The Effect of Highways on Nearby Residential Property Prices in Hungary

By

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Abstract

In this thesis I analyze the effect of the new sectors of highway M6 on the nearby residential property prices. To address the omitted variable problem and endogeneity that appear in a simple cross-section or before-after analysis I use the *difference-in-differences* method. In particular I compare prices between 2008 and 2011. My treatment group consists of those properties that are at most 10 km away from the highway and the control group includes all properties further away but for which highway M6 is the closest highway route. I find that the selling price of properties in the treatment group after the opening of the highway is around 11-15% higher compared to the control group. Using a restricted sample without the two big county capitals in my sample (Pécs and Szekszárd) I find that the "highway premium" is even higher being around 24-27%. I also estimate continuous treatment models that yield much less robust results.

Acknowledgements

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Contents

1. Introduction

It is a commonly asked and investigated question whether the construction of highway routes has a positive effect on regional economic performance. In Hungary one can often read in the newspapers that one alleged purpose of building new highways is to help underdeveloped regions catch up (Bíró et al., 2006). In this thesis I analyze the effect of the vicinity of highway routes on a specific area of the economy, the residential property market, in particular residential property prices.

There are at least two reasons why one might think that the emergence of new motorways has a positive effect on residential property prices. First, it has a direct effect for the residents nearby since they turn out to be "closer" to desirable locations measured by the duration of travel time. The second, and presumably stronger channel of influence on house prices is that the better accessibility attracts new firms and services to the towns. In logistics, the existence of motorways is a key factor when choosing the location of ware-houses as heavy trucks cannot travel on weaker and smaller roads. (Tóth, 2005) The new firms and services might have a positive effect on the demand for residential houses *per se* and also through generating better employment prospects. On the other hand highways might also have negative effect on their environment and thus on property prices through air pollution (Chay and Greenstone, 1998), noise (Nelson, 1982; Ridker and Henning, 1967) or increased traffic, etc. In this thesis I estimate the resultant of all these possible effects.[1]

The recent highway constructions in Hungary allows for a nice opportunity to assess the effect of highways on property prices. In this thesis, I concentrate on the construction of the

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[1] For a review of the effects of transportation or highway access on residential property prices see Giuliano (1989), Huang (1994). Langley (1976, 1981), Voith (1993) and Boarnet and Chalermpong (2001) measure the effect of the closeness of highway ramps on residential property prices in US residential areas.

sectors of highway M6, which were opened to the public on March 31, 2010. Based on the latitude and longitude coordinates of the towns and highway on-ramps in my sample I calculated the straight-line distance from the closest highway on-ramp for each town. For the house prices I use the residential property transactions dataset of the National Tax and Customs Administration of Hungary (NTCA), which contains some information about each transaction, in particular the selling price, the size of the residence in square-meters, the zip-code level location of the property and whether it is an apartment, a flat in a block of flats or an independent house.

The simplest framework to analyze the influence of new highways on property prices is the hedonic method. The hedonic model assumes that the prices of properties, being differentiated products, are composed of the prices of each attributes of the property and its environment (Rosen, 1974). Such attributes are for example whether the property is a flat or an independent house, the number of toilets, the distance from the closest supermarket and the distance from the closest bus stop. When estimating the price effect of such attributes, on the left hand side of an empirical model is a measure of the property price and on the right hand side there are a number of attributes of the property. In our case the distance from the closest highway on-ramp is one of the numerous attributes of a property, the one of the main interest.

During the last two decades an increased attention focused on the shortcomings of the traditional cross-section hedonic model searching for better strategies. Parmeter and Pope (2012) give an exhaustive summary of traditional cross-section hedonic analysis and some newer quasi-experimental methods. They emphasize that the cross-section hedonic model is threatened by the problems of endogeneity and omitted variables, i.e. that we can never be sure if we have controlled for all relevant attributes. Also, highway placement is not based on random selection, but is most probably correlated with unobserved characteristics, which by themselves have some effect on residence prices. For example, highways are usually built in bigger towns but it might also be a policy decision to set highway routes along underdeveloped regions.

In this paper I primarily use a quasi-experimental approach, specifically the *difference-in-differences* method. I start off by estimating a simple two by two model with a treatment group that consists of properties at most 10 km away from the highway. The control group consists of residential properties located further from the highway but within a distance that highway M6 is the closest highway to them. I estimate discrete treatment-control models and I also estimate models in which the treatment is of differing intensity, in particular I estimate the per kilometer effect of distance from highway on property prices.

My simplest model shows a quite robust result that properties being 10 km away or closer to the highway were sold at a premium of around 11-15% compared with those being further away. If I restrict my sample to villages, towns and cities with less than 30,000 inhabitants the effect doubles to around 22-27%. In general, my per-kilometer estimates using the continuous treatment model are very high and much less robust. I did not find a significant difference between the "highway premium" of cities and towns, nor between flats and houses, nor between properties on the west and east side of river Danube.

2. History of Hungarian Highway Construction

The basic strategy of the Hungarian highway construction have been to build new highway routes next to those historical principal routes of the Hungarian road network that are overloaded with traffic and need expansion. So the highway construction beginning during the 1960s did not use the opportunity to develop a new network system with new priorities, but rather it has strengthened the old one, which is originated in the pre-automobile era. (Fleischer, 1993) The first plan for the Hungarian highway network was published in 1942 (Bíró et al., 2006). This plan is based on the central role of the capital, Budapest and five radial highway routes that meet in Budapest. One of the five routes followed the path of the present highway M6. Although later the newer plans for the highway network development set the goal of decentralizing the network by new highway paths that cross the radial highways, the original five radial highway routes remained the basis of the highway network. (Tóth, 2005)

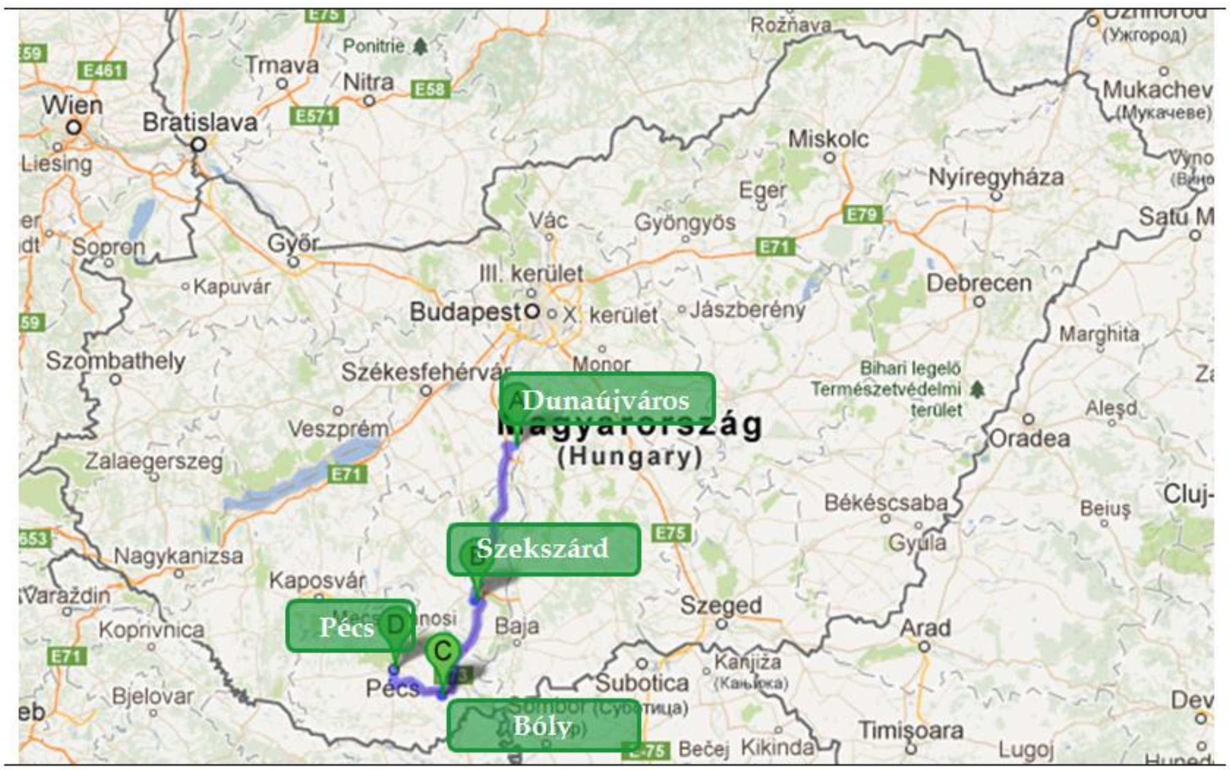
Table 1. Timeline of the construction stages of different sectors of Highway M6

