Technical Paper:
Hedonic House Price Models for Small Geographical Areas

1. INTRODUCTION

This technical paper lays out the methodology used to develop a hedonic price model to measure price trends around The 606, a newly established linear park system on the northwest side of Chicago. Two pricing models were required to understand how the housing market responded to the development of the trail. First, in order to analyze the project's impact by time and geographical area, the Institute for Housing Studies (IHS) examined house price changes after the project was announced in 2012 and segmented its analysis of trends for the areas surrounding The 606 and by different distances from The 606. Second, IHS analyzed the house price premium by distance from the trail after the project was announced. To analyze the impacts to different segments of the market, IHS divided the areas into two distinct markets based on house prices and income levels, the eastern half of the trail east of Western Avenue (higher cost housing market) and the western half of the trail west of Western Avenue (low and average housing market).

2. HEDONIC PRICE INDEX APPROACH

A hedonic price index uses individual level data on property sales prices at any one point in time with data on the characteristics of an individual property and its location. By inputting this information into a statistical model that controls for factors that might affect the sales price of a house, a hedonic model can tell us how much influence certain factors have on sale prices and can be converted into an index tracking price changes over time. Unlike a repeat sale index, a hedonic price index allows for a larger sample in a smaller geographic area while still controlling for the characteristics and location of the properties being sold in a given period. While hedonic models have many advantages, there are also limitations. Hedonic indices require an extensive amount of data on property characteristics and location, and developing such a data set is complex and can have extensive upfront costs. Additionally, hedonic models are the most statistically sophisticated method to track housing prices and require significant expertise to develop and extensive testing to ensure accuracy.

For more information comparing hedonic price indices with other methods, see the IHS technical paper *Description of IHS Hedonic Data Set and Model Developed for PUMA Area Price Index*.

3. SOURCES OF DATA

Utilizing its Clearinghouse of parcel-level administrative data, IHS created a core set of variables related to property and location characteristics found to significantly influence house price with historic data on detached single family home sales within three miles of The 606. The following sections lay out the data used, variables developed, and more detail on the model that IHS used to track price changes around The 606.

- *Sales price* – Data on single family sales activity was taken from two sources, 1) property transfer records the Cook County Recorder of Deeds via Property Insight and 2) sales records from Midwest Real Estate Data (MRED), the northwest Illinois Multiple Listing Service (MLS).

- *Property characteristics* – To identify key physical characteristics of the properties including the building structure, square footage, number of bathrooms, age of building, data from the Cook County Assessor was used.

- *Location* – Geographic variables were calculated using ArcGIS software. These variables include distance from properties to Chicago Transit Authority (CTA) rail stations, to Lake Michigan, to any type of publicly-accessible open space, to Metra rail stations, and to a lake or river other than Lake Michigan. Spatial data for parcels is obtained annually by IHS from the Cook County Assessor. Distances to CTA and Metra rail stations were calculated by joining the Cook County road network from the Cook County Data Portal and CTA and Metra rail station locations obtained from the City of Chicago Data Portal. Lake Michigan, publicly-accessible open space, and lakes and rivers other than Lake Michigan come from data compiled by the Chicago Metropolitan Agency for Planning (CMAPs) land use file for 2005. Additional data on distance variable calculations are available from the Institute for Housing Studies.

- *Distance from 606 Bloomingdale Trail* – The intention of this project was to isolate parcels within the study area surrounding The 606 linear park, specifically all parcels within the 281 census tracts that are within three miles of the trail. IHS calculated the distance of each property both in terms of its Euclidian distance, but also the distance to the closest entrance point to The 606 (Manhattan distance). Identifying distance from the trail at the parcel level allowed IHS to identify the price premium depending upon the closeness of a property to the trail.

Building a final data set for the base hedonic model required creating a large master data set constructed of detached single family property transactions recorded in Cook County from 1997 to the second quarter of 2016. From these records, IHS selected all transactions associated with detached single family homes in the 281 census tracts within three miles of The 606. Hedonic variables were constructed for each property using information from the Cook County Assessor Office and by utilizing the methodologies described above. Properties where there were multiple transactions within a 90 day period were excluded to avoid any potential recording errors and to reduce potential bias in the index due to frequently traded properties. Additionally, transactions were dropped if there was found to be substantial missing information on property characteristics such as number of bedrooms, air conditioning, missing property identification numbers, or conflicting sales price information.

Based on transactions data, the sample size is sufficient to produce a quarterly hedonic house price index for large geographic areas, such as the price index for Chicago area, but large variation in levels of transaction activity made it challenging to produce quarterly updates for small geographies. The Chicago housing market experienced dramatic changes in transaction activity after 2006 with transaction activity declining by over 50 percent by 2008. To compensate for declining transaction volume and the lower number of transactions in small geographies, a rolling sample method with a 365 day window was adopted. This means that in addition to data from the current quarter, sales data from the previous three quarters are also included. Additional data from previous quarters helps smooth out the more volatile nature of transaction activity in small areas. Figure 1 shows the sample size by year after the rolling windows of 365 days. It shows there were 205,314 transactions available in the sample area surrounding The 606 between 1997 and the second quarter of 2016.

