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HOW MUCH DOES A MINUTE OF COMMUTING TIME COST?

AN EXAMINATION OF PROPERTY PRICES IN RELATION TO DISTANCE TO THE CITY CENTER IN PRAGUE, CZECH REPUBLIC

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ABSTRACT

This paper sets out to explore the strength of the relationship between the proximity of a property to the city center and its price. Buyers are willing to pay extra for apartments or houses closer to the city center, but the extent of this willingness remains largely unexplored. Our research question is: How much does a minute of commuting time influence the price of an apartment in Prague? In other words, with every minute of commuting time, how much more is paid for a house or an apartment closer to the central business district (CBD)?

Our analysis has found that on average, every minute of commuting time closer to the city center corresponds to an additional cost of CZK 43,390.45 for an average sized apartment in Prague. A regression analysis is graphically plotted in the Chart 1. We have also found that this relationship changes according to distance from the city center. For a commuting time of 1-20 minutes to the city center, the price increase is the highest: CZK 259,466.18 per minute. However, this figure is only CZK 55,809.01 for the interval of 21-40 minutes, and CZK 33,924.29 per minute for the interval of 41-55 minutes.

KEYWORDS

Property Prices, Proximity to the CBD, Cities, Prague

INTRODUCTION

Among the reasons that people and companies cluster together to form communities, towns and cities, economists most often mention economies of scale and agglomeration economies (Brueckner, 2011). The specialization of work and the scale of production result in more efficient and competitive production, and therefore lower prices. An automobile production company, for example, manufacturing 10 million cars per year is more efficient than a smaller company that produces only a few hundred. In fact, a town's existence can be dependent on a small number of large companies located in them, or even on the existence of only one large company. A good example of this is Wolfsburg, Germany, hometown of Volkswagen.

Agglomeration economies are a more elusive concept and are related to the economies of scale in many respects. They derive their added value from companies in close proximity to each other. They are thus able to create wider range of production chains, and enjoy a larger pool of workers able to highly specialize (and be secure in their future employment prospects). A small town may be able to host a hospital with a few doctors, but their field of specialization will be significantly restricted by the size of the population. On other hand, doctors in large cities can be highly specialized, you might find intestinal tract oncologists or brain surgeons there. Higher specialization results in a higher added value for these professions, a byproduct of being located in a large city (Brueckner, 2011). Technological clusters are another example of agglomeration economies – a pool of workers and companies are able to work more effectively at a larger scale. Put simply, frontier technological advancements are implemented faster when people and companies cluster in close proximity to each other.

These observations led to the development of the Urban Model, originally developed by William Alonso in 1964. The Urban Model describes the relationship between the distance from the city center (or central business district – CBD), and the price of a property (or "land rent," in the model's terminology). The model explains decreasing property prices with increasing distance from the city CBD. Properties in city centers are, predictably, more expensive than their counterparts in city suburbs (Alonso, 1964).

This relationship changes over time, as cities grow and/or become more or less congested. Larger cities reap more of the benefits of the economies of scale and agglomeration economies, and it can be observed that central locations in today's megacities are comparatively more expensive than in cities of a smaller size. Central London, Manhattan and the center of Tokyo regularly lead in high property prices (Cushman & Wakefield, 2016). Moreover, higher differences in property prices between the CBD and the suburbs can be observed in cities with insufficient infrastructure and long commuting times.

New technology has been envisioned to change this relationship between distance and property price. Extensive literature has been written about how ever cheaper transport and information flowing freely across borders will reshape the economy. An influential book by Frances Cairncross argues that proximity to other people, the main reason for the existence of highly concentrated cities, will lose its added value. The book envisions a much less concentrated economy where people are capable of living in a location of their choosing, working distantly, and communicating with ease with their colleagues around the world (Cairncross, 1997).

To a certain degree, this future has arrived. A new class of digital nomads has formed largely around young entrepreneurs and office workers, who may work for companies based in London or San Francisco, yet are personally based in Thailand or Bali (or change locations a few times a year according to their preference) (The Economist, 2008).

However, the phenomenon of being located in proximity to large offices has not yet come to an end. On the contrary, it seems to matter more than ever. Production has spread its supply chains around the world, but the office environment has not (Glaeser, 2011). Many international companies have established numerous local offices in many countries, but paradoxically, this was done to serve the local markets closely. Therefore, even in this case location still plays a significant role. It follows, then, that people are willing to pay ever higher price to be closer to each other (Avent, 2016). Agglomeration economies seem to play an ever-increasing role in the formation of the cities.

