Universities' global research ambitions and their localised effects.

Abstract

The world's top universities compete for the best international students and staff whilst remaining socially, politically and economically intertwined with the cities that they are located in. This paper analyses this relationship through the lens of the housing market to show the impact of universities' global research centres on local house price within five of UK's historic cities. To date, these complex effects have been largely ignored in local and regional modelling. By applying a novel spatio-temporal model, we find that the spatial house price effects are much more pronounced in Cambridge than that witnessed in the other comparable UK cities. This not only suggests the relationship between the university and city economy is more interrelated but that its research centres may create localised spill over effects on both businesses and residents. Whilst these relationships are likely to differ across locations, housing shortages remain a universal issue. This suggests that sustaining international competitiveness of cities requires sound planning and housing policies that support universities' growth trajectories.

Keywords: University growth, Research centres, House prices, Planning policy

1. Introduction

Across the globe, heightened competition has placed universities under considerable pressure to expand and attract talented workers. Continued investment in global research centres has become a critical strategy among the top ranked universities in order to sustain research excellence and compete for national and international recognition (Cattaneo et al. 2016, Paradeise & Thoenig 2013). Local policy makers are equally under pressure from their central governments to accommodate universities' expansion plans, as their growth trajectories are of national and international significance, beyond local concerns (BIS 2016). As Kitson (2010) contends, 'places need embedded economic actors, and universities are one of the most important' (p.4). Unlike increasingly mobile private sector organisations, universities do not move in response to economic shocks (Morrison 2013).

Maintaining growth in university locations relies on their global reach and ability to attract talented workers internationally (Hale and Vina 2016). In terms of research excellence and academic reputation, the most highly sought after locations are those closely linked to universities at the top of the league tables (Time Higher Education Ranking 2017), including those found in the US (MIT, Harvard, Stanford, Berkeley), Switzerland (ETH Zurich) and Singapore (NUS). Whilst high quality of life is amongst the most important factors of international mobility destination choices (Addie 2016, Shapiro 2006), high housing costs increasingly limit location choices of newcomers, restricting their ability to take advantage of these benefits (Szumilo et al 2016).

Although a direct comparison of affordability ratios among countries is difficult, the majority of cities hosting world-class universities suffer from high housing costs. Cambridge in Massachusetts (hosting MIT) has seen its housing costs rise by 47% since 2010, making it inaccessible to newcomers and locals alike (McMullen 2016). San Francisco (hosting Berkeley university) is notoriously unaffordable, with its prices remaining amongst the highest in the US over the past decade (Worstal 2016). At the same time, housing for foreign academics in Singapore is in short supply and home ownership have become increasingly unaffordable for the majority of newcomers (Phang 2015). Zurich faces a similar problem, with its local policy makers working with the Federal Institute of Technology (ETH) to develop a campus outside the city in order to facilitate its growth (Davidson 2010).

UK's universities face similar difficulties, including not enough research space and limited teaching facilities alongside shortages of affordable housing for students and staff. These local constraints not only constrict these global institutions' growth potential but also reduce their positive impact on the national economy (McAdam and McAdam 2008, Laursen 2010). Whilst local constraints on growth in UK cities are comparable to those witnessed internationally, there are distinct aspects at play. These include land use planning regulations, in particular, green belt policy that restricts urban land availability and compounds the difficulty of accommodating universities' growth plans (Morrison 2013).

Moreover, this tension is particularly pronounced in UK's historical cities where paradoxically most of UK's top-ranked universities are located. These historic places are very much intertwined with maintaining the legacy of their universities. Land use planners face a tension between reconciling the need to preserve the university setting and its historic buildings, whilst allowing universities to expand and offer modern state-of-the-art facilities in order to compete with newer universities both nationally and internationally. The Universities of Oxford (founded in 1096), Cambridge (founded in 1209), Durham (founded in 1882), Exeter (founded in 1855) and York (founded in 1959) exemplify this inherent tension. These internationally significant organisations face pressures to expand in order to maintain their competitiveness (Hale and Vina 2016), however, local barriers to growth, including highly constrained urban cores, tightly drawn local authority boundaries and green belt policies, are the most acute (Centre for Cities, 2014).

The purpose of this paper is to examine the spatial house price effects from allowing universities to develop global research centres within these five comparable historic cities. Although the underlying spatial structure of each housing market is determined not only by its employment opportunities but also by its access to transportation networks and other factors, this specific relationship has been largely ignored in local and regional modelling and policy making, to date (Addie 2017). This paper's contribution is therefore three-fold, in that it fills a theoretical, methodological and policy research gap.

The paper's first contribution is through its application of Glaeser's et al (2006) theoretical and analytical framework to studying how cities accommodate university growth plans and analysing the subsequent localised house price effects. The value of Glaeser's et al (2006) framework is that it links local economic development to its surrounding housing market. The approach allows modelling feedback effects between supply and demand for housing in the context of changes in employment and wages. On the one hand, a university's goal is to invest in facilities that attract talented newcomers into the city, on the other hand its new global research centres contribute to further employment growth and demand pressures far outstripping housing supply, which adds pressure onto existing housing stock and creates further localised house price effects (Boddy & Hickman 2016). In this case the traditional conflict between homeowners (who benefit from increasing prices) and renters or newcomers (who are negatively affected by high house prices) is influenced by the fact that local economic growth critically relies on the latter group. To date, no study has built on Glaeser et al (2006) in this novel way and explored these complex relationships. This paper thus fills this theoretical research gap.

The paper's second contribution is to extend and apply a novel spatially autoregressive dynamic panel model to assess the spatial house price effects of universities' research centres on their surrounding neighbourhoods and the region overall (see Szumilo et al 2016). While dynamic panel models are now relatively common (Blundell and Bond, 1998) and spatial econometric models have been well documented (Elhorst, 2003), the analysis of spatio-temporal processes remains underdeveloped especially in policy context (Dubé and Legros 2013). The paper thus fills this methodological research gap.

The key research finding derived from the modelling exercise between 2000 and 2011, is that the University of Cambridge's global research centres have a more pronounced spatial house price effect than that witnessed in the four other comparable UK historic cities. This not only suggests that the relationship between the university and the local economy is more interrelated but that the university may have distinct agglomeration benefits for both businesses and residents. Although the relationship between universities and their surrounding housing markets appears structurally different, the paper contends the universities have created spill over effects to varying degrees in each of the five historic cities.

The paper thus concludes, contributing policy recommendations. Whilst major investment in infrastructure and housing stock have taken place in Cambridge since 2011, the response has been criticised for being lagged and not enough to address the university's growth trajectory

(Centre for Cities 2014, Boddy and Hickman 2016; Cambridge Ahead 2017). Analysing the way universities are intertwined with their host regions through the lens of the housing market offers a fresh angle to these policy debates. We conclude that to sustain international attractiveness of regions requires both central and local planning policies that support universities' expansion through on-going release of additional housing land.

2. The pressure on universities to expand - the context

While UK universities are amongst the most popular in the world, they face increasing competition from international rivals (Boliver 2013). Attracting the best students and researchers from around the world is critical to the future of academic institutions. The simplest economic method to attract the best talent is through offering financial incentives and many world-class institutions apply such an approach (Paradeise and Thoenig 2013). Within the UK, university salaries, however, are limited by national stipends. Although there are opportunities to offer higher individual salary packages, world-class universities need to also find other ways to attract talented workers overall. In this light, continued investment in facilities that are valued by the best students and researchers is crucial for maintaining the international competitiveness of UK's academic institutions (Haskel and Wallis 2013).

