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A Hedonic Analysis of the Value of Rail Transport in the Greater Dublin Area

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Abstract: We use a hedonic house price model to estimate the value of transport networks to homeowners in the Dublin area. Using a dataset of house sales between 2001 and 2006 and combining it with available geographical information system data on the train and tram lines in Dublin, it is possible to assess the values assigned to different transport links by homeowners. We find that the value of transport depends on how far from the property it is located and is also affected by the availability of alternative transport options in the area. There are differences in the values assigned to recently constructed tramlines compared to the traditional rapid transit train stations. The study also takes into account house characteristics and other environmental amenities.

Key words: Hedonic Regression, Train, Tram, Transport Network, Ireland, Geographical Information System.

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1. Introduction

Rapid macroeconomic growth and a very capital-centric pattern of growth have led the city of Dublin to grow immensely both in population and in area over the last 30 years. Urban sprawl has been a characteristic of the development of the Dublin area. This has resulted in the need to provide transport networks and amenities to households situated further and further away from the city centre. However, the construction of transport networks to service the expansion of the city has been slow in comparison to its growth. Public transport in the Irish capital has traditionally depended on the grouped bus system, which has been in operation since the 1950s. It is only since 1984 that an overland rail system was added to public transport services. The Dublin Area Rapid Transit (DART) was a key part of the suburban rail network in County Dublin and, for 20 years, the only rail access available to residents of the Dublin area. Since 2004, residents in certain areas of Dublin also have the option of using the *Luas*, a light rail system which operates two lines on the south side of the city. Despite the growth in the availability of rail, it remains well behind the car, the bus and 'on foot' as a method of commuting to work. According to the 2006 Census of Population (CSO, 2007), only 7% of people in the Greater Dublin Area used rail services to travel to work compared to the 49% using their cars – even though rail is the fastest form of non-car transport in the Greater Dublin Area (faster than bus, cycling or on foot).

Construction of urban transport amenities can involve significant cost and short-term disruption to traffic flows and economic activity. It is important to establish that the value of these amenities to the public outweighs such costs. In order to appraise the value that society attaches to it, we need to use non-market valuation techniques. Valuation techniques can be divided into two groups: stated preference and revealed preference techniques. The former ask people directly how much they would be willing to pay for an environmental amenity or access to a transport network. The latter technique looks at other market variables to assess how much value people implicitly place on amenities. The hedonic house price model is one such technique. It is possible to estimate the value an amenity adds to a house by separating out the value of the different components.

Hedonic valuation of transport networks is well-established, although to our knowledge no such valuations have been performed for Dublin. Spengler (1930) was one of the first to assess changes in the value of land in the vicinity of new rail transit. He examined the effect of rail transit stations constructed at the beginning of the 20th century in New York on the value of land in the surrounding areas. He found that the lines tended to shift land values; owners of land adjacent to the rail network would see their land increase in value while others lost value. Moreover, a new line would have a small effect on areas already served by rail compared to areas that were underserved.

Since this paper, a large literature on hedonic analyses in North America has developed, the bulk of which goes back to the 1980s. Damm et al. (1980) is a very extensive analysis of the impact of the construction of a heavy rail transit system in Washington. In particular, the paper examines the response of property values in anticipation of the rail opening (the ‘announcement effect’). It also looks at the land by type of property (single family dwellings, multi family buildings, and retail establishments). In all models, increasing distance to a metro station was associated with lower property values. Moreover, the effects were found to be more pronounced in retail than residential properties and the opening date effect was substantial.

Another regularly cited paper on the subject is by Gatzlaff and Smith (1993) who look at the impact of the development of the Miami Metrorail system on property values close to the station. They find a weak effect of the new rail system on property prices, regardless of the distance to the station. They also find a weak announcement effect. Gibbons and Machin (2008) provide a comparison of different hedonic analyses on transport networks. Most of the reviewed literature centres on recent studies on American cities and proximity to rail networks. For example, Bowes and Ihlanfeldt (2001) apply a similar methodology to the one used in this paper and find that properties in very close proximity to rail stations in the Atlanta region sold for less than properties at an intermediate distance, i.e. households placed a premium on proximity to transport networks. Baum-Snow and Kan (2000) look at the distance to new transit lines in 5 US cities and find a 5000$ increase in mean prices for a reduction in distance from 3km to 1km. The Armstrong and Rodriguez (2006) analysis is based on Eastern Massachusetts. They conclude that properties within half a mile of a commuter rail station command a 10% premium. They also find a negative coefficient on rail lines, indicating that proximity to these is considered an externality. McMillen and McDonald

(2004) find evidence of pre-opening anticipatory effects for the rail transit line in Chicago.

There is also an extensive literature on European cities. For instance, Forrest et al. (1996) examine the Metrolink in Greater Manchester. They compare data before and after completion and find no discernable impact. Gibbons and Machin (2005) look at the changes arising from the construction of new stations on the London underground and the new Docklands Light Railway (DLR). They find that a reduction in the distance to a station (by the construction of a new station) of 1 km increased house prices affected by this change by 1-4%. Recent literature has examined new rail projects in Asia. Tse (2002) looks at the Mass Transit Railway in Hong Kong while Bae, Jun and Park (2003) find that the construction of a new subway station in Seoul led to an increase in residential prices, but only prior to the line opening. They find that other variables, such as the size of the house or proximity to other environmental amenities (e.g. recreational resources), have a much bigger effect on house prices than access to transit.

Debrezion *et al*. (2007) perform a meta-analysis of 57 hedonic studies of railway stations. Some hedonic analyses find very high positive valuations for close proximity to rail stations and significant announcement effects of rail projects, while others find new lines have negative or no effects. The average effect is a 4.2% premium for residences with .25 mile of a station (Debrezion *et al*., 2007). As the light rail system in Dublin is quite new, our data allow us to test hedonic valuations concurrent with, or in anticipation of, the availability of light rail. Moreover, we are interesting in the relative attractiveness of the new light rail system in comparison to the older commuter rail network. The density of properties is also sufficiently high to allow us to distinguish between the value of proximity to train stations and the disamenity value we expect would arise from proximity to train tracks.

This paper makes use of geographical information system (GIS) data. GIS allows us to integrate different spatial datasets and to precisely map the location of the houses. By overlapping maps with the location of transport and environmental amenities, it is then possible to determine the exact distance of these amenities to each of the houses. The advantage of using GIS is that it allows precise modelling of the interactions and relationships between the houses prices and the local amenities. GIS has been used a lot in more recent hedonic analyses (Bateman, et al. 2003), usually when large datasets or more precisely located amenities are involved.

The remainder of this paper is set out as follows. Section 2 presents the model used in the analysis and the econometric issues underlying the model applied. Section 3 describes the data used in the study both for house prices and transport amenities. Section 4 presents the results of a hedonic house price model for the Dublin area. When presenting the results, we distinguish between transport amenities/disamenities, environmental amenities and house characteristics. Section 5 provides a discussion and conclusions.

