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Valuing the Environmental Benefits of Canals Using House Prices

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Abstract
The canal and waterway network in Britain provides a potentially valuable recreational and environmental amenity. In this paper, we estimate the value of this amenity based on how much households are willing to pay through housing to live close to the canal network, a well-established and theoretically grounded method in the urban and environmental economics literature. To deal with potential omitted confounding factors in our house price regressions we adopt two strategies. First we conduct a cross-sectional analysis, but control for local area fixed effects so we estimate from marginal differences in distance from homes to canals within small geographical neighbourhoods. Secondly, we apply a difference in difference method to analyse the effect of the restoration of the Droitwich canals in the later 2000s. Both methods yield similar conclusions. There is a price premium for living close to a canal, but this is very localised – around 3.4% in 2016 within 100m and zero beyond that. The implication is that the effect is driven predominantly by canal-side properties and others with a direct outlook on the canals or immediate access. The premium fell substantially from the pre-recession to post recession periods. We also find evidence that canal-side locations are attractive for developers, with a much higher proportion of new-build sales within 100m of canals relative to elsewhere - a 5.9% increase on a 7.8% baseline. Some back of the envelope calculations indicate the land value uplift from the canal network was around £0.8-£0.9 billion in 2016.

Key words: canals, waterways, house prices, environment, valuation
JEL Codes: Q51; R3; R2

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1. **Introduction**

Britain has an extensive canal and navigable river network, which played a vital role in transporting goods from the Industrial Revolution through the 18th, 19th and early part of the 20th Century. Their use for transporting freight had all but disappeared by the mid-20th Century, and many had fallen into disrepair or been abandoned. Since then, the canal and waterway network has been restored and developed into a valuable environmental and recreational amenity, providing the venue for extensive range of tourism and leisure activities. The canals [1] also provide transport corridors for walkers and cyclists along the towpaths formerly used by horses for drawing boats. It is estimated that there are more than 4.3 million individuals, making a total of 396 million visits to the canals in 2016 for various purposes, including walks, hikes, boating, fishing, and cycling. (Canal and River Trust, 2016). This paper investigates the value of this amenity to local residents in England and Wales using house prices, a well-established method within urban an environmental economics for establishing 'willingness to pay' to live close to something that provides value. The study focusses on the canals and canalised rivers managed by the Canal and River Trust, a charitable trust which took over management of the canal network in 2012. Previously, the canal network was managed by British Waterways, a public corporation which took control of the canals in the 1960s.

In general, economists look at prices as signals of the value of goods to society, because, in a well-functioning market, relative prices reflect an equilibrium between the satisfaction people derive from something (demand) and the cost of providing it (supply). The challenge with valuing benefits in the case of environmental amenities, and other intangible goods which are publicly available, is that there is usually no explicit market for those amenities. For example, there is no charge for walking along a towpath so no price that directly reveals how much people are willing to pay to do so. Economists working on environmental and other public good problems have developed a range of tools for uncovering values in situations like this where no explicit market exists. The first general set of methods involve asking people directly what they are willing to pay – so called stated preference approaches, often framed in specific ways to try to elicit truthful and unbiased answers (e.g. 'contingent valuation'). The second approach is to try to infer willingness to pay from observing data on the trade-offs people make in their everyday behaviour – so called 'revealed preference approaches'.

[1] We use the term 'canals' to refer to waterways that were dug out where there was no previous waterway, and rivers that were canalised to make them navigable.

Using house prices to uncover amenity values is an example of this revealed preference method. The idea to is to estimate how much money people spend on housing, and hence what they sacrifice in terms of the value of other forms of enjoyable consumption, in order to benefit from an amenity by living near it. There are some important theoretical assumptions behind this method, but the basic idea is that if people are free to move and are well-informed, they will end up living in places where the benefits to them of doing so are at least equal to the costs - otherwise they would move somewhere else. In this situation, the market price of houses with similar size and structural characteristics but in different places, adjusts to trace out the value of those places to the population. In turn, the value of a place can be unpacked into its constituent components – proximity to transport, proximity to jobs, crime, quality of schooling, quality of environment, recreational facilities and so on, using statistical techniques. The price premium associated with each of these components is referred to as an 'implicit price' and captures what is termed the 'marginal willingness to pay' for an amenity.

Although the idea is conceptually simple, there are challenges in terms of estimating these implicit prices. The basic method is to use statistical techniques to estimate the average price difference between houses with a high level of an amenity (or dis-amenity) and similar houses with a lower level. Clearly, a key requirement is data on some variable that represents this exposure e.g. school quality in the catchment area, or distance to closest train station. In our setting, the underlying reasons for wanting to live near to a canal are that: a) doing so reduces the time and cost of travelling to them; and/or b) doing so means a resident has a direct view or experience of them – for example if the property has a canal frontage.[2] We therefore use indicators of distance from a property to its nearest canal as our key variables of interest and estimate to what extent prices are lower or higher at different distances. There are, however, potentially many 'confounding factors' which vary with distance to a canal and also affect the price directly – the physical characteristics of the housing, other amenities like distance to employment or distance to transport. Estimation methods must take account of these confounding factors so we are comparing houses on a like-for-like basis. Failure to do so might lead us to attribute differences in prices to proximity to canals, when in reality the price differences are caused by something else. For example, if canals in urban areas are predominantly in old industrial areas, and these industrial areas have older smaller houses and industrial buildings that are less attractive to residents, it might appear that proximity to canals reduces

[2] The values that can be elicited through house prices are therefore what environmental economists refer to as 'use value', as opposed to, say, the satisfaction one might get from just knowing that such a resource exists without ever intending to visit or use it.

prices when in fact it is the average size of the houses or the industrial character of the environment which reduce prices.

To avoid this type of bias, we adopt two strategies in this study. First, we use standard multiple regression techniques to estimate the association between canal proximity and housing prices, while adjusting for a rich set of structural housing characteristics and local area attributes on which we can obtain data (referred to as 'control variables). This analysis covers England and Wales. The limitation of this approach in general, is that researchers can never be sure that the set of characteristics on which data is available is sufficient to eliminate the biases arising from confounding factors. However, an extensive previous literature has demonstrated that credible estimates can be obtained through this simple approach with careful choice of control variables. Gibbons, Mourato and Resende (2014), for example show values associated with access to woodlands, wetlands, national parks, costs and other environmental features using this method. In this paper, our specifications control for a wide range of land use indicators, distance to geographical features, employment and demographic variables. In our preferred versions of these specifications we further control for 'fixed effects' at a small geographical scale – either Middle Layer Super Output Areas (MSOAS) or Lower Layer Super Output Areas (LSOAs) – and for differing price trends at Local Authority District level. This means we estimate the price effects from variation in the distance to canals, and associated variation in house prices, that occurs within these small geographical areas. Confounding factors that vary at a higher geographical level between LSOAs/MSOAs – such as access to labour markets – are eliminated.

Our second strategy focusses on a specific canal regeneration project, which restored an abandoned canal – the Droitwich Canal in the West Midlands of England. The Droitwich Canals were closed in 1939 and in the early 2000s were mostly overgrown, drained of water, non-navigable or completely destroyed. They underwent a major restoration from 2007 onwards and were re-opened in 2011. The restoration reopened them for boat navigation and recreation, improved the general environment and provided a habitat for aquatic life. In this case, we compare the price changes occurring in a 'treatment group' of properties close to the canal when the canal is restored, with price changes occurring at the same time in appropriate 'control groups'. The assumption behind this method is that prices would have evolved in the treatment group close to the Droitwich canals in much the same way as in the control group, if the Droitwich canals had not been restored. As control groups, we use places further away from the Droitwich canal, and places close to an existing neighbouring canal – the Worcester and Birmingham canal – that has remained in continuous use, and where we would not expect to say any environmental amenity-related price changes at this time. These comparisons allow us to estimate the value of the restoration and the enhanced recreational and environmental amenities it provides, in so far as this value shows up in different price changes in the treatment and control groups. This type of 'difference-in-difference' estimator is widely used for estimating the impact of policies on economic outcomes in the programme evaluation literature.

Our findings from looking at the whole canal system of England and Wales suggest that proximity to canals increases house prices, although the effect is highly localised. Houses within 100 metres of a canal have a price premium of around 5%, relative to those beyond 1km. There is no impact on prices in the 100m-1km range. The short range of this effect suggests it might be associated with canal-side properties and others which have immediate access or views of these waterways. The effect is bigger – around 10% - in dense urban areas. We also look at the association between canal proximity, and the share of new-build homes sold, as a proxy for housing construction. These results indicate that the proportion of sales that are new builds is a 6 percentage points higher within 100m of a canal, compared to further away – a 35% relative increase. The analysis of the re-opening of the Droitwich canals supports the main conclusion on prices, suggesting that renovation caused price increases of around 10% within 100m of the restored canals

In the remainder of this paper, we first briefly outline the existing evidence on the effect of canals on housing prices and willingness to pay. Section 3 describes the data and the methodology in detail. Section 4 presents and discusses the results of the analysis and Section 5 offers some brief conclusions.

2. Existing evidence on waterways and house prices

In this section, we review the existing literature measuring the economic value of canals. We highlight the limitations associated with the existing papers, before recommending some strategies to improve the estimation.

Previous studies examining the economic value of waterbodies study the impact of proximity from a wide range of features that include seaside, rivers, streams, lakes and canals on home prices. For a comprehensive overview of the existing research on the capitalization of different inland waterways on home prices, refer to Nicholls et al. (2017).

Existing research indicates that home-owners pay more to stay near Canals. Garrod and Wills (1994) show that properties in London that are located alongside canals are sold at a premium of 2.9% while properties further away but within 200 metres are sold at a premium of 1.5%. Extending the analysis to a sample of property sales in Milan, Italy, Bonetti et al (2016) examine the difference in the willingness to pay for artificial (canals) and natural waterways (streams). They report that every 1 metre further away from canals reduces home prices by 0.074%. Conversely, homeowners do not pay to stay closer to streams. Examining the WTP for canals from homebuyers in Texas, US, Nelson et al (2005) finds that homes with a canal frontage are sold at a premium of 11%, around $16,298. While homebuyers value canals, the magnitude of the magnitude of the estimates vary widely across these studies. This suggest that the estimates are highly susceptible to the econometric framework adopted.

Another stream of literature particularly related to the current paper is on how waterways restoration can affect home prices. Streiner and Loomis (1996) estimate the value of streams restoration projects using a sample of property sales from 1983 to 1993 in California, USA. These projects conducted by the Department of Water Resources reduce damages from flooding, improve bank stability and restore aesthetic and environmental value of streams. Breaking down the effects of different restoration projects, the authors report that flood-prevention restoration increases home values by 5%, at around $7,804, while stabilizing streams improves housing prices by $4,488. Overall, the authors conclude that the heightened property taxes from the increased home values outweigh the cost of these restoration projects. Mooney and Eisgruber (2001) investigate the impact of riparian buffers on housing values for a sample of 705 property sales in Oregon, USA. Although these buffers provide a more conducive habitat for aquatic species by reducing stream temperature, they obstruct the views of the river. As a result, home prices fell after these buffers are erected. From these results, it is evident that homeowners value both the scenic views and the stability of waterways.

Notable limitations are observed from these studies. First, most of the research is conducted on a smaller sample of sales limited to specific city. In our study, we draw inferences from a larger sample of sales of more than 2 million transactions across England and Wales from 2002 onwards that increases the representativeness of our findings. Second, most of these papers are limited to cross-sectional regressions. These studies compare property prices close to canals with those further away to recover the price premium for proximity to canals. There are concerns of unobserved confounding factors that correlate with the proximity from canals and affect home prices. Hence, other than improving the traditional hedonic framework by adding a rich set of co-variates and micro-geographic fixed effects, we further exploit the natural experiment of the restoration of the Droitwich Canal and compare home prices before and after the restoration to estimate how much home owners value Canals.

3. **Methods and data**

3.1. Estimation methods

3.1.1. Regression specifications for national analysis

The aim of the analysis is to estimate the property price premium caused by proximity to canals, which, as discussed in the introduction, can be interpreted as a measure of 'willingness to pay' for their environmental, recreational and aesthetic benefits. More specifically, this means we want to estimate the difference between the average price of properties close to a canal, and the average price of otherwise-equivalent properties which are not so close to a canal. For this purpose, we start with a standard property price regression specification, with distance indicators:

$$\ln price_{it} = \beta_1 Canal100_i + \beta_2 Canal200_i + \ldots + \beta_{10} Canal1000_i + controlvariables_{it} \qquad (1)$$

where $\ln price_{it}$, the dependent variable, is the natural logarithm of the price of property *i* sold at time *t*. The key variables $Canal100_i, Canal200_i, \ldots Canal1000_i$ are a set of distance band indicators, based on the straight line distance of property *i* – based on its postcode – from its nearest canal/waterway. In our main specifications, these will be 100m bands up to 1km, so $Canal100_i$ indicates that a property is between 0-100m from a canal, $Canal200_i$ indicates that a property is between 100-200m from a canal and so on, up to 900-1000m. The key parameters of interest $\beta_1, \beta_2, \ldots \beta_{10}$, give the average percentage difference between properties in given distance band and properties in a baseline comparison group. These parameters are estimated by least-squares based statistical methods. In our main analysis, we restrict the sample to properties within 1500m of the nearest canal, so the comparison group in the case where we have distance indicators up to 1000m is the set of properties between 1000m and 1500m. This specification is estimated using data on property transactions in England and Wales, spanning 2002 to 2017, which we describe in Section 3.2 below. Figure 1, maps the canals and canalised rivers used in this analysis.

