Centre for Economic Performance

Discussion Paper

ISSN 2042-2695

No. 1990
April 2024

Why delay? Understanding the construction lag, aka the build out rate

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Economic and Social Research Council

Abstract
We explore the determinants of the speed of residential development after dwelling construction starts. Using a sample of over 140,000 residential developments in England from 1996 to 2015 and employing an instrumental variable- and fixed effects-strategy, we find that positive local demand shocks reduce the construction duration in a location with average supply constraints and developer local market power. However, this reduction is less pronounced in areas (i) where local planning is more restrictive, (ii) that are more built-up, and (iii) where competition in the local development sector is lower. We provide a model that rationalises these results. Our findings imply that the slow build out rate in England is the consequence of both market and policy failures.

Keywords: Construction lag, land use regulation, market power, housing supply, housing demand, housing market dynamics
JEL Codes: D43; G28; R21; R31; R38; R52

This paper was produced as part of the Centre's Urban Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

We would like to thank the National House Building Council for allowing us access to their data and especially thank Anders Harrison for explaining the data as well as for helpful comments and suggestions. We thank Brent Ambrose, Martijn Dröes, Isaac Hacamo, Lu Han, Stephan Heblich, Raven Molloy, Max Nathan, Tsur Somerville, Jaehee Song, Scott Wentland, Jiro Yoshida, and conference/seminar participants at London School of Economics, the European Meeting of the Urban Economics Association in London, the North American Meeting of the Urban Economics Association in Washington DC, the International Conference of the American Real Estate and Urban Economics Association in Cambridge, Pennsylvania State University-Federal Reserve Board Conference on Frictions in Real Estate and Infrastructure Investment in Washington DC, and the AREUEA-ASSA Annual Conference in San Antonio for helpful comments and suggestions. All errors are the sole responsibility of the authors.

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Published by
Centre for Economic Performance
London School of Economic and Political Science
Houghton Street
London WC2A 2AE

1. Introduction

Theoretical models of residential and commercial real estate markets usually incorporate 'construction lags' – the time it takes from the start to the completion of a construction site. Construction lags are crucial to explain property price dynamics, for example, as they make the short-run supply curve more price inelastic. Despite the importance of construction lags for real estate markets and property price dynamics, the term is typically used in the abstract. It is essentially a 'black box', and we know very little about either the duration of construction lags or their determinants.

Understanding the causes of the slow rate of conversion of planning permissions into completed housing units is also an important policy concern, especially in the light of the housing affordability crisis that has been developing over the past few decades in many countries, especially in 'superstar cities', and particularly in Greater London and other English cities, which are the focus of our empirical analysis. Concerns have been expressed in Britain that the slow 'build out rate' of sites with planning permission are a failure of the house building industry (Office of Fair Trading 2008, Letwin 2018 & Competition and Markets Authority 2024).

In this paper, we employ a unique dataset of over 140,000 residential sites in England consisting of one or more buildings, themselves representing one or multiple homes ('dwellings'), between 1996 and 2015 to explore what determines the speed of construction of these residential sites and of the individual homes on them after they are initially granted planning permission. Our sample covers between 82% and 92% of all residential developments for that period and records detailed site-level information.

We first develop a simple stylized three period-model to study the process of developers' decision-making about how fast to build out sites in a local market. Our focus is on the duration between the onset and the completion of construction (i.e., the 'construction lag'). This contrasts with the previous literature, which has mainly focused on the time lags between planning application and planning permission or between planning permission and start of construction, respectively.

In our model, locations differ in their long-run scarcity of developable land with planning permission and in their market competitiveness. We explore the response of profit maximizing developers in steady state (period 0) to a positive and auto-correlated local demand shock. Developers must decide whether to build out their entire local land holding quickly (by period 1) or slowly (by period 2). Whether the former or the latter is more profitable depends on the expected relative sales price in period 1 versus period 2 and the discount rate. If developers build and sell slowly (i.e., in period 2), they may benefit from a relatively higher price in the future, however, this price is discounted more. This is the basic trade-off that developers are facing.

In our setting, a developer who has market power – in contrast to a situation with perfect competition – can influence the relative price in period 1 versus period 2. A high market share incentivises a developer to respond to a positive and auto-correlated demand shock by building more slowly, all else equal. This is because if a developer with a high market share were to respond by building all their local land holding quickly, their own additional supply would adversely affect the price in the short run (period 1).[1]

In our model, severe long-run scarcity of developable land with planning permission encourages delaying the construction process. This is because inelastic long-run supply increases the expected real price growth in the longer-run. That is, delayed construction allows a developer to sell their land holding at a higher price later. In contrast, if locations have plenty of developable land and local authorities make much of it available via granting planning permission, then the demand shock will trigger a strong supply response lowering future prices. In this case, the developer has strong incentives to build quickly.

Our theory predicts that in a setting where (i) a developer has a low market share and (ii) land with planning permission is readily available, a positive and serially correlated demand shock can be expected to lead to a reduction in the equilibrium construction duration. This negative impact of a demand shock on construction duration is less pronounced if (i) the developer has a higher market share and/or (ii) the local authority has more severe geographical and regulatory supply constraints.

We empirically test our theoretical predictions, combining our individual site level data with information for local authorities and with other controls such as micro-location weather- and soil-conditions. In our empirical analysis, we employ an instrumental variable- and multiple fixed effects-strategy.

The main empirical challenge is the endogeneity of both local demand shocks and housing supply constraints, as they are highly correlated with the state of local housing markets. To overcome these concerns, we employ a three-pronged strategy. First, we use multiple-fixed-effects to control for time-invariant features of local planning authorities and developers and to account for time trends and the seasonality of real estate development. Second, we employ a Bartik (1991)-type predicted annualized local employment change measure as a proxy for local demand shocks. We do so because this measure is likely to be orthogonal to local housing market conditions. Third, following Hilber and Vermeulen (2016) and Hilber and Mense (2024), we use an instrumental variable strategy to address endogeneity concerns relating to our two measures of long-run housing supply constraints (local regulatory restrictiveness and local scarcity of developable land).

We test the theoretical predictions, employing our panel dataset, which largely consists of sites where developers have limited market power. Our empirical baseline estimates indicate that in a location with average supply constraints and average market power, positive local demand shocks speed up the build-out rate. Our preferred baseline specification suggests that a 1 percentage point increase in housing demand reduces the

[1] In theory, a developer could build quickly and sell slowly. This is extremely unlikely to be the case in practice because developers usually must sell quickly to recoup the cost of financing. Moreover, vacant properties tend to depreciate more in value, and the vacant and unsold properties will send a bad signal to the market. We abstract from these considerations in our model.

construction duration in the ‘average’ location by 2.7%,[2] all else equal. However, the reduction in the construction duration weakens to 0.8%, 1.7%, and 2.1%, respectively, if regulatory constraints, land-scarcity related constraints, or market concentration are one standard deviation higher. These effects are both statistically significant and quantitatively meaningful. We then conduct a counterfactual analysis, using the results from our Local Planning Authority-level analysis, and find that if we reduced regulatory constraints by one standard deviation in the ‘average’ English Local Planning Authority, the construction duration would be 10% shorter. A one standard deviation reduction in land-scarcity-related constraints would reduce the construction duration by another 7% and reducing the market power by one standard deviation would reduce the construction duration by a further 8%.

We carry out a long list of robustness checks including testing the validity of the Bartik-type demand shocks (Goldsmith-Pinkham *et al.* 2020), extending the time window for the sample period, considering time-varying local factors, excluding construction sites in London from the estimation, and so on. The results are consistent with the baseline findings in all cases. We also conduct additional estimates exploring the impacts of the construction of mixed private and social housing, site size (total number of dwellings), and type of building structure on site build-out rates.

We are not the first to study the determinants of the construction duration, aka the build-out rate. Most of the previous work on the housebuilding industry has been within the engineering and planning literature. This literature is largely atheoretical and the most common methods used in previous studies are semi-structured interviews and survey questionnaires (see Payne *et al.* 2019 for a summary) using samples of questionable representativeness. The focus is on project specific determinants such as project management, supervision, or decision-making processes.[3] These studies do not consider the location-specific economic determinants of construction duration – the focus of this paper – nor are they set in the context of a model of developer behaviour.

Two notable exceptions are Dursun and Stoy (2012) and Gandhi *et al.* (2021). Dursun and Stoy (2012) use multiple linear regressions and data for 1,695 projects in Germany to study the determinants of construction duration. They find that gross external floor area and cost of construction works are important explanatory variables. Their findings also indicate that the type of facility, project location, availability of construction area, and market conditions have significant impacts on the construction duration. Gandhi *et*

[2] The preferred estimate of the effect of housing demand on construction duration is -2.72 (see column 6 of Table 3). We therefore obtain an effect equal to $e^{0.01\times-2.72}-1=0.0268$. We use this transformation when making quantitative interpretations of all our estimated coefficients in our log-linear specifications throughout the remainder of the paper.

[3] For instance, Assaf and Al-Hejji (2006) use a field survey including contractors, consultants, and owners in Saudi Arabia to study the causes of construction delay. They find different potential causes such as changes in design or specification during construction, delay in progress payments, ineffective planning and scheduling by contractors, poor site management and supervision by contractors, and so on. Chan and Kumaraswamy (1997) conduct a survey to evaluate the relative importance of 83 potential delay factors for construction projects in Hong Kong. They find five principal factors: poor risk management and supervision, unforeseen site conditions, slow decision making, client-initiated variations, and work variations.

al. (2021) use data from 3,000 real estate projects in Mumbai and employ OLS and matching techniques as well as an IV-approach to explore the impact of litigation on construction duration. They find that litigated projects take approximately 20% longer to complete than non-litigated ones. While this finding has important implications for India, the relevance of litigation is confined to countries with poorly defined property rights.

Our paper relates to the theoretical framework and the empirical analysis of real options (McDonald and Siegel 1986, Caballero 1991, Grenadier 1996, Somerville 2001, Grenadier 2002, and Bulan *et al.* 2009). In contrast to our analysis, which explores the duration between start and completion of the construction of a site (or a unit), these studies focus on the delay between acquisition of a plot of land with planning permission and the decision to start construction.[4] McDonald and Siegel (1986) study the optimal timing of investment in an irreversible project. They demonstrate that increasing uncertainty leads to an increased willingness to postpone investment. Grenadier (1996) points out that increasing volatility may also make it more likely that a substantial increase in demand is reached in a shorter period of time, raising the possibility that falling prices trigger a cascade of development. Caballero (1991), Grenadier (2002), and Bulan *et al.* (2009) all suggest that competition erodes the value of the option to delay real estate investments. Caballero (1991) shows that imperfect competition is vital to predict a negative link between uncertainty and investment. Grenadier (2002) argues that competition might mitigate the value of a real option through the threat of pre-emption. Bulan *et al.* (2009) finally provide empirical evidence, using a sample of over 1200 condominium developments in Vancouver, showing that an increase in the volatility of returns reduces the probability of investment. However, an increase in the number of competitors offsets for the negative relationship between idiosyncratic risk and development.

Our paper ties into several additional strands of the literature. First, it ties into the literature on real estate cycles and dynamics (e.g., Wheaton 1999, Head *et al.* 2014, Oh *et al.* 2024) by exploring the determinants of construction lags, a crucial feature in the theoretical models of real estate markets. Second, it contributes to the literature on the economic and welfare impacts of urban planning and land use regulations in the United Kingdom and the United States (Cheshire and Sheppard 2002, Hilber and Vermeulen 2016, Turner *et al.* 2014). Lastly, we address the issue of market power, estimating its impact on construction duration. This is related to the literature discussing the behaviour, costs, and consequences of monopolistic or oligopolistic companies (for instance, Posner 1975 and Prager 1990).

The contribution of this paper is three-fold. First, we develop a simple stylized model that conceives of the rate of build out as an outcome determined not just by administrative or technical factors, but as being subject to a firm's choice and profit

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[4] We do not have data on the date of the acquisition of a land bank or on the date planning permission has been granted. Most local authorities in England require developers to start construction within three years of the planning permission having been granted. Once construction has started, there are no legal requirements to finish construction within a given time frame.

maximisation considerations. Second, to the best of our knowledge, we are the first to employ a dataset covering the great majority of all residential developments within a sizeable country, over the time span of two decades, in order to study the determinants of the site build-out rate and test the predictions derived from a theoretical model. Our dataset allows us to employ a rigorous multiple fixed effects- and instrumental variable-strategy to identify the determinants of construction lags, so we can be sure the results are representative and statistically robust. In particular, our data allows us to control for Local Planning Authority- and developer-fixed effects, addressing omitted variable concerns related to time-invariant location-specific and developer characteristics. Third, our paper contributes to the ongoing policy discussion in Britain on the causes of the slow build out rate in the house building sector and the inelasticity of housing supply. Our findings suggest that the slow build out rate is not just a monopolistic conspiracy to leave planning permissions unbuilt. Rather it is a mixture of market and policy failure. That is, excessively tight land use planning restrictiveness also contributes to the slow buildout of those permissions.

The rest of this paper is structured as follows. Section 2 describes the details of the British planning system and policy concerns about 'delays' and proposes a simple theory to guide our empirical analysis. Section 3 presents the data sources and descriptive statistics. Section 4 discusses our empirical strategy in detail, presents our main results for the determinants of construction lags, and provides a range of robustness checks and additional findings. Section 5 concludes.

2. Background and Theory

2.1. The British planning system, supply constraints, and policy concerns about 'delays'

Many factors explain the rate at which residential construction sites get built out. Even if only one house is planned and is personally commissioned, still the start may be delayed, or construction paused or accelerated. This could be because of weather or difficulties with the supply of materials or labour, financing, or just idiosyncratic factors. If the development is a commercial scheme of several houses, then even more factors may influence the speed of construction, both of individual houses and of the 'build-out rate' of the site as a whole. For example, a developer of a large site may start the foundation work to secure the planning permission and then pause construction.[5] The aim of this paper is to investigate the factors in England which systematically influence the rate of construction on any given site. One of these, and, as we will show, an important one, is the unusual nature of the British land use planning system.

The fundamental framework of the British planning system is still as set in the 1947 Town and Country Planning Act. This redefined the legal concept of freehold property rights, transferring – expropriating – the right to develop land or property from the owner to the state. How the system was implemented in practice was that any intended development required permission to be granted by the Local Planning Authority (LPA).

[5] Regulation in Britain requires developers to start construction work on the site within three years of full permission being granted, or the permission is lost.

For any legally defined development proposal, the would-be developer has to apply for permission to the LPA and for bigger developments this will often be in two stages: an application for 'outline' permission to establish the principle and then, if that succeeds, applications in detail (so-called 'reserved matters'). Building cannot legally commence until all aspects of a development have been approved and Local Plans (when they exist – see below) provide only schematic outlines of requirements enabling much leeway for judgement or political intervention, which generates significant costs and uncertainty over outcomes for applicants.

Developments may require a series of further permissions as they are built out (Ball, 2010). For example, any proposed changes to a project subsequent to initial approval may require re-submitting the full proposal in its revised form. In addition, since 1990, S106 Agreements[6] may be negotiated to provide a payment in kind for the granting of planning permission. The terms of these 'planning obligations' may be revisited as new home sales proceed. Large schemes built over a number of years will typically be built in phases with reserved matters only settled prior to the start of each new phase. For these, and other reasons, there is more than one negotiation over planning permission for most major housebuilding projects and potentially even for minor ones (Ball, 2011). This leads throughout the build-out period on any site to on-going interlinkages between planning and building, rather than there being an end to the planning process once permission is initially granted.

For the purposes of the present analysis the key characteristic of the British planning system (one shared by that of some former British territories such as New Zealand or Canada) is that it is not 'rule-governed' but discretionary, with the decision-making being essentially political. While LPAs are required to have an approved and up-to-date plan, as of 2023, only one third did (Lichfields, 2023); and even if there is a valid plan, decisions often do not follow it (Barker, 2006). The decision-making body for an LPA is the Planning Committee composed of local politicians. Such committees are sensitive to local feelings – especially those of voters in the wards that the members of the committee may represent – and are subject to fierce lobbying from local residents.

There are powerful incentives for local residents/voters to oppose development (see, for example, Cheshire and Hilber 2008, Hilber and Robert-Nicoud 2013, or Cheshire 2018), so many proposals consistent with local plans may still be rejected. Rejections are subject to a quasi-judicial appeal process involving the Planning Inspectorate and even when that process has been exhausted, a further stage of appeal is possible to the government minister responsible for the planning system. The larger a proposed development is, the more likely it is to go to appeal and the more expensive the whole process is likely to be. This means that in Britain decisions about development are subject to uncertainty and negotiation.

Combined with national policies aimed at restricting land for urban development

[6] These were introduced in Section 106 of the 1990 Town and Country Planning Act, hence Section 106 Agreements. Such agreements are individually negotiated with developers at the time of their application and are now most commonly used to make planning permission contingent on a proportion of below market price, 'affordable' units in any development.

(notably Greenbelt policy preserving very large zones around all major cities in which development is not allowed[7]), the empowerment of those who lose from development, including the great majority of local taxpayers, means that in economic terms there is a shortage of development pushing up the price of land for housing and housing itself. Hilber and Vermeulen (2016) developed a measure of 'planning restrictiveness', based on the proportion of applications for developments of 10 or more houses an LPA had historically rejected. They were then able to show how this restrictiveness measure, in conjunction with growing demand for housing, translated into higher local house prices.

The overall result is that housing has become ever more unaffordable (see Cheshire, 2014) through an absolute shortage of land and a lack of timely responsiveness to changes in demand. We explore how the - by international norms - unusual, but measurable features of Britain's planning system influence the rate at which developers build out their sites informs the theoretical analysis outlined in section 2.2 and is reflected in the empirical results in section 4.

