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Master's Thesis

IMPACT OF NEW METRO LINE ON OFFICE PROPERTY VALUES IN WARSAW:

A QUANTITATIVE APPROACH

MACIEJ ROSTROPOWICZ
Supervisor: dr. Xiaolong Liu

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Abstract

Metro construction has reshaped Warsaw and the impact on all real estate sectors has been considerable. In the west of the city a whole new office district emerged, while many other areas in the city center significantly improved its accessibility. In the empirical literature the effect of underground proximity on real estate prices is ambiguous, however according to the theoretical framework a positive effect of the vicinity should be present due to increase in accessibility which entails growth of attractivity of office properties. The dataset for the study comes from Polish branch of a global real estate consulting company and is of special interest due to scarcity of studies performed in the local context of Central and Eastern Europe. This study uses hedonic model and difference-in-differences approach to find that headline office rents has been significantly positively impacted by metro construction, even before the construction was finished. The model controls for number of lease and properties attributes (such as building size, class and age) and for time and neighborhood fixed effects. The spatiotemporal effects are shown as the research investigates both impact of distance to a metro station and anticipation effect in time. The spatial effect identified in the study is relatively limited, as positive effect of metro line construction after the end of the construction disappears at 275 m from the nearest metro station, however the effect varies over time and anticipation effect is identified. The results may be of interests to developers, investors and policy makers.

Keywords: real estate, office, transportation, difference-in-differences

Title	Impact Of New Metro Line On Office Property Values In Warsaw: A Quantitative Approach
Author	Maciej Rostropowicz
Studentnumber	S3767957
E-mail	m.rostropowicz@student.rug.nl
Supervisor	dr. Xiaolong Liu

Contents

Table of figures

List of tables

1. INTRODUCTION

Urban transport systems remain a crucial contributor to urban economic growth. They significantly increase mobility and accessibility, while reducing congestion, accidents, pollution and CO2 emissions. It impacts daily life of millions of people in Europe, significantly shaping the spatial form of modern cities. (European Commission, 2017). Construction of the new line can be a significant expenditure for a municipal budget (Majszyk, 2013). What is more, costs and benefits coming from the new line often accrue to different parties (Barends & van der Schrier, 1994). Therefore, an in-depth research on different impacts of the line is needed to better understand the significance of the investment and to assess it's real impact on commercial markets. This is especially important due to the further plans of underground network development. What is more, the further growth of underground mass rapid transport has important environmental implications. Warsaw was 28th most congested city in the world in 2018 (INRIX, 2018). According to the long term strategy of the municipality, the further development of transport system is supposed to improve the situation, therefore limiting greenhouse gasses emissions and improving quality of life in the city (Warsaw Municipality, 2011).

The policies on land use and transport are interconnected. Land uses are partially influenced by land value which in turn is supported and stimulated by the web of accessibility created by transport (Banister, et al., 2007). As such important factor, transportation system plays a crucial role in shaping property prices, and metro line construction is a significant external shock to any real estate market. The change of property price is mostly the effect of changing accessibility to a given property. With new metro station in the vicinity of a commercial property the access to a property is easier to all individuals connected to the transportation system. This facilitates the economic activity of companies located in the property, both in terms of access to customers and to the workforce (Weinberger, 2001). Theoretically the car traffic in the surroundings may also relatively diminish, as at least some of the commuters will choose underground over cars (Peftitsi, et al., 2020).

Within the literature focusing on interdependencies between land use and transportation two strands can be identified. The first approach compares how different properties are used, in terms of density, type of use, intensity and the spatial relations between the plots and transportation system. This is the land use approach.

The second approach, called property value approach, focuses on research questions about the relation between value of a property and the transportation system. Both approaches use location theory as a conceptual framework for the research (Vessali, 1996). The location theory refers to body of theoretical models originating from work of Von Thünen (1863) and furtherly developed by bid-rent analysis introduced by Alonso (1964). While studies differ from one another, especially in terms of researched type of properties (residential or commercial), type of transportation system (rail, underground or highways) and functional forms, the most common methodology is hedonic property pricing, introduced by Rosen (1974).

Most of the research within this field use datasets of residential properties to study spatial relations between real estate and urban transport. The reason behind relative scarcity of commercial property analysis is the difficulty of collecting the necessary databases (Seo, et al., 2019). Adding to relative lack of commercial property research, in general no consistent relationship between proximity to rail stations and property values is recorded (Debrezion, et al., 2007). This can be explained by highly localized context of every study (Henneberry, 1998). However, meta-analysis proves that generally commuter railways and commercial property type are expected to have positive impact on property prices (Debrezion, et al., 2007). The prices are usually measured by either asking rents (Bollinger, et al., 1998; Landis & Loutzenheiser, 1995; Ryan, 2005) or effective rents (Sivitanidou, 1995; Weinberger, 2001). Most of the significant studies in the field use datasets from the US (Cambridge Systematics, Inc., 1998; Vessali, 1996), which relatively limits its application, considering specific spatial context present in the United States. Lack of attention paid to European office markets and commercial properties are identified literature gaps. European studies, use mostly residential data to analyze the local context and are limited in numbers (Agostini & Palmucci, 2008; Ahlfeldt, 2013; Celik & Yankaya, 2006; Henneberry, 1998; Trojanek & Gluszak, 2018). Temporal effects are studied to better understand the change brought by new infrastructure (Golub, et al., 2012; Debrezion, et al., 2007). In Polish context, Trojanek and Gluszak (2018) have analyzed spatial and temporal impact of M2 metro line in Warsaw on residential property prices. The study found that new metro line impacts property prices of adjacent apartments before the construction of the line is finished.

The above review proves that there are identified gaps in research, especially in terms of impact of new metro line on commercial properties and European context. The studies located in Europe are relatively scarce, and the results of the existing studies are mixed. The theoretical model of general impact of transportation amenities on rents is well framed, however to the author's best knowledge, the empirical research using commercial property data was never done before in the developing CEE market context. This may provide new insights into understanding the role of infrastructure investments in transition economy, such as economy of Poland (Turala & Sikora-Fernandez, 2014) and into an economy facing different challenges than mature western markets (Trojanek & Gluszak, 2018). What is more, Warsaw lacks development plan, and therefore the real estate development is mainly shaped by market forces. Due to that, the results of the study may prove to be different than previous studies on the matter conducted in Western countries with organized planning system and developed market institutions.

The research aim of this study is to address the gaps in scientific literature and examine how the commercial attractiveness of office space is impacted by new, adjacent metro stations and therefore, how the office rents change as a result of the increased accessibility. The central research question therefore is what the impact of increased transport accessibility on commercial property rents is.

In order to answer the main research question, this study utilize hedonic property pricing model introduced by Rosen (1974). The findings of this study may be useful for capital investors considering investing in assets in the metro stations vicinity and for urban and policy planners making decision on public infrastructure investments. While the general conclusion coming from theoretical literature is that metro station close to the office building may positively impact its performance, the specific magnitude of this influence is unknown and difficult to assess without a rigorous statistical analysis due to the changing landscape of Warsaw office market.

The remainder of this paper is organized as follows. Section 2 describes the existing literature and hypotheses of the study. Section 3 presents methodology and conceptual model of the study. In this section the dataset, as well as empirical model, are presented and described. In section 4 the results of the study are presented and the sensitivity analysis is performed. Section 5 presents discussion and conclusions of the study.

2. LITERATURE REVIEW

In order to determine the impact of metro line on office rents other factors impacting the rents must be understood. The office rents are determined by multiple, different factors. In a simple model, rents are prices, determined by supply and demand of office space. Assuming that in the short run the supply is constant, rent must be a function of demand (DiPasquale & Wheaton, 1992). Therefore, this section investigates what are the most important factors impacting the demand on office space.

In general context, the growth of transportation system serves as a basic mechanism of increasing accessibility from and to certain locations. The increased accessibility serves as an important factor shaping demand on office space in a given location. One of the major aspects shaping spatial patterns in urban framework is transportation system (Jacobs, 1961). As different means of transportations change accessibility to other parts of the city, in particular to the city center, this in turn changes the bid-rent curves. The higher accessibility to the central market entails appreciation of prices in the vicinity of access point, such as metro station. The analysis of accessibility is usually performed by including proximity factor into the examination. This is generally understood simply as a distance to given point or time required to get to that point. The growth in accessibility is then reflected in change of value of real estate. In the earliest works in this matter Von Thünen (1863) explains how farmland is priced, depending partially on its accessibility to a central market. This model was furtherly developed by bid-rent analysis introduced by Alonso (1964).

The researched property type is of great importance to the results as the office sector may value the vicinity of a transportation hub even more than the residential sector (Duncan, 2011). This may be caused by two different factors. First, high office accessibility may be treated as an amenity and be used as a recruitment and retention tool for a company (Dobrian, 1999) or as a benefit for the customers of the company (Seo, et al., 2019). Secondly, the transportation hubs are usually gathering points, which naturally attract commercial activity (Debrezion, et al., 2007). What is more, the transportation hubs produce number of negative externalities, namely noise, pollution, traffic. However it is important to remember, that while nodes of transportation system (stations) produce sum of positive and negative externalities, the links in case of above-ground systems are only negative (Seo, et al., 2019). The negative externalities may be valued differently, depending on a property type.

Empirical studies do not show consistent results in terms of rail transportation effects on property values (measured by both rents and prices) (Debrezion, et al., 2007). Nelson (1999) concludes that the evidence on positive impact of proximity to rail stations on property markets value is "surprisingly sketchy". Weinberger (2001) tested the effect of light rail on effective rents in commercial properties and found out that after controlling of different factors (such as building physical properties, location and economic cycle) properties within 0.8 km had lease agreements with higher effective rents than other properties in the tested area. However, Bollinger, et al. (1998) control for lease term, property characteristics and location attributes and find negative effects of proximity of rail stations on asking office rents, probably due to perception of unsafety of the stations. Pagliara & Papa (2011) performed the study in European context and found significant property value increase in all property types, including offices. The inconsistency proves how important local context is in studies revolving around transportation system impact on property values. What is more, due to relative lack of studies in context other than American it is difficult to assess the impact of underground system, not light or heavy rail systems popular in the US. The difference in effect on property values comes from supposed lack of negative externalities of underground links, contrary to light rail systems, where links produce number of negative effects (Seo, et al., 2019). Furthermore, the European context of study entails different approach to the impact of highways, as urban fabric of European cities is usually less car-oriented than its American counterpart (Victoria Transport Policy Institute, 2002) . By using large pool of high-quality data new insights on the effect of new metro line on office rents in European context may be gained.

The accessibility is perceived both as an attractive quality of an real estate and direct factor shaping the price of products produced on the land and therefore it has positive impact on the price of land itself (McCann, 2001). In modern studies accessibility is measured in a diverse manner. Some studies focus on actual (Euclidean) distance (Golub, et al., 2012), while other create bands around stations. Seo, et al. (2019) came to the conclucion that impacts of rail are captured within 300 m, which corresponds to about 4 minutes by foot. Cervero and Duncan (2002) came to similar conclusions, finding positive impact on values of commercial land values, but only on properties located within 0.25 mi from rail stations.