As discussed in the introduction, unbiased estimation of the average causal effect of canal proximity on prices requires that we control successfully for confounding factors, i.e. factors which are correlated with distance to canals and directly affect prices. These include structural characteristics of the houses being sold and the characteristics of the place in which they are located. We include a wide range of such characteristics in the control variable set, described in the data section below. We take a number of additional steps to control for geographical confounding factors and ensure that we are comparing properties on a like-for-like basis. First, as noted above, we are restricting the sample to properties in a buffer zone within 1500m of canals, so that we compare properties very close to canals with those slightly further away, rather than comparing properties near canals with properties that are remote from them. This step is important if canals tend to be located in places that are atypical, for historical or engineering related reasons. Even so, with this sample, and without any further elements in the research design, we would be comparing properties very close to canals in one part of England and Wales, with properties slightly further away from canals in other parts of England and Wales. To avoid this potential problem, our specifications also control for 'fixed effects' at MSOA or LSOA level. Doing so means that, in effect, we control for all confounding factors at MSOA or LSOA level that are fixed over time, and estimation is based on variation in house-canal distance within MSOAs or LSOAs, and within the 1500m buffer zone on which the sample is based. As an additional ingredient in our design, the control variable set in equation (1) includes fixed effects for each Local Authority District (LAD), year and annual quarter combination. These controls take account of different property price time trends in different LADs, arising from any number of macroeconomic or LAD-level time-varying factors. We therefore only compare property transactions occurring within the same LAD, in a given year and quarter.[3] Note, the structure of equation (1) also helps us establish that the price premium estimates we obtain are 'causal', in that we would theoretically expect to see a distance decay profile in the estimates, with the price premium decreasing as distance and travel cost to the canal increases.

In additional analysis, we investigate the effect of proximity to some specific features of canals, by including distance-to-canal-feature indicators analogous to those in equation (1), alongside the distance-to-canal indicators. Specifically, we look at distance to locks, canalised rivers, aqueducts and wharves. We also investigate whether the canal premium varies according to where a property is located. We might expect proximity to canals to be more valued in places where there are few other water and green-space related amenities. To investigate this issue, we estimate the differences in the estimates of β by urban/non-urban groups, and according to whether properties have other green space nearby and whether they are close to rivers. We also separate out the effects by some major urban Local Authority Districts to look for city differences, and by year to see how the patterns have changed over time. In all these cases, we estimate the differences by interacting indicators for the group in question with the treatment variables in the regression equation (1).

Demand for living near canals may show up in the quantity of housing as well as its price. To investigate this fully we would need construction statistics, but we can shed some light on the

[3] Since canals are fixed in terms of their location, this step might seem superfluous, because the location of canals cannot be correlated with anything that varies over time. The reason it is potentially necessary is that the spatial pattern of sales transactions occurring in our data is time varying.

issue by estimating whether being close to a canal increases the proportion of sales that are new builds. To implement this analysis, we simply replace the dependent variable in equation (1) with an indicator of whether a sale is a new build (and removing any control variables related to the structure of the house).

3.1.2.Difference in difference method applied to the Droitwich Canals restoration

The method described above, although based on data with both cross-sectional (geographical) and time-series dimensions, is essentially cross sectional. The method compares sales of properties close to canals with sales of other properties further away from canals, occurring at a similar same time. An alternative method would be to use a 'difference in difference' design to see what happens to prices of a given set of properties, when they get better access to canals and the various amenities the canals might provide. This method is the standard baseline approach in the field of quantitative policy evaluation and compares the mean change in an outcome in a treatment group exposed to a policy with the mean change occurring in a control group not exposed to a policy. It is frequently applied to look at the impacts of road and rail construction on the local economy (see for example Gibbons and Machin 2005 for an application on the effects of rail construction on house prices). The control group needs to be carefully chosen such that it is likely to have followed the same 'counterfactual' trends in outcomes as the treatment group would have done in the absence of the policy.

Self-evidently, the limiting factor in applying this approach to the evaluation of the environmental benefits of canals is that, in general, accessibility to canals and their environmental benefits is rarely changing. One exception is where there have been substantial canal restoration projects, bringing disused, buried and derelict canals back into use as functioning recreational waterways. Canal restoration projects have occurred throughout Britain over many decades, often carried out by volunteers, but only one significant project lines up with the time period of our data on housing transactions – the restoration of the Droitwich Canal in the West Midlands in the late 2000s.

The Droitwich Canal is a canal formed from two canals – the Droitwich Barge Canal and the Droitwich Junction Canal – linking the River Severn and the Worcester and Birmingham canal, and passing through the centre of Droitwich (formally Droitwich Spa), a town of 25500 people in the county of Worcestershire. The canals were abandoned in 1939 after an Act of Parliament and fell into decline. Parts of the canals had been restored on a voluntary basis, organised by the Droitwich Canals Trust, formed for this purpose in 1973. As a result, a section of the canal in the centre of Droitwich and three locks at the eastern end had been restored by the mid-2000s. Full restoration began in 2007, a major project with a cost of £11 million funded by National Lottery grants, local councils and charitable donations. All of the canal required dredging, repair of locks and other structures. The most significant works were complete reconstruction of a section by canalising 550 metres of the River Salwarpe through Droitwich, a new tunnel under a main road to link the Barge Canal to the River Severn, improvement to a bridge on the M5 motorway, a complete new cut with four new locks, plus extensive environmental mitigations and enhancements. The project was coordinated by British Waterways, the public corporation that managed canals and waterways at that time and was scheduled to start in 2007, with planning applications were submitted in May 2007. The work was due to be completed by 2009, although the canals were not fully restored and opened for navigation until July 2011. The history can be traced through various web sources.[4] The non-technical summary of the project published by British Waterways describes the purpose of the project thus:

> "This project will bring the Canals into navigable use and will create a unique 21-mile cruising ring linking Droitwich Spa to Worcester, which can be completed in a weekend by boat. The project is not solely about navigation as it includes many works to enhance the canal corridors as a recreational and environmental resource for local people as well as visitors to the area. Canal restoration will provide a stimulus to the local economy by encouraging tourism related businesses and will provide many benefits to the local community. … It is intended that the vision will be delivered through a series of objectives including: To restore the canals to good navigable condition; To use the canals as a catalyst to stimulate sustainable regeneration in Droitwich Spa and the surrounding area; To create an environment in which a visit to the waterways is an educational and interpretative experience of the canals' history and environment; To conserve, enhance & promote the built heritage & environmental assets of the canal; To achieve high levels of public accessibility for all; To sustain harmony between environmental, heritage & recreational uses." (British Waterways 2010).

The project was evidently very ambitious in its environmental and recreational aims, and so potentially provides a useful experiment for estimating the value of these benefits to local home owners. Figure 2, provides a before-and-after illustration of the kind of improvement that took place. To implement this idea in a difference-in-difference design we need to define treatment

[4] http://www.droitwichcanals.co.uk
https://www.waterways.org.uk/waterways/history/historic_campaigns/droitwich_canals/droitwich_canals
https://en.wikipedia.org/wiki/Droitwich_Canal

and control groups. Building on equation (1), we use a set of treatment group categories corresponding to the distance of a property from the Droitwich canals, in 100 metre intervals, with properties beyond 1000m acting as a baseline control group. Since there may be other reasons than the canal restoration for prices to have increased or decreased closer to canals around the time of the restoration, we improve on this design by incorporating additional control groups based on proximity to a neighbouring canal which was not subject to the restoration – the Worcester and Birmingham Canal. These properties can work as a 'counterfactual' for properties close to the Droitwich Canal, because they are also close to a canal, share a similar a geographical landscape, are part of the same general local economy. Properties along the Worcester and Birmingham Canal and Droitwich Canals may have increased in price due to the restoration if there was additional local economic demand generated by tourist boat traffic, since the Worcester and Birmingham Canal forms part of the 'cruising ring' referred to in the British Waterways document cited above. However, properties close to the control canal would not have experienced the same improvements in terms of environmental quality and recreational access experienced by residents close to the Droitwich Canal. The differential price effects thus provide plausible estimates of the impact of these environmental and local recreational benefits. To implement this controlled design, we include in our sample, properties within 1500m of either the Droitwich Canal or the Worcester and Birmingham Canal and define a whole series of control groups of properties based on their distance from the Worcester and Birmingham canal, in 100m distance bands corresponding to those for treatment. Figure 3 presents a map of the Droitwich Canal and Worcester and Birmingham Canal overlaid on an satellite photograph, making the general layout and similarity in the landscape crossed by each canal clear.

The second key element in the setup is a definition of the date when we expect the benefits from the restoration of the canals to start to materialise – which we refer to as the post-restoration date (in the policy evaluation context, this is often called the 'policy-on' date). This date is problematic in our context, since the project extended over a number of years from the mid-2000s and there was some restoration activity well before that. There are two plausible choices of this post-restoration date in relation to the major restoration scheme that started in 2007. One date is the submission of planning applications around May 2007. A second is the completion and opening around September 2011. We explore the impacts using one or the other, or both of these dates. Technically, estimation is implemented using the following regression specification:

$$\ln price_{it} = \beta_1 Droitwich100_i \times Post_t + \ldots + \beta_{10} Droitwich1000_i \times Post_t$$
$$+\gamma_1 Canal100_i \times Post_t + \ldots \gamma_{10} Canal1000_i \times Post_t \quad (2)$$
$$+controlvariables_{it}$$

In this specification, the variables $Canal100_i, Canal200_i, \ldots Canal1000_i$ are distance to canal indicators as for equation (1), where the distance is to either the Droitwich or Worcester and Birmingham Canals. The variables $Droitwich100_i, Droitwich200_i, \ldots Droitwich1000_i$ are the equivalent indicators for the Droitwich Canal and are the main 'treatment' variables. The variable $Post_t$ is an indicator that the observed property sale is occurring in the post-intervention period. They key parameters $\beta_1, \beta_2, \ldots \beta_{10}$ give difference between the price change occurring within each distance band close to the Droitwich Canal, and the price change occurring in the same distance band close to the Worcester and Birmingham Canal. The price changes are estimated between the pre-renovation and post-renovation periods. In addition, the price change occurring in each distance band is estimated in relation to the price change occurring in properties between 1000m and 1500m (the limit in the sample). In other words the parameters $\beta_1, \beta_2, \ldots \beta_{10}$ estimate the way the price changes decay with distance from the Droitwich Canal, as compared to the way the price changes decay with distance from the Worcester and Birmingham Canal. The results of the key coefficients are presented graphically, to ease interpretation.

The control variables in equation (2) include a set of fixed effects for the postcode in which a property is located, which implies that we estimate from price changes for properties selling within the same postcode in different years. The control variables also include a set of structural property characteristics, demographic and geographical controls, plus controls for general price trends over time as in equation (1).

3.2. Data sources

The main source of data for the analysis set out above is the *Land Registry* 'price-paid' dataset that provides detailed information on transaction prices and some basic characteristics. This dataset has been linked to information from Energy Performance Certificates (EPC), which are required for all properties bought and sold in England and Wales (this data linking was done for another project by colleagues at LSE). The EPC data provides a much richer description of the structure of the property. Although the EPC information only dates back to 2008, the information can be used for properties with EPCs, when they were sold in earlier periods (assuming the basic structure of the property has not changed). Given this limitation, we do not go back beyond 2002, although the price-paid data extends back to 1995. Our full dataset covers more than 11 million property transactions from 2002 to 2017, falling to around 2 million when we restrict to 1500m buffers around canals. For each property, we observe the postcode, floor area, number of rooms, number of heated rooms, energy efficiency, house type (flat, semi-detached, terrace house) and whether the property is new build and has a fireplace. Other characteristics are available in the EPC data, but much of this is incomplete. We geographically locate each property based on its full postcode – which typically corresponds to around 17 houses. Although the coordinates are accurate to 1m for the postcode centroid, there is a degree of approximation in terms of the exact location of a property due to the potential size of each postcode, particularly in sparse rural areas.

Geo-referenced information of the 371 Canals across England and Wales comes from the Canal & River Trust. The total length of Canals spans across 3,530 km. [5] Using geographical information system software (ArcGIS), we compute the straight line distance between each property postcode and its nearest canal. This is the main variable of interest in this study. We further measure the proximity of each postcode from features of canals (also provided by Canal & River Trust*)* that could affect home prices through channels other than the environmental and local recreational benefits. These features include bridges (benefits as crossing points), docks and wharves (industrial areas), embankments, lakes, overflow outfall and reservoirs (signifying possible flood risk). From Ordnance Survey data (Strategi), we also compute the distance between each postcode from the nearest train lines and stations, as we are concerned that properties closer to canals could be more or less accessible to these transportation modes, given that rail road and canals often follow the same transport corridors. Distance to rivers and distance to green space is taken from the OS Open Rivers and Open Greenspace datasets. Land use comes from Landcover map Landsat remote sensed data, each postcode assigned the land use at its centroid, and categories aggregated up to 9 major groups, urban, suburban, and a rural land cover types.