2. The model

The hedonic technique is based mainly on work by Griliches (1961) and Rosen (1974) and originated in the development of value indices for manufactured products that combined measures of quantity and quality. The seminal paper by Griliches (1961) derived a hedonic price index for motorcars. The technique centres on consumers' choices regarding composite goods. The assumption is that goods are valued for their utility-bearing attributes and that these attributes are internalised into the price of the good. A house has several attributes, for instance, number of rooms, bathrooms and the availability of car park spaces. All of these attributes make different contributions to the price of the house. In addition to house characteristics, neighbourhood characteristics also contribute to house prices.

If you have a large enough sample of housing market transactions, it is possible to use econometrics to separate out the implicit price of the attributes. This is done using a hedonic house price model. The basic technique involves regressing (some transformation of) the property price on the set of variables measuring quality, while controlling for unobserved time and area effects. The regression coefficients are then interpreted as marginal implicit prices of the quality components.

The hedonic price function takes the following form:

$$PRICE = f(S, N, E) + \varepsilon$$

where the price (or logged price of the house) is a function of the house's structural or physical characteristics (number of bedrooms, size in square meters etc.), neighbourhood or location characteristics (such as location in the city, access to transport routes etc.) and environmental characteristics (such as proximity to green spaces, to coast, quality of ambient air). ε is an error term. The house price is thus a function of all of the attributes relating to the house and the resulting coefficients are the marginal implicit prices of the attributes. For a detailed explanation of the structural hedonic model see Gibbons and Machin (2008).

Although hedonic pricing is used extensively in the housing literature it is not without its criticism. Maclennan (1982) points out that the observed price may not be an equilibrium price and the relation between housing attributes and buyer satisfaction is generally unknown. Furthermore, as noted by Maclennan hedonic models do not take account of differences in the quality of the attributes. We include a variable specifying the condition of the property at sale time. This acts as a proxy for the quality of the dwelling. Omitted variable bias is a common problem with hedonic models, as including all variables that influence house price is difficult. Here, as well as the transport and environmental amenities of interest, we include time dummies (to account for inflation and trends in the housing market) and locality dummies (to account for area-specific variation). The importance of using regional dummies is detailed in Conniffe and Duffy (1999). These dummies are fairly extensive and aim to capture as much of the unexplained variation in house prices as possible.

The choice of functional form is also important. Here we use a semilog specification (a common choice; see Bowes and Ihlanfeldt, 2001), as it provides the best model fit. The following section presents the data sources used in the study and the different types of explanatory variables.

3. Data

The dataset used in this analysis is composed of a house price and characteristics dataset, which was then related to information on the location of transport and environmental amenities. The house price data were provided by Sherry FitzGerald, Ireland's largest property advisory group and auctioneer. The dataset consists of a representative sample of house sales facilitated by Sherry FitzGerald in the Dublin area between January 2001 and December 2006. This amounts to just over 9,700 dwellings. The complete addresses were used, along with the An Post Geodirectory, to geo-code the data. Not all addresses in the original database were amenable to geo-coding. Our valid sample size after geo-coding was 6,956, covering most of the Dublin area (see Figure 1) and a wide range of house prices (see Figure 2). This is not only a very large sample but also very detailed and location specific. A comparison of the dataset with other sources of housing market data (Department of the Environment[1]) indicates that our sample has an average price for houses that is much higher than other sources. However, this reflects the fact that the majority of transactions within our sample dataset take place in South Dublin, a part of the city that is generally much more expensive than other areas.

The available structural variables are the floor space, measured in square metres; the number of bedrooms; the presence or not of a utility room, of parking and of a garden; whether the heating system is gas fired or not; and the condition of the house as assessed by the real estate agent (excellent, fair, poor, very poor, unknown). The type of dwelling is also included (apartment, detached house, semi-detached house terraced house and cottage) as well as in what period the house was built (pre-1900, 1900-1950, 1950-1975, 1975-2000, post-2000).

We also use GIS data from a number of sources. The environmental variables include the distance to the nearest bathing beach and to the coastline. These data were provided by the Environmental Protection Agency (EPA). The distance to the nearest public access park is also included; these data were extracted from the CORINE 2000 project courtesy of the EPA. Transport variables include three types of rail transport: proximity to train stations, commuter rail stations and light rail stations, as well as distance to tracks. The location of these variables is visible on Figure 1.

We allow for unobserved heterogeneity in area characteristics through the use of locality dummy variables, and we include quarterly dummy variables (from Q1 2001 to Q4 2006) to control for house price inflation. Potential seasonality in house pricing is also accounted for using a dummy for each calendar month. The 105 locality dummies represent neighbourhoods, and each is made up of one or more electoral districts sharing a common area name. The electoral district data comes from Ordnance Survey Ireland. We considered using individual electoral district variables as locality controls,

[1] Department of the Environment, Heritage and Local Government, *Housing Statistics*, www.environ.ie/en/publications

but we have too few observations to allow the use of such small area dummies (there are over 200 electoral districts in our sample area).

The following section presents the results of the analysis by type of amenity, first looking at the rail network in Dublin, then environmental amenities and finally the structural characteristics of the houses.

4. Results

The full results for the analysis are available in the Appendices. In this section, they will be presented according to the type of explanatory variable (transport, environment, structural) used. Nearly 88% of the variation in the log of sale price is explained by our hedonic model. This is a very high percentage, which is probably accounted for by the good set of explanatory variables available in the dataset and large set of locality and time dummy variables. We find a large number of statistically significant explanatory variables, the interpretation of which we detail below.

4.1. Luas/Light rail

The Luas light rail system, employing on-street trams, is the newest addition to the Dublin rail network and was constructed as a part of the Dublin Transportation Office's strategy for the Greater Dublin Area from 2000 to 2016 (DTO, 2001). It includes two lines that at present do not connect (see Figure 3 for the stations and pricing zones). The Green Line connects the wealthier southeast areas to the city centre, while the Red Line extends to the southwest. Both lines were opened in 2004. As the opening of the two lines lies within the time span of our dataset, it is possible to check whether the value of the Luas was visible through an anticipatory/expectation effect or a lag effect. The "Luas at opening" model assumes the transmission of value from the presence of the Luas line occurs from the time the Luas lines opened.[2] The lag effect assumes the transmission takes a year to take effect and the anticipation effect assumes the transmission occurs a year before opening. Hence dummies are included for the opening dates (or lagged/expected dates) and interacted with the proximity dummies for the Luas.

[2] The Luas green line opened on the 30th June 2004 and the Luas red line on the 28th September 2004.

The Luas Green Line results are more detailed than the Red Line results as more observations were available in our dataset for that area of the city. Looking at Table 4, we find that if a house within 500 metres of a Green Line station in Zone 2 was purchased at or after the Luas opening date, it would command a premium of 12%. In zone 3, the premium would increase to 17%. This is high compared to previous literature (Debrezion *et al*., 2007). For houses within 2000 metres (but greater than 500 metres), the premiums fall to 7% for both zones. Two kilometres was taken as the highest threshold of interest on the basis that it is roughly the maximum distance people would walk to a station. The results for the Red Line are not as significant. We find that dwellings within 1000m of the red line command a 12% premium. Lack of observations may explain the lack of significance of the two other proximity boundaries for the red line.

