantifying impacts of supply constraints on house prices

We conduct our counterfactual analysis on the basis of the two specifications reported in **Table 2b** that identify the impact of regulatory constraints on either the change in delay or the share of votes to Labour separately. Since these two identification strategies yield somewhat distinct estimates, they will provide a bandwidth for plausible magnitudes of effects. Each specification yields a prediction of house prices conditional on earnings, supply constraints and local planning authority and period fixed effects. Counterfactual scenarios are obtained by predicting house prices with supply constraints set to zero one by one. (As noted earlier, although ‘removing’ supply constraints entirely is rather unrealistic in practice, the corresponding counterfactual scenarios allow us to get a sense of how important quantitatively the constraints are for house price levels and housing affordability.) 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 local planning authority 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 an ‘average English local planning authority’. Note in this context that the predicted house prices are identical to average house prices over the regression sample because of the period fixed effects. Finally, we transform the scenarios to levels in 2008 GBP.

Table 8 summarises results for both specifications, while **Figure 3** (based on change in delays) and **Figure 4** (based on share of votes to Labour) illustrate them graphically. Moreover, **Appendix Figures A5 and A6** illustrate scenarios for a few specific local planning authorities: Westminster and Newcastle upon Tyne appeared as the most and least restrictive with respect to office planning in Cheshire and Hilber (2008), whereas Reading and Darlington are chosen as representing a relatively restrictive and a relatively relaxed local authority in Cheshire and Sheppard (1995).

Figures 5 and 6 illustrate counterfactual scenarios that are built up in a slightly different way. In **Figure 5**, refusal rates everywhere are set at the 10th and 90th percentile of their distribution across England, while in **Figure 6**, refusal rates everywhere are set as in the least and most restrictive Government Office Region, which are the North-East and the South-East respectively. These figures show averages of predicted prices over all local planning authorities for both specifications.

Figure 3: The impact of supply constraints on house prices in average English local planning authority: Lowest bound estimate

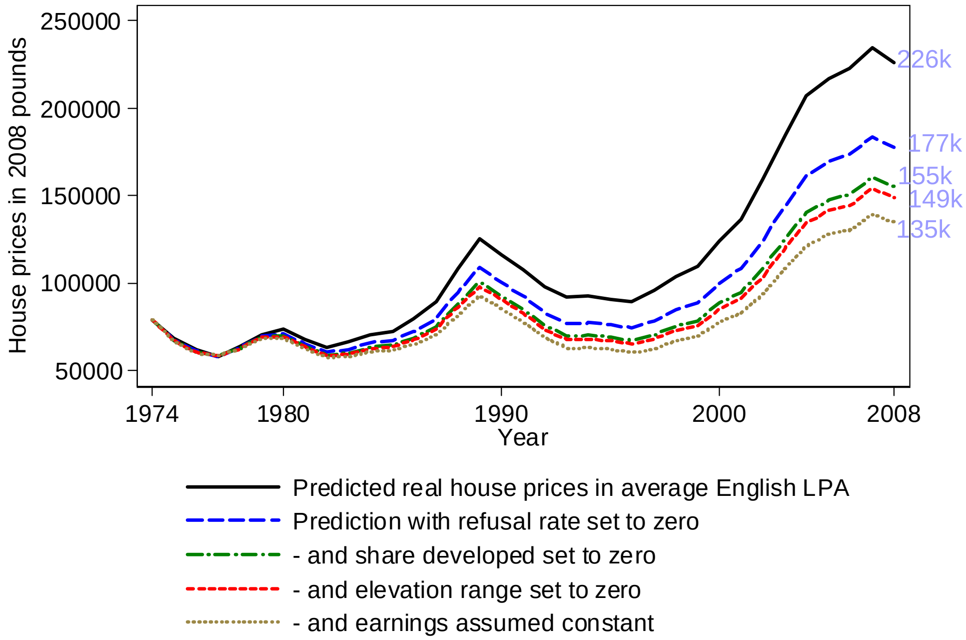


Figure 4: The impact of supply constraints on house prices in average English local planning authority: Lower upper bound estimate

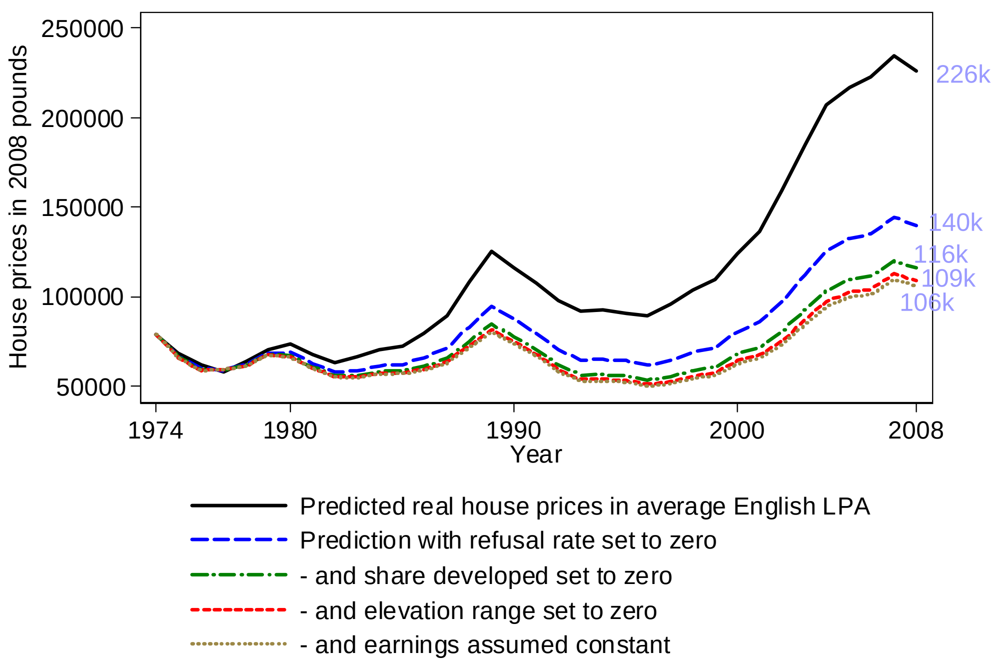


Figure 5: Regulatory restrictiveness and house prices: 90th versus 10th percentile (lowest and lower upper bound estimate)

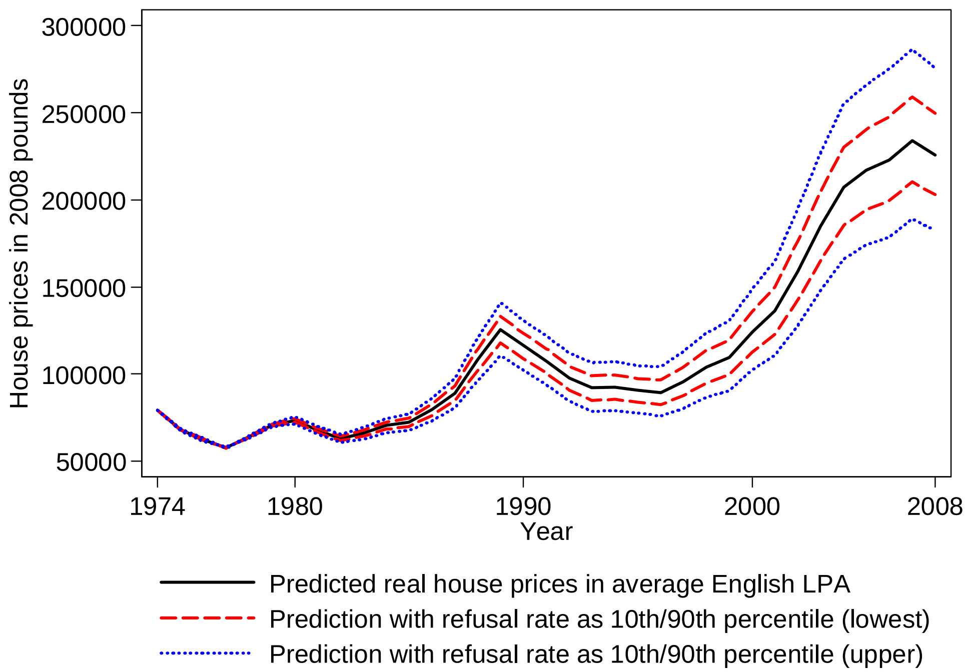
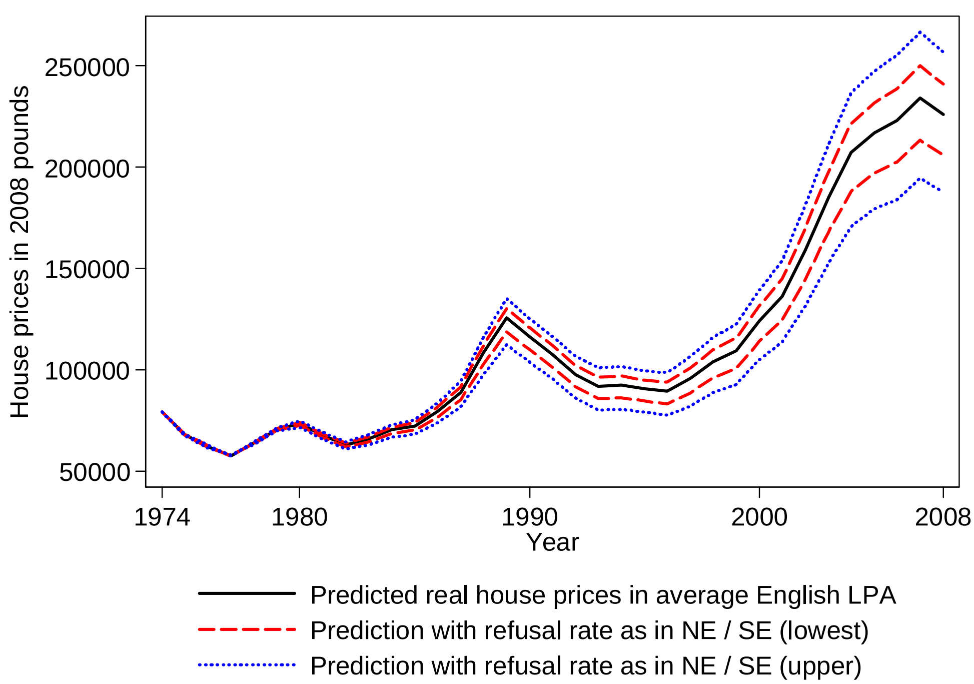


Figure 6: Regulatory restrictiveness and house prices: North East versus South East (lowest and lower upper bound estimate)



Before turning to a discussion of these results, we would like to stress that they should be interpreted with caution. Our counterfactual scenarios are based on the estimated impact of local supply constraints on local house prices. Since the substitutability of housing across local planning authorities 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 (Glaeser and Ward, 2009). 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 report.[29] By implication, our counterfactuals represent a potentially significant underestimation of the aggregate implications of supply constraints and in particular the planning system. It should also be noted that we underestimate the effect of supply constraints even further to the extent that these were binding in 1974 already – which is a real possibility, as the British Town and Country Planning Act was introduced in 1947.[30]

Bearing these caveats in mind, the scenarios point to a substantial impact of regulatory supply constraints: house prices in an average local planning authority in England in 2008 would be 21.5 to 38.1 per cent lower if the planning system were completely relaxed, depending on whether we use estimates identified on change in delays or on the share of votes to Labour, while the standard deviation of prices during the sample period would be 29.7 to 51.6 percent lower. Removing all regulatory barriers to construction is not very realistic, but **Figures 5 and 6** illustrate that even by setting them at the 10th percentile or at their level in the North-East may lead to very substantial price reductions. Physical supply constraints matter as well, although the impact is more modest: house prices (their standard deviation) would be another 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) per cent lower in the absence of any elevation differentials. However, this picture turns out to vary over locations. In the densely developed borough of Westminster it is physical constraints that matter most, regulatory constraints are most important in the prosperous provincial town of Reading, whereas Newcastle and Darlington appear to be pretty much unconstrained. Local earnings have little impact on house prices once supply constraints are removed, consistent with what theory would predict.[31]

[29] Another potential shortcoming of using our econometric model is that it implicitly assumes linearity of effects, whereas the impact of supply constraints may be nonlinear in reality. Results may be affected if differences between scenarios in the stringency of supply constraints are large. The absence of regulatory constraints might influence the development of physical constraints, which is ignored here as a second order effect as well. So clearly, the counterfactual analysis provides only a first pass, even if its driving coefficients have been carefully identified.