Review of the existing literature on hedonic models identifies a core set of variables related to the property characteristics and location characteristics that significantly influence house prices. Figure 2 highlights variables included in the IHS hedonic model. This includes variables related to the characteristics of a property such as the size of the building and lot, the number of bedrooms and bathrooms, the size of the garage, external wall type, etc. Location variables include proximity to a CTA or Metra stop, public open space, and Lake Michigan. Figure 3 covers the summary statistics for the variables included in the hedonic model.

Properties that were likely distressed sales were also flagged. This includes properties identified as short sales, sales at foreclosure auction, and sales after entering bank real estate owned (REO) status. Foreclosure status was determined by identifying the date of a foreclosure filing on a property and tracking subsequent transaction activity. It is important to control for the distressed status of a property, particularly after 2007 when the number of distressed sales increased dramatically. Distressed properties sold within the sample periods typically experienced about a 10 percent discount over comparable non-distressed properties. Prior to 2007, the share of distressed sales was less than 5 percent, but the share of distressed sales in Chicago has regularly exceeded 20 percent since 2009.

4. THE 606 AND HEDONIC PRICE MODEL

There are two main goals in this study. The first is to identify how the market changed as a result of the development of the trail by tracking house price trends after the announcement of the project. The second goal is to determine whether there was a distance premium on house prices and how these premiums differ based on the underlying dynamics of the local housing market. Figure 4 shows a map of The 606 with residential parcels from the IHS Data Clearinghouse that were a part of the study area. Color codes show the boundary of distance from the trail that were used to calculate the house price index. For its data universe, IHS included all detached single family properties in census tracts within three miles of the trail, and developed a house price index by distance group. The inclusion of three miles from the trail serves two important purposes. First, IHS wanted to include the general price trends in local areas similar to the project area. Second, due to slow recovery and low transaction activity in the housing market since 2008, IHS wanted to ensure a large enough sample for reliable statistical results.

The impact of a large public project on house prices in a local community market might be different depending upon the preexisting condition of a community. A recent study by Heckert and Mennis (2012) shows the impacts of the Land Care Program in Philadelphia. The authors found that the positive effects of the program were isolated to moderately distressed regions but not to highly distressed regions nor nondistressed areas. In order to capture the different impacts of trail, IHS divided the sample area into two predetermined areas; the housing market east of Western Avenue as a nondistressed area and the housing market west of Western Avenue as a moderately distressed area.

4.1. The 606 and Hedonic Price Model

We follow the standard semi-log hedonic model proposed by Sirmans et al. (2006). The base model can be expressed as

$$lnP = X\beta 1 + G\beta 2 + Z\beta 3 + \varepsilon \quad (1)$$

where *lnP* is an (N × 1) vector as log of house price, and *G* is a (N × K1) matrix of the property characteristics variables. *G* is a (N × K2) matrix to include a group dummy or geographical dummy variables. *Z* is a (N ×K3) matrix to include a policy dummy variable to find the impacts of a policy intervention or the influence of any event on the house price. The coefficient vectors are vectors of (K1 × 1), (K2 × 1), and (K3 × 1). The first column of X includes ones as an intercept term. The residuals, ε, is i.i.d with variance of σ^2.

4.2. Hedonic Price Index

From the equation (1), we also included the time fixed effects, and construct the price index using

$$lnP = X\beta 1 + G\beta 2 + Z\beta 3 + T\beta 4 + \varepsilon \qquad (2)$$

where *T* is a N × t − 1 matrix of period dummy that consists of a series of binary time variables for the frequency of data in time. For example, if one property was sold in December 2015, the quarterly binary variable called T2015Q4 will be 1 but the rest of the other time dummy variables are all zero. To estimate the model, we needed to exclude one period as a base period to avoid dummy variable trip, so the number of binary variables in T will be t−1 if there are t periods for the entire sample periods. After estimating the coefficients, we are able to construct the hedonic price index using the coefficients of *β4*. The estimated average price level at time t (*Pt*) as a exponential function of estimated coefficient of time intercept at time t, ($\beta 4_t$). The expected price at time t with the condition of all control variables is:

$$E(Pt\ |X, G, Z, Tt) = e\beta 4t \qquad (3)$$

$$Pt = e\beta 4t \qquad (4)$$

The estimated average price level is a relative measurement related to other time periods, so (4) can be redefined and an index based on base year of 0 is

$$It = 100 * Pt/P0 = 100 * exp(\beta 4t - \beta 40) \qquad (5)$$

where subscript 0 means the base period equivalent numbers. The index was created as I_0 = 100. We used the first quarter of 2000 as our base year, and the index as 100.