The locations of the UK's top ranked universities appear to perform well with regard to quality of life indicators against their main rivals (Morais et al. 2013). Limited housing availability and high housing costs, however, are likely to deter newcomers as they restrict their capacity to take advantage of these city features (Szumilo et al. 2016). Consequently, UK universities are not only unable to offer competitive salaries but the disposable income of their employees is eroded by high housing costs. Improving living standards is not the only non-income incentive that universities adopt. Another way of attracting the best people is to offer them a working environment that makes them more productive. As Ackers and Gill (2005) contend, state-of-the-art laboratory equipment attracts scientists, good links to the industry appeal to engineers while all researchers benefit from a large community of like-minded peers who can support each other and share research facilities. Investment in new global research centres that can be used across different disciplines has therefore become an important element of university development strategies. [1]

For Fischer and Varga (2003), the benefit of knowledge spill overs allows academics to create and develop new ideas faster. Interdisciplinary research is much easier in an environment where experts from different fields are easy to contact. Productivity may increase as a result of the ability to share not only facilities but also ideas and experience. Consequently, there are clear agglomeration benefits from having a large and diverse community of scholars. In addition, it would appear that larger academic institutions not only have an advantage in this respect but also an incentive to continue growing in size.

A further incentive to invest in expansion of global research centres comes from the fact that higher education around the world has become very competitive and the most reputable academic institutions can be seen as relatively close substitutes for each other (Taylor and Cantwell 2005). In this light, any institution that wishes to become or remain competitive has to match the offer of its competitors in all of the above areas (quality of life, availability of facilities, size of the research community). In this ‘arms-race’ scenario, the best universities will soon be surpassed by others and be under pressure to expand. Whilst the rationale for

[1] This study defines global research centres as ones that are locationally specific and developed by highly ranked educational institutions, with their size measured by the number of research jobs offered in each centre (see Wildavsky 2012).

university expansion has been well documented, the local house price effects of spatially fixed global research centres on the surrounding area have been under-explored, both theoretically and empirically, to date.

3. Spatial house price effects of universities' global research centres – the theory

The impact of economic growth of an organisation on house price and affordability within its host city is heavily debated (Castells-Quintana and Royuela 2014, Haslam-McKenzie and Rowley 2013, Di Pietro 2007). Individual economic, social and historic conditions of every city can make its housing market respond differently. While the basic laws of economics still apply, the traditional approach used to model prices in housing markets has to be adjusted to reflect the factors that characterize the ability of each city to adapt to a particular organisation's growth plans.

Drawing on Glaeser et al. (2006), this work suggests that the extent to which increases in productivity will create bigger cities or just higher paid workers and more expensive housing depends on the elasticity of housing supply. Their findings show that an initial increase in the productivity of organisations within specific locations will result in higher wages, given that productive opportunities will be exploited to the point where the marginal product of labour equals the wage rate. This higher wage increases the utility provided by the location and attracts new workers.

Glaeser's et al. (2006) theory implies that the reaction of house prices at a location to an increase in productivity will depend on its housing supply elasticity. Should housing supply be restricted, the size of the local population would remain relatively unchanged regardless of how much the demand for labour increases. This would limit the supply of labour and stifle productivity by forcing companies to increase wages. It is likely that increased wages would increase the skill level of the population by pricing low-skill workers out of entering into the housing market (Ortalo-Magne and Rady 2008). This would result in new high-skilled workers moving into the area only if wages are high enough for them to price out other segments of the market. Consequently, the labour force would include the native households and the richest newcomers. Companies that want to attract new workers are therefore forced to increase wages.

UK's historic cities hosting world class universities exemplify inelastic housing markets whilst benefiting from local economies that are growing and reliant on highly skilled labour. Universities situated in Oxford, Cambridge, Durham and Exeter, for example, are confronted by planning regulations governing the expansion of their premises and the development of new housing. This limits opportunities for re-development of land and reduces elasticity of housing supply within those locations (Barker 2008). In addition, tight administrative boundaries and green belt policies are in place which historically hamper outward urban growth and further constrains the supply of new commercial and housing stock within its existing boundaries (Cheshire 2013). Whilst green belts do get reviewed and land is released under exceptional circumstances, variations in policy are partly a reflection of the characteristics of the local district (both spatially and politically) that plans for it and the result of different demands placed on the green belt (CPRE 2018).

Moreover, these cities' economies are also traditionally highly dependent on the skills of the local university graduates and researchers. Private sector companies often locate themselves close to reputable education centres in order to be able to take advantage of research collaboration opportunities, spill over effects and gain access to a skilled labour force (Guerrero and Urbano 2014). Unlike UK universities that are restricted by national pay-scales, private companies have the ability to offer wages at highly competitive market rates in order to attract the best skilled workers. Yet any gains in labour productivity may be offset by losses of capital productivity since this labour would be proportionately more expensive. As Glaeser at al (2006) as well as Ortalo-Magne and Rady (2008) suggest, restricted housing supply in economically growing locations may limit this growth overall.

In the interests of international competitiveness, the potential of the UK's universities' knowledge-based clusters have become too important to be endangered by skilled labour shortages (Morrison 2013). A key element of local and regional strategic planning has been the commitment to allow universities to create global research centres shared with international companies (Widavsky 2012). This strategy has involved working with local authorities to obtain special permissions to either relax the restrictions on redevelopment of existing buildings or to release green belt land in response to the universities' exceptional development needs (see Morrison 2010). Whilst this has resulted in increased employment space in otherwise tightly constrained urban areas, the impact on price is significant. Whilst this has resulted in increased employment space in otherwise tightly constrained urban areas, the spatial house price effects have yet to be investigated. The next section establishes how such an investigation is to be conducted.

4. Empirical Research Methods

Housing choices follow a spatial and temporal diffusion process. On the one hand, changes in the average house price in a certain region affect this value in neighbouring locations. Hence, any local house price shock is propagated to surrounding areas. On the other hand, anchoring effects observed in the real estate market result in an autoregressive dependence over time (Nanda and Yeh, 2014). This makes modelling longitudinal housing data relatively complex, as both these processes need to be adjusted for. Ignoring correlation between spatial units over time or their spatial dependence would, in effect, lead to misspecification (Bouayad-Agha and Védrine, 2010). Szumilo et al. (2016) show that it is possible to formulate a general house price function that accounts for both effects and controls for the spatial impact of university research centres. Building on their work, it is possible to test if growth of locationally specific university research centres has a spatially distributed impact on house prices. This should reflect any benefits of living close to a research location as well as any possible additional effects of employment opportunities arising from companies locating in the area. The function can be expressed in the following form:

$$p_{it} = \phi p_{it-1} + \rho \mathrm{W} p_{it} + \beta_1 U_{it} + \beta_2 wEC_{it} + \beta_3 S_{ti} + \beta_4 wp_{ctr\,t} + \beta_5 I_{it-1} + v_{it}$$

Where p_{it} is the average house price at time t, $\mathrm{W}p_{it}$ is the spatial lag of house prices, $wp_{ctr\,t}$ is the average house price weighted by its geographical distance to the county city that proxies for macroeconomic conditions (Huang et al., 2010), $U_{it}$is unemployment, S_{it} is the current housing stock, wEC_{it} is spatially weighted growth in university research centres, the v_{it} error term is the sum of the usual error ε_{it} and the fixed effects u_{it} for individuals which take into account the inter-location heterogeneity.