[30] There are some additional reasons to expect that our results are conservative. We assume that earnings capture all developments in demand, but other factors may have pushed up prices too. Supply constraints are likely to limit supply of housing land more than supply of housing capital. The crude composition control in our house price index is unlikely to fully capture the induced substitution effect. Finally, the counterfactuals ignore asymmetry between boom and bust periods.

[31] The small difference is consistent with the presence of a slightly upward sloping supply curve, even after eliminating the supply constraints that we consider here. Another possible explanation would be that income growth affects the type of housing in a way that is not captured by our mix-adjustment strategy.

Interestingly our counterfactual analysis for an average English local planning authority reveals that the effect of regulatory constraints on real house prices has been substantially larger than that of local physical constraints – even if the estimated elasticity reported in column (2) of Panel A in **Table 2a** for the share developed interaction term is about as large as the refusal rate interaction term (0.29 vs. 0.30). The impact of supply constraints on prices is a combination of two factors: 1) how sensitive is the house price-earnings elasticity for a particular supply constraint and 2) how severely constrained are local planning authorities with regard to this variable. We can only judge the relative importance of different types of constraints by taking both effects into account. While **Table 1** reveals that the refusal rate measured between 1979 and 2008 and the share developed in 1990 have roughly the same average over all local planning authorities (25 per cent), the distribution of the share developed measure is much more skewed: its median over all local planning authorities equals 15 per cent whereas mean and median are virtually identical for the refusal rate measured between 1979 and 2008. This implies that in the majority of local planning authorities, regulatory constraints may be more severe than physical constraints – only in the most urbanised areas may physical supply constraints be binding.

Finally, it should be noted that 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 would have increased between 1974 and 2008. This residual price dynamics may reflect the aggregate impact of local supply constraints, as discussed previously in this section, but it might also be attributable to macro-economic developments like the mortgage interest rate, financial liberalisation and aggregate income shocks. We cannot exclude the possibility that adaptive expectations in combination with construction lags play a role as well: our findings suggest that strong inhibitions on housing supply in England are not inconsistent with the presence of house price bubbles in recent years. However, we note that Cameron *et al.* (2006) provide evidence against the 'bubble hypothesis' for UK regions and the time period between 1972 and 2003.

6.2 Quantifying impacts of supply constraints on housing affordability

Housing affordability is essentially driven by three factors: house prices (high house prices reduce affordability), household earnings (higher earnings increase affordability) and the availability and cost of debt financing (higher mortgage interest rates reduce affordability, at least for the vast majority of households that do not own their property outright). We develop a Housing Affordability Index (AFI) that takes these aspects into account. This index measures whether or not the average household in a certain local planning authority can qualify for a mortgage loan on a typical home in that local planning authority (see **Appendix 1** for further details). To interpret the AFI: a value of 1 means that in a specific LP, a household with mean local planning authority-specific male weekly earnings has exactly enough income to qualify for a mortgage on a typical home in that local planning authority. The index rises with affordability, so a higher value means that a larger share of households can afford a typical home in an local planning authority. **Table 1** reports summary statistics for this variable, indicating that over our entire sample, the average household could just qualify for a mortgage loan on a typical home in its local planning authority.

Counterfactual scenarios for housing affordability are constructed simply by substituting counterfactual scenarios for house prices into the AFI formula. **Figures 7 to 10** show the housing affordability that corresponds to counterfactual house price scenarios in **Figures 3 to 6**, where the AFI has been averaged over all local planning authorities. **Appendix Figures A7 and A8** show the housing affordability that corresponds to counterfactual house price scenarios in **Appendix Figures A6 and A7**. Turning to average housing affordability in **Figure 7** first, we notice that this index has developed rather stationary: it was about equally low in 2008 as it was back in 1974. Developments in interest rates, which have varied substantially over the past decades, can account for this.[32] Since income growth is comparably stable over time, this suggests that housing affordability is in large parts driven by house prices and nominal interest rate fluctuations. The combined effect in **Figure 7** shows that affordability was lowest in the late 1970s, the late 1980s and around 2007 (despite low nominal interest rates). During these periods, the average household could not qualify for a mortgage loan on a typical home in its local planning authority.

Figures 7 and 8 indicate that according to the AFI, relaxing regulatory supply constraints fully would have tipped housing in the average local planning authority from unaffordable to just or easily affordable, depending on the way in which this effect is identified. Removing physical constraints would have raised the affordability index even further, but this conclusion has little relevance for policy. **Figures 9 and 10** indicate that relaxing regulatory constraints to the 10th percentile or to their level in the North-East would just suffice to render housing affordable if we rely on our ‘lower upper bound estimate’ identified on the share of votes to Labour. Again, the picture varies over locations. In the densely developed borough of Westminster it is physical constraints that matter most, so relaxing regulatory constraints achieves little in terms of housing affordability. Places like Newcastle and Darlington do not appear to have an affordability problem in the first place. In contrast, in severely regulated towns like Reading, the affordability problem seems mainly attributable to the planning system. We reiterate that the counterfactual house price scenarios are cautious (providing lower bound estimates), as discussed in the previous section, so that our estimate of the impact of relaxing regulation on housing affordability is necessarily cautious as well.

[32] Nominal interest rates peaked around 1980 and 1990 to fight inflationary pressures but they remained low during the current crisis. In contrast to the previous major recessions, no inflationary pressure built up (and interest rates were not used as a tool to combat asset bubbles during the late 1990s and early 2000s).

Figure 7: The impact of supply constraints on housing affordability in average English local planning authority: Lowest bound estimate

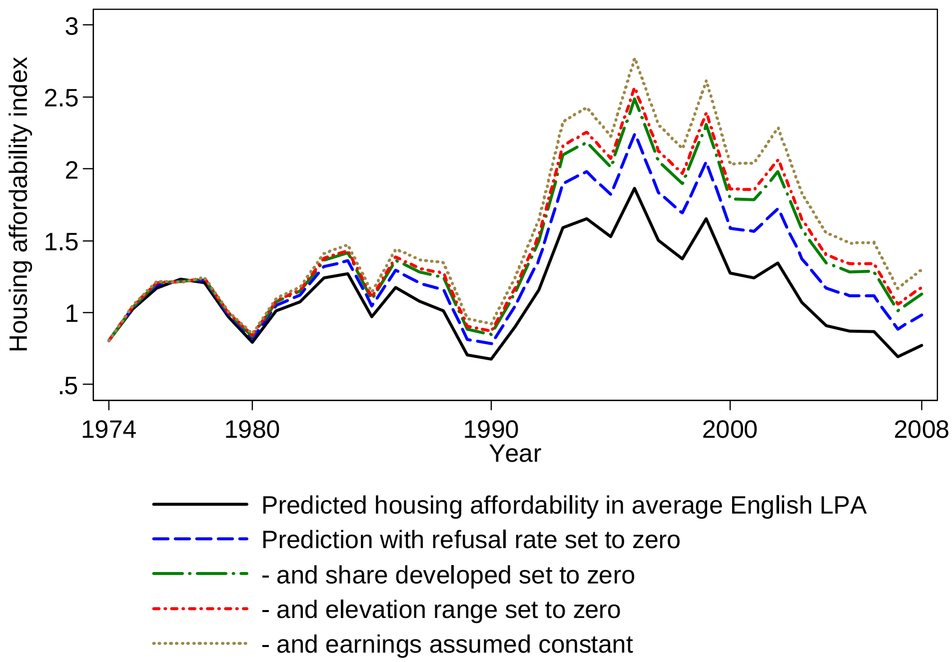


Figure 8: The impact of supply constraints on housing affordability in average English local planning authority: Lower upper bound estimate

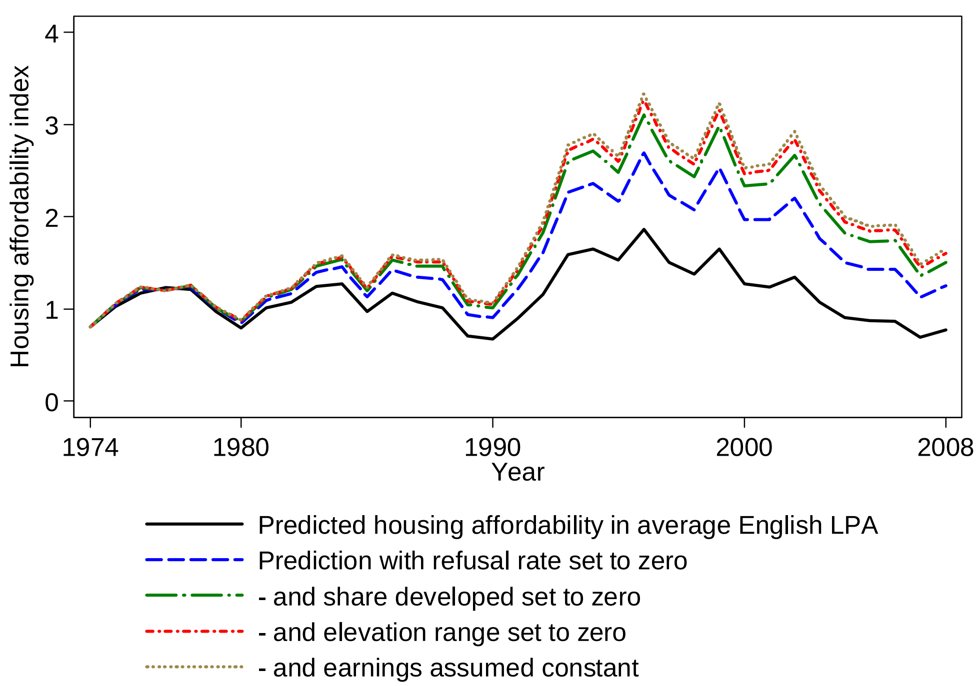


Figure 9: Regulatory restrictiveness and housing affordability: 90th versus 10th percentile (lowest and lower upper bound estimate)

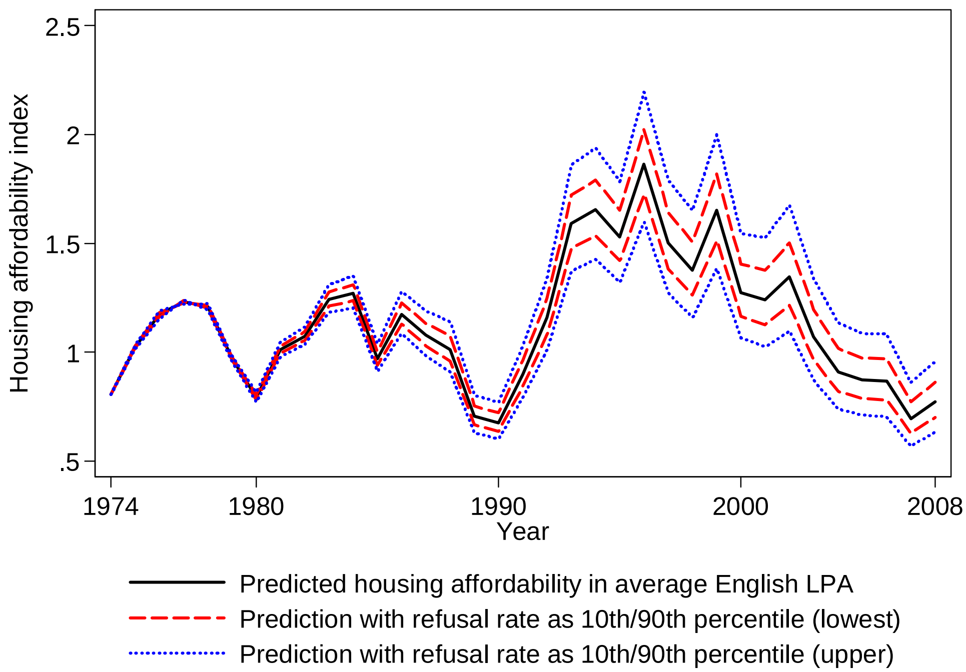
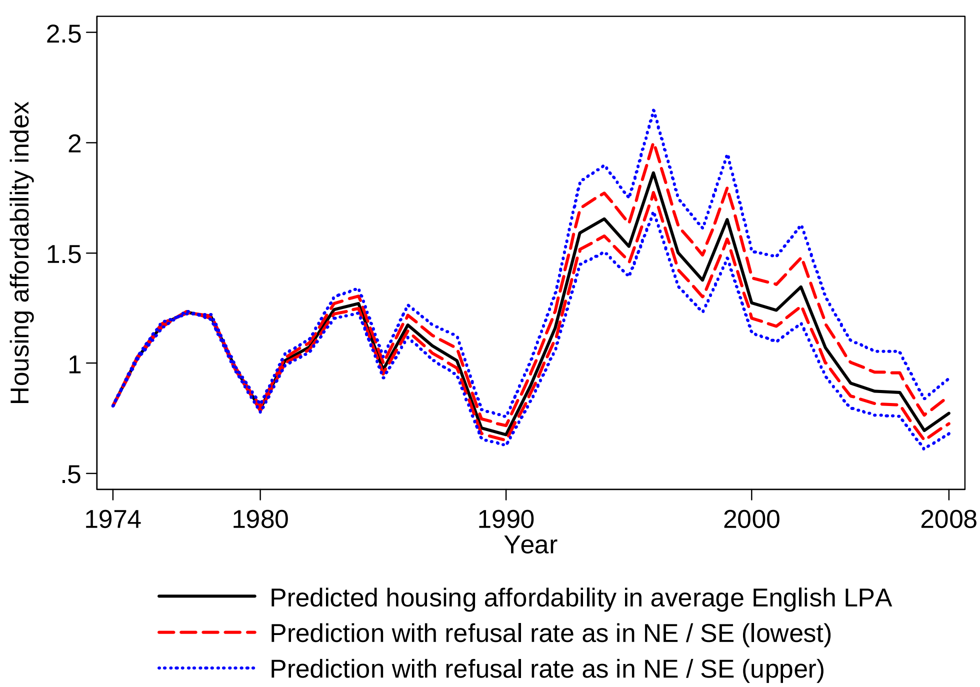