The results taking account of possible anticipation or lag effects are presented in Tables 7 and 8 and summarised in Table 9. Houses within 500 metres of a green line station in Zone 2 and Zone 3, which were purchased after the 30th June 2004 would command a premium of approximately 12% and 14% respectively. This falls to 5% when within the 2 kilometres boundary and the red line figure remains in the same region of 13%. There is no significant difference between the price premium in anticipation and at opening time – but the premium at opening time is generally higher, which is readily explained by time discounting. The situation is however different for the "lag effect". Table 8 presents these results. Not only does the significance of the variable fall but the coefficients are also smaller in absolute terms. The premiums for the Green Line 500 metre boundary are 6% for Zone 2 and 13% for Zone 3. The Luas apparently conferred more limited benefits than people expected. The R^2 for this regression is also slightly lower than for the previous two. However, the lagged effects do not significantly differ from the other estimates.

In summary, properties within 500 metres to 2 kilometres of a light rail station are found to sell for between 7% and 17% more than properties not in proximity of the station. This suggests that there is a significant premium for home owners associated with the construction of a light rail system in their area. As summarised in Table 9, these premiums may vary depending on when the house was purchased, with the premium rising slightly until the opening, and falling after that.

4.2. Trains and Dart

The Dublin Area Rapid Transit system or DART has been in existence since the 1980s. It consists of one line which covers the Dublin bay area. The line is also used by the train network to link Dublin to other Irish cities. Hence the tracks for the DART and train lines are the same. However, some stations in Dublin are solely used by inter-city trains. Table 4 shows the effects of living within 250m, 500m, 1000m and 1500m of a train station as well as living within 1,500m of a DART station. Living very close to a train station (within 250m or 500m) results in a 7% to 8% premium on the house – lower than Luas stations, but still higher than the average estimate in the literature (Debrezion *et al*., 2007). The variables further away are not significant. The value of living very close to a train station in Dublin is due to saved commuting time, as trains are the main form of longer distance commute after cars. The DART station premium is approximately 5%. This lower premium may be due to the fact that areas serviced by the DART tend to benefit from good bus services as well. Certain areas serviced by the Luas did not have a good alternative and were relatively congested, hence the higher premium for light rail. Moreover, the DART service has not been renovated for quite some time and in consequence the light rail is deemed a more comfortable means of travel, which could help to explain why it commands a higher premium.

Table 4 also includes the distance to train tracks, which we expect to be a disamenity. Dummies are included for whether or not the house purchased is located within 200m or 1km of a train/DART track. These variables are significant at the 10% and 1% levels, respectively, and the coefficients for these variables are negative as expected. Proximity to a train track exposes residents to a negative externality, since the noise and visual impact of trains can be considerable.

We have shown that proximity to transport services whether they be light rail, commuter rail or train stations, is valued by house purchasers and adds a premium to the price of a house. Houses that are very close to stations benefit from the transport access provided. Train tracks however are considered a disamenity and reduce the price of a dwelling. We now turn to the various environmental amenities included in the regression.

4.3 Environmental amenities

In order to make the analysis complete and to reduce the likelihood of omitted variable bias, we have included some non-transport related variables in the regression. It has been shown that proximity and access to different environmental amenities can be considered very valuable by homeowners. Here we include a few environmental amenities and assess how important they are.

The first environmental variable is the distance to a bathing beach. As Dublin is located on the coast, there are a number of beaches in the Dublin area. Here we include dummies for whether or not a house is within 250m, 500m, 1km or 1500m of a bathing beach. We find that the variable is only significant for smaller distances. Being very close to a beach, i.e. within 250m of a beach has a negative value, while being within walking distance is positive. There are a number of explanations for the negative coefficient, for instance parking congestion, security concerns and potential risk of flooding and coastal erosion. The coefficient for the 500m boundary is positive and larger than the coefficient from the 1000m boundary. This indicates that home purchasers would like to be close – but not too close – to a beach. We also included distance to the coast. Houses close to the coast tend to enjoy good views and this could add to the value of a home. Although available data did not allow us to test directly for the effect of sea views, the coastal zone dummies are all significant and positive. They are also decreasing with greater distance from the coast. In contrast to the beach, being very close to the coast confers a premium which slowly gets smaller the further away the house is. The difference here could be due to the fact that houses near the coast do not have to deal with as many security and crowding issues as houses near bathing beaches.

Finally, we include the logged distance to the nearest park. The coefficient here is negative, i.e. the closer you are to the park, the higher the premium. This is a fairly crude measure as it is possible that distance to parks is affected by the same negative externalities observed with the beaches. However, the geographical distribution of city parks is complicated, so this amenity will be the subject of a different study. Here we can conclude that parks do have an effect that seems to be measurable by hedonic analysis.

In sum, environmental amenities are an additional factor in a home purchase decision. As with transport they can be considered positive and negative externalities depending on their proximity. The next section presents the effects of the dwelling's structural and qualitative characteristics.

4.4 House characteristics

Any hedonic house price analysis must include a number of variables relating to the specific characteristics of properties. Here we included a number of house characteristics and also some subjective qualitative variables on the condition of the house. Table 6 presents these results.

The first variable is the floor space (in logged square meters) of the house. This is positive and significant. For every extra 1% increase in size the house commands a premium of 0.6%. This value of space is also reflected in the following variables. Every extra bedroom in the property commands a premium of 3.0%. We find a similar figure for the presence of a utility room. This is not surprising, as storage space in the Dublin area tends to be limited. Having a parking space and a garden increases the price of a house by 1.5% and 3.0% respectively.

The type of dwelling is also significant. The reference case here is a semi-detached house. The results show that detached houses are in comparison seen as more valuable to homeowners, whereas terraced houses are less valuable. This is to be expected as a premium is paid for the increased privacy and space of a detached house. The age of the dwelling is also found to be important. Consumers prefer either very new or very old dwellings. 'Period' houses dating from the pre- and early 1900s command a premium of between 9% and 14% over newer houses. In contrast, buildings constructed in the second half of the century have a negative coefficient, indicating they command a lower price than very new dwellings. The condition of the house as evaluated by the real estate agent was the final house characteristic included in the regression. This variable ranges from excellent to very poor with excellent being the reference case. The coefficients on these variables follow a sliding scale: the worse the condition gets the lower the house price. The condition of the house, in comparison to houses in excellent condition, can reduce the price of a house by between 2% and 15%.

As expected, structural and house-specific characteristics are important in the eyes of homebuyers. The size of the house and the number of rooms increase the value of a house. As expected, extras such as a garden and a parking space also add value. Historical and newly-built houses are more valuable than buildings constructed between the 1950s and the 1990s, and consumers place extra value on houses in good condition.

5. Discussion and conclusion

We use a hedonic house price model to estimate the impact of rail transport links on house prices in Ireland. We find that living close to railway stations is considered a positive externality as it improves transportation access. Train tracks however have a negative impact on house prices as they bring about noise and visual intrusion. We have shown that the premium associated with the proximity to a rail link also depends on the type of rail considered. Indeed, the newer transport links in the Dublin area have a greater premium than older rail alternatives. We find the largest premium for light rail, followed by heavy rail and commuter transit. Debrezion *et al*. (2007) find the opposite order, and a generally lower impact. The different pattern in Dublin is probably explained by the age of the different rail systems, the frequency of the connections, and perhaps the location of the lines.