Sector Name	*Length*	*Date*		*Construction Stages*
Dunaújváros - Szekszárd	**67 km**	July 17	2008	Contract is signed
		March 31	2010	Opening
Szekszárd - Bóly	**47 km**	Nov 21	2007	Contract is signed
		March 31	2010	Opening
Bóly – Pécs (M60)	**30.2 km**	Nov 21	2007	Contract is signed
		April 3	2008	Construction starts
		March 31	2010	Opening

Source: National Infrastructure Developer
http://www.nif.hu/hu/fejlesztesek/gyorsforgalmi_utak/m6, last checked: May 30, 2013

Consequently, the trace of the future highways is usually known early before the actual construction of a highway starts. It is crucial in the following analysis whether and since when it could be foreseen that a highway will be built in an area because if this is already known for the public early enough, then house prices might adjust even before the highway has actually opened. On the other hand, it seems reasonable to assume, that due to the political nature of highway construction decisions people cannot be sure about the exact time and final path of the highway construction until the final contract is signed. Table 1 shows the dates when the contracts for building different sectors of highway M6 were signed and when they were opened to the public. The plans for the Szekszárd-Bóly and Bóly-Pécs sectors were finalized on Nov 21, 2007 and the contract for the Dunaújváros-Szekszárd sector was signed on July 17, 2008. All of these sectors were opened to the public on March 31, 2010. Figure 1 shows these highway sectors on a map.

Figure 1. The route of highway M6 between Dunaújváros and Bóly and highway M60 between Bóly and Pécs. All of these were opened to the public on March 31, 2010.



3. Methodology

A naïve observer might try to assess the effect of highways on residential properties by looking at the prices of nearby properties before and after the construction of the highway. Meyer (1995) refers to this research design as the "*One Group Before and After Design*", which is based on the equation

$$y_{it} = \alpha + \beta D_t + \varepsilon_{it},$$

where y_{it} is the outcome of interest for unit i in period t ($t = 0, 1$ i.e. before or after treatment, $i = 1, \dots, N_t$); in this specific case this is some measure of residential property prices at the transactional level or at some aggregate level (mean or median value for a ZIP code, district, town, region, etc.). D_t is a dummy variable indicating being in period 1, so $d_t = 1$ if $t = 1$ and $d_t = 0$ if $t = 0$.

The key identifying assumption is that without the treatment β would be 0, that is, there would be no difference in the mean prices before and after the treatment. This assumption is quite strict as one should have strong evidence that nothing else happens meanwhile which could have a systematic effect on the evolution of house prices.

Another research strategy could be to estimate a cross-section model for the residential property prices including the characteristics of the properties and their environment as right hand side variables. In this design being close to the highway would appear as one characteristic among others on the right hand side. This strategy is originated in the hedonic model for differentiated products introduced by Rosen (1974). Palmquist (2005) and Parmeter and Pope (2013) summarize this model and its consequences for the empirical hedonic method.

Rosen's model assumes that each differentiated product consists of objective characteristics; in the property market case each property is a bundle of attributes such as the number of bathrooms, the material of walls, the closeness of the nearest park, the closeness of the nearest bus or train station, the amount of green area within the close neighborhood of the property, etc. Buyers and sellers evaluate each attribute separately and the equilibrium price is determined through the prices of each separate attribute. In the model the sellers and buyers are fully informed about these attributes and there is a large enough number of different houses, so buyers are in a continuous choice situation. Parmeter and Pope (2012) show that in equilibrium the marginal price reveals the buyers' *marginal willingness to pay*.

The empirical hedonic method is a regression that has the selling price of a property (y_i) on the left hand side and functions of several attributes of the property and its environment ($\boldsymbol{X_i}$) on the right hand side:

$$y_i = \alpha + \boldsymbol{X_i}\boldsymbol{\beta} + \varepsilon_i.$$

The estimated coefficients on these attributes represent the *marginal willingness to pay* in case of linear functional form (Parmeter and Pope, 2012). However, to be able to interpret the results in such a way a number of assumptions must hold, which follow from the theoretical model. Specifically, Parmeter and Pope (2012) name four important issues: 1) the single market assumption; 2) stability over time; 3) Omitted variables bias and endogeneity; and 4) functional form issues.

Of these, omitted variable bias is actually the most important caveat of the cross-sectional hedonic analysis. One can never be entirely sure that all relevant attributes are included in the model even with a very detailed dataset. Omission of any of the relevant features leads to biased estimations and heteroscedasticity. The endogeneity of highway placement with respect to residence prices is also an important issue related to omitted variables. The final highway path is usually not randomly chosen and is most probably correlated to other factors that have an effect on house prices. In Hungary specifically, highways are built to strengthen the most overloaded roads of the road network, that connect the most desirable and popular destinations. (Fleischer, 1994) On the other hand, at a regional level the goal to help underdeveloped regions catch up is also present. (Bíró et al., 2006)

To overcome this problem some quasi-experimental methods have become popular in the recent decades.[2] The simplest of these is the *difference-in-differences (diff-in-diff* or *DiD)* design. To implement a *diff-in-diff* estimation one needs data for two groups, specifically two residential areas: one in which the intervention or treatment takes places – that is called the *treatment group* – and another which is *similar* to the first group except that there was no intervention there – that is called *the control group*. The researcher needs data of these two groups from (at least) two periods: one before (*t=0*) and another after the intervention took place (*t=1*). The basic idea of this strategy is to compare the changes from period 0 to period 1 in the variable of interest in the two groups. In other words, we should calculate the difference between the change in the treatment and the change in the control group:

$$\beta = \overline{y_1^{treatment}} - \overline{y_0^{treatment}} - \left(\overline{y_1^{control}} - \overline{y_0^{control}}\right). \qquad (1)$$

Similarity of the treatment and control groups here does not mean that they should have the same features on average; rather it is a looser condition: in particular the key identifying assumption is that residential property price trends in the two areas are the same in the absence of the treatment, i.e. both areas are affected in the same way by time-varying factors other than the

[2] Parmeter and Pope (2012) give an all-out summary of the theoretical and practical background and application of quasi-experimental designs related to hedonic property valuation, including the difference-in-differences and the regression discontinuity design.

treatment. This assumption is often called the *parallel trend assumption* (Angrist and Pischke, 2008). If this assumption holds, one can identify the effect of the treatment by comparing the differences in the changes in the treatment and control groups. To examine whether the parallel trend assumption can be verified, it is useful to check the historical evolution of the property prices in the treatment and control group on a graph.

The regression representation of a *diff-in-diff* model for property prices is the following:

$$y_{it} = \alpha + \alpha_1 Time_t + \alpha_2 Treat_i + \beta Time_t Treat_i + \varepsilon_{it}, \tag{2}$$

where y_{it} is a measure of the selling price for each transaction, $Time_t$ is a dummy that equals 1 if $\mathrm{t} = 1$ and equals 0 if $\mathrm{t} = 0$ ($\mathrm{t} = 1$ refers to the period after the intervention, while $\mathrm{t} = 0$ refers to the period before the intervention) and $Treat_i$ is a dummy indicating whether property *i* is in the treatment group. To relate this model to equation (1), I show the values of the mean of prices in the four different groups using the diff-in-diff regression coefficient notations.

$$\overline{y_0^{control}} = \alpha$$

$$\overline{y_0^{treatment}} = \alpha + \alpha_2$$

$$\overline{y_1^{control}} = \alpha + \alpha_1$$

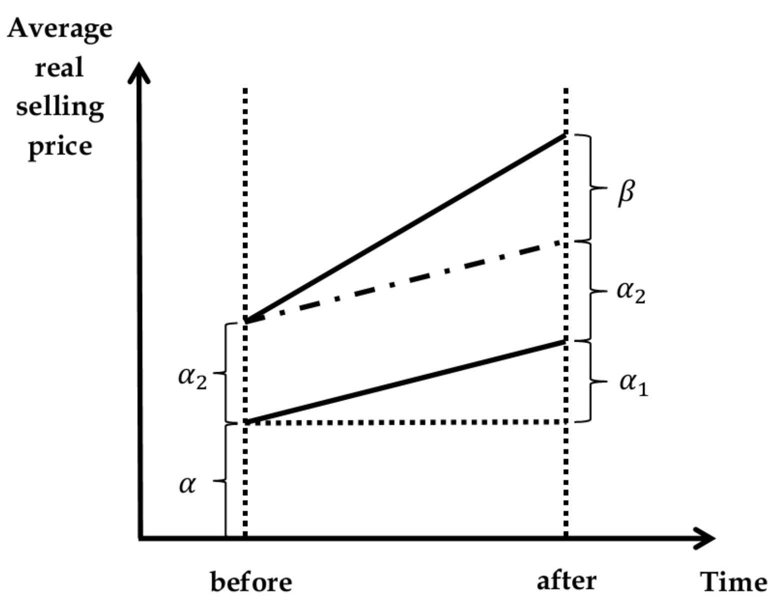
$$\overline{y_1^{treatment}} = \alpha + \alpha_1 + \alpha_2 + \beta$$