This study investigates not only the impact of metro construction in spatial dimension but also the change of this impact in temporal dimension. In theory prices in an efficient market should reflect all anticipated events, so the construction will not have any temporal impact on prices, as it is anticipated and reflected in prices. Lease agreements are usually long-term contracts so by their nature they must account for future events and changes. For example, Agostini and Palmucci (2008) finds that it is the gradual unveiling of the details of new metro line that entails appreciation of house prices. Similarly, McMillen and McDonald (2004) theorize, that the process of price adjustment starts at the moment of project announcement and continues until the project is finished. Then prices should remain constant *ceteris paribus* or be a subject to another adjustment process if the anticipated results of the construction were either over- or under-estimated. However, the assumption of full anticipation is unrealistic. A public infrastructure projects in Poland are subject to major political and financial risks, so the functionality and timing of the investment is uncertain. What is more, the announcement date of line details is very difficult to define, as plans for the metro system in Warsaw exists for a very long time and are sometimes arbitrary changed. Therefore, until the construction is certain, the inclusion of future effects seems unlikely. Finally, the real estate market is not fully efficient (Evans, 2004) so it may only partially incorporate the news of underground construction. Therefore, the price adjustment process can exhibit a range of patterns (Trojanek & Gluszak, 2018).

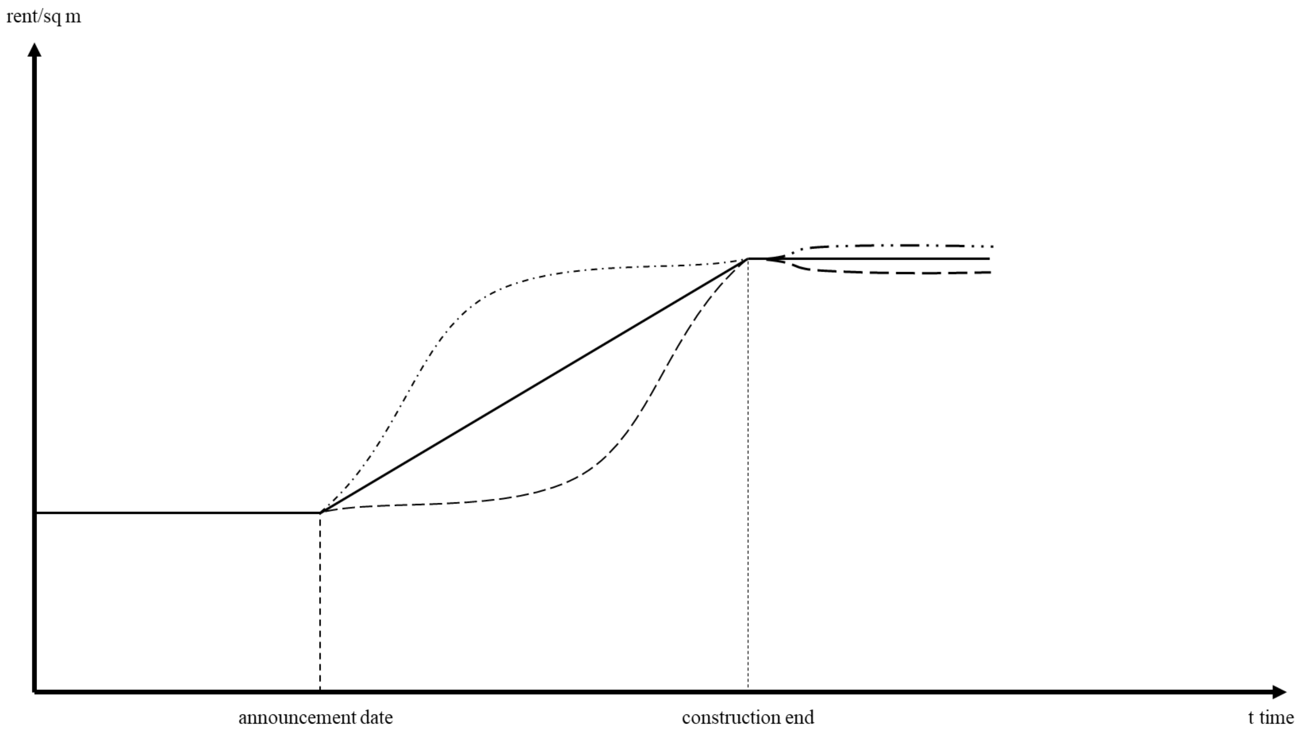


Figure 1 Possible price adjustment patterns and fluctuations in time. *(Trojanek & Gluszak, 2018)*

The other factor shaping office rents is the supply. While this is not a focus of this study, a short discussion is presented in order to explain the choice of some dependent variables. In a real estate market, the assumption of constant supply in the short term is in place, however it is vital to acknowledge that existing stock is not homogenous (Evans, 2004). While main source of the heterogeneity is fixed location of a property, there is number of non-location specific characteristics that add to differences among buildings. For example, large floorplates may be of value for tenants as they facilitate physical interactions between employees, which leads to knowledge spillover effects. That in turn, is one of the main motivations for renting a space in a modern office building (Gottmann, 1966). The differences are one of the reasons for real estate market inefficiency, therefore significantly impacting the prices. In the existing literature, buildings' characteristics, such as total size, the building condition (or class) and construction year were controlled for (Seo, et al., 2019). Finally, the prices are dependent on negotiation power of the parties involved in the process of renting an office space (Evans, 2004). Many factors relating to the discussion in this chapter and impacting the office rents were identified as model variables in the literature focused on creating models of different office markets (Clapp, 1980; Brennan, et al., 1984; Nappi-Choulet, et al., 2007; Dunse & Jones, 1998; Mills, 1992).

On the basis of above examination three hypotheses three hypotheses were formulated:

1. Nodes of transportation – new metro stations have a significant positive impact on the value of office properties located in their vicinity observable after the line is opened.
2. The positive impact is mostly observable within direct walking distance, that is from 300 meters (Seo, et al., 2014) to 600 m (Weinberger, 2001) or 4 to 10 minutes on foot.
3. There is an anticipation effect of the development of the underground line. The property prices gradually increase before the line and the stations are opened.

3. DATA & METHOD

3.1 Conceptual framework

In order to determine the impact of an underground station on commercial attractiveness of an office building the control variables must be identified. By reviewing previous literature in the field in section 2 the conceptual model of the study was created and is presented on *figure 2*.

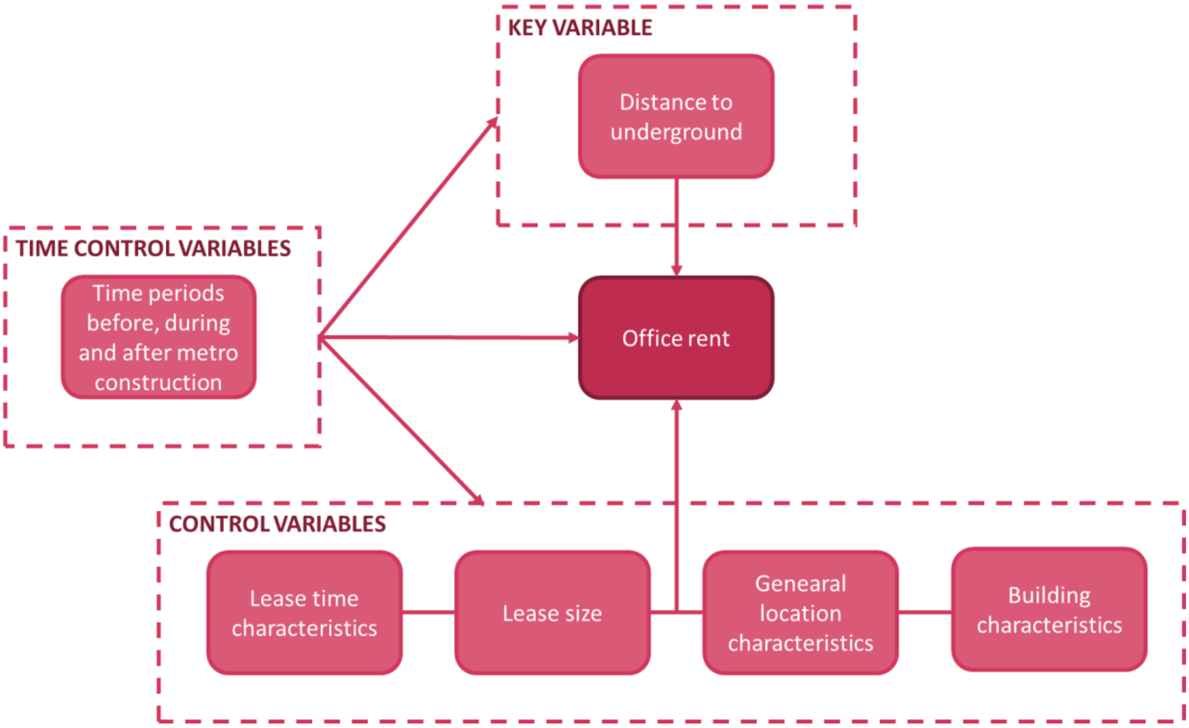


Figure 2 The conceptual model of the study. Source: *Own work*.

Office rent is the explained variable. In this study headline rent is used as a dependent variable. This is a major contribution to the literature, as usually this type of data is unavailable and therefore the asking rents are used (Dunse & Jones, 1998). However, as this is not an effective rent, which could significantly change the rent level, this creates one of studies limitation (Mills, 1992). Effective rents are difficult to obtain and properly calculate, as even within available rent rolls, the property managers tend to hide consumed incentives, such as rent-free periods or fit-out contribution. As discussed in section 2, number of factors may impact the rents. The main variable of interest in this study is distance to a node of transportation i.e. to an underground station. The distance is measured by using Euclidian metric i.e. as a straight line between the station and the building. Number of other factors shape office rents and they constitute the group of control variables. Among them lease time characteristics serves double purpose. Firstly, the length of lease agreement impact the prices directly, by determining the attractivity and risk profile of the offer for both tenant and landlord, secondly three time periods of the study (time before the construction of the metro line, during its construction and after the construction) were designated by using the start date of every lease agreement. This decision comes from data limitation – ideally a lease signature date should be used to determine the moment of rent determination, however this date is not always available. Lease size is understood as Gross Lease Area in squared meters. While the rents are measured per square meter, the size of leased area is an important characteristic of an agreement, determining negotiation power of both parties, therefore it is included in the model of this study. General location characteristics is a variable describing local office market by using office zones. Building characteristics describe the quality of the building, which may highly impact the rent. This is included in number of variables, like the overall building size (GLA), building age at lease start and the class of a building.

To incorporate spatial nonstationarity into the model the difference-in-difference approach is adapted (Heckert, 2015). In case difference-in-differences approach this work draws upon methodology introduced by Schwartz, et al. (2006), van Duijn, et al. (2016) and Trojanek & Gluszak (2018). This approach helps to account for potential endogeneity problem, arising from not random, but rather designated location of underground stations (Trojanek & Gluszak, 2018). This approach also allows multiple-period comparison (Trojanek & Gluszak, 2018). As mentioned before three time periods of the study were introduced. In order to control for the number of unknown spatiotemporal effects and separate the impact of new underground line two groups are designated, i.e. the treatment and the control group. Similarly to Schwartz, et al. (2006) this study controls for previous trends of the price changes. This comes from the assumption that prior trends in prices in the treatment group must be in part caused by the anticipation effect, even many years before the construction start, as the plans of the construction were known for at least half a decade before the proccess started (Warsaw City Council, 2005). Drawing on reviewed literature, properties lying within 400 meters from each new metro station were selected as the treatment group.