We also include a number of environmental and structural variables to enhance the explanatory power of the regression. We find that living close to a bathing beach or coastline is considered a positive amenity. However for beaches, being too close has a negative effect. Parks are also a positive amenity. Structural variables such as the number of bedrooms, the presence of a utility room or parking and the condition of the house are all significant variables when purchasing a house. Very old houses and detached houses are also preferred.

There is considerable scope to use this model to inform policy. Identifying the areas of Dublin underserved by light rail and most likely to benefit from transport projects is crucial. Figure 4 presents the total number of people using buses and trains to get to work or school, by area of Dublin. With regards to bus use, the difference between the north side and the south side of the city is striking. The north side of the city is very much dependent on buses to commute to school and work. This is probably due to a lack of alternative public transport in the area. Looking at the second “rail” panel, it is easy to spot the location of the Luas on the South side of Dublin and the DART line along the coast. There is a clear rail corridor of people using the light rail to get to work and school. Identifying which areas of Dublin would be best served by new rail lines is essential before any type of rail project is initiated.

A number of rail transport projects are being developed in Dublin as part of a major government infrastructure plan called Transport 21. Two of these projects are the "Metro North" and "Metro West" plans and are due to be completed in 2013 and 2014 respectively. It is planned that these rail lines go through certain areas of Dublin with a low level of transport accessibility. By taking into account the results of the Luas regressions presented in Section 4 and the number of houses in the different vicinities of the planned routes it should be possible to calculate the value of these projects to the public. As Figure 4 clearly indicates, the north side of the city is already using public transport and would benefit greatly from the addition of a rail line in the area. The Metro North project seems to be well placed in that respect and would also increase property values in the area. The advantages of the Metro West are however less clear-cut. The current lack of train lines in the area might seem to be a reason to locate a line there. However, the bus map does not clearly indicate a strong collection of bus users from the area. A line on the South side of the city in between and possibly linking elements of the current network may prove to have a larger uptake and a higher overall value. When deciding the appropriate location and scale of these projects, it is essential that public transport use, house density and house prices in the relevant areas be examined first.

The current paper provides a first step towards such an evaluation. It shows clearly that rail connections have value to home owners, but also that not all connections are equally valuable.

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Tables and Figures

Table 1. Summary statistics of house prices in sample by quarter (Quarter 1 2001 to Quarter 4 2006).

Variable	Obs	Mean	Std. Dev.	Min	Max
q101	208	395065	241905	182842	2063324
q201	282	395865	254044	176493	2158554
q301	149	333438	178415	177763	1650659
q401	167	362983	238250	176493	1714146
q102	261	383830	248548	176000	1904607
q202	341	452760	281633	175224	2400000
q302	197	463835	348464	180000	2625000
q402	247	473643	311386	180000	2650000
q103	217	457415	299687	191000	2310000
q203	313	525939	344588	210000	2300000
q303	271	467824	292340	190500	3400000
q403	251	523962	355008	227000	2950000
q104	296	485229	325223	207000	3150000
q204	421	576870	407968	235000	3500000
q304	286	581285	478993	195000	3500000
q404	301	572956	369525	200000	2400000
q105	298	606234	436416	200000	3400000
q205	406	688620	488323	195000	3250000
q305	302	654481	475713	196000	3850000
q405	302	689456	444626	200000	3050000
q106	310	746272	535584	264000	3700000
q206	393	871483	612227	270000	3800000
q306	259	763695	523519	196000	3500000
q406	201	842479	629705	270000	3600000
Full sample	6956	578820	439635	175224	3900000

Table 2. Definition and descriptive statistics of house structure related variables used in the analysis.

Variable	Definition	Mean	Std. Deviation	Minimum	Maximum
Lprice	Logged purchase price	13.089	0.554	12.074	15.176
Lfootage	Logged floor area	4.689	0.375	3.332	8.361
Bedrooms	Number of bedrooms	3.280	0.926	1	13
Utility	Utility rooms	0.258	0.439	0	2
Gas	1 if gas heating, zero otherwise	0.483	0.500	0	1
Ddgardn	1 if garden, zero otherwise	0.837	0.369	0	1
Dvparking	1 if parking available, zero otherwise	0.635	0.481	0	1
Cond_gd	1 if condition good, zero otherwise (excellent omitted)	0.385	0.487	0	1
Cond_fr	1 if condition fair, zero otherwise	0.108	0.310	0	1
Cond_pr	1 if condition poor, zero otherwise	0.032	0.175	0	1
Cond_vpr	1 if condition very poor, zero otherwise	0.006	0.078	0	1
Cond_ukn	1 if condition unknown, zero otherwise	0.008	0.090	0	1
Apt	1 if apartment, zero otherwise (semi-detached omitted)	0.032	0.176	0	1
Det	1 if detached house, zero otherwise	0.133	0.340	0	1
Tce	1 if terraced house, zero otherwise	0.306	0.461	0	1
Cottage	1 if cottage, zero otherwise	0.007	0.081	0	1
Pre1900	1 if property was built before 1900, zero otherwise	0.046	0.209	0	1
Pre1950	1 if property was built before 1950, zero otherwise	0.160	0.366	0	1
Pre1975	1 if property was built before 1975, zero otherwise	0.194	0.396	0	1
Pre2000	1 if property was built before 2000, zero otherwise	0.346	0.476	0	1
LL1-99	Grouped house district electoral division (LL65 dropped)	-	-	-	-
Q	Quarter of sale	-	-	-	-
Dmth	Month of sale	-	-	-	-

Table 3. Definition of transport and environmental related variables used in the analysis.

Variable	**Definition**
z500g2	1 if house bought after "aftgr" date and within 500m of a station in green zone 2
z500g3	1 if house bought after "aftgr" date and within 500m of a station in green zone 3
z1000g2	1 if house bought after "aftgr" date and between 500m and 1km of a station in
z1000g3	1 if house bought after "aftgr" date and between 500m and 1km of a station in
z2000g2	1 if house bought after "aftgr" date and between 1km and 2km of a station in red
z2000g3	1 if house bought after "aftgr" date and between 1km and 2km of a station in
z500r	1 if house bought after "aftred" date and within 500m of a station in any red zone
z1000r	1 if house bought after "aftred" date and between 500m and 1km of a station in
z2000r	1 if house bought after "aftred" date and between 1km and 2km of a station in
dtrain250	1 if house within 250m of a train station, 0 otherwise
dtrain500	1 if house between 250m and 500m of a train station, 0 otherwise
dtrain1000	1 if house between 500m and 1km of a train station, 0 otherwise
dtrain1500	1 if house between 1km and 1.5km of a train station, 0 otherwise
dartstation	1 if house within 1.5km of a DART station, 0 otherwise
dtrk200	1 if house within 200m of a train track, 0 otherwise
dtrk1000	1 if house between 200m and 1km of a train track, 0 otherwise
zoneg2500	1 if house within 500m of a station in green zone 2 of the luas, 0 otherwise
zoneg3500	1 if house within 500m of a station in green zone 3 of the luas, 0 otherwise
zoner500	1 if house within 500m of a station in any red zone of the luas, 0 otherwise
zoneg21000	1 if house between 500m and 1km of a station in red zone 2 of the luas, 0
zoneg31000	1 if house between 500m and 1km of a station in red zone 3 of the luas, 0
zoner1000	1 if house between 500m and 1km of a station in any red zone of the luas, 0
zoneg22000	1 if house between 1km and 2km of a station in red zone 4 of the luas, 0
zoneg32000	1 if house between 1km and 2km of a station in green zone 2 of the luas, 0
zoner2000	1 if house between 1km and 2km of a station in any red zone of the luas, 0
Aftgr	1 if date > 30jun2004
Aftred	1 if date > 28Sept2004
ldist2nearst	Logged distance to nearest public access park
dbeach250m	1 if house within 250m of a beach, 0 otherwise
dbeach500m	1 if house between 250m and 500m of a beach, 0 otherwise
dbeach1km	1 if house between 500m and 1km of a beach, 0 otherwise
dbeach1500m	1 if house between 1km and 1.5km of a beach, 0 otherwise
dcoast250m	1 if house within 250m of the coast, 0 otherwise
dcoast500m	1 if house between 250m and 500m of the coast, 0 otherwise
dcoast1km	1 if house between 500m and 1km of the coast, 0 otherwise
dcoast1500m	1 if house between 1km and 1.5km of the coast, 0 otherwise