The coefficient of the interaction term (β) is the main parameter of interest, which shows the effect of the treatment:

$$\overline{y_1^{treatment}} - \overline{y_1^{control}} - \left(\overline{y_0^{treatment}} - \overline{y_0^{control}}\right) = \alpha + \alpha_1 + \alpha_2 + \beta - \alpha + \alpha_1 - (\alpha + \alpha_2 - \alpha) = \beta. \tag{3}$$

In Figure 2 the visual representation of the *diff-in-diff* coefficients are depicted. The upper line refers to the treatment group and the lower line represents the control group. In this specific case, in the treatment group there were already higher property prices before the intervention. So if one were trying to assess the treatment effect simply by comparing the two groups after the treatment, one would over- or underestimate the real treatment effect thinking that this original difference is also due to the intervention. Also, there is a positive change in the control group. So if one would use the simple "*One Group Before and After*" setup for the treatment group one would wrongly conclude that the treatment effect was $\alpha_1 + \beta$, although the actual treatment effect is indeed just β.

Figure 2. Visual representation of diff-in-diff coefficients



Source: created by the author

Figure 2 also illustrates the importance of the parallel trend assumption. The identification strategy builds on the assumption that without the intervention the prices in the treatment group would have evolved in the same way as in the control group (shown with the dot-dash line on

Figure 2). As nobody can actually observe what would have happened in the treatment group without the intervention, we have to assume something about this counterfactual path. That is why we need a control group.

As an extension of the basic diff-in-diff model Card (1992) exploits the regional variation in the minimal wage to assess the impact of it on employment, i.e. instead of a treatment dummy they use a *treatment variable with differing treatment intensity*. In my analysis I use this variation of the *diff-in-diff* method, in which I replace the treatment variable by a continuous distance variable to assess the effect of the highway:

$$y_{it} = \alpha + \alpha_1 Time_t + \alpha_2 Distance_i + \beta Time_t Distance_i + \varepsilon_{it}.$$

Difference-in-differences method is used in a wide variety of topics (amongst many others) by Bergemann et al. (2005), Card and Krueger (1994), Meyer et al. (1995), Meyer and Rosenbaum (2001) and Pischke (2007). *Diff-in-diff* have been used specifically to assess residential property outcomes for example by Davis (2004), Kiel and McClain (1995), Linden and Rockoff (2013), and Pope and Pope (2012).

4. Data

In my analysis I focus on the construction of highway M6 between Dunaújváros and Bóly and highway M60 which connects Bóly to Pécs. Both of these were opened to the public on March 31, 2010. In my estimations I include all cities, towns and villages to which highway M6 is the closest highway on this date. By this restriction I exclude the possibility that the results are biased because of the effect of the construction or construction plan of another nearby highway. From the longitude and latitude coordinates of the towns and the highway on-ramps I calculate the straight-line distance of each town from the nearest highway ramps in each year.[3]

Regarding data on property prices, I use the residential property transactions dataset of the National Tax and Customs Administration of Hungary (NTCA). This dataset includes some basic data about all residential property transactions in Hungary between 2000 and 2012 quarterly. Specifically, it includes the selling price, the size of the property in square meters, the location of the property in the ZIP-code level and the type of the property (flat, house, block of flats[4]). For my analysis I computed real prices comparable over time using the quarterly FHB House Market Index; in particular I discounted each period's transaction prices to the price level of 2000. There was a change in the structure of offices responsible for the collection of this database in the beginning of 2008.[5] Due to that change there is a lack of data in the last quarter of 2007, so in my

[3] Street-network or travel-time distance measure would definitely yield more accurate estimates. However, Boarnet and Chalermpong (2001) also use the straight-line distance measures in their similar study. They argue that the straight-line distance measure is highly correlated with the street-network distance. By visual examination of the map this is true in this case too.

[4] "Block of flats" refers to the typical Eastern-European „panelház", which were mostly built during the communist era. On the one hand this type of flats is usually of lower quality than their peer flats with similar other characteristics. On the other hand, according to many real estate market experts these flats are evaluated at a lower price by buyers being "panel"-s *per se*.

[5] Based on personal conversation with Áron Horváth (ELTINGA Centre for Real Estate Research) in May, 2013.

analysis I omit the data from this period. From the house transaction database I dropped those observations which had unrealistic or extreme values in the square-meter or price variables.[6]

[6] In particular I dropped each observation with size less than 20 square-meters and more than 500 square-meters, with price lower than HUF 100,000 and higher than HUF 100 million and with price per square-meters lower than HUF 10,000 and higher than HUF 600,000.

5. Models

If we want to measure the effect of a new highway in a *diff-in-diff* setup, we should answer a very simple question: when does the intervention takes place? As I already mentioned in the second chapter, usually the pathway of new highways is known quite a few years before they are actually built. Thus, it might well happen that the adjustment in nearby residential property prices already begins before the actual construction and opening of the highway. This problem is not that substantial, because if it exists it just weakens the results of the estimation, but does not lead to false identification.

In addition to this problem, the construction of a highway takes a while, in particular the construction of the relevant sectors of highway M6 took around two years. Due to this it is hard to pick one point in time when the treatment took place. If one wanted to pick one point in time as being the time of the intervention, it is quite an arbitrary choice. It can be the date of the announcement of the new highway, the date when the contract is signed with the construction company or the date when the highway is opened, etc.

In my baseline difference-in-differences specification I chose 2008 to be the "before-treatment" period and 2011 to be the "after-treatment" period. I define the treatment group being closer than 10 kilometers to highway M6. The remainder of the sample, i.e. those towns that are further away from the highway, but for which M6 is the closest highway, belong to the control group.

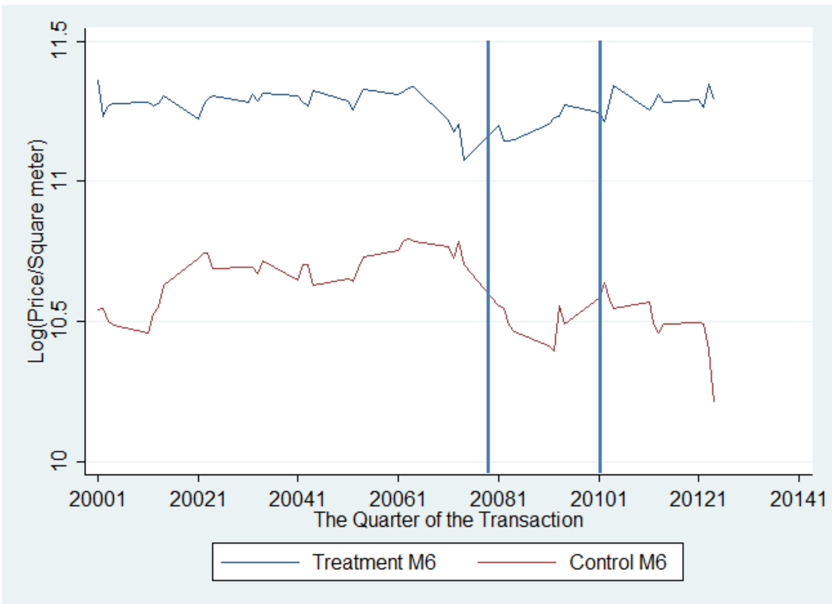
To visually verify the parallel trend assumption, which is the key identification assumption of my analysis, I depict the time series of quarterly average real selling prices in logarithm separately for the treatment and control group in panel A of Figure 3. Panel B of Figure 3 shows a similar picture about the evolution of prices: however on this graph instead of average prices I depict the residuals from a simple OLS regression in which I regress the logarithm of real prices on the observable characteristics of the properties and quarter dummies. This regression is the following:

$$\log(\frac{price}{m^2})_{ijt} = \alpha + \beta_1 * D_i^{house} + \beta_2 * D_i^{block\ of\ flat} + \beta_3 * D_j^{county\ capital} + \beta_4 * D_j^{county\ city} + \beta_5 * D_j^{city} + \boldsymbol{D_t \theta} + e_{ijt}$$