Using the location of each sale, we further map each postcode to Census data units, the Middle Layer Super Output Areas (MSOA), Lower Super Output Areas (LSOA) and Output Areas (OA). There are around 180,000 OAs and 35,000 LSOAs and 7,200 MSOAs across England and Wales. OAs are the smallest geographical area in which Census data from the Office of National Statistics is collected at every decade. There are in total two waves of Census collected in 2001 and 2011 over the sample period, though we use data from the 2001 Census only. To control for neighbourhood differences between properties, we account for a wide array of characteristics, specifically unemployment rate, proportions owning cars, social renting, home-

[5] For more details, refer to https://data.gov.uk/dataset/660ab8be-2912-4ef5-a8a9-7ed3111e34d1/canal-centre-line

owning, with no education, ethnic minority residents, non-EU residents, share of lone-parent households, population and population density, all at OA level. The LSOA codes are also used to merge in employment data and employment industry sector shares at LSOA-level. These data come from the Business Register and Employment Survey supplied via Nomis. The earliest comprehensive data readily available at a small area level is 2015 and we only use this year of data (matched to all years of transaction data). The data sources are set out in Table A1.

4. Results

4.1. Descriptive Statistics

Our main estimation sample contains 2,048,723 transactions from 159,788 postcodes, 6,979 LSOAs, 1,861 MSOAs and 160 Local Authority Districts. The means and standard deviations of the variables in our main estimation dataset of transactions are summarised in the Appendix, Table A2. Since our analysis compares house prices in places close to canals with prices in places further away, the table splits the information into three groups 0-100m from a canal, between 100 and 1500 metres of a canal, and between 1000 and 1500m of a canal. We do not report the figures for the full set of distance variables, but report those for rail, town centres and rivers. A key thing to note is that there are differences in the characteristics of properties sold close to canals and those further away on many dimensions, but on others the areas seem quite similar and it is hard to see systematic patterns.

Evidently, simply looking at mean prices is not very informative. On average, in these unadjusted figures, property prices are slightly more expensive in the 100m zone than the 100-1000m zone, but both of these zones are slightly cheaper on average than the zone beyond 1500m. The estimated gap between prices in the 100m zone and the 100-1000m depends on how it is measured, around 1% in the simple means, around 5% when based on the average differences in log prices (0.05), and around 10% when looking at price per square metre. At the same time, properties within 100m of canals are smaller, more likely to be new builds, and much more likely to be flats (37% as compared to 16.5% elsewhere). Population density is lower, there are more social renters and more unqualified people in OAs within 100m of canals, but otherwise the demographic characteristics look similar across all the groups. Canals tend to follow paths of least resistance and natural lines of communication, so properties close to canals tend to be close to railways, rail stations, close to other rivers and closer to town centres. Given the canals' original purpose for transporting goods, it is not surprising to find that there is more employment on average in MSOAs close to canals, slightly more heavily represented by manufacturing, mining/utilities, accommodation/food, and business administration, and less represented by health and education services. Interestingly, residential properties within 100m of canals are 52% urban and 45% suburban, whereas the rest of the sample is split 65-69% suburban, 28-32% urban. This presumably reflects that if a canal passes through a town, it typically passes through its centre, again because of their historical transportation role. Only a small proportion of properties within 1500m of a canal are in places with non-urban/suburban of land cover. It is important to correct for all these structural and geographical differences when comparing prices in the various distance zones, and the results from the regression analysis we use to do this are reported in Section 4.2 below.

The sample for the analysis of the Droitwich Canal restoration is obviously much smaller, as it is restricted to properties within 1500m of either the Droitwich or Worcester and Birmingham Canals. A selected set of descriptive statistics for this group are reported in the Appendix Table A3. There we report means and standard deviations for the three distance groups related to the Droitwich Canal (<100m, 100-1000m and 1000-1500m) and for the overall sample for the Worcester and Birmingham control group (<1500m from the Worcester and Birmingham canal). Again there are dissimilarities along some dimensions when we compare these groups. However, the patterns are different from those in the full England and Wales sample and even less systematic. Properties 100m from the Droitwich canal are marginally smaller than those 100m-1000m away, and considerably smaller than those near the Worcester and Birmingham canal. There is a higher proportion of terraced houses close to the Droitwich Canal than elsewhere and more social renters. In general, statistical tests of the difference between these groups indicate that only a few of the differences are statistically significant (i.e. more than we would expect by chance, given the sample size). The simple mean price differences are not revealing of any strong patterns. The results of the difference-in-difference analysis using these data are presented below in Section 4.3.

4.2. Regression results for canals nationally

The results from the regression analysis discussed in 3.1.1 are presented graphically in Figure 4. The figures have distance on the x-axis, measured in 100m units. The y-axis represents the difference in log house prices relative to the baseline group, the group of properties beyond 1000m from a canal up to the 1500m limit of the estimation sample. Each dot is a coefficient (corresponding to the estimates of $\beta_1, \beta_2, \ldots \beta_{10}$ in equation 1) and its value is shown alongside. The value, multiplied by 100, can be interpreted as the approximate percentage difference between the average price in a given distance band, and the average price in the 1000-1500m control group, adjusting for whatever control variables are included in the regression (the exact formula is ($\exp(\beta)$-1) $\times$100). The vertical capped bars indicate confidence intervals, i.e. a measure of the precision of the estimate. If the bar crosses the x-axis, the estimate is not statistically significant at the 5% level, meaning that there is a 1 in 20 chance that the coefficient estimate would be what it is, even if there was no actual relationship between canal proximity and prices. A full set of regression coefficients and standard errors for an example specification is provided in the Appendix, Table A4.

The first panel (a) of Figure 4 shows the pattern with no control variables, other than a set of LAD-year-quarter indicator variables (to capture general variation between LADs and over time), and basic house structure variables, house type (detached, semi, terraced, flat), new/old, leasehold/freehold, floor area, number of rooms, heated rooms, fireplace, energy performance rating (a 10-point scale). The second panel (b) retains these control variables, but adds in controls for geographical location, specifically the distances to various features, predominant land cover, employment, and a set of MSOA fixed effects to eliminate price variation between MSOAs, as discussed in Section 3. The third panel (c) replaces MSOA with LSOA fixed effects (the employment variables are now excluded as these do not vary within LSOA). The last panel (d) includes additional controls for neighbourhood (OA) demographics.

The striking feature of the plots is the 3-5% price premium for properties within 100m of canals. Beyond this distance threshold, the effects in panel (a) become slightly negative before becoming near zero and insignificant at around 600m. This pattern of negative effects between 200 and 600m is evidently related to confounding factors near canals because, when we control for geographical factors in the remaining panels, these effects disappear. Likely explanations are, as discussed earlier, that canals often pass through industrial areas in towns, and these areas are likely to be less attractive to residents. The difference between the top and remaining panels illustrates the importance of carefully controlling for these kind of geographical influences. In panels (c) and (d), when we control for LSOA fixed effects and neighbourhood demographics – including education, ethnicity, and unemployment – it is likely we are over-controlling, and that the estimated price premium is an underestimate. The estimates are also less precisely measured (wider confidence intervals). The reasons for this are firstly that LSOAs are relatively small spatial units, so within each LSOA there is relatively little variation in distance to canals, particularly in dense locations. Also the problem with controlling for demographic characteristics is that these will respond to the local housing price, because people chose where to live based on the housing costs. Poorer, less educated and ethnic minorities tend to live in lower cost places. This implies that including controls for these demographics may eliminate some of the price effects we intend to estimate. We therefore regard panels (c) and (d) as robustness checks, and our preferred estimate is that in panel (b).

How should we interpret the key result of Figure 4, a 5% premium for living within 100m of a canal? The result implies that people are willing to pay up to this amount to live within 100m of a canal, relative to what they are prepared to pay to live elsewhere. The short distance range of this effect suggests that the value is primarily associated with canal-side properties and others with immediate access or views of the canals. There is no premium for living near a canal other than right up close to it. This lack of a price premium for moderate proximity suggests that residents are not, on average, paying to save the time it takes to walk the additional distance from home that is, say, 1500m rather than 500m away. If canal users are doing so only occasionally, or if their primary motivation is to exercise, this finding is not too surprising. It is worth noting that people likely differ in the value they place on canal-side properties and immediate access to canals. Because properties with this access are scarce, the values estimated here cannot safely be generalised to the whole population, because residents with the highest willingness to pay are those who end up owning the homes, and it is their willingness to pay which determines the market price. See Bayer, Ferreira and McMillan (2007) for discussion of these issues. The values should thus be seen as upper bounds to the value of canal-side locations to the average person in the population.

These results do not identify any specific feature of canals that might be attractive. In additional analysis we looked at the effects of specific features – locks, aqueducts, wharves, and canalised rivers – alongside the basic effects of canal proximity. We found no interesting patterns related to aqueducts or wharves, but there is a significant (at 10% level) price premium associated with canal locks, and an insignificant effect of canalised rivers within 100m, of a similar magnitude to that for canals.[6] This pattern for locks is illustrated in Figure 5, in which we separate out the basic canal effect (top panel) and the additional lock effect (bottom panel). Note, the distance scale for the locks plot is in 100m, but has a different range, because the nearest lock can be much further than 1500m away, even though the sample restriction means that the nearest canal is within 1500m. There is evidently an additional effect from locks, of around 4.5% within 100m falling to 3% at 200m, although the estimates are only statistically significant at the 10% level (i.e. there is a 1 in 10 chance that they could be spurious). Some of this effect may be driven by former lock keeper's canal-side cottages, but there may be some heritage value associated with locks in general.

[6] The coefficients on our control variables indicate that there is also a premium of a similar magnitude for living near other natural rivers that extends over a wider range of distance, but again these are not statistically significant, and not the primary focus of this analysis.

In the next analysis in this section, we look at how the price effects from canal proximity vary by type of location. Here we focus only on the effects of being within 0-100 metres, given the lack of any effects elsewhere. Table 1, column (1) shows the differences by built-up urban and non-urban locations (using the land cover categories described in 3.2). The table presents the coefficients and standard errors. The first row of column 1 indicates that outside urban areas, the price premium for the 0-100m band is 2.7%. This increases by an additional 7% in urban areas, making the total effect in urban areas around 10%. A plausible explanation for this finding is that canals offer particular environmental and recreational benefits in urban areas, where there is limited green space available, and canal-side locations may be particularly coveted. Urban in this land cover data refers to the densest parts of cities. Column (2) repeats the analysis for suburban and urban areas, which represent over 95% of the sample. Here we can see that all of the basic premium for canal proximity is driven by urban and suburban locations, and the effect in rural places (given by the first row) is insignificantly negative. The implied premium for living within 100m in urban and suburban areas in these estimates is 5.9% (this is slightly higher than in Figure 4, because here we are comparing 0-100m, with 100-1500m). We also double checked for effects at higher distance bands in the urban/suburban sample, but found none (see the Appendix, Figure 10). Column (3)-(4) look at differences by whether a property is close to other rivers or green space which might provide alternative recreational and environmental services, but we find no evidence that this matters in general in the national sample, even if it matters to urban populations as evidenced by column (1).

Figure 6 shows differences across the major urban Local Authorities which have sufficient length of canal to allow us to estimate. The first point and bar shows the coefficient and confidence interval for the rest of England and Wales outside the listed LADs, a figure of 3.7%. The remaining points show LAD specific effects relative to this, and need to be added to the 3.7% to get the total price premium. The main message is that there are differences across LADs, although the confidence intervals are sometimes very wide (and the coefficient for Manchester is implausibly large), implying it is hard to detect a clear effect in the smaller LAD specific samples. In general, the urban LADs have a higher canal premium, reflecting the urban effect shown in Table 1, column (1), although in Birmingham – a city famed for its canals and their industrial heritage – proximity to a canal has no positive effect: once we add its coefficient (-0.044) to the main effect in the rest of England and Wales (0.035) the coefficient is negative. We find a significant positive additional premium in the LAD of Bradford, which is crossed by the picturesque Leeds and Liverpool canal, renowned for its industrial heritage. The Bradford district also contains the town of Bingley, and its spectacular staircases of locks, which is a popular tourist attraction.