Aim of this paper is to explore the strength of the relationship between proximity and price. For all of the reasons mentioned above, people are willing to pay extra money for apartments or houses closer to the city center, but the extent of this willingness is often unexplored. The research question at hand is: How much does a minute of commuting time influence the price of an apartment in Prague? In other words, with every minute of commuting time, how much more is paid for a house or an apartment closer to the central business district (CBD)? Similar research was conducted by Carl Bialik (2016) into the case of New York City, but based solely on asking prices and without the theoretical underpinnings of the Urban Model. This paper conducts an analysis of the relationship between distance and property price with a wider theoretical foundation and with a data set of property prices adjusted to real transaction level.

METHODOLOGY

For this analysis, a data set of apartment asking prices has been collected. A data mining tool ParseHub was used to collect the asking prices from the biggest Czech real estate listing website, Sreality.cz. During a data mining session on 13th November 2016, 2542 property prices were collected, together with the size of the property and location (street name, land registry districts, city district), and number of rooms. After removing duplicate entries and those with missing information, the data set included 2038 unique properties for sale at the time (Sreality.cz, 2016).

This data set is sufficiently large and the properties listed are distributed across Prague land registry areas (95 out of 112 land registry areas included at least one listing), so an average property asking prices per square meter in each district has been calculated. Because asking prices deviate from real transaction costs, we then corrected them using average transaction costs, available at the city district level (Deloitte, 2016). As real transaction costs are published only at the city district level (Prague 1-10), the option of using only available transaction prices was not possible, as the analysis would be influenced by the districts' excessive size.

Instead, listed asking prices available at the land registry area were adjusted according to the real transaction prices. This combination of two resources of property prices gives us a data set reasonably close to the real transaction prices while maintaining the variety present among city neighborhoods.

The CBD was set at Můstek metro station, a commuting hub with the highest number of commuters in Prague (DPP, 2008). Commuting times were collected from Google Maps between 8 and 9am on Monday, 14th of November 2016, purposely chosen at the height of the commuting rush.

The relation between property prices and commuting time is examined based on the Alonso Urban model, which states that:

$$r = y - td, \tag{1}$$

where r represents rent form land, y signifies income, t the cost of traveling per unit of distance, and d distance. For simplicity, the urban model assumes all city inhabitants have the same income y, so the rent decreases with increasing distance from the CBD (Alonso, 1964).

I here conduct a similar analysis, but instead of rent r, I am going to find the relationship between property price p and distance, for our purposes measured in minutes of commuting time.

This examination is based on a regression analysis. In the first step, we found a simple linear regression in the following format:

$$p = a - bt, \tag{2}$$

where p is the property price per meter square, t is commuting time in minutes, a represents the price at commuting time zero, and b represents the slope of the regression and our research objective – the property price per square meter, increased per minute of commuting time. We can state that:

$$p_t = bs_{average} \tag{3}$$

By multiplying the stope b by the average size of an apartment in Prague at the time of the analysis $s_{average}$, we receive an average cost of property price increase equivalent to one minute closer to the CBD, p_t.

While the linear regression offers simple and telling information for our problem, it is not without drawbacks. Our rigorous analysis of the residuals has pointed to systematic errors these residuals display when simple linear regression is applied. This is a serious flaw in the analysis. For this reason, we have conducted a regression analysis of higher orders and along other mathematical functions, in order to find out that the systematic error disappears from the analysis when a logarithmic regression is used in combination with other so far excluded factors, such as existence of large part (of a minimum size of 80ha), which is included linearly as a dummy variable. This confirmed that the logarithmic regression analysis is the most suitable for our problem at hand, even though it lacks the simplicity of a simple linear regression.

We can adjust our regression formula to:

$$p=a - b \log(t) + c \, dummy\,(green), \tag{4}$$

where p is the property price per meter square, t is the commuting time in minutes, dummy (green) is a dummy variable representing a proximity of a large park, a represents the price at commuting time zero, b is the constant representing the slope of the logarithmic regression and c is the constant representing the slope associated with the proximity of a large park.

Our research objective – to determine the relationship between property price and commuting time – is more complicated when using a logarithmic regression, as the slope changes with the distance from the CBD.