The above price function combines supply for new houses with demand factors but also allows them to interact by introducing the spatial effect of a specific research centre. The endogeneity problem of the reduced-form equation is adjusted for by using a dynamic model and lagged levels as instruments for contemporary changes. The impact of research centres is identified by including its spatial and temporal influences on prices. The equation is estimated by assuming that house prices in spatial units are jointly determined by their regional characteristics, past values and prices in neighbouring regions. In doing so, we obtain a spatially autoregressive dynamic panel model with individual fixed effects. The estimated model can be expressed as:

$$Y = \phi Y_{t-1} + \rho WY + \beta X + (\mu + \varepsilon)$$

Where Y = $[p_{1,t},\dots, p_{N,T}]'$ is a vector of house price for N regions and T time units, Y_{t-1} is a vector of lagged house prices, X = $[E_{it}, wEC_{it}, S_{crt,t}, S_t, wp_{crt,t}]'$ is a matrix of exogenous variables which characterize supply and demand on real estate market, $W = I_T \otimes W_N$ is a nonstochastic, time-invariant row-standardized spatial weight matrix, such that diag (W) = 0, β is a vector of structural parameters, μ = $[\mu_1,\dots,\mu_N]'$ is a vector of individual fixed-effects, ε is a vector of error terms, ρ is an endogenous interaction effect (spatial autoregressive term) and φ is an autoregressive time effect.

The model captures any unobserved characteristics by individual fixed-effects μi. These represent time-invariant features specific to individual locations and differences in real estate markets between them. This also means that any time invariant differences between research centres are controlled for. In addition, we adjust for spatial dependence by including a spatially autoregressive component ρ WY. The temporal dependence factor (ϕY_{t-1}) allows reflecting housing market imperfections (like a lagged price reaction) by accounting for temporal dependence. Following a selection process outlined by Ezcurra and Rios (2015), the spatial weight matrix has been set using an algorithm of k closest neighbours with k = 25. As we found that equal spatial weight matrices outperform distance weighted matrices, all neighbours have equal weights. In the interest of space, further technical detail available in Szumilo et al. (2016) is omitted.

In order to examine the spatial price effects of different universities' global research centres, UK cities with a certain ratio of student to regular residents were selected to ensure that local economies were highly dependent on university-related businesses. Furthermore, the requirement of high-level of dependency on skilled labour resulted in choosing cities with universities from the Russell Group, which is an association of the best higher education institutes in the UK (UK Russell Group 2017). Planning restrictions and green belt policies were also a requirement for selection. Finally, the research was limited to five comparable historic cities that host UK's top-ranked universities, namely Cambridge, Oxford, Durham, Exeter and York. All of them, bar York, have their university buildings centrally located. Although the University of York is a comparatively new campus-based university and located outside the city, its expansion plans are still affected by restrictive planning regulations. Quantitative analysis includes the five cities and their surrounding counties and summary statistics can be seen in Table A1 of the Appendix.

The majority of the data collected for this study comes from publicly available sources provided by the UK government. The Land Registry provides data on all housing transactions in selected locations. This information was supplemented with the data from the Office for National Statistics on Small Area Model-Based Income Estimates[2]. However, the information on income is not available at the same level of geographical detail as the transactional data. In order to match the two datasets, all sales transactions have been grouped at a middle layer output area[3] using a model-based index of prices. In addition, due to the fact that the income data is only available for certain years, the study has been limited to years 2000, 2004, 2008 and 2011. Information on the geographical location of different university research centres

[2] We note that this dataset has several limitations as the estimates are based on a combination of survey data with local area covariates taken from other sources. While they cannot be used to reflect the distribution of income across MSOAs but to are reliable for ranking MSOAs against each other (which is how we use this data) both cross-sectionally and over time. More information is available in technical reports at the ONS website.

[3] Super Output Areas are a geography for the collection and publication of small area statistics. They are used on the Neighbourhood Statistics site and across National Statistics. Middle Layer SOAs are generated automatically by the UK government using zone-design software using census data from groups of LSOAs. They have a minimum size of 5,000 residents and 2,000 households with an average population size of 7,500. They fit within local authority boundaries.

has been obtained from local council reports individually for each district. Expansion of research facilities was approximated through using the number of university research centres opened at a particular location and their employment levels.

Reliable data on the total dwelling stock in the period of interest proved difficult to obtain. It was estimated by adjusting the total stock reported by the 2011 population census for any new additions. New supply was estimated based on the number of newly built houses sold in a particular location in a particular year reported by the Land Registry database. Although this may not be a perfect approximation, we have found that the correlation of data obtained through this process with numbers reported by local authorities to be around 70%. Prices of individual units have been converted into small area indices by aggregating all transactions in Middle Layer Super Output Areas (MSOAs) and controlling for the type of property, its status as new or existing dwelling and transaction type (leasehold/freehold). The index is calculated as the coefficient of the interaction term of time and MSOA fixed effects in an OLS regression of the average price of a house on its characteristics and time-location fixed effects. It has been calculated using data in 2000 as base and reflects the average change in house prices in each MSOA. Prices in past periods and their growth used for estimation have been taken from intermediate periods between years of income measurements. Overall, the study investigates 903 middle layer SOAs in the five counties (73 in Cambridgeshire)[4] in order to assess the spatial price effects of the different universities' research centres on neighbouring locations and their respective counties overall. The total number of research centres identified in this dataset is eight, with the University of Cambridge having developed two of them in the given 2000-2011 timeframe of analysis.

[4] Note that that our model is estimated using temporal lags of the left hand side variable. This means that although we have n=903 in each of the four periods, we can only estimate over three time periods.

It is acknowledged that the above results do not necessarily reflect recent developments, given that subsequent green belt release and infrastructure and housing investment have taken place within the five chosen historic cities, albeit to varying degrees (CPRE 2018). However, they do clearly illustrate the process under investigation. To show that research centres continue to affect their cities in the same way we present supplementary data, including comparative house price data and affordability ratios. Table 1 shows that affordability ratios in four out of five selected cities are not only much higher than in England but also that residential properties grew increasingly unaffordable between 2002 and 2011. In 2017 housing in Cambridge and Oxford was amongst the most unaffordable in the country (next to London). In 2018, Cambridge was top of the league table for being Britain's most unequal city in terms of income distribution (Ferguson 2018).

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Figure 1 shows that house prices in 4 out these 5 cities are not only higher than the England's average (including London) but also grew quicker over the examined period. Cambridge and Oxford clearly not only have the highest prices but also the fastest rate of growth. It is also noticeable that house prices in all of the analysed cities grew much faster than in England after the financial crisis of 2008/2009.