Table 4. Transport results – regression with Luas at opening

Variable	Coefficient	t	95% Confidence Interval	
z500g2	0.116	4.62***	0.067	0.166
z500g3	0.170	2.89***	0.054	0.285
z1000g2	0.155	6.11***	0.106	0.205
z1000g3	0.101	2.15**	0.009	0.192
z2000g2	0.070	3.3***	0.029	0.112
z2000g3	0.073	3.06***	0.026	0.120
z500r	0.001	0.03	-0.093	0.096
z1000r	0.125	2.2**	0.014	0.236
z2000r	-0.016	-0.42	-0.089	0.058
dtrain250	0.085	2.52**	0.019	0.151
dtrain500	0.072	3.38***	0.030	0.113
dtrain1000	0.004	0.24	-0.026	0.033
dtrain1500	0.010	0.65	-0.019	0.039
dartstation	0.046	3.35***	0.019	0.072
dtrk200	-0.024	-1.8*	-0.049	0.002
dtrk1000	-0.027	-2.8***	-0.046	-0.008

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively.*
Number of observations = 6956; $R^2 = 0.8864$; *Adjusted* $R^2 = 0.8835$

Table 5. Selected results – environmental variables with Luas at opening

Variable	Coefficient	t	95% Confidence Interval	
dbeach250m	-0.244	-3.86***	-0.368	-0.120
dbeach500m	0.142	3.02***	0.050	0.235
dbeach1km	0.072	3.6***	0.033	0.111
dbeach1500m	0.020	1.21	-0.012	0.053
dcoast250m	0.172	9.91***	0.138	0.206
dcoast500m	0.119	7.48***	0.088	0.151
dcoast1km	0.095	6.61***	0.067	0.123
dcoast1500m	0.052	4.11***	0.027	0.077
ldist2nearst	-0.062	-9.74***	-0.075	-0.050

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively.*
Number of observations = 6956; R^2 = 0.8864; Adjusted R^2 = 0.8835

Table 6. Selected results – house related variables with Luas at opening

Variable	**Coefficient**	**t**	**95% Confidence Interval**	
Lfootage	0.645	57.01***	0.623	0.667
bedrooms	0.036	8.78***	0.028	0.045
Utility	0.037	6.24***	0.025	0.048
Gas	-0.026	-4.87***	-0.036	-0.015
Ddgardn	0.033	4.78***	0.019	0.047
dvparking	0.016	3.03***	0.006	0.027
cond_gd	-0.029	-5.52***	-0.039	-0.019
cond_fr	-0.074	-8.97***	-0.091	-0.058
cond_pr	-0.086	-6.22***	-0.113	-0.059
cond_vpr	-0.155	-5.21***	-0.213	-0.097
cond_ukn	-0.012	-0.43	-0.068	0.044
Apt	-0.025	-1.62	-0.055	0.005
Det	0.171	21.7***	0.155	0.186
Tce	-0.074	-11.53***	-0.087	-0.061
Cottage	-0.071	-2.38**	-0.130	-0.012
pre1900	0.145	10.79***	0.119	0.172
pre1950	0.092	10.29***	0.074	0.109
pre1975	-0.024	-2.95***	-0.041	-0.008
pre2000	-0.025	-3.47***	-0.040	-0.011

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively.*
Number of observations = 6956; $R^2 = 0.8864$; *Adjusted* $R^2 = 0.8835$

Table 7. Selected results – transport variables with Luas in anticipation

Variable	Coefficient	t	95% Confidence Interval	
z500g2	0.128	4.87***	0.077	0.180
z500g3	0.144	2.48**	0.030	0.258
z1000g2	0.147	5.43***	0.094	0.200
z1000g3	0.138	2.8***	0.041	0.235
z2000g2	0.058	2.69***	0.016	0.101
z2000g3	0.057	2.39**	0.010	0.103
z500r	-0.002	-0.05	-0.108	0.103
z1000r	0.136	2.27**	0.019	0.252
z2000r	-0.050	-1.23	-0.129	0.029

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively.*

Number of observations = 6956; R^2 = 0.8863; Adjusted R^2 = 0.8833

Table 8. Selected results – transport variables with Luas lagged

Variable	Coefficient	t	95% Confidence Interval	
z500g2	0.060	2.13**	0.005	0.115
z500g3	0.132	1.75*	-0.016	0.279
z1000g2	0.115	4.24***	0.062	0.168
z1000g3	0.088	1.72*	-0.012	0.187
z2000g2	-0.012	-0.51	-0.061	0.036
z2000g3	0.107	3.96***	0.054	0.160
z500r	0.019	0.4	-0.076	0.115
z1000r	0.096	1.57	-0.024	0.216
z2000r	0.022	0.53	-0.059	0.103

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively.*
Number of observations = 6956; $R^2 = 0.8857$*; Adjusted* $R^2 = 0.8827$

Table 9. Coefficient rankings for Luas variables across time regressions

Variable	Smallest coefficient	Medium coefficient	Largest coefficient
z500g2	Lag effect	Opening effect	Anticipation effect
z500g3	Lag effect	Anticipation effect	Opening effect
z1000g2	Lag effect	Anticipation effect	Opening effect
z1000g3	Lag effect	Opening effect	Anticipation effect
z2000g2	Not significant	Anticipation effect	Opening effect
z2000g3	Anticipation effect	Opening effect	Lag effect
z500r	Not significant	Not significant	Not significant
z1000r	Not significant	Opening effect	Anticipation effect
z2000r	Not significant	Not significant	Not significant