ANALYSIS

The dataset of average asking property prices per meter square at the land registry level, real transaction prices at the city district level, and property prices per land registry level adjusted for the difference between asking and real prices, are included in Appendix 1. The same appendix also includes commuting times from each land registry area to the CDB.

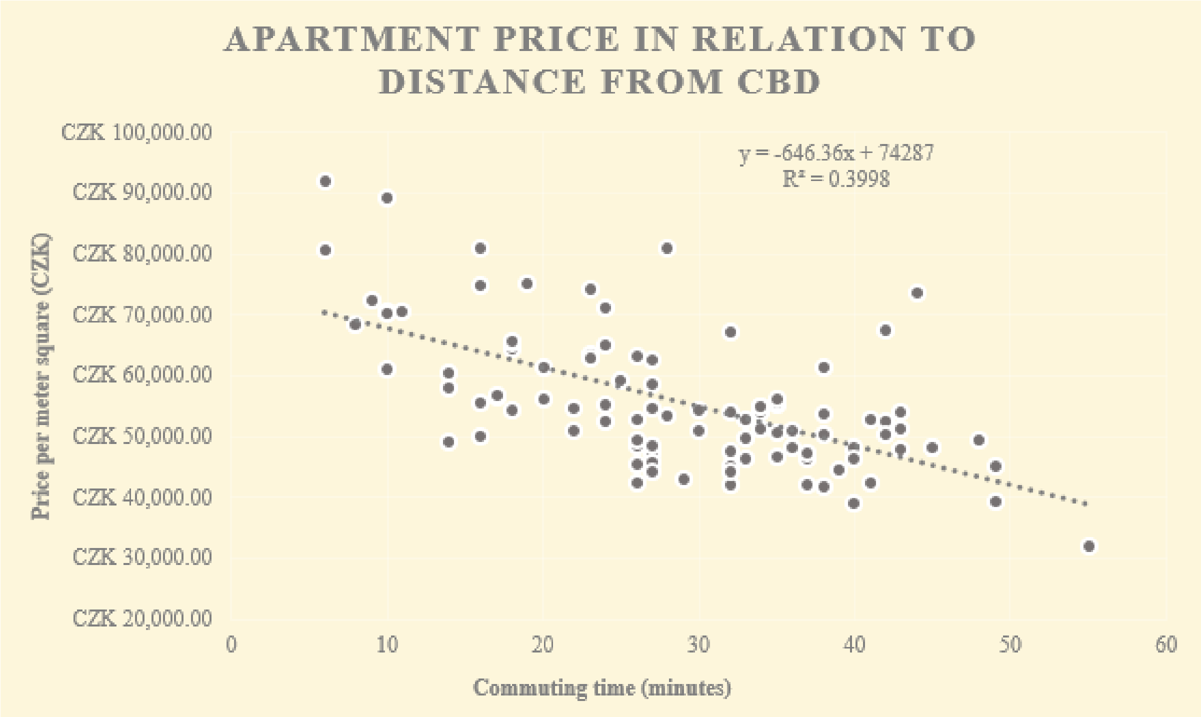
A simple linear regression analysis was conducted after removing 4 outliners with a standardized residual higher than 3, as per Appendix 2. The result is the following relationship:

$$p = 74287\text{-}646.36t$$

$R^2 = 0.3998$

This relationship is plotted in the Figure 1.

Fig. 1 – Linear Regression chart



The slope in this equation, *-646,36t* is equivalent to the price per square meter decrease associated with one extra minute of commuting time to the CBD. Substituting in the formula (3), *t* with an average flat size in Prague of 67.13 square meters (Cenová Mapa, 2016), we find:

$$p_t = - CZK\ 646.36 * 67.12 =- CZK\ 43,390.45$$

In conclusion, one extra minute of commuting time saves CZK 43,390.45 of the price of an average apartment in Prague.

As stated above, linear regression has a number of drawbacks. The high systematic error in the residuals resulted in the need to remove of 4 outliners, especially in the areas close to the CBD. This is apparent from the coefficient *a*, which in this analysis is only CZK 74,287, and does not truly represent the mean property price per meter square in the CBD. The systematic error in regression residuals has also resulted in a comparatively smaller value of R2.