5. Results

Table 2 presents estimation results for the model outlined above. Two sets of coefficients are presented: one for a dataset containing all five counties included in the study and one for Cambridgeshire alone (see Table A2 in the appendix for results for each location separately). This has been done in order to investigate if the housing market around the city of Cambridge has any structural differences to the rest of the sample. Despite the fact that all other locations have been selected based on their similarity to Cambridge, it would appear that the results for the full sample cannot be generalized. Interactions between prices and their key determinants in most counties appear to be driven by their individual market characteristics. There are, however, some interesting relationships that have been found to be common across all markets.

--- Table 2 ---

The lagged value of price appears to be a universal determinant of current house prices in all locations. This indicates a momentum effect but can also be indicative of expectations of future price growth based on past market behaviour. Importantly, the magnitude of this effect is statistically the same in Cambridge as in the rest of the sample, which suggests that this is a structural characteristic of all housing markets. This is consistent with the findings of Ho and Kwong (2002), Cho (1995) or Zabel (1999). Unfortunately, the available dataset does not allow for testing how much of this effect can be attributed to the momentum effect and how much to price speculation. The reported coefficient represents their combined dependence on historical prices and impact on current transactions.

Although present in all models of housing markets, the amount of available stock does not seem to be a significant determinant of prices in this research. This is an expected finding as markets selected for this study were locations with fast economic growth and restricted supply of new housing. This results in increased price elasticity of housing demand and decreased elasticity of supply. Under these conditions, any marginal changes in the available stock are unlikely to translate into significant changes in price. This is confirmed by the results in Table 1 (and Table A2 in the Appendix for each location), as available stock is not a statistically significant determinant of prices.

On average, the spatially weighted distance to the centre of a specific university research centre is a factor that positively influences housing transactions. However, in Cambridge there appears to be a much stronger relationship between the spatially weighted number of University of Cambridge's research centres built at Addenbrooke's NHS Trust and West Cambridge sites and house price then in the overall model. The closer a property is to a location with a high amount of university research centres the higher its sale price. In other words, research centres strongly influence residential property prices in its immediate area but have an impact that losses its magnitude with distance, a finding which is consistent also with Breznitz (2010). Naturally, the fact that the magnitude of this in Cambridge is significantly higher than in other locations could be an artefact of how we constructed the variable and reflect the difference in the speed of growth of the research centres or their location in relation to the rest of the region.

Unemployment appears to be strongly negatively correlated with house prices. Areas where the rate of unemployment is growing will, in effect, have fewer people searching for new housing (Meen 1999). In addition, if housing supply is restricted then higher income households who migrate into the area will price the unemployed out of the market. Those without employment have lower ability to access financing which further reduces their ability to bid for housing in attractive locations, even if living in those areas would improve their job prospects (Ortalo-Magne and Rady 2008). The coefficient for Cambridgeshire is higher than for other locations but this is mainly driven by the lower starting values and variance of the unemployment rate rather than a difference in effects of employment on prices.

On average, the spatially weighted price index in each of the cities is also found to be influential. As most locations are developing economically, they are affected by macro-level conditions such as interest rates, economic cycle or consumer spending. However, it is possible that in some locations, where economic development is strong enough to be relatively independent of macroeconomic conditions, the spatially weighted impact of macroeconomic factors could be overshadowed by the strength of the local economy. This can be the case for very specialized regions that can outpace growth of the rest of their economies. It has been shown to be the case in locations such as the Silicon Valley or Northen Virginia which focus heavily on innovation and can be developing much faster than the rest of the US economy (Bresnahan et al. 2001). This appears to also be the case in Cambridge (UK), which has maintained a healthy rate of growth even throughout the financial crisis of 2008/09. Consequently, changes in the state of the economy appear to be a poor indicator of house price in Cambridge. In Cambridgeshire, spatially weighted average house price have no significant influence on transactions. Yet it is likely that in Cambridge, more location-specific factors have much higher influence over prices than in the other examined locations, where changes in values in the centre of the city affect the rest of the area. It is also difficult to judge if the insignificant effect could simply be a problem of estimation precision. As the coefficients are similar across the two samples but standard errors are bigger for Cambridgeshire (as they are for all results due to smaller sample) the effect could simply not be estimated precisely enough to be reported as significant.

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On average, spatial lags of prices had no significant influence on transactions. Although this is an unexpected result, it should be interpreted in the context of the fact that an index of average price in each location (spatially weighted by distance to its biggest city) has also been controlled for. Consequently, spatial effects are reflected in the model through their distance to each county's centre of economic activity and their spatial lag. It appears that only one of these factors reflects spatial effects within a location accurately. Indeed, the spatial effect for the full sample is a relatively precisely estimated zero but in Cambridgeshire spatially lagged changes in prices around a location have a very strong statistical relationship to values within it but not to the centre of Cambridge. It is worth noting that the magnitude of the effect is relatively large so changes in neighbouring locations may be affecting prices by a significant nominal amount.

Cambridge-specific results

The findings show that, unlike in any other location in the sample, house prices in Cambridgeshire are strongly influenced by a spatially weighted growth of the university's research centres, namely the Addenbrooke's NHS Trust and West Cambridge sites. This is consistent with the argument that expansion of the University of Cambridge is an influential element in the regional economy (Boddy & Hickman 2016). Figures 2 and 3 suggest that whilst on average the correlation between income and value of the price index is quite low both in Cambridge and in the whole of Cambridgeshire, around these two global research centres both incomes and house prices appear to be relatively high.

--- Figures 2 & 3 ---

It is possible that speculation in the housing market contributes to this spatial price effect around the University of Cambridge's two global research centres. Continually rising house prices and developing research centres create an impression of a safe property investment environment and encourage speculation (Himmelberg et al 2005). There is some evidence that this effect is taking place, as historical prices have a positive relationship with their current values. However, it is difficult to distinguish between the proportion of the marginal increase in prices attributable to speculation and the part that is an effect of other factors that constitute the added value not reflected by fundamental indicators.

It has been well documented that access to amenities such as transportation links, parks, recreation grounds and community facilities may increase prices without affecting short-term income or unemployment (Meen 1999, Glaeser et al 2006). In Cambridge, however, the two research centres appear to share a spatial characteristic that cannot be explained by fundamental economic indicators nor has been identified in academic literature (De Bruyne and Van Hove 2013, Lu et al 2014). One spatial characteristic that is shared between the two university research centres is the vibrant and diverse scientific community of excellent quality (Boddy & Hickman 2016). The business value of tapping into this resource can be indirectly valued through examining salaries offered by companies in the area. Cambridge and South Cambridgeshire are ranked amongst the locations that offer the highest earnings in the UK, which filters down to household income through salaries that businesses are prepared to offer (Anderson 2014). However, despite the fact that salaries are higher, Cambridge house prices are less affordable than in other UK locations (with the exception of Oxford and London). Households are in effect willing to sacrifice a higher proportion of their income to cover housing costs**.** In addition, this proportion grows as university research centres grow in size.