A further influence of the British planning system is on the firm structure of the housebuilding industry. Both the substantial fixed costs imposed on developers to operate the complexities of the system and the uncertainty and extra risk imposed on the development process have encouraged a concentration of housebuilding into large-scale firms. This contrasts with the much greater dispersion of firm sizes in most other countries and their regions (Ball, 2003). Official enquiries have downplayed potential market distortions (Office of Fair Trading 2008, Letwin 2018, Competition Markets Authority 2024). By contrast, consumer-focused commentators have highlighted notable declines in product quality and consumer satisfaction as indicators of limited competition (e.g., Ali, 2019). While the planning system is not the only cause of the secular increase in market concentration, indirectly concentration has been promoted through the induced restrictions on the location and volume of housebuilding, the resultant higher land prices and the escalating costs and uncertainty of regulatory approval. Taken together, they have raised substantially the cost of new entry and undermined the viability of what was once a thriving small firm sector (Ball, 2013). A potential outcome of increased concentration in the industry is the speed at which firms respond to demand increases, because in the absence of local competition housebuilders have little to fear from competitors grabbing their markets by building faster. So, we explore this as well in section 4.

2.2. Theory

To guide our empirical analysis on the determinants of the construction duration, we develop a simple stylized model. This explores the decision of developers whether to build out their local land holdings quickly or slowly in response to a positive demand shock. In our stylized setting, each developer takes into consideration the behavior of their competitors and the construction decision is made based on local demand and

[7] The administrative area of London's government – the Greater London Authority area- is 159,624 ha: its Greenbelt covers some 514,000 ha. Just over 22 percent of the GLA area is in the Greenbelt but the great majority of London's Greenbelt – some 94 percent - is outside the GLA in the South East and East of England (see Cheshire *et al.* 2014 or Cheshire and Buyuklieva 2019).

supply conditions. Importantly, the actions of larger developers with some power over short term prices will differ from those of smaller developers, who are price-takers.

The model consists of three periods: period 0, period 1, and period 2. In period 0, developers decide independently whether to build out their entire local land holding (which they possess in period 0) quickly, meaning that they will construct sites and sell housing units in period 1, or they build slowly, meaning that they will complete construction and sell only in period 2.[8]

House price

In reference to Grenadier (1996), we define that the house price in period t, $P(t)$, is determined by the following equation:

$$P(t) = X(t) \cdot D[Q(t)] \quad (1)$$

Where $Q(t)$ represents housing supply in period t, and $D(\cdot)$ is a differentiable function with $D'(\cdot) < 0$, meaning that increasing housing supply will reduce house prices. Given the three discrete periods of the model, we assume that $X(t)$ represents a multiplicative demand shock and is determined by the following equation for any $t \geq 1$:

$$X(t) = (1+\mu)(1+\gamma\mu)^{t-1}X \quad (2)$$

Where the constant μ is the expected percentage change in X per period with $\mu > 0$.[9] The constant γ captures the degree of autocorrelation of the demand shock and $\gamma \in (-1,1)$.

Supply side

In period 0, there are in total Q_1 units of unbuilt plots of land for housing with planning permission. These land plots are owned by n homogenous developers, each having the same market share $\frac{1}{n}$.[10]

In period 1, the supply of housing is determined by the developers' construction decisions. For instance, if one developer decides to build out quickly and all the other developers decide to build out slowly, the supply of housing in period 1 will be $\frac{Q_1}{n}$.

In period 2, there will be new supply of unbuilt land plots $\frac{Q_1}{S}$, where S denotes local

[8] The three-period model ignores the possibility of off-plan sales. The proportion of new homes being sold off-plan is relatively low in England and Wales. The share of completions sold off-plan during 2021 is 35% (Hamptons, 2022). This share is likely to be significantly lower during our sample period between 1996 and 2015.

[9] The model assumes a positive demand shock $\mu > 0$. We do not discuss the case with negative demand shocks, as under the assumptions of a kinked supply curve and zero depreciation, a negative demand shock won't trigger any new construction from developers.

[10] Under similar assumptions, a duopoly model with two developers differing in market shares has the same mechanism and propositions.

supply constraints including both regulatory restrictiveness and the geographical scarcity of developable land. A large S implies inelastic long-term supply of housing. Total housing supply in period 2 is thus $Q_1 + \frac{Q_1}{S}$.

The model excludes the role of existing homes in the local housing markets. However, including an exogenous existing housing stock sector would not influence the main mechanism and propositions of the model.[11]

The optimal construction strategy for developers

Given the construction speed decision of each of the n developers in period 0, there will be in total n potential scenarios when developer 1 considers their optimal construction strategy. The selling price of developer 1's housing units under each scenario is summarized in Table 1.

Let r denote the discount rate, K denotes the construction cost per unit that will appreciate by r in each period, and C denotes the additional cost per unit that each developer needs to pay if they decide to build out quickly. The difference in the discounted profit per housing unit $\Delta\pi$ (excess profit when developing slowly) for developer 1 under scenario 1 is:

$$\Delta\pi = \frac{P(2)}{(1+r)^2} - \frac{K(1+r)^2}{(1+r)^2} - \left[\frac{P(1)}{1+r} - \frac{K(1+r)}{1+r} - C\right]$$

$$= \frac{(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1 + \frac{Q_1}{S}\right)}{(1+r)^2} - \frac{(1+\mu)X \cdot D\left(\frac{Q_1}{n}\right)}{1+r} + C \quad (3)$$

Developer 1 makes the decision on whether to build slowly or quickly based on the following indicator function:

$$\mathbb{I}_{\Delta\pi}(Slow) = \begin{cases} 1, \Delta\pi \geq 0 \\ 0, \Delta\pi < 0 \end{cases} \quad (4)$$

We assume that $\frac{(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1 + \frac{Q_1}{S}\right)}{(1+r)^2} > \frac{(1+\mu)X \cdot D(Q_1)}{1+r} - C$, meaning that the discounted price in period 2 is higher than the discounted price in period 1 when all developers decide to build out quickly.[12] If instead, $\frac{(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1 + \frac{Q_1}{S}\right)}{(1+r)^2} \leq \frac{(1+\mu)X \cdot D(Q_1)}{1+r} - C$, it will always be more profitable for each developer to build out quickly, regardless of other developers' construction speeds. This is because $D'(\cdot) < 0$, and in this case, $\frac{(1+\mu)X \cdot D\left(\frac{Q_1}{n}\right)}{1+r} - C > \frac{(1+\mu)X \cdot D\left(\frac{2Q_1}{n}\right)}{1+r} - C > \cdots > \frac{(1+\mu)X \cdot D(Q_1)}{1+r} - C \geq \frac{(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1 + \frac{Q_1}{S}\right)}{(1+r)^2}$.

[11] In the empirical analysis, we conduct a robustness check by considering the role of existing home transactions when we measure developer market share. The results are reported in the Appendix and are consistent with our main findings.

[12] This assumption is plausible given the general appreciation of housing prices in the UK over the past decades.

Therefore, if $\frac{(1+\mu)(1+\gamma\mu)X\cdot D\left(Q_1+\frac{Q_1}{S}\right)}{(1+r)^2} \leq \frac{(1+\mu)X\cdot D(Q_1)}{1+r} - C$, building out quickly will become a dominant strategy for all developers, and their construction speed decisions will not be influenced by any market factors. This case is not likely to occur, and our theoretical framework thus does not consider it.

We explore the impact of a positive demand shock to μ on the probability of developer 1 building slowly under scenario 1 by taking the first order derivative of $\Delta\pi$ with respect to μ:

$$\frac{\partial\Delta\pi}{\partial\mu} = \frac{(1+\gamma+2\gamma\mu)X\cdot D\left(Q_1+\frac{Q_1}{S}\right)}{(1+r)^2} - \frac{X\cdot D\left(\frac{Q_1}{n}\right)}{1+r} \tag{5}$$

The sign of $\frac{\partial\Delta\pi}{\partial\mu}$ is ambiguous, suggesting that the overall impact of the demand shock on construction duration depends on the developer's market power $\frac{1}{n}$ and magnitude of local supply constraints S. If both S and $\frac{1}{n}$ are high (e.g., a developer with strong market power in a tightly supply constrained market), $\frac{\partial\Delta\pi}{\partial\mu}$ is likely to be positive, meaning that developers are more likely to build slowly in response to a positive demand shock.

We then explore the effects of market power and supply constraints, respectively, interacted with positive demand shocks on the probability of developer 1 building slowly. We do so by taking the second order derivatives:

$$\frac{\partial^2\Delta\pi}{\partial\mu\partial S} = \frac{-(1+\gamma+2\gamma\mu)X\cdot D'\left(Q_1+\frac{Q_1}{S}\right)\cdot\frac{Q_1}{S^2}}{(1+r)^2} > 0 \tag{6}$$

$$\frac{\partial^2\Delta\pi}{\partial\mu\partial n} = \frac{X\cdot D'\left(\frac{Q_1}{n}\right)\cdot\frac{Q_1}{n^2}}{1+r} < 0 \tag{7}$$

Inequalities (6) and (7) lead to the following two empirically testable propositions:

Proposition 1: A positive demand shock is less likely to speed up construction if the site is built in a location with more restrictive supply constraints (i.e., a larger S).

Proposition 2: A positive demand shock is less likely to speed up construction if the developer has a higher market share (i.e., a larger $\frac{1}{n}$).

Our theoretical framework discusses the optimal construction decision for developer 1 under scenario 1 to illustrate the key mechanism. It is easy to prove that Propositions 1 and 2 also hold under scenarios 2 to $n-1$. The only exception for proposition 2 is scenario n, when all developers decide to build out quickly. This scenario, however, is unlikely to occur. As $\frac{(1+\mu)(1+\gamma\mu)X\cdot D\left(Q_1+\frac{Q_1}{S}\right)}{(1+r)^2} > \frac{(1+\mu)X\cdot D(Q_1)}{1+r} - C$, developers are aware that if all developers decide to build out quickly, the payoff will be less than that of building out slowly. We therefore assume that developers will coordinate and avoid all developers building out quickly (i.e., scenario n) to reduce the possibility of the least favourable market outcome from the developers' perspective.[13]

Graphical illustration

Figure 1 illustrates the main mechanism of proposition 1. Suppose that the local housing demand is expected to increase from D_0 to D_2 between period 0 and period 2 in two locations A and B. Both the short-run supply in period 1 and the long-run supply in period 2 are more restrictive in location A compared with location B because of more geographical and regulatory constraints in location A. As shown in Figure 1, developers in location A would prefer to delay the construction when the demand shock increases because it is more lucrative for them to sell housing units in period 2 ($P_2^A > P_1^A$), while developers in location B would prefer to speed up the construction when they observe strong positive demand shocks because $P_2^B < P_1^B$.

Figure 2 then presents the intuition of proposition 2. Suppose there are two developers X and Y in two different local housing markets with the same long-run supply conditions but different levels of market competitiveness. Local housing demand is expected to increase from D_0 to D_2 between period 0 and period 2. Developer X has more land reserves ($\theta_X Q$) than developer Y ($\theta_Y Q$). The house price in period 2, P_2, will be determined by the long-run supply, LRS_2, and the demand in period 2, D_2. If developer X decides to build out quickly and all the other developers in the same market decide to build out slowly, housing supply in period 1 will be $\theta_X Q$. In this case, $P_1^X < P_2$, and, thus, it is not a favourable decision for developer X to build out quickly. On the contrary, if developer Y decides to speed up the construction and all the other developers in the same market decide to delay construction, housing supply in period 1 will be $\theta_Y Q$. Under this scenario, $P_2 < P_1^Y$, and developer Y could get higher profits if construction were completed in period 1. The behaviors of developers X and Y together suggest that a developer is more likely to delay the construction as the positive demand shock increases if they have a relatively higher market share. This is because the higher market share creates a more significant supply shock to the local market and so reduces house prices.

3. Data and Descriptive Statistics

Our empirical analysis employs unique geo-located data on construction sites in England, covering – for the years in our regression sample – the vast majority of all sites and including detailed information on the site build-out rate (i.e., the speed at which the site is developed) and both site- and dwelling-characteristics.

Our main data source is the National House Building Council (NHBC), the leading

[13] Even if developers do not coordinate and make completely independent construction speed decisions, the probability of scenario n is likely to be low. This is because if all developers choose to build out quickly, each developer will find it more profitable to build out slowly, suggesting that scenario n is not in a state of Nash equilibrium where individual developers have no incentive to deviate from their construction speed strategy.

provider of new home warranty and insurance in the UK. The NHBC is a non-profit company independent of government and the construction industry. It records inspections for construction sites at key build stages and, as Figure 3 shows, covers most residential developments in the UK since the 1990s. The NHBC dataset used in our analysis contains information on completed sites, comprising 3,373,364 dwellings, constructed in England between 1986 and 2020. The information includes dwelling start and completion dates, site locations, dwelling types (flats or houses), the number of bedrooms for each dwelling, a unique construction site identifier, a unique dwelling identifier, the site developer, and whether a housing association participates in the development. For the purpose of our analysis, a dwelling is labelled as a 'public unit' if it is either built by a housing association or jointly developed by a private developer and a housing association.[14]

To perform our empirical analysis, we aggregate the NHBC dwelling-level records to the construction site level. For each construction site, we compute the share of public dwellings to measure its public housing intensity. We also calculate the share of flats within a site to characterise its physical structure and count the number of dwellings within a site to measure its size. We employ the National Statistics Postcode Lookup Directory to match construction sites to coordinates and local planning authorities.[15]

Figure 3 illustrates, respectively, the number of NHBC dwellings and the total number of dwellings started in England as reported by the Ministry of Housing, Communities and Local Government (MHCLG). As we show in Figure 4, the share of all residential construction covered by the NHBC improved steadily during the late 1980s until 1996. It reached 83% in 1996 and coverage remained very high, between 82% and 92%, all the way through until 2015. During this period, the NHBC covered essentially the entire country, that is, there was coverage in nearly all 353 LPAs in England. The coverage of the dataset starts to drop very significantly from 2015 for a technical reason: the data set only records construction sites that are fully completed. Thus, it increasingly misses dwellings on sites still under construction the more recent the year, creating a sample selection issue.

To deal with this issue we confine the sample for our baseline regression to the period from 1996 to 2015. We start with 1996 because this is the first year the NHBC's digital recording covers much of the market (i.e., 83%). We drop the years from 2016 onwards to minimise the concern that our results might be affected by sample selection. We pick 2015 as our final year for three reasons. First, as Figure 4 illustrates, coverage of total housebuilding starts to drop dramatically from 2016 onwards. Second, and related, the average construction duration for large sites with more than 100 dwellings in our sample is 1,547 days (around 4.2 years). This implies that most sites that started in 2015 were in fact completed by 2020, when the coverage of our NHBC dataset ends. Put

[14] Usually as part of S106 agreements, a site once entirely belonged to a developer who then 'sells' part of the site to a housing association to build it out.

[15] We use the most frequently occurring postcode within a construction site to geocode it. In the dataset, approximately 3% of dwellings do not contain full postcode information, and we use their postcode district or postcode sector information to geocode them.

differently, our sample of NHBC dwellings in 2015 is likely to be very close to the final count, but that count is not available to us since our data ends in 2020. Third, and again related, picking 2015 as final year ensures our analysis is not affected by COVID-19, which, for a time, brought construction nearly to a stand-still.[16] Using data for the period from 1996 until 2015 ensures that our regression sample provides a comprehensive coverage of the market (i.e., 87%) for new homes in England.

Before turning in more detail to the variables included in our empirical analysis, it is worth stressing the worldwide unique character of the NHBC dataset. We are unaware of any other dataset that provides a similarly comprehensive coverage of detailed construction activity at site-level for a large country such as England. Apart from the excellent coverage of the construction market in England, the NHBC dataset has several important additional advantages. First, it contains detailed information on the size of construction sites, the structures built, locations and developers. This enables us to study build-out rates and their determinants. Second, the NHBC is an independent, non-profit organisation and its detailed inspections provide accurate records of the residential development process. Third, the large spatial variation in land use planning restrictiveness across the LPAs of England provides an ideal institutional setting to explore regulatory impacts on site build-out rates.

We define the 'construction duration' for each site as the time between its start and its completion-date.[17] Panel A of Figure 5 shows that the construction duration for most sites in our baseline sample is less than 2,000 days, although there are a few sites with a significantly longer construction duration, up to 7,246 days in the extreme.[18] Figure 6 presents the yearly average construction duration across projects of different sizes in England. The average construction lag is in general stable over time, with an exceptional increase between 2007 and 2009, likely to be explained by the financial crisis.

To measure local developer market power, we first draw a 10-km radius buffer for each construction site and then normalize the radius of each buffer based on each site's corresponding LPA population density in 2001. The mean population density at the LPA level in 2001 is 14 persons per hectare. If a site is in an LPA with population density higher than 14, we will adjust its corresponding radius based on its LPA population density and the national mean value. Otherwise, we compute the local market share within the 10-km radius buffer. We then compute the market share of each site project's developer within the adjusted buffer. The reason to adjust the radius of each buffer is

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[16] As we report in Section 4.5, our results are essentially unchanged if we replicate our analysis and make use of more NHBC data from 1986 to 2018.

[17] For each site, the start date is observed when the first slab of site is completed and a NHBC inspection is triggered (usually on the stages related to excavation and foundation). Before the start date recorded by the NHBC, there may be some time for land preparation, infrastructure development, and the digging out and laying of the first batch of dwellings' foundations and services. The completion date is the NHBC inspection date of the last completed dwelling. There might still be some final works after that such as landscaping, roads, etc. Both definitions suggest that the actual construction duration for each site might be even longer than our dataset records.

[18] We dropped sites with construction duration either fewer than 6 weeks or more than 20 years in our baseline sample to mitigate potential measurement errors.

because we want to define local housing markets with more comparable population size and numbers of potential buyers. In the Appendix, we report estimation results using local market share measures with no adjustment and our findings are robust.

Figure 7 presents an example. We first draw a 10-km-radius buffer for site A. Within this buffer, three construction sites (A, B, and C) all start in the same year. Both sites A and B are constructed by developer X, and site C is constructed by developer Y. Site A's local market share is then defined as the number of dwellings within sites A and B (both constructed by developer X) relative to the total number of dwellings within sites A, B, and C. Panel B of Figure 5 presents the histogram of the local market share based on our main estimation sample. For the vast majority of site locations, the corresponding developer has a local market share of below 20%. There are however a few large sites, where the developer has a (near) monopolistic market share of up to 100%.