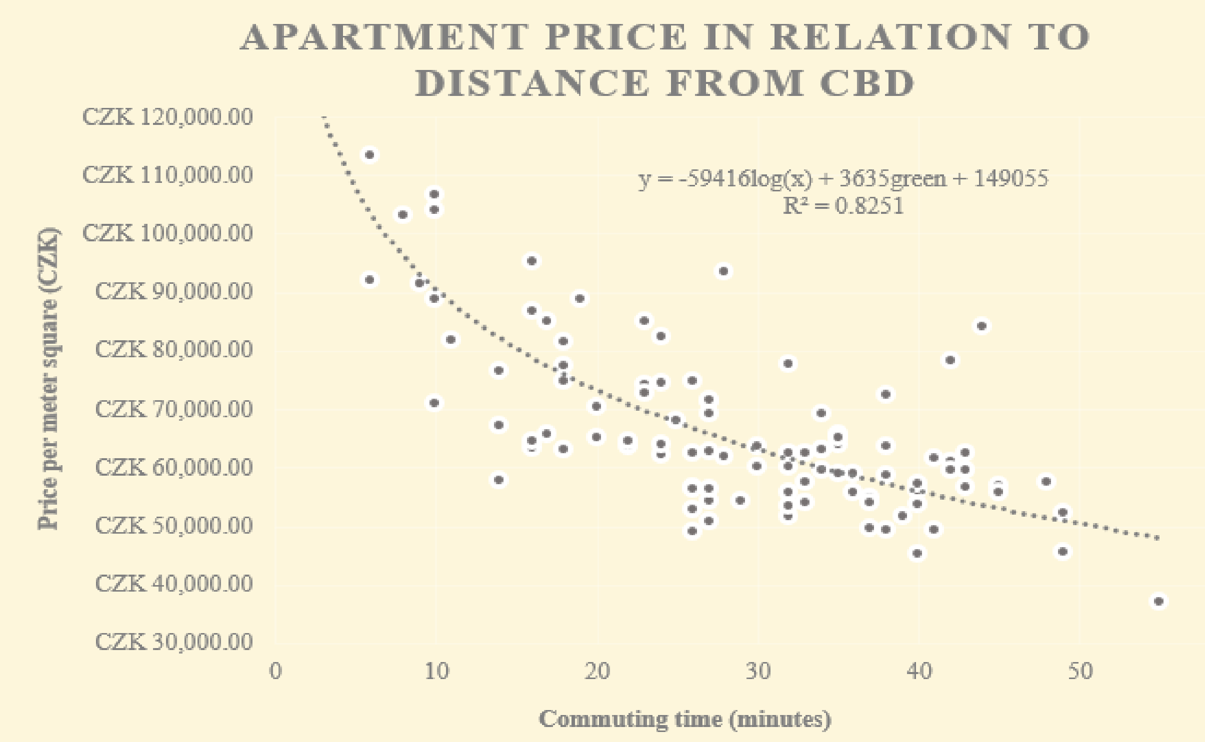
A logarithmic regression with a linear inclusion of a proximity of a larger park (minimum size of 80ha) was conducted, as per Appendix 3, and I have found the following relationship:

$$y = -59416 log(t) + 3635 green + 149055$$

$R^2 = 0.8251$

This relationship is graphically illustrated in the Figure 2. The l-shaped curve of the plotted relationship signifies a very steep slope in the proximity of the CBD, which is gentler with increasing distance from the city center.

Fig. 2 – Logarithmic regression chart



To simplify our interpretation of this relationship, we can split the distance between the city districts and the CBD according to commuting time into 3 intervals (1-20, 21-40 and 41-55 minutes from the CBD, with 55 minutes being the longest commuting time for any of the land registry areas). We can then calculate linear increases in price.

Interval 1-20 minutes of commuting time: slope CZK 3,865.13

Interval 21-40 minutes: slope CZK 831.36

Interval 41-55 minutes: slope CZK 505.35

Substituting in formula (3), we find that with an average flat size in Prague of 67.13 square meters (Cenová Mapa, 2016).

Interval 1-20 minutes of commuting time: CZK 259,466.18 per minute of commuting time

Interval 21-40 minutes: CZK 55,809.01 per minute of commuting time

Interval 41-55 minutes: CZK 33,924.29 per minute of commuting time

The proximity of a large park increases the price per meter square by CZK 3,635.26. This increase translated to CZK 244,034.71 for an average apartment in Prague.

