Housing Affordability and Economic Productivity

Estimating the Effect of Housing Affordability on Economic Productivity in the Greater London Area

27 September 2024

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1. Executive Summary

The new government has placed economic growth as its number one priority. The London Partnership Board identified London's housing crisis as a key issue for Londoners, which is also having a significant impact on the city's economic growth and productivity.

Housing affordability in London has deteriorated substantially over the past 20 years. Between 2002 and 2021, median house prices have grown twice as fast as wages in London, with potential adverse impacts on economic prosperity and social welfare.

Under the umbrella of the London Partnership Board, the Greater London Authority, London Councils, Trust for London, and the G15 network of major housing associations came together to commission research to model the relationship between housing supply and affordability and economic productivity. Following a competitive process NERA won the commission to undertake this work. An initial draft of the analysis and findings was presented at a workshop which included policy makers, practitioners, NGOs, and academics from various organisations specialising in housing and economics, and we thank the participants for their useful feedback that has been used to improve this report.

This study estimates the relationship between housing affordability and productivity. Using data from all local authorities in the Greater Southeast Region of England between 2002 and 2021 and by applying econometric methods, the study finds that declining housing affordability has had a significant negative effect on London's economic productivity.

Data sources

The analysis is carried out on 142 local authorities in the regions of London, the Southeast, and the East of England between 2002-2021. This wider area around London was selected to ensure a large enough data source and capture the interrelationships of the greater south east's housing market.

Housing affordability is measured as the median house price divided by median wage within a 20 km radius of each local authority.[1] Economic productivity is measured as GVA divided by number of employees in each local authority.[2]

Methodology

The data shows that worsening housing affordability has a negative effect on productivity when aggregate changes between areas and over time are taken into account (based on OLS regression).[3] However, this finding may underestimate the true effect due to reverse causality between productivity and housing costs as demand for housing is higher in more productive locations.

To address reverse causality, an Instrumental Variables (IV) approach is applied, using the share of greenbelt land as an instrument for increasing housing costs. It is harder to develop greenbelt land

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1 House prices are a proxy for housing costs and are highly correlated to private rental prices at the regional level.

2 GVA is a measure of the economic value generated by a sector and represents the difference between the value of goods and services produced by the sector (output) and the cost of inputs used in the production process (including raw materials, power and fuel, rental on buildings and business services).

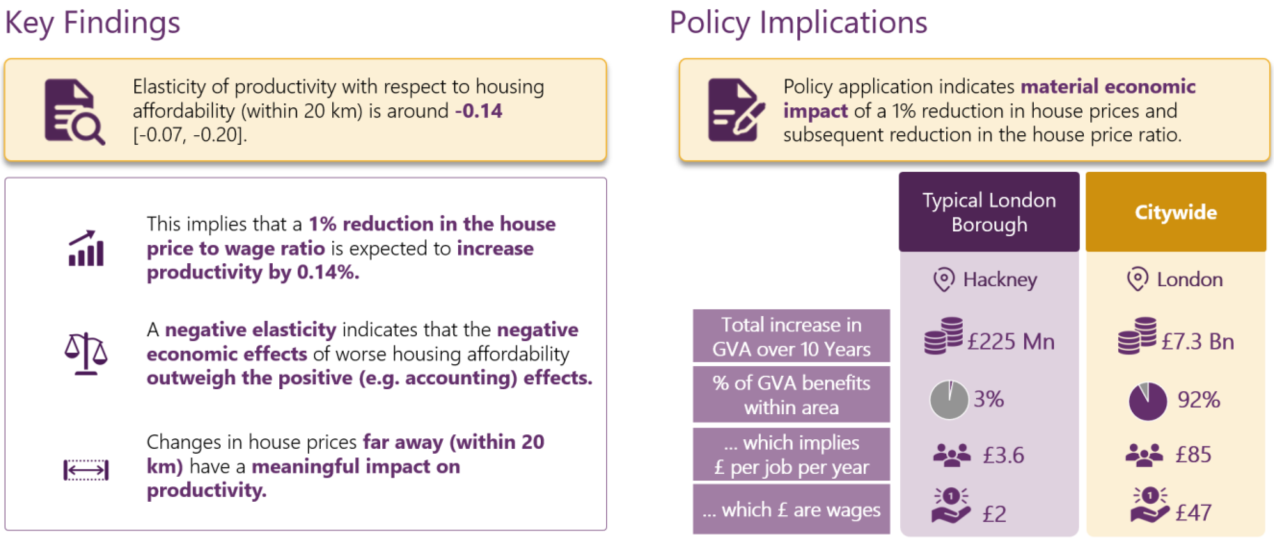
3 OLS regression, or Ordinary Least Squares regression, is a widely used statistical method that estimates the best-fitting line through a set of data points by minimising the overall distance between the line and the points.

due to planning (supply) constraints. Therefore, over time housing costs increase faster in areas with a higher share of greenbelt land. This is confirmed in other economic studies as well as in our data.[4]

Results

The key findings are summarised in Figure 1.1. Based on the IV approach, the estimated elasticity of productivity with respect to housing affordability is around -0.14 [with uncertainty bounds between -0.07 and -0.20] and is robust across various sensitivity checks. This implies that, on average, a 1% increase (worsening) in the house price to wage ratio within a 20 km radius results in a -0.14% reduction in productivity at the local authority level.

Figure 1.1: Summary of Key Findings and Policy Implications



Source: NERA analysis.

Applying the elasticity estimate to a targeted policy application demonstrates that a 1% reduction in house prices and subsequent improvement in affordability in a typical London borough (Hackney),[5] compared to the existing trend, could result in an undiscounted increase in GVA of approximately £225 million over 10 years in the local authority and the surrounding areas. Given the large number of jobs within the 20 km radius surrounding Hackney (6.3 million), this corresponds to an increase of £3.60 per job per year, of which approximately £2 would result in improved wages. Furthermore, most of the total GVA benefits (97%) occur due to improvements in productivity outside the local authority where house prices changed.

Considering the same targeted policy in a typical inner London (Islington) and outer London (Bromley) borough implies an increase in GVA of approximately £226 million over 10 years (undiscounted) or £3.60 per job per year (£2 wages) in Islington and the surrounding areas, and an increase in GVA of approximately £133 million over 10 years (undiscounted) or £3.70 per job per

4 See e.g. Koster, H. R. (2024). The Welfare Effects of Greenbelt Policy: Evidence from England. The Economic Journal, 134(657), 363-401.

5 Hackney is selected as a typical London borough based on similarities in productivity, house prices, and the house price to wage ratio to London averages.

year (£2 wages) in Bromley and the surrounding areas. Similarly to the case of Hackney, most of the GVA improvements (95%) occur outside the local authorities where house prices change.

Applying the elasticity to a citywide policy indicates that a 1% reduction in house prices in all London boroughs is expected to result in an increase in GVA of approximately £7.3 billion over 10 years (undiscounted) or £85 per job per year, of which £47 are wages. In this case however, the benefits do largely materialise within the London region (92%), as the productivity impacts within 20 km are minor outside of London.

In either the targeted or citywide policy application, the benefits would have to be compared to the costs of the policy intervention (as well as any other societal benefits of lower housing costs) to assess the net impact of improved housing affordability.

These findings highlight the importance of housing affordability in relation to productivity and provide a quantitative estimate of the potential economic benefits from policies and initiatives aimed at improving affordability in the Greater London Area. The findings also indicate the very large external effects on productivity in surrounding local authorities from targeted housing policy interventions. This provides an economic rationale for regional government bodies (rather than just individual local authorities) to be involved in housing supply decisions that affect housing prices and affordability.

Further research

In the process of carrying out this study, several potential extensions to the approach and application were identified. Extensions to the approach could include assessing the impact of housing affordability at the sectoral level, capturing commuting areas based on travel times, considering other metrics of housing affordability, exploring other relevant control variables, and considering other plausibly valid instrumental variables. Meanwhile, extensions to the application could include extending the scope of the analysis nationally or to other UK cities, carrying out international benchmarking, assessing the contribution of housing affordability to stagnating productivity, disentangling the economic mechanisms, and building the evidence base for the effectiveness of housing policy on affordability. Overall, these extensions would be valuable to provide more detailed insights and a broader policy perspective.

2. Overview

In this section we outline the context of this project (Section 2.1), the mechanism for the relationship we are interested in exploring empirically (Section 2.2), the key requirements (Section 2.3), and the structure of the subsequent report (Section 2.4).

2.1. Context

The London Partnership Board and Commissioning Partners (which include the Greater London Authority (GLA), London Councils, Trust for London, and the G15 network) are exploring various options to fulfil a Mayoral commitment to make housing in Greater London more affordable. This hinges on developing an evidence-based economic case to support housing-related interventions. Part of the case building involves empirically estimating the effect of unaffordable housing on London's economic productivity and growth so that the impact of relevant policy and programme interventions can be forecast.

This type of analysis could be done at three different levels:

1. **The first level ('Level 1')** would be to generate an overall relationship between housing affordability and productivity.
2. **The second level ('Level 2')** would be focused literature reviews and analyses on some or all the specific mechanisms linking housing affordability to productivity.
3. **The third level ('Level 3')** would be specific pieces of analysis evaluating the impact of £Xmn per annum investment in different types of housing stock. For example, this could examine the extent to which an intervention to lower housing costs in a particular area in London is expected to lower housing costs and thereby affect productivity.

In this report, we focus on Level 1 analysis because this is most aligned with the London Partnership Board's immediate requirements and also provide a methodology for, and illustrative example of, how to apply the estimate in a Level 3 type analysis.

2.2. Mechanism for Key Relationship

Housing affordability can negatively impact economic productivity via several channels, such as:

1. **Spatial Mismatch**. High housing costs in productive urban areas limit workers ability to move closer to high-productivity jobs, leading to longer commutes and reduced labour mobility.[6] Skilled workers and potential innovators may leave high productivity but expensive cities, depriving these areas of human capital that drives productivity growth, while low-skilled workers may be forced out of expensive cities, leaving these areas with a labour shortage. This spatial mismatch between affordable housing and job opportunities erodes benefits of labour matching present in dense urban areas and reduces the positive productivity effects of

[6] All types of jobs (high and low skilled) may be affected if there is spatial mismatch, e.g. lawyers, bankers, and policymakers, as well as teachers, healthcare workers, and cleaners will be less productive if they cannot work in their most productive locations due to high housing costs.

agglomeration economies.[7] Longer commutes may also reduce productivity by cutting into available working hours and causing fatigue.

2. **Consumption Constraints**. High housing costs, especially for lower income individuals and renters, leave households with less disposable income to spend on other goods and services, such as healthy food, access to exercise facilities, and training and education, reducing overall demand as well as the consumption of productivity enhancing goods and services (such as educational training and physical exercise).[8]
3. **Capital Misallocation**. Rising property prices may result in unproductive firms continuing to operate. If firms that own property benefit from higher property prices as their assets appreciate in value, this allows them to produce less efficiently while still having opportunity to expand their market share at the expense of more productive firms that do not own property. This reallocation of resources to less productive firms can lead to a decrease in overall aggregate productivity.[9]
4. **Diversion of Investment**. Channelling large sources of debt into housing stock, an asset with relatively low productivity growth compared to other capital investments such as machinery and technology, can impair productivity gains.[10]

However, there may also be reasons why higher housing costs increase productivity. For example, GVA per worker may increase if people have to work longer to afford higher house prices (however GVA per hour worked may be unaffected or may even be negative). Furthermore, GVA includes rental income, so on a purely accounting basis, it is possible that higher housing costs result in higher GVA and productivity.

2.3. Key Requirements

The approach to quantifying the impact of housing affordability on productivity needs to:

1. Strike an appropriate balance between rigour and certainty on the one hand and simplicity on the other (given the available data and the time available).
2. Generate insight into whether, and if so, to what extent housing affordability in the London area affects productivity.
3. Make best use of, and build on, existing best available data and modelling approaches.
4. Be transparent, accessible, and readily auditable.

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7 Economics Observatory (2023). How does the housing market affect UK productivity? Available at: https://www.economicsobservatory.com/how-does-the-housing-market-affect-uk-productivity

8 Economics Observatory (2023).

9 Doerr (2020). Housing booms, reallocation and productivity. BIS Working Papers. Available at: https://www.bis.org/publ/work904.htm

10 Gholipour, Farzanegan, and Abu Al-Foul (2023). House prices and labour productivity growth: Evidence from OECD countries. Construction Management and Economics. Available at: https://www.tandfonline.com/doi/full/10.1080/01446193.2023.2291082#d1e149

2.4. Structure of the Report

The remainder of the report is structured into five main sections, with two supporting appendices:

1. Section 3 covers the key issues that need to be addressed in order to obtain a credible estimate of the effect of housing affordability on productivity.
2. Section 4 outlines the econometric model we use to address the key empirical and data issues.
3. Section 5 describes the data we have obtained and presents descriptive statistics.
4. Section 6 presents the main results of the effect of housing costs on productivity and the sensitivity checks carried out.
5. Section 7 provides a methodology to apply the results obtained to develop the economic case for housing investment in London.
6. Appendix A provides additional details on the methodological approach and data available.
7. Appendix B provides the full set of regression tables and results.