To capture local developer competitiveness at the LPA level, we compute three measures: a standard Herfindahl–Hirschman Index [19] and the top-5 and top-10 developers' market shares, respectively, for each LPA. Panel A of Figure 8 documents the spatial variation in the top-10 developers' market power at LPA-level. This shows that the largest developers in the North of the country tend to have more market power. At the national level, Figure 9 illustrates how the Herfindahl–Hirschman index and the top-5 and top-10 developers' market shares in England evolve over time. The figure reveals that the construction market in England is heavily influenced by large developers, with the top-10 developers producing more than 40% of all new homes, in almost every year between 1996 and 2015.[20] Figure 9 also shows that after the financial crisis in 2007, both the top developers' market share and the Herfindahl–Hirschman index increased, suggesting that big developers were more likely to survive the crisis and thus gain a higher market share.

We spatially merge the NHBC dataset with data from other sources to get information about local housing demand and supply conditions, and to control for a wide range of geographical and weather conditions. We collect data about the refusal rate of major projects from the MHCLG. We compute the average refusal rate at the LPA level between 1996 and 2015, the same period for our main empirical specification, as a proxy for local regulatory restrictiveness. As shown in Panel B of Figure 8, LPAs in London and the Southeast region tend to have higher refusal rates for major applications and are thus more likely to have restrictive planning environments. We use a Bartik (1991)-type shift-share measure (i.e., the predicted local employment based on an LPA's

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[19] The Herfindahl-Hirschman index, calculated as the sum of the market share percentages of developer k within a buffer, is a common measure of market concentration. It can range from 0 to 1. The higher the index, the greater is the market concentration. A low value implies a competitive marketplace.

[20] Table A1 presents the market share of the top 10 developers in England between 1996 and 2015 based on our estimation sample. Top 10 developers in total account for 48% of all new homes in England during our main estimation period. It is also worth noting that there have been extensive mergers and acquisitions amongst housebuilding firms during the sample period, leading to greater concentration, but that for computational purposes we assume named builders in the sample are independent whereas some may have been jointly owned at the time. Our concentration estimates thus should be regarded as minima.

industry composition and the national-level employment growth rates of these industries), taken from Hilber and Mense (2024), to capture shifts in local housing demand. Panel C of Figure 8 presents the annualised change in predicted employment at the LPA level between 1996 and 2015. As the figure shows, housing demand and economic prosperity are highest in the Southeast and in Greater London. We discuss the predicted local employment measure in more detail in Section 4.1.

We also use data from Hilber and Mense (2024) to measure local geographical constraints (the share of developed land relative to developable land in 1990) and to construct instruments for our supply constraint variables. As shown in Panel D of Figure 8, there are more severe geographical constraints in Greater London. We discuss the identification strategies in section 4.1. Following Gibbons *et al.* (2019), we consider the centroid of each Travel to Work Area (TTWA) as a proxy for the city centre (CBD) and compute each geocoded site's distance to these. Panel D of Figure 5 presents the distribution of the distance to the CBDs. Finally, we obtain housing transaction, weather, and soil condition data from the Land Registry, the Met Office, and the British Geology Survey, respectively, and spatially merge each site with its corresponding weather and soil conditions so that we can control for within-LPA features. We adjust all the LPA-level variables to the 2001 Census LPA administrative boundaries to stay consistent in our empirical estimation.

In Panel A of Table 2, we present the summary statistics for the sample of construction sites between 1996 and 2015 in England. There are 143,856 completed construction sites in this sample. The average construction duration of build out is 574 days, and on average, there are 17 units per construction site. The average number of bedrooms per dwelling is 3, and the average share of public units within a site is 12%. Panels B and C show the summary statistics for the LPA-level variables. The average refusal rate for major projects is 19% and the average top 10 developers' market share is 68%. Panel C also presents the summary statistics for four instrumental variables that we apply to generate exogenous variations in supply-side constraints. We discuss these variables and the details of our identification strategy in Section 4.1.

Panel C of Figure 5 presents a histogram of the number of dwellings within each site based on our baseline sample. Most sites have between 1 and 100 dwellings, though a few large sites have more than 1000. Figure B1 presents the time-series of both the average number of dwellings within each site and the number of medium and large sites relative to all sites[21] in England between 1996 and 2015. The average size of a construction site has been relatively stable between 15 and 20 units between 1996 and 2009. It increased markedly after 2009 to around 25 units. This phenomenon might be driven by the fact that big developers were more likely to survive the financial crisis.

The construction duration also varies substantially spatially in our sample. Panel A of Figure 10 illustrates that it takes significantly longer for developers to build sites in the Northeast compared to the Southeast. We have two explanations for this. First, housing

[21] Medium refers to projects with 25 to 100 unit. Large refers to projects with more than 100 units (Ball, 2011).

demand growth is much higher in the Southeast (see Panel C of Figure 8). Second, consistent with developable land being scarcer and planning restrictions being tighter, more small sites tend to be built in the Southeast. Conversely, Panel B of Figure 10 documents the average construction duration at *dwelling-level,* suggesting that the construction of individual units takes longer in the Southeast and Greater London than in the Northeast. While demand pressures are higher in the Southeast and in Greater London, these regions are also characterised by tight planning controls and a high degree of physical development, both potentially slowing down the construction speed per dwelling.

Appendix Figure B2 finally shows significant seasonality for the start and completion months of construction sites. Panels A to D suggest that more projects start and complete during the summer (especially in June), while comparably few projects start and complete in December and January. We control for the seasonality of residential development by including both the start month and the completion month fixed effects in our baseline specification.

4. Empirical Analysis

4.1. Endogeneity Concerns and Identification Strategy

The focus of our empirical analysis is to test our theoretical propositions that an increase in housing demand, all else equal, are less likely to speed up construction in:

i) locations where supply constraints are more restrictive; and
ii) competition in the development sector is lower.

To test these hypotheses, we interact a variable that captures housing demand with supply constraint-variables and our measure of developer competitiveness, respectively.

As previously noted, our local housing demand shifter is the annualised change of a Bartik (1991)-style shift-share measure – the predicted local employment change – taken from Hilber and Mense (2024). The shift-share measure is derived by transforming the time-series industry variation (‘shift’) at the national level into local shocks based on the local industrial composition (‘share’) at the LPA level in 1971 - so pre-dating our main sample period by 25 years. The predicted employment arguably introduces an exogenous demand shock to local housing markets, as both the ‘shift’ and the ‘share’ variables are likely to be orthogonal to the state of the local housing market between 1996 and 2015. We compute the annualized change in local predicted employment (ACLE) for each site as:

$$ACLE_{jt^s t^e} = \left[\frac{predicted\ employment_{jt^e}}{predicted\ employment_{j(t^s-1)}}\right]^{\frac{1}{t^e - t^s + 1}} - 1 \quad (8)$$

where t^s and t^e refer to the start- and completion-year of each construction site. $ACLE_{jt^s t^e}$ represents the annualised change in the predicted local employment in local authority j between year t^s and year t^e. This variable thus captures the annualised demand shock for each construction site during its development period. Since the start-and completion-years vary from site to site, our demand measure may vary within an LPA across sites.

As the actual completion year of the construction site could be influenced by different time-varying local economic factors and therefore be endogenous to the construction duration, we employ the variations coming from the size of each construction site, measured by the number of dwellings within the site, to mitigate this concern. To do so, we apply a fractional polynomial regression approach to predict the completion date of each site and take into account the economies of scale for large sites. Figure 11 presents our predicted construction duration based on site size and shows that the predicted line fits the actual construction duration at a given site size quite well. We then follow equation (8) and use the predicted completion year to compute the ACLE at the site level.[22] For each construction site, its corresponding ACLE provides a measure of how the local housing demand changes during the construction process. Figure 12 presents the time trends of site-level ACLE between 1996 and 2015. Unsurprisingly, most sites experience positive demand shocks during their construction periods, but between 2007 and 2009, the ACLEs are more likely to be negative due to the global financial crisis. Using LPA-level data between 1996 and 2015, Panel A of Figure 13 plots a negative correlation between house price growth and construction duration, and Panel B of Figure 13 presents a negative correlation between ACLE and construction duration. Both panels suggest that positive local demand shocks will speed up site build-out rates. We test this formally in section 4.2.

To capture developer competitiveness, we use both the local market share measures and the Herfindahl–Hirschman index, discussed in Section 3. One concern related to our measure of developer competitiveness is that tighter land use regulations may themselves impose a greater hurdle that requires a more complex process and corresponding skills to negotiate planning permission. This in turn may make it more difficult for smaller developers to enter or compete in the market. To address this endogeneity concern, all our specifications include LPA fixed effects. These control for all time-invariant unobserved characteristics at the local level including regulatory restrictiveness (to the extent we do not capture it in our specification by our instrumented proxy for regulatory restrictiveness), so our estimate of the impact of developer competitiveness is conditional on the local regulatory restrictiveness.

Our measure of regulatory restrictiveness is the average refusal rate of major residential planning applications between 1996 and 2015 derived from the MHCLG. The refusal rate of 'major applications' (i.e., applications for projects consisting of ten or more dwellings) is the standard measure used in the literature to capture regulatory restrictiveness in Britain – see Cheshire and Sheppard (1989), Bramley (1998), or Hilber and Vermeulen (2016). We compute the average refusal rate between 1996 and 2015 to mitigate the concern regarding the pro-cyclical nature of local planning decisions. The other supply constraint measure, the share of developable land already

[22] As we report in Section 4.5, our results are essentially unchanged if we replicate our analysis using the actual start and completion years to compute ACLE at the site level.

developed in 1990, is taken from Hilber and Vermeulen (2016) and is used as a proxy for local physical restrictions on construction.

Although our housing demand shifter, ACLE, is likely to be exogenous to local housing market conditions, two of our supply constraint variables, the refusal rate and the share developed measures, are arguably endogenous. The concern is that these measures are correlated with local housing demand (see e.g., Davidoff 2016), which could have a direct impact on the site build-out rate. Moreover, as local planning decisions are the outcome of a political economical process and are shaped by homeowners, developers, and politicians (see e.g., Hilber and Robert-Nicoud 2013), the local refusal rate is likely to be correlated with developer characteristics. For example, larger developers may be better equipped to deal with restrictive planning authorities and may be more likely to gain planning approval. These developers may also have specific construction and project management techniques that could affect the site build-out rate. These larger developers can thus 'prosper' in more restrictive LPAs and crowd out smaller ones. We first mitigate this endogeneity concern by controlling for developer fixed effects, effectively comparing within-developer variation in construction duration across sites. However, confounding factors such as time-varying developer characteristics or local political features might still bias our estimates. If more capable developers were able to reduce both the likelihood of rejected planning applications and the site construction duration, the OLS estimate of the impact of planning restrictiveness would be biased. In addition, the 'share developed' variable is potentially endogenous as it is determined by contemporaneous demand and supply conditions.

To address these endogeneity concerns, we follow Hilber and Vermeulen (2016) and Hilber and Mense (2024) and employ an instrumental variable strategy. We utilise three instrumental variables for the refusal rate. Our first instrument is the LPA share of Greenbelt land in 1973, 23 years prior to the start of our sample period. Greenbelts in England represent major obstacles to new development. We would expect that those LPAs that were assigned a large share of Greenbelt land back in 1973 were also those LPAs with strong cohorts of Not-in-My-Backyard (NIMBY)-residents who benefited from proximity to open land and lobbied to protect asset values by opposing building. These LPAs, therefore, might be likely to have more restrictive planning generally, so the 1973 share Greenbelt land could be expected to be positively correlated with our refusal rate measure. Nevertheless, the historic share of Greenbelt land should not affect contemporaneous changes in the speed of the build-out rate other than through regulatory restrictiveness.

Our instruments two and three for the refusal rate were initially proposed by Hilber and Vermeulen (2016). The second instrument is derived from a reform of the English planning system in 2002, which imposed a speed-of-decision target for major developments but did not alter an LPA's ability to refuse planning applications. LPAs therefore had the option of substituting one form of 'penalised' restrictiveness (not meeting a delay target) with another 'non-penalised' form (refusing planning applications). Hilber and Vermeulen (2016) show that changes in the delay rate and changes in the refusal rate were uncorrelated before the delay rate targets were introduced but that the two measures become strongly negatively correlated afterwards. Our identifying assumption is that the reform had a differential impact on less and more restrictive LPAs: the most restrictive LPAs should have had the strongest incentives pre-reform (measured between 1994 and 1996) to delay residential applications and the strongest incentives post-reform (measured between 2004 and 2006) to reduce their delay rate by refusing more of them. We would not expect the change in the delay rate pre- vs. post-reform to directly (other than through regulatory restrictiveness) explain changes in contemporaneous build out-rates.

The third instrument is the vote share of the Labour party in the 1983 General Election (derived from the British Election Studies Information System). On average, voters of the Labour party have below-average incomes and housing wealth and they are significantly more likely to rent. Hence, we expect this group to care less about the protection of housing wealth, to be more likely to vote for politicians who favour a laxer planning environment and less likely to engage in lobbying against development. This suggests a negative correlation between the Labour vote share and local planning restrictiveness. Our identifying assumption is that the share of Labour votes affects construction duration only through its impact on local restrictiveness, after controlling for LPA-, developer-, and time-fixed effects.

The share of developable land already built-on in 1990 is potentially endogenous to local demand conditions. We adopt the strategy proposed by Hilber and Vermeulen (2016) and instrument the share of developed land in 1990 with the historic population density in 1911. The rationale is that population density in 1911 can be expected to be strongly correlated with time-invariant local amenities and the inherent productivity of a place, which in turn can be expected to be positively correlated with the share of developed land in 1990. Meanwhile, the direct impacts of these amenities and productivity on construction duration will be captured by the LPA-fixed effects. Historic population density can therefore be expected to only influence the site build-out rate through affecting the scarcity of developable land in 1990.

4.2. Econometric Specifications

Our baseline specification at the construction site level is:

$$Log(construction\ duration)_{ijkt^st^em^sm^e} = \beta_1 ACLE_{jt^st^e} + \beta_2 ACLE_{jt^st^e} \times \overline{refusal\ rate_j} + \beta_3 ACLE_{jt^st^e} \times \%developed_j + \beta_4 ACLE_{jt^st^e} \times market\ share_{ik} + X_i + D_j + D_k + D_{t^s} + D_{m^s} + D_{m^e} + \varepsilon_{ijkt^st^em^sm^e} \quad (9)$$

$Log(construction\ duration)_{ijkt^st^em^sm^e}$ represents the construction duration for site i, which is developed by developer k in LPA j, starts in month m^s of year t^s, and completes in month m^e of year t^e.[23] $ACLE_{jt^st^e}$ measures the annualized change in local employment in local authority j between year t^s and year t^e. We interact $ACLE_{jt^st^e}$ with the average refusal rate of major planning applications in LPA j,

[23] t^e represents the predicted completion year based on the site size.

$\overline{refusal\ rate_j}$, the share of developable land already developed in LPA j in 1990, $\%developed_j$, and developer k's local market share $market\ share_{ik}$.

All three measures of interest are in standardized form (i.e., normalized to the mean being equal to zero and the standard deviation being equal to one), so that the interpretation of the coefficients $\beta_1,\ldots,\beta_4$ is straightforward: β_1 captures the impact of a labour demand shock on the site build-out rate in an LPA with average supply constraints and developer competitiveness. The coefficients $\beta_2,\ldots,\beta_4$ capture the change in the impact of the local demand shock when the housing supply constraint or developer monopoly power increases by one standard deviation. We instrument for the interaction of the refusal rate and the interaction of the share developed by the interactions of the annualised change in local employment with the four instrumental variables discussed above.

In addition, we control for a wide range of site-level characteristics X_i including number of dwellings, share of public dwellings, share of flats, distance to CBD, average number of bedrooms per unit, and a dummy denoting whether there is a change of developer.[24] We include LPA fixed effects D_j, developer fixed effects D_k, year fixed effects D_{t^s}, start month fixed effects D_{m^s}, and completion month fixed effects D_{m^e} to control for time-invariant features at LPA-level, time-invariant characteristics for each developer (e.g. project management ability and the speed of decision making), the national macro trend, and the seasonality of real estate development respectively. Finally, we include weather and soil conditions[25] at the site level to control for within-LPA differences in geological and weather conditions. We cluster our standard errors at LPA-level to account for potential spatial correlation in construction duration.

Most – though not all – of our key explanatory variables of interest are LPA-specific and one could argue that because we exploit variation in these variables only at LPA-level, there is little benefit to estimating our baseline specification at site-level. Besides, the LPA is an important geographical unit for the local planning system and the estimation results at the LPA level are also quantitatively meaningful. Thus, to test for the robustness of our site-level estimation, we also estimate the impacts of supply constraints and developer monopoly power on the construction duration-local labour demand shock (LLDS) elasticity at the LPA level:

$$Log(construction\ duration)_{jt} = \beta_1 LLDS_{jt} + \beta_2 LLDS_{jt} \times \overline{refusal\ rate_j} + \beta_3 LLDS_{jt} \times \%developed_j + \beta_4 LLDS_{jt} \times market\ share_j + X_{jt} + D_t + D_j + \varepsilon_{jt} \quad (10)$$

$LLDS_{jt}$ is the natural logarithm of predicted local employment in local authority j in

[24] Occasionally we observe the change of developer within a construction site. This can be driven by either mergers and acquisitions of developers or the split of a large construction site into several smaller projects.

[25] We control for soil texture fixed effects which include 38 different types such as clayey, loam, peat, sand, and so on.

year t. $market\ share_j$ denotes the top 10 developers' market share in local authority j. We aggregate construction sites starting in year t in LPA j to create time-varying variables at the LPA level. $Log(construction\ duration)_{jt}$ is the average of construction duration in local authority j in year t, which is computed based on construction sites starting in year t in LPA j. X_{jt} denotes time-varying LPA-level features including the average size of sites, the average share of public dwellings on a site, the average share of flats, and the average number of bedrooms in local authority j in year t. We include LPA fixed effects D_j and year fixed effects D_t in the specification to control for time-invariant LPA-level unobserved features and the nation-wide macro trends respectively. We instrument for the two supply constraint interaction variables following the strategy discussed above. We also conduct a counterfactual analysis based on the estimates from specification (10) and the details will be discussed in section 4.4.