4.3. Hedonic Price Model and Multiple Time Difference Factors

Different groups within a geographic area may have different levels of exposure to an intervention, and an intervention may have lag effects. For example, one group may not be exposed to any intervention during the sample period, while a second group may be exposed to an intervention in a later period but not in an earlier period. The unbiased net effect for this case is the difference between the average gain or loss of the first group and that of the second group. This will remove the bias in the second period comparisons between the control and treatment group that could be the result from permanent differences between these groups, as well as biases from comparisons over time in the treatment group that could be the results of an intervention. One easy method is to estimate the model separately for each group, but the size of the sample in the treatment group is too small and cannot be estimated. One alternative way is to borrow the difference-in-difference method. If we rewrite the model (2) with the intervention by adding a time difference factor,

$$lnP = X\beta 1 + G\beta 2 + Z\beta 3 + T\beta 4 + ZT\beta 5 + \varepsilon \quad (6)$$

where Z is N × 1 a dummy variable for the two groups, and ZT is a N × t − 1 matrix of a group times the period dummy that consists of a series of binary time variables for the frequency of data in time. From (6), IHS developed a series of two price indices, one without an intervention (I_{Nt}) and with an intervention (I_{Tt}) as the following equations:

$$INt = 100 * PNt/PN0 = 100 * exp(\beta 4t - \beta 40) \quad (7)$$

$$ITt = 100 * PTt/PT0 = 100 * exp((\beta 4t + \beta 5t) - (\beta 40 + \beta 50)) \quad (8)$$

where subscript 0 means the base period equivalent numbers. The index was created as I_0 = 100 by normalizing at the time of 0. The price index for the treatment group can then be a group without enough observations to create a stable price index. This method will give us the price index for the targeted study area. For example, Z can be defined as a dummy variable to be within 0.5 mile or not, and the price difference between the properties within 0.5 mile vs outside of 0.5 mile can be calculated.

4.4. Hedonic Price with Spatial Component Model

This adapted hedonic model allows for the impacts to be studied within a certain predetermined boundary or distance before the estimation. In order to investigate the spatial relationship with distance, IHS extended the hedonic price model to the following quadratic form in the distance premium equation:

$$lnP = X\beta 1 + G\beta 2 + Z\beta 3 + T\beta 4 + \pi + \varepsilon \quad (9)$$

where

$$\pi = \alpha_0 d + \alpha_1 d^2 + \delta_0 D*d + \delta_1 D*d^2 + \gamma_0 D*W*d + \gamma_1 D*W*d^2$$

where D = a binary variable after 2012
d = distance from 606 trail
W = a binary variable for west of Western Avenue

From the equation (9), the following simulation based on the estimated coefficients can be derived:

$$\begin{aligned} \hat{\pi}_0 &= \hat{\alpha}_0 d + \hat{\alpha}_1 d^2 \\ \hat{\pi}_{East\ after\ 2012} &= (\hat{\alpha}_0 + \hat{\delta}_0)d + (\hat{\alpha}_1 + \hat{\delta}_1)d^2 \\ \hat{\pi}_{West\ after\ 2012} &= (\hat{\alpha}_0 + \hat{\delta}_0 + \hat{\gamma}_0)d + (\hat{\alpha}_1 + \hat{\delta}_1 + \hat{\gamma}_1)d^2 \end{aligned} \quad (10)$$

All regression results and related calculations are found in the following appendix figures.

5. RESULTS AND SUMMARY OF FINDINGS

Figure 5 shows the hedonic model regression results with all controlled variables. The table omitted all geographical and time of sale variables for brevity. The regression model fits well with adjusted r-square of 0.7688 and most of the variables are significant except the distance from the central business districts, public open space, distance from Metra stop, etc. The non-significant variables might be redundant variables due to the fact that many of the variables are highly correlated. All significant variables show correct directions with consistent magnitude as McMillen's (2004) estimated hedonic model. To avoid the under-estimation of standard error, IHS used White's (1980) heteroscedasticity corrected robust standard errors as Stevenson (2004) shows the possibility of non-constant variance in hedonic house price model.

From the estimation of model (6), the price index has been generated and Figures 6 and 7 show the price trend by distance from The 606. Price trends within ½ mile are significantly different from the surrounding areas, respectfully. The price indices are also divided into two geographical areas, east and west of Western Avenue. The west of Western avenue area shows much more volatile changes while the east of Western area shows stable growth.

To understand the impact of The 606 on house prices at different distances from the trail, IHS estimated the spatial component model as described in Figure 8. The results also confirm the impact of distance from The 606 is significant especially in the housing market west of Western Avenue. As the equation allows the nonlinear relation, $\hat{\gamma}_0$ and $\hat{\gamma}_1$ indicates the marginal effects of distance in the areas west of Western Avenue. These effects are highly significant and the magnitude is very high, which is consistent with the price trend results.

As an extension the estimation IHS performed the distance premium simulation in areas both east and west of Western Avenue. The distance premium reported in Figure 9shows very similar results to those found by Heckert and Mennis (2012). IHS found very significant impacts on house price in the housing market west of Western Avenue as a modestly distressed area while the prices east of Western Avenue as a nondistressed market did not show any noticeable impact from the development of The 606 trail.Figure 10 shows the estimated distance premium for 606 West and the confidence interval for the estimate for house prices at different distances from The 606.

APPENDIX: RESULTS OF HEDONIC PRICE MODELS

Figure 1: Single Family Sample Data (1997-2016 Q2)

Year	Cook County	606 Bloomingdale Trail Areas
1997	77,206	6,314
1998	113,540	8,892
1999	130,585	10,588
2000	146,785	12,043
2001	155,051	12,398
2002	165,039	12,884
2003	176,737	13,334
2004	195,209	14,607
2005	215,302	16,142
2006	196,952	14,607
2007	147,933	10,917
2008	100,591	7,089
2009	89,621	6,559
2010	103,731	8,207
2011	92,233	7,742
2012	107,278	8,421
2013	137,219	10,310
2014	136,329	10,216
2015	123,397	9,344
2016*	62,478	4,700
Total	2,673,216	205,314

Source: IHS Data Clearinghouse

*: Includes until the second quarter of 2016.