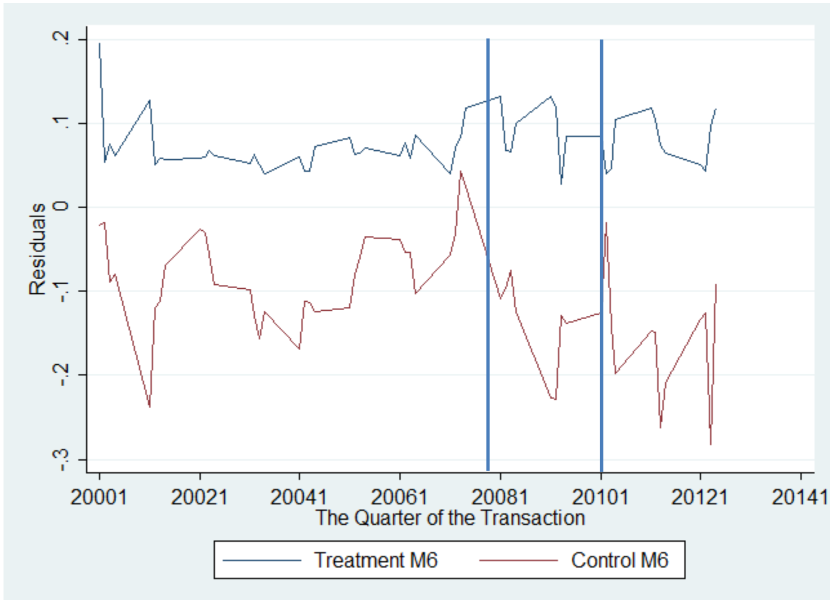
where *i* refers to the house that is sold, *j* refers to the town in which it is located and *t* refers to the quarter when the transaction took place. The first and the second explanatory variables are dummies which is equal to 1 if the property is a house and is equal to 1 if the property is in a "block of flats", respectively. The next three variables are dummies for the category of the city in which the property is located. $\boldsymbol{D_t}$ is a vector of quarterly dummy variables, which control for real estate market trends.

Figure 3. The visual verification of paralel trend assumption

Panel A



Panel B



In Figure 3 we can see that prices in the treatment group are generally higher than the prices in the control group. Both graphs suggest that until the beginning of 2007 the prices in the treatment and control group evolved more or less similarly and did not change much. At the beginning of 2007 there is a drop in the logarithm of real prices per square meter in the treatment group. Since 2007 we can observe a growing difference between the two groups; this is the result of the different trends in the two groups. The real prices in the treatment group seem to remain constant, while the real prices in the control group started to decrease around 2007. The parallel trend assumption seems to work without controls and with controls also, however the time variance is higher in the latter case.

The graphs suggest that there might be an effect of the new highway on nearby transaction prices. However, I must point out that the examined sector of the highway opened to the public right in the middle of the recent economic crisis, which affected the real estate markets. This is problematic because it causes a break in the price trends that have been constant previously. I have no fully convincing evidence that the treatment and control groups are influenced in the same way by the crisis, although this is necessary to get credible results. If this is not the case, then the seemingly positive effect of the new highway on house prices might be due to some other effect that has a different impact on the treatment and control group.

5.1. Baseline Model

Initially, I focus on two time periods, 2008 (as the before-treatment period) and 2011 (as the after-treatment period). In Table 2 the summary statistics of the variables are shown. In an ideal case the composition of the treatment and control group regarding their observables should be the same. Also, it is ideal to have similar composition in the two time periods both in the treatment and control groups to avoid showing a significant "highway-effect" that is based on the differences due to the systematically different kind of the properties being sold. (Abadie, 2005, Pope and Pope, 2012)

The selling price differs largely across the control and treatment group in both years. In the control group the average real price is around HUF 45,000 in both periods. In the treatment group the average real price is HUF 79,804 in 2008 and is HUF 88,447 in 2011. The size of the properties is similar in the four groups: it is about 70-73 square meters, except in the treatment group in 2011, where it is only about 63 square meters. There is a remarkable difference in the composition of observations regarding the type of the property. Generally, there are more houses in the control group than in the treatment group which is not surprising as the control group consists of more rural areas. Unsurprisingly, in the treatment group there are both more flats and block of flats, because generally highways pass by bigger cities and towns in which these kinds of properties are more common.

Table 2. Descriptive Statistics of Variables on the full sample

	2008		2011	
	Control	Treatment	Control	Treatment
Variable	Mean	Mean	Mean	Mean
Real Price per Square Meter	44872	79804	45160	88447
	24292	33658	27808	38460
Size in Square Meters	73.09	70.51	72.19	62.84
	48.00	59.52	43.75	42.39
House Dummy	0.473	0.191	0.443	0.134
	0.499	0.393	0.497	0.341
Flat Dummy	0.422	0.607	0.478	0.700
	0.494	0.489	0.500	0.458
Block of Flats Dummy	0.105	0.202	0.079	0.165
	0.307	0.402	0.270	0.372
Town Dummy	0.407	0.125	0.353	0.074
	0.491	0.330	0.479	0.262
City Dummy	0.593	0.223	0.647	0.175
	0.491	0.416	0.479	0.380
Capital of County Dummy	0.000	0.652	0.000	0.751
	0.000	0.476	0.000	0.433
Distance from Budapest	147.78	156.40	148.02	159.76
	34.54	28.53	35.34	26.63
Distance from Pécs	40.48	18.38	40.85	13.78
	26.72	29.84	26.50	27.97
Distance from Closest Ramp	39.62	42.49	19.53	6.81
	19.07	13.64	6.70	1.57
Observations	1075	2013	481	1681

In the composition of settlement category there is a huge difference between the control and treatment groups, which is due to the fact that the highway passes by bigger cities and towns. Most of the treatment observations – 65% in 2008 and 75% in 2011 – are taken from two county capitals, Pécs and Szekszárd (the capitals of Baranya and Tolna County, respectively). These two cities are much bigger than any other cities in the sample.

The distance from the closest highway-ramp is 39.6 km in the control and 42.5 km in the treatment group in 2008, so they are quite similar. In 2011, the control observations are 19.5 km away from the highway on average, while the treatment observations are only 6.8 km away from the highway.

For my models I use a pooled cross section transaction level dataset. In my baseline specification I use the logarithm of real prices as the dependent variable. In Table 3 the simplest two-by-two average log prices are presented. The log values of the prices are not very informative by themselves, but the difference between the treatment and control group and the change in the two groups by time are noteworthy. It is remarkable that there is a huge difference between the treatment and control groups in both periods. In 2008 properties in the treatment group are sold for 89.6% higher price on average. In 2011 this difference is even higher, 117%. It can be seen from the table that there is a slight decrease in prices in the control group. However, in the treatment group there is a large increase in the selling prices, around 12.7%.

Table 3. Simple difference-in-differences

Full Sample			
	Control	*Treatment*	*Difference*
2008	10.52	11.16	0.64
2011	10.5039	11.2819	0.778
Difference	-0.0161	0.1219	***0.138***

In Table 4 in the first four columns I present some modifications of the basic two-by-two diff-in-diff model. In these models I use different sets of time-invariant control variables that make my estimation more precise and credible. Credibility is enhanced because the control variables help to tackle the problem if there are systematic differences in the types of properties that are sold before and after the treatment. I control for the type of the property, the type of the town the property is located in and the distance and its square from Budapest and Pécs. I always use clustered standard error calculation on the town level as I use town level explanatory variables, while my dependent variable is observed on the transaction level.