4.3. Baseline Estimation Results

Key explanatory variables (supply constraints and developer market power)

Table 3 summarizes our main findings for estimating equation (9). Columns (1) to (3) report results for naïve OLS specifications, sequentially adding additional controls: first only LPA-, year-, and month- fixed effects plus site characteristics, then developer fixed effects, and, finally, micro-location weather and soil condition controls. All observations are clustered at the 2001 LPA-level to account for potential spatial autocorrelation in construction duration.

The coefficients on the impacts of ACLE on construction duration are highly statistically significant and negative in all three columns. Column (3) implies that in an LPA with average supply constraints and average developer competitiveness, a 1 percentage point increase in local demand decreases construction duration by 2.7%. The coefficients on the ACLE-interaction with the refusal rate are positive and statistically significant in most specifications. Column (3), the most rigorous of the OLS specifications, implies if an 'average LPA' observes a one standard deviation increase in its refusal rate, a 1 percentage point increase in local demand will decrease the construction duration only by 1.5% instead of 2.7%. The coefficient on the ACLE-local market share interaction is also statistically significant and positive in most specifications. The coefficient in column (3) is 0.48, implying that a construction site with a one standard deviation higher market share than the mean level (all else equal) will see the speed of construction decrease by 2.2% instead of 2.7% as a consequence of a 1 percentage point increase in local housing demand.

The OLS specifications ignore endogeneity concerns related to the local regulatory restrictiveness and the share developed land measures. In columns (4) to (6), we estimate the same regression using Two-Stage Least Squares (2SLS), instrumenting the refusal rate-ACLE and share developed-ACLE interactions. As with the OLS specifications reported in columns (1) to (3), we sequentially add developer fixed effects and micro-location weather and soil conditions. Consistent with the OLS estimates, the coefficients on the refusal rate-ACLE, the share developer-ACLE, and the local market concentration-ACLE interactions are all positive and highly significant. Moreover, the Kleibergen-Paap F statistics do not indicate that weak identification is a problem.

Our most rigorous specification reported in column (6) suggests that a 1 percentage point increase in local demand increases the speed of construction by 2.7%. The estimated coefficient is almost identical to the one reported in column (3). Moreover, the estimated coefficients in column (6) reveal that the speed of construction only decreases by 0.8% (instead of 2.7%), 1.7%, and 2.1% respectively, if the refusal rate, the share developed and market concentration increase by one standard deviation, all else equal. These effects are thus not only statistically significant but also quantitatively very meaningful. We explore the magnitude of these quantitative effects further, in Section 4.4 below. The fact that the estimated coefficient, especially of the refusal rate measure, is larger in magnitude in the IV- than the OLS-specifications is moreover consistent with our argument that the confounding factors in the OLS specification are likely to lead to downwardly biased estimates of the impact of planning restrictiveness. We also include a wide range of site-level controls in column (6). We discuss the estimated results for these controls in detail in below.

We report the first-stage regression results, corresponding to columns (4) to (6) of Table 3, in Table 4. In all first-stage regressions, the share of Greenbelt land in 1973, the reform-based change in the delay rate, and the Labour party vote share correlate strongly and in the expected way with the refusal rate of major planning applications. In addition, the historic population density in 1911 has a positive and statistically significant correlation with the share of developable land already built-on in 1990.

Table 5 presents our OLS and IV estimates at the LPA-level. The estimates for our variables of interest are consistent with the construction-site level findings. Table 5 also documents that it takes longer to build sites with more dwellings, more bedrooms, and more flats, and it takes less time to build sites with more public units, perhaps because this facilitates interactions with LPAs or the motivations of social housing associations are not profit-driven. The corresponding first-stage results at the LPA-level are as expected and are shown in Table 6. Kleibergen-Papp F-statistics again do not reveal a problem with weak identification.

Additional controls

To provide further insights into the determinants of construction lags, we report the coefficients of our additional control variables in Appendix Table A2. Columns (1) to (3) report the coefficients of our OLS estimates and columns (4) to (6) report the results when we instrument for the potentially endogenous supply constraints. Our estimates for the control variables are robust across all six specifications.

Focusing first on site characteristics, we find that both the number of dwellings per site and the number of bedrooms per unit significantly increase construction duration. The estimated coefficient for the share of flats is negative and statistically significant, suggesting that conditional on the number of dwellings, it takes longer to build single-family houses rather than flats. We also find, not surprisingly, that if a site is constructed by multiple developers during the construction period, its build-out rate will be slower. This is likely due to potential planning adjustments and rearrangements and interruptions caused by the replacement of the developer. The estimated coefficient for the share of public units is negative and statistically significant, suggesting that sites with more public units tend to be constructed faster. As noted above this finding is plausible since such housing is typically constructed by housing associations. Besides, housing associations have guaranteed funding, use contractors with time penalties to build, and usually have 'pre-let' tenants to fill completed dwellings and so are not so dependent on market conditions in order to sell. We also find that spatial controls and micro-location weather characteristics matter in the expected ways. Table A2 shows that there is a positive and statistically significant correlation between a site's distance to the CBD and the construction duration, as housing demand tends to be higher for places closer to city centres. Meanwhile, we observe a negative and statistically significant association between temperature and construction duration, and a positive and statistically significant association between wind speed and construction duration. Overall, these latter findings suggest that spatial variation in weather conditions matters even within relatively small geographical units since our analysis controls for LPA fixed effects and hence, our weather variables only exploit variation within LPAs.

4.4. Quantitative Analysis

We conduct two separate counterfactual analyses. The first builds on our most rigorous baseline specification – column (6) of Table 3 – and is illustrated in Figure 14. Panel A of this figure uses individual site-level data[26] to show the distribution of the estimated impact of a 1 percentage point increase in our annualised demand shock-measure (ACLE) on construction duration. The mean ACLE-shock in our sample is 0.72 percentage points, but ranges from -2.36 percentage points to +3.27 percentage points (see Table 2). A 1 percentage point increase is thus a 'meaningful but not unusual' positive shock. As we measure construction duration in natural logs, we can interpret the change in the construction duration documented on the x-axis as a percentage change. Panel A shows that the vast majority of implied changes in the construction duration as a result of a positive 1 percentage point shock are negative, with the peak of the distribution being at around -4.5 percent (around -26 days for the average site), so a meaningful reduction in the construction duration.

Panels B to D report the additional (interaction) impact of local supply constraints – capturing the long-term supply price elasticity – and of the developer's local market share on the estimated effect of a 1 percentage point increase in the local demand shock on construction duration. The blue solid line in Panel B plots the implied effect on construction duration depending on the mean refusal rate in the LPA, holding the share developed land and the developer's market share constant at the sample mean. The line crosses the red-dotted zero-line at a refusal rate of around 0.3. The mean refusal rate in our sample is 0.19 and the standard deviation is 0.08 (see Table 2). This suggests that

[26] The coefficients reported in column (6) of Table 3 are estimated using a regression sample dropping singleton observations and covering slightly over 125k sites. We report implied quantitative effects for all the nearly 144k sites for which we have data (i.e., including the singleton observations).

for the majority of locations, a 1 percentage point increase in the ACLE-measure, reduces construction duration. However, 36 out of 353 LPAs have a refusal rate exceeding the cutoff of around 0.3. That is, in these about 10 percent of the most restrictive LPAs, holding the share developed land and the local market share constant at the sample mean, a positive demand shock actually increases the construction duration, consistent with our theoretical model. The grey dots in Panel B represent the site-level implied effects depending on the refusal rate, but taking account of the fact that the sites also vary in the share developed land and the developer's local market share.

Panel C and D conduct the same exercise as in Panel B, but for the share developed land and the developer's local market share respectively (holding the other measures constant – i.e., the solid blue line, or not – i.e., the grey dots). Panels C and D suggest that for the vast majority of sites, a positive demand shock reduces construction duration. However, at sites in more urbanized areas and with a higher market share, a positive demand shock is more likely to increase rather than to decrease the construction duration. All these estimated effects are consistent with our theoretical model, which predicts that the impact of a demand shock on construction duration can lead to 'speed up' or 'delay' depending on the long-term supply price elasticity and the developer's own market share in the local area.

Our second counterfactual analysis builds on the TSLS specification reported in Table 5. Our preferred specification is the most rigorous one reported in column (4). The specification yields a prediction of construction duration conditional on the local labour demand shock, supply constraints, developer market power, as well as LPA and year fixed effects.

We first obtain counterfactual scenarios by predicting local construction duration with supply constraints and developer market power set sequentially to zero. We then remove the independent effect of the LLDS, in order to identify the counterfactual construction duration holding constant all relevant local demand and supply measures. This exercise allows us to understand the quantitative importance of our variables of interest.

Removing all supply constraints and creating a setting with perfect competition in the residential construction market are of course unrealistic scenarios in practice. Hence, we explore an alternative exercise, where we remove one standard deviation of each of the two supply constraint measures and of the market power measure, sequentially. We first conduct this exercise for each LPA separately and then take the average of the predicted construction durations over all local authorities to derive a counterfactual scenario for the 'average' English LPA. To explore the relative importance of our variables of interest, we also conduct two exercises by separately removing supply constraints and market power, and by separately lowering these variables by one standard deviation.

The results of these quantitative exercises are summarised in Table 7. The corresponding Figures 15 and 16 illustrate the predicted construction duration between

1996 and 2015 for the 'average' English LPA under two scenarios: variables of interest set to zero and reduced by one standard deviation. Figure 17 illustrates the scenarios for a few distinctive LPAs that are known to have tight or comparably relaxed planning constraints: Westminster and Newcastle upon Tyne were the most and least restrictive markets with respect to regulating office space (Cheshire and Hilber 2008). Reading and Darlington represent a relatively restrictive and a relatively relaxed LPA (Cheshire and Sheppard 1995). The predicted construction durations are in logarithms to improve comparability.

Our exercises suggest a substantial impact of supply constraints and developer market power on construction duration. Panel A of Table 7 suggests that, based on our baseline estimates, in 2015 the pure construction duration (i.e., the time from start to finish of a project *post initial planning approval*) in the 'average' LPA in England (with average local demand shocks) would be 24 percent faster if the planning system were completely relaxed. Panel B then shows that reducing the restrictiveness by one standard deviation would lead to a 10 percent reduction in construction duration. If we reduced both supply-side constraints and the developer market power by one standard deviation, the construction duration in the 'average' English LPA in 2015 would be 23 percent lower. Regarding the relative importance of these variables, both panels C and D suggest that reducing regulatory restrictiveness would have a larger quantitative impact compared with reducing other variables in the 'average' English LPA.

As Figure 17 illustrates, the impacts of regulatory constraints, physical (scarcity related) constraints and developer market power, vary significantly across locations. Physical constraints matter most in the densely developed borough of Westminster, while regulatory constraints are most important in the prosperous town of Reading. In Newcastle and Darlington, supply constraints have a relatively small positive impact on the construction duration. In these locations, local developer market power is more important.

4.5. Additional Results and Robustness Checks

In this section, we carry out several additional exercises and robustness checks.

Public vs. private sites

This section explores the extent to which the impacts of supply constraints and developer market power on construction lags varies between public and private sites. These two types of sites are developed by companies with different aims: private sites are constructed by profit-maximizing developers, while public dwellings are usually developed by housing associations and local authorities who aim to provide more affordable housing in a local community. To explore this, we split our baseline estimation sites into two categories, public and private ones,[27] based on the share of public dwellings within each site. We then estimate these two subsamples separately and results are reported in Appendix Table A3. The findings of our preferred IV

[27] Private sites refer to sites with less than 50% public dwellings. Public sites refer to sites with more than or equal to 50% public dwellings.

estimates, reported in columns (1) and (2), can be summarised as follows. First, while the ACLE has a negative and statistically significant impact on private units' construction duration, this impact is insignificant for public units. As already noted, this is plausible given the differences between the two categories of developers. Second, in line with our baseline estimates, regulatory constraint-ACLE interaction has a positive and significant impact on construction duration, regardless of whether the site consists of predominately private or public units. Third, our estimate of the impact of local market power-ACLE interaction on construction duration is positive and statistically significant for private sites but it is less significant for public sites. We interpret this finding as further evidence showing that public dwellings are provided by developers with different incentives compared to private, profit maximising, developers. Local developer competitiveness is less significant for housing associations when they provide public housing to the local community compared with private developers.

Sites with different housing mixes

To explore whether the mix of housing types on a site matters for the impact of our variables of interest, we split our baseline estimation sites into two categories: single-family house-type sites and flat-type sites,[28] based on the share of flats within each site. We then estimate these two subsamples separately and our estimates are reported in Appendix Table A3. Columns (3) and (4) indicate that in line with our baseline results, the estimated coefficients for our variables of interest are positive and statistically significant, suggesting that regulatory supply constraints- and local market power-ACLE interactions have positive impacts on construction duration regardless of the site's housing mix. However, there is a quantitative difference between the flat-type estimate and the single-family house-type estimate. We find that flat-type sites are more responsive to local demand shocks compared with single-family house-type sites, as the estimated coefficient for ACLE is more negative in column (4) compared with column (3). This finding is plausible as flat-type sites are more likely to be located in city centres and purchased by investors and young professionals, who are more sensitive to market conditions. Conversely, single-family house-type sites are more likely to be purchased by households with children, who tend to be more stable in residence. In addition, the impact of regulatory constraints is more pronounced for flat-type sites compared with single-family house-type sites, potentially because flat-type sites have more complex structures, are associated with more negative externalities and may be subject to more complex ongoing planning-related negotiations. Therefore, existing homeowners have stronger incentives to oppose these projects and will put in more efforts to persuade local authorities to delay construction and changes may be more complex to negotiate.

Sites with different sizes

Construction sites with different sizes tend to have different building structures and are constructed by different types of developers. To study the heterogeneous effects of

[28] House-type sites refer to sites with less than 50% flats. Flat-type sites refer to sites with more than or equal to 50% flats.

supply constraints and developer monopoly power on construction lags for sites with different sizes, we split our baseline estimation sample into two sub-samples (small sites versus medium and large sites) based on the number of dwellings within each site. We re-estimate a specification similar to equation (9) using these two sub-samples separately. We exclude the developer market power-ACLE interaction in this exercise because the developer market share measure is highly correlated with the size of construction site.

Our IV estimates in columns (5) and (6) of Appendix Table A3 suggest the following. First, while local demand shocks measured by ACLE speed up the build-out rates of small sites, they do not have a significant impact on the construction duration of medium and large sites. The finding might be driven by the fact that large sites tend to have a pre-determined plan for build out and are thus not so influenced by short-term fluctuations in demand. Second, both regulatory constraint- and physical constraint-ACLE interactions have positive and statistically significant impacts on the construction duration across both subsamples. This finding is in line with our baseline estimates and indicates that the impact of supply constraints on construction duration is consistent and substantial regardless of site size.

Robustness check: The validity of the Bartik-type local demand shock measure

We then conduct the diagnostic analysis of our Bartik-type local demand shock measure following the tests suggested in Goldsmith-Pinkham *et al.* (2020). First, in our research context, a particular challenge to the exclusion restriction of the local demand shock measure is that employment in the construction sector might have a direct influence on construction duration via, for example, labour shortages. With reference to Acemoglu and Restrepo (2020), and Couture and Handbury (2020), we verify that our results are robust to dropping the construction sector from the computation of our local demand shock measure. Our estimated results are reported in Table A4. In line with Table 3, all the variables of interest have the expected signs and are statistically significant based on the IV specifications, suggesting that our main results are not driven by the trends in the construction sector. Second, one consideration when we apply the Bartik-type local demand shock measure is accounting for serial correlation in local housing market conditions. There could be local unobserved history that influences both housing demand changes and construction durations. A legitimate endogeneity concern is thus that our predicted local employment change may be correlated with such unobserved historical housing market conditions. Following Goldsmiths-Pinkham *et al.* (2020) and Baum-Snow and Han (2023), we estimate the pre-treatment effect of the local demand shocks at the LPA level. Results presented in Table A5 suggest small and insignificant relationships between the log difference in our predicted local employment and the pre-treatment trends in key endogenous variables including the average construction duration, the log difference in construction duration, and the house price growth. This pre-trend evidence suggests that our predicted local employment is unlikely to be correlated with unobserved historical housing market conditions in a way that biases our main estimates.

Robustness check: Time-varying local factors

We then take into account the impacts of time-varying local economic and social factors by controlling for different variables in our baseline specification. Columns (1) to (3) of Table A6 present our estimates when we include the local employment level, LPA interacted with year trends, and LPA interacted with year fixed effects, respectively, in our baseline specification. The estimated coefficients for our variables of interest are positive and statistically significant, suggesting that regulatory supply constraints- and local market power-ACLE interactions have positive impacts on construction duration even after we allow for potential confounding local trends and factors.

Robustness check: Selection of instrumental variables

In our baseline specification, we employ 3 separate instrumental variables jointly to identify the refusal rate: the share of Greenbelt land in 1973, the change in the delay rate, and the vote share of the Labour party in the 1983 General Election. One might be concerned that some of these instrumental variables may not be valid. In Appendix Table A7, we therefore report results for six alterations of our most rigorous baseline specification (column (6) of Table 3). The first three models drop one instrument at a time. Columns (4) to (6) then report estimates keeping only one of the three instruments at a time. The coefficients of interest remain stable across all six specifications, and the Kleibergen-Paap F-statistic suggests that weakness of identification is in general not a concern.

Robustness check: Alternative estimation period (between 1986 and 2018)

Next, we conduct an exercise to test for the robustness of our main findings with respect to the sample period. To do so, we re-estimate our baseline specification extending the sample period to the window '1986 to 2018'. The results for the extended window are reported in column (1) of Appendix Table A8. In line with Table 3, all the variables of interest have the expected signs and are statistically significant. These findings further support our baseline results and indicate that the impacts of supply constraints and developer market power are substantial over an even longer period of 33 years.