3.2 Empirical model

The conceptual model described in section 3.1 serves as a basis for creating the statistical model of this study. As mentioned in the literature review, the most common methodology to determine the price effect of proximity to transportation nodes is hedonic property price model. The hedonic model can be described as a way of decomposing prices into measurable prices and quantities in order to allow for comparison between different properties (Malpezzi, 2008). However, the use of this method is relatively recent in terms of office property market as compared to housing market (Nappi-Choulet, et al., 2007). On the basis of reviewed literature, especially meta-analysis of Seo, et al., (2019) the following empirical model was created:

$$\ln(R_{it}) = \alpha + \beta_1 B_{itg} + \beta_2 Period + \beta_3 B_{itg} * Period + \beta_4 B_{itg} * Period * D_i + \beta_5 B_{itg} * Period * D_i^2 + \beta_6 LA_i + \beta_7 X_i + \beta_8 T_t + \beta_9 Z_z + \varepsilon_{it}$$

Equation 1 Empirical model of the study.

where R_{it} is the headline rent per square meter per month of a lease agreement *i* in a specific point of time *t*. The natural logarithm was used for transformation purpose in order to ensure the linear relationship between variables. The semi-log form allows for easier interpretation of the results and, more importantly, it adjusts for more proportional variation of value added by each growing unit of a selected feature of a property. Log-linear form often mitigates changing variance of the error term, or heteroskedasticity (Malpezzi, 2008). α represents constant. R_{itg} is a dummy band variable (or ring variable) defining if a lease agreement *i* that started in a year *t* was part of treatment group g (=1 if part of a treatment group). The lease start date was chosen instead of lease signature data due to the data availability. Variable *Period* represents different time periods of construction process of M2 line – BEFORE the start of the construction, BETWEEN the start and the completion and AFTER the completion of the construction. What is more, additional variables are added to adjust for trends in rents – i.e. TREND_BEFORE to adjust for trend before the construction of the metro central section is finished, and TREND_AFTER to adjust for trend after the construction is finished. TREND_BEFORE variable calculates the number of years between lease start date and an intervention (start or end of M2 line construction) for lease agreements signed before the metro line was constructed. TREND_AFTER variable calculates the number of years between the end of the construction and lease start date for leases signed after the construction. Some of the anticipation effect is also included in BETWEEN variable (van Duijn, et al., 2016). The interaction variables allow for consideration of differences in rents between target group and control group after the underground line was finished. R_{itg}*Period* shows the temporal effect on relative price change between treatment and control area, while the spatiotemporal effects are shown in the variable R_{itg}*Period*D_i. D_i is a variable describing the distance from the building in which the lease agreement *i* was signed to the nearest metro station (in meters). In the sensitivity analysis a model with squared value of D_i is tested. LA_i is a vector of lease agreement-related characteristics (including the size of leased area, lease term), X_i is a vector of property-related characteristics (building size, building age at lease start and building class). Set of interaction variables was added to the model in order to account for spatiotemporal effects. Finally, two dummy variables were added to the model to control for time and spatial fixed effects i.e. variable T_t to control for irregularities arising every year and Z_z to control for each of delimited office zones *z*. Inclusion of T_t and Z_z controls for local trends in rents (Schwartz, et al., 2006). The coefficients to be estimated are β_1, β_2, β_3, β_4, β_5, β_6, β_7 and β_8. ε is random error.

3.3 Data & study area

In this context transacted rents in office buildings across Warsaw, Poland are analyzed. The construction of the central section of M2 line in Warsaw started at 16th August 2010 (Public Transport Authority of Warsaw, 2015) and finished at 8th March 2015 (Murator Plus, 2010). Seven new stations appeared in the central part of the capital of Poland, reaching from western part of the city center to the central part of Praga district on the right side of Vistula river. The stations were named, from the most western one: Rondo Daszyńskiego, Rondo ONZ, Świętokrzyska (interchange station with M1 line), Nowy Świat-Uniwersytet, Centrum Nauki Kopernik, Stadion Narodowy, Dworzec Wileński. The construction of the main section of new metro line was followed by a significant change in urban landscape of Warsaw. Neighborhoods previously overlooked by investors thrived after the stations were opened (CBRE, 2017). The most significant change was visible in Wola district (City Centre West), a post-industrial area full of neglected pre and post-war, low-grade buildings, that between 2014 and 2019 has become main business destination of the city (Cushman & Wakefield, H1 2019).

Figure 3 Map of Warsaw with M1 line (blue) and M2 line (red) as of April 2020. Dotted lines represent planned sections of M2 line
Source: *Authors of Wikipedia, Jurij and Szcureq.*

Warsaw was divided into office zones by Polish Office Research Forum, a cooperation platform between major leasing agencies present in the market, i.e. CBRE, Colliers International, Cushman & Wakefield, JLL, Knight Frank and Savills (ISB News, 2017). The office zones were delimited according to both physical characteristics of each and the commercial prospects defined by senior research analysts (Colliers International, 2017). Due to the holistic approach undertaken in the process of delimiting the zones, the variable taking the zones into account is highly valuable in capturing different characteristics of each neighborhood. The map of zones is presented on *figure 4*.

As of the end of 2019 the Warsaw office stock amounted to 5.59 million square meters with the majority located in Mokotów (26%) and City Centre (23%) office zones. The prime rents in this office zones reached €14,5 per sq m/per month and €20 per sq m/per month, respectively. The prime rent for the whole market was recorded in CBD zone and reached €24 per sq m/per month. Vacancy rate in Warsaw stood at 7,8%. The new supply in 2019 was at the lowest level since 2011, with the record high supply recorded in 2016. The prime office yield stood at 4.75% (Cushman & Wakefield, 2019). In the period of 2013 – 2016 there was a noticeable shift in developers' activity which concentrated in central office zones, due to new transport infrastructure and shift in tenants' preferences (Cushman & Wakefield, 2017).

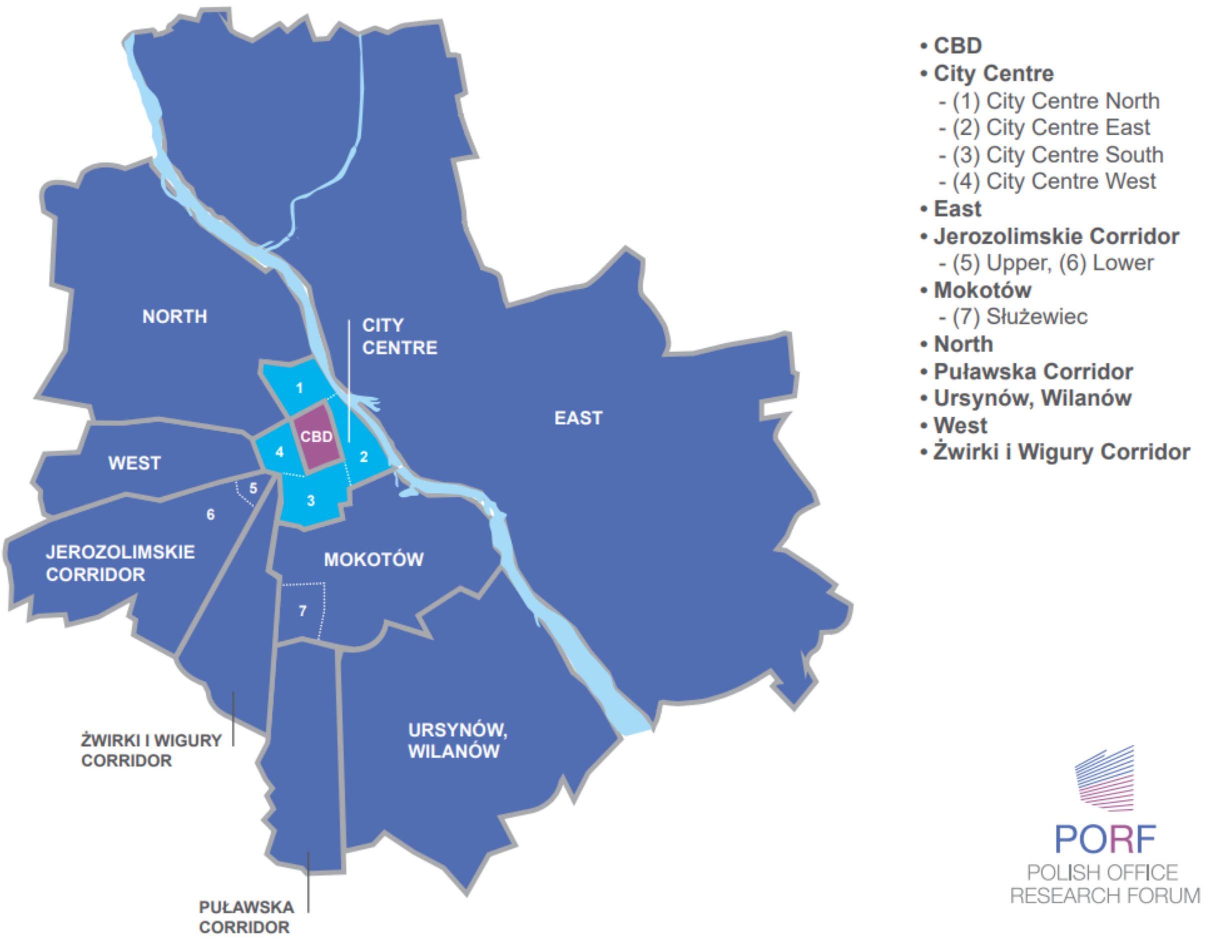


Figure 4 Office zones in Warsaw. Source: *Polish Office Research Forum*.

The dataset used in this study comes from internal database of Cushman & Wakefield in Poland. Cushman & Wakefield is a global real estate service company. It is one of the major companies of this type in Poland, having thorough market overview (Cushman & Wakefield, 2018) and it is one of the most reliable sources of real estate data. The dataset consists of anonymized office lease agreement data and was provided on the basis of confidentiality agreement between the author of this study and the company.

Originally the dataset attained consisted of unique 2,307 observations from the period between 2004 and 2018. This was subsequently limited to 1,047 observations located in the office zones impacted by the new M2 line – i.e. Jerozolimskie Corridor Upper, City Centre West, Central Business District and City Centre East (zone East was excluded from the research due to the lack of data from Praga district) within 1500 meters from the nearest metro station and in the buildings constructed before the start of the metro line construction. The distance limitation was performed in order to eliminate lease agreements signed in buildings theoretically located in the office zone with new metro line impact, but virtually being out of reach of the effect. Out of all observations, 842 make up the control group with the remainder located further than 400 meters of a metro station, the distance delineating the target group. In order to use the dataset in the study number of steps were undertaken in order to transform the original information acquired. Firstly, the dataset was matched with Cushman & Wakefield's database of office properties in order to determine each building characteristics, like its class, location, size and completion date. Subsequently, by using building completion date, the building age at the lease start date was determined. The lease duration was determined by using YEARFRAC function in Excel. The metro stations' latitudes and longitudes were acquired manually from Google Maps. The distance between the building of each lease agreement and the nearest metro station was calculated by a simple JavaScript application prepared by the author (Appendix III). The calculation used simple Euclidian distance between two points, i.e. the *Equation 2*. Eventually the distance in degrees was transformed into meters.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Equation 3 Distance between two points.

Due to the confidentiality agreement between the provider of the data and the user the data location cannot be plotted on a map.

3.4 Descriptive statistics

Table 1 Descriptive statistics of pooled, treatment and control groups. Source: Own work based on datasheet.