It is useful to translate the percentage premium on house prices into monetary equivalents, which represent willingness to pay for canal-side amenities – i.e. how much households are willing to give up on other expenditure in order to enjoy homes close to canals. Some care is needed in doing this, as we have estimated an average percentage premium over the whole period, but average house prices have doubled over the period from 2002 to 2017 so it is not necessarily appropriate to apply the percentage uplift to current prices to get the monetary equivalent. Instead, we first estimate the percentage price premium for properties within 0-100m in each year. Figure 7 plots these results. We do not report 2017 as our data only spans part of this year. The figures for each year after 2002 need to be added to the figure of 0.081 in 2002 to get the relevant percentage increase in that year. From the graph it is clear that the percentage premium remained stable from 2002 up until 2007. From then on it fell considerably, the obvious explanation being a shift in the housing market following the great recession in 2008. It is well known that the character of the housing market has changed since then, with much lower transaction volumes. Table 2 reports the monetary equivalents for each year, obtained by multiplying the percentage canal premium for each year by the mean price in the sample of properties 0-1500m from a canal in each year. The table shows the amounts in nominal terms, converted to 2016 prices using the Consumer Price Index, and the annual equivalents assuming a discount rate of 3.5% (obtained by multiplying the real capitalised value by the discount rate). Evidently, willingness to pay has declined substantially post-recession. Prior to 2008, households were willing to pay around £520 per year to live within 100 metres of a canal (the mean in the 2002-2007 period). From 2008 onwards, this figure has fallen to half that at £260. The average overall is £370 in 2016 prices.

As a final step in this analysis, we look at the availability of new build homes, as explained at the end of Section 3.1.1. The results are reported in Figure 8, which shows the effect of canal distance on the proportion of new build sales. As can be seen from the figure, the proportion of new builds is significantly higher closer to canals. Without any control variables, other than MSOA and LAD-year-quarter fixed effects, we find effects of 8.5 percentage points within 100m, falling to zero by around 600m, in panel (a). The most likely explanation for this higher proportion, is number of new builds being constructed. Such a relationship will arise because of demand in these places and/or greater supply due to lower construction costs due to the availability of land for building or industrial premises for conversion (e.g. former warehouses). As a basic step to control for factors affecting the supply side, the lower panel introduces more control variables for location, land use and employment share (as for Figure 4, panel (b)). Doing so reduces the estimates slightly, and – as with the price analysis – indicates that any effects are constrained to within 100m, where we find a 5.9 percentage point higher proportion of new builds.

What does this mean in terms of the number of new homes attributable to the canal? There are around 63,700 unique homes in the 100m buffer sold between 2002 and 2017, and 10,500 of these are newly built over this period. The rate of new building in the area outside the 100m zone is 7.8%, so the additional 5.9% means the rate of new building in the 100m zone is 76% higher. This means that we would expect 0.078 ×63,700 = 4967 new homes in the 100m zone if the new-build rate was the same as elsewhere. Our estimates attribute an additional 0.059 × 63,700 = 3758 homes to the existence of demand for a canal-side location (rather than other features of the land near the canal; the remaining 10,500 – 3758 = 6742 is presumably due to these other factors). Although it is impossible to rule out that this effect is still partly due to the kind of land and existing buildings available, i.e. is driven by the supply side of the market, the combination of more new builds and positive price effects from the previous analysis suggests, fairly unambiguously, that these effects are demand driven.

4.3. Difference-in-Difference estimates for the restoration of the Droitwich Canals

In this section, we report the results of the difference-in-difference analysis of the Droitwich Canal restoration described in Section 3.1.2. As discussed in that section, these results relate to the impact that the restoration had on the relationship between canal distance and price in the Droitwich area, compared to a control area near the Worcester and Birmingham Canal. The presentation of the results is otherwise similar to the main results in Section 4.2 above.

Figure 9 summarises our key estimates graphically, with point estimates and 90% confidence intervals. Panel (a) shows the impact of the restoration using a post-intervention date of May 2007, the date the main restoration period began, Panel (b) shows the additional effects – on top of those related to the start of the renovation – occurring around the official opening date in 2011. The impact shown in panel (a) is thus a short run effect from 2007 to 2011. Panel (c) simply reports the effect of the start of renovation in May 2007, without controlling for opening, to give a clearer picture of the overall change before and after this time. Note, the regressions used to derive these estimates control for full postcode fixed effects – i.e. eliminate all fixed over time differences in prices between postcodes – hence do not include the controls for distance to transport and other features or employment, since these do not vary within postcode. We include interactions between neighbourhood (OA) 2001 census demographics and the post-intervention indicator to control for possible spurious price trends related to these characteristics.

The plots in Figure 8 (a) and (c) bear a similarity to those from the national estimates in Figure 4, although the methods used to estimate them are substantially different. Here we are estimating only from the changes in prices over time near the Droitwich Canal around the time of the start of the major restoration, compared to the changes over time occurring over the same time in the control group. The effect of the restoration within 0-100m is large before opening, at around 15%, although there is a marked decline after opening. Taken together the overall impact reported in panel (c) is around 10%, which is substantially larger than the 5% found on the national cross-sectional analysis in Figure 4, although given the wider confidence intervals the figures are statistically similar. These patterns of distance decay in these estimates are not so clear cut, with some evidence of price uplift in 400-1000m bands. It is possible that the effects are spuriously related to confounding factors specific to the Droitwich area compared to the control Worcester area. Nevertheless, the sharp distance decay between 0-100m and the rest provides some assurance that the 0-100m effect can be treated as a 'causal' impact of the canal restoration on immediately proximate property prices.

The estimates from this difference-in-difference evaluation are less precise than those from the cross sectional analysis, and are based on a single case study area and much smaller sample. There are risks in looking at a single case like this, in that the estimates may be influenced by local price trends specific to the area. The number of affected properties is very small – around 289 sales occur in 36 postcodes within 100m band between 2002 and 2017. It is, however, reassuring that this methodology arrives at results which point in the same direction as the national cross sectional analysis. The likely interpretation is that households value the environmental amenities associated with living very near to a canal, or alongside the canal, and the Droitwich Canal restoration increased the quality of these amenities as the project intended. A back-of-the-envelope calculation, multiplying the number of unique properties transacted since 2007 within 100m of the Droitwich Canal (176), by the mean price in 2007 in the 0-1500m sample area (£195,000) and the percentage increase implied by Figure 9 (10%), suggests that the total gain in value for these homes was £3.4 million. This figure of course ignores the homes that have not yet sold, the value uplift to land that has yet to be developed, and the value ignores any benefits not captured in the housing market.

5. Conclusion

Canals potentially provide a desirable recreational and environmental amenity. In this paper, we used house prices to estimate the monetary-equivalent value of this amenity to local residents, a standard approach to valuing non-market goods in the environmental and urban economics literature. Analysis of the effects of canal proximity for the whole of the England and Wales network indicates that households were willing to pay a 5% premium to live within 100m of a canal, on average over the 2002-2017 period. The price premium fell substantially after the great recession from about 8.1% down to 3.4% in 2016, corresponding to annual monetary willingness to pay of around £520 pre-recession, and £260 post recession, in 2016 prices. We find no price premium for living close to a canal but beyond 100m, which suggests that the effect is driven predominantly by canal-side properties, and others with a direct outlook on the canals or immediate access. The analysis also shows a much higher proportion of new-build sales within 100m of canals relative to elsewhere - a 5.9% increase on an 7.8% baseline, so around 75% higher - suggesting considerable response in construction to this demand for canal-side homes. A unique application of a difference in difference evaluation methodology to the restoration and environmental rehabilitation of the Droitwich Canal in the West Midlands supports the key findings on prices.

As an interesting, if very imprecise exercise, we can calculate the potential implied land and property value uplift from the canal network. The length of the network covered in this analysis is 3500km. The price effects extend over 100m either side of the canal, so the affected area is $0.2 \times 3500\text{km} = 700\text{km}^2$, which is just under half the area of Greater London. Though we do not have the exact figure in our data, around 10% of the land of England is urban/suburban and so developed or hypothetically developable, so the price uplift from canals would affect about 70km^2, or 70 million m^2 of residential or potentially residential land. Price per square metre of residential floor space in our sample of postcodes with 1.5km of the canals in 2016 is around £2700. If residential land prices are around two-thirds of this, they would be around £1800 per square metre on average. The 3.4% premium for living close to canals in 2016, thus implies a land value uplift of $0.045 \times 1800 \times 70$ million = £4.3 billion pounds.

Of course not all of this urban land is built on for housing or ever likely to be. The proportion built on is more like 2.2%, so the implied increase in value of developed land is closer to £0.9 billion.[7] A similar figure can be obtained by aggregating the implied increased in value in the housing stock in our data. There are around 100,000 unique properties within 100m of a canal that transacted at least once over the entire 1995-2017 period on which we have data. The

[7] These urban land cover figures come from NEA (2011)

average price outside this distance band is £235,000 in 2016. The 3.4% uplift to property prices therefore implies a total increase in value of around £0.8 billion (0.034 ×235,000 ×100,000) aggregating across all the affected homes.[8]

[8] This value is relative to other places, so is not necessarily an addition to the total value of the land or housing stock in England and Wales.

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Figures and Tables

Figure 1: Map of waterways managed by the Canal and River Trust and used in this analysis

Figure 2: Droitwich canals before and after restoration

Lock prior to restoration 2007

Lock after restoration 2013

Figure 3: Droitwich Canals and Worcester Canal

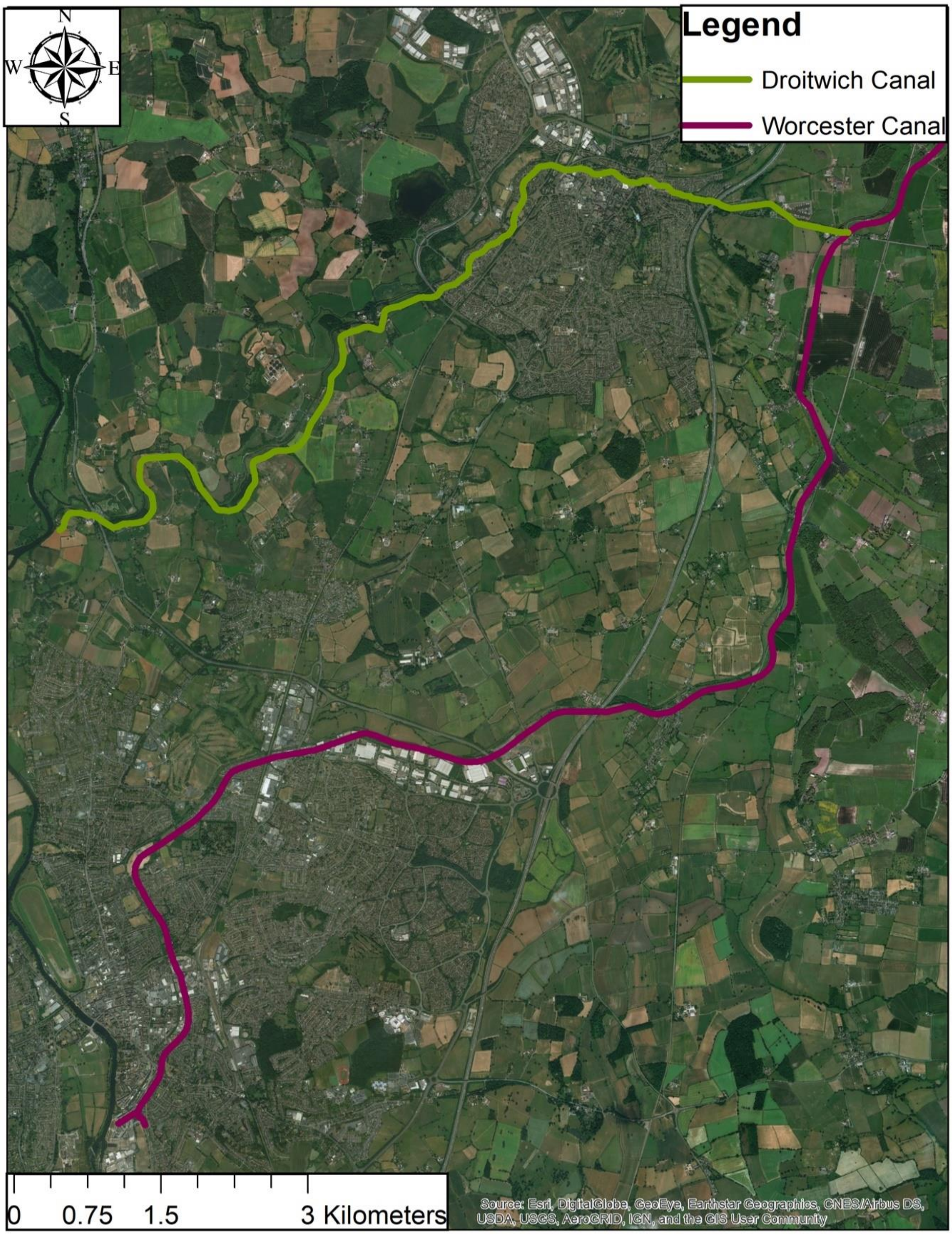
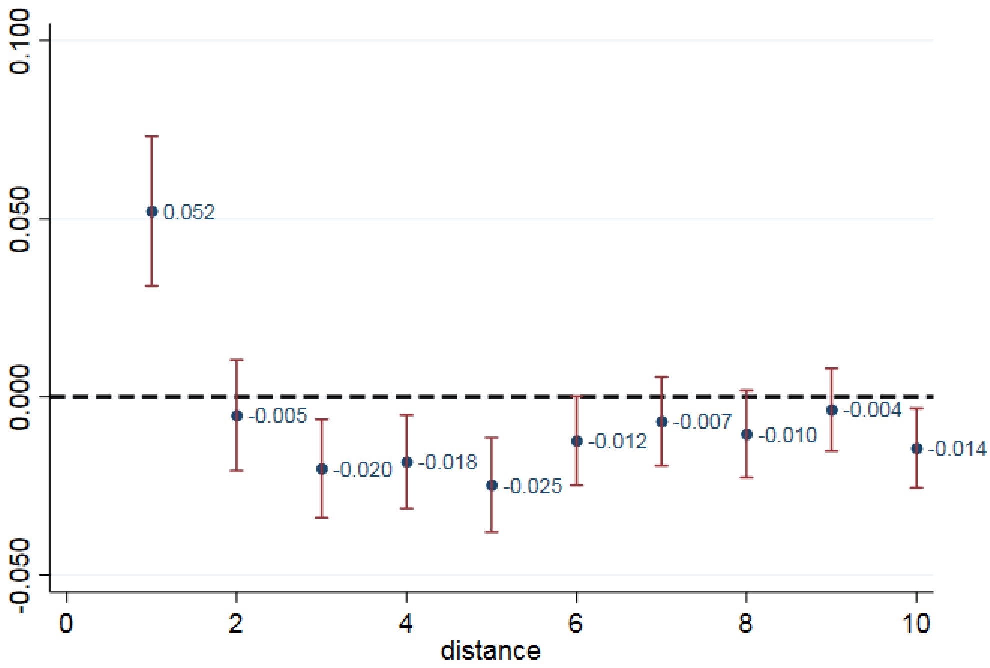
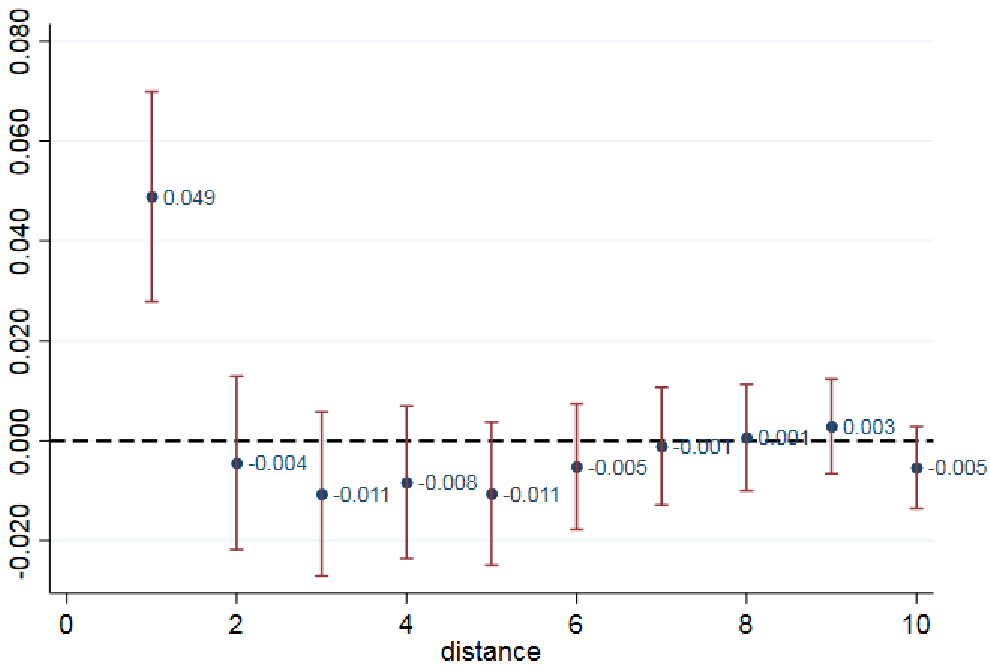