Additional robustness checks

We carry out four exercises to test for the robustness of our developer competitiveness estimates. At the site level, we draw a 10-km-radius buffer for each site but do not adjust the radius of the buffer based on LPA-level population density. We then compute each site's local market share using the constant 10-km-radius buffer and re-estimate equation (9) with this new measure of local market power. We report the findings in column (2) of Appendix Table A8. The estimated coefficient of the interaction between local market share and ACLE is positive and statistically significant. The estimates for our variables of interest are also quantitatively similar to our baseline estimates in Table 3. We next try to account for the role of existing home transactions, using housing transaction data from the Land Registry between 1996 and 2015 to create a local new build transaction ratio. This is defined as the total number of new build transactions divided by the total number of all housing transactions (i.e., new build transactions plus existing home transactions) at the LPA level. We then adjust the local market share measure used in the baseline specification by multiplying it with the local new build transaction ratio. This adjustment allows us to consider the potential effect of existing home transactions on a developer's market power. We then re-estimate equation (9) using this adjusted market share measure. Column (3) of Table A8 reports the results. All the estimates for our variables of interest are still statistically significant and in line with our baseline estimates in Table 3. In addition, at the LPA level, we use either the Herfindahl-Hirschman index or the top 5 largest developers' market share (instead of the top 10 largest developers' market share) within each LPA to measure developer competitiveness. We re-estimate equation (10) with either of these two new measures and the results are reported in Appendix Table A9. In line with Table 5, the estimated coefficients for the interaction terms between the Herfindahl-Hirschman index and LLDS and between the top 5 developers' market share and LLDS are positive and statistically significant in the OLS and IV specifications, suggesting that developer market power has a positive impact on the construction duration-LLDS elasticity.

We then exclude all the construction sites with one dwelling only in our baseline sample and re-estimate equation (9) to test for the robustness of our main results. The estimates are reported in column (4) of Table A8 and are in line with our baseline estimates in Table 3. We also exclude all the LPAs in Greater London Authority and re-estimate equation (9) to mitigate the endogeneity concern of unobserved spatial trends in this superstar city. Column (5) of Table A8 presents the estimated results, and the estimates for our variables of interest on ACLE, ACLE-regulatory supply constraint interaction, and ACLE-market power interaction are all robust. In addition, we use the actual start and completion dates of each construction site to re-compute the ACLE at the site level, and then apply the ACLE based on actual start and completion dates to re-estimate equation (9). As column (6) in Table A8 report, the estimates for our variables of interest are consistent with the baseline results.

Plot-level results

In our baseline estimation sample, some construction sites may experience a change of developer during their build-out periods, and one might argue that this issue might not be fully controlled for since we could only include one developer fixed effect at the site level. To address this concern and to further test for the robustness of our baseline results, we estimate a specification similar to equation (9) but at the dwelling level. Our estimated results, using over 2.37 million dwellings and controlling for the construction site fixed effects, are reported in Appendix Table A10. The estimated coefficients for our variables of interest are in line with the baseline findings and are robust across different specifications, suggesting that the main results are statistically consistent regardless of the level of observation used in our empirical analysis. In addition, Appendix Table A10 presents the estimates for the dwelling-level control variables. Both columns (2) and (4) suggest that private dwellings and dwellings with more bedrooms have a longer construction duration. The estimated coefficient for the flat dummy is positive and statistically significant, indicating that it takes longer, all else equal, to build flats than single-family houses. This may be because flat-type sites usually require more complex structures.

Year fixed effects and interest rate

Finally, we estimate the correlation between the coefficients of the year fixed effect dummies from our baseline specification and the real interest rate in the UK.[29] Panel A of Figure B3 shows there is a negative correlation with a correlation coefficient of –0.6881 based on the site-level specification, and Panel B of Figure B3 presents a correlation coefficient of –0.4592 based on the LPA-level specification. These findings are in line with our expectation. When the real interest rate increases, the financial costs of developers delaying construction will be higher, so developers will be less likely to slow down the site build-out rate.

5. Conclusion

In this paper, we offer a rare insight into the determinants of 'construction lags', defined as the rate at which construction sites are built out. We do this by analysing a unique and comprehensive dataset covering most residential developments in England between 1996 and 2015. We find that positive local demand shocks increase site build-out rates (i.e., reduce construction duration), but this impact is significantly reduced for sites located in places with more severe housing supply constraints and for sites constructed by developers with greater market power. Build-out rates on developments where public housing providers have a greater role are less affected. Our main results are consistent across different specifications and robustness checks.

Our empirical findings have important policy implications in that they suggest that the slow build out rate in England is the result of both market and policy failure. It is the result of market failure in that market power of developers in certain areas of the country contributes to a slower build out rate. It is the result of policy failure in that tighter planning restrictiveness in parts of the country further slows down the suite build out rate. An intriguing question for further research is whether the restrictive British planning system itself has led to a higher market concentration in the house building sector.

[29] The data on real interest rate in the UK comes from the World Bank.

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Tables

Table 1:
The Selling Price of Housing Units for a Representative Developer

	Developer 1 builds quickly	Developer 1 builds slowly
Scenario 1: No other developer builds quickly	$(1+\mu)X \cdot D\left(\frac{Q_1}{n}\right)$	$(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1+\frac{Q_1}{S}\right)$
Scenario 2: Among all the other developers, only one developer builds quickly	$(1+\mu)X \cdot D\left(\frac{2Q_1}{n}\right)$	$(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1+\frac{Q_1}{S}\right)$
Scenario 3: Among all the other developers, two developers build quickly	$(1+\mu)X \cdot D\left(\frac{3Q_1}{n}\right)$	$(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1+\frac{Q_1}{S}\right)$
……		
Scenario $n-1$: Among all the other developers, $n-2$ developers build quickly	$(1+\mu)X \cdot D\left(\frac{n-1}{n}Q_1\right)$	$(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1+\frac{Q_1}{S}\right)$
Scenario n: All the other $n-1$ developers build quickly	$(1+\mu)X \cdot D(Q_1)$	$(1+\mu)(1+\gamma\mu)X \cdot D\left(Q_1+\frac{Q_1}{S}\right)$

Table 2:
Descriptive Statistics (Baseline Sample)

	Observations	Mean	SD	Max	Min
Panel A: Construction site level					
Construction duration (days)	143856	574.48	498.7	7246	42
Annualized change in local employment (%)	143856	0.72	0.79	3.27	-2.36
Number of dwellings per site	143856	16.61	39.19	1369	1
Avg. number of bedrooms per dwelling	143856	3.24	1.99	296	0
Share of flats on the construction site	143856	0.17	0.35	1	0
Dummy - multiple developers	143856	0.01	0.1	1	0
Share of public dwellings	143856	0.12	0.31	1	0
Local market share (within a 10km buffer)	143856	0.08	0.15	1	0
Distance to CBD (km)	143856	11.88	6.62	45.75	0.05
Average temperature (Celsius)	143055	10.24	0.62	11.83	6.44
Average wind speed (metre per second)	143055	3.98	0.7	7.93	2.08
Panel B: Local Planning Authority level, panel data (N=353, T=20)					
Predicted local employment (1,000 people)	7012	60.97	49.93	499.32	4.15
Construction duration (days)	7012	608.82	219.62	3593	183
Avg. number of dwellings	7012	21.39	22.86	532	1
Avg. number of bedrooms	7012	3.17	0.77	33.66	1
Share of flats	7012	0.17	0.18	1	0
Share of public units	7012	0.14	0.16	1	0
Panel C: Local Planning Authority level, cross-section (N=353)					
Avg. refusal rate	353	0.19	0.08	0.43	0
% Developable land developed	353	0.26	0.23	0.98	0.01
Top 5 developers' market share	353	0.52	0.1	0.82	0.25
Top 10 developers' market share	353	0.68	0.1	0.96	0.39
Herfindahl-Hirschman index	353	0.08	0.04	0.28	0.02
Change in delay rate	353	-0.03	0.22	0.53	-0.63
Share of votes for Labour	353	0.16	0.09	0.41	0
Share of Greenbelt land in 1973	353	0.09	0.22	1	0
Population density in 1911	353	733.27	2561.63	22028.80	3.25

Table 3:
Baseline Estimation Results

Specifications	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)
	OLS	OLS	OLS	IV	IV	IV
ACLE [1)]	-3.493***	-2.730***	-2.686***	-3.530***	-2.767***	-2.720***
	(0.604)	(0.587)	(0.588)	(0.604)	(0.585)	(0.586)
Refusal rate × ACLE	0.294	1.123***	1.133***	0.728*	1.897***	1.892***
	(0.260)	(0.230)	(0.232)	(0.438)	(0.378)	(0.379)
% Developed × ACLE	0.147	0.329	0.348	0.570	0.985**	0.980**
	(0.312)	(0.294)	(0.293)	(0.427)	(0.455)	(0.448)
Local market share × ACLE	0.243	0.566***	0.483***	0.312*	0.683***	0.598***
	(0.164)	(0.149)	(0.152)	(0.172)	(0.156)	(0.159)
LPA FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Site characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Seasonality [2)]	Yes	Yes	Yes	Yes	Yes	Yes
Developer FEs	No	Yes	Yes	No	Yes	Yes
Weather controls	No	No	Yes	No	No	Yes
Soil conditions	No	No	Yes	No	No	Yes
Time Period	1996-2015					
N	143856	126090	125324	143856	126090	125324
R^2	0.318	0.573	0.575			
Kleibergen-Paap F				26.964	27.221	27.385

Notes: [1)] ACLE refers to the annualised change in local employment. [2)] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table 4:
First Stage Results

Specifications	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Refusal rate ×ACLE	%Developed ×ACLE	Refusal rate ×ACLE	%Developed ×ACLE	Refusal rate ×ACLE	%Developed ×ACLE
ACLE [1)]	0.054	0.063	0.039	0.054	0.038	0.053
	(0.054)	(0.053)	(0.055)	(0.053)	(0.055)	(0.053)
Change in delay rate × ACLE	-0.118*	-0.070	-0.116*	-0.069	-0.116*	-0.069
	(0.062)	(0.044)	(0.062)	(0.043)	(0.062)	(0.043)
% Labour vote in 1983 × ACLE	-0.619***	0.387***	-0.616***	0.398***	-0.616***	0.399***
	(0.050)	(0.052)	(0.050)	(0.053)	(0.050)	(0.053)
% Greenbelt in 1973 × ACLE	0.309***	0.073**	0.306***	0.067**	0.307***	0.068**
	(0.049)	(0.030)	(0.049)	(0.030)	(0.049)	(0.030)
Pop. density in 1911 × ACLE	0.150***	0.511***	0.148***	0.498***	0.148***	0.498***
	(0.049)	(0.067)	(0.049)	(0.065)	(0.049)	(0.065)
Local market share × ACLE	-0.060***	-0.041***	-0.058***	-0.041***	-0.059***	-0.041***
	(0.009)	(0.007)	(0.010)	(0.007)	(0.010)	(0.007)
LPA FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Site characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Seasonality [2)]	Yes	Yes	Yes	Yes	Yes	Yes
Developer FEs	No	No	Yes	Yes	Yes	Yes
Weather controls	No	No	No	No	Yes	Yes
Soil conditions	No	No	No	No	Yes	Yes
Time Period	1996-2015					
N	143856	143856	126090	126090	125324	125324
R^2	0.730	0.736	0.783	0.783	0.783	0.784

Notes: [1)] ACLE refers to the annualised change in local employment. [2)] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table 5:
Estimation Results at the LPA Level

Specifications	(1)	(2)	(3)	(4)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)
	OLS	OLS	IV	IV
LLDS [1)]	0.151	-0.221	-0.030	-0.456**
	(0.245)	(0.189)	(0.264)	(0.210)
Refusal rate × LLDS	0.268***	0.207**	0.638**	0.789***
	(0.103)	(0.081)	(0.254)	(0.209)
% Developed × LLDS	0.353***	0.234***	0.802***	0.554***
	(0.106)	(0.078)	(0.155)	(0.146)
Top 10 developers' market share × LLDS	0.398***	0.265***	0.613***	0.573***
	(0.133)	(0.097)	(0.181)	(0.150)
Log (number of dwellings)		0.210***		0.210***
		(0.007)		(0.007)
Avg. number of bedrooms per dwelling		0.018**		0.018**
		(0.008)		(0.008)
Share of flats		-0.111***		-0.127***
		(0.036)		(0.035)
Share of public units		-0.638***		-0.625***
		(0.031)		(0.032)
LPA FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Time Period	1996-2015			
Number of LPAs	353			
N	7012	7012	7012	7012
R^2	0.362	0.588		
Kleibergen-Paap F			15.276	15.412

Notes: [1)] LLDS refers to the natural logarithm of predicted local employment. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table 6:
First Stage Results at the LPA Level

Specifications	(1)	(2)	(3)	(4)
Dependent variable:	Refusal rate ×LLDS	%Developed ×LLDS	Refusal rate ×ACLE	%Developed ×LLDS
LLDS [1)]	0.079	0.175**	0.069	0.173**
	(0.066)	(0.083)	(0.066)	(0.083)
Change in delay rate × LLDS	-0.106**	-0.045	-0.105**	-0.044
	(0.053)	(0.051)	(0.053)	(0.051)
Share Labour vote in 1983 × LLDS	-0.349***	0.341***	-0.354***	0.339***
	(0.058)	(0.061)	(0.058)	(0.061)
Share Greenbelt in 1973 × LLDS	0.322***	0.081**	0.320***	0.078**
	(0.049)	(0.035)	(0.049)	(0.035)
Population density in 1911 × LLDS	-0.053	0.525***	-0.054	0.525***
	(0.062)	(0.057)	(0.062)	(0.057)
Top 10 developers' market share × LLDS	-0.419***	-0.019	-0.417***	-0.016
	(0.065)	(0.064)	(0.065)	(0.064)
LPA FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Other controls [2)]	No	No	Yes	Yes
Time Period	1996-2015			
N	7012	7012	7012	7012
R^2	1.000	1.000	1.000	1.000

Notes: 1) LLDS refers to the natural logarithm of predicted local employment. 2) Other controls include log (number of dwellings), avg. number of bedrooms per dwelling, share of flats, and share of public units. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table 7:
Effect of Shifts in LLDS on Construction Duration in Average English LPA
(Counterfactual Outcomes)

Variable	Value in 1996	Value in 2015	SD	Max	Min
Predicted construction duration (in days)	529	690	196	1536	355
Panel A: supply constraints, market power, and demand shock set to zero sequentially					
Predicted without any planning refusals	529	521	148	1159	268
- and share developed set to zero	529	478	136	1064	246
- and top developers' mkt. share set to zero	529	400	114	890	206
- and independent effect of LLDS removed	529	426	121	948	219
Panel B: supply constraints and market power lowered by 1 SD sequentially					
Predicted with refusal rate lowered by 1 SD	529	618	176	1376	318
- and share developed lowered by 1 SD	529	573	163	1274	295
- and top developers' mkt. share lowered by 1 SD	529	529	150	1177	272
Panel C: supply constraints and market power set to zero separately					
Predicted without any planning refusals	529	521	148	1159	268
Predicted with share developed set to zero	529	633	180	1409	326
Predicted with top developers' mkt. share set to zero	529	578	164	1285	297
Panel D: supply constraints and market power lowered by 1 SD separately					
Predicted with refusal rate lowered by 1 SD	529	618	176	1376	318
Predicted with share developed lowered by 1 SD	529	639	182	1422	329
Predicted with top developers' mkt. share lowered by 1 SD	529	637	181	1418	328