CONCLUSION

Our analysis has found that on average, every minute of commuting time closer to the city center corresponds with an additional cost of CZK 43,390.45 for an average-sized apartment in Prague. A regression analysis is graphically plotted in the Chart 1. We have also found that this relationship changes with the distance from the city center. For a commuting time of 1-20 minutes to the city center, the price increase is the highest: CZK 259,466.18 per minute. However, this cost drops to CZK 55,809.01 for the interval of 21-40 minutes, and CZK 33,924.29 per minute for the interval of 41-55 minutes from the central business district.

The proximity of a large park increases the price per meter square by CZK 3,635.26. This increase translates to CZK 244,034.71 for an average apartment in Prague.

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APPENDICES

Appendix 1 – Dataset

City district (land registry)	Average of Price per m2	Deloitte real transaction index (q2 2016)	Distance to CBD	Distance Log	Greenery	Price adjusted
Praha 1	**CZK 131,868.96**	**CZK 107,300.00**				**CZK 107,300.00**
Josefov	CZK 185,272.13		3	0.477121	0	CZK 150,753.44
MaláStrana	CZK 141,291.69		14	1.146128	1	CZK 114,967.15
NovéMěsto	CZK 113,167.57		6	0.778151	0	CZK 92,082.93
StaréMěsto	CZK 166,042.84		1	0	0	CZK 135,106.83
Praha 10	**CZK 65,992.91**	**CZK 56,600.00**				**CZK 56,600.00**
DolníMěcholupy	CZK 54,008.01		33	1.518514	0	CZK 46,320.94
Dubeč	CZK 55,924.80		40	1.60206	1	CZK 47,964.90
HorníMěcholupy	CZK 58,729.61		38	1.579784	1	CZK 50,370.50
Hostivař	CZK 62,918.18		34	1.531479	1	CZK 53,962.90
Kolovraty	CZK 37,107.44		55	1.740363	0	CZK 31,825.86
Malešice	CZK 56,493.55		26	1.414973	0	CZK 48,452.71
Michle	CZK 52,885.17		26	1.414973	0	CZK 45,357.91
Petrovice	CZK 49,238.98		41	1.612784	1	CZK 42,230.69
Pitkovice	CZK 61,039.40		42	1.623249	1	CZK 52,351.53
Štěrboholy	CZK 61,639.34		41	1.612784	1	CZK 52,866.09
Strašnice	CZK 63,703.16		22	1.342423	0	CZK 54,636.16
Uhříněves	CZK 59,599.77		43	1.633468	1	CZK 51,116.81
Vinohrady	CZK 104,068.66		10	1	0	CZK 89,256.35
Vršovice	CZK 74,091.99		23	1.361728	0	CZK 63,546.32
Záběhlice	CZK 63,466.15		30	1.477121	1	CZK 54,432.88
Praha 2	**CZK 104,614.54**	**CZK 69,300.00**				**CZK 69,300.00**
NovéMěsto	CZK 103,159.91		8	0.90309	0	CZK 68,336.40
Nusle	CZK 71,305.56		27	1.431364	0	CZK 47,235.07
Vinohrady	CZK 106,653.26		10	1	0	CZK 70,650.51
Vyšehrad	CZK 85,000.00		17	1.230449	0	CZK 56,306.70
Praha 3	**CZK 81,338.40**	**CZK 64,300.00**				**CZK 64,300.00**
Strašnice	CZK 64,382.80		22	1.342423	0	CZK 50,896.18
Vinohrady	CZK 88,752.38		10	1	0	CZK 70,160.93
Vysočany	CZK 63,220.79		16	1.20412	0	CZK 49,977.59
Žižkov	CZK 81,316.08		18	1.255273	0	CZK 64,282.36

City district (land registry)	Average of Price per m2	Deloitte real transaction index (q2 2016)	Distance to CBD	Distance Log	Greenery	Price adjusted
Praha 4	**CZK 63,766.16**	**CZK 53,900.00**				**CZK 53,900.00**
Braník	CZK 74,668.33		26	1.414973	0	CZK 63,115.34