3. Key Issues that Need to be Addressed

In order to estimate the effect of housing affordability on productivity we need to overcome several conceptual and empirical challenges. Section 3.1 outlines the issue of measuring productivity and housing affordability. Section 3.2 explains why we cannot apply simple OLS regression techniques, Section 3.3 discusses the level at which housing costs may affect productivity, and Section 3.4 outlines why we consider the wider geographical area of the Greater Southeast Region.

3.1. Measuring Productivity and Housing Affordability

There are various metrics for productivity and housing affordability in the UK. The choice of which data metric to use is important because different variables may have different relationships which may in turn impact the final estimates we obtain and the applicability of the results. Therefore, we will need to carefully select and decide upon which key variables to analyse to ensure that we obtain the most useful and reliable estimate of housing affordability on productivity.

3.1.1. Productivity

Economic productivity is commonly defined as a ratio between the volume of output and the volume of inputs. The OECD explains that productivity "*measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output*".[11] Given that outputs and inputs can be defined in various ways, there are various forms of how productivity can be measured, which can usually be broken down into three categories:

- **Labour Productivity**. Measures the efficiency with which labour inputs are used in the production process and can be calculated by dividing total output by labour inputs.
- **Capital Productivity**. Measures the efficiency with which capital inputs, such as machinery, equipment, and infrastructure, are utilised in the production process and can be calculated by dividing the total output by the value of capital inputs.
- **Multifactor Productivity**. Measures the efficiency with which multiple inputs, including labour, capital, and other factors of production, are combined to produce output (often also called Total Factor Productivity or TFP). It captures the overall technological progress and efficiency gains in the production process that cannot be attributed to labour or capital inputs alone and is generally estimated using econometrics.

The most applied and well-known metric of productivity is labour productivity as measuring inputs in terms of labour is generally straightforward and data is relatively available. We therefore focus on labour productivity in this report. The two main components of labour productivity are GDP or GVA (Gross Value Added)[12] and a measure of employment (such as hours worked or number of employees).

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11 OECD (2024). Compendium of Productivity Indicators. Available at: https://www.oecd-ilibrary.org/industry-and-services/oecd-compendium-of-productivity-indicators-2024_b96cd88a-en

12 Value added represents the difference between the value of the final goods or services produced in an area (i.e. revenues) and the value of the inputs used in their production (i.e. costs).

3.1.2. Housing Affordability

Housing affordability refers to the ability of individuals or households to afford suitable and adequate housing without experiencing excessive financial burden. The ONS defines a "*property "affordable" if a household would spend the equivalent of 30% or less of their income on rent*".[13] Housing affordability is therefore co-determined by housing costs, income levels, and disposable income (i.e. income after other expenses).

Housing costs include various expenses associated with housing, such as mortgage or rent payments, property taxes, insurance, utilities, and maintenance. Prices for housing, meanwhile, refer to the market value of purchasing a home and are generally associated to housing costs as higher housing prices in an area are generally associated with higher mortgage and rent payments. The income level of individuals or households also plays a crucial role in housing affordability. If incomes do not keep pace with rising housing costs or prices, it can lead to a decrease in housing affordability.

Housing affordability is challenging to measure due to several factors:

- **Subjective**. Affordability is a subjective concept that can vary from person to person and from one geographic location to another. What is considered affordable for one individual or household may not be affordable for another. Different people have different income levels, financial obligations, and preferences, which can influence their perception of affordability and therefore whether and where they decide to live and work. Therefore, it may be relevant to consider different deciles at which housing costs and wages are measured.
- **Multiple Components**. Housing affordability involves considering various components, such as housing costs, income levels, and household expenses. It requires analysing the relationship between these factors to determine whether housing costs are within a reasonable range relative to income. This complexity makes it challenging to develop a standardised and universally applicable measure of affordability.
- **Data Availability**. Obtaining accurate and comprehensive data on housing costs and income levels across different regions and cities is challenging. Housing costs and income levels can differ greatly between urban and rural areas, as well as between high-cost and low-cost housing markets. Therefore, a measure of affordability that works well in one region may not accurately reflect the situation in another and data collection methods, sample sizes, and data quality can vary, making it difficult to compare affordability across different studies or regions.
- **Relevant labour market**. Firms are able to source employment from a wider commuting area which generally spans about one hour in travel time. Therefore, local authority housing costs may only be partially relevant to explain productivity, whereas average house costs in the wider commuting area, surrounding a local authority, may be more relevant to whether firms are able to find suitable employees to fill roles within the area. Therefore, we need to carefully consider how to define the area at which housing affordability is measured.

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[13] ONS (2023). Private rental affordability, England, Wales and Northern Ireland QMI. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/housing/methodologies/privaterentalaffordabilityenglandwalesandnorthernirelandqmi

In Section 5 we outline the relevant data available and compare the options for measuring productivity and housing affordability. Based on the various pros and cons of each metric and dataset available, we review what is the most appropriate dataset to select for our analysis.

3.2. Reverse Causality

One of the critical issues that we need to address is reverse causality (or simultaneity bias) between productivity and housing costs. In other words, we want to explore how an increase in housing costs (e.g. proxied by house prices) affects productivity but there will also be a simultaneous reverse effect, whereby a change in productivity affects housing costs via the demand for housing. This can be seen by means of a simple plot of productivity on house prices for the 33 London local authorities in Figure 3.1 below.

This is a particular issue here because, as can be seen in Figure 3.1, house prices are highly positively correlated to productivity across areas (i.e. house prices in central London are high and so is productivity). This is at least partly caused by an agglomeration effect as firms are willing to pay higher prices for rent to co-locate around other firms and a sorting effect because only the most productive firms are able to locate in high rent locations or households wanting to locate closer to where the highest paying jobs are. It might also be related to the fact that GVA includes a small but significant share of rental income, therefore on a purely accounting basis, there may be a positive relationship between housing costs and productivity.

Figure 3.1: Productivity and House Price Relationship in London Local Authorities, 2021

Notes: Productivity is measured as Total GVA/Employment in each local authority. Simple linear regression plotted in dots. Source: NERA analysis of ONS and HM Land Registry.

Therefore, if one estimates the relationship using conventional statistical approaches (e.g. OLS), the effect of house prices on productivity will be biased upwards (i.e. it will be underestimated) and may even be positive, as can be seen by the simple linear regression plotted in Figure 3.1 (even though theory may suggest that that the relationship is negative). This is the main rationale for why an instrumental variables approach is required, which we set out in Section 4.

3.3. Level at which Housing Costs Affect Productivity

Firms are able to source employment from a wider commuting area which generally spans about one hour in travel time. Therefore, local authority housing costs may only be partially relevant to explain productivity, whereas average housing costs in the wider commuting area, surrounding a local authority, may be more relevant to whether firms are able to find suitable employees to fill roles within the area. We therefore need to carefully consider how to define the area at which housing affordability is measured.

There are several approaches that could be adopted to consider the impact of housing affordability at different geographical levels, which range from simple to complex:

- **Simple**. Aggregate housing costs within a certain distance buffer surrounding a local authority (e.g. 0, 5, 10, and 20 km). Buffer distances between local authorities is based on their centroids. The housing affordability of a local authority can be then computed by taking the average housing affordability of that local authority and the average housing affordability of all local authorities located within 20 km (see Figure A.1).
- **Complex**. Aggregate housing costs within a certain travel time buffer surrounding a local authority (e.g. 0, 30, and 60 minutes).

It is plausible that the strongest effects of housing affordability would be at the location of the local authority itself. Therefore, we focus on the level of the local authority and test whether housing affordability metrics aggregated at different distance buffers (the 'simple' approach) is relevant to estimate the impacts on productivity. In Section 5.2 we discuss the approach we adopt to define the appropriate area and how the data is prepared.

3.4. Including Sufficient Variation to Estimate a Precise Effect

Including sufficient variation in housing affordability is crucial for estimating a precise causal effect of housing affordability on productivity. To ensure sufficient variation across geographic areas, we need to carefully consider the regions on which our analysis should focus. While the primary focus of this study is on London, it is important to note that the variation in productivity and housing affordability within London alone may be limited due to the relatively low number of local authorities available (33 local authorities from 2002 until 2021). Therefore, it may be relevant to expand our analysis beyond London to incorporate a broader range of sufficiently similar areas.

Including all local authorities in England may provide more variation in housing affordability to accurately identify the effect precisely. However, the impact may differ between areas outside of London and London itself, which means that an England-wide estimate may differ somewhat from the effect observed in London. We therefore expand the analysis to focus on the Greater Southeast of England, which includes the regions of London, the Southeast, and the East of England. These areas are in close proximity to London and have interrelated housing markets, hence are likely to exhibit similar dynamics between housing affordability and productivity, while also providing enough variation to estimate precise effects.

4. The Econometric Model

This section outlines the econometric model we develop in order to estimate the effect of housing affordability on productivity. Section 4.1 provides an overview of the key variables, Section 4.2 outlines the baseline OLS regression specification, Section 4.3 outlines the Instrumental Variables regression specification, and Section 4.4 describes how to choose an appropriate instrument. Finally, Section 4.5 outlines potential limitations and extensions.

4.1. Overview

The main model includes the following components:

- **Dependent variable.** Metric for labour productivity (GVA per employee in each local authority area).
- **Key Explanatory variable.** Metric for housing affordability (median house price divided by wages in each local authority area and in the surrounding areas).
- **Control variables.** Factors that affect productivity and housing affordability include fixed effects for local areas to capture time invariant features of an area that lead to higher productivity (e.g. its distance to the centre of London) and year to capture macroeconomic changes (e.g. aggregate trends in housing affordability and interest rates).

Given that the analysis is at the level of the local authority, the key mechanism we explore is whether spatial mismatch and consumption constraints (mechanisms 1 and 2 in Section 2.2) have a detrimental impact of economic productivity at the local level.[14]

4.2. OLS Regression

As a first step of the analysis, we adopt a simple linear regression using ordinary least squares (OLS) regression to examine the relationship between productivity and housing affordability. OLS regression is a widely used statistical technique that allows us to estimate the link between the dependent variable, which in this case is productivity, and the key independent variable, housing affordability. By controlling for other factors that may affect changes in productivity, we aim to identify the extent to which changes in housing affordability affect productivity.

The regression is specified as follows:

$$\ln(Productivity)_{it} = \alpha_0 + \beta \ln(Affordability)_{jt} + \alpha_1 X'_{jt} + \theta_i + \theta_t + e_{it},$$

where $\ln(Productivity)_{it}$ is the natural logarithm of productivity in local authority, i, in year, t, $\ln(Affordability)_{jt}$ is the natural logarithm of the metric of housing affordability in area j which are aggregated within distance bands (0, 5, 10, 20, 30, and 50 km) around the centroid of local authority i in year t,[15] X'_{jt} are vectors of control variables which change over time for area j, θ_i is an

14 Given that we focus on local effects, we are unable to infer whether macroeconomic mechanisms that may be at play such as (3) capital misallocation and (4) diversion of investment have a meaningful impact on productivity at the national level, although there may be a local effect of these mechanisms.

15 See Section 3.3 and 5.2 on how we propose defining the area, j, surrounding the local authority relevant to estimate the effect of housing costs on productivity.

area fixed effect, θ_t is a year fixed effect, and e_{it} is the error term.[16] We use the natural logarithm of productivity and housing affordability to estimate an elasticity relationship, i.e. the coefficient, β, can then be interpreted as a 1% increase in the affordability is associated with a β% increase/decrease in productivity.

The key assumption for OLS to estimate the causal effect is exogeneity, which implies that there should be no other factors (outside of the model) driving housing affordability and productivity. This assumption may however be violated due to omitted variables bias or reverse causality.

Omitted variable bias occurs when a relevant variable, which is correlated with both the dependent and independent variable, is omitted from a regression model. When such variables are omitted from the model, the estimate of the coefficient of interest, β, will become biased (i.e. different to the true value). The usual solution to omitted variable bias is to include the relevant explanatory variables. In this case, we include area fixed effects, which control for any time invariant differences in productivity and housing affordability between locations (e.g. that productivity in the City of London is higher, on average, than other local authorities due to historical reasons and the attractiveness of the location to firms and households). Additionally, we include year fixed effects, which control for differences in productivity and housing costs between years that are the same across all local authorities (e.g. general increases in housing prices, cost inflation and the global financial crisis of 2008).

There may however still be variables that change over time at the area level or that are different over space at the macro level that may cause omitted variable bias. For example, areas with higher employment density may experience higher levels of productivity if employment density increases due to economies of agglomeration which may also be associated with higher housing costs and affordability. If employment density is omitted from the analysis, the relationship between housing costs and productivity may therefore be biased. A similar situation may arise when considering the effect of interest rates over space. Section 5.4 outlines additional control variables that may be useful to include in X_{jt} to avoid omitted variables bias issues and we test the sensitivity of the results to the inclusion of certain time varying control variables.

Reverse causality (simultaneity bias) occurs when there is bi-directional causality, i.e. the dependent variable (productivity) also influences housing costs and affordability directly. In instances of reverse causality, the OLS estimation result will become biased. Given that demand for housing is likely to be higher in more productive places, these locations are also likely to have higher housing costs. Therefore, the direction of bias is likely to be positive, resulting in a β coefficient that is underestimated (biased upwards) and which does not reflect the causal effect of housing affordability on productivity. In order to address this issue, we use an Instrumental Variables approach, which allows us to identify the effect of housing affordability on productivity via changes in housing costs that are not directly related to productivity, thereby establishing a causal relationship.