Figures

Figure 1:
The Role of Supply Constraints

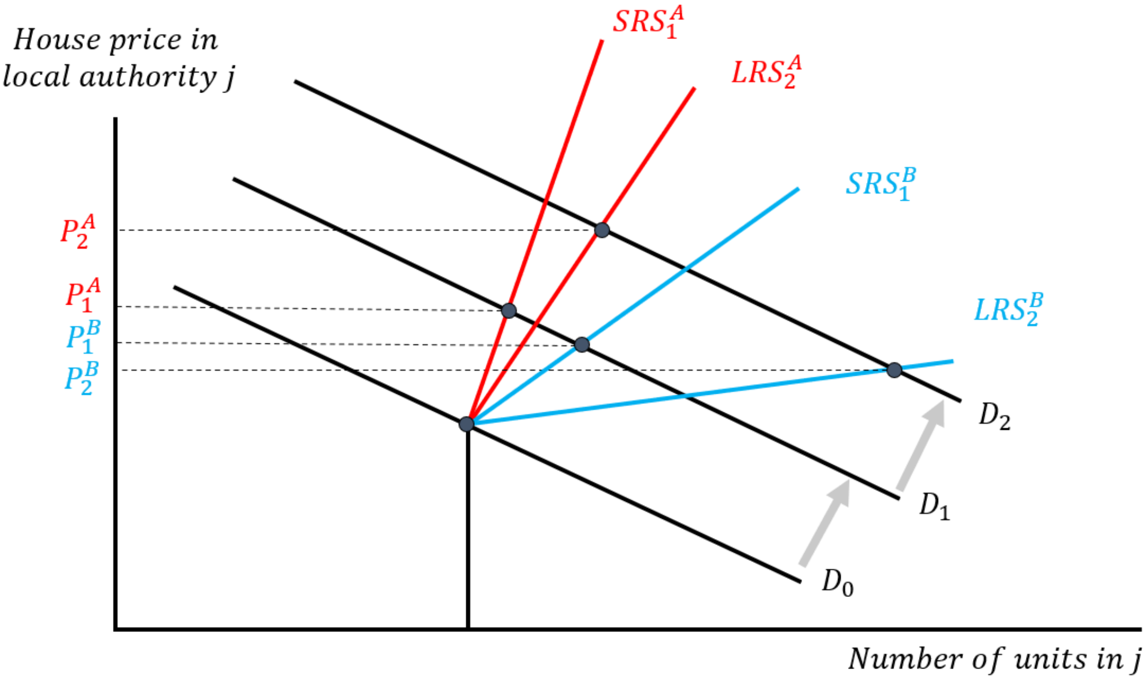


Figure 2:
The Role of Market Power

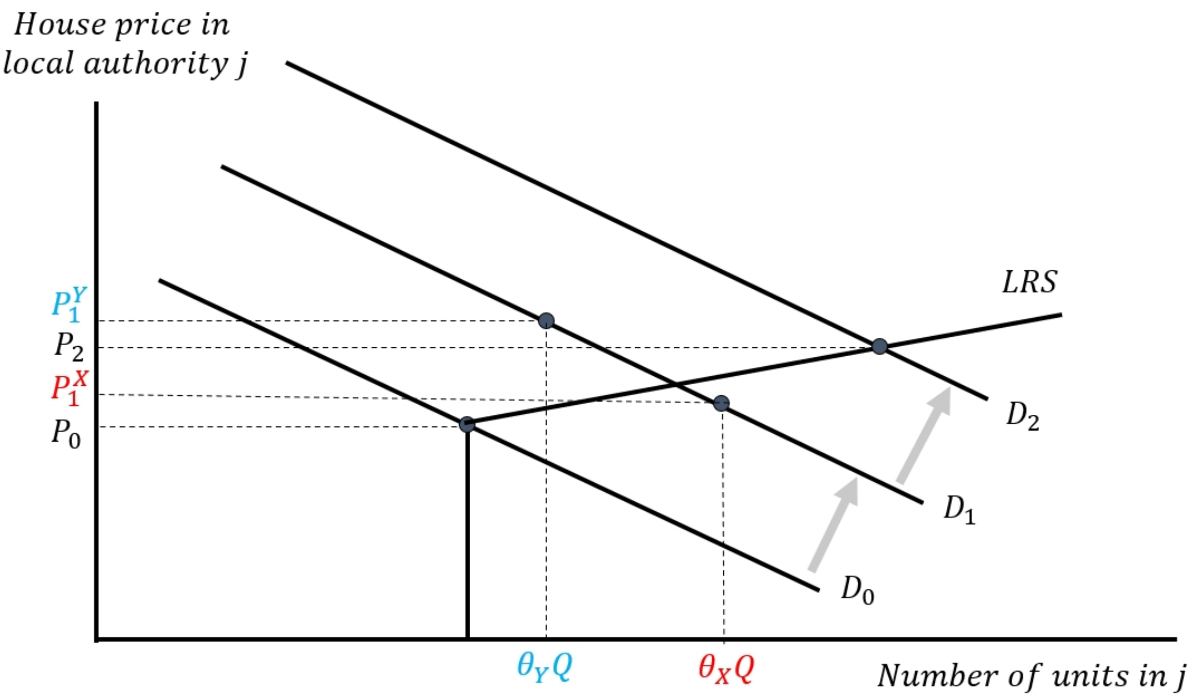
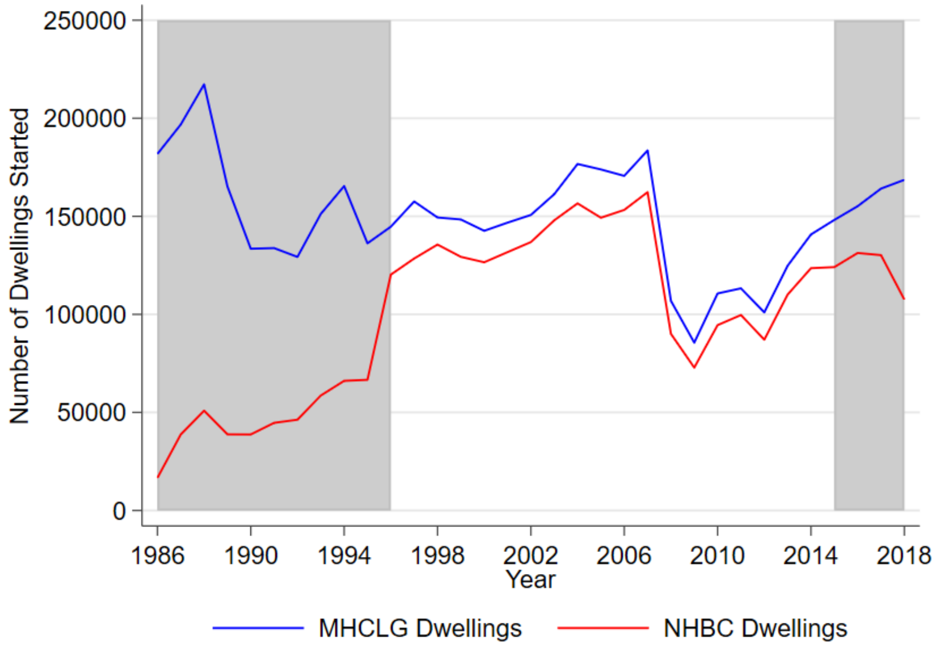
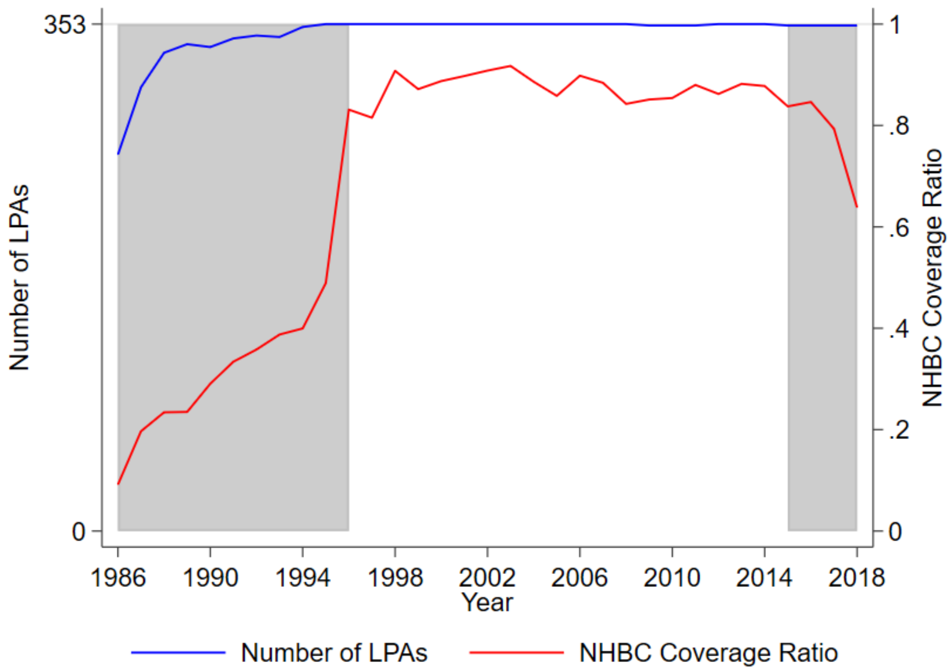


Figure 3:
NHBC and MHCLG Number of Dwellings



Notes: The shaded years (1986 to 1995, 2016 to 2020) are excluded from the baseline estimation sample. The major estimation period is between 1996 and 2015 (20 years in total).

Figure 4:
NHBC Coverage Ratio



Notes: NHBC coverage ratio represents the ratio of NHBC units relative to the units recorded by MHCLG. Number of LPAs denotes the number of local authorities in England that are covered in the NHBC dataset.

Figure 5:
Histograms

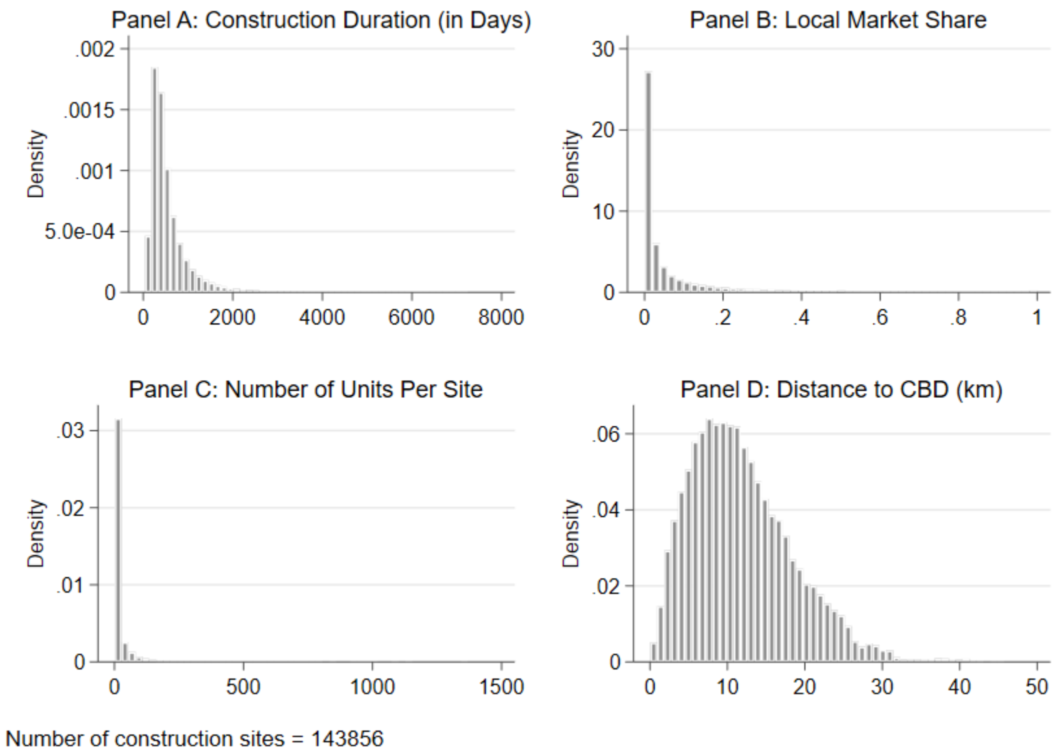
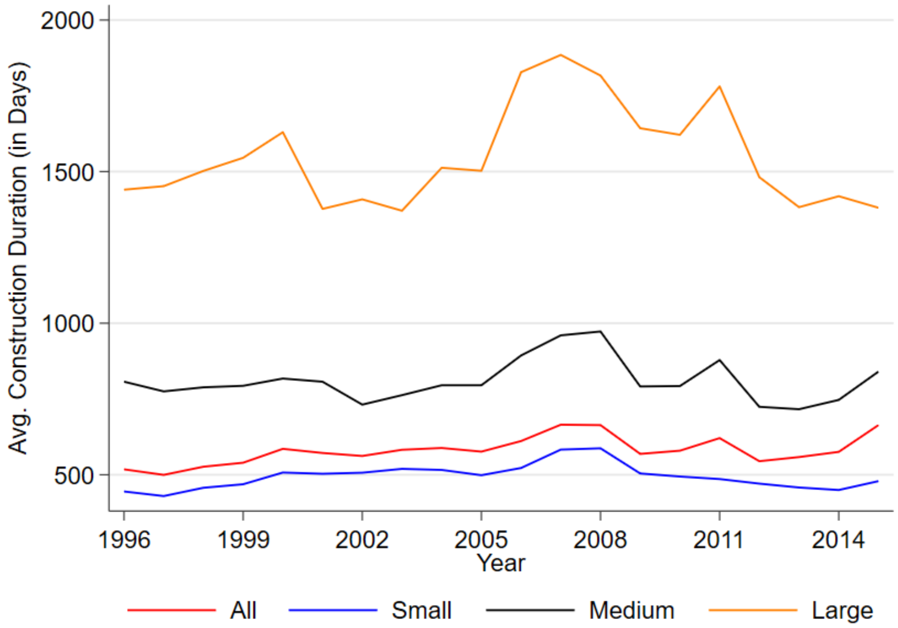
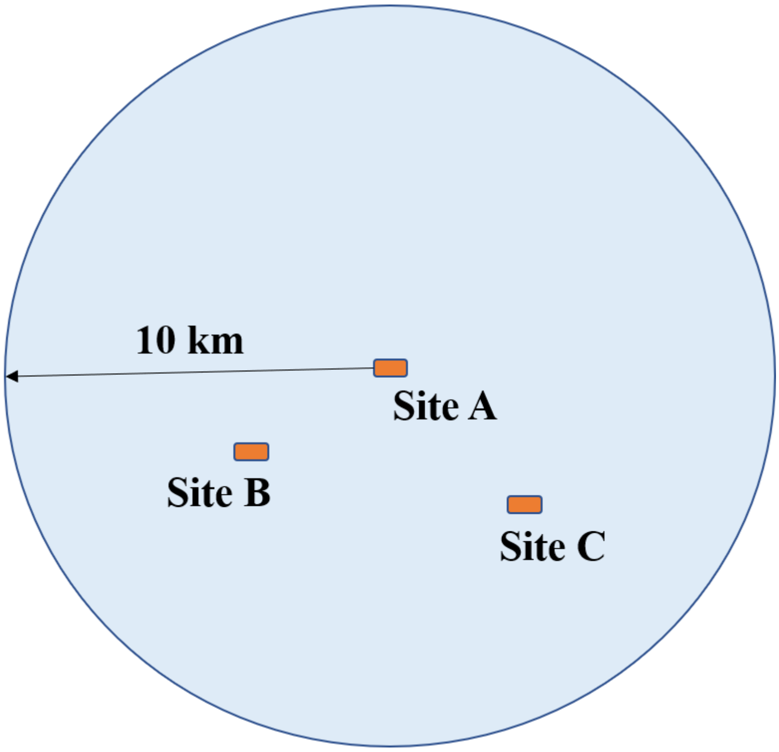


Figure 6:
Average Construction Duration in England



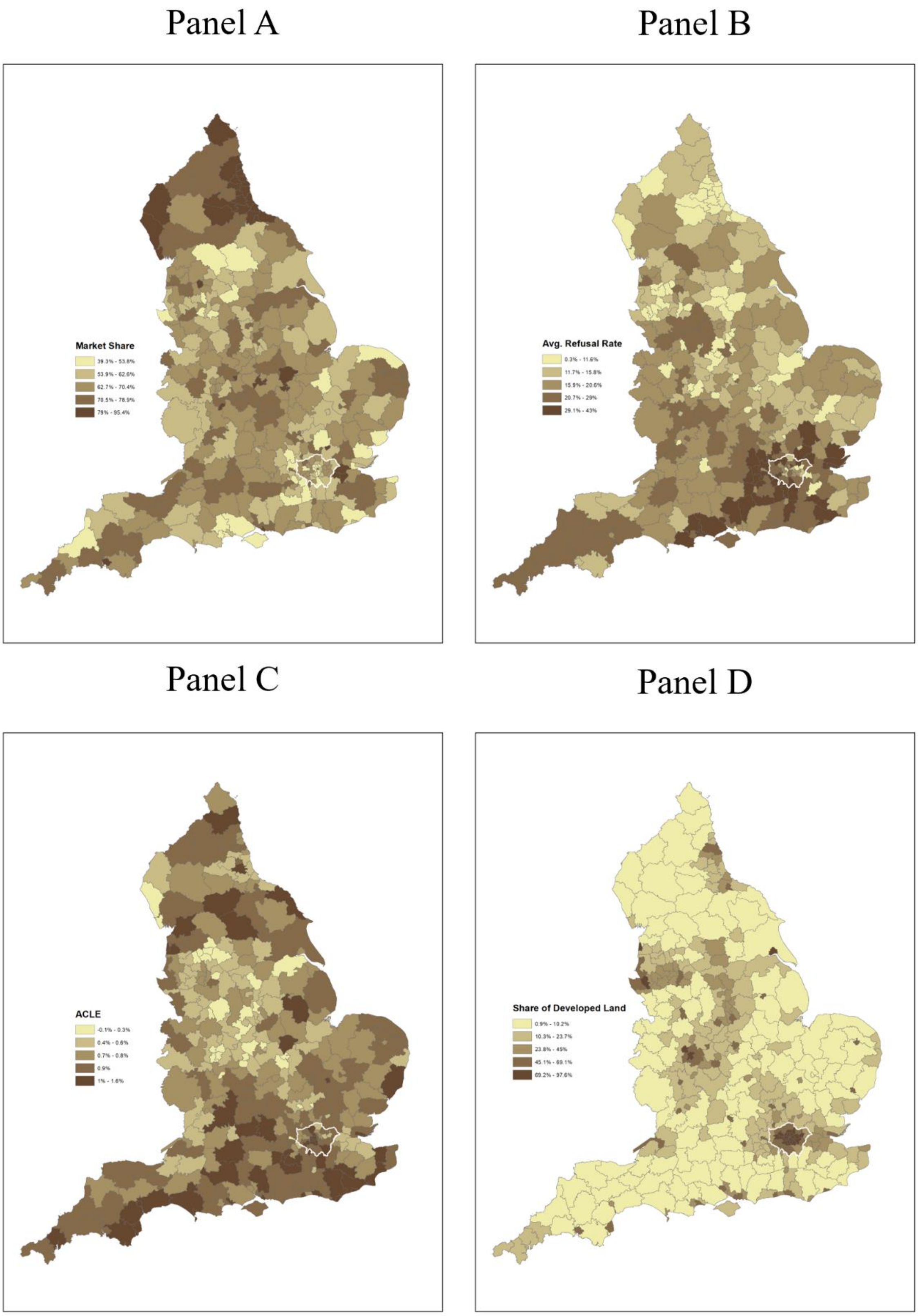
Notes: Small refers to projects with less than 25 units. Medium refers to projects with 25 to 100 unit. Large refers to projects with more than 100 units (Ball, 2011).

Figure 7:
Measure Local Market Share



Note: The radius of the circle is normalized based on LPA population density in 2001.

Figure 8:
Spatial Variations in Demand Shock, Supply Constraints, & Developer Market Power



Notes: The white line corresponds to the Greater London Authority boundary. Missing value for Council of the Isles of Scilly.