Table 4. Model specifications

Sample	***Full Sample***				***Without Biggest Two Cities***			
	1	2	3	4	5	6	7	8
Time	-0.0161	-0.0547	-0.0573	-0.0576	-0.0161	-0.0500	-0.0522	-0.0574
	(0.788)	(0.280)	(0.265)	(0.260)	(0.788)	(0.333)	(0.319)	(0.262)
Treatment	0.640***	0.290***	0.281***	0.276***	0.263*	0.223***	0.223***	0.235***
	(7.55e-05)	(0.00119)	(0.00134)	(0.000801)	(0.0697)	(0.00330)	(0.00519)	(0.00309)
Time*Treatment	*0.138*	*0.110**	*0.110**	*0.116**	*0.238****	*0.223****	*0.218****	*0.226****
	(0.119)	*(0.0982)*	*(0.0942)*	*(0.0769)*	*(0.00576)*	*(0.00217)*	*(0.00252)*	*(0.00190)*
Type of town	-	yes	yes	yes	-	yes	yes	yes
Type of property	-	yes	yes	-	-	yes	yes	-
Distance and Square of Distance from Budapest	-	-	yes	yes	-	-	yes	yes
Distance and Square of Distance from Pécs	-	-	-	yes	-	-	-	yes
Constant	10.52***	10.52***	11.16***	11.87***	10.52***	10.45***	10.93***	11.85***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Observations	5,250	5,250	5,250	5,250	2,675	2,675	2,675	2,675
R-squared	0.226	0.498	0.500	0.460	0.067	0.371	0.373	0.336

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

Consistently with Table 3 the result for the coefficient of *Time*Treatment* interaction is 13.8, which means a 14.8% "highway premium" in the simplest two-by-two model and it is significant at the 12% significance level. Meyer (1995) draws attention to the case when the coefficient of *Time* and *Treatment* is relatively large. This would mean in the first case that period-to-period changes in the dependent variable are common, and some further evidence on its variance should be incorporated in the estimation. Similarly, if the coefficient of *Treatment* is relatively large it suggests that the two groups are far from each other, so it has a higher chance that they react differently on the same shocks. The presence of any of these issues makes the results less credible. In the simplest model the treatment coefficient is quite large: 0.64. However, adding the different mix of control variables leads to treatment coefficients that are less than half of it being around 0.27-0.29. So the controls help to break down difference between the treatment and control groups and lead to more significant results and also lower coefficient estimates that correspond to around 11.5% higher prices.

Table 5. Descriptive statistics of variables in the sample without the two biggest cities.

	2008		2011	
	Control	**Treatment**	**Control**	**Treatment**
Variable	**Mean**	**Mean**	**Mean**	**Mean**
Real Price per Square Meter	44872	58281	45160	73186
	24292	30354	27808	36853
Size in Square Meters	73.09	85.05	72.19	80.04
	48.00	63.76	43.75	54.79
House Dummy	0.473	0.451	0.443	0.399
	0.499	0.498	0.497	0.490
Flat Dummy	0.422	0.273	0.478	0.305
	0.494	0.446	0.500	0.461
Block of Flats Dummy	0.105	0.276	0.079	0.296
	0.307	0.447	0.270	0.457
Town Dummy	0.407	0.359	0.353	0.298
	0.491	0.480	0.479	0.458
City Dummy	0.593	0.641	0.647	0.702
	0.491	0.480	0.479	0.458
Capital of County Dummy	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000
Distance from Budapest	147.78	129.77	148.02	127.11
	34.54	35.42	35.34	37.79
Distance from Pécs	40.48	52.86	40.85	55.30
	26.72	27.18	26.50	29.04
Distance from Closest Ramp	39.62	28.78	19.53	4.86
	19.07	15.72	6.70	2.21
Observations	1075	700	481	419

Up to now, I have shown the results of models estimated on the full sample. However, the two big county capitals (Szekszárd and Pécs) make the sample composition quite unbalanced. Intuitively, the real estate markets in bigger cities differ substantially from that of smaller towns or villages. To deal with this issue I re-estimated the same models on a sample in which the two big cities are excluded from the treatment sample. In Table 5 I present the summary statistics for the treatment and control groups in 2008 and 2011 without the two big cities. Naturally, the statistics of the control group remain the same.

There are much smaller differences in the prices both in 2008 and 2011. In this sample the average real selling price in the treatment group is HUF 58,281 in 2008 and is HUF 73,186 in 2011. The house type composition is also closer to each other in the two groups. In specific, the treatment group still has a significant share of "panel flats", but the share of houses is around the same value: it is 47.3% and 44.3% in the control group and 45,1% and 39,9% in the treatment group in 2008 and 2011, respectively. Now, the distance from the closest highway ramp is 40 km on average in the control and 29 km in average in the treatment before the opening of the highway. After the opening of the highway the average distance from it decreases to 20 km in the control and to 5 km in the treatment group.

Columns 5-8 in Table 4 show the results of the new models. In all specifications there is a very significant difference between the control and treatment groups amounting about 24-27%. The results for the effect of highways on house prices are twice as much as on the full sample, they are around 24-27%. Also these coefficient estimates are much more significant; all of them are significant on the 1% level. The higher result is in line with the intuition that smaller towns might realize higher marginal benefit from having the highway around.

5.2. Models with Continuous Treatment

Until this point in the paper I used a simple model specification that assumes that the highway has the same effect on each residential property located closer than 10 kms to the highway and has a lower and equal effect on the properties further away. More precisely I compared the effect on selling price between two groups of properties, one being on average 6.8 km away from the highway and another being 19.5 km away from the highway. Of course this assumption is a very restrictive. It is much more plausible that the positive effect of a highway fades away gradually being further away from it. In this section I present my results when I estimate models in which instead of a binary treatment I use a continuous distance measure from the highway.

Table 6. The estimation results with continuous effect of distance from highway

Sample	*Full Sample*				*Without Biggest Two Cities*			
Distance Measure	linear	linear	log	log	linear	linear	log	log
	1	2	3	4	5	6	7	8
Time	0.963***	0.128	2.077***	0.283	0.407***	0.173*	0.693**	0.198
	(0.000124)	(0.340)	(0.00320)	(0.242)	(0.00258)	(0.0871)	(0.0360)	(0.284)
Distance	0.00874	-0.00247	0.272*	-0.0910	-0.00212	-0.00651***	-0.0447	-0.156***
	(0.117)	(0.356)	(0.0964)	(0.123)	(0.450)	(0.00723)	(0.529)	(0.00333)
Time*Distance	-0.0532***	-0.0175***	-0.709***	-0.183**	-0.0269***	-0.0204***	-0.280**	-0.139**
	(3.36e-05)	(0.00671)	(0.00149)	(0.0257)	(0.00430)	(0.000502)	(0.0255)	(0.0336)
Type of town	-	yes	-	yes	-	yes	-	yes
Type of property	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Budapest	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Pécs	-	yes	-	yes	-	yes	-	yes
Constant	10.57***	13.25***	9.955***	13.20***	10.70***	13.38***	10.78***	12.71***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Average Difference Between Previous Control and Treatment Group in %	-49.17	-19.96	-27.70	-8.03	-32.61	-25.86	-15.56	-8.05
Observations	5,250	5,250	5,250	5,250	2,675	2,675	2,675	2,675
R-squared	0.110	0.489	0.093	0.495	0.050	0.364	0.051	0.372

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results are summarized in Table 6. As in the previous results table columns 1 to 4 refer to the estimations on the full sample and columns 5 to 8 shows the coefficient estimates of the models on the sample without the two biggest cities. Additional to the type of information I already included in the previous output table this table also includes the estimated percentage difference between the original treatment and control group, which serves as a basis for comparison between the discrete and continuous models (the calculation to get comparable results can be found in Appendix A).

Generally, the results of the distance-models are much less robust when I include different control variables than in the discrete case. Also, these coefficients imply that the highway has a very huge effect on residence prices. In the linear-distance specification on the full sample we see that the house prices decrease by 1.75 – 5.32% per kilometer being further away from the highway. This means that in the baseline control group house prices are about 20 – 49% lower than in the treatment group (control group properties are on average 12.72 km further from the highway). Estimation of linear-distance effect on the sample without the biggest two cities is yield more stable results over specifications; the effect is around 2 – 2.6% decrease in prices per kilometer. This means around 26 – 33% lower prices in the baseline control group compared to the baseline treatment group.

The log-distance coefficients are generally a bit smaller than the linear ones, but they are still not very similar to the previous results and are unrealistically high. It is also noteworthy that while in the discrete setup I found higher coefficients in the sample without the biggest cities, in the continuous models an opposite tendency is present.

Table 7. Falsification test. Estimating the baseline models in a sample of 2002 and 2005.