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16 Driscoll-Kraay standard errors for panel data are used to capture correlation within areas over time and depends on the number of lags in the data that are considered to be correlated over time. The lag length is selected based on the procedure recommended in Hoechle (2007), Robust standard errors for panel regressions with cross-sectional dependence, The Stata Journal, where the default number of lags m(T) can be calculated as m(T)=floor[4(T/100)^(2/9)]. Given that there are twenty years of data for each local authority (T=20), the default number of lags can be calculated as m(20)=floor(2.8)=2, so as a baseline we select 2 lags in our models.

4.3. Instrumental Variables Regression

To account for reverse causality, we use an Instrumental Variable (IV) approach. This econometric technique involves a two-step process. In the first step, we regress the natural logarithm of housing affordability against the instrumental variable and control variables:

$$\ln(Affordability)_{jt} = \gamma_0 + \gamma_1 IV_j \times Year_t + \gamma_2 X'_{jt} + \mu_j + \mu_t + u_{jt},$$

where $\ln(Affordability)_{jt}$ is the natural logarithm of housing affordability in area, j,[17] in year, t, $IV_j \times Year_t$ is a set of geographical instruments, IV_j, interacted with the year, $Year_t$,[18] X_{jt} is a vector of control variables which change over time, μ_j is an area fixed effect, μ_t is a year fixed effect, and u_{jt} is the error term.

In the second step, we use the fitted values ($\ln(\widehat{Affordability})$) from the first stage regression to examine the impact of housing affordability on productivity for each local authority:

$$\ln(Productivity)_{it} = \alpha_0 + \beta \ln(\widehat{Affordability})_{jt} + \alpha_1 X'_{jt} + \theta_i + \theta_t + e_{it},$$

where $\ln(Productivity)_{it}$ is the natural logarithm of productivity in local authority, i, in year, t, $\ln(\widehat{Affordability})_{jt}$ are the fitted values of the natural logarithm of housing affordability from the first-stage regression, X_{jt} is a vector of control variables which change over time in area j, θ_i is an area fixed effect, θ_t is a year fixed effect, and e_{it} is the error term.[19]

As with the OLS analysis, we use the natural logarithm of productivity and housing affordability which allows us to estimate an elasticity relationship. Under the assumption that the estimated relationship is causal, the coefficient of interest, β, on housing affordability can then be interpreted as a 1% increase in the affordability causes a β% increase/decrease in productivity.

4.4. Choosing an Appropriate Instrument

To obtain an appropriate instrumental variable, two conditions need to be met:

- **Relevance.** The instrument needs to be *relevant* in the sense that it needs to cause a large enough shift in supply to be able to identify relevant changes in housing costs and thereby affordability. Relevance can be tested using an F-test which assesses the "joint significance" of the instrument in the first-stage regression.
- **Validity.** The instrument also needs to be *valid* in the sense that it needs to be unrelated to other factors that influence productivity in an area. The validity of an instrument cannot be

17 Areas j are aggregated metrics within distance bands (0, 5, 10, 20, 30, and 50 km) around the centroid of local authority i (see Section 5.2 for further details on aggregation approach).

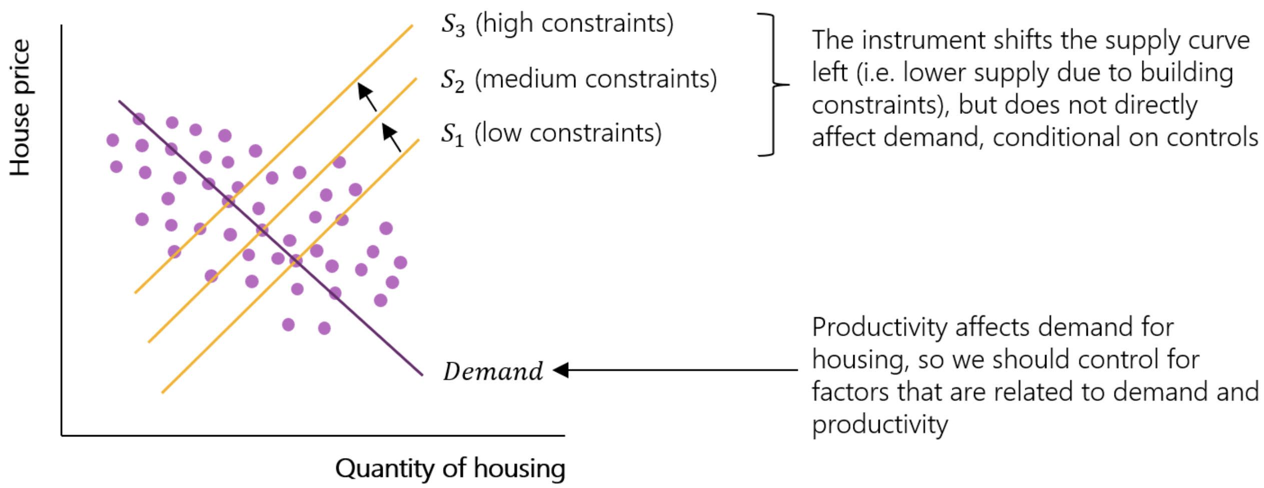
18 As the instruments considered are geographic and do not change over time (they are only observed for one period), including an area fixed effect will capture all the variation in the instruments, so the instruments would be irrelevant to explain changes in housing affordability over time. By interacting the instrument with a year trend (multiplying the two variables together), we capture differences in trends for locations with a higher or lower share of e.g. greenbelt land (see further details on this in Section 4.4 and Appendix A.3).

19 Driscoll-Kraay standard errors for panel data are used to capture correlation within areas over time. See footnote 14 for further details on lag selection.

tested through any statistical technique, so it rests on a clear explanation of why the instrument is not related to factors determining productivity.

Our intention is to use variables that are uncorrelated to productivity directly but raise supply restrictions and thereby housing prices and costs. As illustrated in Figure 4.1, housing prices are determined by a combination of demand and supply for housing in a particular location. Each observation of quantity and price (the light purple dots) represents a unique intersection of a demand curve and a supply curve for a particular local authority. The issue we face (and the reason why an IV approach is justified) is that productivity in an area is going to affect demand for housing in that area (i.e. reverse causality). Therefore, in order to obtain a valid instrument, we need to obtain a variable that shifts the supply of housing (via supply as shown by S_i in the figure) but is unrelated to housing demand (directly influenced by productivity), conditional on the control variables included in the first-stage regression.

Figure 4.1: The Instrumental Variable Should Affect the Supply of Housing



Source: NERA illustration.

Several instruments that satisfy the relevance and validity criteria have been proposed in the urban economic literature, such as Hilber and Vermeulen (2016) and Saiz (2010),[20] which predominantly relate to geographical factors that affect housing costs due to construction cost or difficulties to obtain planning permissions. Obtaining a credible and robust instrument that can be applied consistently across varying geographies and time periods is challenging. We therefore follow the rationale of earlier studies and consider several potential instruments which are expected to shift the supply of housing, but may be unrelated to productivity directly. These include: the share of developable land developed (DLD) in a historic time period, the share of developable land semi-developable (DLSD), the share of greenbelt land, and terrain.[21]

20 Hilber, C. A., & Vermeulen, W. (2016). The impact of supply constraints on house prices in England. The Economic Journal, 126(591), 358-405. Saiz, A. (2010). The geographic determinants of housing supply. The Quarterly Journal of Economics, 125(3), 1253-1296.

21 DLD excludes undevelopable land (e.g. water) and divides the total developed land in 1990 by the total developed and developable land in 1990 to obtain a share. DLSD excludes undevelopable and developed land and divides the

Table 4.1 outlines the intuition for each instrument considered and the rationale for the instrument selected in this analysis. Given the potential instruments, we exclude DLSD and terrain as the coefficients on these variables in the first stage are negative, which goes against expectations and therefore we cannot be confident these are valid instruments. Furthermore, we are concerned that the share of DLD is also not valid as areas with less land available to develop in a historic time period may in fact grow faster over time (e.g. the City of London had very little developable land and grew a lot faster than other local authorities). We therefore select the share of greenbelt land for our IV analysis as first-stage coefficient is strong and positive, which matches expectations on the direction of the effect.

Table 4.1: Instruments Considered and Selection Rationale

Instrument	Intuition and potential limitations	Rationale
Share of Developable Land Developed (DLD)	Over time, supply constraints (land & construction costs) will be higher in areas where there is less land available to develop and hence housing costs will increase faster in these locations. However, economic growth may be faster in locations with less initially available land (e.g. in the city of London), which could result in an invalid instrument.	Excluded. Due to concerns of theoretical validity of instrument.
Share of Developable Land Semi-Developable (DLSD)	Over time, construction costs will be higher in areas where more of the developable land is hard to develop (i.e. semi-developable) due to flood risk and geographical considerations. However, it is potentially correlated to flood risk and coastal regions which face lower house price growth.	Excluded. Likely invalid as first stage coefficient is negative.
Share of Greenbelt Land	Over time, housing costs will be higher in areas with a higher share of greenbelt land as it is harder to develop due to planning (supply) constraints. While greenbelt land may change over time (which may be correlated to productivity), our sensitivity checks indicate that this is not a concern.	Selected. Positive and strong first-stage coefficient indicates plausible IV.
Terrain (Ruggedness and Slope)	Over time, construction costs will be higher in areas where it is difficult to build due to more rugged terrain and higher slopes. However, there may be insufficient variation in terrain to estimate a precise effect in the regions considered.	Excluded. Likely invalid as first stage coefficient is negative.

Notes: See first-stage regression results in Table B.7.
Source: NERA analysis.

4.5. Limitations and Extensions

We are unaware of any studies that have explicitly explored the quantitative effect of housing affordability on productivity in the UK or globally. Therefore, this report applies a novel IV approach that, to our knowledge, has not been carried out before in this setting. While the instrument selected is in line with the urban economic literature and is plausibly valid, it is not possible to prove validity. Therefore, we acknowledge that there will always a degree of uncertainty

total semi-developable land (e.g. rock) by the total developable land to obtain a share. The share of greenbelt land divides the total area that is designated greenbelt by the total land in an area. Terrain includes ruggedness, which is measured as the difference between the mean and the minimum and the maximum elevation in an area, and the share of slopes greater than 10% elevation, which proxies for whether an area is mountainous.

regarding whether the instrument is truly valid. This is why we present the OLS results alongside the IV results and encourage further research into replicating the analysis in other settings and with other plausible instrumental variables.

The main analysis focuses on labour productivity at the level of the local authority and housing affordability within a specified distance buffer around the local authority. We also test sensitivity of the main results to a variety of robustness checks, however there may be several avenues for extensions in future work. Four potential extensions may be to:

1. **Assess sectoral impacts**. This would involve analysing the extent to which some sectors may be more impacted than others. This could be done by examining productivity data at the sectoral level (e.g. construction, business services, public administration), which may provide more granular estimates and better understand the causal mechanism.
2. **Capture commuting area based on travel time**. Our methodology focuses on the impact of housing affordability on productivity within a 20 km buffer from the centroid of a local authority. Distance buffers may, however, not perfectly capture the fact that travel time by train, car, or other modes may be different within and between local authorities (e.g. in London travel distances are shorter but travel times are higher), which may be better captured based on travel times. There are also a number of different ways of incorporating buffers in policy appraisal: see section 7 and A.2 for more detail.
3. **Consider other metrics of housing affordability**. Our analysis focuses on housing affordability as measured by median house prices divided by median wages in a local authority. However, there are various other metrics that could be used to capture housing costs (such as rents and mortgage payments) as well as affordability (such as for different income deciles or disposable income after housing expenses have been deducted). While we have not been able to consider all these various alternatives, this should be considered in further research.
4. **Consider other relevant control variables**. We account for the high-level aggregate impact of interest rates across the whole Greater Southeast region by including year fixed effects, however it is likely that interest rates affect some areas in the UK more than in other areas. Further research could therefore be done to allow the impact of interest rates on productivity to be different depending on the area.

5. Data and Descriptive Analysis

This section outlines the data available and explains how we narrow down the various data sources and metrics to the key variables we analyse in the regression analysis. Sections 5.1, 5.2, 5.3, and 5.4 outline the key data sources, trends, and relationships for the dependent, key independent, instrumental, and controls variables, respectively. Section 5.5 outlines how we combine these data sets into the final dataset we use for regression analysis and presents the key descriptive statistics.

5.1. The Dependent Variable

There are several potential options to measure labour productivity (the dependent variable). Table A.1 (in Appendix A.5) outlines the potential metrics available, including a description, data availability in terms of time period and spatial scope, as well the source of the data, and any pros and cons of utilising a particular metric.