Figure 4: Main results for effects from canal proximity on house prices

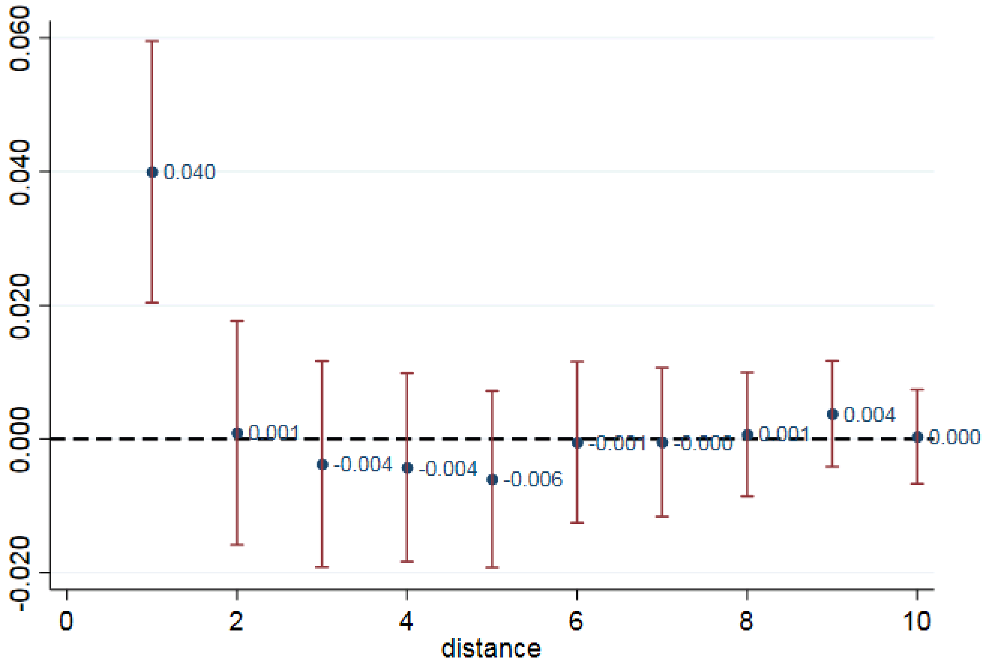
(a) Adjusting for LAD × year × quarter trends and housing characteristics



(b) Adjusting for LAD × year × quarter trends, housing, distances, land cover, employment and MSOAs



(c) Adjusting for LAD × year × quarter trends, housing, distances, land cover, employment and LSOAs



(d) Adjusting for LAD × year × quarter trends, housing, distances, land cover, OA demographics and LSOAs

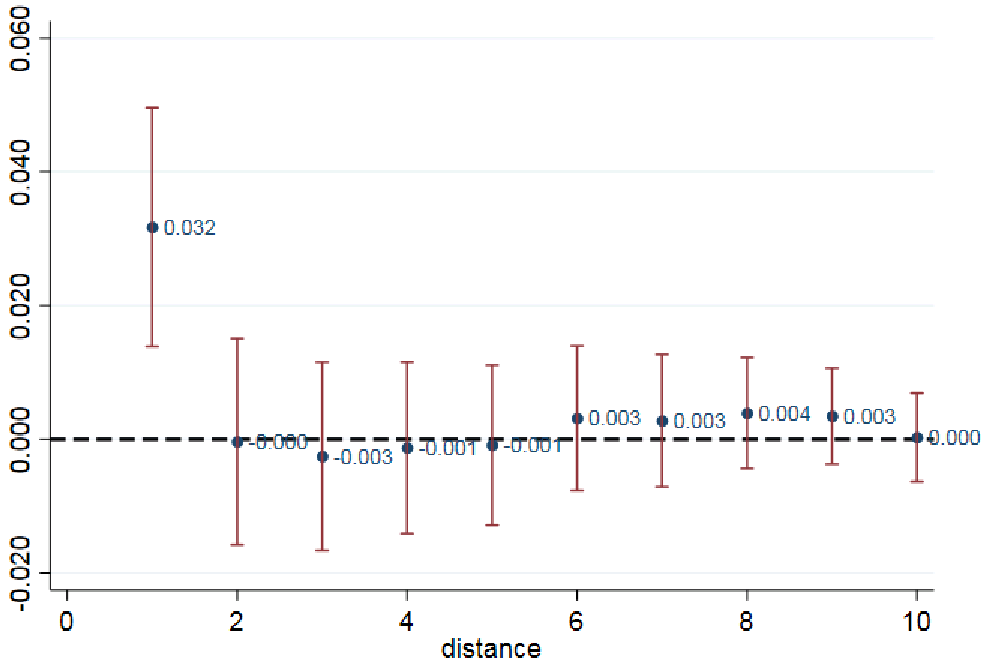
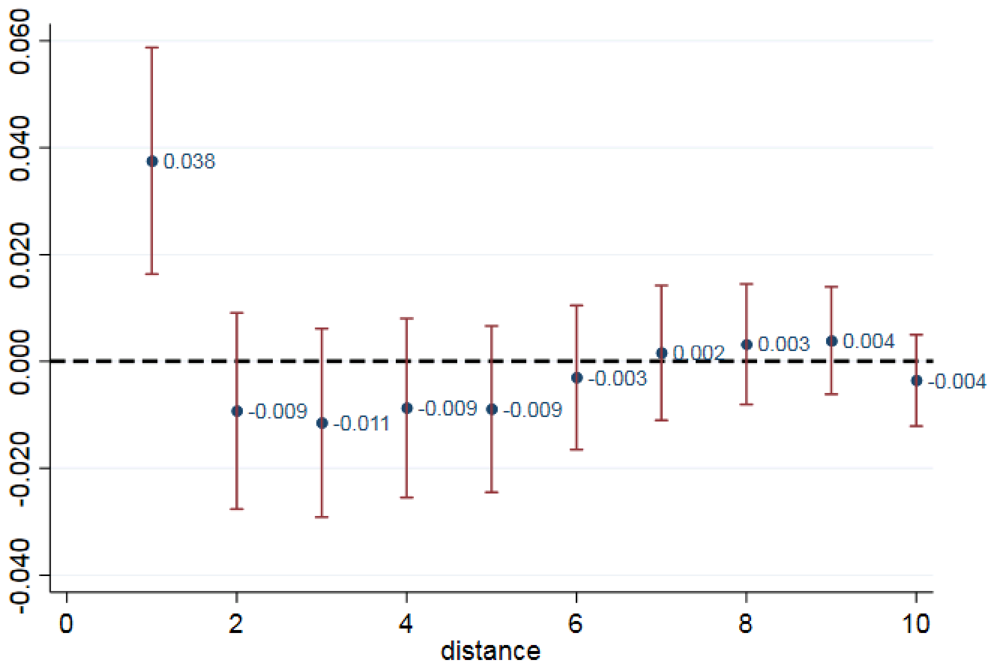
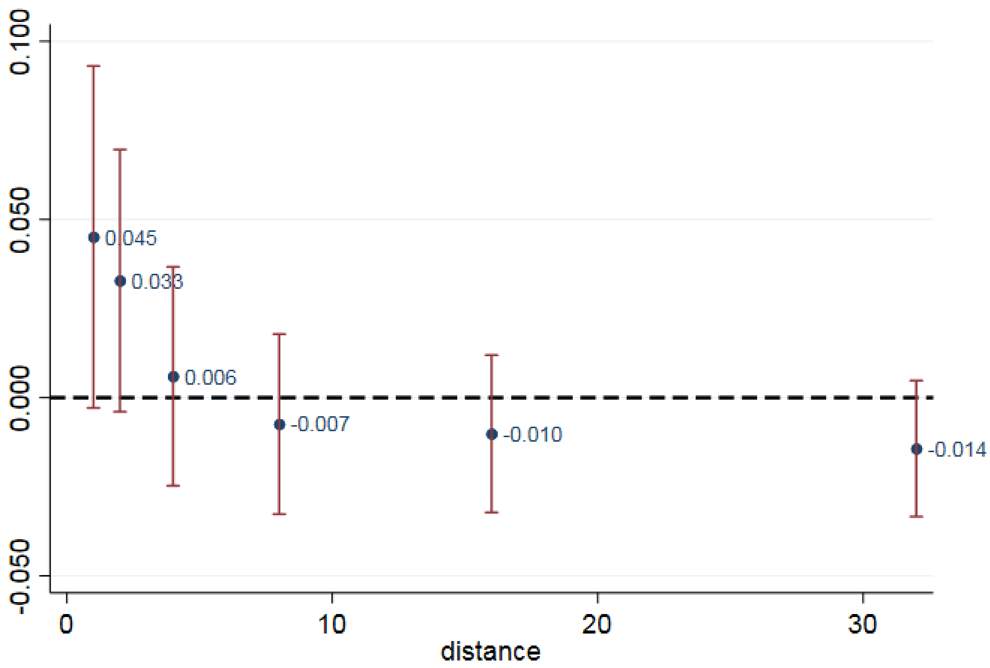


Figure 5: Effects of proximity to locks on house prices

(a) Canals:



(b) Locks: effects additional to canal distance



Lock effects significant at 10% level from 0-200m. Regressions control additionally for distance to wharves and aqueducts, where no significant effects were found. Regressions which restrict to effects from canals and locks within 0-100m show significant effects: canals 0.052 (0.008); locks 0.041 (0.021). Distances in 100m. Distance scale for locks differs from canals, because sample is restricted to 1500m from canals, but not 1500m from locks.