Business around Cambridge is strongly dominated by bio and high technology companies (Cambridge Ahead 2017). The university's decision to expand its experimental facilities for bio-medical facilities at Addenbrooke's NHS Trust and physical sciences at West Cambridge site created further opportunities for businesses to benefit from collaborations with academics.[5] Tech businesses not only take advantage of the spill over effects of working

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[5] Addenbrooke's hospital, first opened in the city centre in 1766, relocated its facilities to a 70-acre site in south Cambridge in 1962. The Addenbrooke's NHS Trust in partnership with the University of Cambridge and the Medical Research Council formed the Cambridge University Hospitals NHS Foundation Trust in 2004 to crystallize its expansion plans, including new clinical facilities and bio medical companies co-located (Cambridge University Hospitals NHS Foundation Trust 2017). The university's West Cambridge site consists

with the best researchers but also have access to a highly skilled labour force produced by the university[6]. The source of the value to households locating next to the two university research centres, however, seems far more difficult to quantify. Households who purchase homes in those locations would be ones with the highest utility derived from doing so. Those who have an ability to pay more are likely to outbid those whose maximum price is constrained not by their utility but by their income. This means that identifying the source of the premium found in house prices is not straightforward.

6. Discussion

Overall, whilst Cambridge shares the restrictive planning polices with other comparable UK cities, this study has demonstrated that Cambridge's housing market does not seem to behave identically to the rest of the sample. It would appear that spatial relationships around Cambridge are different than in other markets. Variations of average prices in Cambridge do not translate into corresponding changes in surrounding locations, even after adjusting for distance. On the other hand, the fact that the spatial lag of prices is significant suggests that values in areas around a particular location influence prices within it. This leads to the conclusion that in Cambridge, the main spatial centre is not the centre of the city. Instead house prices are spatially determined by their location in relation to the main university global research centres, namely Addenbrooke's NHS Trust and West Cambridge sites.

The results show that during the given study period between 2000-2011, the restricted size of the housing stock in the city and the growth of the University of Cambridge's two global

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of a 66- hectare site on university-owned land, with development commencing in the 1960s. Planning permission granted in 1999 allowed the site to be redeveloped to include relocated science and engineering faculties alongside commercial research institutes.

[6] Oxford Economics estimate that there were 2,100 high technology companies in the Cambridge area, totalling the sales of around £14billion per annum in July 2015 (cited in SQW 2013, Savills 2015).

research centres created a spatial price effect that has not been observed in comparable cities in the UK. Moreover, the university is currently expanding both these research centres, in order to further strengthen the agglomeration benefits and the university's international competitiveness. The Addenbrooke's NHS Trust site is being expanded in order to accommodate one of the largest global science and medical research campuses. On completion, it will occupy almost the same footprint as the University does within the city (Cambridge University Hospitals 2017).[7] Proposals are also underway to make the West Cambridge site a premier location for physical sciences and technology (University of Cambridge 2017a).[8] Further economic development of these two areas will encourage incoming labour attracted by the growth of employment prospects and wages[9]. Despite significant release of green belt land and investment in infrastructure and housing taking place in Cambridge, there is concern that the response has been not only lagged (to date), but has not overcome the city's growing affordability problems (Centre for Cities, 2014). Whilst Cambridge City Council has made considerable progress in this respect and collaborates well with South Cambridgeshire District Council through joint Local Plan reviews, on-going housing shortages create a further upward pressure on house prices. A lagged response also have a spatial effect of pushing lower income earners and the unemployed further away from Cambridge over the long term.

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[7] A planning application was approved in 2015 to build Cambridge biomedical campus in 2 phases, consisting of 140-acre site in total built on land released from the greenbelt. It is to host, for example, GSK and AstraZeneca's Corporate Headquarters and its global research and development The campus is predicted to create as many as 8000 new jobs, in total, by 2026 (Cambridge University Hospitals NHS Foundation Trust 2017).

[8] Expansion of West Cambridge site is to include the Departments of Physics, Chemical Engineering and Biotechnology building, and part of Electrical Engineering A university planning application was submitted in June 2016 seeking up to 383,300sqm of commercial development (University of Cambridge 2017a).

[9] Oxford Economics predicts that employment in human health and social work will grow by 1,200. 2,800 new employees will also take-up new research and scientific positions. This is expected to be accompanied by growth of supporting services such as administrative or IT workers (cited in Savills 2015). Cambridgeshire County Council predicts the total growth in jobs to be 22,000 in the period from 2011 to 2030, representing a significant increase in total employment from around 100,000 jobs reported by the 2011 census. (CCCRPT 2013)

The closest comparison, Oxford equally experiences tight administrative boundaries, with its growth historically hampered by an inability to expand into neighbouring authorities. Its economy is, however, much more diverse, with its university best known for its achievements in social sciences and humanities. It has started investing into its bio-medical facilities much more recently than Cambridge (Smith and Bagchi-Sen 2012). In addition, its new facilities have not been dedicated to experimental sciences but include a diverse range of structures. While Oxford has also experienced a period of strong growth in both economic output and house prices, these have not been spatially concentrated around new university facilities (see Appendix 1). Although this does not suggest that the University of Oxford has less of an impact on its local economy, the research findings show that its link to local house price is structurally different. In particular, the difference lies in the spatial distribution of demand. While in Cambridge university-led employment centres are clearly the places with the most expensive houses, in Oxford there are other areas that attract high prices. This can be seen from figures 4 and 5 which compare employment density and house prices in the two cities. Housing and employment show far less spatial correlation in Oxford where there is much more spatial variation in employment. Oxford also has much more industrial diversification both within the city and across space. This means that it is not just employment density that drives the housing market but also the type of the industry.

--- Figures 4 & 5 ---

7. Conclusions

Through applying Glaeser's et al (2006) analytical framework to a specific policy concern and using empirical evidence from a dynamic spatial panel model, this paper offers critical insights into accommodating universities' global ambitions and its localised price effects.

Top ranked UK universities are under pressure to invest in global research centres and welcome firms clustering beside their newly developed facilities as a way to sustain international research excellence and attract talented workers (BIS 2016). There are well-documented agglomeration benefits available to private sector companies that locate close to the best academic researchers (Fisher & Varga 2003). To date, little research, however, has focused on the spatial house price effects from allowing university expansion within tightly constrained urban areas. This paper suggests that unlike any other comparable UK location, house prices in Cambridge are strongly influenced by a spatially weighted growth of employment of University of Cambridge's two existing global research centres.

New housing supply restricted by tight planning controls is not unique to Cambridge as many cities around the world have similar constraints put in place to protect their historical and natural heritage (Baker 2008). Very few cities, however, have witnessed the same rate of economic growth as a result of its university's expansion or are as concentrated on the high-tech research industry, which makes Cambridge an extreme example of the effects of the interaction between planning policies and expansion of research employment. Nevertheless, high-tech companies continue to locate in Cambridge despite comparatively high employment costs. New workers also continue to move into the city from all around the world despite relatively high living costs. Locating in Cambridge appears to offer the unique benefit of working alongside the best academic researchers in their fields and the possible gains in productivity outweigh the cost of locating in the area. This is best exemplified by the global company AstraZenaca's decision to move its Corporate Headquarters and global R&D centre to Cambridge's new biomedical campus, with over 2000 employees already relocated to the city (Quested 2017).

It is well documented, however, that agglomeration benefits have a tipping point beyond which further growth in concentration will yield declining economic benefits and put pressure on existing social and urban infrastructures (Richardson 1995). This leads to overcrowding and congestion and results in inefficiencies that reduce the economic benefits of agglomeration. As soon as labour demand outpaces the capacity of the housing stock, marginal benefits of increasing density are significantly increased. However, in order to allow further growth, housing stock needs to expand (Mayer and Somerville 2000). Proposals to release more land around UK cities hosting top-ranked universities is crucial in this process (Morrison 2013). Assuming that labour is a critical factor of production, growing areas require more dwellings to house its workers. Yet there remain other critical factors that can constrain agglomeration benefits. Investment in transportation infrastructure or social amenities is equally necessary to support growth. If any of these systems are put under too much pressure, economic development becomes exogenously restricted (Kline and Moretti 2013).