Based on the data available, two metrics are relevant for this analysis (i) GVA divided by number of jobs filled and (ii) GVA divided by hours worked, both sourced from the ONS. GVA is a measure of the economic value generated by a sector within a specific region and represents the difference between the value of goods and services produced by the sector (output) and the cost of inputs used in the production process (including raw materials, power and fuel, rental on buildings and business services, but excluding wages and capital investment).[22] GVA is predominantly composed of wages (55%), gross trading profit (23%), rental income (14%), and other GVA (8%, which includes mixed income, non-market capital consumption, taxes, subsidies, and holding gains).[23]

The OECD considers that the "*volume of labour input is generally most appropriately measured by the total number of hours actually worked, i.e. hours effectively used in production, whether paid or not*".[24] Hours worked is generally considered most appropriate because it accounts for variations in working time patterns (e.g. part-time or full-time employment). However, in this case hours worked is a problematic metric for productivity, as the employment data reflects residential location rather than workplace location.[25]

To ensure our productivity measure is accurate, we require the GVA and employment metric to be both at the location where individuals work. Therefore, we consider it more appropriate to measure productivity per filled job at the location of employment. This employment metric relies on a survey distributed to employers which is more likely to accurately reflect the local authority

22 This definition of GVA is based on the production approach (see ONS, Regional accounts methodology guide: June 2019). GVA can also be calculated using the income approach, which involves summing income from wages, profits, rents, and taxes minus subsidies within a specific area.

23 Based on the income approach (in 2017), decomposing GVA results in wages (55%), profits (23%), rental income (14%), mixed income (5%), with the remainder (3%) being non-market capital consumption, taxes, subsidies, and holding gains. Rental income includes income from financial corporations, non-financial corporations, households (via renting of private dwellings and an imputed rental value for owner-occupied housing), and public corporations.

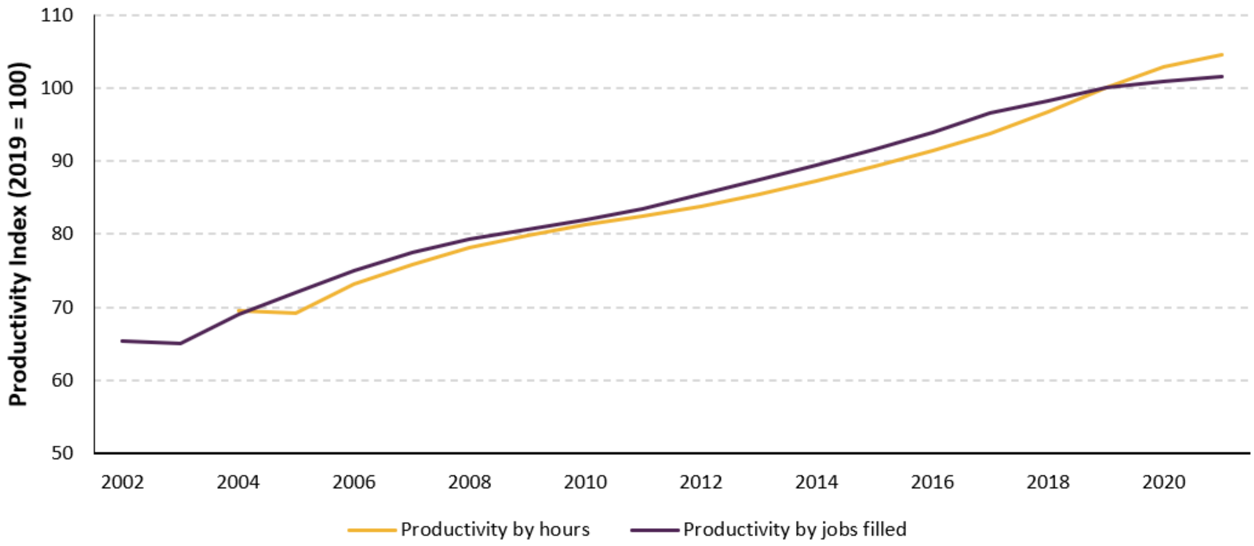
24 OECD (2024). Compendium of Productivity Indicators.

25 Data on hours worked is collected through the LFS survey which is distributed to households rather than employers and does not collect information on the workplace location at the local authority level (see the Labour Force Survey – user guidance, ONS). Therefore, hours worked by local authority depends on where residents live rather than where they work. If a significant part of the residents in a local authority work in a different local authority, the resulting productivity by local authority will not be accurate.

where employees work. This approach is also supported by the OECD which explains that "*total employment (i.e. the number of persons employed) is often used as a proxy for labour input, particularly when data on total hours worked cannot be estimated*".[26]

In Figure 5.1, we show that at the national level, the two measures follow similar trends from 2004 onwards. Correlation analysis at the local authority level between 2004-2022 indicates that linear (Pearson) correlation between the two productivity measures is 0.98, which indicates the variables are highly correlated. Our main specification is therefore total GVA per filled jobs.[27]

Figure 5.1: Trends in National Productivity (Current Prices)



Source: ONS data on productivity at the national level.

5.2. The Key Independent Variable

The main independent variable of interest in this analysis is housing affordability, which is composed of housing costs and income, and can also be measured in different ways. One distinct feature of London's housing market is the relatively large share of private (31%) and social renters (21%), with the remaining share of residents being owner occupiers (49%).[28] Therefore, housing costs will be determined by both house prices as well as rental prices. Based on the data available, we consider two broad categories to measure housing affordability for this analysis (see Table A.2 in Appendix A.5):

1. **House prices**. Refer to the market value of purchasing a home. Are a *proxy* for housing costs as higher housing prices in an area are associated with higher mortgage and rent payments.

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[26] OECD (2024). Compendium of Productivity Indicators.

[27] One potential caveat with this metric is that the number of jobs is reported by employers and is based on head offices' location rather than local offices, therefore, it may contain errors.

[28] DLUHC (2023). Annex Tables for English Housing Survey Headline Report 2022-23, Chapter 1, tab AT1.2: Tenure, by region, 2022-23.

This includes Average House Prices (Unweighted), Average House Prices (Weighted), and Median House Prices.[29]

2. **House prices as a share of income**. A ratio of housing costs to income. An increase in the ratio usually occurs when incomes do not keep pace with rising housing costs (or prices), indicating a worsening of housing affordability. The ratio of house price to workplace-based earnings and the same ratio focusing on the lower quartile of house prices and earnings are two examples of indices for monthly housing costs as a share of income.

While we are unable to obtain sufficiently granular data on rental prices at the local authority level and therefore the analysis focuses on house prices, we note that the correlation between house prices and private rental prices is high (around 0.96 at the regional level in England between 2005-2021).[30] Therefore, we consider that house prices are a suitable proxy for private housing related costs more generally.

Figure 5.2 presents trends in the two housing affordability metrics at the national level. An increase in the metric is associated with higher housing costs and thereby lower housing affordability. The house price metrics appear to grow very similarly over time, with periods of strong growth from 2002 to 2008, a plateau from 2008 to 2013, and stronger growth from 2013 to 2021.[31]

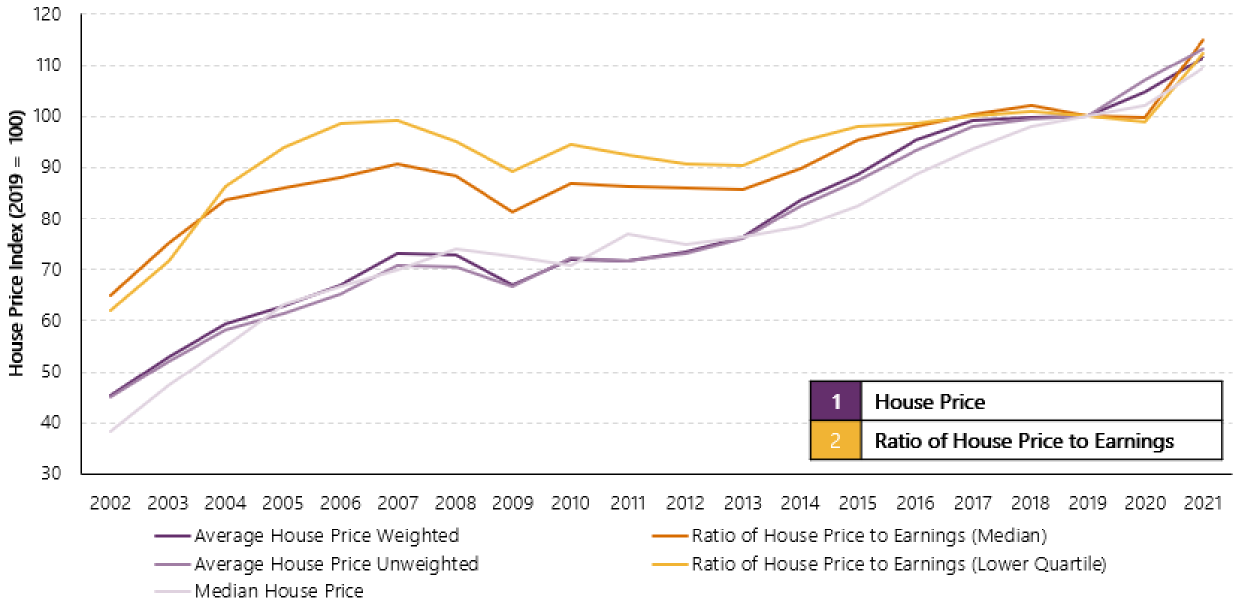
House prices grow faster than the ratio of prices to earnings in the period 2013 to 2021, indicating that increases in wages are compensating some (but not all) of the house price growth. Furthermore, the ratio for lower quartile price and earnings exhibits somewhat different variability than does the median house price to earnings ratio.

[29] House price data can be weighted by taking the average house price for each housing type (flat, terraced, semi-detached, and detached) and then multiplying these averages by the proportion of each housing type within the local authority. For example, if the average price of a flat in Hammersmith is £500,000 and flats make up 50% of properties, flats then contribute 50% * £500,000 to the weighted average house price of Hammersmith. This approach is consistent with ONS's methodology to develop the single official house price index (see ONS "Development of a single Official House Price Index", 2016). As shown in Figure 5.2 we observe minor differences between the weighted and unweighted average house prices at the national level, however these differences may be larger at the local authority level.

[30] See analysis comparing house price and rental price relationship at the regional level in London in Appendix A.3.

[31] This strong co-movement pattern can also be confirmed by a simple correlation analysis. For instance, the (Pearson) correlation between Average House Prices and the Ratio of House Prices to Earnings at the local authority level is 0.91, implying a strong positive linear relationship between the two metrics.

Figure 5.2: Trends in National Metrics of Housing Affordability Indices



Source: NERA analysis of ONS and HM Land Registry.

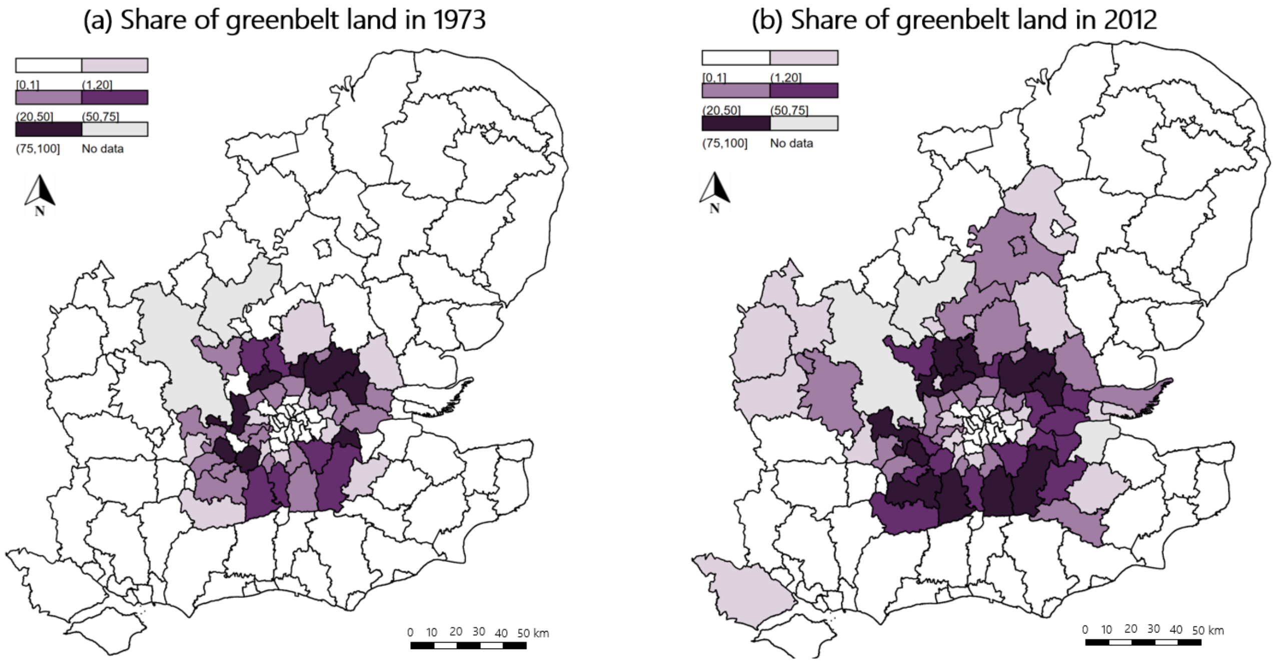
The advantages and disadvantages of all the data considered are summarised in Table A.2 (see Appendix A.5). Given that housing affordability is generally composed of both housing costs and income, we decide to proceed with our main regression analysis using the Ratio of House Prices to Earnings as the key independent variable of interest.