Table 1: Differences in canal premium for urban areas and places with other constraints

	(1) Urban	(2) Urban or suburban	(3) No rivers	(4) No green space
Canal within 100m	0.026c8***	-0.0136	0.0583***	0.0567***
	(0.0058)	(0.0164)	(0.0086)	(0.0090)
Canal within 100m in area specified	0.0710***	0.0726***	-0.0151	-0.0015
	(0.0168)	(0.0181)	(0.0174)	(0.0128)

Dependent variable is natural logarithm of transacted house prices. Coefficients multiplied by 100 give the approximate percentage premium on prices for properties within 100 metres of canals. Top row pair gives baseline effect of being within 100m of a canal and its standard error. Second row pair gives the additional effect associated with the property being within 100m of a canal in the type of area defined by column heading. Column headings: 1 Urban land cover predominant; 2 Urban or suburban landover predominant; 3 No rivers within 870 metres (top quartile); 4 No green space within 250 metres (top quartile). Specification controls for structural characteristics, distances to other water features, rail and town centres, land cover categories, employment variables at LSOA level, MSOA fixed effects, LAD x year x quarter fixed effects. Significance: ***1%, **5%, *10%.

Figure 6: Differences in price effects across major Local Authority Districts

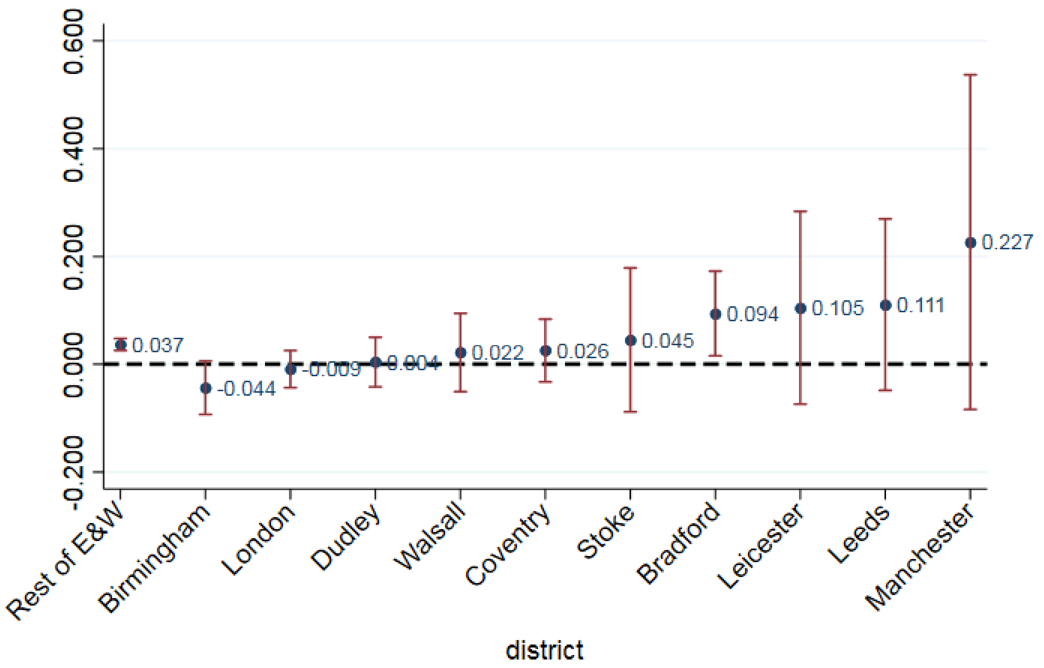


Figure 7: Differences in percentage price effects by year

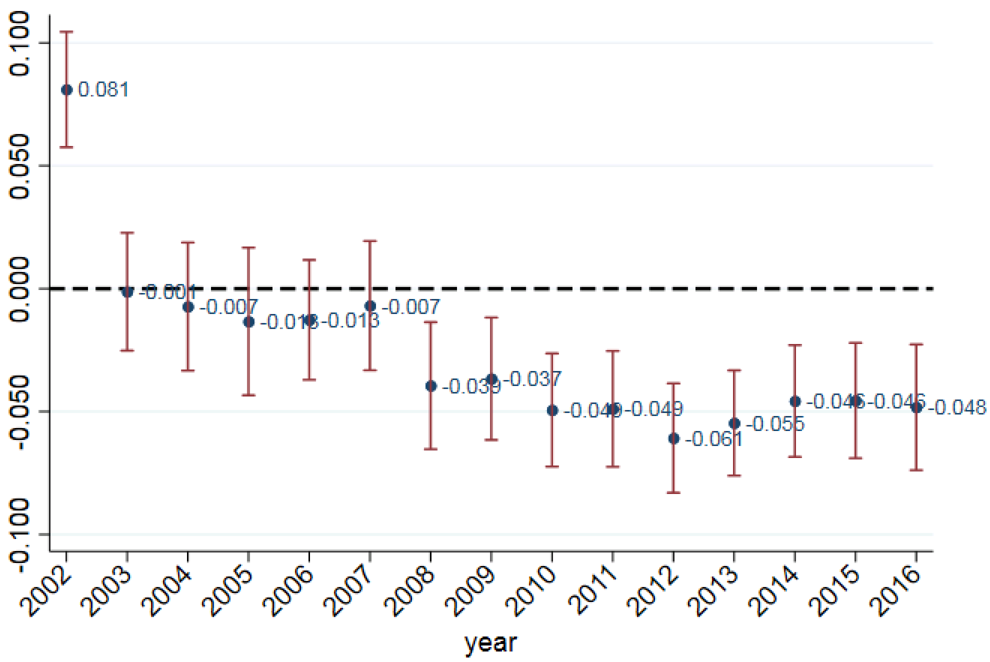
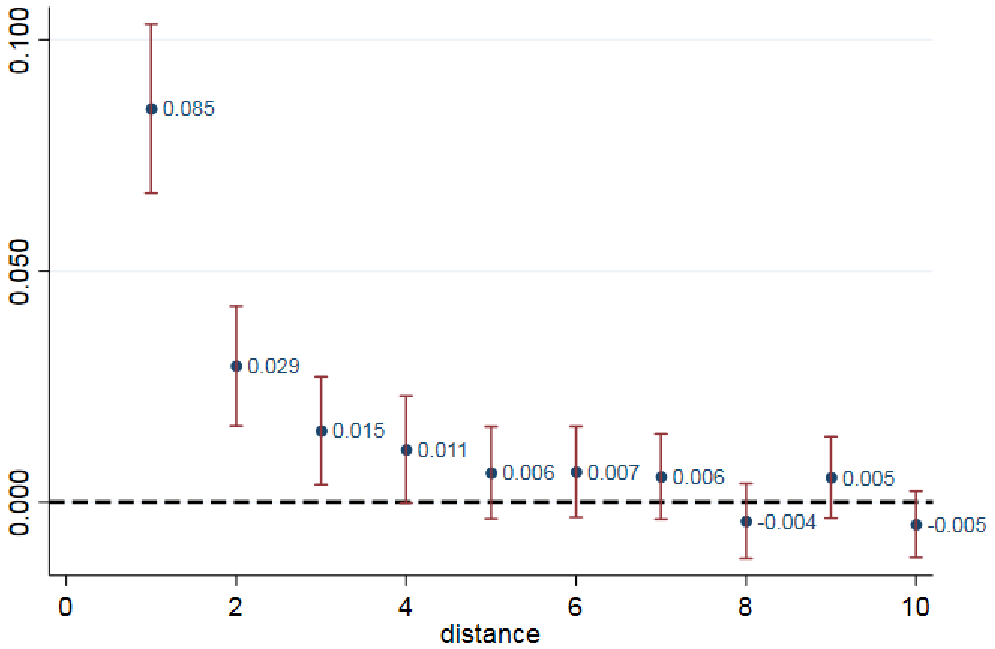


Figure 8: Effect of proximity to canals on new-build sales

(a) Adjusting for LAD × year × quarter trends and MSOA effects



(a) Adjusting for LAD × year × quarter trends, location, land use, employment and MSOA effects

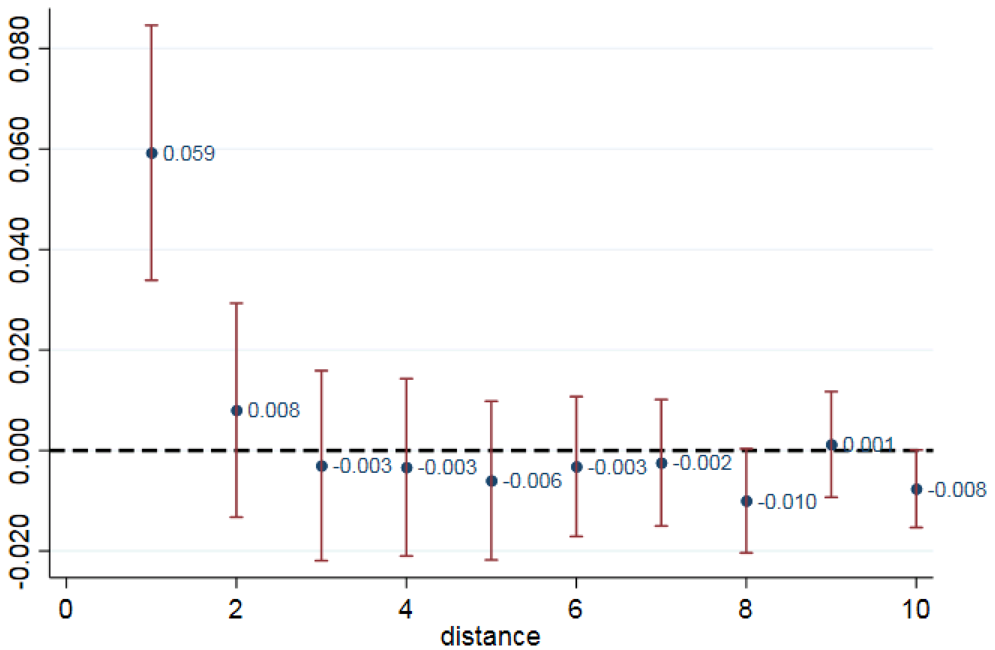


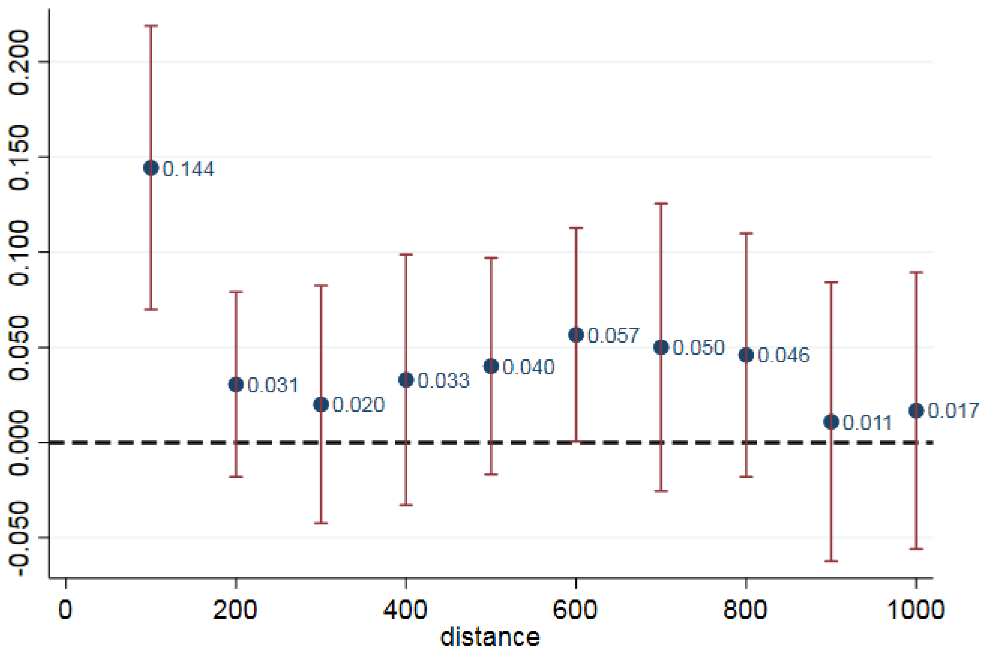
Table 2: Willingness to pay for property 0-100m from canals, by year

Year	£ Willingness to pay nominal	£ Willingness to pay 2016 prices	Annual equivalent at 3.5% discount rate
2002	9660	13058	457
2003	10886	14520	508
2004	11622	15298	535
2005	11278	14542	509
2006	12180	15350	537
2007	14211	17494	612
2008	7755	9220	323
2009	8226	9566	335
2010	6447	7262	254
2011	6393	6892	241
2012	4096	4292	150
2013	5612	5738	201
2014	7836	7891	276
2015	8155	8212	287
2016	7826	7826	274
Mean	8812	10477	367

Notes: a 3.5% discount rate is the standard rate in the Government's Green Book on guidance for public sector project appraisal.