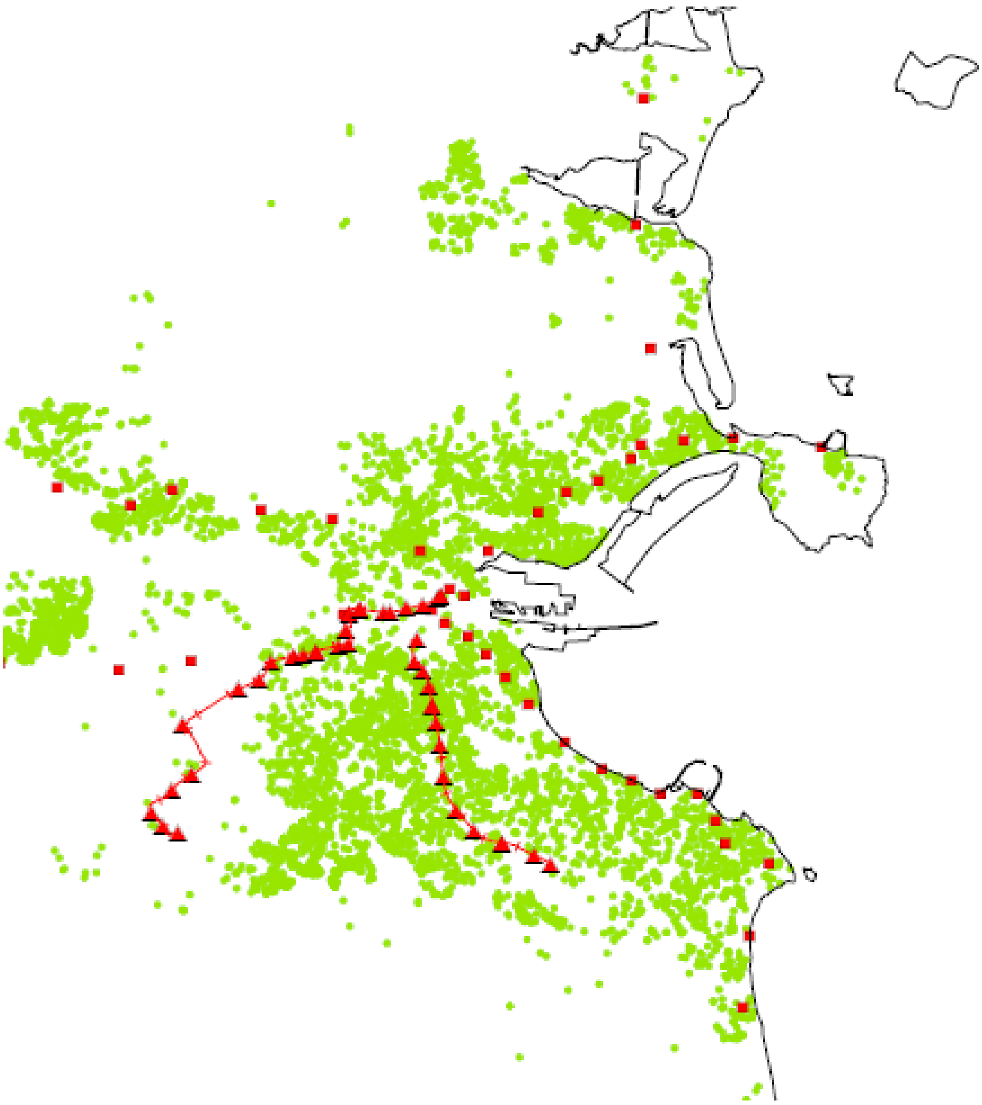


Figure 1. Map of Dublin with location of sample houses (in green) with Luas stations (red triangles) and train (red squares) stations.

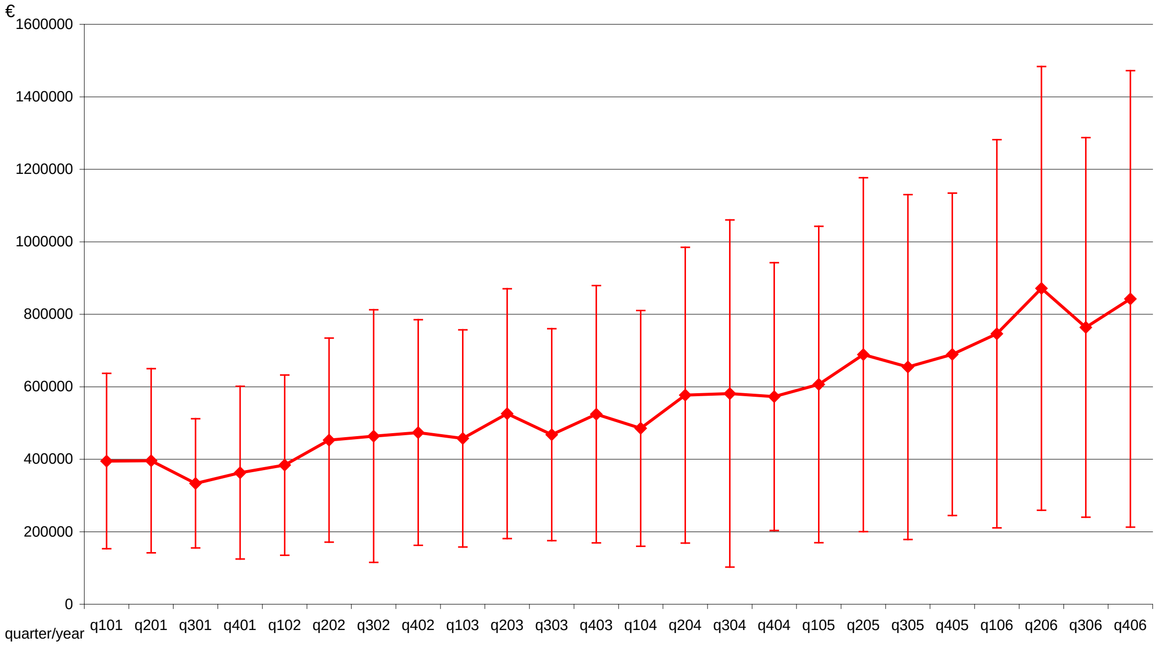
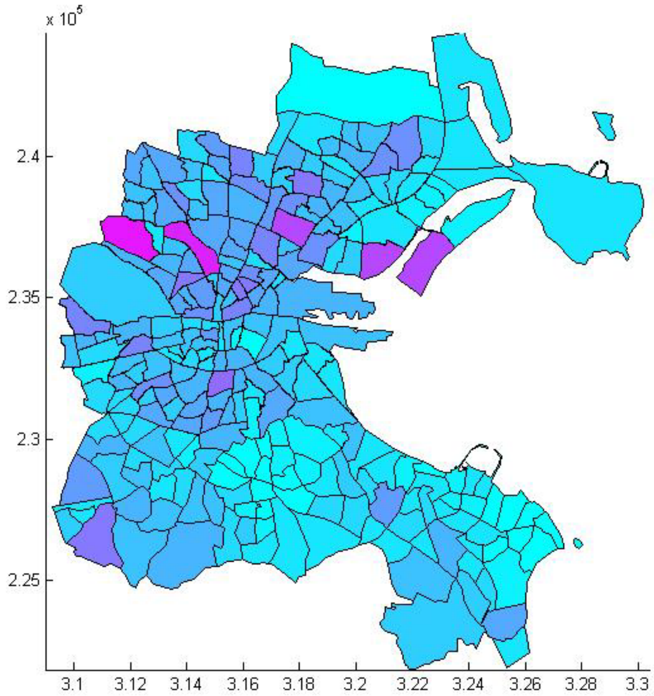
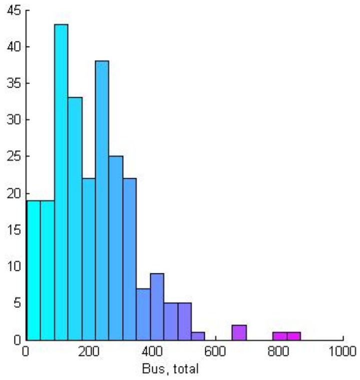


Figure 2. Graph of average house prices in the sample (and standard deviation) by quarter and year.