Ultimately, the competitiveness of UK's top universities will depend not just on the research environments that they can offer, they need to match the kind of housing services and quality of life that comparable international locations are able to provide. Many universities across the globe have recognised this phenomenon and have offered their key staff various housing services from on-campus rented accommodation at discounted prices to assistance with searching for housing in the local market (Davidson 2010, Phang 2015). Moreover, rival universities in Europe, like ETH in Zurich have led the way in developing whole campuses outside their city boundaries to deal with the problem of space shortages (Davidson 2010). The University of Cambridge's expansion plans at its two existing global research centres, alongside its North West development site comprising 100,000 square metres of research facilities and a total of 5,000 new housing units (consisting of 1,500 dedicated to key university and college staff and 2,000 for postgraduate students). The site had been planned to be completed in phases by 2030, but uncertainty about EU funding availability after the Brexit referendum has delayed the project. These new developments will undoubtedly allow the university to internationally compete (see University of Cambridge 2018). However, unless UK's national and local policy makers respond to the call to release additional housing land on an on-going basis, its historic cities hosting top-ranked universities are likely to continue to struggle to address affordability problems now and in the foreseeable future (Centre for Cities 2018).

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Figure 1. Average house prices in the 5 analysed markets and in England.

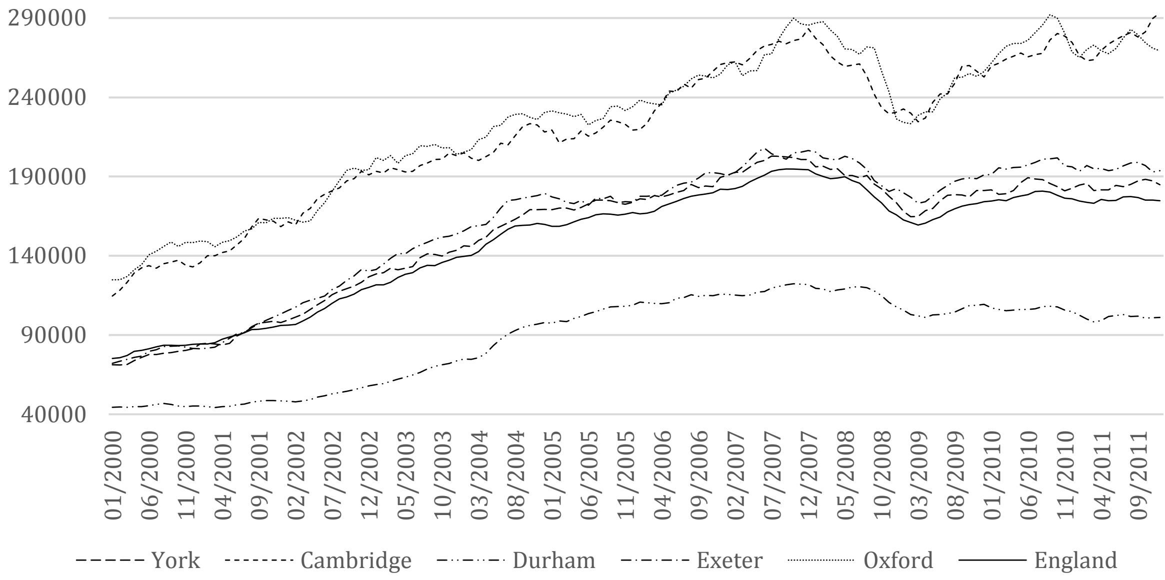


Table 1. House price to annual wage ratios (left) and ranking in the UK university league table (right).

	2002		2011		2017	
York	5.18	8	6.88	10	8.79	21
Cambridge	7.14	2	8.49	2	13.35	1
Oxford	8.67	1	9.21	1	12.34	2
Durham	3.42	13	5.16	4	4.86	6
Exeter	5.77	35	8.04	24	9.06	12
England	5.11		6.79		7.91	

Source: ONS and The complete university guide

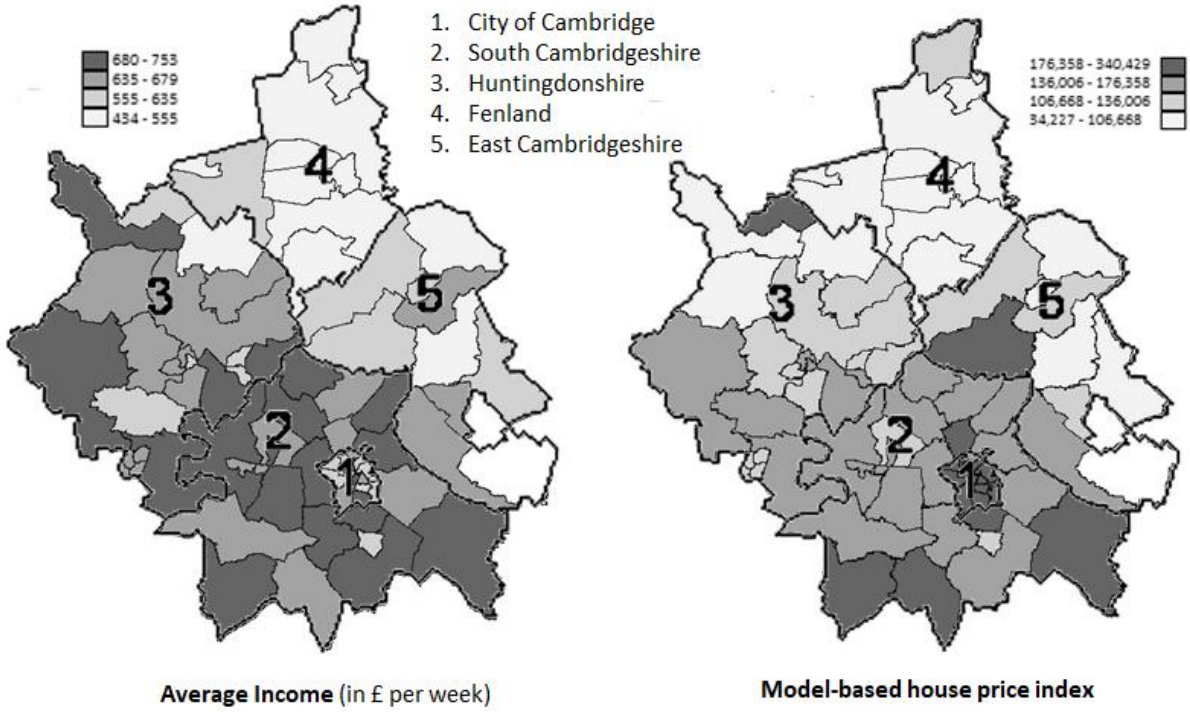


Figure 2. Levels of income and price index in middle layer super output areas in Cambridgeshire in 2011.

Darker shades of grey indicate higher average values in the area.