To define the most relevant buffer to capture housing costs within the wider commuting area (see Section 3.3), we consider various data sources on commuting distances. Based on 2009 data from the DfT, people living in rural areas in the UK travel on average 17.7 km, while people living in London travel on average 11.2 km. Meanwhile, more detailed commuting flow data from 2021 indicates that a 20 km buffer zone accounts for 80% or more (in most cases over 90%) of the commuters in all Greater London local authorities, except the City of London (see Appendix A.1). Using buffers below 20 km results in a substantially smaller share of commuters captured, meanwhile using buffers larger than 20 km is expected to capture a substantial share of irrelevant housing data, particularly for Greater London (see Appendix A.1). Therefore, we carry out our baseline analysis using 20 km buffers, but also test whether the effect differs when considering various distance buffers (0, 5, 10, 30, and 50 km) of each local authority.

5.3. The Instrumental Variable

In order to construct our main instrument, we utilise data on the share of greenbelt land in 2012, available at the local authority level from the Land Cover Map of Great Britain (LCMGB). The share of greenbelt land captures the proportion of land within a local authority that is defined as greenbelt.

Figure 5.3: Share of Greenbelt Land in the Greater Southeast Region by Local Authority in 1973 and 2012 (%)



Source: NERA analysis of Land Cover Map of Great Britain (LCMGB).

Figure 5.3 illustrates the spatial distribution of greenbelt land in the Greater Southeast in 1973 and 2012. As can be seen, the share of greenbelt land in 2012 is highest around the periphery of London as well as around the urban areas of Oxford and Cambridge and has changed very little since 1973.

5.4. The Control Variables

In our baseline models, we incorporate fixed effects to account for specific characteristics of each local area and year. The inclusion of fixed effects for the local area helps capture time invariant features that affect productivity in a local authority, while the year fixed effect captures macroeconomic changes such as interest rates. By including these fixed effects, we aim to adequately capture variations in the data and isolate the causal effects of housing affordability on productivity.

We test the robustness of the results by introducing additional time varying controls and examining the impact on the coefficients. One such sensitivity test involves adding the log of job density as a control variable, which is a measure of employment concentration and is related to agglomeration economies and the productivity of an area. Areas with higher job density are also likely to have higher housing costs, as these locations tend to be more attractive for living and working. The results of the sensitivity analysis are summarised in Section 6.

5.5. Construction of the Final Dataset

Using all of the above, we are able to develop a panel dataset with 142 local authorities in the Greater Southeast region across a 20-year time period from 2002 to 2021 (a total of 2,840 local authority-year observations).[32] Overall, the final panel should provide a reasonable sample size and sufficient variation to explore the impact of housing affordability on productivity.

Table 5.1: Summary Statistics of Key Variables

Variable	Unit	Mean	Std. Dev	Min	Max
Productivity	Current price GVA (£) per filled job	51,700	15,753	24,859	139,110
House Price	Average Current Price (£)	330,856	194,446	91,413	1,949,417
Ratio of house price to workplace-based earnings	Ratio of median house price (£) to median gross annual earnings (£).	9.5	3.3	3.5	44.0
Share of Greenbelt	Percentage	19.9%	28.3%	0%	93.8%

Source: NERA analysis.

Table 5.1 summarises the key statistics of the variables. As can be seen:

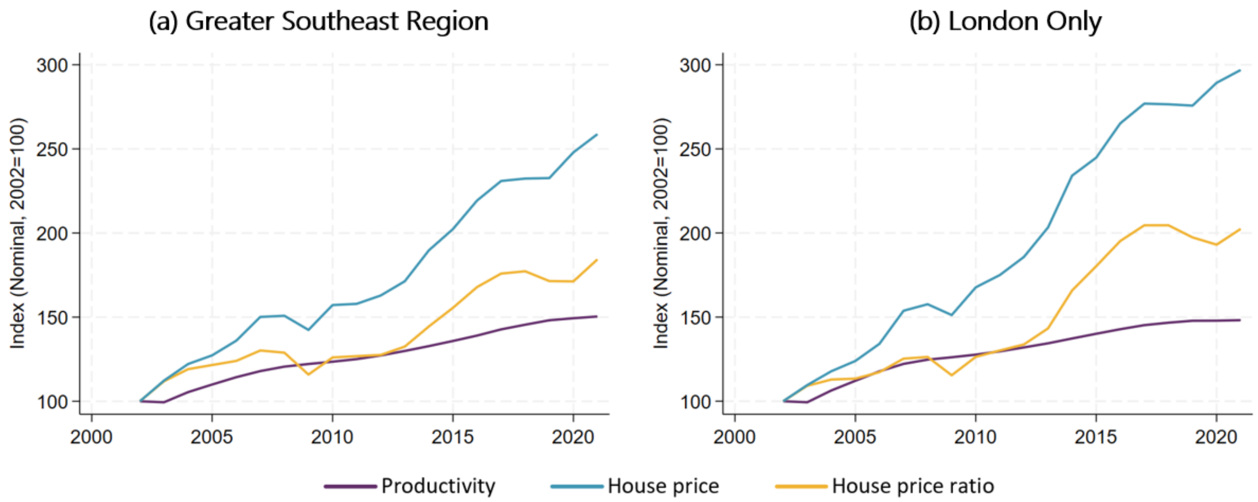
- Productivity is around £52k per employee on average over the time period and ranges between £25k (LA "Norwich" in 2003) and £139k (LA "City of London" in 2021).
- House prices are around £331k on average over the time period and ranges between £91k (LA "Great Yarmouth" in 2002) and £1.9 million (LA "Westminster" in 2017).
- The ratio of median house price to median workplace earnings is around 9.5 on average over the time period and ranges between 3.5 (LA "Great Yarmouth" in 2002) and 44.0 (LA "Kensington and Chelsea" in 2018). This implies that median house prices were around 9.5 times higher than median wages, on average.
- The share of greenbelt land is around 20% on average over the time period and ranges between 0% and 94% (LA "Tandridge").

We illustrate the relationship between the dependent and key independent variable of interest by means of trends over time for the Greater Southeast region and London. Figure 5.4 illustrates that housing prices have increased and affordability has worsened at a faster rate than productivity, and this difference is more pronounced for London than for the Greater Southeast region. Between 2002 and 2021, median house prices grew twice as fast as wages in London, while house prices tripled.

Figure 5.5 presents a scatter plot of the key relationship between productivity and the house price to wage ratio in logs. A similar positive relationship is observed between productivity and the house price to wage ratio, which appears to be slightly weaker in London (yellow dots). This re-affirms that it will be important to include area and year controls as well as applying an IV approach.

[32] We also obtain a subset of the data on a 5-year interval basis to examine the longer-term implications of productivity growth. This subset of the panel consists of data from 2002, 2007, 2012, 2017 and 2021 and contains 710 local authority-year observations. As the panel dataset only includes data up until 2021, the final period between 2017 and 2021 is 4 years.

Figure 5.4: Trends in Productivity and Housing Costs Indices (Current Prices)



Notes: Productivity is the average GVA divided by number of employees, house prices are average unweighted, and the house price ratio is the average median house price divided by median wages of all local authorities in the area.
Source: NERA analysis.

Figure 5.5: Scatter Plot of Productivity and Housing Affordability

Notes: Each point represents a local authority-year observation.
Source: NERA analysis.

6. Results

In this section, we provide a summary of the key findings from our statistical analysis. In Section 6.1, we discuss the results of the main regression analysis using both OLS and IV methods and in Section 6.2 we present the results of sensitivity checks of the main results.

6.1. Main Regression Analysis

Table 6.1 summarises the main results of our regression analysis. Column (1) presents the OLS results and column (2) the IV results.

Table 6.1: Main Regression Results

	OLS	**IV**
	(1)	(2)
House price to wage ratio 20 km (log)	-0.062**	-0.14***
	(0.030)	(0.034)
Observations	2838	2838
Within R^2	0.82	
First-stage F-stat		25.7
Year FE	Y	Y
Area FE	Y	Y

*Notes: Dependent variable is Productivity per employee (log). Driscoll-Kraay standard errors in parenthesis (2 lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively. Driscoll-Kraay lags selected based on Hoechle (2007) approach, see Section 4.2 and 4.3 for further details.*
Source: NERA analysis.

As can be seen in column (1), the OLS regression results in a statistically significant coefficient on housing affordability (at the 5% level) of -0.06. This indicates that a 1% increase in the housing affordability ratio (indicating less affordability) within a 20 km buffer around a local authority is associated with average decrease in productivity per job of 0.06%. The OLS result is however likely to provide an underestimate of the effect of interest due to reverse causality, therefore this elasticity should be considered a lower bound of the effect of interest.

To address reverse causality between housing costs and productivity, we employ an IV approach in column (2), using the share of greenbelt land as the instrument. The first stage coefficient is positive and strong (first stage F-stat is 25), indicating the IV is relevant and in line with expectations. Therefore, the second stage coefficients presented in column (2) can be interpreted meaningfully.[33]

The second stage IV regression produces a coefficient of -0.14,[34] indicating that a 1% increase in the housing affordability ratio (worsening of affordability) results in an average 0.14% reduction in productivity. This elasticity estimate is larger than the OLS regression result of -0.06, which is in line

33 See full list of first-stage regression results in Table B.2.

34 The 95% confidence interval ranges between [-0.07, -0.20].

with expectations as reverse causality is expected to introduce a positive bias (i.e. make the coefficient less negative). This indicates that the negative economic effect of worsening housing affordability on productivity outweighs the positive accounting effect of higher house prices on GVA.

6.2. Sensitivity Checks

To ensure the robustness of the statistical analysis, we conduct several additional sensitivity checks to assess the stability of the results. These checks involve alternative model specifications, subsets of the data, variations in instrument specifications, as well as tests of buffer zone sizes and standard errors, summarised in Table 6.2. Overall, we conclude that the baseline elasticity from the IV regression of -0.14 is robust across a range of sensitivity checks.

Table 6.2: Summary of Sensitivity Results

#	Check	OLS effect	IV effect	Pass
1	Baseline	-0.06**	-0.14***	
2	Dep var: Productivity per hour	-0.07**	-0.24***	✓
3	Exp var: House price and gross income	-0.02	-0.10	~
4	Add regional specific time trends	-0.06**	-0.11***	✓
5	Exclude COVID years (2020-21)	-0.04*	-0.14***	✓
6	Five-year interval	-0.11***	-0.16***	✓
7	Alternative Instrument (Historic)	NA	-0.21***	✓
8	Instrument without buffers	NA	-0.14*	~
9	Add employment density	0.036	-0.14***	✓
10	London only	-0.16	Negative First stage	✗
A	Buffer Zone Analysis	[-0.04, -0.08**]	[-0.05, -0.37***]	✓
B	Standard Error Analysis	* (3 lags); *** (10 lags)	*** with 3 and 10 lags	✓

*Notes: Full regression result tables from sensitivity tests can be seen in Appendix B. Statistical significance indicated by *.*
Source: NERA analysis.

The sensitivity tests and results are outlined as follows:

(1) **Baseline**. The results of the sensitivity tests are compared to the baseline results presented in the main regression table for comparison.

(2) **Alternative dependent variable**. We replace GVA per job by GVA per hour worked as the dependent variable and find that the effect is also negative and of a similar magnitude, but slightly larger than our baseline result.

(3) **Alternative independent variable**. We replace the ratio of house price to gross income as the measure of housing affordability with two separate variables for house price and gross income, where house prices are instrumented in the first stage. The sign on house prices remains negative and of a similar magnitude but becomes statistically insignificant. This may be because house prices on their own are less significant to explain labour matching, as house prices are considered relative to the potential wages from working in an area.

(4) **Adding regional specific time trends**. We incorporate region specific time trends (London, the South East, and the East of England) to capture differences in trends in productivity and housing affordability across regions. The coefficient remains stable and statistically significant, with a slight decrease in magnitude.

(5) **Excluding Covid period**. We exclude the Covid period (2020-2021) from the analysis to account for the unexpected temporary external shock to the economy caused by the pandemic. The coefficient remains stable and statistically significant, suggesting that year fixed effects already capture the shock to the economy effectively.

(6) **Five-year interval**. To capture longer term changes in affordability and productivity, we focus on data every 5 years. The coefficient remains stable and statistically significant, with a slight increase in the magnitude.

(7) **Alternative instrument**. To test the stability of the IV approach, we also considered the historical share of greenbelt in 1973, which can be argued to be less likely to be correlated with productivity during the period of analysis. The results indicate that the coefficient estimates remain negative, statistically significant, and are slightly larger in magnitude.

(8) **Instrument without buffers**. In the baseline IV model, we measure the instrument at the same level as the affordability variable (20 km buffer in our baseline model). We test the sensitivity of the results to using the share of greenbelt without a buffer as the instrument and find that while the coefficient of interest remains the same, the precision declines, and becomes only statistically significant at the 10% level. This indicates that it is important for precision to measure the instrument at the same level as the key independent variable.

(9) **Adding employment density**. We include employment density as an additional time varying control variable to capture potential changes in agglomeration (which is expected to impact productivity and possibly also housing costs) in an area over time. The results indicate that the estimated coefficient remains stable and statistically significant.

(10) **London only**. We also test whether the results hold for the London region only. The first stage coefficient however becomes negative, which is not intuitive, and the F-statistic becomes a lot smaller, therefore we do not interpret the second stage coefficient from the IV regression.