	Pooled		Treatment		Control	
	Mean	SD	Mean	SD	Mean	SD
Headline rent (log)	2.935	0.216	2.968	0.259	2.927	0.204
Distance to metro (in meters)	607.52	234.555	226.783	95.388	700.217	149.27
GLA (in sq m)	562.227	592.102	661.746	692.219	537.997	562.858
Lease duration (in years)	5.945	2.262	6.111	2.316	5.905	2.248
Building age at lease start (in years)	9.534	6.077	7.424	7.242	10.048	5.644
Building's GLA (in sq m)	22,084.3	13,956.01	31,302.25	22,517.69	19,840.03	9,669.464
Observations	1,047		205		842	

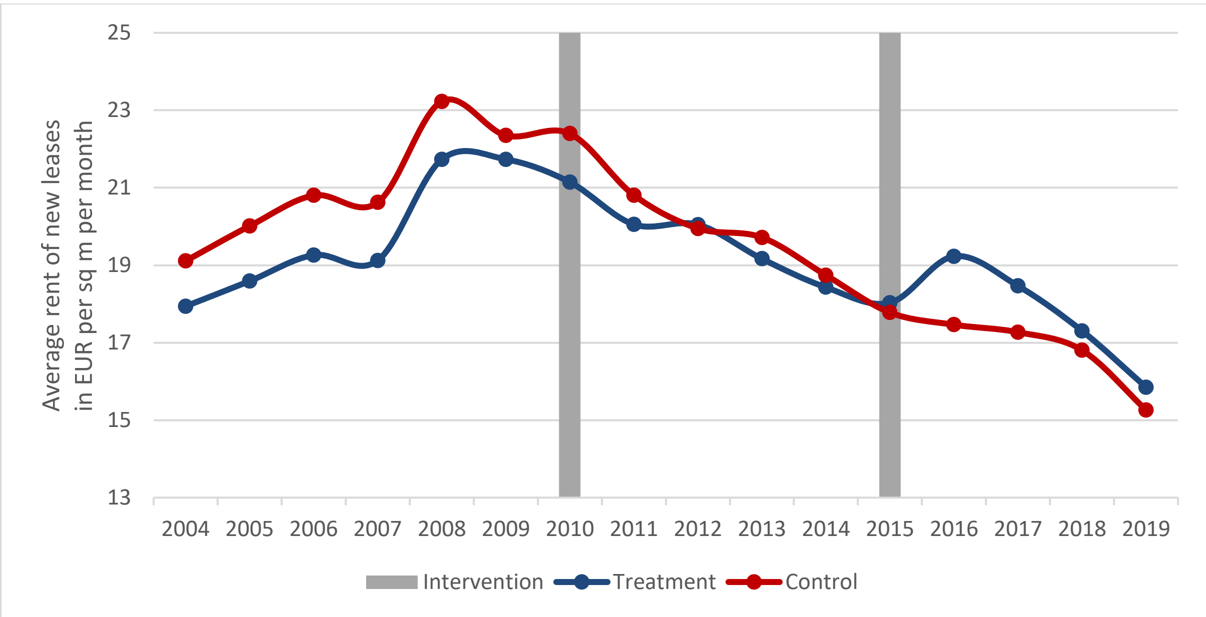
Table 1 presents the summary of descriptive statistics of variables used in the model. The table suggests that, despite the major differences in distance to metro station, the samples are similar. On average the properties located closer to metro stations are newer and larger than properties located further away from the stations. What is more, tenants, on average, lease larger areas near metro station, comparing to the leases further away.

3.5 Methodology assumptions

The two research methods used in the study have their assumptions. Five OLS assumptions and difference-in-differences assumption of parallel trends have been tested in order to check if the model used meet the assumptions. The OLS assumption that the error term has a population mean of zero is met. The autocorrelation is not present in the model, which mean that the second assumption is met. The Breusch-Pagan and Cook-Weisberg test for linear heteroskedasticity is performed and it indicates that heteroscedasticity is potentially a problem in the model. Therefore, the model uses robust standard errors. The no multicollinearity assumption is tested through VIF analysis. As the model uses many interaction variables the factors are relatively high, however the correlation matrix of the study (Appendix II) does not show anything worrying. Endogeneity problem is furtherly discussed in Chapter 4. The test for normality of error term distribution shows that it is not normally distributed, however it is not one of BLUE assumptions, and it does not mean that OLS is biased.

The assumption of parallel trends says that the two tested groups should follow the same trends, especially before the intervention analyzed. If the assumption states that the trends need to be parallel only in the pre-intervention period, the second assumption has to be made – the common shocks assumptions (Dimick & Ryan, 2014). The common shocks assumptions states that in the post-intervention period all external shocks affect two groups equally. The common shocks statement can be assumed, by analyzing the local context. No other major investment, that could potentially impact the office rents and would not be captured by neighborhood fixed effects was identified. On the other hand, the parallel trends assumption can be generally tested. This is performed by the analysis of Figure 6. The figure presents a simple averages of headline rents in the lease agreements signed every year. While this type of analysis is very general and omits important factors, that later on are incorporated into hedonic models, it can be treated as a general overview of two groups. As shown on the figure before the start of the M2 line construction the average rent of new leases follows roughly the same trends. After the start of the construction, the difference between two groups starts to slowly diminish, showing the anticipation effect. After the construction ended, the treatment group average becomes higher than control group averages. Interestingly, from 2017 onwards (after the predicted adjustment process) the averages again follow the same trend, which could indicate the correctness of the common shocks assumption.

Figure 5 Changing pattern of average rent of new leases in treatment and control group in the period of 2004 - 2019.
Source: *own work based on data.*
Note: Due to small samples in some years the average rent may not reflect the real market average for new leases starting in these years. This could especially be the case in pre-2008 period. Average rents from before 2004 are not presented due to very small datasample (~ 5 observations per group).



4. RESULTS

4.1 OLS Regression

In this section the results of empirical model are presented, then sensitivity analyses are performed. Table 2 presents results of 3 initial hedonic property price models. The preferred model is chosen on the basis of Bayesian Information Criterion (BIC). Minimizing the BIC can be thought as a way for selecting the most probable model (Wit, et al., 2012), therefore this criterion is used in this study to compare models. This is of special importance in case of using robust standard errors, when the adjusted R-squared coefficient is not calculated, and R-squared coefficient can be misleading, as it may rise with additional predictors. Model 1 is a naive specification and controls only for the key variables and year fixed effects. None of the coefficients is statistically significant and the R-squared coefficient is the lowest among all three models. Model 2 control for building and lease characteristics and spatial fixed effects, and its R-squared coefficient is significantly higher (62.5% of variance of dependent variable is explained by independent variables). Model 3 includes the trend variables (namely TREND_BEFORE and TREND_AFTER), which controls for trends in rents before and after the construction of the central section of M2 line ended. In model 3, the interaction variables between trend variables and other independent variables are found to be insignificant. What is more, the BIC of model 3 is higher than the criterion of model 2, while R-squared is very similar. Therefore, the model 2 is preferred. The statistically insignificant coefficient of interaction variable TREND_BEFORE * Treatment suggests that the anticipation effect was not present before the start of construction of M2 line. What is more, statistically insignificant coefficient of interaction variable TREND_BEFORE * Treatment * Distance indicates that even if we incorporate spatial factor, there was no anticipation effect before the start of the construction. The exclusion of TREND_AFTER variable means that the model does not predict a posterior trend in rent adjustment process after the metro line construction had ended. Not including TREND_AFTER variable in the model can be explained by theory – the rents are expected to increase with metro station opening and are expected to remain high after that (McMillen & McDonald, 2004).

Table 2 Regression results of models 1, 2 and 3. Source: *Own work based on datasheet*.
Note: Standard errors are in brackets. Dependent variable is log of headline rent. Full table may be found in Appendix I

	Model 1	Model 2	Model 3
Treatment	-0.1290	-0,404***	-0.472***
	(0.212)	(0,12)	(0.162)

BETWEEN	-0.0480 (0.044)	-0,033 (0,029)	-0.0240 (0.029)
AFTER	-0.0460 (0.082)	-0,021 (0,047)	-0.0130 (0.051)
BETWEEN * Treatment	-0.1150 (0.159)	0,163** (0,075)	0.191** (0.087)
AFTER * Treatment	-0.0970 (0.321)	0,318*** (0,12)	0.584*** (0.188)
TREND_BEFORE * Treatment	0.0870 (0.056)		0.0090 (0.027)
TREND_AFTER * Treatment			-0.0470 (0.052)
Treatment * Distance	0.0840 (0.073)	0,143*** (0,051)	0.191*** (0.07)
BETWEEN * Treatment * Distance	0.0040 (0.053)	-0,074** (0,031)	-0.094*** (0.036)
AFTER * Treatment * Distance	-0.0080 (0.103)	-0,116*** (0,041)	-0.213*** (0.061)
TREND_BEFORE * Treatment * Distance	-0.031* (0.018)		-0.010 (0.01)
TREND_AFTER * Treatment * Distance			0.0040 (0.017)
Lease area (log)		-0,016** (0,006)	-0.016** (0.006)
Lease duration		0,003 (0,002)	0.0030 (0.002)
Lease start year	YES	YES	YES
Building total GLA (log)		0,063*** (0,022)	0.066*** (0.021)
Building age at lease start		-0,01*** (0,003)	-0.011*** (0.003)
Building completion year	NO	YES	YES
Building class	NO	YES	YES
Zoning	NO	YES	YES
Constant	3.201*** (0.108)	2,551*** (0,21)	2.605*** (0.228)
R-squared	0.157	0.625	0.625

Treatment area (0 – 400 m)

Control area (400 – 1,500 m)

Robust standard errors in parentheses.

*** p<0.01 ** p<0.05 *p<0.1

In order to evaluate the impact of metro construction the interaction variable AFTER * Treatment is examined. The variable is statistically significant on 99% level and its coefficient is positive. The coefficient value of 0.318 means that in the period after the construction of central section of M2 line ended, rents in the treatment area are 37% higher[1] than rents in the control area. As the minimum value of Distance variable is approx. 150 meters, the relative price difference is disproportionately high. The results partially answer main research question of the study – there is the effect of proximity to metro station, and the effect on rent is positive. This is in line with theory discussed in chapter 2, especially lack of negative externalities of underground stations (Seo, et al., 2019) and positive effects of metro lines observed in European spatial context (Pagliara & Papa, 2011). The result confirms the hypothesis no. 1 of the study, that there is a positive effect of a metro station construction.

The investigation of anticipation effect can be performed by analysis of BETWEEN * Treatment interaction variable. The statistically significant, positive coefficient of 0.163 suggests that during the construction of the metro line the relative price difference between treatment and control areas was observable and rents in the treatment area were 18% higher[2] than in the control area. The results prove that the impact of M2 line construction was present even before the construction has ended, therefore before the accessibility of properties located in the vicinity of a new metro station increased. This, again, is in line with previously discussed literature and expected price adjustment pattern (Trojanek & Gluszak, 2018). The result confirms hypothesis no. 3 of the study – that there indeed was an anticipation effect of the construction of the M2 line.