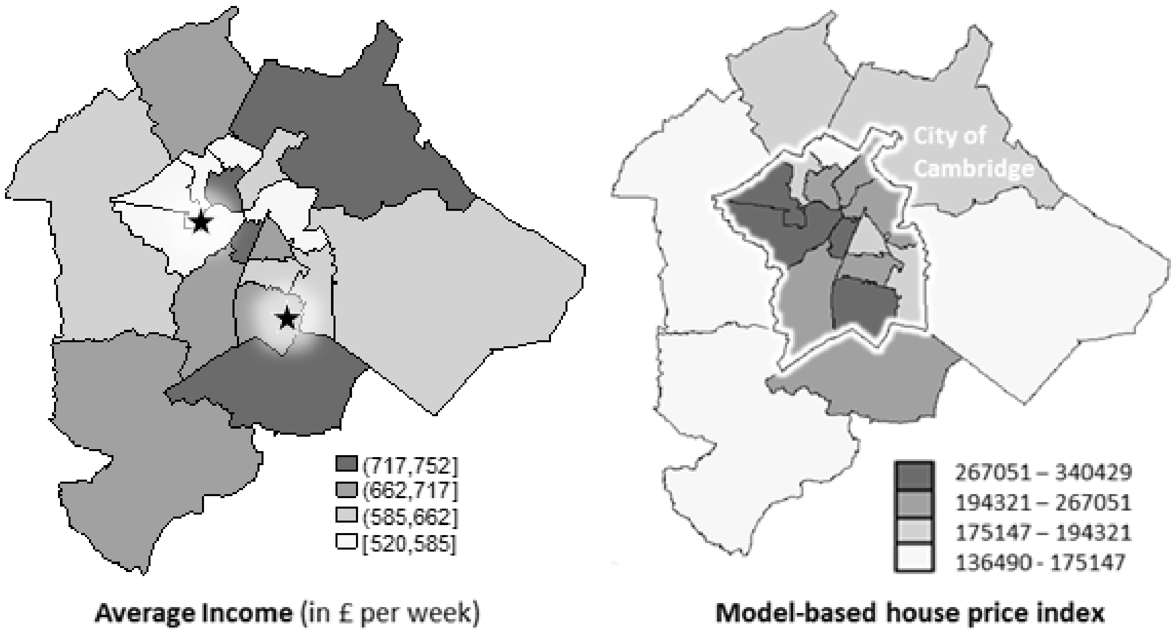


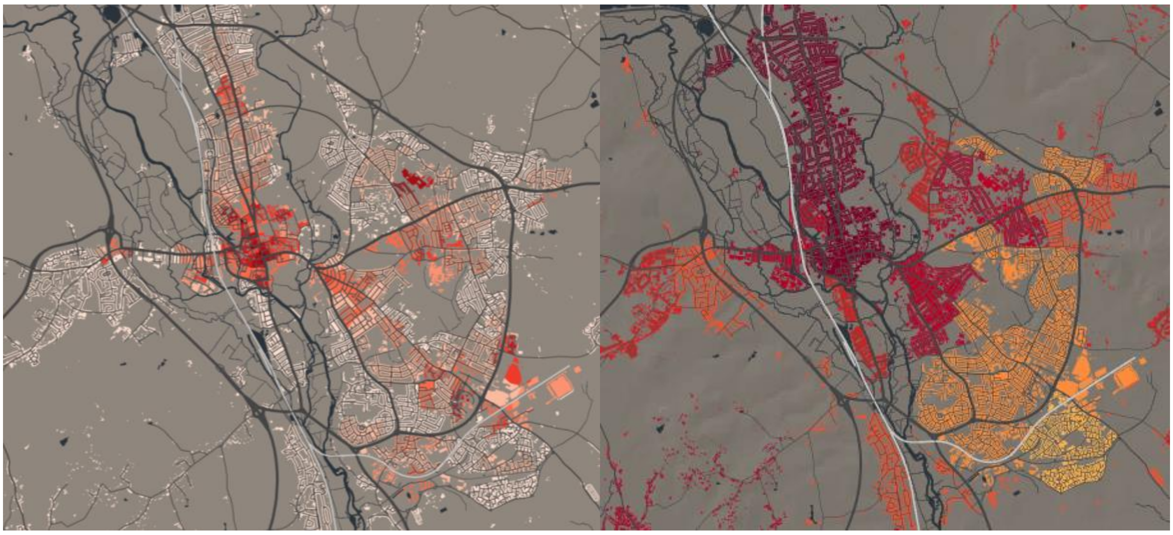
Figure 3. Levels of income and price index in middle layer super output areas in and around the City of Cambridge in 2011. Darker shades of gray indicate higher average values in the area. The black stars indicate the location of West Cambridge and Addenbrooke's.

Table 2. Estimation results for a spatially auto-correlated panel model.

Variable		All areas except Cambridgeshire		Cambridgeshire	
		Coefficient	St. Error	Coefficient	St. Error
ϕ	Time lag of Price	0.19	0.01***	0.24	0.06***
β_3	Stock of housing	70.86	2.74	-11.58	17.98
β_2	Dist. lag emp. centre size	16.71	8.97*	95.68	54.65*
β_1	Unemployment	-1546.65	448***	-5461.46	2475**
β_4	Dist. lag of price in city centre	0.53	0.04***	0.2	0.14
β_5	Income	104.19	8.85***	84	37.59**
ρ	Spatial lag of Price	-0.046387	0.05	0.3936	0.16**
Overall R2		0.23		0.5	
Within R2		0.35		0.55	
Between R2		0.21		0.49	
R2		0.7687		0.7067	
LL		-29080		-2565	
N		2,487		219	

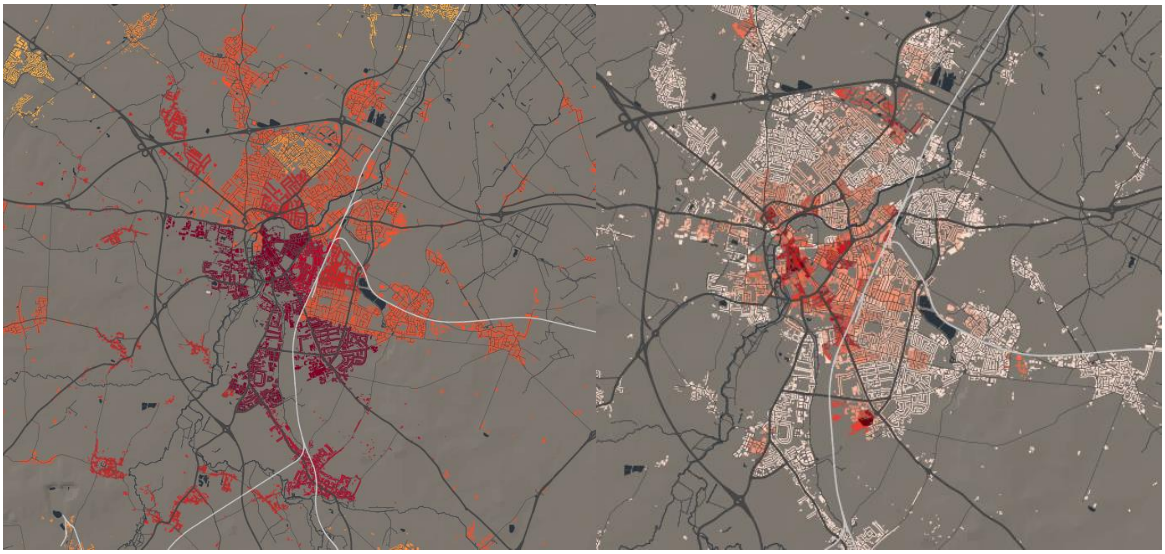
A Baltagi, Song and Koh marginal LM test confirmed that a fixed-effect spatial model was better than a random alternative, A Pesaran test confirmed cross-sectional dependence in spatial fixed-effects model leading to the conclusion that a dynamic model was necessary. Post estimation testing of residuals confirmed their normal distribution around the value of zero. Coefficients are significant at the * 10% level, ** 5% level, *** 1% level
Test results: Hausman test (p-value=0.006) confirmed that individual-level effects were adequately modelled by fixed effects. Wooldridge test for serial correlation in panel data indicated the presence of first-order autocorrelation in the dependant variable. Harris-Tzavalis (1999) unit-root test (p-value = 0.000) indicated that the panel was stationary. Residuals of the static fixed effects models were tested for spatial autocorrelation using the Lagrange multiplier test for the lagged dependant variable (LM-LAG) and spatial autocorrelation of residuals (LM-ERR). Following the work of Elhorst (2014), both tests are also performed using robust estimates. Test results confirm that a null hypothesis of no spatial autoregression can be rejected while one of no spatial autocorrelation cannot.