In addition to the sensitivity tests using alternative model specifications, we also conduct two additional sets of analyses of:

A. **Buffer zones**. We conduct additional tests using alternative buffer zones for both the OLS and IV models. As can be seen, the estimated coefficients generally remain negative across different specifications, but the magnitudes and significance levels vary. Generally, the magnitude is higher as the buffer size increases, but then becomes imprecise at very large buffers, suggesting that it is important to consider the wider housing market outside the local authority, but including irrelevant housing data (outside a reasonable commute) simply adds noise and reduces the precision of the estimates.

B. **Standard errors**. Our baseline model uses Driscoll-Kraay standard errors with a bandwidth of 2, which therefore accounts for spatial clustering of standard errors with a 2-year lag. We also consider 3- and 10-year lags and find that the interpretation of significance of the regression results remains largely unchanged.

7. Application of the Estimates

Ultimately, the London Partnership Board are interested in measuring the effect of improving housing affordability on productivity. This will entail applying the coefficient estimated in Section 6 in the real world. The following sections outline measures that the London Partnership Board can consider to improve housing affordability (Section 7.1), lay out a methodology to estimate the effect of a change in housing affordability on productivity (Section 7.2), provides an illustration of how the estimate can be applied in practice (Section 7.3), and presents any limitations and caveats of the approach (Section 7.4).

7.1. Measures to Improve Housing Affordability

When considering measures to improve housing affordability policy makers have several options, including:

1. **Zoning and Building Regulations**. Revising zoning and building regulations involves relaxing restrictions on land use and building height limits, allowing for higher density development in appropriate areas. By doing so, it may be possible to increase the overall housing supply, which could help alleviate affordability pressures.
2. **Higher Density and Affordable Developments**. Incentivising developers to build higher density and affordable accommodation through schemes such as offering density bonuses or streamlined approval processes for projects that include a certain percentage of affordable housing units. By encouraging higher density and affordable development, more housing units can be created within limited land areas, potentially increasing affordability.
3. **Construction of Social Housing**. The construction of social housing can also play a crucial role in improving housing affordability for those least able to pay higher rents/house prices. By investing in the development of affordable homes specifically targeted towards low-income individuals and families, policy makers could help address the affordability gap and provide stable housing options. This, in turn, could positively impact productivity by reducing housing-related financial stress and instability.

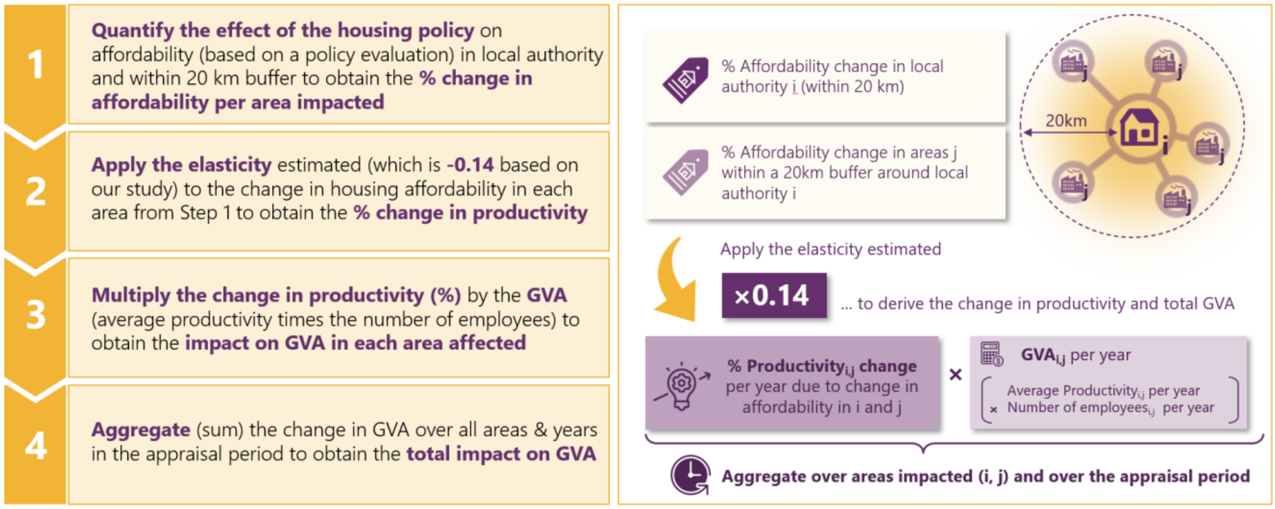
7.2. Methodology to Estimate Impact on Productivity

When modelling the productivity impacts of these measures, it is important to consider the potential increase in housing supply, the affordability gains in average housing costs, and the potential spillover effects on other sectors of the economy. In order to assess these impacts, a separate counterfactual model has been developed which breaks down the effect into a four-step approach (see Figure 7.1):

1. **Step 1:** Quantify the effect of the policy on affordability in local authority *and* within 20 km buffer based on a policy evaluation or appraisal approach.
2. **Step 2:** Apply the elasticity estimated (which is -0.14 based on our current study) to the change in housing affordability from Step 1.
3. **Step 3:** Multiply the change in productivity (%) by average productivity and the number of jobs per year in the areas affected.

4. **Step 4:** Aggregate the change in GVA per year over the appraisal period.

Figure 7.1: Four-Step Approach to Estimate Impact of Policy Measure on GVA



Source: NERA illustration.

By incorporating these measures into a simple framework to model productivity impacts, it is possible to approximate their potential effectiveness and inform evidence-based policy decisions for marginal changes in housing costs under ceteris paribus assumptions (i.e. assuming the impact on housing costs is small, less than 10%, and only housing costs change). In the following subsection, we outline how this might work by means of a hypothetical worked example.

7.3. Example Application of Methodology

To help understand how the key elasticity from Section 6 can help to estimate the effect of measures to improve housing affordability on productivity and GVA, we estimate the implied effect of a hypothetical *targeted policy* intervention in a typical London local authority (Hackney) as well as a hypothetical *citywide policy* intervention that affects London wide housing costs, based on several simplifying assumptions.[35]

In Step 1, we assume that the measure to increase house affordability reduces average house prices in the targeted local authority i by 1% for each year over a ten-year period between 2024-2033.[36] While the policy does not directly change prices in neighbouring local authorities, the change in housing affordability in local authority i affects housing affordability within a 20 km buffer for neighbouring local authorities j (i.e. the analysis considers the specific local authority as well as the wider commuting area).[37]

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35 The median productivity in 2021 (£66,000), average house price (£461,000), and average house price ratio (11.3) between 2002 and 2021 in Hackney is similar to the London region as a whole (£64,000, £465,000, and 11.6).

36 I.e. we assume the policy resulted in lasting 1% reduction of house prices in 2024, 2025, …, 2033 in the targeted local authority, rather than only once in 2024. We assume wages are held constant when house prices change by 1%, therefore a 1% change in the house prices leads to a 1% change in the house price ratio.

37 Therefore productivity in areas j surrounding i will also change as housing becomes more affordable in i (see details in Appendix A.2).

In Step 2, we adopt the estimated elasticity of productivity with respect to housing affordability from our baseline IV regression (-0.14), i.e. a 1% increase in housing affordability within a 20 km buffer is associated with a reduction in productivity of about 0.14% for each area impacted. The effect on productivity (in percentage terms) is therefore equal to the elasticity times the change in housing affordability in area i and areas j within a 20 km buffer.

In Step 3 we calculate the change in GVA in areas i and j per year as the effect on productivity from Step 2 times the GVA (productivity times number of employees) in each area affected for each year.[38]

In Step 4 we aggregate these GVA changes to come up with a total GVA impact of £22.5 million per year in the areas affected, resulting in a total undiscounted impact of £225 million over an appraisal period of 10 years. This overall increase would be split between gross wages to employees (~55%) and other GVA (~45%) and would be aggregated over all employees within a 20 km buffer zone around the local authority, which translates to an increase of roughly £3.60 per job per year, of which £2 are wages.[39] This indicates that the benefits of targeting housing policy in a local authority have substantial benefits in the wider area surrounding the local authority, with around £6 million (undiscounted) GVA impact over the appraisal period (or 3%) materialising in Hackney and the remaining £219 million (97%) occurring in neighbouring local authorities within 20 km.

We also apply the approach to a typical inner London (Islington) and outer London (Bromley) local authority.[40] A 1% reduction in house prices in Islington implies an increase in GVA of approximately £226 million over 10 years (undiscounted) or £3.60 per job per year (£2 wages), while in Bromley the same reduction in house prices implies an increase in GVA of approximately £133 million over 10 years (undiscounted) or £3.70 per job per year (£2 wages).[41] We find similar effects with most of the GVA benefits (95%) materialising in the local authorities surrounding the area where house prices decline for Islington and Bromley.

If the application of a 1% reduction in house prices is extended to all 33 local authorities in the London region, this would imply an increase in GVA of approximately £7.3 billion over 10 years (undiscounted) or £85 per job per year, of which £47 are wages.[42] In the London wide case, the benefits do largely materialise within the London region (92%), as the productivity impacts within 20 km are minor outside of London. Figure 7.2 summarises the results from the policy application.

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38 In our simplified application, we assume real GVA between 2024 and 2033 is the same as current GVA in 2021 and productivity effects are not compounded over time (so any real growth in productivity is equal to the discount rate).

39 Other GVA includes gross operating surplus (gross profit to employers) and mixed income. As the share of GVA that is wages is based on the UK national income breakdown from 2017 the share may vary from area to area. There are approximately 6.3 million jobs within a 20 km buffer around Hackney.

40 These locations are selected based on their similarity to average productivity and house prices within inner and outer London local authorities, where inner London local authorities include Camden, Greenwich, Hackney, Hammersmith and Fulham, Islington, Kensington and Chelsea, Lambeth, Lewisham, Southwark, Tower Hamlets, Wandsworth, and Westminster.

41 There are approximately 6.3 and 3.6 million jobs within a 20 km buffer of Islington and Bromley, respectively.

42 The assumes that average house prices decline by 1% per year for a period of 10 years for all local authorities in London. There are approximately 8.5 million jobs within a 20 km buffer of all London boroughs.

Figure 7.2: Summary of Results from Policy Application

Example: A housing policy which reduces average house prices in an area by ~1% per year over a period of 10 years.

	Typical London Borough	Typical Inner London Borough	Typical Outer London Borough	Citywide
	Hackney	Islington	Bromley	London
Total increase in GVA over 10 Years	£225 Mn	£226 Mn	£133 Mn	£7.3 Bn
% of GVA benefits within area	3%	5%	5%	92%
... which implies £X per job per year	£3.6	£3.6	£3.7	£85
... of which £X are wages	£2	£2	£2	£47

Source: NERA illustration.

In each case, the GVA benefits would have to be compared to the costs of the policy intervention to assess the net impact of improved housing affordability.

7.4. Limitations and Extensions

In the calculations above, we show how the elasticity can be applied to a hypothetical policy case, making several simplifying assumptions which would need to be worked through more fully in a proper analysis. *First*, we do not apply any public discount rate, so future economic benefits (which will have a lower weight than current benefits) are likely to be smaller than estimated above. *Second*, we assume there are no costs of implementing the housing intervention. In reality there may be administrative or other costs, which would need to be weighed against the benefits. *Third*, we assume that the productivity gains do not compound over time. If the gains to productivity do compound over time, the benefits are likely to be higher.[43] *Fourth*, the effects on productivity at the local level are dispersed over the areas impacted, so these findings should not be considered with regards to the local authority (e.g. Hackney) alone but will also affect other neighbouring local authorities in the wider area. *Finally*, the share of GVA benefits within the area calculated depends on the assumption of how the relevant buffer zone around a local authority is defined and calculated, so considering more complex methods to account for commuting areas (e.g. accounting for travel time) may result in different magnitudes of impact in the surrounding areas.

43 Given the period of analysis (20 years), it is likely that our estimates are short-run and therefore it is likely to be more appropriate not to compound changes over time.

During a workshop, where we presented the analysis and findings of the report and elicited feedback from policy makers, practitioners, and academics, several interesting and relevant avenues to extend this work in the future work were discussed, including:

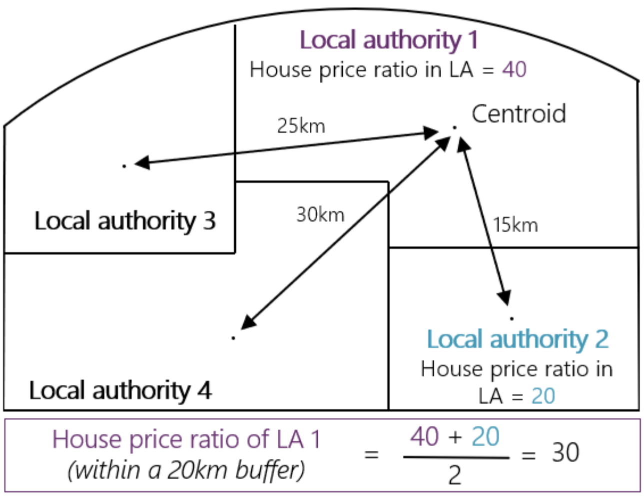
1. **Extending the geographic scope of the analysis**. This could extend the scope of the analysis to the UK as a whole or by focusing on other cities and their wider commuting/labour markets.
2. **International benchmarking**. Other major global cities are also facing housing market pressures. Therefore, it may be relevant to assess whether the situation is better or worse in London as compared to other similarly sized cities (e.g. Paris or New York) to better understand the extent to which productivity in London is constrained by high housing costs as compared to other cities.
3. **Contribution of housing affordability to stagnating productivity**. One potential implication of the research is to assess the extent to which worsening housing affordability in London has contributed to the low level of productivity growth over the past 20 years.
4. **Identifying the economic mechanisms**. The literature proposes several economic mechanisms to explain why deteriorating housing affordability may negatively affect economic productivity (see Section 2.2), however this analysis has not focused on distinguishing these mechanisms and is best suited to identify local impacts. Further research could focus on developing new methodologies to disentangle the mechanisms so that policy makers can better understand the causal channels through which housing affordability impacts productivity.
5. **Evidence base for the effect of housing policies on affordability**. Policy makers have various options for measures to improve housing affordability. While this study does not examine the effectiveness of housing policies on affordability (the application considers a hypothetical housing policy which reduces house prices by 1%) policy makers would benefit from a better understanding of this to more clearly assess the benefits and costs of policy options and support decision making.