Figure 10: Regulatory restrictiveness and housing affordability: North East versus South East (lowest and lower upper bound estimate)



7 Conclusions from empirical analysis and assessment of policy implications

Housing affordability has been a vital policy concern in England 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 East of the country but also elsewhere. The financial crisis has temporarily shifted concerns to a potential collapse of the housing market, but even though housing affordability has marginally risen during the crisis, partly due to lower housing prices and partly due to artificially low interest rates, the topic is likely to make a comeback on the political agenda once the economy recovers, house prices reach or break the previous price peak and/or mortgage interest rates start to rise. Our findings point to the planning system as an important causal factor behind the 'affordability crisis'. Moreover, recent studies have suggested that regulatory constraints have become more binding over the last few decades (Cheshire and Hilber, 2008; Glaeser *et al.* 2005b) and are likely to become even more binding in the future (Hilber and Robert-Nicoud, 2009). To the extent that the latter is true, our findings imply that housing affordability problems may become even worse during upswings and house price booms in the future, especially in highly urbanized areas, where the ratio between house prices and income may rise even more dramatically than elsewhere.[33]

The stylised fact that real house prices have grown stronger in England over the last 40 years than in any other European country implies that young households – in particular young families living in London or the South East of England – who want to get their feet on the (owner-occupied) housing ladder are hardest hit by the affordability crisis, whereas many older households who became home owners decades ago and have now accumulated – at least on paper – significant financial wealth in their property are the seeming beneficiaries of the long-standing British house price expansion. The gains for elderly home owners are in fact smaller than one might think as they have to live somewhere and cannot realise any gains unless they sell their house and move abroad, significantly downsize their housing consumption or give up owner-occupation and rent.

Our empirical analysis suggests that the planning system has also made house prices substantially more volatile. Most owner-occupiers have to 'overinvest' in housing due to an 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 the risk associated with uncertainty about future house price changes. An increase in house price volatility increases this portfolio distortion and therefore, all else equal, reduces the likelihood of

[33] Hilber and Robert-Nicoud (2009) demonstrate both theoretically – using a political-economy framework – and empirically that more physically developed places are (and can be expected to be) more tightly regulated. Hence, as long as populations across the world are growing and a greater share of the population will be living in urbanised areas, the implication is that regulatory tightness is set to increase for the decades to come.

owning, particularly in places with high price risk (Hilber, 2005). Existing homeowners may be to some extent protected from price fluctuations. If they move within the same market, then if they buy at a high point they should be able to sell high and if they have to sell at a low point they should also be able to buy low. 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, 2009).[34] However, this argument does not apply to first-time buyers who (i) typically face severe credit constraints (having low levels of accumulated wealth and relatively junior salaries), (ii) are in need of high leverage and (iii) are fully exposed to the market conditions (e.g., to cycles that are driven by fundamentals or by 'irrational exuberance' or to interest rate conditions).[35] These young households are also the ones that are most adversely affected by the 'affordability crisis' (and may possibly cause an 'intergenerational crisis' in the longer run as the conflicting interests of the young and the elderly become even more glaring). So the only escape for young low income households in England is to get on the waiting list for social rental housing, which is often not particularly adequate for the needs of young households with children (i.e., in areas with low quality schools) and is 'out of reach' for young households with middle incomes that would not qualify for social housing.

An increase in house price volatility also has important negative consequences for the macro-economy. Specifically, at the aggregate level housing market dynamics feeds into consumption, which in turn affects the entire macro economy. A higher degree of house price volatility may thus 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). The current financial crisis has highlighted even more clearly the extreme adverse consequences volatile housing prices/markets can have on the macro-economy and in particular on certain local economies.

While our empirical analysis reveals that both regulatory and physical constraints are important factors explaining house price volatility, it is important to note that neither regulatory constraints nor regulatory and physical constraints jointly can fully explain the price volatility of local housing markets in England. Interestingly, once we control for the impact of the various supply constraints, the remaining (implied) price dynamic becomes rather more similar across local markets. The fact that the year fixed effects in our regressions pick up a very significant share of the remaining house price cyclicality may be indicative that macroeconomic factors such as interest rates and general economic growth may also play an important additional role in explaining the high volatility of

[34] In their predecessor paper (Sinai and Souleles, 2005) the two authors pointed out that homeownership does provide a hedge against rent risk. Hence, in relative terms homeownership may be less risky than earlier anticipated. However, this does not imply that volatile housing markets are not a policy concern, particularly in the light of credit constrained (young) borrowers who are highly leveraged and may have to switch back from owning to renting if the are affected by an adverse shock (e.g., a divorce or unemployment).

[35] 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 that is determined by market conditions. Hence housing affordability is adversely affected if interest rates increase unexpectedly.

housing markets in England. We conjecture that short-term housing market dynamics that are driven by factors such as unanticipated demand shocks, transaction costs, myopic behaviour, asset durability, and credit constraints may too explain a significant fraction of the remaining unexplained volatility in house prices.

So what can be done to make housing in England more affordable again, particularly in the most constrained areas? Our empirical analysis has identified restrictive planning constraints – and to a lesser extent – physical constraints to be the main causal drivers of the housing affordability crisis in large parts of England. Reducing physical supply constraints – although not entirely impossible as the example of Hong Kong illustrates – is extremely difficult and costly and the scope for making more land available by removing physical constraints appears to be quite limited.

The more obvious solution therefore is to provide greater incentives to local planning authorities to permit more residential developments. However, how can such incentives be introduced? Three approaches seem sensible and deserve further consideration:

- Use fiscal system to provide serious fiscal incentives to permit residential developments
- Allow local planning authorities to benefit from land price uplifts for example via land auctions
- Reform planning system so price signals become a material consideration

Provide serious fiscal incentives to local planning authorities

Our empirical findings imply that local planning authorities have strong fiscal *dis*incentives to permit new residential developments. This is due to a misalignment of costs (too much burden on local planning authorities) and benefits (too low long-term payback) associated with residential developments. The costs associated with residential development to the local planning authorities are substantial as they have to provide infrastructure, additional public services etc.; and there are real costs to residents in the immediate surroundings of proposed developments. An existing match-funding scheme provides some very partial compensation to local planning authorities for these costs. However, our findings imply that these funds are not effective in inducing local authorities to permit residential development. Impact fees to be paid by the developers to the local planning authorities in compensation for infrastructure costs and other burden have been shown in the US to make local communities more willing to accept developments and could induce local planning authorities to become less restrictive.

The lions-share of future revenue streams associated with local residential development (all national taxes and fees with the exception of the council tax) is collected by the central government and redistributed to all local planning authorities via the central government grant system. As a consequence of this allocation mechanism, local planning authorities do not directly participate in a substantive way from the long-run benefits associated with any residential development they permit within their boundaries (e.g., through local tax increases), generating strong adverse incentives to permit residential developments.

Experience from other countries with fiscal federalism (e.g., Switzerland or the United States) where benefits and costs of local development are more aligned (local residents can reap the benefits from local development via increased local tax revenue and do not merely bear the cost) suggest that genuine incentives at the local level to permit residential development can have a substantial soothing impact on housing affordability. For example, whereas according to the Bank for International Settlement real house prices more than quadrupled in the UK between 1970 and 2006, they increased by merely 12.7 per cent in Switzerland during the same time period. (For a cross-country comparison of planning systems and a further discussion of the role of fiscal incentives to permit development, see for example Evans and Hartwich, 2005b, or Hilber, 2009.)

Allow local planning authorities to benefit from planning gain

When land is first zoned for development it observes a massive uplift in values. One way to provide incentives to local planning authorities to permit development would be to let them capture all or at least parts of these planning gains. Various proposals have been suggested to achieve this objective (e.g., planning gain supplements, betterment taxes etc.) but one proposal appears to be particularly appealing: making use of a land auction mechanism (see, for example, Leunig, 2007, for a detailed proposal).

Reform the planning system so price signals become a material consideration

Cheshire and Sheppard (2005) propose the use of price signals in land use planning decision making. The idea is to exploit information embodied in price premiums of neighbouring parcels of land zoned for different purposes. The proposed mechanism envisages that if the price premium were above some threshold level, *"this should provide a presumption of development unless maintaining the land in its current use could be shown to be in the public interest."* The burden of proof would be allocated to the local planning authority so as to increase the likelihood of development. Such a mechanism arguably would make housing supply more elastic and the planning system more transparent. For a more in-depth discussion of the proposal see Cheshire and Sheppard (2005).

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Tables

Table 1: Summary statistics for regression sample

	Obs.	Mean	Std. Dev. overall	between	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
Share of population aged between 45 and 64 years (%), Census years 1981, 1991 & 2001	1059	23.1	2.1	1.5	1.5	14.5	32.1
Share of workforce employed in manufacturing (%, Census)	1059	19.9	8.2	5.7	5.9	4.5	52.8
Share higher educated (%, Census)	1059	9.3	8.8	3.2	8.2	0.24	59.1
Total number of households (Census)	1059	52819	37240	36872	5467	2001	390792
Housing affordability index (see Appendix 1)	12002	1.00	0.38	0.28	0.26	0.14	2.66
Cross-sectional data							
Average refusal rate over the 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
Share of developable land developed in 1990 (%) if semi-developable land is classified as non-developable	353	26.2	23.3			0.9	97.6
Change in delays between 1994-1996 and 2004-2006	353	-3.1	22.0			-63.5	53.1
Change in delays between 1993-1995 and 2004-2006	353	-0.1	21.1			-69.8	61.7
Change in delays between 1994-1996 and 2003-2005	353	4.4	21.5			-65.6	72.4
Change in delays between 1993-1995 and 2003-2005	353	7.4	20.4			-63.5	81.7
Share of votes for Labour, 1983 General Election (%)	353	16.3	9.1			0.1	41.0
Share of votes for Labour, 1997 General Election (%)	353	28.5	11.1			5.4	53.0
Share of votes for Labour, 2005 General Election (%)	353	33.0	13.9			7.8	67.2
Average share of votes for Labour, 83 & 97 & 05 (%)	353	25.9	11.0			6.4	52.9
Population density in 1911 (persons per km2)	353	668.3	2434.6			0	22028.8
Range between highest and lowest altitude (m)	353	208.8	171.2			5.0	975.0
Standard deviation of slope (degrees)	353	2.3	1.4			0.15	8.8
Price of bulk land (in Million £ per hectare), 2007	353	3.4	2.9			0.7	25.2
Standard deviation of log house price index (x 100)	353	42.8	5.2			29.9	69.4
Standard deviation of house price growth (x 100)	353	10.4	1.6			7.5	23.2

Table 2a: Baseline specifications: OLS and TSLS (both instruments)