Interpreting the coefficients in that matter refers to properties located directly next to a metro stations (Distance = 0). To furtherly study the positive effect the interaction between Period variables, Treatment and Distance has been introduced. This allows for detailed examination of price change with growing distance to the nearest metro station[3]. The effect of examination is presented at Figure 7. As depicted, the positive effect in both time periods gradually decrease with growing distance to the nearest metro station. Interestingly, by looking at the interaction variables coefficients it can be observed that the decrease is steeper in the AFTER period. The positive effect disappears after 219 m in case of BETWEEN period and after 275 m in case of AFTER period. When the distance

[1] $e^{0.318} - 1 \approx 0.37$
[2] $e^{0.163} - 1 \approx 0.18$
[3] For BETWEEN period: $e^{0.163+(-0.074*Distance)} - 1$ For AFTER period: $e^{0.318+(-0.116*Distance)} - 1$

is considered, a negative effect can be observed after the aforementioned distances. This may be due several factors. Firstly, the linearity of the function may lead to these results, therefore in model 4, an alternative specification is tested. Secondly, especially in the between period a positive anticipation effect of a metro line construction may not outweigh the negative externalities of metro line construction, such as difficulties in commuting due to road closures. In the after period the negative effect is significantly smaller and could be possibly accounted to the linear shape of the graph. Figure 7 confirms the hypotheses no. 3 – that there is an anticipation effect of the metro station construction. However, as shown, the positive spatial effect in the study proves to be significantly smaller than in the literature, as it is observable only within 275 m, while according to Seo, et al. (2014) it usually is observable within at least 300 m.

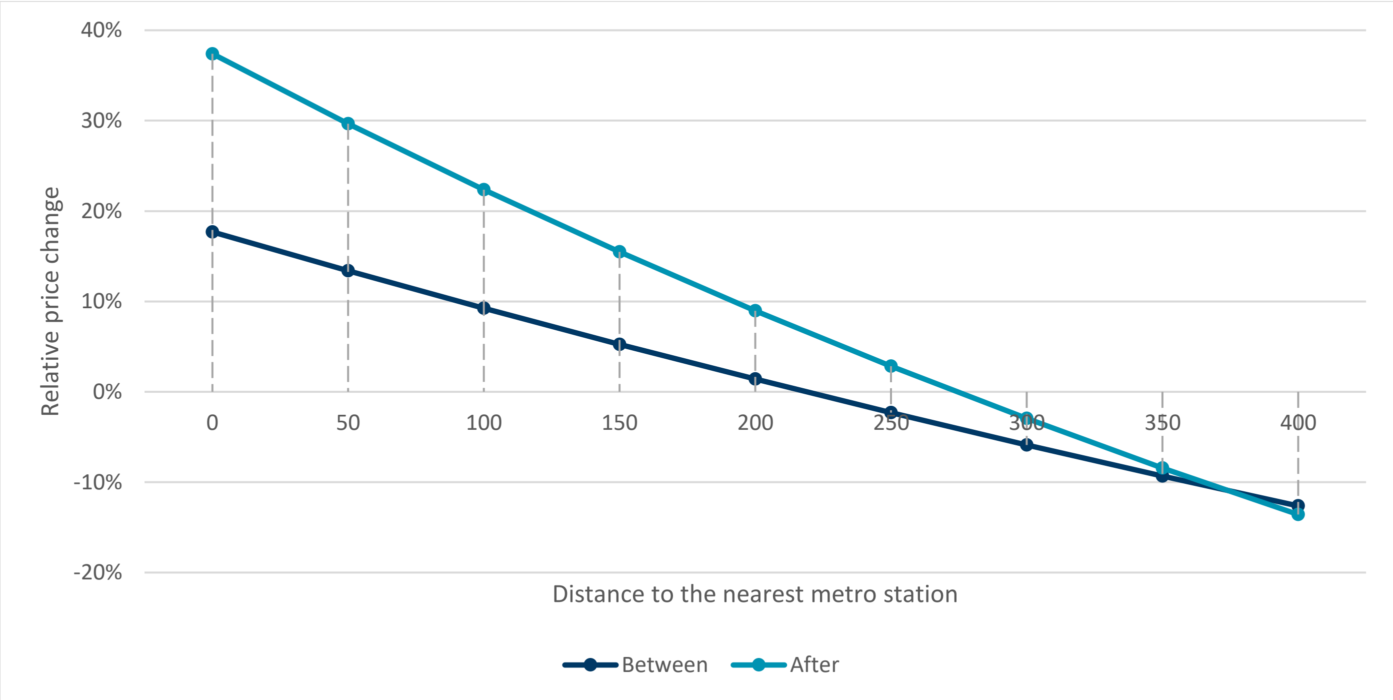


Figure 6 Relationship between relative price change (treatment group vs control group) and distance in two times periods.
Source: *own work based on regression results.*

4.2 Sensitivity analysis

In order to test model performance and its robustness different sensitivity analysis are performed and presented in this section. First, the assumption of linear impact of distance is changed, as suggested by Trojanek & Gluszak (2018), by implementing squared Distance variable into the model 4.

While in model 4 the key variables are statistically significant and the nonlinearity of the effect is a plausible pattern, the effects are nonrealistic. The BETWEEN*Treatment interaction variable's coefficient suggests that the

M2 station construction has the positive effect of 594%[4] on the headline rent. The coefficients of interaction variables incorporating spatial effect suggests steep slope within first 100 m and the positive effect disappears approximately at 180 m. Such strong difference between strength of the effect at distance equal to 0 m and distance equal to 180 m seem unrealistic. What is more, the positive effect reappears after approx. 360 m, which again is difficult to explain on the basis of theory. Furthermore, the BIC of the model is higher than the criterion of model 2, therefore the model 2 is preferred.

The study performs spatiotemporal analysis, and while model 4 analyze the spatial component, other test is needed to test the temporal effect. In order to analyze this component, the Chow test for structural breaks is performed. The test's results show that null hypothesis of three periods' coefficients being equal can be rejected. Therefore, the time periods in the study were chosen in a justified manner, as the structural breaks are present in the data.

As endogeneity if often present in spatial studies (Fingleton & Le Gallo, 2008) the potential endogeneity in this study must be examined. Model 2 accounts for spatial autocorrelation by inclusion of neighborhood fixed effects, however there is potential endogeneity of explanatory variables. Even in the difference-in-differences approach the endogeneity of an intervention may be a concern (Lee & Reagan, 2006). In order to test for endogeneity of Distance variable, a Durbin-Wu-Hausman test is performed. There may be different reasons of endogeneity of the variable. Firstly, the problem may arise as a result of measurement error of Distance. The Euclidian distance is measured without an error, but it does not always fully correspond with the real distance between two points, especially in a dense urban environment. Secondly, there may be a mutual dependence between the dependent and the independent variables. It is possible, that future distance to metro station is an important factor for developers in the process of planning an investment, and the policy makers may not choose the investment locations at random but rather where they expect the largest external effect (van Duijn, et al., 2016). What is more, there are evidences that more valuable land is more likely to receive underground service (Redding & Turner, 2015) and the land value may be reflected in rent level. The results of the test, however, suggest that in case of this study, endogeneity is not a problem of Distance variable.

[4] $e^{1.938} - 1 \approx 5.94$

Table 3 Regression results of model 4. Source: *Own work based on datasheet*.
Note: Standard errors are in brackets. Dependent variable is log of headline rent. Full table may be found in Appendix I

	Model 4
Treatment	-1,679***
	(0,372)
BETWEEN	-0,03
	(0,029)
AFTER	-0,025
	(0,047)
BETWEEN * Treatment	1,938***
	(0,342)
AFTER * Treatment	1,805***
	(0,354)
TREND_BEFORE * Treatment	1,373***
	(0,317)
Treatment * Distance	-0,252***
	(0,063)
Treatment * Distance^2	-1,799***
	(0,318)
BETWEEN * Treatment * Distance	0,351***
	(0,065)
BETWEEN * Treatment * Distance^2	-1,507***
	(0,314)
AFTER * Treatment * Distance	0,28***
	(0,063)
AFTER * Treatment * Distance^2	-0,016***
	(0,006)
Lease area (log)	0,003
	(0,002)
Lease duration	-1,679***
	(0,372)
Lease start year	YES
Building total GLA (log)	0,057***
	(0,021)
Building age at lease start	-0,011***
	(0,003)
Building completion year	YES
Building class	YES
Zoning	YES
Constant	2,657***
	(0,203)
R-squared	0.628

5. DISCUSSION

This study performs a quantitative analysis of impact of construction of a metro line on office headline rents. The analysis was applying a hedonic property price model and difference-in-differences method. The positive effect of metro proximity is identified, accounting to 37% and decaying with distance. However, the spatial impact is relatively limited, as it is observable only within 275 meters from the nearest metro station. What is more, the anticipation effect is observed, as the effect is observable before the end of construction of the metro line. In the period between the start and the end of metro construction line, the effect in the treatment group shows is 18%. The results of the model are in line with expectations and previous studies on the subject, disregarding the spatial limitation of the effect. The findings support two hypotheses of the study, while not confirming the remaining one. The hypothesis of significant positive impact of new metro station on the headline rents is confirmed, as well as the hypothesis of the anticipation effect. The hypothesis of positive impact within 300 m is not confirmed, however 275 m identified in the study is a direct walking distance, which is in line with theory expecting the effects within distance approachable on foot. One of the reasons behind limited spatial impact of the new metro station can be high saturation of transportation network (commuter rail, trams) in the central part of Warsaw.

As in the previous literature on the subject (Landis & Loutzenheiser, 1995; Bollinger, et al., 1998; Seo, et al., 2019), the positive effects in this study are hypothesized to be in relation with accessibility. As the study focuses on underground metro line, the negative externalities of transportation links are not assumed, contrary to studies on a light rail impact (Golub, et al., 2012). While using difference-in-differences approach, this study incorporates methodology introduced by Schwartz, et al. (2006) and van Duijn, et al. (2016). As mentioned in the chapter 2 if the study, the local context is crucial in assessing the implications of construction of new transportation line on rent. The results of the study are comparable to the results of Trojanek & Gluszak (2018) which was conducted in the same local context, however on residential properties' prices. The similarity between the two studies furtherly strengthen the reliability of the results of this paper.

The findings of the research may contribute to the understanding and forecasting of future rental growth of properties located within certain distance from a planned metro station. As metro network is still in the development in Warsaw and regional cities in Poland, the implications should be of special value to the long-term investors underwriting properties located in the impact area of a potential metro station. The lack of data to confirm the significant adjustment process of rents after the construction of a metro line has ended should help in deepening the understanding of prospects of properties located within newly built metro stations. What is more, the findings may be of use to the policy makers, furtherly proving the economic advantages and investment value of a metro line construction. The implications of the observed effect and anticipation effect may be interesting for developers in time planning of the investments. As mentioned before, the results should be of special value to the market participants in Central and Eastern Europe countries, which face different spatial challenges than mature real estate markets in Western Europe or the US.

There are aspects in which the conducted research could be expanded as the study has its limitations. Firstly, the research on effective rents should be perceived as more in-depth and could be of more use to the market participants. Large data samples of lease agreements with effective rents are difficult to obtain, however this could be feasible in a more developed market. In this study, due to the relatively low maturity level of Polish office market, even the headline rent data sample could be perceived as small. The lease start date is used instead of lease signature date, due to the data availability. While some studies assume the lease signature date, due to the large variance of length period between the two, this assumption seems unrealistic in Polish office market. Researchers could further the analysis by incorporating data on other nodes of transportation (bus, trams, light rail). What is more, due to changing landscape of Warsaw after the construction of M2 line, the other large office investments concentrated in some areas may be perceived as another factor impacting neighboring properties and the effect of those investments could be measured. While this study considers submarkets fixed effects, the areas of impact of i.e. a new commercial complex may be more limited than a large office zone. As the study focuses on growing accessibility of certain areas of the city, an interesting research could be performed on older metro line (M1) in Warsaw, which may saw an increase in attractiveness due to the M2 line construction. The further research on M2 line could also be performed when the line is entirely finished.