Figure 9:
Market Share and Herfindahl-Hirschman Index in England

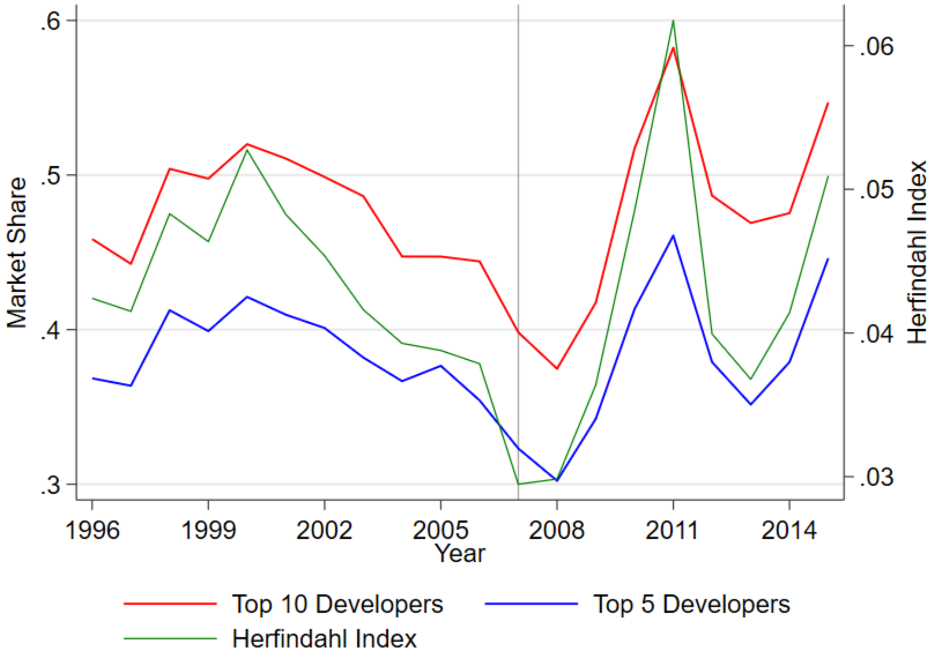
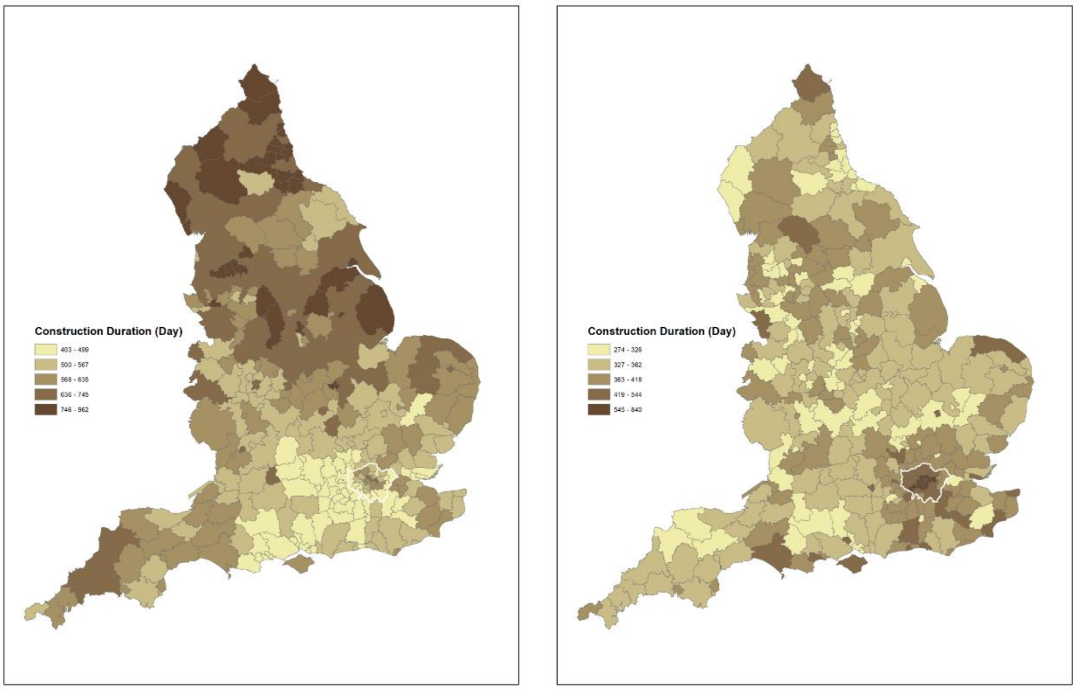


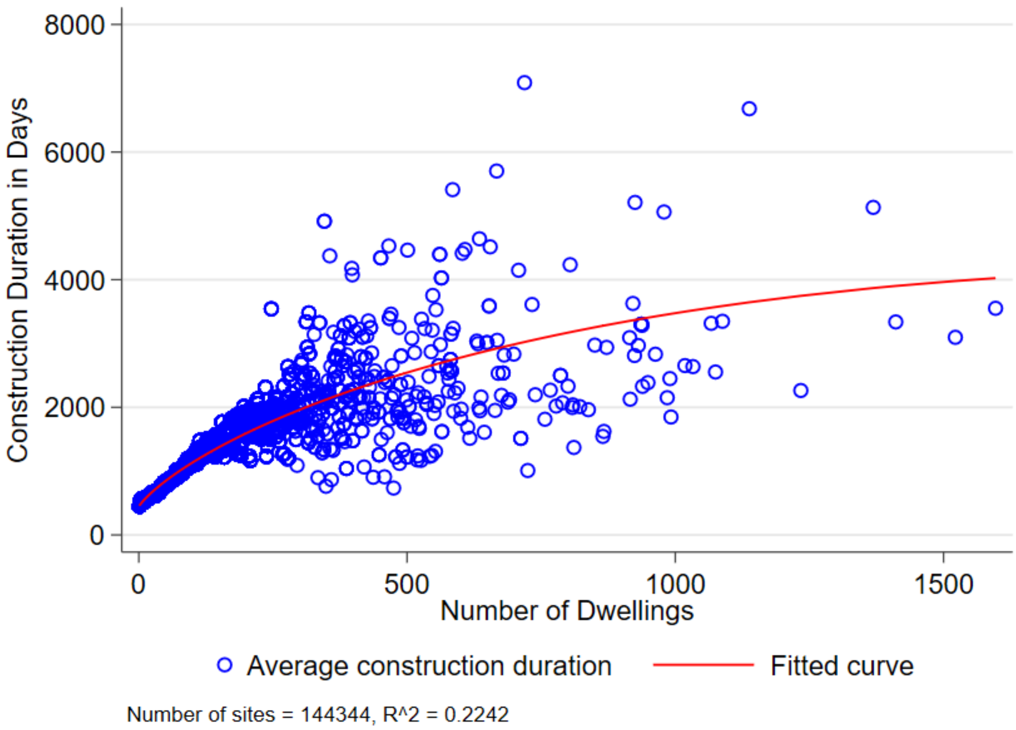
Figure 10:
Spatial Variations in Construction Duration

Panel A Panel B



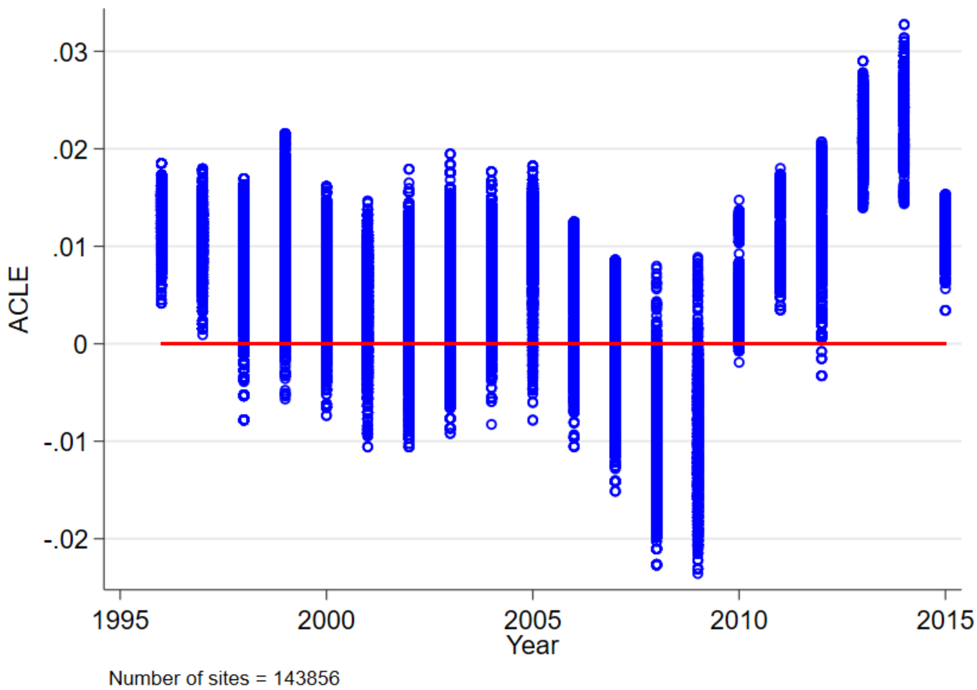
Notes: The white line corresponds to the Greater London Authority boundary. Missing value for Council of the Isles of Scilly.

Figure 11:
Predicted Construction Duration Based on Site Size for ACLE Calculation



Note: Each dot represents the average construction duration for a given site size.

Figure 12:
Time Trends of ACLE



Note: Each dot represents the ACLE for a construction site.

Figure 13:
Construction Duration, House Price, and Local Demand

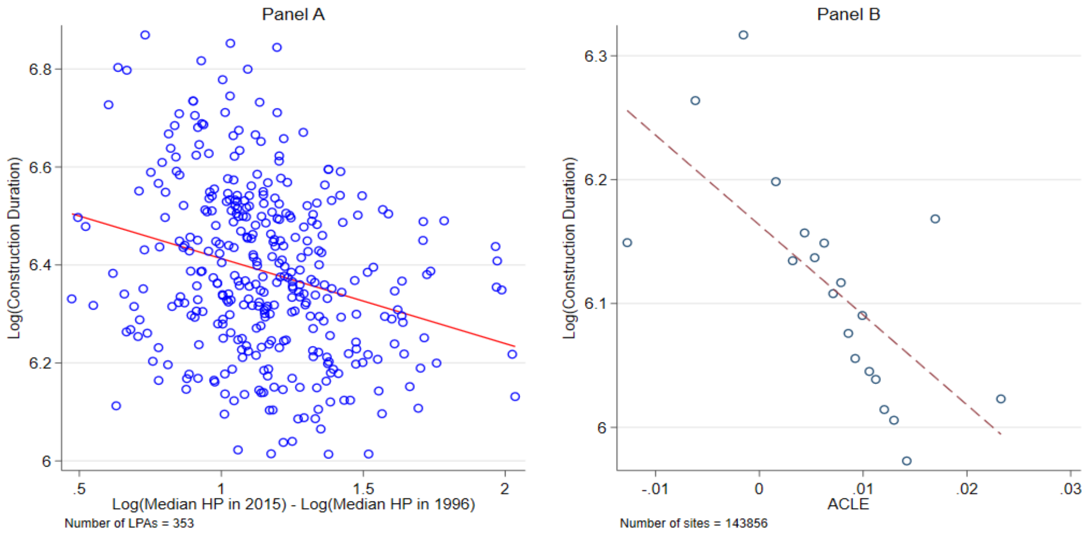
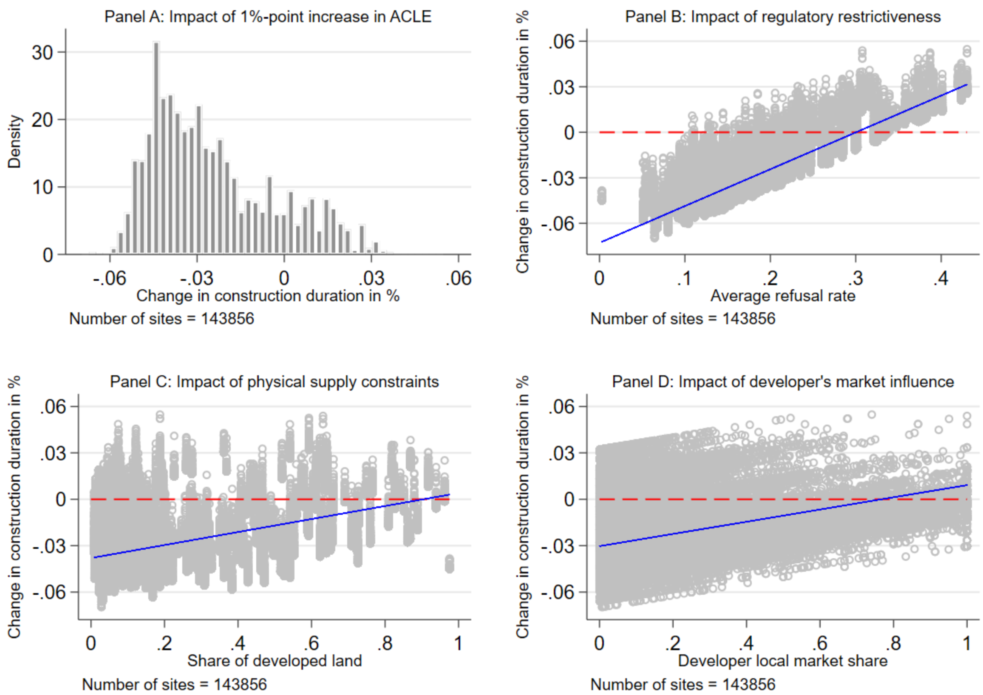


Figure 14:
Estimated Effect of Positive Demand Shock on Construction Duration and Interaction Effects of Supply Constraints and Developer's Market Influence



Notes: Using the estimates from column (6) of Table 3, Panel A measures the impact of a 1 percentage point increase in the ACLE, measured at site level, on construction duration, measured as a percentage change. The blue line in Panels B to D represents how the ACLE impact on construction duration changes with the focal variable on the X-axis, while holding the other variables constant at the sample average.

Figure 15:
Impact of Removing Supply Constraints and Developer Market Power on Construction Duration in Average English LPA

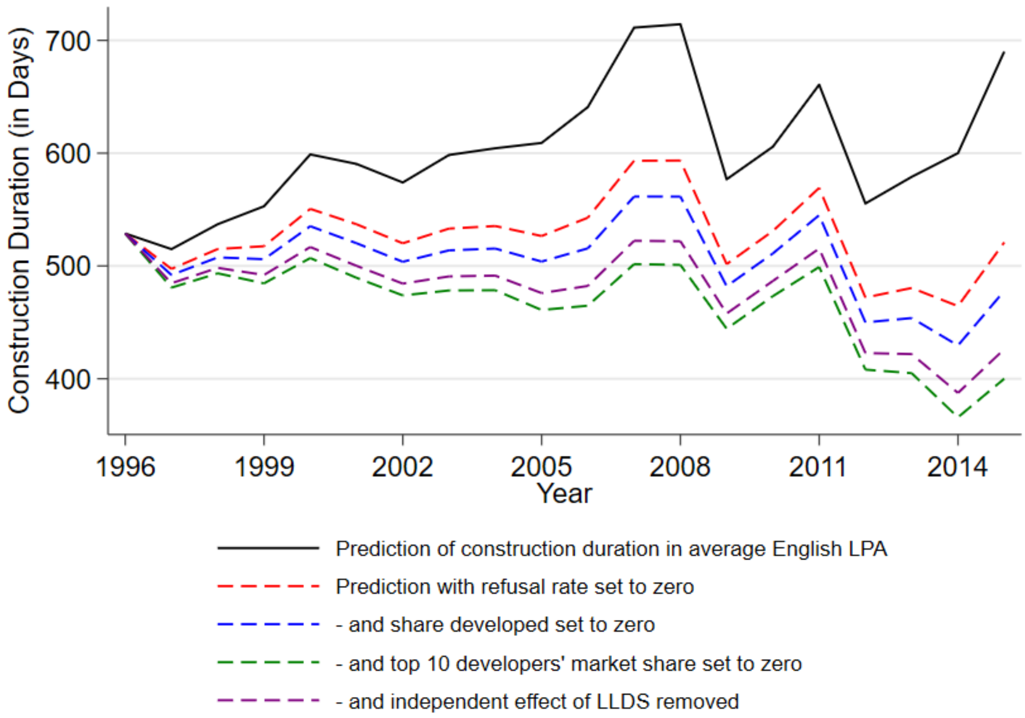


Figure 16:
Impact of Reducing Supply Constraints and Developer Market Power on Construction Duration in Average English LPA

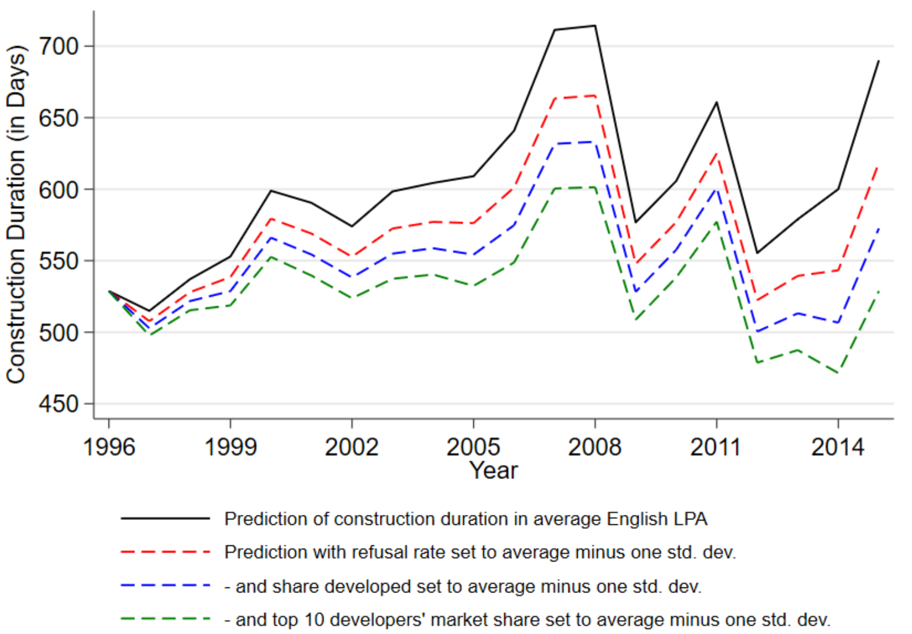


Figure 17:
Predicted Log of Construction Duration in Selected LPAs

Appendices

Appendix A: Appendix Tables

Table A1:
Top 10 Developers' Market Share in England Between 1996 and 2015

Rank	Developer name	Market share
1	Taylor Wimpey UK Limited	12.11%
2	BDW Trading Limited (Barratt)	11.52%
3	Persimmon Homes Ltd	7.96%
4	Bellway Homes Ltd	4.50%
5	Redrow Homes Ltd	2.37%
6	Galliford Try Plc	2.32%
7	Berkeley Group Plc	1.88%
8	Bovis Homes Ltd	1.87%
9	Crest Nicholson Residential Limited	1.84%
10	Westbury Homes (Holdings) Ltd	1.42%

Note: Top 10 developers account for 48% of all new dwellings in our estimation sample.