PANEL A		
	Dependent variable: Log(real house price index)	
	(1)	(2)
	OLS	TSLS: Second stage (use both instruments)
Log(real male weekly earnings)	0.317***	0.0887
	(0.0494)	(0.0859)
Av. refusal rate of major residential projects × log(real male weekly earnings)	0.0669***	**0.293*** **
	(0.0157)	**(0.0566)**
Share of developable land developed in 1990 × log(real male weekly earnings)	0.0935**	**0.295*** **
	(0.0399)	**(0.0493)**
Range between highest and lowest altitude × log(real male weekly earnings)	-0.000473	0.0951**
	(0.0214)	(0.0388)
local planning authority fixed effects (and constant)	Yes	Yes
Year fixed effects	Yes	Yes
Observations	12355	12355
Number of local planning authorities	353	353
R-squared overall model	0.327	
R-squared within model	0.957	
R-squared between model	0.0877	
Kleibergen-Paap F		11.75

PANEL B			
		(1)	(2)
		TSLS: First stage	
	Dependent variable:	Refusal × Earnings	Developed × Earnings
Log(real male weekly earnings)		0.523**	-0.0486
		(0.215)	(0.105)
Change in delays b/w 1994-1996 and 2004-2006 × log(real male weekly earnings)		-0.139***	-0.0364
		(0.0410)	(0.0306)
Share votes for Labour in 1983 × log(real male weekly earnings)		-0.516***	0.278***
		(0.0746)	(0.0505)
Population density in 1911 (persons per km2) × log(real male weekly earnings)		-0.154***	0.429***
		(0.0211)	(0.0379)
Range between highest and lowest altitude × log(real male weekly earnings)		-0.00296	-0.400***
		(0.0550)	(0.0842)
local planning authority fixed effects (and constant)		Yes	Yes
Year fixed effects		Yes	Yes
Observations		12355	12355
Number of local planning authorities		353	353
R-squared overall model		0.363	0.560
R-squared within model		0.376	0.655
R-squared between model		0.363	0.560

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 standardized. Observations are clustered by pre-1996 counties.

Table 2b: Baseline specification: Alternative instrumental variable strategies

PANEL A: Second stage (TSLS)		
	Dependent variable: Log(real house price index)	
	(1)	(2)
	Use only *change in delays* as excluded instrument	Use only *share labour* as excluded instrument
Log(real male weekly earnings)	0.200**	0.0436
	(0.0811)	(0.103)
Av. refusal rate of major residential projects × log(real male weekly earnings)	**0.164*** (0.0627)**	**0.339*** (0.0635)**
Share of developable land developed in 1990 × log(real male weekly earnings)	**0.234*** (0.0437)**	**0.331*** (0.0498)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.0714** (0.0322)	0.112*** (0.0427)
local planning authority fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	12355	12355
Number of local planning authorities	353	353
Kleibergen-Paap F	10.70	10.54

PANEL B: First stage (TSLS)				
	(1)	(2)	(3)	(4)
Dependent variable:	Refusal × Earnings	Developed × Earnings	Refusal × Earnings	Developed × Earnings
Log(real male weekly earnings)	0.926***	-0.266**	0.562**	-0.0383
	(0.310)	(0.126)	(0.236)	(0.107)
Change in delays b/w 1994-1996 and 2004-2006 × log(real male weekly earnings)	-0.241*** (0.0556)	0.0188 (0.0326)		
Share votes for Labour in 1983 × log(real male weekly earnings)			-0.549*** (0.0789)	0.269*** (0.0486)
Population density in 1911 (persons per km2) × log(real male weekly earnings)	-0.250*** (0.0312)	0.480*** (0.0405)	-0.159*** (0.0225)	0.428*** (0.0386)
Range between highest and lowest altitude × log(real male weekly earnings)	0.0361 (0.0616)	-0.421*** (0.0901)	-0.0226 (0.0564)	-0.405*** (0.0858)
local planning authority fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353
R-squared overall model	0.106	0.495	0.345	0.559
R-squared within model	0.205	0.609	0.361	0.654
R-squared between model	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 standardized. Observations are clustered by pre-1996 counties.

Table 3: The impact of supply constraints during boom and bust periods (TSLS, 2nd stage)

	Use both excluded instruments		Use only *change in delays* as excluded instrument		Use only *share labour* as excluded instrument	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Boom	Bust	Boom	Bust	Boom	Bust
Log(real male weekly earnings)	0.115	0.0651	0.213***	0.138	0.0783	0.0273
	(0.0792)	(0.104)	(0.0721)	(0.122)	(0.0930)	(0.112)
Refusal rate × log(real male weekly earnings) †	**0.267*** **	**0.152** **	**0.136** **	**0.0894**	**0.312*** **	**0.179*** **
	(0.0549)	**(0.0605)**	**(0.0632)**	**(0.0686)**	**(0.0612)**	**(0.0687)**
Share developed in 1990 × log(real male weekly earnings) †	**0.290*** **	**0.200*** **	**0.228*** **	**0.168*** **	**0.325*** **	**0.222*** **
	(0.0447)	**(0.0508)**	**(0.0404)**	**(0.0524)**	**(0.0457)**	**(0.0514)**
Range in altitude × log(real male weekly earnings)	0.0967**	0.0938***	0.0721**	0.0821***	0.113**	0.103***
	(0.0415)	(0.0337)	(0.0364)	(0.0315)	(0.0453)	(0.0353)
Local authority fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7766	4589	7766	4589	7766	4589
Number of local planning authorities	353	353	353	353	353	353
Kleibergen-Paap F	11.37	11.52	10.27	11.59	10.76	9.01

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 standardized. Observations are clustered by pre-1996 counties. Boom is defined as: national real HP growth > 0% (N=7766). Bust is defined as: national real HP growth < 0% (N=4589). † 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: Adding composition controls (TSLS, 2nd stage, based on Census years 1981, 1991 and 2001 only)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Log(real house price index)							
	Use both excluded instruments						Use only *change in delays* as instrument	Use only *share labour* as instrument
	No controls	Add age	Add industry	Add education	Add age & industry	All controls	All controls	All controls
Log(real male weekly earnings)	0.0621	0.141	0.0193	0.0814	0.114	0.127	0.372***	0.0358
	(0.165)	(0.137)	(0.197)	(0.161)	(0.155)	(0.149)	(0.115)	(0.194)
Av. refusal rate of major residential projects × log(real male weekly earnings)	**0.631***	**0.590***	**0.676***	**0.601***	**0.621***	**0.588***	**0.255***	**0.718***
	(0.106)	**(0.0804)**	**(0.135)**	**(0.111)**	**(0.0971)**	**(0.0995)**	**(0.134)**	**(0.136)**
Share of developable land developed in 1990 × log(real male weekly earnings)	**0.508***	**0.584***	**0.537***	**0.476***	**0.610***	**0.563***	**0.267***	**0.710***
	(0.0865)	**(0.0793)**	**(0.105)**	**(0.105)**	**(0.0998)**	**(0.118)**	**(0.151)**	**(0.160)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.0775	0.0802	0.0922	0.0640	0.0914	0.0744	-0.0296	0.128
	(0.0649)	(0.0543)	(0.0738)	(0.0658)	(0.0606)	(0.0596)	(0.0602)	(0.0799)
Share of residents aged between 45 and 64		0.0272***			0.0288***	0.0263***	0.0119	0.0346***
		(0.00668)			(0.00860)	(0.00916)	(0.0107)	(0.0117)
Share of residents employed in manufacturing			-0.00188		-0.00137	-0.00114	0.00223	-0.00235
			(0.00265)		(0.00242)	(0.00235)	(0.00182)	(0.00282)
Share of highly educated residents				0.00112		0.00157	0.00713	-0.00119
				(0.00337)		(0.00358)	(0.00473)	(0.00371)
Local authority fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1059	1059	1059	1059	1059	1059	1059	1059
Number of local planning authorities	353	353	353	353	353	353	353	353
Kleibergen-Paap F	9.958	16.32	6.269	3.038	9.870	3.481	3.679	2.663

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 standardized. Observations are clustered by pre-1996 counties.

Table 5: Robustness check: Baseline specification for different geographical scales (TSLS, 2nd stage)

	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Log(real house price index)				
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. All supply constraints measures are standardized. The coefficients can be interpreted as an increase in the house price-earnings elasticity due to a one standard deviation increase (based on the local planning authority-sample) in one of the constraint measures. Observations are clustered by pre-1996 counties.

Table 6a: Robustness check: Use 'shadow price' as alternative regulatory measure (OLS and TSLS/both instruments; TTWA-level)

PANEL A		
	Dependent variable: Log(real house price index)	
	(1)	(2)
	OLS	TSLS: Second stage (use both instruments)
Log(real male weekly earnings)	0.465***	0.140
	(0.0813)	(0.0975)
Log(price of bulk land (shadow price)) × log(real male weekly earnings)	0.0974*** (0.0188)	**0.195*** (0.0275)**
Share of developable land developed in 1990 × log(real male weekly earnings)	0.0134 (0.0381)	**-0.0545 (0.0415)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.0185 (0.0203)	0.0140 (0.0231)
TTWA fixed effects (and constant)	Yes	Yes
Year fixed effects	Yes	Yes
Observations	5250	5250
Number of TTWAs	150	150
R-squared overall model	0.315	
R-squared within model	0.966	
R-squared between model	0.0816	
Kleibergen-Paap F		25.10

PANEL B			
		(1)	(2)
		TSLS: First stage	
	Dependent variable:	Shad. price × Earnings	Developed × Earnings
Log(real male weekly earnings)		1.668***	0.0233
		(0.285)	(0.0776)
Change in delays b/w 1994-1996 and 2004-2006 × log(real male weekly earnings)		-0.384*** (0.119)	-0.0278 (0.0499)
Share votes for Labour in 1983 × log(real male weekly earnings)		-0.432*** (0.0826)	0.248*** (0.0361)
Population density in 1911 (persons per km2) × log(real male weekly earnings)		3.158*** (0.230)	1.925*** (0.118)
Range between highest and lowest altitude × log(real male weekly earnings)		0.0246 (0.0756)	-0.138*** (0.0262)
TTWA fixed effects (and constant)		Yes	Yes
Year fixed effects		Yes	Yes
Observations		5250	5250
Number of TTWAs		150	150
R-squared overall model		0.178	0.582
R-squared within model		0.767	0.881
R-squared between model		0.178	0.582

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 standardized. Observations are clustered by pre-1996 counties.

Table 6b: Robustness check: Use 'shadow price' as alternative regulatory measure (OLS and TSLS/alternative instrumental variable strategies; TTWA-level)

PANEL A: Second stage (TSLS)		
	Dependent variable: Log(real house price index)	
	(1)	(2)
	Use only *change in delays* as excluded instrument	Use only *share labour* as excluded instrument
Log(real male weekly earnings)	0.244*	0.112
	(0.125)	(0.108)
Log(price of bulk land (shadow price)) × log(real male weekly earnings)	0.159***	0.204***
	(0.0420)	(0.0297)
Share of developable land developed in 1990 × log(real male weekly earnings)	-0.00648	-0.0624
	(0.0585)	(0.0433)
Range between highest and lowest altitude × log(real male weekly earnings)	0.0173	0.0134
	(0.0209)	(0.0237)
TTWA fixed effects (and constant)	Yes	Yes
Year fixed effects	Yes	Yes
Observations	5250	5250
Number of TTWAs	150	150
Kleibergen-Paap F	6.86	32.59

PANEL B: First stage (TSLS)				
	(1)	(2)	(3)	(4)
Dependent variable:	Shad. Price × Earnings	Developed × Earnings	Shad. Price × Earnings	Developed × Earnings
Log(real male weekly earnings)	2.164***	-0.262**	1.861***	0.0373
	(0.322)	(0.106)	(0.314)	(0.0868)
Change in delays b/w 1994-1996 and 2004-2006 × log(real male weekly earnings)	-0.507***	0.0431		
	(0.117)	(0.0555)		
Share votes for Labour in 1983 × log(real male weekly earnings)			-0.504***	0.243***
			(0.0874)	(0.0339)
Population density in 1911 (persons per km2) × log(real male weekly earnings)	2.780***	2.142***	3.131***	1.923***
	(0.296)	(0.161)	(0.241)	(0.119)
Range between highest and lowest altitude × log(real male weekly earnings)	-0.0272	-0.108***	0.0198	-0.138***
	(0.0748)	(0.0385)	(0.0811)	(0.0262)
TTWA fixed effects (and constant)	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	5250	5250	5250	5250
Number of TTWAs	150	150	150	150
R-squared overall model	0.116	0.564	0.118	0.580
R-squared within model	0.732	0.834	0.749	0.881
R-squared between model	0.116	0.564	0.118	0.580

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 standardized. Observations are clustered by pre-1996 counties.