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Appendix I: Table 4 Full regression results

Dependent variable is natural logarithm of headline rent.

	Model 1	Model **2**	Model 3	Model 4
Treatment	-0.1290	-0,404***	-0.472***	-1,679***
	(0.212)	(0,12)	(0.162)	(0,372)
BETWEEN	-0.0480	-0,033	-0.0240	-0,03
	(0.044)	(0,029)	(0.029)	(0,029)
AFTER	-0.0460	-0,021	-0.0130	-0,025
	(0.082)	(0,047)	(0.051)	(0,047)
BETWEEN *	-0.1150	0,163**	0.191**	1,938***
Treatment	(0.159)	(0,075)	(0.087)	(0,342)
AFTER *	-0.0970	0,318***	0.584***	1,805***
Treatment	(0.321)	(0,12)	(0.188)	(0,354)
TREND_BEFORE *	0.0870		0.0090	
Treatment	(0.056)		(0.027)	
TREND_AFTER *			-0.0470	
Treatment			(0.052)	
Treatment * Distance	0.0840	0,143***	0.191***	1,373***
	(0.073)	(0,051)	(0.07)	(0,317)
BETWEEN *	0.0040	-0,074**	-0.094***	-1,799***
Treatment * Distance	(0.053)	(0,031)	(0.036)	(0,318)
AFTER *	-0.0080	-0,116***	-0.213***	-1,507***
Treatment * Distance	(0.103)	(0,041)	(0.061)	(0,314)
TREND_BEFORE *	-0.031*		-0.010	
Treatment * Distance	(0.018)		(0.01)	
TREND_AFTER *			0.0040	
Treatment * Distance			(0.017)	
Lease area		-0,016**	-0.016**	-0,016***
(log)		(0,006)	(0.006)	(0,006)
Lease duration		0,003	0.0030	0,003
		(0,002)	(0.002)	(0,002)
Lease start year				
2003	-0.1460	-0,133	-0.180	-0,145
	(0.115)	(0,093)	(0.118)	(0,095)
2004	-0.325***	-0,256***	-0.314***	-0,277***
	(0.11)	(0,086)	(0.118)	(0,091)
2005	-0.309***	-0,204***	-0.264**	-0,221***
	(0.107)	(0,078)	(0.114)	(0,083)
2006	-0.333***	-0,228***	-0.287**	-0,243***
	(0.11)	(0,081)	(0.116)	(0,086)
2007	-0.285***	-0,122	-0.1820	-0,139
	(0.11)	(0,082)	(0.117)	(0,087)

	Model 1	Model **2**	Model 3	Model 4
2008	-0.1820	0,032	-0.0280	0,012
	(0.115)	(0,084)	(0.119)	(0,089)
2009	-0.212*	-0,008	-0.0710	-0,032
	(0.112)	(0,084)	(0.12)	(0,089)
2010	-0.199*	-0,074	-0.1370	-0,095
	(0.113)	(0,084)	(0.119)	(0,088)
2011	-0.1390	-0,048	-0.1120	-0,067
	(0.12)	(0,089)	(0.123)	(0,093)
2012	-0.1750	0,02	-0.0450	0,001
	(0.122)	(0,09)	(0.125)	(0,094)
2013	-0.1840	-0,012	-0.0780	-0,025
	(0.122)	(0,091)	(0.126)	(0,095)
2014	-0.233*	-0,009	-0.0780	-0,026
	(0.124)	(0,09)	(0.125)	(0,094)
2015	-0.274*	-0,056	-0.1340	-0,062
	(0.143)	(0,099)	(0.137)	(0,103)
2016	-0.327**	-0,072	-0.1380	-0,08
	(0.147)	(0,102)	(0.139)	(0,106)
2017	-0.374**	-0,065	-0.1240	-0,072
	(0.147)	(0,104)	(0.14)	(0,107)
2018	-0.345**	-0,095	-0.1440	-0,101
	(0.147)	(0,107)	(0.143)	(0,11)
2019	-0.492***	-0,116	-0.1730	-0,125
	(0.16)	(0,112)	(0.147)	(0,116)
Building total GLA		0,063***	0.066***	0,057***
(log)		(0,022)	(0.021)	(0,021)
Building age at lease		-0,01***	-0.011***	-0,011***
start		(0,003)	(0.003)	(0,003)
Building completion year				
		-0,055	-0.0580	-0,048
1993		(0,061)	(0.061)	(0,061)
		0,101**	0.096**	0,081*
1995		(0,048)	(0.048)	(0,047)
		-0,028	-0.040	-0,05
1996		(0,049)	(0.048)	(0,049)
		0,007	0.0030	-0,021
1997		(0,05)	(0.05)	(0,05)
		-0,03	-0.0450	-0,045
1998		(0,045)	(0.045)	(0,045)
		-0,108*	-0.127**	-0,109*
1999		(0,056)	(0.055)	(0,056)
		-0,223***	-0.237***	-0,238***
2000		(0,056)	(0.056)	(0,057)

	Model 1	Model **2**	Model 3	Model 4
		0,013	-0.0040	-0,028
2001		(0,056)	(0.055)	(0,056)
		-0,101**	-0.095*	-0,1**
2002		(0,049)	(0.052)	(0,051)
		-0,043	-0.0660	-0,041
2003		(0,074)	(0.071)	(0,073)
		0,31***	0.321***	0,243***
2004		(0,079)	(0.091)	(0,079)
		0,061	0.0420	0,017
2006		(0,064)	(0.063)	(0,063)
		-0,016	-0.040	-0,017
2007		(0,08)	(0.077)	(0,079)
		-0,023	-0.0430	-0,036
2008		(0,073)	(0.073)	(0,073)
Building class				
A		0,192***	0.193***	0,161***
		(0,034)	(0.032)	(0,033)
A+		0,273***	0.282***	0,314***
		(0,102)	(0.096)	(0,098)
Zoning				
City Centre West		-0,156***	-0.156***	-0,142***
		(0,033)	(0.032)	(0,032)
City Centre East		0,086**	0.084**	0,105***
		(0,035)	(0.034)	(0,035)
Jerezolimskie corridor		-0,278***	-0.28***	-0,261***
Upper		(0,029)	(0.028)	(0,028)
Squared interactions				
Treatment * Distance^2				-0,252***
				(0,063)
BETWEEN *				0,351***
Treatment * Distance^2				(0,065)
AFTER *				0,28***
Treatment * Distance^2				(0,063)
Constant	3.201***	2,551***	2.605***	2,657***
	(0.108)	(0,21)	(0.228)	(0,203)
R-squared	0.157	0.625	0.625	0.628

Appendix II: Table 5 Correlation matrix

The table below presents correlation between all the variables used in the model 2. Positive values are presented in blue cells, while negative values in red cells.

Source: own work based on data**.**

	LogR	Treatm~t	Distance	AFTER	BETWEEN	TREND_~E	LogGLA	LeaseD~n	Lea~2003	Lea~2004	Lea~2005	Lea~2006	Lea~2007	Lea~2008
LogR	1													
Treatment	0,0743	1												
Distance	-0,0458	-0,8013	1											
AFTER	-0,272	0,0454	0,0615	1										
BETWEEN	0,1077	-0,0556	0,0571	-0,348	1									
TREND_BEFORE	0,1639	0,0255	-0,1226	-0,6163	0,144	1								
LogGLA	0,0155	0,0857	-0,1713	-0,0212	0,0322	0,1102	1							
LeaseDurat~n	0,1552	0,0362	-0,0804	-0,2657	0,0168	0,2946	0,2695	1						
Leasest~2003	0,0757	0,0318	-0,0257	-0,0628	-0,0914	0,3096	0,028	0,1556	1					
Leasest~2004	-0,0307	-0,0097	-0,0322	-0,0647	-0,0941	0,2494	0,0327	0,0875	-0,017	1				
Leasest~2005	-0,0284	-0,0371	-0,0382	-0,1195	-0,1739	0,3326	0,0279	0,0561	-0,0314	-0,0323	1			
Leasest~2006	-0,0197	0,1342	-0,2052	-0,1751	-0,2548	0,2997	0,1084	0,1229	-0,046	-0,0474	-0,0875	1		
Leasest~2007	0,008	0,0099	-0,0277	-0,1641	-0,2389	0,1049	-0,0455	0,0469	-0,0431	-0,0444	-0,082	-0,1202	1	
Leasest~2008	0,099	-0,0622	0,0495	-0,1151	-0,1676	-0,0499	-0,0826	0,0145	-0,0303	-0,0311	-0,0575	-0,0843	-0,079	1
Leasest~2009	0,0762	-0,0438	0,0383	-0,1299	-0,189	-0,1955	-0,0617	-0,0424	-0,0341	-0,0351	-0,0649	-0,0951	-0,0891	-0,0625
Leasest~2010	0,0647	-0,0785	0,1389	-0,1406	0,0617	-0,0327	-0,0529	-0,0377	-0,037	-0,038	-0,0703	-0,103	-0,0965	-0,0677
Leasest~2011	0,1225	-0,0473	0,0666	-0,165	0,4741	0,2823	0,068	0,0514	-0,0433	-0,0446	-0,0824	-0,1208	-0,1132	-0,0794
Leasest~2012	0,0448	-0,0506	0,0062	-0,1072	0,308	0,0685	-0,0147	-0,0069	-0,0282	-0,029	-0,0536	-0,0785	-0,0736	-0,0516
Leasest~2013	0,0428	-0,0155	-0,0062	-0,1508	0,4335	-0,0654	0,0391	0,0409	-0,0396	-0,0408	-0,0754	-0,1105	-0,1035	-0,0726
Leasest~2014	-0,0258	0,0178	-0,0027	-0,1129	0,3245	-0,17	-0,0306	-0,0116	-0,0297	-0,0305	-0,0564	-0,0827	-0,0775	-0,0544
Leasest~2015	-0,06	0,0594	-0,0651	0,3048	-0,0133	-0,3053	-0,0186	-0,0874	-0,0311	-0,032	-0,0592	-0,0867	-0,0813	-0,057
Leasest~2016	-0,1028	0,0337	0,0154	0,4628	-0,161	-0,2852	-0,0449	-0,131	-0,0291	-0,0299	-0,0553	-0,081	-0,0759	-0,0533
Leasest~2017	-0,1377	-0,0162	0,0438	0,3915	-0,1362	-0,2413	-0,0209	-0,0966	-0,0246	-0,0253	-0,0468	-0,0685	-0,0642	-0,0451
Leasest~2018	-0,1443	0,044	0,0474	0,5043	-0,1755	-0,3108	0,021	-0,1583	-0,0317	-0,0326	-0,0603	-0,0883	-0,0828	-0,0581
Leasest~2019	-0,1516	-0,0365	0,0913	0,2381	-0,0829	-0,1467	0,0175	-0,0704	-0,015	-0,0154	-0,0284	-0,0417	-0,0391	-0,0274
LogBGLA	0,2512	0,1707	-0,2477	-0,1054	0,0722	0,1708	0,1827	0,215	-0,03	0,024	-0,002	0,2034	0,0579	-0,1049
BuildingAge	-0,4621	-0,1714	0,2778	0,4284	0,1821	-0,5395	-0,1874	-0,3078	-0,1755	-0,1411	-0,2138	-0,3431	-0,1239	-0,0214
ClassAplus	0,2745	0,6014	-0,5819	-0,1296	-0,0824	0,1231	0,114	0,1717	-0,0387	-0,0398	-0,0285	0,3065	0,1513	-0,0244
ClassA	0,3364	-0,2438	0,2048	-0,0327	0,099	0,125	0,1364	0,0148	0,0851	0,0894	0,0947	-0,0533	-0,1695	-0,0811
ClassB	-0,5051	-0,093	0,1222	0,1081	-0,055	-0,1998	-0,2064	-0,1138	-0,0658	-0,0695	-0,0815	-0,1207	0,0884	0,0978
Buildin~1993	-0,017	-0,0833	0,2231	0,0502	0,077	-0,1059	-0,0641	-0,0232	-0,0217	-0,0223	-0,016	-0,0604	-0,0566	-0,0397
Buildin~1995	0,0048	-0,0265	-0,035	-0,0262	-0,0381	-0,0582	-0,0071	0,025	-0,0069	-0,0071	-0,0131	-0,0192	-0,018	-0,0126
Buildin~1996	-0,1161	-0,1759	0,2318	-0,1666	-0,0107	-0,0248	-0,3018	-0,0933	-0,0458	-0,0471	-0,0871	-0,1181	0,1808	0,1192
Buildin~1997	-0,2565	0,1982	-0,2651	0,0386	0,0544	-0,0815	-0,0023	-0,0492	-0,0259	-0,0267	-0,028	-0,0258	-0,0678	-0,0034
Buildin~1998	-0,205	0,041	-0,0791	0,0441	0,0076	-0,0091	-0,0272	-0,0599	-0,0503	-0,0084	0,0387	0,055	-0,0287	-0,0164
Buildin~1999	-0,0781	-0,1708	-0,0949	-0,0283	-0,0108	0,0855	0,1211	-0,0278	0,0289	0,1206	0,0896	-0,0168	-0,0035	-0,0122
Buildin~2000	-0,1078	-0,0904	0,1183	-0,0896	0,0065	-0,0021	0,054	0,1167	-0,0235	-0,0242	-0,0214	-0,0486	0,0278	0,1501
Buildin~2001	-0,2235	-0,1056	0,0951	0,1923	-0,0815	-0,107	0,0284	-0,0252	0,0248	-0,0359	0,0154	-0,0022	-0,0537	-0,0471
Buildin~2002	0,0286	0,4073	-0,2041	0,1915	-0,1065	-0,011	-0,0456	-0,0524	0,1638	0,0097	0,0329	-0,0589	-0,0695	-0,0487
Buildin~2003	0,2862	-0,2157	0,2384	-0,2006	0,0304	0,269	-0,0006	0,0653	0,088	0,0623	0,1189	0,1222	-0,0173	-0,0679
Buildin~2004	0,0205	0,1086	-0,0605	-0,0262	-0,0003	0,0636	0,0427	-0,0309	-0,0069	0,2678	-0,0131	-0,0192	-0,018	-0,0126
Buildin~2006	0,1667	0,4628	-0,4868	-0,0205	-0,0713	0,0207	0,1418	0,1301	-0,0469	-0,0483	-0,0506	0,2245	0,1431	-0,046
Buildin~2007	0,3167	-0,1647	0,0889	0,0946	0,1393	-0,1174	0,0667	0,1032	-0,0429	-0,0442	-0,0816	-0,1196	-0,1121	-0,0074
Buildin~2008	-0,0143	-0,0847	0,2111	0,1627	-0,1222	-0,1895	-0,04	-0,1203	-0,0221	-0,0227	-0,042	-0,0615	-0,0576	0,0622
Buildin~2010	0,0637	0,2132	-0,1015	-0,0609	0,1256	0,0593	0,0982	-0,0341	-0,016	-0,0165	-0,0304	-0,0446	-0,0418	-0,0293
Zone_CBD	0,3897	0,0417	0,0554	-0,2129	-0,0617	0,1319	-0,1699	0,0697	0,0536	-0,0823	0,0187	0,0785	0,1194	0,0804
Zone_CCW	-0,2703	0,0237	-0,1846	0,0273	0,116	-0,0049	0,1799	-0,0267	-0,0409	0,1093	0,0139	-0,0359	-0,0841	-0,0664
Zone_CCE	0,0037	-0,0433	-0,0135	-0,0429	0,0536	0,0217	0,0696	0,003	-0,0113	-0,0116	-0,0214	-0,0314	-0,0295	0,0285
Zone_JcU	-0,2917	-0,1093	0,231	0,3959	-0,1098	-0,2651	-0,0154	-0,0926	-0,0285	-0,0293	-0,0541	-0,0793	-0,0744	-0,0522