Chodov	CZK 54,819.80		37	1.568202	1	CZK 46,337.86
Cholupice	CZK 56,567.16		43	1.633468	1	CZK 47,814.86
Háje	CZK 54,236.14		27	1.431364	1	CZK 45,844.50
Hodkovičky	CZK 65,489.59		35	1.544068	0	CZK 55,356.77
Kamýk	CZK 57,133.93		40	1.60206	0	CZK 48,293.93
Komořany	CZK 65,674.16		35	1.544068	1	CZK 55,512.78
Krč	CZK 62,087.37		24	1.380211	0	CZK 52,480.95
Kunratice	CZK 63,693.21		38	1.579784	1	CZK 53,838.33
Lhotka	CZK 49,409.89		38	1.579784	0	CZK 41,764.99
Libuš	CZK 72,411.50		38	1.579784	1	CZK 61,207.70
Michle	CZK 62,515.12		26	1.414973	0	CZK 52,842.53
Modřany	CZK 62,492.11		33	1.518514	1	CZK 52,823.07
Nusle	CZK 69,253.74		27	1.431364	0	CZK 58,538.52
Písnice	CZK 59,601.97		42	1.623249	1	CZK 50,380.11
Podolí	CZK 88,843.09		19	1.278754	0	CZK 75,096.92
Šeberov	CZK 49,598.43		37	1.568202	0	CZK 41,924.35
ÚjezduPrůhonic	CZK 56,870.03		45	1.653213	0	CZK 48,070.87
Záběhlice	CZK 60,171.06		30	1.477121	0	CZK 50,861.15
Praha 5	**CZK 73,648.71**	**CZK 64,400.00**				**CZK 64,400.00**
Břevnov	CZK 85,018.83		23	1.361728	1	CZK 74,342.28
Hlubočepy	CZK 67,872.32		25	1.39794	1	CZK 59,349.00
Jinonice	CZK 70,292.26		20	1.30103	1	CZK 61,465.05
Košíře	CZK 74,368.64		24	1.380211	1	CZK 65,029.52
MaláStrana	CZK 138,775.61		14	1.146128	1	CZK 121,348.34
Motol	CZK 50,633.21		27	1.431364	1	CZK 44,274.76
Radlice	CZK 74,714.21		18	1.255273	1	CZK 65,331.69
Radotín	CZK 53,944.16		37	1.568202	1	CZK 47,169.92
Řeporyje	CZK 51,489.82		32	1.50515	1	CZK 45,023.79
Slivenec	CZK 84,016.43		44	1.643453	1	CZK 73,465.76
Smíchov	CZK 92,079.13		6	0.778151	0	CZK 80,515.95
Stodůlky	CZK 62,622.27		27	1.431364	1	CZK 54,758.25
VelkáChuchle	CZK 71,493.12		27	1.431364	1	CZK 62,515.10
Zbraslav	CZK 56,435.50		26	1.414973	1	CZK 49,348.40
Zličín	CZK 62,907.23		34	1.531479	0	CZK 55,007.42

City district (land registry)	Average of Price per m2	Deloitte real transaction index (q2 2016)	Distance to CBD	Distance Log	Greenery	Price adjusted
Praha 6	**CZK 74,379.23**	**CZK 64,300.00**				**CZK 64,300.00**
Břevnov	CZK 72,739.11		23	1.361728	1	CZK 62,882.13
Bubeneč	CZK 86,704.77		16	1.20412	1	CZK 74,955.28
Dejvice	CZK 81,656.46		11	1.041393	1	CZK 70,591.07
Hradčany	CZK 70,776.12		10	1	0	CZK 61,185.15
Liboc	CZK 93,500.15		28	1.447158	1	CZK 80,829.82
PředníKopanina	CZK 57,600.97		33	1.518514	1	CZK 49,795.38
Řepy	CZK 53,694.38		40	1.60206	0	CZK 46,418.18
Ruzyně	CZK 61,922.65		28	1.447158	1	CZK 53,531.42
Střešovice	CZK 82,201.39		24	1.380211	0	CZK 71,062.17
Suchdol	CZK 56,209.44		27	1.431364	1	CZK 48,592.42
Veleslavín	CZK 65,670.20		17	1.230449	1	CZK 56,771.14
Vokovice	CZK 65,038.91		20	1.30103	1	CZK 56,225.39
Praha 7	**CZK 80,420.02**	**CZK 68,300.00**				**CZK 68,300.00**
Bubeneč	CZK 95,119.53		16	1.20412	1	CZK 80,784.17
Holešovice	CZK 77,367.50		18	1.255273	0	CZK 65,707.52
Libeň	CZK 57,777.78		14	1.146128	0	CZK 49,070.15
Praha 8	**CZK 74,179.98**	**CZK 58,700.00**				**CZK 58,700.00**
Bohnice	CZK 58,970.70		35	1.544068	1	CZK 46,664.62
Čimice	CZK 53,269.85		32	1.50515	1	CZK 42,153.43
Ďáblice	CZK 63,900.72		35	1.544068	1	CZK 50,565.83
DolníChabry	CZK 69,209.19		34	1.531479	1	CZK 54,766.53
Karlín	CZK 91,483.95		9	0.954243	0	CZK 72,392.96
Kobylisy	CZK 54,299.67		29	1.462398	1	CZK 42,968.34
Libeň	CZK 76,425.42		14	1.146128	0	CZK 60,476.86
Střížkov	CZK 55,842.70		32	1.50515	0	CZK 44,189.37
Troja	CZK 60,027.55		32	1.50515	1	CZK 47,500.92