Table 7: Do supply constraints affect house price volatility? (OLS and TSLS, 2nd stage)

PANEL A: Explaining long-term volatility				
	Dependent variable: Standard deviation of log house prices			
	(1)	(2)	(3)	(4)
	OLS	TSLS		
		Both instruments	Only *change in delays*	Only *share labour*
Av. refusal rate of major residential projects	1.764***	**6.573*** **	**3.489*** **	**7.349*** **
	(0.377)	**(0.977)**	**(1.139)**	**(1.037)**
Share of developable land developed in 1990	2.005	**7.105*** **	**6.470*** **	**7.766*** **
	(1.206)	**(1.172)**	**(0.767)**	**(0.979)**
Range between highest and lowest altitude	-0.267	2.110**	1.838***	2.416***
	(0.356)	(0.898)	(0.697)	(0.919)
Constant	42.76***	42.76***	42.76***	42.76***
	(0.554)	(0.711)	(0.602)	(0.813)
Observations	353	353	353	353
Adjusted R-squared	0.209			
Kleibergen-Paap F		25.94	10.32	25.99

PANEL B: Explaining short-term volatility				
	Dependent variable: Standard deviation of house price growth			
	(1)	(2)	(3)	(4)
	OLS	TSLS		
		Both instruments	Only *change in delays*	Only *share labour*
Av. refusal rate of major residential projects	0.169	**1.432*** **	**0.503* **	**1.665*** **
	(0.121)	**(0.300)**	**(0.279)**	**(0.329)**
Share of developable land developed in 1990	0.616*	**1.893*** **	**1.702*** **	**2.092*** **
	(0.318)	**(0.303)**	**(0.173)**	**(0.260)**
Range between highest and lowest altitude	-0.210**	0.385*	0.303*	0.477**
	(0.101)	(0.226)	(0.158)	(0.239)
Constant	10.43***	10.43***	10.43***	10.43***
	(0.164)	(0.191)	(0.159)	(0.219)
Observations	353	353	353	353
Adjusted R-squared	0.193			
Kleibergen-Paap F		25.94	10.32	25.99

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 standardized. Observations are clustered by pre-1996 counties.

Table 8: Counterfactual analysis for average English local planning authority

PANEL A

Counterfactual volatility of real house prices in average English local planning authority (in 2008 GBP), N=35

Lowest Bound Estimates

Variable	Value in 1974	Value in 2008	Std. Dev.	Min	Max
Predicted	79183.6	225820.2	53265.2	57659.7	234176.3
Predicted without planning	79183.6	177377.8	37448.2	58183.9	183677.9
- and share developed set to zero	79183.6	155025.9	30450.2	58450.9	160445.6
- and elevation range set to zero	79183.6	148765.1	28547.5	58492.1	153991.2
- and earnings assumed constant	79183.6	134690.0	24347.7	57466.0	139342.1

PANEL B

Counterfactual volatility of real house prices in average English local planning authority (in 2008 GBP), N=35

Lower Upper Bound Estimates

Panel B2: Counterfactual volatility of real house prices in average English local planning authority (in 2008 GBP), N=35

Variable	Value in 1974	Value in 2008	Std. Dev.	Min	Max
Predicted	79183.6	225820.2	53265.2	57659.7	234176.3
Predicted without planning	79183.6	139698.8	25776.3	57854.3	144455.7
- and share developed set to zero	79183.6	115884.6	19077.1	53591.8	119741.0
- and elevation range set to zero	79183.6	108848.4	17296.7	51047.7	112498.7
- and earnings assumed constant	79183.6	105890.7	16578.3	49980.6	109424.5

Appendices

Appendix 1: Construction and Interpretation of the Housing Affordability Index (AFI) (Technical Appendix)

The Housing Affordability Index (AFI) measures whether or not the average household in a certain local planning authority can qualify for a mortgage loan on a typical home in that local planning authority. The price of this home is determined using the mix-adjustment method described in Section 3, so it could be thought of as a combination of the housing types that are sold in the local planning authority, weighted by their relative frequency. The average household in a specific local planning authority is defined as one earning the mean male weekly earnings, as observed in our data. The calculations are based on a mortgage that fully amortizes in 25 years. Furthermore, a qualifying mortgage-to-income ratio of 30% and a down payment of 25% are assumed. That means the monthly mortgage interest payment cannot exceed 30% of the monthly household income. It should be noted that since we measure gross earnings, this percentage is rather high, but on the other hand, many households have more than one earner. To interpret the AFI, a value of 1 means that in a specific local planning authority the household with mean local planning authority-specific male weekly earnings has exactly enough income to qualify for a mortgage on an averagely-priced home in that local planning authority. The index rises with affordability, so a high value means that the larger part of all households can afford a typical home in an local planning authority.

Mathematically, the AFI can be expressed as follows:

$$AFI = \frac{AHP}{Mean\ HP}, \qquad \text{(A6)}$$

where *AHP* is the 'Affordable House Price' and *Mean HP* is the mean mix-adjusted house price in the local planning authority. The AHP itself can be derived from the following equation:

$$Monthly\ Earnings \times Qualifying\ Ratio = AHP \times LTV \times \frac{Monthly\ Mortgage\ Payment}{Loan\ Amount}, \qquad \text{(A7)}$$

As we assume a Qualifying Ratio of 30% (0.3) and a Loan to Value Ratio (LTV) of 75% (0.8), the AHP can be expressed as:

$$AHP = \frac{0.3 \times (52/12) \times Earnings}{0.75 \times M_m / L}, \qquad \text{(A8)}$$

where mean male weekly earnings are denoted with *Earnings* and where M_m/L is the ratio between the monthly mortgage payment M_m and the loan amount L. This ratio itself is a function of the (monthly) interest rate r_m such that $M_m / L = f(r_m)$. More specifically, the ratio between the monthly mortgage payment and the loan amount can be expressed as

$$\frac{M_m}{L} = f(r_m) = \frac{r_m}{(1+r_m)\times\left(1-\left(\frac{1}{1+r_m}\right)^{300}\right)}. \tag{A9}$$

Consequently, the formula for the AFI can be expressed as

$$AFI = \frac{0.3\times(1+r_m)\times\left(1-\left(\frac{1}{1+r_m}\right)^{300}\right)}{0.75\times r_m}\times\frac{(52/12)\times Earnings}{Median\ HP}. \tag{A10}$$

Clearly, the choice of interest rate is important for the resulting AFI. For this report, we have used the Standard Variable Rate as reported in the Economic Fact book from Lloyds Banking Group, which is based on Halifax and the Bank of England. This rate was divided by 12 in order to get a monthly interest rate.

Appendix 2: Appendix tables

Appendix Table A1: Classification of land cover classes – LCMGB 1990

Developed land
Suburban/rural developed
Urban development
Non-developable land
Sea / Estuary
Inland water
Costal bare ground
Saltmarsh
Ruderal weed
Felled Forest
Semi-developable land
Rough / Marsh Grass
Moorland Grass
Open Shrub Moor
Dense Shrub Moor
Upland bog
Lowland bog
Developable land
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
Open Shrub Heath

Appendix Table A2: Year fixed effects corresponding to baseline specifications (Table 2a/2b, Panels A, Columns 1-2)

	(1)	(2)	(3)	(4)
	Dependent variable: Log(real house price index)			
		TSLS		
Year fixed effects	OLS	Both instruments	Only *change in delays*	Only *share labour*
Year = 1974	(Omitted)	(Omitted)	(Omitted)	(Omitted)
Year = 1975	-0.160***	-0.156***	-0.158***	-0.155***
Year = 1976	-0.254***	-0.245***	-0.249***	-0.243***
Year = 1977	-0.311***	-0.315***	-0.313***	-0.316***
Year = 1978	-0.225***	-0.217***	-0.221***	-0.216***
Year = 1979	-0.126***	-0.117***	-0.121***	-0.115***
Year = 1980	-0.0984***	-0.0831***	-0.0906***	-0.0801***
Year = 1981	-0.182***	-0.165***	-0.174***	-0.162***
Year = 1982	-0.257***	-0.239***	-0.248***	-0.235***
Year = 1983	-0.223***	-0.197***	-0.210***	-0.192***
Year = 1984	-0.164***	-0.135***	-0.149***	-0.129***
Year = 1985	-0.141***	-0.109***	-0.125***	-0.103***
Year = 1986	-0.0589***	-0.0182	-0.0380	-0.0101
Year = 1987	0.0420	0.0897***	0.0665**	0.0991***
Year = 1988	0.224***	0.282***	0.254***	0.293***
Year = 1989	0.366***	0.426***	0.397***	0.438***
Year = 1990	0.287***	0.348***	0.318***	0.360***
Year = 1991	0.204***	0.270***	0.238***	0.283***
Year = 1992	0.0994***	0.172***	0.137***	0.186***
Year = 1993	0.0302	0.107***	0.0696***	0.122***
Year = 1994	0.0349	0.112***	0.0748***	0.128***
Year = 1995	0.0167	0.0924***	0.0554**	0.107***
Year = 1996	-0.00271	0.0774***	0.0384	0.0932***
Year = 1997	0.0553**	0.143***	0.0999***	0.160***
Year = 1998	0.134***	0.224***	0.180***	0.242***
Year = 1999	0.180***	0.273***	0.228***	0.292***
Year = 2000	0.303***	0.397***	0.351***	0.415***
Year = 2001	0.387***	0.487***	0.438***	0.506***
Year = 2002	0.531***	0.638***	0.587***	0.660***
Year = 2003	0.681***	0.789***	0.737***	0.811***
Year = 2004	0.794***	0.904***	0.851***	0.926***
Year = 2005	0.841***	0.950***	0.897***	0.971***
Year = 2006	0.867***	0.978***	0.924***	1.000***
Year = 2007	0.922***	1.028***	0.977***	1.049***
Year = 2008	0.886***	0.991***	0.940***	1.012***
Observations	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353
Adjusted R-squared	0.957			
Kleibergen-Paap F		11.75	10.70	10.54

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix table A3: Robustness check: Use alternative time windows to define *change in delays*-instrument (TSLS)

PANEL A: Different time windows for planning instrument – TSLS / Second-stage				
	(1)	(2)	(3)	(4)
	Dependent variable: Log(real house price index)			
Log(real male weekly earnings)	0.200**	0.215***	0.192**	0.208**
	(0.0811)	(0.0763)	(0.0898)	(0.0854)
Av. refusal rate of major residential projects × log(real male weekly earnings)	**0.164***	**0.147***	**0.173**	**0.155**
	(0.0627)	**(0.0551)**	**(0.0710)**	**(0.0643)**
Share of developable land developed in 1990 × log(real male weekly earnings)	**0.234***	**0.224***	**0.239***	**0.229***
	(0.0437)	**(0.0392)**	**(0.0504)**	**(0.0463)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.0714**	0.0675**	0.0736**	0.0694**
	(0.0322)	(0.0305)	(0.0344)	(0.0326)
local planning authority fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353
Kleibergen-Paap F	10.70	9.861	9.967	8.957

Panel B: Different time windows for planning instrument – TSLS / First-stage				
	(1)	(2)	(3)	(4)
	Windows: 94-96/04-06	*Windows: 93-95/04-06*	*Windows: 94-96/03-05*	*Windows: 93-95/03-05*
	Dependent variable: Average refusal rate of major residential projects × log(real male weekly earnings)			
Log(real male weekly earnings)	0.926***	0.938***	0.929***	0.939***
	(0.310)	(0.318)	(0.319)	(0.328)
Change in delays *(4 different time windows*) × log(real male weekly earnings)	-0.241***	-0.242***	-0.229***	-0.231***
	(0.0556)	(0.0567)	(0.0579)	(0.0590)
Population density in 1911 (persons per km2) × log(real male weekly earnings)	-0.250***	-0.254***	-0.254***	-0.258***
	(0.0312)	(0.0320)	(0.0323)	(0.0333)
Range between highest and lowest altitude × log(real male weekly earnings)	0.0361	0.0245	0.0302	0.0189
	(0.0616)	(0.0612)	(0.0625)	(0.0622)
local planning authority fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353
R-squared overall model	0.106	0.106	0.104	0.105
R-squared within model	0.205	0.206	0.200	0.201
R-squared between model	0.106	0.106	0.103	0.105

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 standardized. Observations are clustered by pre-1996 counties.