Figure 9 Price effects from Droitwich Canal restoration at different distances.

(a) Post May 2007, pre 2011



(b) Post Sept 2011

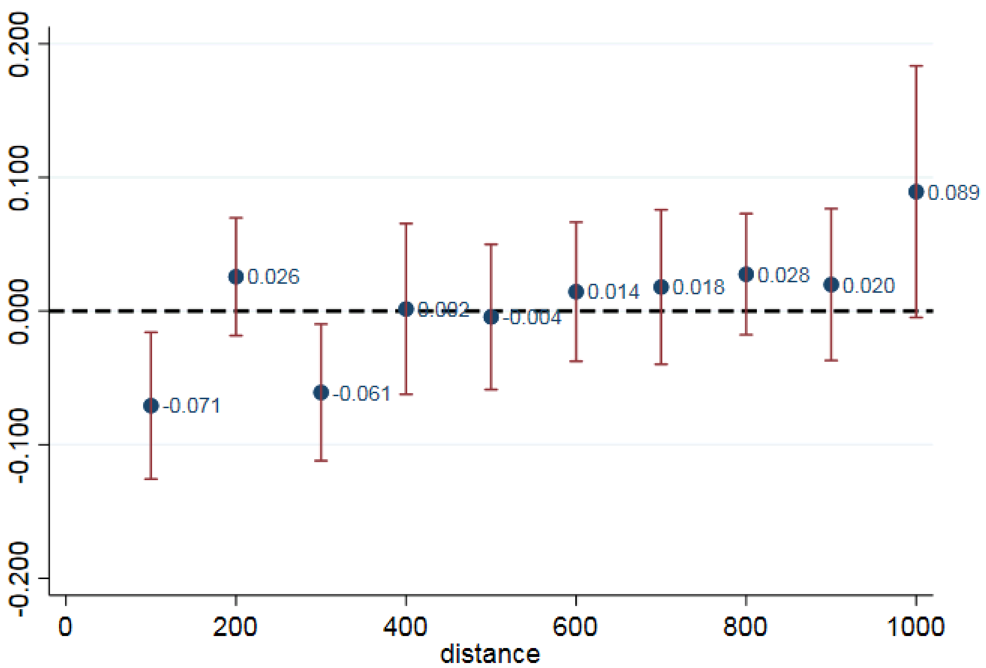
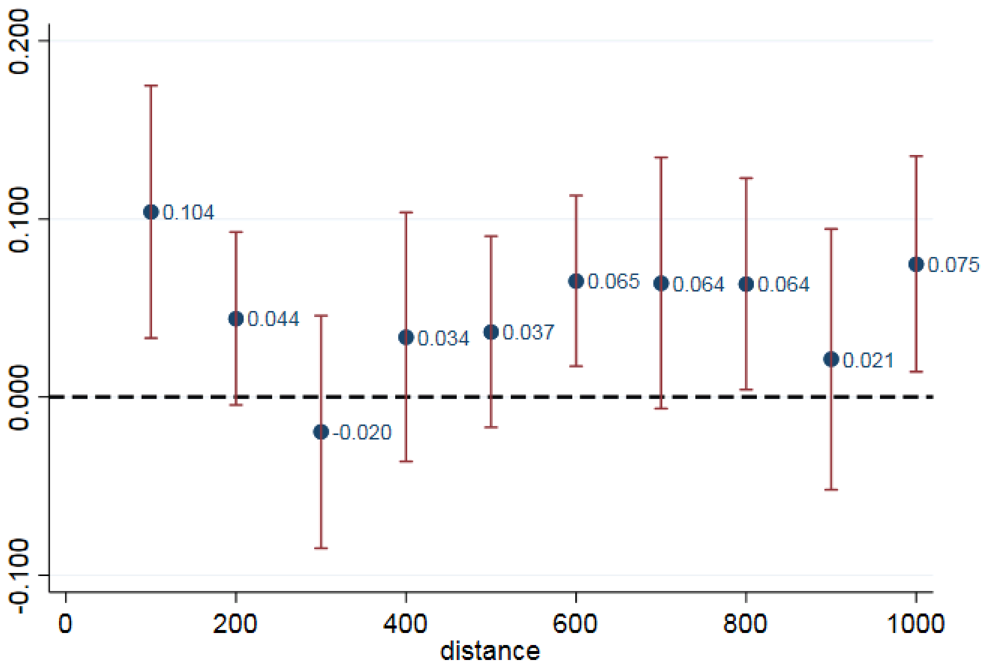


Figure continued …

(c) Post May 2007



Appendix Tables

Table A1: Definitions of variables used and the respective data sources

Variable	Source	Definition
Dependent Variable		
Ln Price	Land Registry	Natural Log of Transacted House Price
Structure		
Floor area (m2)	Land Registry	Size of transacted unit
Number rooms	Land Registry	Number of rooms in transacted unit
Number heated rms	Land Registry	Number of heated rooms in transacted unit
Fireplace	Land Registry	Binary variable =1 if transacted unit has a fireplace, = 0 otherwise
Energy efficiency	Land Registry	Overall Energy Efficiency (scaled from 1-100)
Leasehold	Land Registry	Binary variable =1 if transacted unit is leasehold, = 0 otherwise
Tenure missing	Land Registry	Binary variable =1 if tenure variable is missing, = 0 otherwise
New	Land Registry	Binary variable =1 if transacted unit is new build, = 0 otherwise
Terraced	Land Registry	Binary variable =1 if transacted unit is terrace house, = 0 otherwise
Flat	Land Registry	Binary variable =1 if transacted unit is flat, = 0 otherwise
Semi-detached	Land Registry	Binary variable =1 if transacted unit is semi-detached, = 0 otherwise
Land cover		
Arable	Ordnance Survey	Binary variable =1 if the centroid of the postcode is on arable land, = 0 otherwise
Freshwater	Ordnance Survey	Binary variable =1 if the centroid of the postcode is on freshwater, = 0 otherwise
Improved grass	Ordnance Survey	Binary variable =1 if the centroid of the postcode is on improved grassland, = 0 otherwise
Urban	Ordnance Survey	Binary variable =1 if the centroid of the postcode is urban land, = 0 otherwise
Heather, bog, rock	Ordnance Survey	Binary variable =1 if the centroid of the postcode is on heather, bog or rock land, = 0 otherwise
Grassland	Ordnance Survey	Binary variable =1 if the centroid of the postcode is on grassland, = 0 otherwise
Sediment/marsh	Ordnance Survey	Binary variable =1 if the centroid of the postcode is on sediment or marsh land, = 0 otherwise
Woodland	Ordnance Survey	Binary variable =1 if the centroid of the postcode is on woodland, = 0 otherwise
Dist to greenspace	UCL	Euclidean distance from the nearest green space
Green area	UCL	Size of nearest green space
Other river		
100m	Ordnance Survey	Binary variable =1 if the distance to the nearest other river is below 100m, = 0 otherwise
200m	Ordnance Survey	Binary variable =1 if the distance to the nearest other river is between 100m and 200m, = 0 otherwise
400m	Ordnance Survey	Binary variable =1 if the distance to the nearest other river is between 200m and 400m, = 0 otherwise
800m	Ordnance Survey	Binary variable =1 if the distance to the nearest other river is between 400m and 800m, = 0 otherwise
1600m	Ordnance Survey	Binary variable =1 if the distance to the nearest other river is between 800m and 1600m, = 0 otherwise
3200m	Ordnance Survey	Binary variable =1 if the distance to the nearest other river is between 1600m and 3200m, = 0 otherwise

Other distances (km)		
Dist lakes	Ordnance Survey	Euclidean distance from the nearest lake
Lakes >10km	Ordnance Survey	Binary variable =1 if the distance to the nearest lake is above 10km, = 0 otherwise
Dist docks	Canal Trust	Euclidean distance from the nearest dock
Docks > 10km	Canal Trust	Binary variable =1 if the distance to the nearest dock is above 10km, = 0 otherwise
Dist bridges	Canal Trust	Euclidean distance from the nearest bridge
Bridges > 10km	Canal Trust	Binary variable =1 if the distance to the nearest bridge is above 10km, = 0 otherwise
Dist embankments	Canal Trust	Euclidean distance from the nearest embankment
Embankments > 10km	Canal Trust	Binary variable =1 if the distance to the nearest embankment is above 10km, = 0 otherwise
Dist reservoirs	Canal Trust	Euclidean distance from the nearest reservoir
Reservoirs > 10km	Canal Trust	Binary variable =1 if the distance to the nearest reservoir is above 10km, = 0 otherwise
Dist rapid rail	Ordnance Survey	Euclidean distance from the nearest rapid rail line
Rapid rail > 10km	Ordnance Survey	Binary variable =1 if the distance to the nearest rapid rail lines above 10km, = 0 otherwise
Dist railways	Ordnance Survey	Euclidean distance from the nearest railway
Railways > 10km	Ordnance Survey	Binary variable =1 if the distance to the nearest railway is above 10km, = 0 otherwise
Dist town centre	UCL	Euclidean distance from the nearest town centre
Town centre > 10km	UCL	Binary variable =1 if the distance to the nearest town centre is above 10km, = 0 otherwise
Dist rail stations	Ordnance Survey	Euclidean distance from the nearest rail station
Rail stations > 10km	Ordnance Survey	Binary variable =1 if the distance to the nearest rail station is above 10km, = 0 otherwise
Dist rapid rail stat.	Ordnance Survey	Euclidean distance from the nearest rapid rail station
Rapid rail stat > 10km	Ordnance Survey	Binary variable =1 if the distance to the nearest rapid rail station is above 10km, = 0 otherwise
Dist outfall	Canal Trust	Euclidean distance from the nearest outfall
Outfall > 10km	Canal Trust	Binary variable =1 if the distance to the nearest outfall is above 10km, = 0 otherwise
Employment		
Total employment (1000s)	Nomis	Number of employment in thousands
No employment	Nomis	Number of unemployed
Agriculture share	Nomis	Share of employment in agriculture in LSOA
Mining utilities share	Nomis	Share of employment in mining utilities share in LSOA
Manufacturing share	Nomis	Share of employment in manufacturing in LSOA
Construction share	Nomis	Share of employment in construction in LSOA
Motor industry share	Nomis	Share of employment in motor industry in LSOA
Wholesale share	Nomis	Share of employment in wholesale in LSOA
Retail share	Nomis	Share of employment in retail in LSOA
Transport share	Nomis	Share of employment in transport in LSOA
Accom/food share	Nomis	Share of employment in accommodation and food services in LSOA
Financial services share	Nomis	Share of employment in financial service in LSOA
Property services share	Nomis	Share of employment in property service in LSOA
Prof, science, tech share	Nomis	Share of employment in professional, science and technical activities in LSOA
Business admin share	Nomis	Share of employment in business administration in LSOA

Public admin share	Nomis	Share of employment in public administration in LSOA
Education share	Nomis	Share of employment in education in LSOA
Health share	Nomis	Share of employment in health in LSOA
Arts entertainment share	Nomis	Share of employment in arts, entertainment and recreation in LSOA
IT share	Nomis	Share of employment in information and communication in LSOA
Demographics		
No education share	Census 2001	Share of residents with no education qualifications
No car share	Census 2001	Share of households without cars
Unemployment rate	Census 2001	Share of unemployed for the economically active
Lone parent household share	Census 2001	Share of single parent households
Non EU residents share	Census 2001	Share of non EU residents
Social renters share	Census 2001	Share of households who are social renters
Owners share	Census 2001	Share of households who are property owners
Non-white share	Census 2001	Share of non white residents
Population	Census 2001	Population size
Population density	Census 2001	Population size per unit area