Sample	*Full Sample*				*Without Biggest Two Cities*			
	1	2	3	4	5	6	7	8
Time	-0.0518	0.0543	0.0517	0.0428	-0.0518	0.0572	0.0544	0.0426
	(0.476)	(0.324)	(0.320)	(0.406)	(0.477)	(0.286)	(0.285)	(0.409)
Treatment	0.550***	0.165**	0.178**	0.177**	0.134	0.201***	0.215***	0.200***
	(9.37e-08)	(0.0350)	(0.0207)	(0.0198)	(0.116)	(0.00642)	(0.00392)	(0.00611)
Time*Treatment	0.0635	0.0268	0.0284	0.0247	0.00531	-0.0448	-0.0408	-0.0229
	(0.469)	(0.659)	(0.618)	(0.646)	(0.956)	(0.528)	(0.563)	(0.768)
Type of town	-	yes	yes	yes	-	yes	yes	yes
Type of property	-	yes	yes	-	-	yes	yes	-
Distance and Square of Distance from Budapest	-	-	yes	yes	-	-	yes	yes
Distance and Square of Distance from Pécs	-	-	-	yes	-	-	-	yes
Constant	10.73***	10.37***	10.32***	9.038***	10.73***	10.40***	10.34***	9.036***
	(0)	(0)	(0)	(7.32e-09)	(0)	(0)	(0)	(8.10e-09)
Observations	12,101	12,101	12,101	12,101	5,928	5,928	5,928	5,928
R-squared	0.266	0.553	0.554	0.546	0.017	0.322	0.325	0.314

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.3. Falsification Test

In order to better make sure about the credibility of my results, I estimated the same models in random points in time many years before the highway was built. If these models would also show similar and significant results as my baseline model, it would be a serious concern about my results. Table 7 shows the results of a set of models estimated on a sample in which the 2002 is the before-period and 2005 is the after-period. None of the models have significant coefficient estimates for the interaction term. Also the results are smaller in absolute sense. (Other falsification tables can be found in Appendix B.) In Table 8 a falsification table for the continuous models is presented.

Table 8. Falsification test. Estimating the baseline models in a sample of 2000 and 2003.

Sample	*Full Sample*				*Without Biggest Two Cities*			
Distance Measure	linear	linear	log	log	linear	linear	log	log
	1	2	3	4	5	6	7	8
Time	-0.302	-0.0449	-0.388	-0.0418	-1.954**	0.142	-1.124	0.178
	(0.220)	(0.816)	(0.263)	(0.832)	(0.0295)	(0.867)	(0.397)	(0.837)
Distance	0.00768*	-0.00215	0.000997	-0.00238	0.296*	-0.165	-0.00147	-0.165
	(0.0584)	(0.559)	(0.641)	(0.531)	(0.0513)	(0.137)	(0.984)	(0.150)
Time*Distance	-0.00174	0.00105	0.00155	0.00137	0.358*	-0.00782	0.207	-0.0155
	(0.603)	(0.519)	(0.636)	(0.430)	(0.0623)	(0.963)	(0.465)	(0.929)
Type of town	-	yes	-	yes	-	yes	-	yes
Type of property	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Budapest	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Pécs	-	yes	-	yes	-	yes	-	yes
Constant	10.75***	11.40***	10.71***	11.58***	9.988***	11.68***	10.76***	11.66***
	(0)	(2.90e-10)	(0)	(6.07e-10)	(0)	(1.44e-10)	(0)	(4.38e-10)
Observations	8,982	8,982	4,141	4,141	8,982	8,982	4,141	4,141
R-squared	0.041	0.556	0.031	0.252	0.055	0.563	0.029	0.258

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.4. Robustness Checks and Other Model Specifications

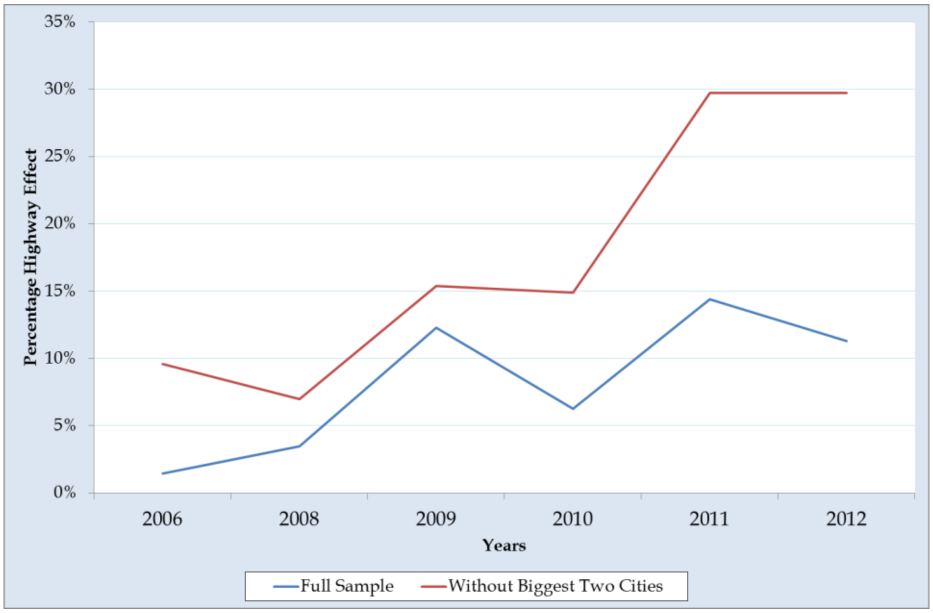
Besides the models I reported until this point I estimated many other model specifications to check the robustness of the results.

First, I estimated models with more periods. In fact, the structure of these models is similar to that of Kiel and McClain (1995):

$$y_{it} = \alpha + \boldsymbol{Year_t \alpha_t} + \alpha_2 Treat_i + \boldsymbol{Year_t Time_i \beta} + \boldsymbol{X_i \theta_i} + \varepsilon_{it},$$

where $\boldsymbol{Year_t}$ is a vector of year dummies; each one is equal to one if the observation comes from that year. $\boldsymbol{X_i}$ is a vector of controls for the property characteristics, such as the type of the property. The estimation outputs of these models can be found in Table 13 of Appendix C.

Figure 4. The evolution of the "highway effect" since 2006 without 2007.



Note: On the graph the coefficients of the Year*Treatment interactions can be seen from model 3 and model 7 of Table 13 in Appendix C

This setup helps to reveal the dynamics of the "highway effect". In general these models tend to show higher highway effects than the simple two period models, but are more or less similar to my original findings. In Figure 4 the evolution of the effect of the highway can be seen. Year 2007 is left out of the model because of lack of data. The two lines represent the effect for the estimation on the full sample (blue) and for the estimation on the sample without the two biggest cities (red). The graph suggests that already in 2008 there was a small increase in house prices in the treatment group relative to the control group, but a larger effect emerged in 2011. Namely, this effect was around 15% for the full sample and 30% for the sample without the biggest two cities.

Second, I investigated whether the highway leads to a different price premium in towns and cities. I did not find any evidence that this is the case. However, the coefficients I got from these models are in line with my baseline model on the sample without the biggest two cities (see Table

14 of Appendix C). Also, I checked whether there is a difference regarding the type of the properties, but I got inconclusive estimates.

Finally, I considered that there might be a different effect for settlements situated to the west and to the east of river Danube. Highway M6 is situated on the right side of river (west). As there are only a few bridges on the river (four big bridges along the highway), the straight-line distance measurement for settlements located to the east of the river is probably much less correlated with the street-network or travel-time distance measurement which are of real interest here. Consequently, one would expect a smaller highway effect for the properties located on the left side of the river. The sign of my estimated coefficients are in line with my original hypotheses, but they are a bit too extreme. (see Table 15 of Appendix C).

6. Conclusion and Further Research

In this thesis I measured the effect of highways on the prices of nearby residential properties. In particular I examined the sectors of highway M6 that were opened to the public on March 31, 2010. I used different variants of the simple *difference-in-differences* method that helps overcome the problem of omitted variables and endogeneity that appear in the simpler cross-section hedonic method or before-after analysis. In my baseline specification I investigate property transaction data of 2008 and 2011.

I found that residential properties not being further than 10 km away from the highway were sold at around 11-15% higher prices on average compared to properties being further away from the highway. When I conducted the estimation on a smaller sample excluding the two big county capitals (Pécs and Szekszárd) I got an even larger estimation for the "highway premium", around 24-27%. I also estimated models in which I used the distance from the nearest highway on-ramp as the treatment variable instead of a binary treatment variable. These models did not yield robust results and also the estimated coefficients seem to be very large.

My study could be improved in several aspects for further research both methodologically and regarding the scope of the analysis. For example, it would be instructive to analyze the effect of the other newly built highways in Hungary, such as the Kiskunfélegyháza-Szeged part of highway M5, which was opened at the end of 2005. This would help us to better understand whether highways in different regions have similar effects on the property prices or not. Tóth (2005) mentions that highways by themselves may not lead to the economic development of a region without some other factors being present in the regions. This suggests that we should observe the presence of new highways within an interaction term with other regional characteristics for example regarding the labor market to determine what are these factors. Also, some further investigation about the effect of the recent economic crisis on the residential property market would be useful to make the identification more credible.