Appendix table A4: Robustness check: Use alternative election years for share labour-instrument

PANEL A: Different election years for share labour-instrument – TSLS / Second-stage				
	(1)	(2)	(3)	(4)
	Dependent variable: Log(real house price index)			
Log(real male weekly earnings)	0.0436 (0.103)	0.0702 (0.106)	0.0507 (0.115)	0.0554 (0.107)
Av. refusal rate of major residential projects × log(real male weekly earnings)	**0.339***** **(0.0635)**	**0.309***** **(0.0779)**	**0.331***** **(0.0861)**	**0.326***** **(0.0750)**
Share of developable land developed in 1990 × log(real male weekly earnings)	**0.331***** **(0.0498)**	**0.315***** **(0.0600)**	**0.327***** **(0.0656)**	**0.324***** **(0.0589)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.112*** (0.0427)	0.105** (0.0450)	0.110** (0.0480)	0.109** (0.0454)
local planning authority fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353
Kleibergen-Paap F	10.54	9.069	8.025	9.349
Panel B: Different election years for share labour-instrument – TSLS / First-stage				
	(1)	(2)	(3)	(4)
	Election year: 1983	*Election year: 1997*	*Election year: 2005*	*Average all three years*
	Dependent variable: Average refusal rate of major residential projects × log(real male weekly earnings)			
Log(real male weekly earnings)	0.562** (0.236)	0.521** (0.194)	0.481*** (0.176)	0.476** (0.187)
Share votes for Labour *(different base years)* × log(real male weekly earnings)	-0.549*** (0.0789)	-0.565*** (0.0895)	-0.596*** (0.0956)	-0.598*** (0.0891)
Population density in 1911 (persons per km2) × log(real male weekly earnings)	-0.159*** (0.0225)	-0.195*** (0.0219)	-0.181*** (0.0205)	-0.172*** (0.0210)
Range between highest and lowest altitude × log(real male weekly earnings)	-0.0226 (0.0564)	-0.0952 (0.0573)	-0.103* (0.0584)	-0.0847 (0.0575)
local planning authority fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353
R-squared overall model	0.345	0.345	0.380	0.379
R-squared within model	0.361	0.383	0.407	0.404
R-squared between model	0.345	0.345	0.380	0.379

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 standardized. Observations are clustered by pre-1996 counties.

Appendix table A5: Robustness check: Baseline specification for different geographical scales using alternative identification strategies (TSLS, 2nd stage)

PANEL A: Use only *change in delays* as excluded instrument to identify average refusal rate / TSLS – Second-stage					
	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Log(real house price index)				
Geographical unit:	local planning authority	TTWA	*Urban* TTWA	FUR	Pre-1996 County
Log(real male weekly earnings)	0.200**	0.206	0.244	0.709**	0.262
	(0.0811)	(0.173)	(0.331)	(0.290)	(0.295)
Av. refusal rate of major residential	**0.164*** **	**0.274*** **	**0.267** **	**0.134**	**0.252** **
projects × log(real male weekly earnings)	**(0.0627)**	**(0.0985)**	**(0.135)**	**(0.128)**	**(0.123)**
Share of developable land developed in	**0.234*** **	**0.218*** **	**0.242*** **	**0.233*** **	**0.199*** **
1990 × log(real male weekly earnings)	**(0.0437)**	**(0.0329)**	**(0.0431)**	**(0.0847)**	**(0.0350)**
Range between highest and lowest altitude	0.0714**	0.0586**	0.0891**	0.0668*	0.0641**
×	(0.0322)	(0.0278)	(0.0373)	(0.0400)	(0.0306)
log(real male weekly earnings)					
Geographical unit & 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	10.70	4.107	2.201	1.421	4.748
PANEL B: Use only *share labour in 1983* as excluded instrument to identify average refusal rate / TSLS – Second-stage					
	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Log(real house price index)				
Geographical unit:	local planning authority	TTWA	*Urban* TTWA	FUR	Pre-1996 County
Log(real male weekly earnings)	0.0436	0.218	0.350*	0.343	0.0359
	(0.103)	(0.141)	(0.181)	(0.212)	(0.281)
Av. refusal rate of major residential	**0.339*** **	**0.267*** **	**0.225*** **	**0.284*** **	**0.340*** **
projects × log(real male weekly earnings)	**(0.0635)**	**(0.0382)**	**(0.0406)**	**(0.0705)**	**(0.0723)**
Share of developable land developed in	**0.331*** **	**0.217*** **	**0.234*** **	**0.256*** **	**0.222*** **
1990 × log(real male weekly earnings)	**(0.0498)**	**(0.0351)**	**(0.0413)**	**(0.0847)**	**(0.0358)**
Range between highest and lowest altitude	0.112***	0.0579**	0.0841***	0.0788**	0.0726**
×	(0.0427)	(0.0250)	(0.0321)	(0.0400)	(0.0314)
log(real male weekly earnings)					
Geographical unit & 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	10.54	92.77	59.27	38.62	40.49

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 standardized. Observations are clustered by pre-1996 counties.

Appendix table A6: Robustness check: Exclude Corporation of London (City of London) or Greater London Area (GLA) (TSLS, 2nd stage)

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Log(real house price index)					
Identification strategy:	Use both instruments		Use only *change in delays*		Use only *share labour*	
Exclude:	City of London	GLA	City of London	GLA	City of London	GLA
Log(real male weekly earnings)	0.0843	0.112**	0.194**	0.173***	0.0497	0.101*
	(0.0821)	(0.0535)	(0.0843)	(0.0592)	(0.0925)	(0.0571)
Av. refusal rate of major residential projects × log(real male weekly earnings)	**0.277*****	**0.158*****	**0.162*****	**0.0996****	**0.310*****	**0.174*****
	(0.0447)	**(0.0337)**	**(0.0597)**	**(0.0405)**	**(0.0465)**	**(0.0371)**
Share of developable land developed in 1990 × log(real male weekly earnings)	**0.272*****	**-0.0142**	**0.226*****	**-0.0364**	**0.298*****	**0.00550**
	(0.0407)	**(0.0404)**	**(0.0389)**	**(0.0387)**	**(0.0365)**	**(0.0438)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.0874**	-0.0191	0.0690**	-0.0267	0.0996***	-0.0122
	(0.0361)	(0.0223)	(0.0313)	(0.0219)	(0.0376)	(0.0233)
local planning authority fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12320	11200	12320	11200	12320	11200
Number of local planning authorities	352	320	352	320	352	320
Kleibergen-Paap F	19.85	13.60	12.39	10.10	22.62	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 standardized. Observations are clustered by pre-1996 counties.

Appendix table A7: Robustness check: Base specification but use alternative share developed measure (‘Semi-developable’ land is classified as non-developable) (OLS and TSLS, 2nd stage)

	(1)	(2)	(3)	(4)
	Dependent variable: Log(real house price index)			
	OLS	TSLS		
		Both instruments	Only *change in delays*	Only *share labour*
Log(real male weekly earnings)	0.320***	0.0895	0.205**	0.0390
	(0.0500)	(0.0868)	(0.0806)	(0.106)
Av. refusal rate of major residential projects × log(real male weekly earnings)	0.0665***	**0.298*** **	**0.162*** **	**0.350*** **
	(0.0158)	**(0.0582)**	**(0.0626)**	**(0.0659)**
Share of developable land developed in 1990 × log(real male weekly earnings)	0.0910**	**0.296*** **	**0.232*** **	**0.337*** **
	(0.0404)	**(0.0513)**	**(0.0437)**	**(0.0518)**
Range between highest and lowest altitude × log(real male weekly earnings)	-0.00328	0.0902**	0.0671**	0.108**
	(0.0210)	(0.0388)	(0.0318)	(0.0432)
local planning authority fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353
R-squared overall model	0.333			
R-squared within model	0.957			
R-squared between model	0.0894			
Kleibergen-Paap F		11.60	10.78	10.13

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 standardized. Observations are clustered by pre-1996 counties.

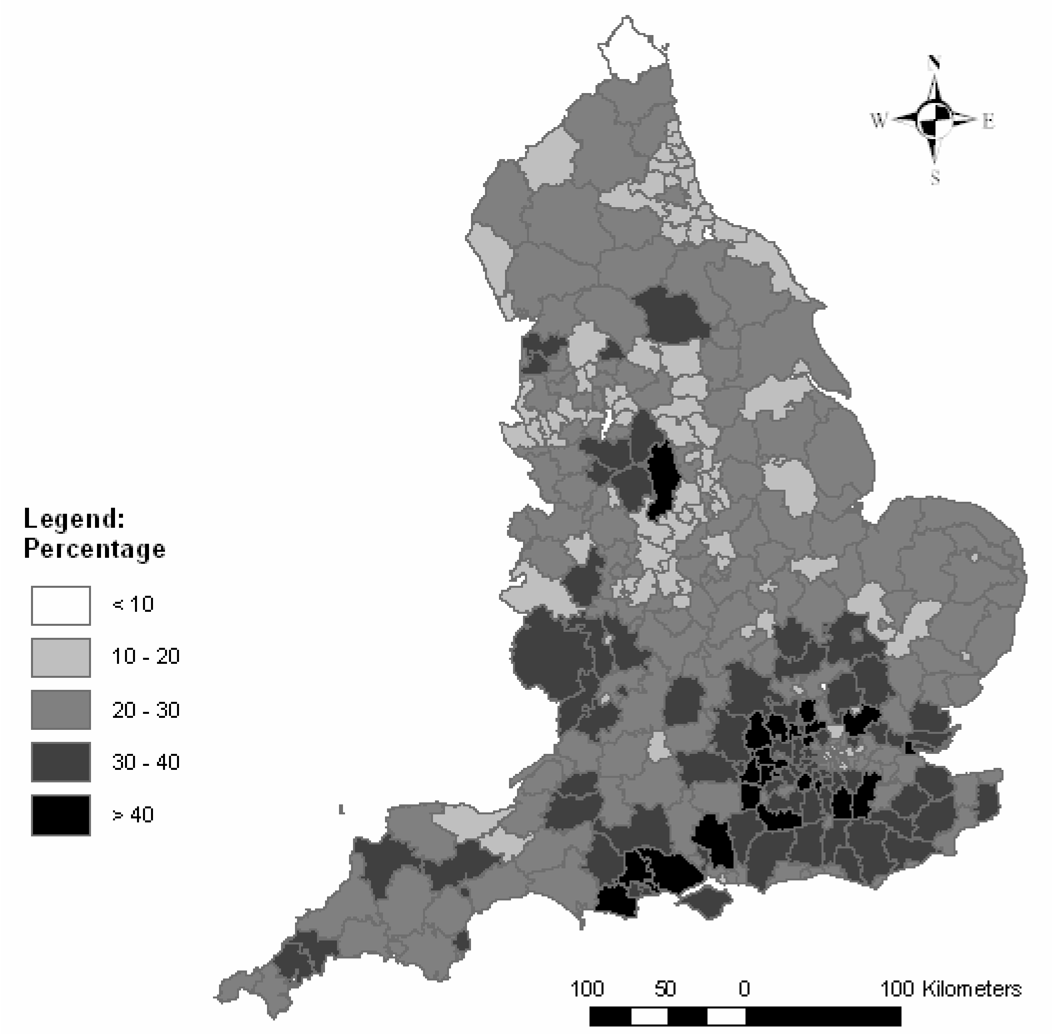
Appendix table A8: Robustness check: Base specification but use alternative elevation measures (TSLS, 2nd stage, use both instruments)

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Log(real house price index)					
Log(real male weekly earnings)	0.0887	0.0908	0.0829	0.0714	0.0738	0.0735
	(0.0859)	(0.0868)	(0.0890)	(0.0872)	(0.0861)	(0.0898)
Av. refusal rate of major residential projects × log(real male weekly earnings)	**0.293*****	**0.284*****	**0.279*****	**0.275*****	**0.267*****	**0.276*****
	(0.0566)	**(0.0530)**	**(0.0526)**	**(0.0521)**	**(0.0483)**	**(0.0514)**
Share of developable land developed in 1990 × log(real male weekly earnings)	**0.295*****	**0.281*****	**0.266*****	**0.273*****	**0.263*****	**0.265*****
	(0.0493)	**(0.0443)**	**(0.0429)**	**(0.0461)**	**(0.0408)**	**(0.0418)**
Range between highest and lowest altitude × log(real male weekly earnings)	0.0951**					
	(0.0388)					
Dummy range in meters 75th percentile × log(real earnings)		0.0970***				
		(0.0329)				
Dummy range in meters 90th percentile × log(real earnings)			0.0645**			
			(0.0258)			
Standard deviation of slope (degrees)				0.0375		
				(0.0312)		
Dummy standard dev. of slope 75th percentile × log(real earnings)					0.0316	
					(0.0270)	
Dummy standard dev. of slope 90th percentile × log(real earnings)						0.0498**
						(0.0235)
local planning authority fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12355	12355	12355	12355	12355	12355
Number of local planning authorities	353	353	353	353	353	353
Kleibergen-Paap F	11.75	12.22	13.36	13.20	14.18	13.49

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 standardized. Observations are clustered by pre-1996 counties.