	Lea~2009	Lea~2010	Lea~2011	Lea~2012	Lea~2013	Lea~2014	Lea~2015	Lea~2016	Lea~2017	Lea~2018	Lea~2019	LogBGLA	Build~ge	ClassA~s
Leasest~2009	1													
Leasest~2010	-0,0764	1												
Leasest~2011	-0,0896	-0,097	1											
Leasest~2012	-0,0582	-0,063	-0,074	1										
Leasest~2013	-0,0819	-0,0887	-0,1041	-0,0676	1									
Leasest~2014	-0,0613	-0,0664	-0,0779	-0,0506	-0,0712	1								
Leasest~2015	-0,0643	-0,0697	-0,0817	-0,0531	-0,0747	-0,0559	1							
Leasest~2016	-0,0601	-0,0651	-0,0763	-0,0496	-0,0698	-0,0523	-0,0548	1						
Leasest~2017	-0,0508	-0,0551	-0,0646	-0,042	-0,0591	-0,0442	-0,0464	-0,0433	1					
Leasest~2018	-0,0655	-0,0709	-0,0832	-0,054	-0,0761	-0,0569	-0,0597	-0,0558	-0,0472	1				
Leasest~2019	-0,0309	-0,0335	-0,0393	-0,0255	-0,0359	-0,0269	-0,0282	-0,0263	-0,0223	-0,0287	1			
LogBGLA	-0,0815	-0,0689	0,0642	0,0415	0,0193	-0,0268	-0,0695	-0,0844	0,0358	-0,0744	0,0328	1		
BuildingAge	0,0217	-0,0572	-0,0504	0,0815	0,1454	0,1468	0,187	0,2022	0,1961	0,2043	0,1116	-0,2233	1	
ClassAplus	-0,08	-0,0605	-0,0901	-0,0164	0,0054	-0,0064	-0,0578	-0,0681	-0,0576	-0,0593	-0,0049	0,5538	-0,3688	1
ClassA	-0,009	0,0344	0,1638	0,0042	0,0114	-0,0641	0,0078	0,0071	-0,0152	-0,0098	-0,0626	-0,0054	-0,2385	-0,3348
ClassB	0,0551	-0,0008	-0,1176	0,0051	-0,0149	0,0698	0,0251	0,0317	0,0488	0,0441	0,0675	-0,3121	0,4581	-0,2277
Buildin~1993	0,0021	-0,0047	-0,0377	-0,037	0,0925	0,0938	0,1372	0,07	-0,0323	-0,0416	-0,0196	-0,2153	0,2975	-0,0508
Buildin~1995	0,0578	0,1191	-0,0181	-0,0118	-0,0165	-0,0124	-0,013	-0,0121	-0,0103	-0,0132	-0,0062	-0,0606	0,0453	-0,0161
Buildin~1996	0,1731	0,1476	-0,0704	0,0374	-0,0135	-0,0134	-0,0863	-0,0806	-0,0519	-0,0879	-0,0415	-0,1486	0,2267	-0,1073
Buildin~1997	0,0456	-0,0581	-0,0031	0,0499	-0,0098	0,1106	0,0587	0,0687	0,0147	-0,0498	-0,0235	-0,1609	0,1898	-0,0608
Buildin~1998	-0,0585	-0,0702	0,0074	-0,0185	0,0491	-0,0261	0,0406	0,0291	0,0166	0,0367	-0,0455	-0,123	0,2196	-0,1178
Buildin~1999	-0,0047	-0,0647	-0,0658	0,0719	0,0249	-0,0376	-0,0298	-0,0353	0,0677	-0,0056	-0,0403	0,1976	0,0759	-0,1042
Buildin~2000	0,0599	0,0082	-0,0084	0,0629	0,0009	-0,0177	-0,0444	-0,0415	-0,0351	-0,0452	-0,0213	-0,2392	-0,0046	-0,0552
Buildin~2001	0,0039	-0,0782	-0,0294	-0,0596	-0,0436	0,0406	0,0167	0,0963	0,132	-0,0183	0,2312	-0,0036	0,0936	-0,0818
Buildin~2002	-0,055	-0,0595	-0,0698	-0,0454	-0,0638	-0,0039	0,1182	0,1544	0,0125	0,0939	-0,0241	-0,3	0,0072	-0,0449
Buildin~2003	-0,0112	0,0506	0,1274	0,0286	-0,0795	-0,0535	-0,0945	-0,0989	-0,0696	-0,0966	-0,0509	0,1965	-0,3006	-0,1316
Buildin~2004	-0,0142	-0,0154	-0,0181	-0,0118	0,0469	-0,0124	-0,013	-0,0121	-0,0103	-0,0132	-0,0062	-0,0642	-0,0577	-0,0161
Buildin~2006	-0,0969	-0,0826	-0,1133	-0,0091	0,0033	0,0375	0,0154	-0,0826	-0,0698	0,0887	0,0092	0,4465	-0,3344	0,8144
Buildin~2007	-0,0246	0,0356	0,1498	-0,0428	0,1002	-0,0046	0,0442	0,0131	0,005	0,1092	-0,0112	0,0542	-0,1927	-0,1005
Buildin~2008	-0,0225	0,123	-0,0579	-0,0376	-0,053	-0,0397	-0,0416	0,1207	0,0912	0,0562	0,1295	-0,2294	-0,1056	-0,0517
Buildin~2010	-0,0017	0,1107	0,1893	-0,0273	-0,0384	0,0068	-0,0302	-0,0282	-0,0238	-0,0307	-0,0145	-0,039	-0,1802	-0,0375
Zone_CBD	0,0479	0,0836	0,0092	-0,0611	-0,0122	-0,0461	-0,0425	-0,0206	-0,1495	-0,134	-0,1703	-0,1142	-0,153	0,1673
Zone_CCW	-0,0352	-0,0608	0,0211	0,0745	0,0483	0,0382	0,0593	-0,072	0,0173	0,1078	-0,0332	0,1252	0,0863	-0,1417
Zone_CCE	0,0651	0,0161	0,0428	0,0857	-0,0271	-0,0203	-0,0212	-0,0199	-0,0168	-0,0216	-0,0102	-0,1179	0,0103	-0,0264
Zone_JcU	-0,0589	-0,0637	-0,0748	-0,0486	-0,0523	0,0313	-0,0141	0,1809	0,276	0,0816	0,4073	0,0499	0,1458	-0,0667