Regarding methodological issues, spatial autocorrelation of property characteristics and prices are absolutely not taken into account in my thesis. The studies of Basu and Thibodeau (1998) and Haider and Miller (2007) would serve as a nice starting point to the development of my analysis in that direction.

Appendix A

The Calculation to Get Comparable Results Between the Discrete and Continuous Models

This calculation is based on the formula in the econometric course book of Wooldridge (p 184, 2002). The basic idea is to calculate the comparable coefficients, which show what difference the continuous models predict between the baseline control and treatment group.

Linear-distance models:

$$\%\Delta \log(\widehat{real\,price}) = 100 * \left[e^{\delta*(distance_{control} - distance_{treatment})} - 1\right]$$

Log-distance models:

$$\%\Delta \log(\widehat{real\,price}) = 100 * \left[e^{\delta*(\log(distance_{control}) - \log(distance_{treatment}))} - 1\right]$$

where δ is the coefficient of distance in kilometers.

Appendix B

The Estimation Outputs of the Falsification Tests

In Table 8 the coefficient of the simple model without controls is significant and is around the same level as my results for the "highway premium". However, adding controls fully kills this result both in terms of robustness and significance, which probably means that the significant coefficient in the simple model is due to the different composition of treatment and control group.

Table 9. Falsification Test. The estimation output of the baseline models with 2000 being the before-period and 2003 being the after-period

Sample	*Full Sample*				*Without Biggest Two Cities*			
	1	2	3	4	5	6	7	8
Time	-0.180***	-0.00762	-0.0127	-0.00952	-0.180***	-0.00595	-0.0106	-0.00939
	(0.00214)	(0.901)	(0.820)	(0.846)	(0.00215)	(0.921)	(0.850)	(0.848)
Treatment	0.607***	0.231***	0.241***	0.256***	0.187**	0.236***	0.251***	0.255***
	(1.97e-07)	(0.00245)	(0.000733)	(0.000504)	(0.0330)	(0.00229)	(0.000708)	(0.000871)
Time*Treatment	0.153**	-0.0124	-0.00962	-0.0542	0.0562	-0.0258	-0.0406	-0.0483
	(0.0178)	(0.852)	(0.866)	(0.273)	(0.565)	(0.728)	(0.525)	(0.451)
Type of town	-	yes	yes	yes	-	yes	yes	yes
Type of property	-	yes	yes	-	-	yes	yes	-
Distance and Square of Distance from Budapest	-	-	yes	yes	-	-	yes	yes
Distance and Square of Distance from Pécs	-	-	-	yes	-	-	-	yes
Constant	10.69***	10.37***	10.84***	11.11***	10.69***	10.38***	10.73***	11.12***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Observations	8,982	8,982	8,982	8,982	4,141	4,141	4,141	4,141
R-squared	0.351	0.575	0.579	0.574	0.062	0.291	0.300	0.296

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

In Table 9 there is a similar situation as with Table 8, except that here the significant coefficient of the simplest model is negative.

Table 10. Falsification Test. The estimation output of the baseline models with 2001 being the before-period and 2003 being the after-period

Sample	*Full Sample*				*Without Biggest Two Cities*			
	1	2	3	4	5	6	7	8
Time	0.158***	0.0969***	0.0939***	0.0962***	0.158***	0.0949***	0.0925***	0.0959***
	(2.31e-05)	(0.000596)	(0.00113)	(0.00152)	(2.32e-05)	(0.000954)	(0.00162)	(0.00150)
Treatment	0.748***	0.286***	0.297***	0.281***	0.249*	0.297***	0.297***	0.292***
	(0)	(0.000375)	(3.98e-05)	(0.000137)	(0.0955)	(0.000543)	(0.000319)	(0.000300)
Time*Treatment	-0.141***	-0.0505*	-0.0463	-0.0279	-0.0621	-0.0619	-0.0428	-0.0438
	(0.00851)	(0.0785)	(0.145)	(0.406)	(0.592)	(0.301)	(0.542)	(0.553)
Type of town	-	yes	yes	yes	-	yes	yes	yes
Type of property	-	yes	yes	-	-	yes	yes	-
Distance and Square of Distance from Budapest	-	-	yes	yes	-	-	yes	yes
Distance and Square of Distance from Pécs	-	-	-	yes	-	-	-	yes
Constant	10.53***	10.28***	11.17***	11.15***	10.53***	10.29***	11.13***	11.19***
	(0)	(0)	(0)	(1.27e-10)	(0)	(0)	(0)	(1.68e-10)
Observations	10,355	10,355	10,355	10,355	4,623	4,623	4,623	4,623
R-squared	0.362	0.571	0.581	0.575	0.061	0.278	0.300	0.293

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 11 and Table 12 consist of the results of falsification regression models in the continuous treatment case. In Table 11 we can see some significant coefficient estimates for the *Time*Distance* interactions, but much less than in my original model.

Table 11. Falsification Test. The estimation output of the baseline continuous models with 2001 being the before-period and 2003 being the after-period

Sample	*Full Sample*				*Without Biggest Two Cities*			
Distance Measure	linear	linear	log	log	linear	linear	log	log
	1	2	3	4	5	6	7	8
Time	0.614**	0.386	0.580*	0.386	3.214***	0.972	1.928	0.896
	(0.0318)	(0.108)	(0.0969)	(0.129)	(0.00975)	(0.371)	(0.184)	(0.426)
Distance	0.00927**	0.00143	0.00474	0.00130	0.933***	0.0528	0.387	0.0363
	(0.0153)	(0.686)	(0.211)	(0.726)	(0.00502)	(0.860)	(0.252)	(0.907)
Time*Distance	-0.00159	-0.00505**	-0.00375	-0.00473**	-0.637**	-0.225	-0.389	-0.205
	(0.620)	(0.0177)	(0.264)	(0.0311)	(0.0166)	(0.319)	(0.213)	(0.382)
Type of town	-	yes	-	yes	-	yes	-	yes
Type of property	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Budapest	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Pécs	-	yes	-	yes	-	yes	-	yes
Constant	10.13***	11.03***	10.13***	10.93***	6.774***	10.50***	8.829***	10.52***
	(0)	(1.22e-07)	(0)	(2.10e-07)	(3.96e-06)	(2.62e-05)	(2.45e-08)	(3.17e-05)
Observations	10,355	10,355	4,623	4,623	10,355	10,355	4,623	4,623
R-squared	0.049	0.560	0.038	0.250	0.064	0.562	0.035	0.254

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 12. Falsification Test. The estimation output of the baseline continuous models with 2002 being the before-period and 2005 being the after-period

Sample	*Full Sample*				*Without Biggest Two Cities*			
Distance Measure	linear	linear	log	log	linear	linear	log	log
	1	2	3	4	5	6	7	8
Time	0.568**	0.524***	0.302*	0.520***	2.151***	1.645***	1.105**	1.802***
	(0.0179)	(8.29e-05)	(0.0564)	(0.000264)	(0.00496)	(0.00599)	(0.0378)	(0.00198)
Distance	0.00677**	0.00664***	0.00210	0.00678***	0.587**	0.411**	0.159	0.431**
	(0.0265)	(0.000448)	(0.342)	(0.000543)	(0.0118)	(0.0164)	(0.295)	(0.0109)
Time*Distance	-0.00746***	-0.00381**	-0.00601***	-0.00451***	-0.479***	-0.343***	-0.283**	-0.394***
	(0.00165)	(0.0167)	(0.00783)	(0.00482)	(0.00243)	(0.00768)	(0.0183)	(0.00130)
Type of town	-	yes	-	yes	-	yes	-	yes
Type of property	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Budapest	-	yes	-	yes	-	yes	-	yes
Distance and Square of Distance from Pécs	-	yes	-	yes	-	yes	-	yes
Constant	10.51***	9.599***	10.59***	9.635***	8.492***	8.446***	10.07***	8.402***
	(0)	(8.54e-11)	(0)	(1.44e-10)	(0)	(3.93e-09)	(0)	(7.87e-09)
Observations	12,101	12,101	5,928	5,928	12,101	12,101	5,928	5,928
R-squared	0.023	0.548	0.018	0.314	0.033	0.547	0.015	0.312