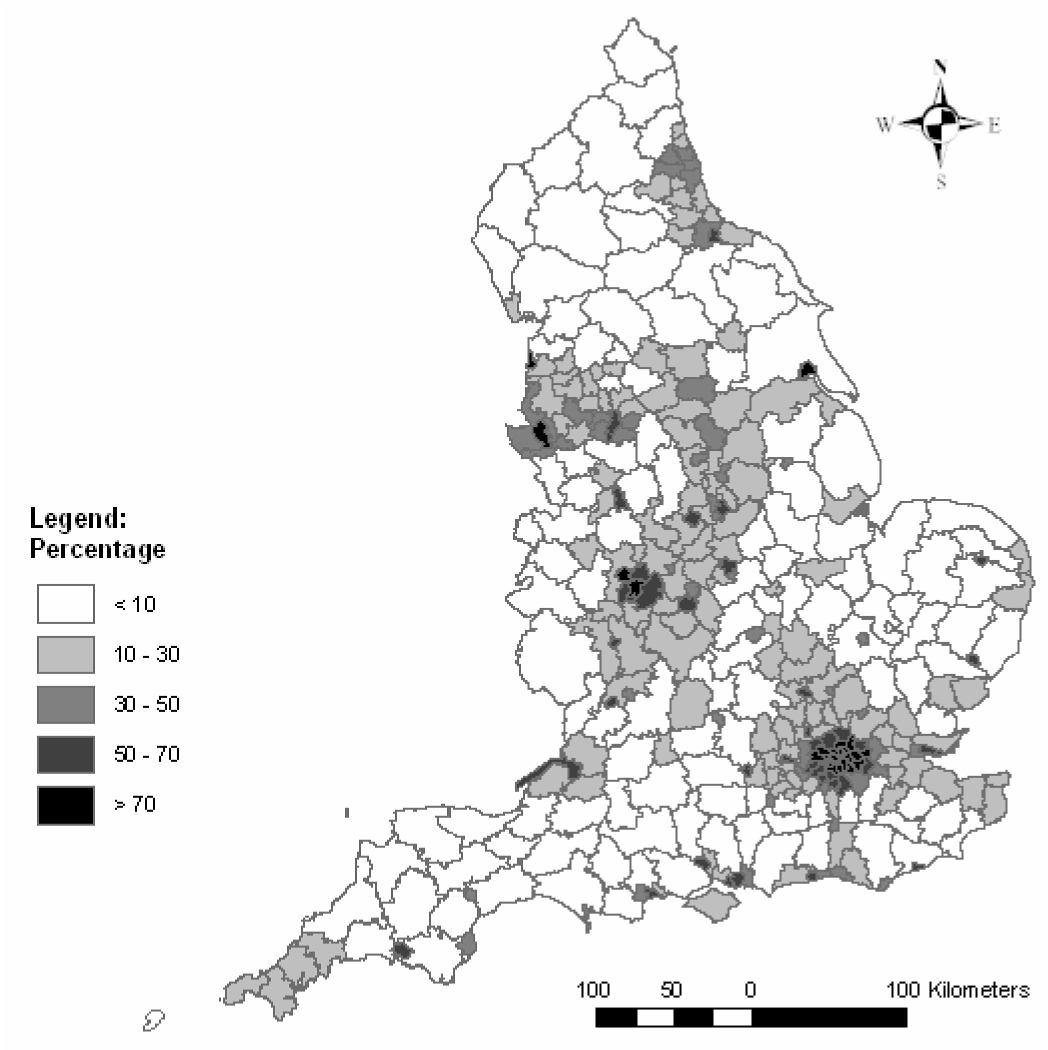
Appendix 3: Appendix figures

Appendix figure A1: Average refusal rate – major residential projects over 1979-2008



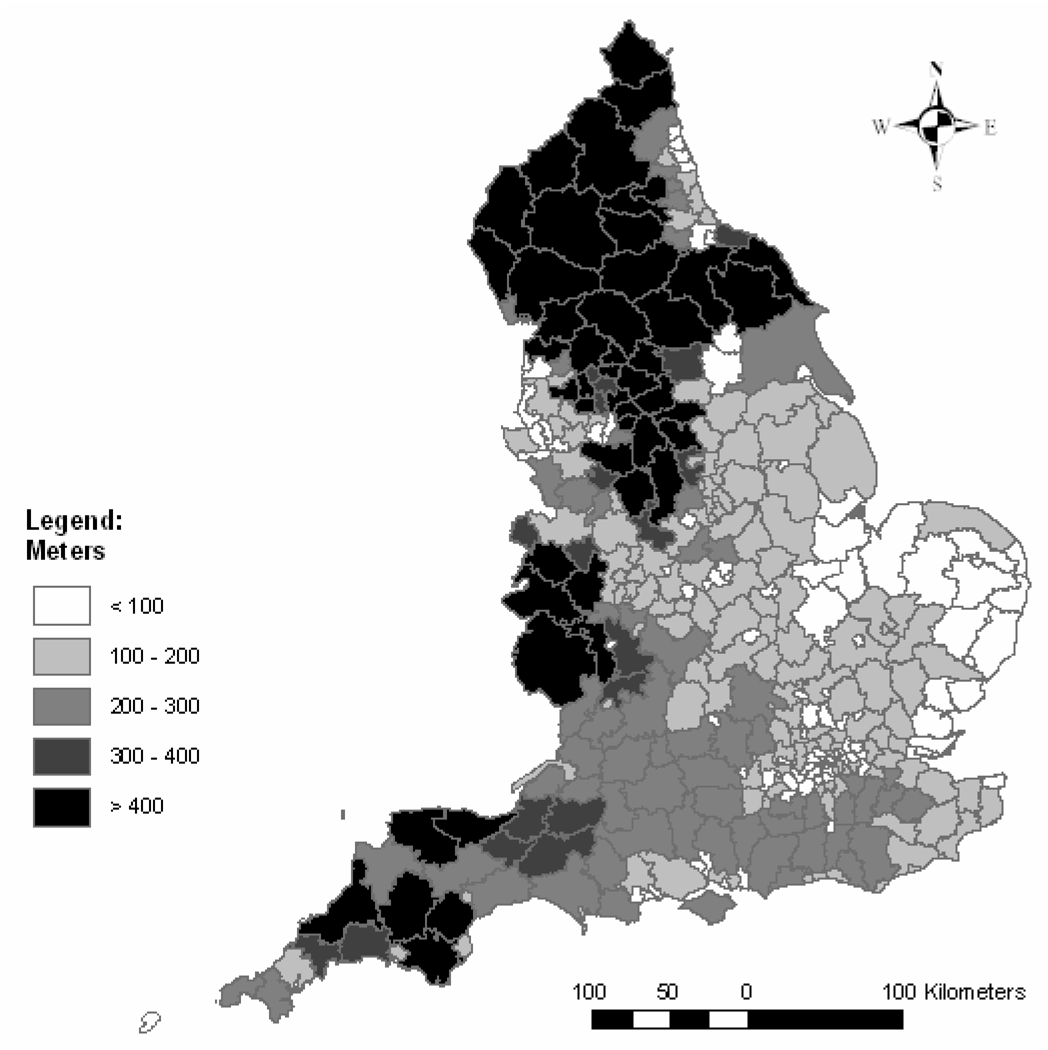
Note: Missing value for Council of the Isles of Scilly

Appendix figure A2: Share developable land developed in 1990



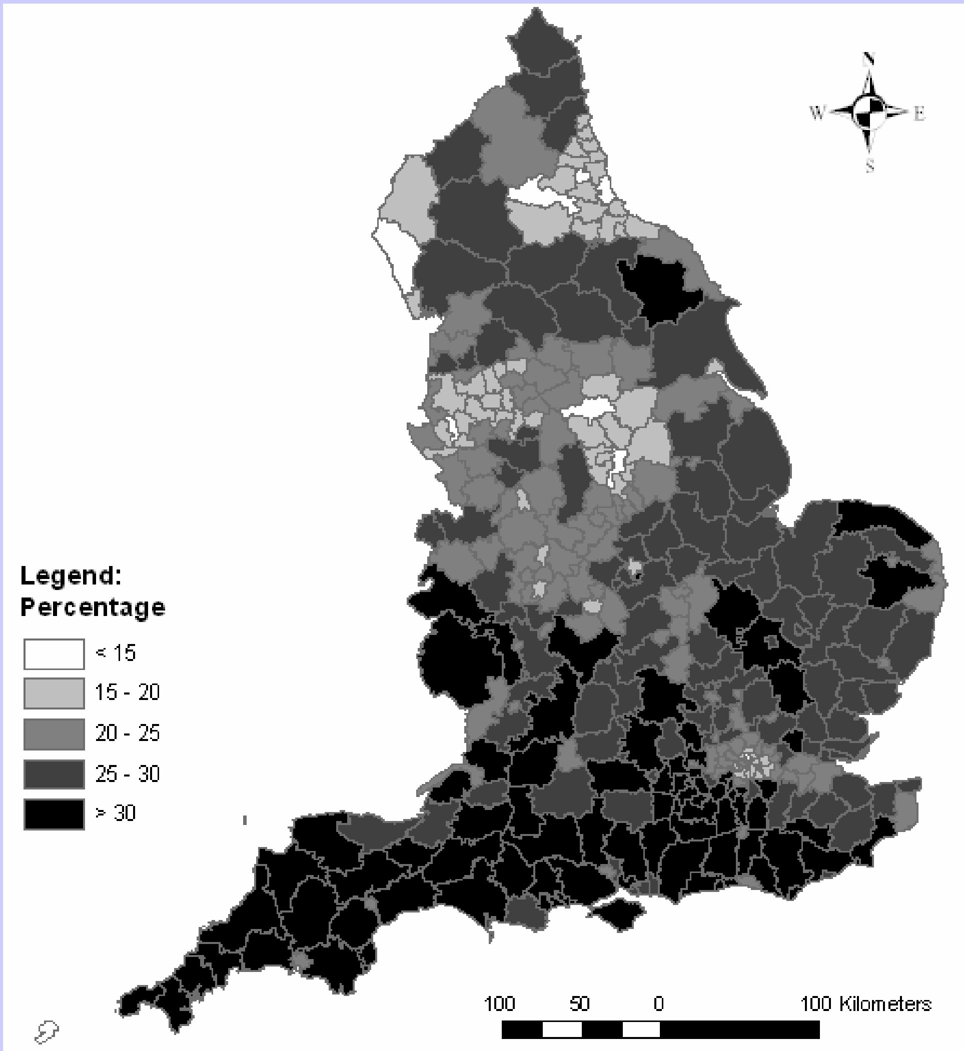
Note: Missing value for Council of the Isles of Scilly