Figure 2: Descriptions of Variables

Variable Name	Description of Variable
Sale Price and Distressed Sale	
house price	House Price Sold ($)
log_price	Log of House Price
dsale	=1 if sold as a distress sale (Short Sale, Foreclosure, REO)
Property Characteristics	
sqft	Square Feet of Building Area
lotsize	Square Feet of Lot Size
log_sqft	Log of Square Feet of Building Area
log_lot	Log of Square feet of Lot Size
bedroom	Number of Bedroom
bathroom	Number of Bathroom (Full.Half)
totalroom	Total Number of Rooms in the Property
garage	Number of Cars in Garage
brick	=1 if full or partial Brick Building)
age	Building Age or Age after Improvement
age_sq	Square of age
centralair	=1 if Central Air conditioning
replace	Number of Fireplace
Location and Distance Variables	
waterfront	=1 if located at waterfront
cta_stop	=1 if within 660 feet near CTA Station
cta_nearstop	=1 if within 661 to 1320 feet near CTA Station
cc_cal_dist	Distance from the Central Business District (CBD)
matra_stop	=1 if located within a quarter mile
pubopen	=1 if having a public open space within 660 feet
michlake	=1 if located within 1 mile from Lake Michigan
lake_river	=1 if located within 660 feet from river and lake
Dist_606ml	Distance from the Bloomingdale Trail

Figure 3: Summary Statistics for the sample

Variable	N	Mean	Std Dev	Minimum	Maximum
Log(P)	205314	12.5	0.8	9.2	14.2
LOG_SQFT	205314	7.3	0.4	6.0	9.2
LOG_LOT	205314	7.9	0.5	1.9	10.8
BEDROOM	205314	3.5	1.0	0.0	10.0
BATHROOM	205314	1.8	0.8	0.0	8.3
TOTALROOM	205314	8.0	1.9	1.0	20.0
GARAGE	205314	1.8	0.7	0.0	9.0
BRICK	205314	0.5	0.5	0.0	1.0
AGE_TR	205314	63.2	43.9	0.0	189.0
AGE_SQ	205314	5914.7	5210.7	0.0	35721.0
WATERFRONT	205314	0.0	0.1	0.0	1.0
CENTRALAIR	205314	0.7	0.5	0.0	1.0
FIREPLACE	205314	0.6	0.9	0.0	8.0
EL_STOP	205314	0.0	0.1	0.0	1.0
EL_NEARSTOP	205314	0.1	0.2	0.0	1.0
CC_CALC_DIST	205314	5.5	2.0	0.8	13.1
MATRA_STOP	205314	0.0	0.1	0.0	1.0
PUBOPEN	205314	0.3	0.4	0.0	1.0
MICHLAKE	205314	0.1	0.2	0.0	1.0
LAKE_RIVER	205314	0.1	0.2	0.0	1.0
DIST_606ml	205314	1.9	1.0	0.0	4.3