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

Appendix C

Table 13. Estimation output for multiple period models

Sample	*Full Sample*				*Without Biggestv Two Cities*			
	1	2	3	4	5	6	7	8
Year 2006	0.106**	-0.00528	-0.0218	-0.0160	0.106**	-0.00337	-0.0219	-0.0156
	(0.0122)	(0.882)	(0.489)	(0.603)	(0.0122)	(0.922)	(0.485)	(0.612)
Year 2008	-0.154***	-0.151***	-0.140***	-0.127***	-0.154***	-0.151***	-0.140***	-0.127***
	(0.00189)	(6.32e-05)	(1.45e-05)	(2.57e-05)	(0.00189)	(6.53e-05)	(1.40e-05)	(2.76e-05)
Year 2009	-0.218***	-0.192***	-0.185***	-0.167***	-0.218***	-0.193***	-0.185***	-0.167***
	(0.000228)	(1.31e-05)	(7.50e-06)	(1.29e-05)	(0.000230)	(1.31e-05)	(7.32e-06)	(1.24e-05)
Year 2010	-0.0848	-0.115**	-0.113**	-0.0979*	-0.0848	-0.115**	-0.113**	-0.0975*
	(0.208)	(0.0337)	(0.0287)	(0.0581)	(0.209)	(0.0347)	(0.0284)	(0.0588)
Year 2011	-0.170**	-0.188***	-0.193***	-0.180***	-0.170**	-0.188***	-0.193***	-0.179***
	(0.0115)	(0.00178)	(0.000582)	(0.00112)	(0.0115)	(0.00178)	(0.000587)	(0.00116)
Year 2012	-0.220**	-0.183***	-0.168***	-0.135**	-0.220**	-0.184***	-0.168***	-0.135**
	(0.0465)	(0.00945)	(0.00765)	(0.0265)	(0.0465)	(0.00971)	(0.00764)	(0.0266)
Treatment	0.613***	0.423***	0.225***	0.241***	0.140	0.154**	0.162**	0.176**
	(6.65e-05)	(2.63e-05)	(0.00459)	(0.00408)	(0.270)	(0.0162)	(0.0197)	(0.0173)
Year 2006*Treatment	-0.0677	0.00166	0.0145	0.00830	0.0581	0.0959*	0.0958**	0.0867**
	(0.273)	(0.974)	(0.714)	(0.826)	(0.392)	(0.0613)	(0.0357)	(0.0304)
Year 2008*Treatment	0.0265	0.0207	0.0345	0.0271	0.124*	0.0949*	0.0698	0.0729
	(0.622)	(0.607)	(0.329)	(0.427)	(0.0889)	(0.0987)	(0.171)	(0.141)
Year 2009*Treatment	0.163**	0.126***	0.123***	0.107**	0.260***	0.192***	0.154**	0.145**
	(0.0109)	(0.00807)	(0.00551)	(0.0108)	(0.00316)	(0.00480)	(0.0191)	(0.0230)
Year 2010*Treatment	0.0672	0.0769	0.0626	0.0495	0.183*	0.191**	0.149*	0.141
	(0.404)	(0.255)	(0.302)	(0.426)	(0.0943)	(0.0455)	(0.0882)	(0.117)
Year 2011*Treatment	0.165*	0.140*	0.144*	0.133*	0.362***	0.317***	0.297***	0.292***
	(0.0742)	(0.0838)	(0.0515)	(0.0740)	(0.00101)	(0.00134)	(0.000448)	(0.000583)
Year 2012*Treatment	0.234*	0.147	0.113	0.0817	0.420**	0.338***	0.297***	0.271***
	(0.0846)	(0.109)	(0.154)	(0.303)	(0.0166)	(0.00359)	(0.00310)	(0.00857)
Type of settlement	-	-	***yes***	***yes***	-	-	***yes***	***yes***
Type of property	-	***yes***	***yes***	***yes***	-	***yes***	***yes***	***yes***
Distance and Square of Distance from Budapest	-	-	-	***yes***	-	-	-	***yes***
Distance and Square of Distance from Pécs	-	-	-	***yes***	-	-	-	***yes***
Constant	10.67***	11.00***	10.51***	11.44***	10.67***	11.00***	10.52***	11.38***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Observations	21,539	21,539	21,539	21,539	10,561	10,561	10,561	10,561
R-squared	0.241	0.452	0.522	0.527	0.063	0.329	0.395	0.403

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 14. Estimation output of models that separate the "highway effect" for towns and cities

	1	2	3	4	5	6
Time	-0.108	-0.0977	-0.0986	-0.106	-0.103	-0.0992
	(0.172)	(0.208)	(0.213)	(0.187)	(0.194)	(0.211)
Treatment	0.207**	0.197**	0.196**	0.216**	0.183**	0.152
	(0.0248)	(0.0274)	(0.0338)	(0.0234)	(0.0409)	(0.118)
City Dummy	0.738***	0.395***	0.397***	0.746***	0.697***	0.360***
	(0)	(6.82e-06)	(1.00e-05)	(0)	(0)	(0.000321)
Time*Treatment	*0.249**	*0.246**	*0.235**	*0.240**	*0.222**	*0.225**
	(0.0536)	*(0.0556)*	*(0.0722)*	*(0.0667)*	*(0.0837)*	*(0.0841)*
Time*City	0.0812	0.0736	0.0718	0.0760	0.0797	0.0764
	(0.429)	(0.471)	(0.491)	(0.465)	(0.431)	(0.467)
Treat*City	0.0326	0.0599	0.0553	0.0284	0.101	0.129
	(0.815)	(0.667)	(0.679)	(0.839)	(0.478)	(0.320)
Time*Treatment*City	*-0.0323*	*-0.0405*	*-0.0322*	*-0.0202*	*-0.0112*	*-0.0287*
	(0.829)	*(0.789)*	*(0.835)*	*(0.894)*	*(0.938)*	*(0.850)*
Type of property	-	yes	yes	-	-	yes
Distance and Square of Distance from Budapest	-	-	yes	yes	-	yes
Distance and Square of Distance from Pécs	-	-	-	-	yes	yes
Constant	10.08***	10.49***	11.01***	10.30***	10.28***	12.59***
	(0)	(0)	(0)	(0)	(0)	(0)
Observations	2,675	2,675	2,675	2,675	2,675	2,675
R-squared	0.330	0.371	0.373	0.331	0.336	0.377

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1, the models are estimated on the sample without the biggest two cities.

Table 15. Estimation output of models that separate the "highway effect" for settlements on the west and east side of the Danube.

	1	2	3	4	5	6	7
Time	0.0947	0.0610	0.0923	0.0918	0.0612	0.0613	0.0761
	(0.144)	(0.306)	(0.158)	(0.177)	(0.308)	(0.317)	(0.323)
Treatment	-0.573**	-0.161**	-0.128	-0.137	-0.156*	-0.162**	-0.316***
	(0.0141)	(0.0355)	(0.110)	(0.103)	(0.0553)	(0.0493)	(0.00522)
West	0.107	0.0512	0.0399	0.0471	0.0298	-0.00849	-0.279*
	(0.662)	(0.467)	(0.620)	(0.636)	(0.742)	(0.928)	(0.0583)
Time*Treatment	*-0.242*	*-0.208*	*-0.239*	*-0.241*	*-0.209*	*-0.209*	*-0.237*
	(0.266)	*(0.335)*	*(0.271)*	*(0.269)*	*(0.333)*	*(0.334)*	*(0.278)*
Time*West	-0.144	-0.153*	-0.190**	-0.193**	-0.155*	-0.150*	-0.176*
	(0.118)	(0.0584)	(0.0200)	(0.0216)	(0.0561)	(0.0698)	(0.0556)
Treat*West	1.196***	0.427***	0.417***	0.415***	0.432***	0.459***	0.673***
	(2.70e-05)	(0.000159)	(0.00146)	(0.00121)	(0.000165)	(0.000181)	(1.46e-05)
Time*Treatment*West	*0.409**	*0.360*	*0.392**	*0.394**	*0.362*	*0.356*	*0.389**
	(0.0834)	*(0.112)*	*(0.0846)*	*(0.0829)*	*(0.110)*	*(0.117)*	*(0.0875)*
Type of settlement	-	yes	yes	yes	yes	yes	yes
Type of property	-	-	yes	yes	-	-	yes
Distance and Square of Distance from Budapest	-	-	-	yes	yes	-	yes
Distance and Square of Distance from Pécs	-	-	-	-	-	yes	yes
Constant	10.44***	10.03***	10.50***	11.14***	10.31***	10.25***	16.64***
	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Observations	5,250	5,250	5,250	5,250	5,250	5,250	5,250
R-squared	0.240	0.458	0.501	0.503	0.459	0.461	0.508

Note: Robust p-values in parentheses *** p<0.01, ** p<0.05, * p<0.1

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