Table A2:
Baseline Results with Controls

Specifications	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)
	OLS	OLS	OLS	IV	IV	IV
ACLE [1]	-3.493***	-2.730***	-2.686***	-3.530***	-2.767***	-2.720***
	(0.604)	(0.587)	(0.588)	(0.604)	(0.585)	(0.586)
Refusal rate × ACLE	0.294	1.123***	1.133***	0.728*	1.897***	1.892***
	(0.260)	(0.230)	(0.232)	(0.438)	(0.378)	(0.379)
% Developed × ACLE	0.147	0.329	0.348	0.570	0.985**	0.980**
	(0.312)	(0.294)	(0.293)	(0.427)	(0.455)	(0.448)
Local market share × ACLE	0.243	0.566***	0.483***	0.312*	0.683***	0.598***
	(0.164)	(0.149)	(0.152)	(0.172)	(0.156)	(0.159)
Log (number of dwellings)	0.240***	0.350***	0.352***	0.240***	0.350***	0.351***
	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)
Avg. # of bedrooms	0.030***	0.030***	0.030***	0.030***	0.030***	0.030***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Share of flats	-0.212***	-0.218***	-0.214***	-0.212***	-0.218***	-0.214***
	(0.012)	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
Dummy – multiple developers	0.624***	0.578***	0.577***	0.624***	0.578***	0.577***
	(0.019)	(0.022)	(0.022)	(0.019)	(0.022)	(0.022)
Share of public units	-0.574***	-0.457***	-0.455***	-0.574***	-0.457***	-0.455***
	(0.013)	(0.015)	(0.015)	(0.013)	(0.015)	(0.015)
Log (distance to CBD)	0.023***	0.022***	0.015***	0.023***	0.022***	0.015***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Weather – temperature			-0.766***			-0.765***
			(0.092)			(0.092)
Weather – wind speed			0.053**			0.053**
			(0.023)			(0.023)
LPA FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Seasonality [2]	Yes	Yes	Yes	Yes	Yes	Yes
Developer FEs	No	Yes	Yes	No	Yes	Yes
Soil conditions	No	No	Yes	No	No	Yes
Time Period	1996-2015					
N	143856	126090	125324	143856	126090	125324
R^2	0.318	0.573	0.575			
Kleibergen-Paap F				26.964	27.221	27.385

Notes: [1] ACLE refers to the annualised change in local employment. [2] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A3:
Different Types of Development Projects

Specifications	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)
Project:	Private	Public	Houses	Flats	Small	Medium & Large
ACLE [1)]	-2.419***	-0.270	-2.468***	-3.808***	-2.911***	0.761
	(0.615)	(1.143)	(0.652)	(1.448)	(0.755)	(1.101)
Refusal rate × ACLE	1.999***	2.790***	1.661***	1.888**	0.964**	4.329***
	(0.402)	(0.736)	(0.387)	(0.938)	(0.384)	(0.884)
% Developed × ACLE	0.753	0.611	-0.009	1.559*	0.896**	1.586*
	(0.564)	(0.618)	(0.531)	(0.888)	(0.412)	(0.868)
Local market share × ACLE	0.416**	0.441*	0.524***	0.866**		
	(0.185)	(0.254)	(0.177)	(0.407)		
LPA FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Site characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Seasonality [2)]	Yes	Yes	Yes	Yes	Yes	Yes
Developer FEs	Yes	Yes	Yes	Yes	Yes	Yes
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
Soil conditions	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	1996-2015					
N	110116	14504	103211	19041	102083	22453
Kleibergen-Paap F	25.450	21.908	21.277	16.388	25.763	27.821

Notes: [1)] ACLE refers to the annualised change in local employment. [2)] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Only the IV specifications are included in this table. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A4:
Leave-out Approach (Construction Sector)

Specifications	(1)	(2)	(3)	(4)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)
	OLS	OLS	IV	IV
ACLE [1)]	-2.224***	-2.183***	-2.237***	-2.194***
	(0.605)	(0.605)	(0.602)	(0.601)
Refusal rate × ACLE	1.141***	1.148***	1.787***	1.783***
	(0.245)	(0.247)	(0.391)	(0.392)
% Developed × ACLE	0.414	0.435	1.129**	1.131**
	(0.308)	(0.307)	(0.474)	(0.467)
Local market share × ACLE	0.661***	0.575***	0.762***	0.674***
	(0.154)	(0.157)	(0.160)	(0.162)
LPA FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Site characteristics	Yes	Yes	Yes	Yes
Seasonality [2)]	Yes	Yes	Yes	Yes
Developer FEs	Yes	Yes	Yes	Yes
Weather controls	No	Yes	No	Yes
Soil conditions	No	Yes	No	Yes
Time Period	1996-2015			
N	126090	125324	126090	125324
R^2	0.573	0.575		
Kleibergen-Paap F			27.852	28.005

Notes: [1)] ACLE refers to the annualised change in local employment. In this exercise, we exclude the construction sector employment when computing the Bartik-type local employment measure. [2)] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A5:
Pre-Treatment Test

Specifications	(1)	(2)	(3)	(4)
Dependent variable	log (avg. construction duration, 1986-1995)	△log construction duration, 1986-1995	△log house price, 1986-1995	△log house price, 1974-1995
△log local employment, 1996-2015	0.208	0.032	0.099	0.144
	(0.242)	(0.962)	(0.224)	(0.158)
Region FEs	Yes	Yes	Yes	Yes
N	353	261	353	353
R^2	0.397	0.055	0.758	0.273

Notes: Standard errors are clustered at the region level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A6:
Baseline Specification Considering Local Time Varying Factors

Specifications	(1)	(2)	(3)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)
ACLE [1)]	-2.780***	-2.414***	-4.979***
	(0.587)	(0.580)	(0.786)
Refusal rate × ACLE	1.882***	1.908***	3.123**
	(0.376)	(0.378)	(1.207)
% Developed × ACLE	0.975**	0.934**	1.382
	(0.447)	(0.445)	(1.099)
Local market share × ACLE	0.597***	0.688***	0.681***
	(0.159)	(0.161)	(0.175)
LPA FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Site characteristics	Yes	Yes	Yes
Seasonality [2)]	Yes	Yes	Yes
Developer FEs	Yes	Yes	Yes
Weather controls	Yes	Yes	Yes
Soil conditions	Yes	Yes	Yes
Log (predicted local employment)	Yes	No	No
LPA × Year Trends	No	Yes	No
LPA × Year FEs	No	No	Yes
Time Period		1996-2015	
N	125324	125324	125212
Kleibergen-Paap F	27.405	27.370	29.562

Notes: [1)] ACLE refers to the annualised change in local employment. [2)] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Only the IV specifications are included in this table. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A7:
Selection of Instrumental Variables

Specifications	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)
	IV exclude change in delay rate	IV exclude share of labour party	IV exclude Greenbelt	Greenbelt only	change in delay rate only	share of labour party only
ACLE [1]	-2.718***	-2.738***	-2.736***	-2.736***	-2.736***	-2.743***
	(0.586)	(0.585)	(0.588)	(0.588)	(0.588)	(0.586)
Refusal rate × ACLE	1.852***	1.500***	2.349***	2.333**	2.353***	1.143**
	(0.391)	(0.463)	(0.511)	(0.982)	(0.559)	(0.469)
% Developed × ACLE	0.942**	1.175**	1.293**	1.294**	1.296**	1.188**
	(0.453)	(0.488)	(0.523)	(0.528)	(0.552)	(0.480)
Local market share × ACLE	0.591***	0.573***	0.662***	0.660***	0.662***	0.539***
	(0.159)	(0.161)	(0.165)	(0.186)	(0.167)	(0.160)
LPA FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Site characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Seasonality [2]	Yes	Yes	Yes	Yes	Yes	Yes
Developer FEs	Yes	Yes	Yes	Yes	Yes	Yes
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
Soil conditions	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	1996-2015					
N	125324	125324	125324	125324	125324	125324
Kleibergen-Paap F	35.210	12.737	26.560	7.482	33.718	14.414

Notes: [1] ACLE refers to the annualised change in local employment. [2] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A8:
Additional Robustness Checks

Specifications	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)	Log(lag)
Project:	Extended time period	10km buffer	Adjusted market share	Exclude one-unit sites	Exclude London LPAs	ACLE based on actual dates
ACLE [1]	-2.334***	-2.714***	-2.723***	-1.734***	-2.574***	-4.249***
	(0.489)	(0.586)	(0.587)	(0.667)	(0.617)	(0.531)
Refusal rate × ACLE	2.316***	1.892***	1.896***	2.116***	1.942***	1.836***
	(0.323)	(0.379)	(0.382)	(0.477)	(0.396)	(0.323)
% Developed × ACLE	2.253***	1.023**	0.961**	1.582***	0.368	1.309***
	(0.325)	(0.453)	(0.448)	(0.559)	(0.509)	(0.330)
Local market share × ACLE	0.414***	0.623***	0.568***	0.502***	0.558***	1.327***
	(0.144)	(0.164)	(0.166)	(0.167)	(0.160)	(0.179)
LPA FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Site characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Seasonality [2]	Yes	Yes	Yes	Yes	Yes	Yes
Developer FEs	Yes	Yes	Yes	Yes	Yes	Yes
Weather controls	Yes	Yes	Yes	Yes	Yes	Yes
Soil conditions	Yes	Yes	Yes	Yes	Yes	Yes
Time Period	1986-2018	1996-2015	1996-2015	1996-2015	1996-2015	1996-2015
N	150152	125324	125324	82936	113962	124893
Kleibergen-Paap F	23.296	26.996	27.420	26.786	17.560	28.314

Notes: 1) ACLE refers to the annualised change in local employment. 2) We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Only the IV specifications are included in this table. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A9:
Estimation Results at the LPA Level with Alternative Market Power Measures

Specifications Dependent variable:	(1) Log(lag) OLS	(2) Log(lag) IV	(3) Log(lag) OLS	(4) Log(lag) IV
LLDS [1)]	-0.281	-0.468**	-0.243	-0.477**
	(0.183)	(0.207)	(0.188)	(0.211)
Refusal rate × LLDS	0.230***	0.604***	0.208***	0.721***
	(0.077)	(0.172)	(0.080)	(0.195)
% Developed × LLDS	0.218***	0.434***	0.238***	0.538***
	(0.066)	(0.097)	(0.077)	(0.137)
Herfindahl-Hirschman index × LLDS	0.330***	0.484***		
	(0.087)	(0.095)		
Top 5 developers' market share × LLDS			0.301***	0.555***
			(0.099)	(0.137)
Log (number of dwellings)	0.210***	0.210***	0.210***	0.210***
	(0.006)	(0.006)	(0.007)	(0.007)
Avg. number of bedrooms per dwelling	0.018**	0.018**	0.018**	0.018**
	(0.008)	(0.008)	(0.008)	(0.008)
Share of flats	-0.109***	-0.119***	-0.110***	-0.125***
	(0.036)	(0.035)	(0.036)	(0.035)
Share of public units	-0.638***	-0.628***	-0.638***	-0.625***
	(0.031)	(0.032)	(0.031)	(0.032)
LPA FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Time Period	1996-2015			
Number of LPAs	353			
N	7012	7012	7012	7012
R^2	0.589		0.588	
Kleibergen-Paap F		27.131		17.184

Notes: [1)] LLDS refers to the natural logarithm of predicted local employment. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Table A10:
Estimation at the Dwelling Level

Specifications	(1)	(2)	(3)	(4)
Dependent variable:	Log(lag)	Log(lag)	Log(lag)	Log(lag)
	OLS	OLS	IV	IV
ACLE [1)]	-9.075***	-9.120***	-8.658***	-8.729***
	(0.957)	(0.942)	(0.974)	(0.956)
Refusal rate × ACLE	1.149**	1.080**	2.587**	2.389**
	(0.476)	(0.467)	(1.053)	(1.006)
% Developed × ACLE	1.248**	1.195**	2.128	1.935
	(0.590)	(0.558)	(1.379)	(1.299)
Local market share × ACLE	1.536***	1.516***	1.615***	1.577***
	(0.212)	(0.209)	(0.254)	(0.246)
Number of bedrooms		0.011***		0.011***
		(0.002)		(0.002)
Dummy – flat		0.142***		0.142***
		(0.005)		(0.005)
Dummy – public dwelling		-0.064***		-0.064***
		(0.007)		(0.007)
Year FEs	Yes	Yes	Yes	Yes
Construction site FEs	Yes	Yes	Yes	Yes
Seasonality [2)]	Yes	Yes	Yes	Yes
Time Period	1996-2015			
N	2370268	2370268	2370268	2370268
R^2	0.644	0.648		
Kleibergen-Paap F			24.052	24.037

Notes: [1)] ACLE refers to the annualised change in local employment. [2)] We control for the seasonality of real estate development by including both the start month and the completion month FEs in the specification. Standard errors are clustered at the LPA level. *, **, and *** represent 10%, 5%, and 1% significance levels, respectively.

Appendix B: Appendix Figures

Figure B1:
Average Size of Construction Site in England

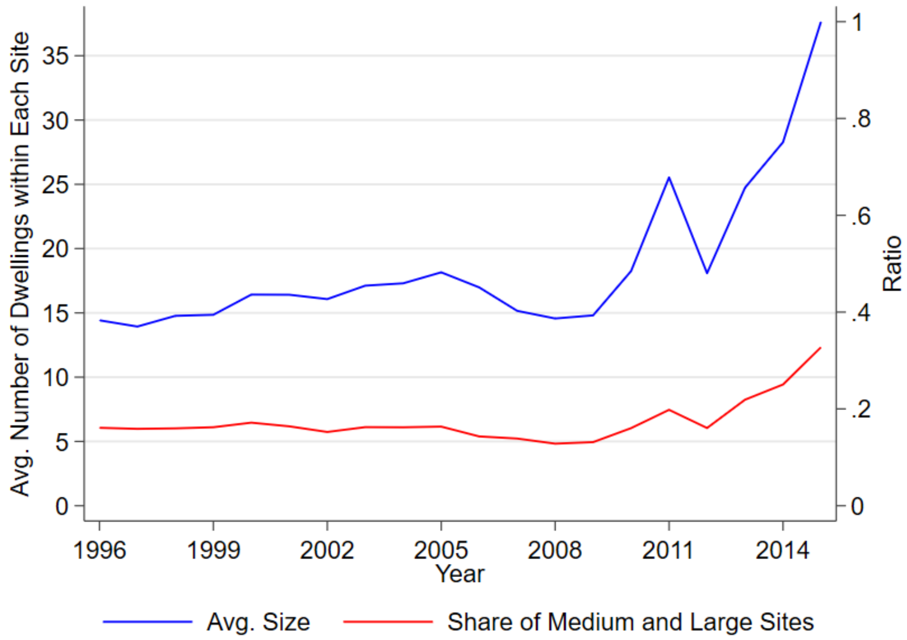


Figure B2:
Seasonality of Site Construction

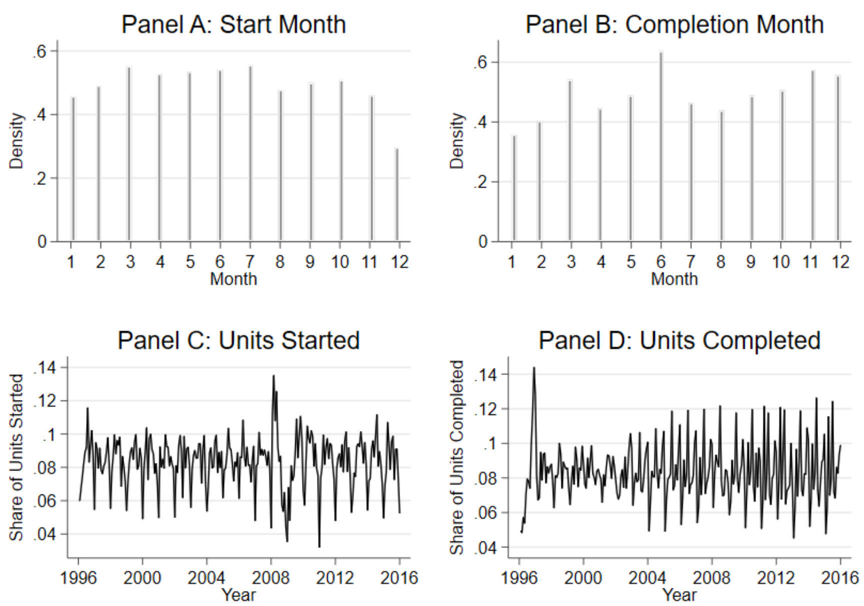
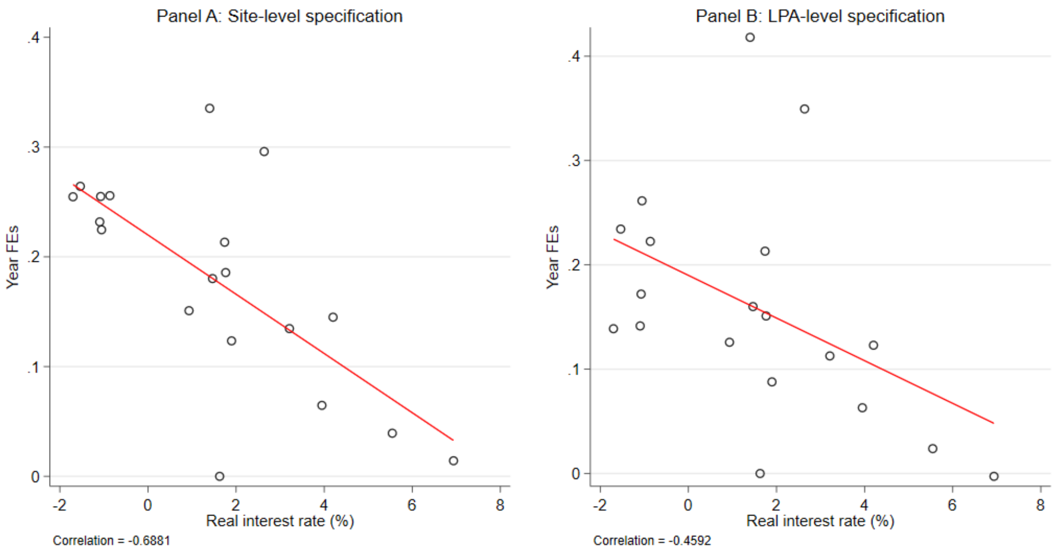


Figure B3:
Year Fixed Effect Estimates and Interest Rate



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