Source: IHS Data Clearinghouse

Figure 4: Bloomingdale Trail Map by Distance

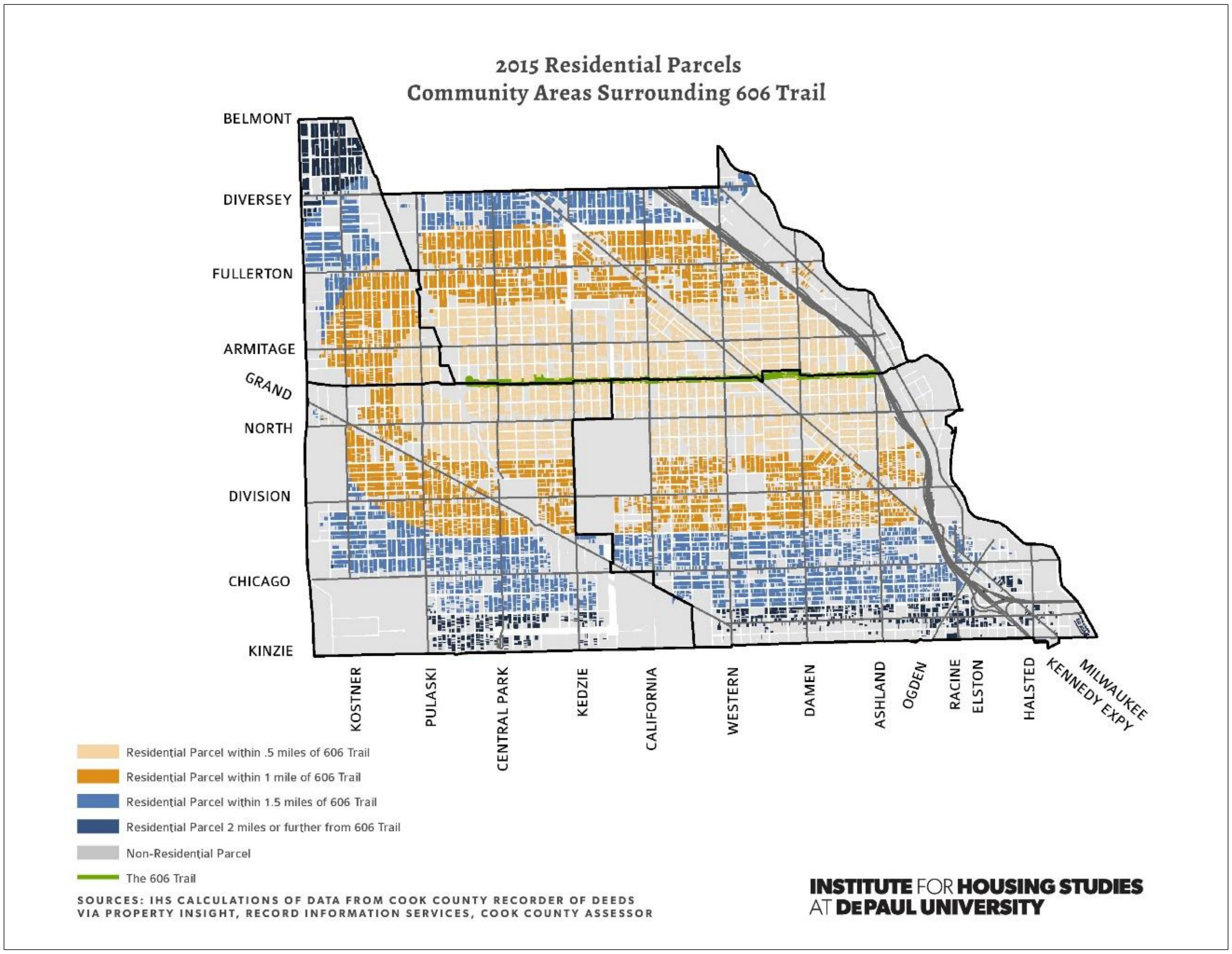


Figure 5: Hedonic Regression, 1997-2016Q1

Variable	Parameter	Standard	t Value	Pr > |t|
Intercept	9.2225	0.1691	54.55	<.0001
LOG_SQFT	0.3041	0.0039	78.57	<.0001
LOG_LOT	0.1402	0.0031	45.12	<.0001
BEDROOM	0.0094	0.0014	6.98	<.0001
BATHROOM	0.0097	0.0017	5.62	<.0001
TOTALROOM	0.0188	0.0007	26.31	<.0001
GARAGE	0.0285	0.0014	20.7	<.0001
BRICK	0.0071	0.0022	3.25	0.0011
AGE_TR	-0.0014	0.0001	-9.65	<.0001
AGE_SQ	0.0000	0.0000	6	<.0001
WATERFRONT	0.0459	0.0095	4.85	<.0001
CENTRALAIR	0.0667	0.0024	27.37	<.0001
FIREPLACE	0.0244	0.0015	16.04	<.0001
EL_STOP	-0.0392	0.0105	-3.73	0.0002
EL_NEARSTOP	-0.0179	0.0051	-3.51	0.0004
CC_CALC_DIST	0.0125	0.0112	1.12	0.2642
MATRA_STOP	-0.0131	0.0095	-1.38	0.1676
PUBOPEN	-0.0001	0.0026	-0.06	0.9547
MICHLAKE	-0.0895	0.0161	-5.57	<.0001
LAKE_RIVER	0.0516	0.0067	7.74	<.0001
Adjusted R square	0.7688			
Observations	205,314			

Source: IHS Data Clearinghouse

Note) The results are controlled by the census tract, time of sales (year and quarter). The coefficients of variables consistent with McMillen, D. (2004).
t statistics are calculated using White (1980) heteroscedasticity corrected robust standard errors as Stevenson (2004) shows the possibility of non-constant variance in hedonic house price model .