Figure 3. Luas light rail map with zones and lines. From www.luas.ie.


x 10^5
2.4
2.35
2.3
2.25
3.1
3.12
3.14
3.16
3.18
3.2
3.22
3.24
3.26
3.28
3.3


45
40
35
30
25
20
15
10
5
0
0
200
400
600
800
1000
Bus, total

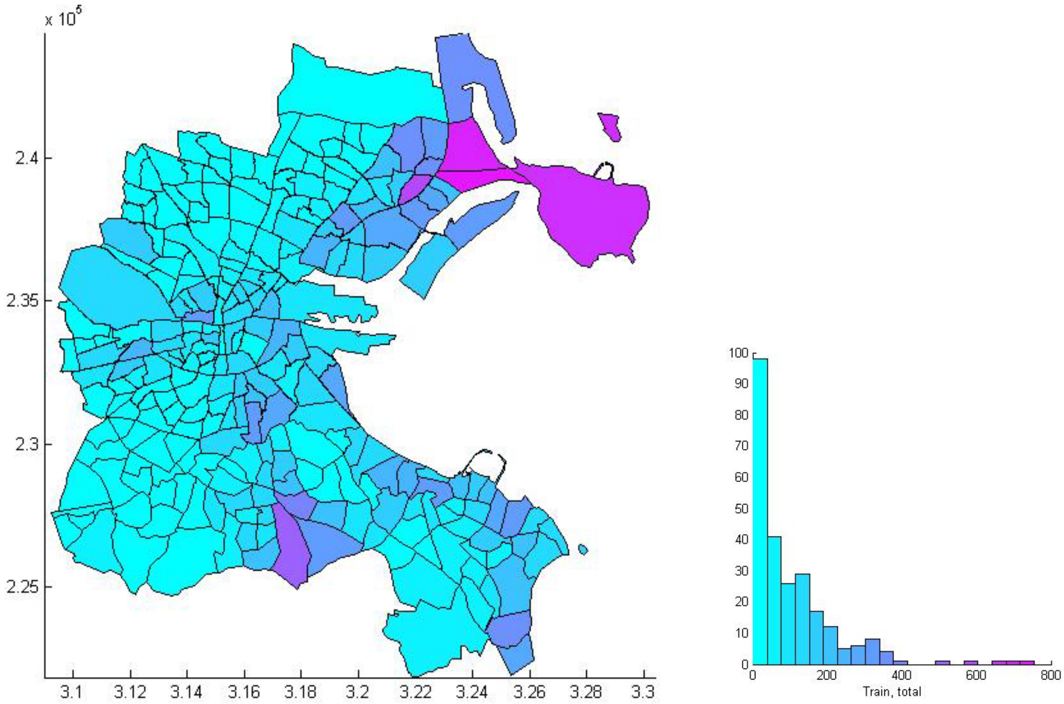


Figure 4. Number of people using bus (top panel) and rail (bottom panel) to get to work/school by area of Dublin. Image by authors using Irish Census data.

Appendix

Table A1. Full regression results – all variables with Luas on time effect

Variable	Coefficient	t-stat	95% Confidence Interval	
z500g2	0.116	4.62***	0.067	0.166
z500g3	0.170	2.89***	0.054	0.285
z1000g2	0.155	6.11***	0.106	0.205
z1000g3	0.101	2.15**	0.009	0.192
z2000g2	0.070	3.3***	0.029	0.112
z2000g3	0.073	3.06***	0.026	0.120
z500r	0.001	0.03	-0.093	0.096
z1000r	0.125	2.2**	0.014	0.236
z2000r	-0.016	-0.42	-0.089	0.058
dtrain250	0.085	2.52**	0.019	0.151
dtrain500	0.072	3.38***	0.030	0.113
dtrain1000	0.004	0.24	-0.026	0.033
dtrain1500	0.010	0.65	-0.019	0.039
dartstation	0.046	3.35***	0.019	0.072
dtrk200	-0.024	-1.8*	-0.049	0.002
dtrk1000	-0.027	-2.8***	-0.046	-0.008
dbeach250m	-0.244	-3.86***	-0.368	-0.120
dbeach500m	0.142	3.02***	0.050	0.235
dbeach1km	0.072	3.6***	0.033	0.111
dbeach1500m	0.020	1.21	-0.012	0.053
dcoast250m	0.172	9.91***	0.138	0.206
dcoast500m	0.119	7.48***	0.088	0.151
dcoast1km	0.095	6.61***	0.067	0.123
dcoast1500m	0.052	4.11***	0.027	0.077
lfootage	0.645	57.01***	0.623	0.667
bedrooms	0.036	8.78***	0.028	0.045
utility	0.037	6.24***	0.025	0.048
gas	-0.026	-4.87***	-0.036	-0.015
ddgardn	0.033	4.78***	0.019	0.047
dvparking	0.016	3.03***	0.006	0.027
cond_gd	-0.029	-5.52***	-0.039	-0.019
cond_fr	-0.074	-8.97***	-0.091	-0.058
cond_pr	-0.086	-6.22***	-0.113	-0.059
cond_vpr	-0.155	-5.21***	-0.213	-0.097
cond_ukn	-0.012	-0.43	-0.068	0.044
apt	-0.025	-1.62	-0.055	0.005
det	0.171	21.7***	0.155	0.186
tce	-0.074	-11.53***	-0.087	-0.061
cottage	-0.071	-2.38**	-0.130	-0.012
pre1900	0.145	10.79***	0.119	0.172
pre1950	0.092	10.29***	0.074	0.109