Appendix A. Additional Descriptives

A.1. Buffer Zone Analysis

Figure A.1 illustrates how buffers are computed using the distances between local authorities and averaging over the independent variable. The same approach is applied to the IV.

Figure A.1: Conceptual Illustration Buffer Computation

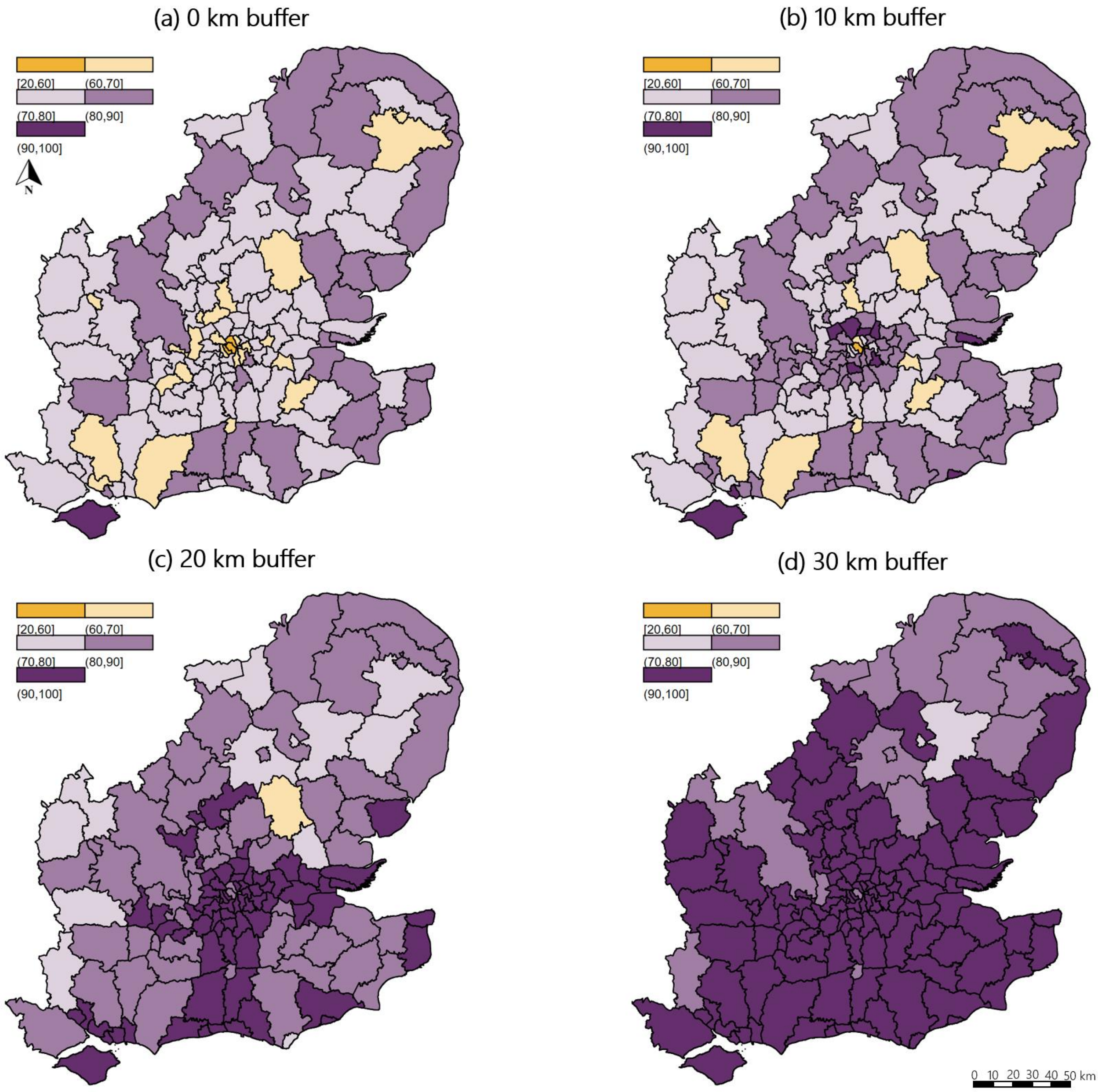


Source: NERA illustration.

We define the relevant buffer for our baseline analysis to be 20 km (see Section 5.2). As can be seen in Figure A.2, buffer zones below 20 km capture less than 60% of commuters for some local authorities in London, while buffers larger than 20 km are potentially too large and capture irrelevant information on housing costs. A 20 km buffer captures 80% or more commuters for all local authorities in London, except the City of London (72%), and 90% or more for most local authorities in London. In comparison, buffers below 20 km do not capture more than 60% of commuters in some local authorities in London and in the rest of the Greater Southeast region. Meanwhile a buffer of 30 km or more captures more commuters, but is likely to include housing costs that are less relevant, particularly for London where commuting distances are shorter but take more time.[44]

[44] For example, the distance between the local authority furthest East and West in Greater London is approximately 45km, while the distance between the local authority furthest North and South is about 30km. Therefore, a 30 km buffer is likely to be too large.

Figure A.2: Proportion of Workers Living Within 0, 10, 20, and 30 km Buffers



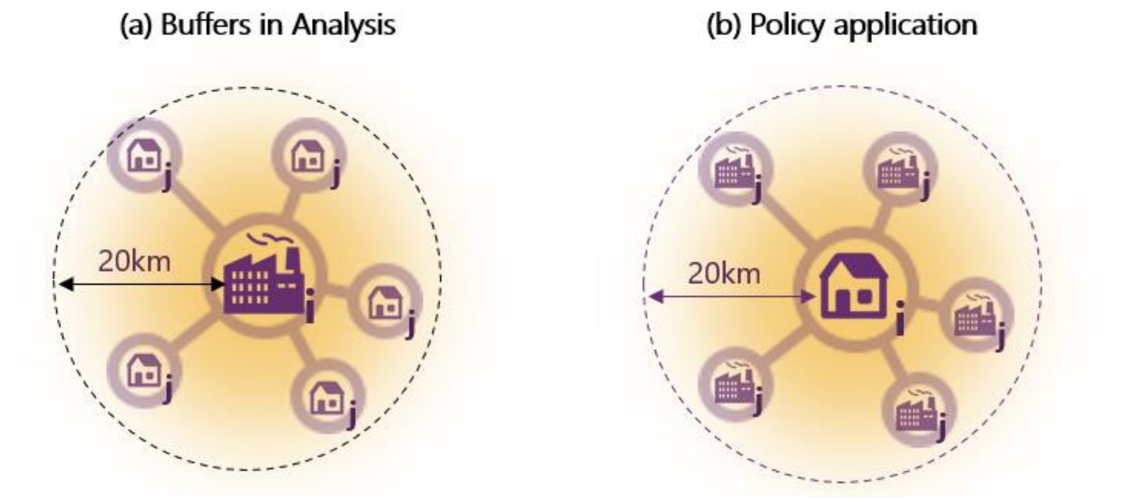
Source: NERA analysis of ONS data on commuting distance.

A.2. Buffer Zones in Policy Application

In our analysis, we calculate housing affordability within a 20 km buffer zone to determine the effect of housing affordability in the commuting area j on productivity in a local authority i (plot (a) in Figure A.3).

Meanwhile in the policy application, we consider how a change in house prices in a local authority i affects housing affordability within a 20 km buffer of local authority i as well as housing affordability in other local authorities j in the 20 km buffer (plot (b) in Figure A.3). While housing affordability does not improve directly in areas j, affordability for people working in areas j improves because they have access to cheaper housing within 20 km due to the reduction in house prices in area i. Therefore, the changes in productivity are not concentrated in local authority i (in the case of a targeted housing policy), but also impact surrounding local authorities j.

Figure A.3: Buffer Zones in Analysis and Policy Application



Source: NERA illustration.

A.3. House Prices as a Proxy for Housing Costs

To validate the assumption that house prices are a suitable proxy housing costs more generally, we examine the relationship between house prices and private rental prices for London as a whole between 2005-2021. As can be seen in Figure A.4, there is a strong positive relationship between prices and rents and the linear correlation between house prices and rents is high (0.96). Therefore, we consider that house prices are a suitable proxy for private housing related costs.

Figure A.4: Relationship Between House Prices and Private Rents in London, 2005-2021

Notes: Simple linear regression plotted in dots.
Source: NERA analysis of ONS.

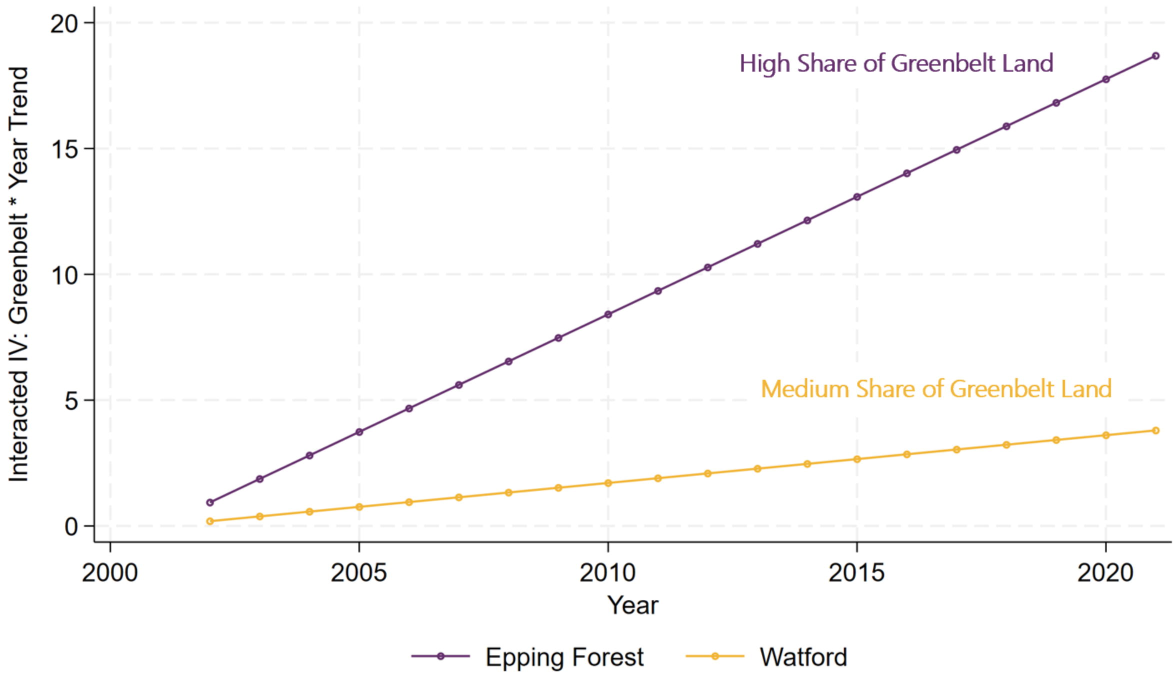
A.4. Additional Details on Methodological Approach

Figure A.5 illustrates how the time interaction between share of greenbelt and the year trend works. As can be seen, the expectation is that over time, the supply constraint is higher in the area with a higher share of greenbelt land in 2012, where the slope of the relationship is equal to the share of greenbelt land. The general idea is that:

- Areas will become more supply constrained over time.
- This tightening of supply constraints is higher in areas with a higher share of greenbelt land.
- The ratio of the IV between areas will remain the same but the analysis will tell us whether there is a linear relationship between the IV and housing costs.

It is possible that the relationship between the IV and housing costs is not linear, i.e. that housing costs are more sensitive when areas have higher shares of greenbelt land. This may be an area of further research.

Figure A.5: Illustration of IV for Medium and High Share of Greenbelt Land



Note: This figure is for illustration purpose only.
Source: NERA illustration.

We validate the motivation behind the use of instrumental variables by examining the sign of the first-stage regression coefficient on the instrument. We also assess this descriptively by assessing the relationship between house prices and the share of greenbelt variable interacted with the year trend (i.e. the actual instrument we use in our analysis).

As can be seen in Figure A.6, we observe a positive relationship between the instrumental variable and the average house price variable. As explained, the interaction between the share of greenbelt land and the year trend serves as an indicator of the supply constraint. The upward sloping fitted line indicates the positive relationship, aligning with our expectation that a higher level of supply constraint is associated with higher housing prices overall.