Figure 6: Hedonic Price Index by Distance of the Bloomingdale Trail, 1997-2016Q1

YEARQ	All Census Tracts within 3.0 Miles	Within .25 miles	Within 0.5 miles	Within 0.5 miles in East of Western	Within 0.5 miles in West of Western	Within 1.0 miles	Within 2.0 miles
1997Q1	74.50	69.33	69.00	70.13	64.79	72.41	69.74
1997Q2	75.33	74.00	71.06	74.20	60.81	72.86	73.34
1997Q3	79.45	72.29	70.90	74.29	63.09	76.28	76.63
1997Q4	79.39	68.05	67.45	69.78	62.32	73.31	74.74
1998Q1	80.99	69.96	68.91	72.09	62.36	74.86	76.99
1998Q2	83.83	68.73	70.28	74.20	64.02	77.17	79.88
1998Q3	84.91	73.08	73.95	77.10	67.73	78.56	81.02
1998Q4	87.92	85.44	83.32	87.13	75.50	85.80	86.88
1999Q1	93.38	87.80	85.85	90.07	77.04	89.18	96.32
1999Q2	95.41	87.61	85.38	89.56	77.89	90.41	95.25
1999Q3	97.47	86.78	86.31	94.36	74.48	91.74	96.88
1999Q4	100.37	87.42	89.18	97.68	77.61	96.42	100.66
2000Q1	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2000Q2	104.09	103.45	102.63	111.08	91.12	106.76	105.36
2000Q3	110.39	119.47	115.27	111.93	118.69	115.48	111.34
2000Q4	114.79	122.56	117.15	113.01	121.34	117.86	114.35
2001Q1	118.14	127.70	122.46	114.27	130.63	122.76	118.10
2001Q2	123.08	128.73	124.59	118.93	129.48	125.58	120.76
2001Q3	124.08	123.76	120.63	123.57	117.68	124.36	121.41
2001Q4	126.63	127.24	125.29	127.52	122.51	127.76	125.24
2002Q1	127.81	131.75	128.30	129.66	125.94	129.37	127.18
2002Q2	131.99	140.00	135.40	130.72	140.42	136.70	133.01
2002Q3	136.22	147.01	141.55	136.54	147.14	143.08	136.34
2002Q4	138.85	150.45	144.82	137.46	153.32	145.73	137.39
2003Q1	143.03	151.70	146.79	138.42	156.49	148.66	139.34
2003Q2	146.26	153.14	148.16	139.14	158.79	150.17	141.64
2003Q3	149.14	147.07	143.61	135.47	152.34	147.51	141.64
2003Q4	151.99	144.99	143.32	135.23	151.80	148.81	144.45
2004Q1	155.88	149.71	148.20	140.32	156.55	153.65	149.71
2004Q2	161.14	155.69	153.54	143.17	163.64	161.07	156.52
2004Q3	168.24	169.29	166.08	153.77	178.41	172.08	166.98
2004Q4	173.75	177.34	172.31	155.97	187.85	178.06	171.70
2005Q1	177.99	178.89	173.31	155.11	188.72	180.04	174.24
2005Q2	184.93	182.14	176.14	157.77	192.18	181.20	179.11
2005Q3	190.68	187.55	180.53	156.76	200.24	187.07	183.45
2005Q4	196.45	189.12	184.01	161.49	203.89	191.93	189.36
2006Q1	201.51	193.69	188.83	164.88	210.79	197.02	194.99
2006Q2	206.25	201.62	195.64	168.06	221.30	205.32	200.88
2006Q3	211.57	212.17	205.69	179.44	228.21	212.92	206.35
2006Q4	214.02	216.01	210.99	182.99	236.71	218.92	210.12
2007Q1	215.57	220.43	215.00	184.83	242.94	222.63	212.66
2007Q2	216.00	219.34	214.56	187.62	245.89	221.46	211.19
2007Q3	213.56	214.60	207.50	183.68	242.99	217.66	208.25
2007Q4	204.95	207.37	200.95	180.15	231.57	208.58	202.23
2008Q1	206.57	213.61	204.52	184.72	237.17	209.91	203.81
2008Q2	202.48	215.83	207.57	189.39	233.52	210.26	203.51
2008Q3	197.47	208.22	205.15	195.81	217.49	204.65	197.18
2008Q4	189.08	213.07	207.93	204.90	211.69	203.67	188.65
2009Q1	182.05	199.85	197.80	200.77	193.70	194.66	180.66
2009Q2	170.81	194.14	184.65	195.86	174.06	181.78	169.23
2009Q3	161.35	181.28	171.27	189.21	156.65	165.84	159.86
2009Q4	157.15	180.26	166.87	183.07	152.47	160.03	154.98
2010Q1	153.40	173.71	161.05	184.61	143.52	154.22	150.58
2010Q2	151.83	169.57	162.15	181.79	143.11	156.24	150.21
2010Q3	150.65	174.46	164.37	183.38	145.88	160.16	150.33
2010Q4	148.70	172.49	161.26	188.59	139.62	160.86	151.00
2011Q1	146.91	178.05	166.74	187.77	146.85	163.17	150.85
2011Q2	143.94	172.98	160.36	184.54	141.25	159.50	148.44
2011Q3	143.49	177.30	162.13	176.65	148.88	157.27	148.17
2011Q4	141.12	171.96	157.99	174.73	141.80	154.69	144.77
2012Q1	140.10	163.67	152.33	172.60	135.18	149.67	142.31
2012Q2	140.07	163.67	154.38	173.84	134.41	150.93	142.72
2012Q3	139.61	156.44	148.49	173.00	126.85	148.51	141.57
2012Q4	141.60	159.10	153.47	174.19	135.37	154.02	145.28
2013Q1	143.54	161.33	156.78	174.05	141.48	157.72	148.58
2013Q2	149.23	170.88	166.08	180.54	154.69	166.22	155.82
2013Q3	155.23	181.43	173.74	187.54	161.78	173.83	163.55
2013Q4	157.83	189.05	177.55	191.72	164.40	176.02	166.93
2014Q1	161.30	196.10	184.11	195.74	173.24	181.08	171.78
2014Q2	165.71	205.61	189.64	200.23	180.27	186.50	176.69
2014Q3	171.91	215.58	204.17	202.57	206.03	195.60	184.14
2014Q4	174.46	214.37	202.34	203.22	202.20	197.43	184.91
2015Q1	179.11	214.98	204.60	200.16	208.97	201.13	188.57
2015Q2	182.33	221.70	211.71	204.62	219.01	209.21	192.36
2015Q3	184.58	226.13	214.02	204.03	225.63	209.62	195.13
2015Q4	188.36	231.28	222.04	208.37	238.00	218.77	202.52
2016Q1	189.29	234.69	224.96	212.21	238.53	220.63	201.72
2016Q2	194.37	237.70	226.86	213.40	239.67	224.50	209.12