City district (land registry)	Average of Price per m2	Deloitte real transaction index (q2 2016)	Distance to CBD	Distance Log	Greenery	Price adjusted
Praha 9	**CZK 60,765.89**	**CZK 52,500.00**				**CZK 52,500.00**
Běchovice	CZK 62,519.69		43	1.633468	1	CZK 54,015.23
Čakovice	CZK 55,707.54		45	1.653213	0	CZK 48,129.73
ČernýMost	CZK 48,879.22		26	1.414973	0	CZK 42,230.25
DolníPočernice	CZK 78,246.38		42	1.623249	1	CZK 67,602.65
Hloubětín	CZK 62,904.84		18	1.255273	0	CZK 54,348.00
HorníPočernice	CZK 59,433.31		34	1.531479	0	CZK 51,348.69
Hrdlořezy	CZK 77,718.09		32	1.50515	0	CZK 67,146.22
Kbely	CZK 51,645.59		39	1.591065	0	CZK 44,620.32
Klánovice	CZK 45,431.47		49	1.690196	1	CZK 39,251.50
Kyje	CZK 65,070.15		35	1.544068	0	CZK 56,218.76
Letňany	CZK 58,932.74		36	1.556303	0	CZK 50,916.21
Libeň	CZK 67,237.80		14	1.146128	0	CZK 58,091.55
Miškovice	CZK 57,351.42		48	1.681241	0	CZK 49,550.00
Prosek	CZK 63,859.95		24	1.380211	0	CZK 55,173.18
Satalice	CZK 55,789.47		36	1.556303	0	CZK 48,200.52
Střížkov	CZK 62,556.95		32	1.50515	0	CZK 54,047.42
ÚjezdnadLesy	CZK 52,292.40		49	1.690196	1	CZK 45,179.14
Vinoř	CZK 45,237.17		40	1.60206	0	CZK 39,083.63
Vysočany	CZK 64,396.51		16	1.20412	0	**CZK 55,636.75**

Appendix 2 – linear regression

Regression Statistics	
Multiple R	0.632292955
R Square	0.39979438
Adjusted R Square	0.393669833
Standard Error	8761.535175
Observations	100

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5010985216	5010985216	65.2773783	1.71675E-12
Residual	98	7522920864	76764498.61		
Total	99	12533906080			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	74286.62731	2467.240975	30.10919001	2.51321E-51	69390.46789	79182.78673	69390.46789	79182.78673
Distance to CBD	-646.364576	80.00114358	-8.079441707	1.71675E-12	-805.1242418	-487.6049103	-805.1242418	-487.6049103

Appendix 3 – Logarithmic regression with a dummy variable

Regression Statistics	
Multiple R	0.825182264
R Square	0.680925769
Adjusted R Square	0.67441405
Standard Error	9930.802848
Observations	101

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	20625421579	10312710790	104.5692801	4.90563E-25
Residual	98	9664842831	98620845.21		
Total	100	30290264410			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	149054.7708	5739.22573	25.97123337	9.93033E-46	137665.4642	160444.0775	137665.4642	160444.0775
Distance Log	-59416.46516	4178.618097	-14.21916619	1.46892E-25	-67708.79678	-51124.13355	-67708.79678	-51124.13355
Greenery	3635.255696	2074.375381	1.752457983	0.082822719	-481.2747368	7751.786129	-481.2747368	7751.786129

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