Figure 4. Employment density (left) and house prices (right) in Oxford.



Notes: Employment density is from the 2011 census and house prices are from Land Registry in 2014. Map is created by Consumer Data Research Centre.

Figure 5. Employment density (left) and house prices (right) in Cambridge.



Notes: Employment density is from the 2011 census and house prices are from Land Registry in 2014. Map is created by Consumer Data Research Centre.

Appendix

Table A1. Summary statistics of the data

Location	Variable	min	mean	max
Cambridgeshire	Index value	-84766.98	110913.3	340429.5
N:292	Index value in Cambridge	53933.72	134515.8	193183
	housing Stock	1667	3332.842	5767
	Income	434.8766	696.7848	1020
	Unemployment	2.4	4.115753	9.2
	New supply	0	19.47603	367
	Supply in Cambridge	822	979.5	1204
County Durham	Index value	-6819.051	78379.02	216745.9
N:188	Index value in Durham	30807.8	80834.85	108512
	housing Stock	2384	3584.968	6163
	Income	300	481.9458	820
	Unemployment	2.787033	8.87055	23.01289
	New supply	0	16.10106	149
	Supply in Durham	602	742.5	903
Devonshire	Index value	3054.417	155038.1	483000
N:376	Index value in Exeter	102345.2	177270.8	212761.6
	housing Stock	418	3216.822	5760
	Income	310	537.3087	750
	Unemployment	2.275	3.619667	8.729787
	New supply	0	14.17819	494
	Supply in Exeter	66	156.75	216
Oxfordshire	Index value	33601.78	166194.6	1065870
N:352	Index value in Oxford	86711.26	187225.3	258038.1
	housing Stock	2200	3076.213	5448
	Income	479.5979	766.8738	1620
	Unemployment	1.4	3.68521	6.975
	New supply	0	12.05682	252
	Supply in Oxford	63	266.75	434
Yorkshire and The Humber	Index value	-42814.2	85349.23	395369.6
N:2400	Index value in York	6399.62	96267.73	143444.8
	housing Stock	2095	3281.462	6465
	Income	282.65	530.4352	990
	Unemployment	1.525	6.769768	13.02
	New supply	0	13.15375	461
	Supply in York	79	150.5	302

Table A2. Estimation results for a spatially auto-correlated panel model.

	All areas except Cambridgeshire		Cambridgeshire	
Variable	Coefficient	St. Error	Coefficient	St. Error
ϕ Time lag of Price	0.19	0.01***	0.24	0.06***
β_3 Stock of housing	70.86	2.74	-11.58	17.98
β_2 Dist. lag emp. centre size	16.71	8.97*	95.68	54.65*
β_1 Unemployment	-1546.65	448***	-5461.46	2475**
β_4 Dist. lag of price in city centre	0.53	0.04***	0.2	0.14
β_5 Income	104.19	8.85***	84	37.59**
ρ Spatial lag of Price	-0.046387	0.05	0.3936	0.16**
Overall R^2	0.23		0.5	
Within R^2	0.35		0.55	
Between R^2	0.21		0.49	
R^2	0.7687		0.7067	
LL	-29080		-2565	
N	2,487		219	
	Yorkshire and The Humber		Oxfordshire	
Variable	Coefficient	St. Error	Coefficient	St. Error
ϕ Time lag of Price	0.07	0.01***	0.99	0.07***
β_3 Stock of housing	50.27	1.79	-369.51	30.67
β_2 Dist. lag emp. centre size	-2.19	7.8	16.22	24.31
β_1 Unemployment	1712.94	933*	-302.05	1904
β_4 Dist. lag of price in city centre	0.17	0.06***	-0.06	0.2
β_5 Income	83.19	9.8***	167.6	22.09***
ρ Spatial lag of Price	0.48	0.04***	-0.31	0.16*
Overall R^2	0.16		0.16	
Within R^2	0.46		0.33	
Between R^2	0.12		0.16	
LL	-19450		-3157	
N	1800		264	
	Exeter		Durham	
Variable	Coefficient	St. Error	Coefficient	St. Error
ϕ Time lag of Price	0.23	0.07***	-0.07	0.06
β_3 Stock of housing	-5.45	17.45*	-4.97	2.79*
β_2 Dist. lag emp. centre size	111.68	101.87	1871.45	1041.98*
β_1 Unemployment	-4652.99	2487*	N/A	N/A
β_4 Dist. lag of price in city centre	-0.5	0.69	1.89	0.39***
β_5 Income	223.42	61.84***	-72.35	45.5
ρ Spatial lag of Price	-0.18	0.24	-0.18	0.26
Overall R^2	0.29		0.23	
Within R^2	0.3		0.35	
Between R^2	0.3		0.21	
LL	-3256		-29080	
N	282		2487	

A Baltagi, Song and Koh marginal LM test confirmed that a fixed-effect spatial model was better than a random alternative, A Pesaran test confirmed cross-sectional dependence in spatial fixed-effects model leading to the conclusion that a dynamic model was necessary. Post estimation testing of residuals confirmed their normal distribution around the value of zero. Coefficients are significant at the * 10% level, ** 5% level, *** 1% level. Test results: Hausman test (p-value=0.006) confirmed that individual-level effects were adequately modelled by fixed effects. Wooldridge test for serial correlation in panel data indicated the presence of first-order autocorrelation in the dependant variable. Harris-Tzavalis (1999) unit-root test (p-value = 0.000) indicated that the panel was stationary. Residuals of the static fixed effects models were tested for spatial autocorrelation using the Lagrange multiplier test for the lagged dependant variable (LM-LAG) and spatial autocorrelation of residuals (LM-ERR). Following the work of Elhorst (2014), both tests are also performed using robust estimates. Test results confirm that a null hypothesis of no spatial autoregression can be rejected while one of no spatial autocorrelation cannot.