Figure A.6: Relationship Between House Prices and the Instrumental Variable

Notes: House prices are over 2002-2021. The X-axis in the figure represents the share of greenbelt land multiplied by the year trend. The year trend starts from 2002, which is defined as year 1, and goes up to 2021, which is defined as year 20. For example, if a local authority had 25% of greenbelt land in 2002, the x-value would be 0.25 multiplied by 1, resulting in an x-value of 0.25. Meanwhile, if a local authority has 90% greenbelt land, the x-value in 2021 would be 0.90 multiplied by 20, resulting in an x-value of 18.
Source: NERA analysis.

A.5. Overview of Data Availability

Table A.1: Potential Metrics to Measure Productivity

Metric	Description and Source	Availability	Source	Pros	Cons
Productivity per number of filled jobs*	Computed as GVA divided by number of filled jobs. GVA is sourced from the UK National Accounts and the number of filled jobs is mainly from the Short-term Employment Survey (STES).	309 local authorities in England from 2002 to 2021.	ONS	Data is available 2 years earlier than productivity per hours. The number of filled jobs is estimated using a survey distributed to the employer, which provides more confidence the metrics relate to workplace locations.	'Number of jobs' is reported by employers, which can contain errors and false reporting. It is also based on head offices' location rather than local offices.
Productivity per total hours worked	Computed as GVA divided by total hours worked. GVA is sourced from the UK National Accounts and the average weekly hours worked from the Labour Force Survey (LFS).	309 local authorities in England from 2004 to 2021.	ONS	Using hours worked can provide more accuracy when measuring productivity (preferred measure by ONS and OECD).	'Hours worked' is collected through surveys distributed to households, which may be based on a different local authority to where the employee works.
Productivity per worker	Computed as GVA divided by workers. GVA is sourced from the UK National Accounts and the number of workers is based on the Labour Force Survey (LFS).	Nationally, from 1959 until 2023.	ONS		Data is not available at the local authority level and therefore cannot be used in our analysis.

*Notes: Data by industry is available through the ONS dataset on GVA and the Nomis dataset on employment. *The data includes employed, self-employed, HM forces jobs (LFS), and Government Supported Trainee jobs (LFS).*
Source: ONS Labour Productivity QMI.

Table A.2: Potential Metrics to Measure Housing Affordability

Metric	Description and Source	Availability	Source	Pros	Cons
Average (or Median) House Price (Unweighted/Weighted)	Average (or Median) price paid for residential property transactions, by property type and administrative geographies. Available in both index form (HPI), average price, and at the transaction level.	353 local authorities in England from 1968 to 2024.	HM Land Registry and ONS	Various levels of aggregation available (e.g. by country, by LA, by region). Prices account for housing characteristics (based on hedonic regression method).[45] Prices can also be weighted by property type. The median is less susceptible than the mean to outliers and is widely used as a metric for housing prices. Interpreting the results using house prices in the regression is straightforward.	No direct inference to affordability through earnings.
Index of Private Housing Rental Prices	The IPHRP measures the change in the price that tenants face when renting residential property from private landlords.	Region and country level from 2005 to 2024.	ONS	The index not only measures the change in newly advertised rental prices, but reflects price changes for all private rental properties, including for existing tenancies. It captures the change in house price from a rental market perspective.	ONS marked this index as "experimental" in its annual statistical bulletin. It is also only published at a country and regional level. Average rental price is not available due to data access constraints.

45 Hedonic regression is a common method used to estimate the value of different characteristics of a property. It applies econometric analysis to determine how certain factors contribute to the overall price or value of the property. For instance, these attributes could include the number of bedrooms and the location. This approach is widely applied in the academic literature and is considered to be a credible approach by ONS.

Metric	Description and Source	Availability	Source	Pros	Cons
Ratio of House Price to Workplace-Based Earnings	Ratio of median house price to median gross annual workplace-based earnings.	309 local authorities in England from 1997 to 2022.	ONS	The ratio serves as an indicator of relative affordability of people that work in a particular location.	Annual data refers to a 12-month period with April in the middle, which is inconsistent with other variables in our dataset. Annual gross earnings data is only available after 2003 for some LA. House prices are not mix adjusted, so represent a varying mix of property types sold over time.
Ratio of lower quartile house price to lower quartile workplace-based earnings ratio	Ratio of lower quartile house price to lower quartile gross annual workplace-based earnings	309 local authorities in England from 1997 to 2022.	ONS	Same as median ratio, but particularly focuses on the lower quartile income earners and lower quartile house prices.	Same as median ratio, however additionally, the lower quartile is not published as part of the latest release by ONS.

Source: *NERA analysis of ONS and HM Land Registry data on House Price Index (2024), median house price (2024), Index of Private Housing Rental Price (2024), ratio of median house price to median gross annual workplace-based earnings (2024), ratio of lower quartile house price to lower quartile gross annual workplace-based earnings (2023).*

Appendix B. Additional Results

Table B.1: OLS Sensitivity Analysis

	Baseline	**Diff. dep. variable**	**Diff. exp. variable**	**Incl. region trends**	**Exclude Covid years**	**5-year intervals**	**Incl. jobs density**	**London only**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
House price ratio 20 km (log)	-0.0618**	-0.0708**		-0.0627**	-0.0407*	-0.109***	0.0355	-0.164
	(0.0298)	(0.0306)		(0.0298)	(0.0233)	(0.0385)	(0.0226)	(0.129)
House price (log)			-0.0180					
			(0.0367)					
Gross income (log)			0.0953***					
			(0.0252)					
London* Year Trend				0.00223				
				(0.00167)				
South East * Year Trend				0.00334***				
				(0.000240)				
Jobs density 20 km (log)							-0.145***	
							(0.0405)	
Observations	2838	2556	2690	2838	2554	708	2799	660
R2 (within)	0.82	0.78	0.82	0.82	0.83	0.83	0.82	0.82
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Area FE	Y	Y	Y	Y	Y	Y	Y	Y

*Notes: Dependent variable is Productivity per employee (log), except in column (2) where it is Productivity per hour worked. Driscoll-Kraay standard errors in parenthesis (2 lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively. "Diff. dep. Variable" in column (2) uses an alternative measure of productivity (by hours), while "Diff. exp. variable" in column (3) uses an alternative measure of housing affordability (splitting housing prices and wages).*
Source: NERA analysis.

Table B.2: IV First Stage Sensitivity Analysis

	Baseline (1)	Diff. dep. variable (2)	Diff. exp. variable (3)	Incl. reg. trends (4)	Excl. Covid years (5)	5-year intervals (6)	Alt. IV (historical) (7)	IV no buffer (8)	Incl. jobs density (9)	London only (10)
Share Greenbelt (20 km) x Year	0.018***	0.022***	0.010***	0.020***	0.019***	0.013***			0.016***	-0.022***
	(0.0035)	(0.0031)	(0.0021)	(0.0039)	(0.0043)	(0.0037)			(0.0029)	(0.0061)
Gross income (log)			-0.12***							
			(0.037)							
London* Year Trend				0.017***						
				(0.0033)						
South East * Year Trend				-0.00074						
				(0.00076)						
Share Hist. Greenbelt (20 km) x Year							0.026***			
							(0.0048)			
Share Greenbelt x Year								0.0082***		
								(0.0020)		
Jobs density 20 km (log)									0.63***	
									(0.069)	
Observations	2838	2556	2690	2838	2554	708	2838	2778	2799	660
R2 (within)	0.88	0.86	0.95	0.93	0.86	0.94	0.89	0.87	0.94	0.99
First-stage F-stat	25.7	51.8	22.3	26.8	20.4	11.9	29.9	17.2	31.4	13.1
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Area FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

*Notes: Dependent variable is house price to wage ratio (log), except in column (3) where it is the average house price (log). Driscoll-Kraay standard errors in parenthesis (2 lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively. "Diff. dep. Variable" in column (2) uses an alternative measure of productivity (by hours), while "Diff. exp. variable" in column (3) uses an alternative measure of housing affordability (splitting housing prices and wages).*
Source: NERA analysis.

Table B.3: IV Second Stage Sensitivity Analysis

	Baseline	Diff. dep. variable	Diff. exp. variable	Incl. reg. trends	Excl. Covid years	5-year intervals	Alt. IV (historical)	IV no buffer	Incl. jobs density	London only
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
House price ratio 20 km (log)	-0.14***	-0.24***		-0.11***	-0.14***	-0.16***	-0.21***	-0.14*	-0.14***	1.88***
	(0.034)	(0.049)		(0.029)	(0.042)	(0.040)	(0.039)	(0.081)	(0.040)	(0.58)
House price (log)			-0.097							
			(0.070)							
Gross income (log)			0.083***							
			(0.028)							
London # Year trend				0.0030**						
				(0.0015)						
South East # Year trend				0.0033***						
				(0.00024)						
Jobs density 20 km (log)									-0.031	
									(0.056)	
Observations	2838	2556	2690	2838	2554	708	2838	2778	2799	660
First-stage F-stat	25.7	51.8	22.3	26.8	20.4	11.9	29.9	17.2	31.4	13.1
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Area FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

*Notes: Dependent variable is Productivity per employee (log), except in column (2) where it is Productivity per hour worked. Column (6) only includes 5-year interval. Driscoll-Kraay standard errors in parenthesis (2 lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively. First-stage F-stats are taken directly from the first stage regression. "Diff. dep. Variable" in column (2) uses an alternative measure of productivity (by hours), while "Diff. exp. variable" in column (3) uses an alternative measure of housing affordability (splitting housing prices and wages).*
Source: NERA analysis.

Table B.4: Buffer Zone Sensitivity Analysis (OLS)

	(1)	(2)	(3)	(4)	(5)	(6)
House price to wage ratio no buffer (log)	-0.037					
	(0.026)					
House price to wage ratio 5 km (log)		-0.040				
		(0.027)				
House price to wage ratio 10 km (log)			-0.049			
			(0.030)			
House price to wage ratio 20 km (log)				-0.062**		
				(0.030)		
House price to wage ratio 30 km (log)					-0.081**	
					(0.033)	
House price to wage ratio 50 km (log)						-0.071**
						(0.034)
Observations	2833	2833	2834	2838	2840	2840
Area FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y

*Notes: Column (4) is the baseline result. Dependent variable is Productivity per employee (log). Driscoll-Kraay standard errors in parenthesis (2 lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively.*
Source: NERA analysis.

Table B.5: Buffer Zone Sensitivity Analysis (IV)

	(1)	(2)	(3)	(4)	(5)	(6)
House price to wage ratio no buffer (log)	-0.16					
	(0.12)					
House price to wage ratio 5 km (log)		-0.22				
		(0.15)				
House price to wage ratio 10 km (log)			-0.37***			
			(0.090)			
House price to wage ratio 20 km (log)				-0.14***		
				(0.034)		
House price to wage ratio 30 km (log)					-0.051	
					(0.039)	
House price to wage ratio 50 km (log)						-0.076*
						(0.041)
Observations	2774	2774	2775	2838	2840	2840
First-stage F-stat	6.4	5.7	13.3	25.7	28.3	29.3
Area FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y

*Notes: Column (4) is the baseline result. Dependent variable is Productivity per employee (log). Driscoll-Kraay standard errors in parenthesis (2 lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively. Buffer zones applied to the instrumental variable adopted and are consistent with the buffers zone of the key independent variable in this exercise. For instance, share of greenbelt with 20 km buffer zone is used as the instrument for House Price Ratio with 20 km buffer zone.*
Source: NERA analysis.

Table B.6: Standard Error Sensitivity Analysis

	OLS results			IV results		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
House price to wage ratio 20 km (log)	-0.0618**	-0.0618*	-0.0618***	-0.14***	-0.14***	-0.14***
	(0.0298)	(0.0329)	(0.0213)	(0.034)	(0.038)	(0.044)
Observations	2838	2838	2838	2838	2838	2838
First-stage F-stat				25.7	19.6	32.0
Year FE	Y	Y	Y	Y	Y	Y
Area FE	Y	Y	Y	Y	Y	Y
Lag (Bandwidth)	2	3	10	2	3	10

*Notes: Column (1) and (4) are the baseline results for OLS and IV. Dependent variable is Productivity per employee (log). Driscoll-Kraay standard errors in parenthesis (varying lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively.*
Source: NERA analysis.

Table B.7: Alternative Instrument Sensitivity Analysis (First Stage)

	Share DLD (1)	Share DLSD (no coastal) (2)	Share of Greenbelt (3)	Terrain (4)
Share DLD (20 km) x Year	0.031***			
	(0.0058)			
Share DLSD (20 km) x Year		-0.074***		
		(0.0054)		
Share Greenbelt (20 km) x Year			0.018***	
			(0.0035)	
Share slope >10% (20 km) x Year				0.16
				(0.51)
Ruggedness (20 km) x Year				-0.024***
				(0.0038)
Observations	2799	2799	2838	2799
First-stage F-stat	27.9	189.9	25.7	23.4
R2 (within)	0.92	0.87	0.88	0.88
Area FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y

*Notes: Dependent variable is house price to wage ratio (log). The Share of DLSD excludes coastal regions to reduce potential impacts of flood risk on house prices (demand side response). Driscoll-Kraay standard errors in parenthesis (2 lags) with ***, **, * indicating statistical significance at the 1%, 5%, and 10% levels, respectively.*
Source: NERA analysis

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