Source: IHS Data Clearinghouse

Figure 7: Single Family House Price Trends by Distance from Bloomingdale Trail (1997 Q1 – 2016 Q2)

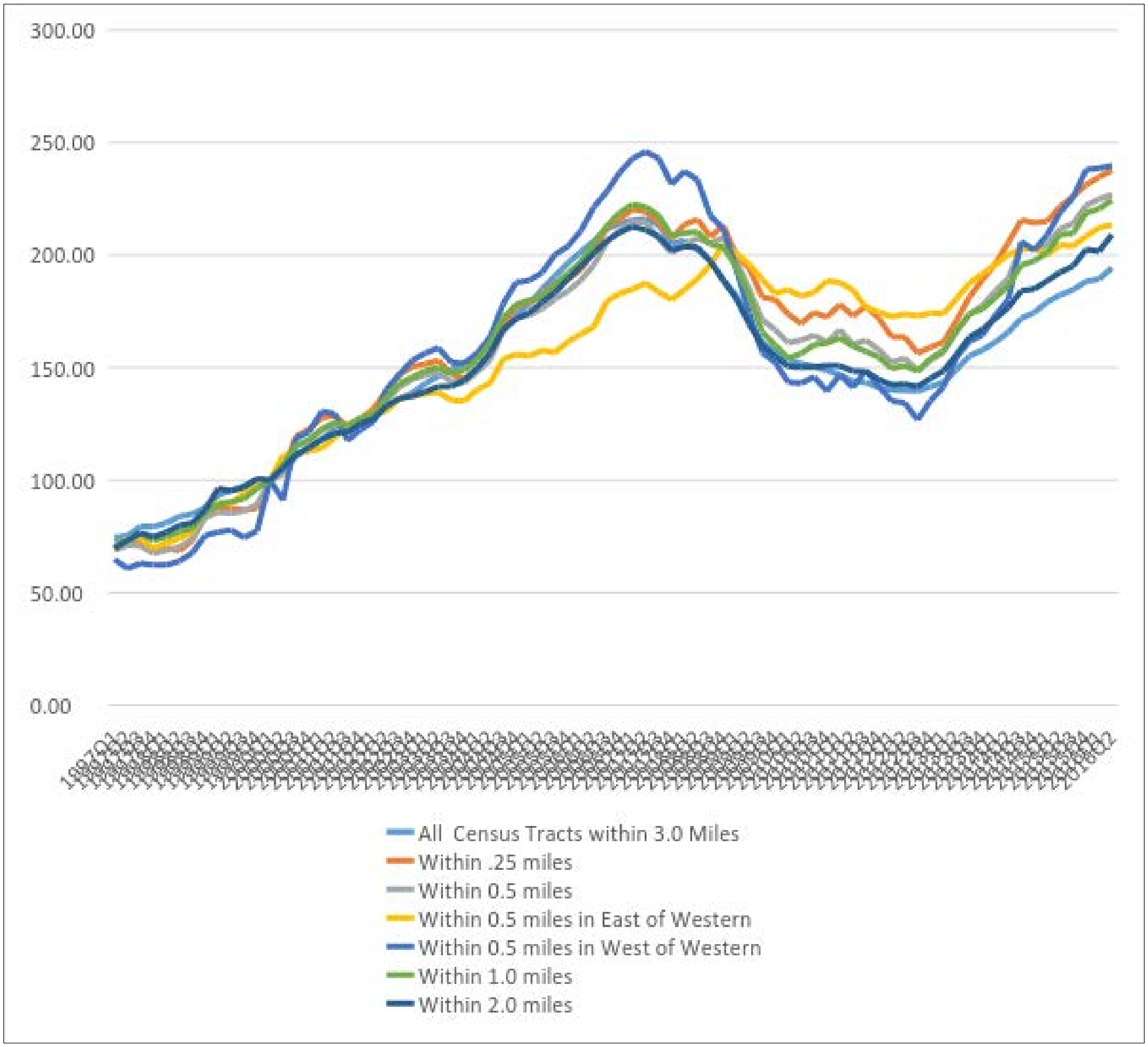


Figure 8. Distance Premium Estimation

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|
$\hat{\alpha}_0$	-0.0765	0.0189	-4.06	<.0001
$\hat{\alpha}_1$	0.0206	0.0040	5.08	<.0001
$\hat{\delta}_0$	-0.0054	0.0117	-0.46	0.6456
$\hat{\delta}_1$	0.0003	0.0037	0.09	0.9285
$\hat{\gamma}_0$	-0.3704	0.0102	-36.39	<.0001
$\hat{\gamma}_1$	0.0909	0.0039	23.56	<.0001

Source: IHS Data Clearinghouse

* All results are controlled by property characteristics, geographic and economic location factors, distressed sales, time of sales (year and quarter). All t statistics are calculated using heteroscedasticity corrected robust standard errors.