Variable	Coefficient	t-stat	95% Confidence Interval	
pre1975	-0.024	-2.95***	-0.041	-0.008
pre2000	-0.025	-3.47***	-0.040	-0.011
ll1	0.370	9.26***	0.292	0.448
ll2	0.221	7.87***	0.166	0.276
ll3	0.025	0.6	-0.056	0.106
ll4	-0.100	-3.62***	-0.154	-0.046
ll5	0.121	4.19***	0.065	0.178
ll6	0.762	4***	0.389	1.135
ll7	0.163	6.47***	0.114	0.213
ll8	0.188	6.59***	0.132	0.244
ll20	0.140	3.45***	0.060	0.220
ll21	0.212	4.44***	0.119	0.306
ll22	0.210	6.35***	0.145	0.274
ll23	0.088	1.92*	-0.002	0.177
ll24	0.166	7.05***	0.120	0.212
ll25	0.454	19.31***	0.408	0.500
ll26	-0.018	-1.22	-0.046	0.011
ll27	0.095	1	-0.091	0.282
ll28	0.296	10.35***	0.240	0.353
ll29	0.376	17.21***	0.334	0.419
ll30	0.227	8.1***	0.172	0.282
ll31	0.298	16.61***	0.262	0.333
ll32	0.284	5.31***	0.179	0.389
ll33	0.087	0.77	-0.135	0.309
ll34	0.246	8.95***	0.192	0.300
ll35	-0.104	-1.42	-0.247	0.039
ll37	0.362	12.55***	0.306	0.419
ll38	0.493	21.89***	0.448	0.537
ll39	0.290	12.89***	0.246	0.334
ll40	0.228	4.87***	0.136	0.320
ll41	0.582	22.37***	0.531	0.633
ll42	0.042	0.82	-0.058	0.141
ll43	0.243	8.79***	0.188	0.297
ll44	0.429	20.38***	0.388	0.471
ll45	0.282	9.37***	0.223	0.340
ll46	0.056	0.57	-0.134	0.245
ll47	0.144	5.6***	0.093	0.194
ll48	-0.040	-0.36	-0.257	0.176
ll49	0.195	10.58***	0.159	0.231
ll50	0.524	21.06***	0.475	0.573
ll51	0.280	10.19***	0.226	0.334
ll52	0.189	5.9***	0.126	0.252
ll53	0.053	2.13**	0.004	0.102
ll54	0.149	4.19***	0.079	0.218
ll55	0.592	3.1***	0.218	0.967

Variable	Coefficient	t-stat	95% Confidence Interval	
ll56	0.453	15.86***	0.397	0.509
ll57	0.179	1.95*	-0.001	0.359
ll58	0.237	5.02***	0.145	0.330
ll59	0.351	12.04***	0.294	0.408
ll60	0.158	2.58***	0.038	0.277
ll61	0.045	0.96	-0.047	0.136
ll62	0.492	2.59***	0.119	0.864
ll63	0.340	9.7***	0.272	0.409
ll64	0.461	6.36***	0.319	0.603
ll66	-0.008	-0.18	-0.090	0.075
ll67	0.299	11.79***	0.249	0.349
ll68	0.546	7.23***	0.398	0.694
ll69	0.502	15.89***	0.440	0.564
ll70	0.088	1.18	-0.058	0.235
ll72	0.461	3.38***	0.194	0.727
ll73	0.092	2.5**	0.020	0.164
ll74	0.195	4.02***	0.100	0.291
ll75	0.655	24.46***	0.603	0.708
ll76	0.722	23.67***	0.662	0.782
ll77	0.280	1.46	-0.096	0.655
ll78	0.153	3.59***	0.069	0.236
ll79	-0.014	-0.26	-0.124	0.096
ll80	0.218	7.26***	0.159	0.277
ll82	0.360	16.95***	0.318	0.401
ll83	0.572	19.88***	0.515	0.628
ll84	0.517	19.59***	0.465	0.569
ll85	0.228	3.55***	0.102	0.354
ll86	0.319	1.67*	-0.056	0.694
ll87	-0.140	-2.21**	-0.265	-0.016
ll88	0.254	7.55***	0.188	0.320
ll89	-0.082	-0.73	-0.302	0.139
ll90	0.497	8.24***	0.379	0.616
ll91	0.515	10.21***	0.416	0.614
ll92	0.519	17.36***	0.460	0.578
ll93	0.210	7.27***	0.153	0.266
ll94	0.067	3.88***	0.033	0.100
ll95	0.046	0.85	-0.060	0.151
ll96	0.359	16.18***	0.315	0.402
ll97	0.399	16.21***	0.351	0.447
ll98	-0.082	-1.21	-0.215	0.051
ll99	0.517	5.4***	0.329	0.705
ll100	0.093	1.19	-0.061	0.247
ll101	0.324	5.11***	0.200	0.448
ll102	0.218	3.87***	0.108	0.328
ll103	0.221	8.24***	0.168	0.273

Variable	Coefficient	t-stat	95% Confidence Interval	
ll104	0.553	15.91***	0.485	0.621
q101	-0.054	-1.38	-0.131	0.023
q401	-0.182	-4.56***	-0.260	-0.104
q102	-0.064	-1.66*	-0.139	0.012
q202	0.089	5.76***	0.059	0.120
q302	0.219	10.52***	0.178	0.260
q402	0.053	1.37	-0.023	0.130
q103	0.165	4.25***	0.089	0.242
q203	0.298	18.79***	0.267	0.329
q303	0.359	18.33***	0.320	0.397
q403	0.179	4.59***	0.103	0.256
q104	0.279	7.26***	0.203	0.354
q204	0.392	26.23***	0.363	0.421
q304	-0.112	-1.66*	-0.244	0.020
q404	-0.352	-20.14***	-0.386	-0.317
q105	-0.247	-14.87***	-0.279	-0.214
q205	-0.123	-3.63***	-0.189	-0.056
q305	-0.004	-0.11	-0.082	0.073
q405	-0.154	-8.86***	-0.189	-0.120
q106	-0.032	-1.94*	-0.064	0.000
q206	0.120	3.53***	0.053	0.186
q306	0.196	4.93***	0.118	0.274
dmth_2	0.029	2.25**	0.004	0.053
dmth_3	0.070	5.65***	0.045	0.094
dmth_4	-0.038	-1.07	-0.107	0.031
dmth_5	-0.018	-0.48	-0.090	0.055
dmth_6	-0.006	-0.16	-0.078	0.067
dmth_7	-0.093	-2.25**	-0.174	-0.012
dmth_8	-0.104	-2.51**	-0.186	-0.023
dmth_9	-0.080	-1.93*	-0.162	0.001
dmth_10	0.099	4.62***	0.057	0.142
dmth_11	0.092	4.33***	0.051	0.134
dmth_12	0.096	4.21***	0.051	0.140
aftgr	0.571	8.58***	0.440	0.701
aftred	0.084	1.48	-0.027	0.196
zoneg2500	0.140	5.49***	0.090	0.190
zoneg3500	-0.051	-1.19	-0.136	0.033
zoner500	-0.001	-0.01	-0.115	0.114
zoneg21000	0.154	6.44***	0.107	0.200
zoneg31000	-0.050	-1.36	-0.123	0.022
zoner1000	-0.136	-2.88***	-0.229	-0.043
zoneg22000	0.135	7.49***	0.099	0.170
zoneg32000	0.024	1.16	-0.017	0.065
zoner2000	-0.075	-2.2**	-0.141	-0.008
ldist2nearst	-0.062	-9.74***	-0.075	-0.050

Variable	Coefficient	t-stat	95% Confidence Interval	
_cons	9.692	117.66***	9.530	9.853

*Note: *, ** and *** denote significant at the 10%, 5% and 1% level respectively.*
Number of observations = 6956; R^2 = 0.8864; Adjusted R^2 = 0.8835

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