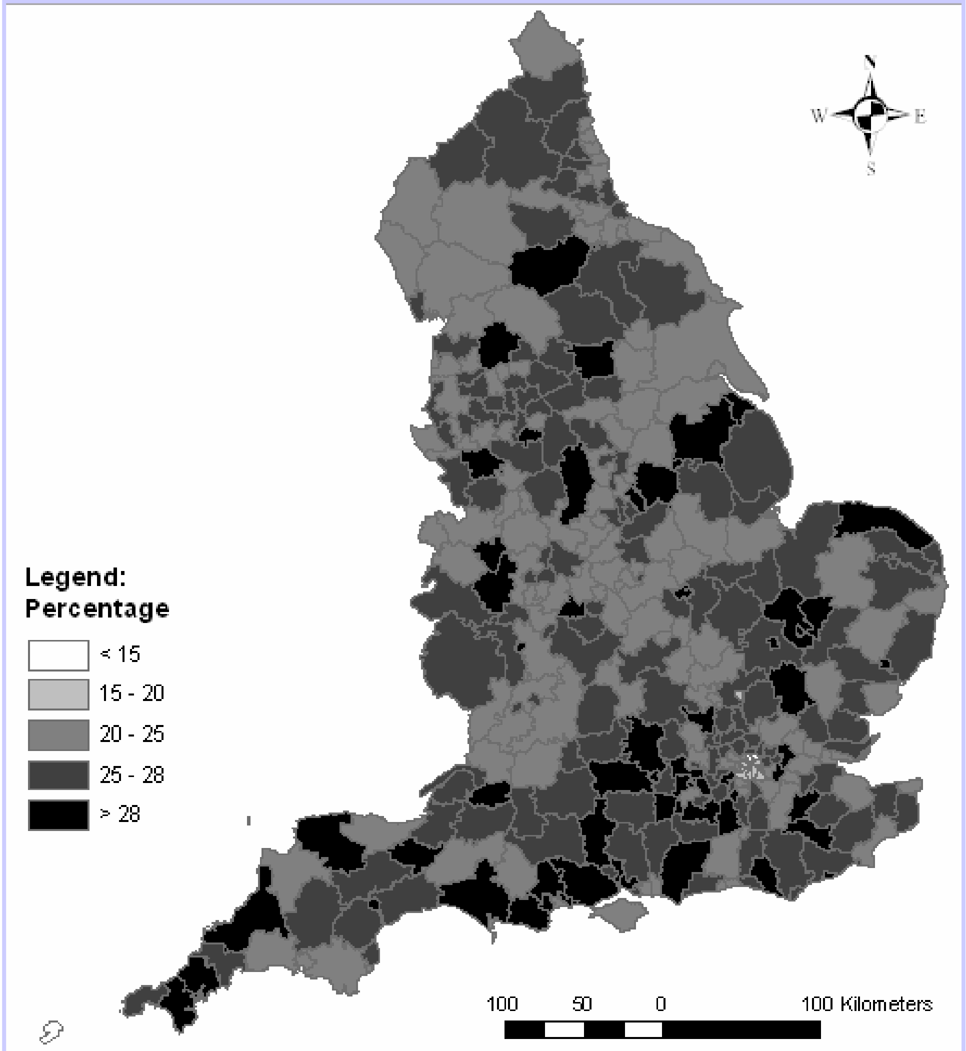
Appendix figure A3: Elevation range



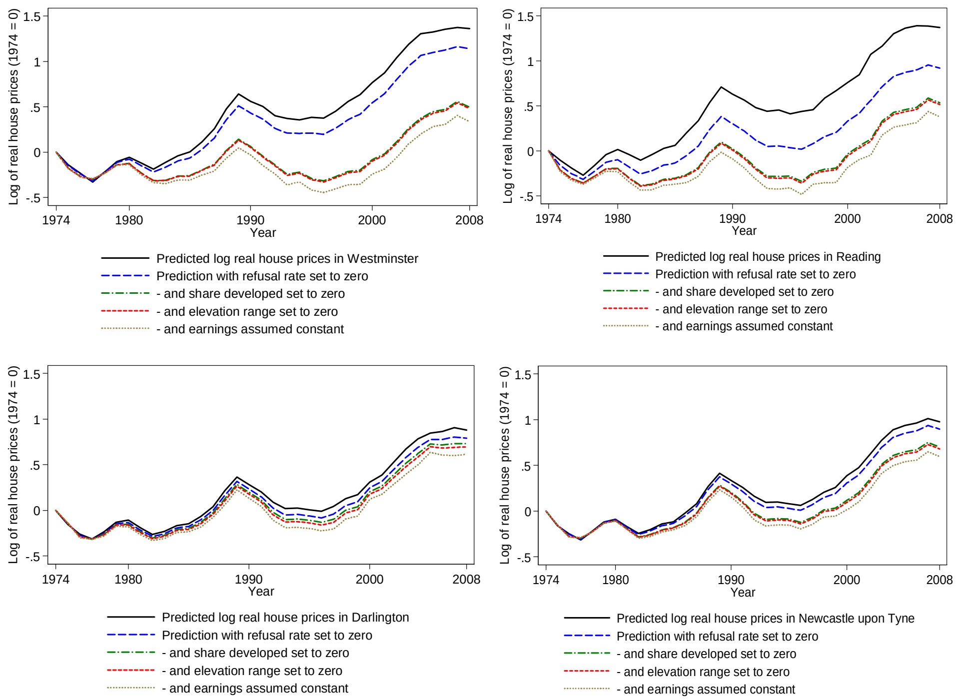
Note: Missing value for Council of the Isles of Scilly

Appendix figure A4: Predicted average refusal rate – major residential projects over 1979-2008 based on alternative identification strategies (Left figure: uses *change in delay rate*; right figure: uses *share Labour* votes)

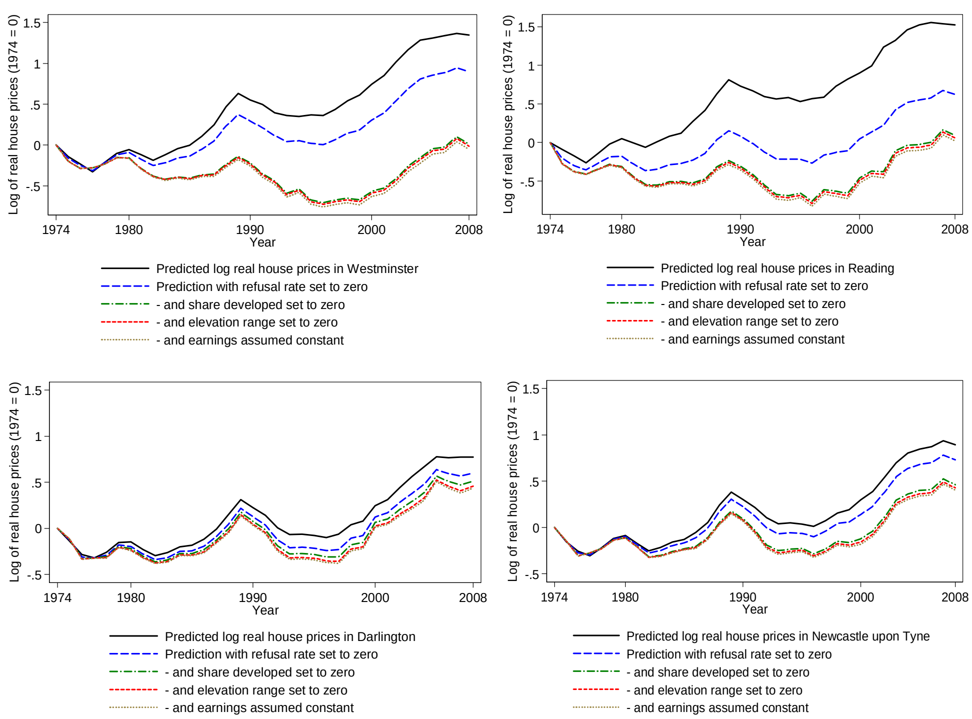




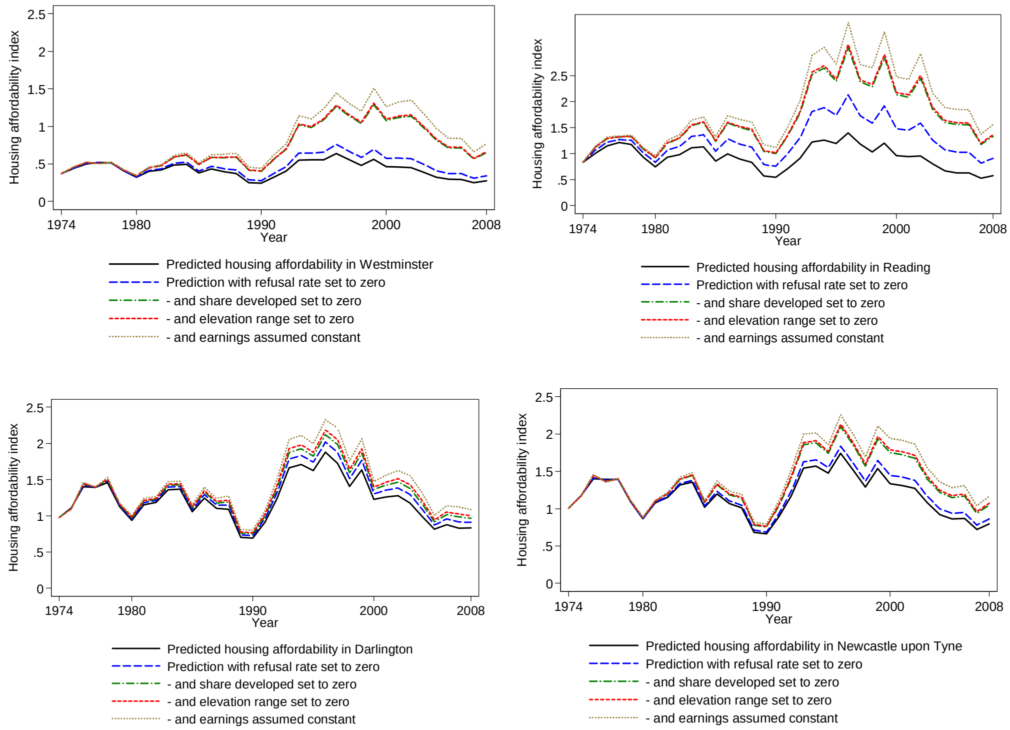
Appendix figure A5: Predicted log of real house prices in selected local planning authorities under alternative supply constraints-scenarios: Lowest bound



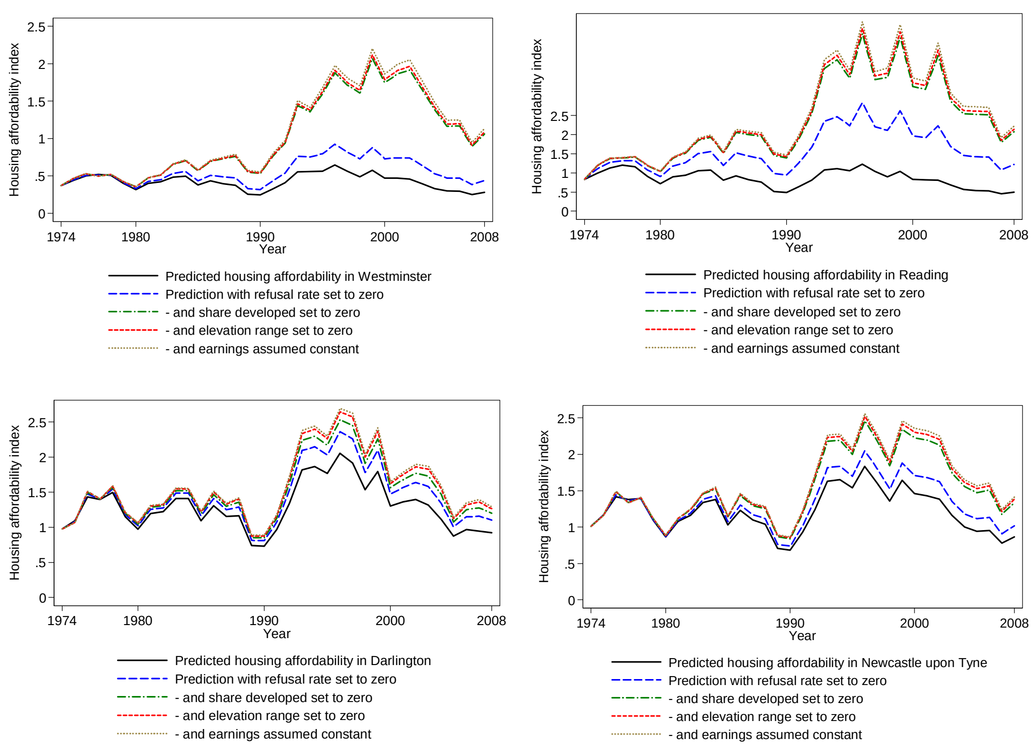
Appendix figure A6: Predicted log of real house prices in selected local planning authorities under alternative supply constraints-scenarios: Lower upper bound



Appendix figure A7: Predicted housing affordability in selected local planning authorities: Lowest bound



Appendix figure A8: Predicted housing affordability in selected local planning authorities: Lower upper bound



End note

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