Figure 9: Price Premium Simulation Results by Distance from 606 Bloomingdale Trail

Miles From 606 Trail	Price Premium Until 2012	Price Premium of the East of Western Ave After 2012	Price Premium of the West of Western Ave After 2012
0.0	5.1%	5.6%	33.6%
0.1	4.4%	4.8%	29.2%
0.2	3.7%	4.1%	25.0%
0.3	3.0%	3.4%	21.1%
0.4	2.4%	2.8%	17.4%
0.5	1.9%	2.2%	13.9%
0.6	1.4%	1.6%	10.6%
0.7	1.0%	1.2%	7.6%
0.8	0.6%	0.7%	4.9%
0.9	0.3%	0.3%	2.3%
1.0	0.0%	0.0%	0.0%

Source: IHS Data Clearinghouse

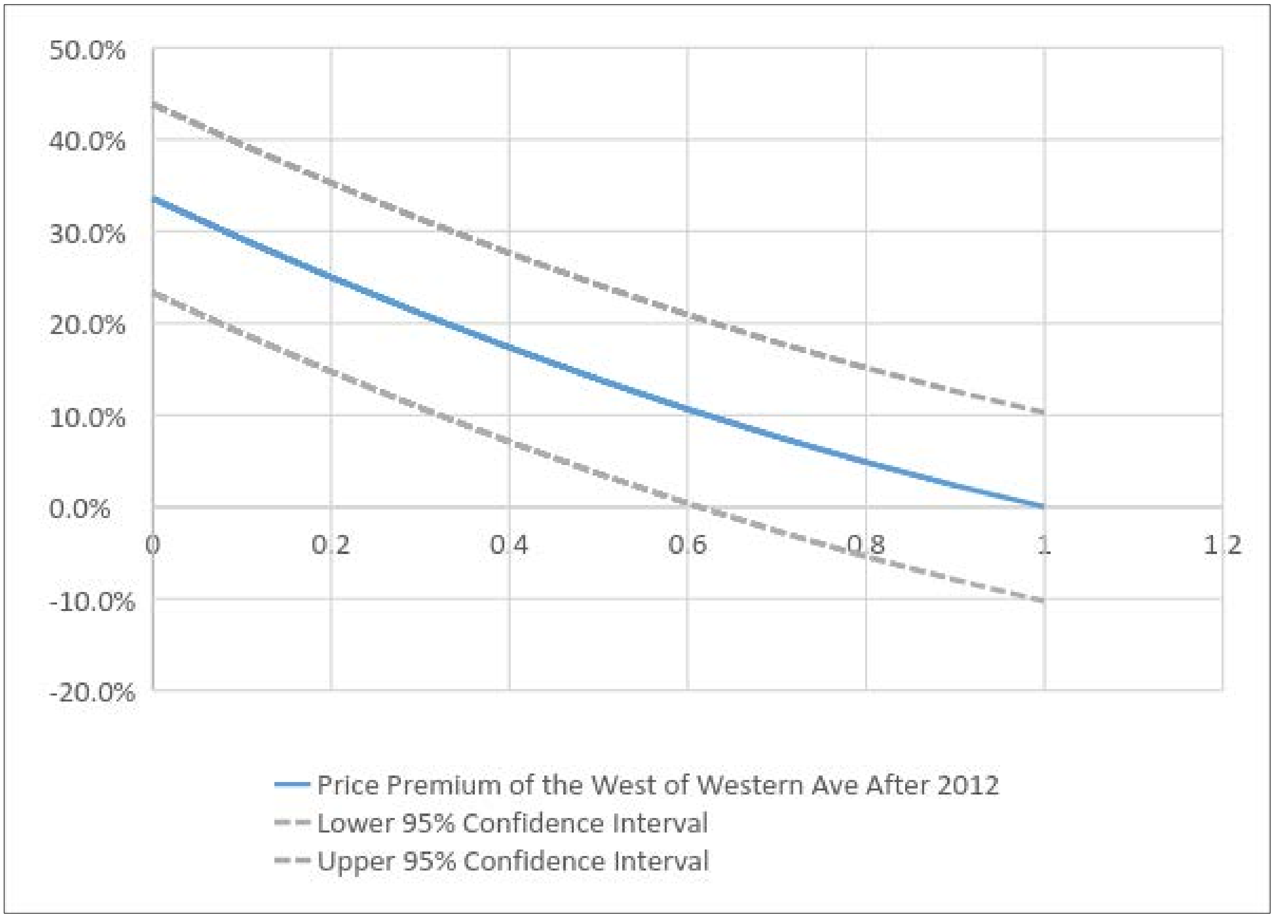
The estimated log of predicted price are calculated using the regression output from the equation (9), and the price premium is calculated assuming a fixed price in one mile from the trail as a base price.

* The price premium by distance has the following quadratic model

$$\pi_d = \alpha_0 d + \alpha_1 d^2 + \delta_0 D*d + \delta_1 D*d^2 + \gamma_0 D*W*d + \gamma_1 D*W*d^2$$

$$\begin{aligned} where\ & \mathrm{D} = \text{a binary variable after 2012} \\ & \mathrm{d} = \text{distance from 606 trail} \\ & \mathrm{W} = \text{a binary variable for west of Western Avenue} \end{aligned}$$

Figure 10: 95 percent confidence interval of the Price Premium at the West of Western Avenue after 2012



Source: IHS Data Clearinghouse

Note) The confidence interval is based on the standard error of estimated coefficients in one mile to understand the possible variation of predicted price premium of the simulated model.

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