Table A2: Descriptive statistics for the England and Wales sample

	(a) 0-100 metres Transactions: 115577		(b) 100-1000 metres Transactions: 1168074		(c) 1000-1500 metres Transactions: 623030	
	mean	sd	mean	sd	mean	sd
Natural log of price	11.867	0.618	11.815	0.673	11.886	0.667
Price	175685.1	236664.8	173885.9	245630.6	187898.7	273691.9
Price per metre squared	2313.448	3251.735	2111.266	13422.47	2231.633	3303.369
Size(sqm)	79.684	39.543	86.25	40.247	87.285	42.968
No.of Rooms	4.036	1.569	4.465	1.535	4.504	1.565
Fireplace	0.115	0.308	0.149	0.344	0.149	0.345
Energy Efficiency	64.07	13.801	59.564	13.157	59.87	12.827
Freehold	0.545	0.498	0.74	0.438	0.748	0.434
New Built	0.169	0.375	0.066	0.248	0.061	0.239
Terrace House	0.306	0.461	0.381	0.486	0.351	0.477
Flats	0.368	0.482	0.165	0.371	0.166	0.372
Semi-Detached	0.194	0.395	0.292	0.455	0.307	0.461
Low qualifications	0.275	0.133	0.296	0.13	0.289	0.128
Households no car	0.287	0.18	0.278	0.17	0.267	0.171
Unemployment Rate	0.055	0.047	0.055	0.044	0.052	0.042
Lone Parent HH	0.061	0.051	0.064	0.048	0.063	0.049
Non EU Residents	0.078	0.099	0.071	0.098	0.077	0.102
Social Renters	0.155	0.193	0.146	0.184	0.143	0.184
Property Owners	0.679	0.247	0.724	0.222	0.738	0.219
Non-white Residents	0.112	0.168	0.106	0.164	0.109	0.162
Population	291.622	76.55	301.933	71.815	304.437	68.526
Pop Density	34.705	36.889	52.758	52.61	56.005	67.125
Distance to rail (m)	785.977	1071.971	941.253	1135.31	1128.576	1167.526
Distance to town centre (m)	1582.133	1640.985	1665.24	1655.186	1653.508	1583.84
Distance to rail station (m)	1626.303	1800.961	1808.862	1870.892	1934.246	1835.618
Other river 100m	0.192	0.394	115577	0.065	0.246	1168074
Other river 200-100m	0.202	0.401	115577	0.096	0.295	1168074
Other river 200-400m	0.22	0.414	115577	0.219	0.414	1168074
Other river 400-800m	0.238	0.426	115577	0.37	0.483	1168074
Other river 800-1600m	0.12	0.325	115577	0.21	0.407	1168074
Other river 1600-3200m	0.027	0.163	115577	0.037	0.19	1168074
Total employment	1655.35	3172.158	1144.229	2852.941	1038.609	3386.612
No employment	0	0.013	0.001	0.027	0.002	0.046
Non-farm agriculture	0.002	0.012	0.001	0.011	0.001	0.009
Mining & utilities	0.01	0.038	0.008	0.037	0.007	0.035
Manufacturing	0.095	0.136	0.086	0.142	0.065	0.128
Construction	0.067	0.079	0.077	0.101	0.08	0.106
Motot	0.023	0.04	0.023	0.051	0.02	0.045
Wholesale	0.047	0.069	0.041	0.075	0.036	0.073

Retail	0.107	0.121	0.101	0.125	0.1	0.132
Transport	0.046	0.087	0.046	0.093	0.039	0.093
Accommodation & food	0.083	0.094	0.075	0.096	0.07	0.095
Financial and insurance	0.019	0.057	0.013	0.052	0.013	0.052
Property	0.018	0.04	0.015	0.04	0.016	0.04
Prof science technical	0.079	0.088	0.077	0.096	0.081	0.099
Communications	0.036	0.051	0.034	0.065	0.035	0.063
Business admin	0.077	0.113	0.068	0.101	0.068	0.104
Public admin	0.024	0.072	0.021	0.071	0.021	0.077
Education	0.094	0.161	0.126	0.188	0.141	0.205
Health	0.117	0.145	0.134	0.173	0.147	0.185
Arts and entertainment	0.055	0.08	0.053	0.078	0.056	0.084
Arable	0.003	0.052	0.003	0.054	0.003	0.057
Freshwater	0.002	0.043	0	0.022	0.001	0.029
Improved grass	0.018	0.131	0.021	0.143	0.024	0.153
Suburban	0.516	0.5	0.653	0.476	0.686	0.464
Urban	0.448	0.497	0.317	0.465	0.28	0.449
Heather bog rock	0	0	0	0.004	0	0.004
Grassland	0.001	0.034	0.001	0.031	0.001	0.032
Sediment marsh	0	0.005	0	0.009	0	0.01
Woodland	0.012	0.11	0.005	0.071	0.005	0.07
Distance to green space	191.093	184.947	172.989	137.552	176.873	141.505
Area of nearest green space (m2)	58174.78	262329.9	76117.79	574594.6	64821.44	346820

Table A3: Descriptive statistics for the Droitwich sample

	(a) 0-100 m Droit. N: 387		(b) 100-1000m Droit N:310		(c) 1000-1500m Droit N: 2047		(d)<1500m W&Birm. N 20427	
	mean	sd	mean	sd	mean	sd	mean	sd
Natural log of price	11.928	0.475	11.954	0.485	12.265	0.456	11.932	0.449
Price	173564.9	130386.2	178095.9	150709.7	234656.0	111832.0	169158.4	123812.6
Price per m²	1984.42	804.16	2027.83	1223.39	2202.61	1010.34	2021.58	1890.03
Size(m²)	91.318	49.206	91.606	46.269	112.179	57.611	87.863	40.671
No.of Rooms	4.525	1.699	4.623	1.703	5.495	1.843	4.579	1.66
Fireplace	0.068	0.233	0.112	0.307	0.17	0.366	0.169	0.366
Energy Efficiency	63.88	12.284	62.91	12.152	59.219	11.578	58.935	13.478
Freehold	0.744	0.437	0.775	0.417	0.871	0.336	0.809	0.393
New Built	0.034	0.18	0.064	0.245	0.026	0.16	0.056	0.23
Terrace House	0.388	0.488	0.287	0.453	0.082	0.275	0.309	0.462
Flats	0.176	0.381	0.211	0.408	0.043	0.202	0.171	0.377
Semi-Detached	0.147	0.355	0.256	0.437	0.307	0.461	0.307	0.461
Low qualifications	0.325	0.072	0.307	0.119	0.199	0.077	0.251	0.111
Households no car	0.223	0.138	0.222	0.139	0.078	0.058	0.215	0.144
Unemployment Rate	0.05	0.029	0.041	0.033	0.029	0.013	0.038	0.029
Lone Parent HH	0.04	0.033	0.056	0.047	0.035	0.028	0.05	0.036
Non EU Residents	0.019	0.02	0.026	0.032	0.02	0.011	0.035	0.033
Social Renters	0.146	0.138	0.209	0.198	0.037	0.08	0.099	0.154
Property Owners	0.743	0.146	0.724	0.188	0.918	0.093	0.774	0.193
Non-white	0.013	0.008	0.012	0.013	0.015	0.013	0.04	0.061
Population	275	66.561	282.672	55.054	304.461	43.953	291.599	53.937
Pop Density	24.128	18.375	38.827	25.857	35.302	18.31	45.577	26.077

Table A4: Example full regression output: dependent variable ln price

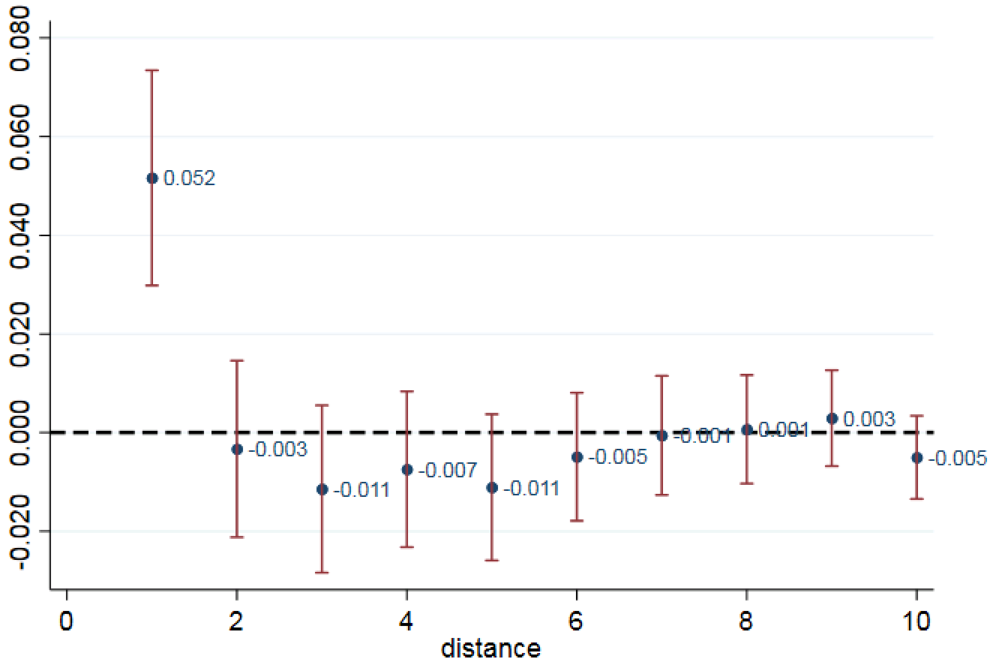
Canals		**Other river**		**Employment**	
100m	0.0368***	100m	0.0597	Total employment (1000s)	0.0049***
	(0.0095)		(0.0435)		(0.0009)
200m	-0.0047	200m	0.0487	No employment	-0.0755*
	(0.0078)		(0.0434)		(0.0394)
300m	-0.0073	400m	0.0458	Agriculture share	0.1647*
	(0.0074)		(0.0435)		(0.0901)
400m	-0.0046	800m	0.0442	Mining utilities share	-0.0824*
	(0.0068)		(0.0432)		(0.0433)
500m	-0.0039	1600m	0.0446	Manufacturing share	-0.0538*
	(0.0064)		(0.0429)		(0.0294)
600m	-0.0006	3200m+	0.0307	Construction share	-0.0372
	(0.0056)		(0.0419)		(0.0300)
700m	0.0018	**Other distances (km)**		Motor industry share	-0.0782**
	(0.0053)	Dist lakes	0.0011		(0.0359)
800m	0.0033		(0.0084)	Wholesale share	-0.0980***
	(0.0046)	Lakes >10km	-0.0220		(0.0326)
900m	0.0026		(0.0160)	Retail share	-0.0583**
	(0.0041)	Dist docks	0.0191**		(0.0282)
1000m	-0.0041		(0.0088)	Transport share	-0.0312
	(0.0038)	Docks > 10km	-0.0383		(0.0294)
Structure			(0.0326)	Accom/food share	0.0617*
Floor area (m2)	0.0024***	Dist bridges	-0.0071		(0.0317)
	(0.0001)		(0.0067)	Financial services share	0.0227
Number rooms	0.0434***	Bridges > 10km	0.0598*		(0.0432)
	(0.0027)		(0.0330)	Property services share	0.1943***
Number heated rms	0.0088***	Dist embankments	0.0103**		(0.0465)
	(0.0007)		(0.0043)	Prof, science, tech share	0.0446
Fireplace	0.0638***	Embankments > 10km	-0.0017		(0.0382)
	(0.0017)		(0.0207)	Business admin share	-0.0261
Energy efficiency	0.0018***	Dist reservoirs	0.0042		(0.0299)
	(0.0001)		(0.0039)	Public admin share	0.0048
Leasehold	-0.0998***	Reservoirs > 10km	-0.0143		(0.0315)
	(0.0062)		(0.0108)	Education share	-0.0178
Tenure missing	-0.0263	Dist rapid rail	-0.0055		(0.0275)
	(0.0714)		(0.0062)	Health share	-0.0124
New	0.2361***	Rapid rail > 10km	-0.0080		(0.0280)
	(0.0056)		(0.0213)	Arts entertainment share	0.0369
Terraced	-0.3850***	Dist railways	0.0087**		(0.0330)
	(0.0044)		(0.0042)	IT share	Baseline
Flat	-0.4211***	Railways > 10km	-0.0182	**Demographics**	
	(0.0085)		(0.0378)	No education share	-0.3988***
Semi-detached	-0.2504***	Dist town centre	-0.0160***		(0.0247)
	(0.0033)		(0.0038)	No car share	-0.4360***
Land cover		Town centre > 10km	0.0063		(0.0274)

Arable	0.0400***		(0.0367)	Unemployment rate	-0.3901***
	(0.0116)	Dist rail stations	0.0026		(0.0497)
Freshwater	0.0784**		(0.0043)	Lone parent household share	-0.8988***
	(0.0316)	Rail stations > 10km	0.0537**		(0.0485)
Improved grass	0.0499***		(0.0244)	Non EU residents share	0.3973***
	(0.0049)	Dist rapid rail stat.	-0.0000		(0.0643)
Urban	-0.0332***		(0.0022)	Social renters share	0.2588***
	(0.0037)	Rapid rail stat > 10km	-0.0069		(0.0273)
Heather, bog, rock	0.3331***		(0.0230)	Owners share	0.0662**
	(0.1288)	Dist outfall	0.0007		(0.0259)
Grassland	0.0114		(0.0046)	Non-white share	-0.2996***
	(0.0278)	Outfall > 10km	0.0333*		(0.0371)
Sediment/marsh	-0.0060		(0.0196)	Population	-0.0000
	(0.0422)				(0.0000)
Woodland	0.0158			Population density	-0.0006***
	(0.0097)				(0.0001)
Dist to greenspace	0.0610***				
	(0.0091)			Implicit price	£8801
Green area	0.0000*				
	(0.0000)			Observations	2048723
Urban	Baseline			R-squared	0.8

Table reports regression coefficients and standard errors. All columns relate to a single regression. Specification includes Local Authority District by Year by Quarter fixed effects and Middle Layer Super Output Area (MSOA) fixed effects. Standard errors clustered on MSOA. Estimated by reghdfe in Stata 15 MP

Figure 10: Distance to canal effects on prices, for urban and suburban areas only

Adjusting for housing, distances, land cover, employment and MSOAs



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