	ClassA	ClassB	Bui~1993	Bui~1995	Bui~1996	Bui~1997	Bui~1998	Bui~1999	Bui~2000	Bui~2001	Bui~2002	Bui~2003	Bui~2004	Bui~2006
ClassA	1													
ClassB	-0,8413	1												
Buildin~1993	0,1517	-0,1277	1											
Buildin~1995	-0,0596	0,0709	-0,009	1										
Buildin~1996	-0,3964	0,4712	-0,0602	-0,0191	1									
Buildin~1997	-0,2245	0,2669	-0,0341	-0,0108	-0,0719	1								
Buildin~1998	-0,1408	0,2131	-0,066	-0,021	-0,1394	-0,079	1							
Buildin~1999	0,3112	-0,2618	-0,0584	-0,0186	-0,1233	-0,0699	-0,1354	1						
Buildin~2000	0,0347	-0,0042	-0,0309	-0,0098	-0,0653	-0,037	-0,0717	-0,0634	1					
Buildin~2001	-0,2795	0,3358	-0,0459	-0,0146	-0,0968	-0,0549	-0,1063	-0,0941	-0,0498	1				
Buildin~2002	0,1764	-0,1565	-0,0349	-0,0111	-0,0738	-0,0418	-0,081	-0,0716	-0,0379	-0,0562	1			
Buildin~2003	0,393	-0,3307	-0,0738	-0,0234	-0,1558	-0,0883	-0,1711	-0,1513	-0,0801	-0,1188	-0,0905	1		
Buildin~2004	-0,0596	0,0709	-0,009	-0,0029	-0,0191	-0,0108	-0,021	-0,0186	-0,0098	-0,0146	-0,0111	-0,0234	1	
Buildin~2006	-0,4058	-0,0478	-0,0616	-0,0196	-0,13	-0,0737	-0,1428	-0,1263	-0,0668	-0,0991	-0,0755	-0,1595	-0,0196	1
Buildin~2007	0,3002	-0,2525	-0,0564	-0,0179	-0,119	-0,0674	-0,1306	-0,1156	-0,0612	-0,0907	-0,0691	-0,146	-0,0179	-0,1218
Buildin~2008	0,1544	-0,1299	-0,029	-0,0092	-0,0612	-0,0347	-0,0672	-0,0594	-0,0315	-0,0467	-0,0355	-0,0751	-0,0092	-0,0627
Buildin~2010	0,112	-0,0942	-0,021	-0,0067	-0,0444	-0,0251	-0,0487	-0,0431	-0,0228	-0,0339	-0,0258	-0,0545	-0,0067	-0,0455
Zone_CBD	-0,0652	-0,0286	0,0938	0,0298	0,198	-0,1662	-0,1008	-0,2517	-0,0378	-0,1335	0,115	0,2429	-0,0965	-0,0558
Zone_CCW	0,1043	-0,0265	-0,0795	-0,0252	-0,1678	0,2116	0,1663	0,3261	-0,0443	-0,128	-0,0974	-0,2058	0,1138	0,113
Zone_CCE	0,0789	-0,0664	-0,0148	-0,0047	-0,0313	-0,0177	-0,0343	-0,0304	0,479	-0,0238	-0,0182	-0,0384	-0,0047	-0,032
Zone_JcU	-0,0918	0,1332	-0,0374	-0,0119	-0,079	-0,0447	-0,0867	-0,0767	-0,0406	0,5116	-0,0459	-0,0969	-0,0119	-0,0808

	ClassA	ClassB	Bui~1993	Bui~1995	Bui~1996	Bui~1997	Bui~1998
Buildin~2007	1						
Buildin~2008	-0,0573	1					
Buildin~2010	-0,0416	-0,0214	1				
Zone_CBD	0,1855	-0,1338	-0,1875	1			
Zone_CCW	-0,1572	-0,0809	0,2242	-0,8474	1		
Zone_CCE	-0,0293	-0,0151	-0,0109	-0,1579	-0,0413	1	
Zone_JcU	-0,074	0,4227	-0,0276	-0,3988	-0,1043	-0,0194	1

Appendix III: JavaScript calculating distance

```
<html>
<head>
</head>
<body>
<script type="application/javascript">
    var SEPARATOR = ';';
    var EOL = "\n";
    var inputA = [];
    var inputB = [];
    var output = [];
    function distance(a, b, c, d) {
        var result = Math.sqrt((a - c) * (a - c) + (b - d) * (b - d));
        return result;
    }
    function readInput() {
        inputA = [];
        inputB = [];
        output = [];
        var lines = document.getElementById('input').value.split(EOL);
        for (var i = 0; i < lines.length; i++) {
            var line = lines[i].split(SEPARATOR);
            if (line[0] != '') {
                inputA.push([parseFloat(line[0]), parseFloat(line[1])]);
            }
            if (line[2] != '') {
                inputB.push([parseFloat(line[2]), parseFloat(line[3])]);
            }
        }
    }
    function calculate() {
        for (var a = 0; a < inputA.length; a++) {
            var ptA = inputA[a];
            var closestPoint = [0, 0];
            var distClosest = Number.MAX_SAFE_INTEGER;
            for (var b = 0; b < inputB.length; b++) {
                var ptB = inputB[b];
                var currentDist = distance(ptA[0], ptA[1], ptB[0], ptB[1]);
                if (currentDist < distClosest) {
                    distClosest = currentDist;
                    closestPoint = [ptB[0], ptB[1]];
                }
            }
            output.push([ptA[0], ptA[1], closestPoint[0], closestPoint[1], distClosest].join(SEPARATOR));
        }
    }
    function writeOutput() {
        document.getElementById('output').innerHTML = output.join(EOL);
    }
    document.addEventListener('DOMContentLoaded', function(){
        document.getElementById('calculate-finale').onclick = function () {
```

```
            readInput();
            calculate();
            writeOutput();
        };
    }, false);
</script>
<div>
    INPUT <br/>
    <textarea id="input"></textarea>
</div>
<div>
    OUTPUT <br/>
    <textarea id="output"></textarea>
</div>
<button id="calculate-finale">CALCULATE</button>
</body>
</html>
```

Appendix IV: Stata scrypt

```
drop if BuildingCompletionYear > 2010
replace Treatment = 0
replace Treatment = 1 if Distance <= 400
gen LogR = ln(Rent)
gen LogGLA = ln(GLA)
gen LogBGLA = ln(BuildingGLA)
gen Zoning = 0
replace Zoning = 1 if Zone == "CBD"
replace Zoning = 2 if Zone == "City Centre West"
replace Zoning = 3 if Zone == "City Centre East"
replace Zoning = 4 if Zone == "East"
replace Zoning = 5 if Zone == "Jerozolimskie corridor Upper"
gen Class = 0
replace Class = 1 if BuildingClass == "A"
replace Class = 2 if BuildingClass == "A+"
gen BETWEEN = 0
replace BETWEEN = 1 if Period == "During"
gen AFTER = 0
replace AFTER = 1 if Period == "After"
gen Dist = Distance/100

**generating dummies**
gen LeasestartYEAR_1999 = 0
replace LeasestartYEAR_1999 = 1 if LeasestartYEAR == 1999
gen LeasestartYEAR_2003 = 0
replace LeasestartYEAR_2003 = 1 if LeasestartYEAR == 2003
gen LeasestartYEAR_2004 = 0
replace LeasestartYEAR_2004 = 1 if LeasestartYEAR == 2004
gen LeasestartYEAR_2005 = 0
replace LeasestartYEAR_2005 = 1 if LeasestartYEAR == 2005
gen LeasestartYEAR_2006 = 0
replace LeasestartYEAR_2006 = 1 if LeasestartYEAR == 2006
gen LeasestartYEAR_2007 = 0
replace LeasestartYEAR_2007 = 1 if LeasestartYEAR == 2007
gen LeasestartYEAR_2008 = 0
replace LeasestartYEAR_2008 = 1 if LeasestartYEAR == 2008
gen LeasestartYEAR_2009 = 0
replace LeasestartYEAR_2009 = 1 if LeasestartYEAR == 2009
gen LeasestartYEAR_2010 = 0
replace LeasestartYEAR_2010 = 1 if LeasestartYEAR == 2010
gen LeasestartYEAR_2011 = 0
replace LeasestartYEAR_2011 = 1 if LeasestartYEAR == 2011
gen LeasestartYEAR_2012 = 0
replace LeasestartYEAR_2012 = 1 if LeasestartYEAR == 2012
gen LeasestartYEAR_2013 = 0
replace LeasestartYEAR_2013 = 1 if LeasestartYEAR == 2013
gen LeasestartYEAR_2014 = 0
replace LeasestartYEAR_2014 = 1 if LeasestartYEAR == 2014
gen LeasestartYEAR_2015 = 0
replace LeasestartYEAR_2015 = 1 if LeasestartYEAR == 2015
```

```
gen LeasestartYEAR_2016 = 0
replace LeasestartYEAR_2016 = 1 if LeasestartYEAR == 2016
gen LeasestartYEAR_2017 = 0
replace LeasestartYEAR_2017 = 1 if LeasestartYEAR == 2017
gen LeasestartYEAR_2018 = 0
replace LeasestartYEAR_2018 = 1 if LeasestartYEAR == 2018
gen LeasestartYEAR_2019 = 0
replace LeasestartYEAR_2019 = 1 if LeasestartYEAR == 2019
gen LeasestartYEAR_2020 = 0
replace LeasestartYEAR_2020 = 1 if LeasestartYEAR == 2020
gen LeasestartYEAR_2021 = 0
replace LeasestartYEAR_2021 = 1 if LeasestartYEAR == 2021

gen ClassAplus = 0
replace ClassAplus = 1 if Class == 2
gen ClassA=0
replace ClassA = 1 if Class == 1
gen ClassB=0
replace ClassB = 1 if Class == 0

gen Zone_CBD = 0
replace Zone_CBD = 1 if Zone == "CBD"
gen Zone_CCW = 0
replace Zone_CCW = 1 if Zone == "City Centre West"
gen Zone_CCE = 0
replace Zone_CCE = 1 if Zone == "City Centre East"
gen Zone_East = 0
replace Zone_East = 1 if Zone == "East"
gen Zone_JcU = 0
replace Zone_JcU = 1 if Zone == "Jerozolimskie corridor Upper"

gen BuildingCompletionYear_1993 = 0
replace BuildingCompletionYear_1993 = 1 if BuildingCompletionYear == 1993
gen BuildingCompletionYear_1995 = 0
replace BuildingCompletionYear_1995 = 1 if BuildingCompletionYear == 1995
gen BuildingCompletionYear_1996 = 0
replace BuildingCompletionYear_1996 = 1 if BuildingCompletionYear == 1996
gen BuildingCompletionYear_1997 = 0
replace BuildingCompletionYear_1997 = 1 if BuildingCompletionYear == 1997
gen BuildingCompletionYear_1998 = 0
replace BuildingCompletionYear_1998 = 1 if BuildingCompletionYear == 1998
gen BuildingCompletionYear_1999 = 0
replace BuildingCompletionYear_1999 = 1 if BuildingCompletionYear == 1999
gen BuildingCompletionYear_2000 = 0
replace BuildingCompletionYear_2000 = 1 if BuildingCompletionYear == 2000
gen BuildingCompletionYear_2001 = 0
replace BuildingCompletionYear_2001 = 1 if BuildingCompletionYear == 2001
gen BuildingCompletionYear_2002 = 0
replace BuildingCompletionYear_2002 = 1 if BuildingCompletionYear == 2002
gen BuildingCompletionYear_2003 = 0
replace BuildingCompletionYear_2003 = 1 if BuildingCompletionYear == 2003
gen BuildingCompletionYear_2004 = 0
```

```
replace BuildingCompletionYear_2004 = 1 if BuildingCompletionYear == 2004
gen BuildingCompletionYear_2006 = 0
replace BuildingCompletionYear_2006 = 1 if BuildingCompletionYear == 2006
gen BuildingCompletionYear_2007 = 0
replace BuildingCompletionYear_2007 = 1 if BuildingCompletionYear == 2007
gen BuildingCompletionYear_2008 = 0
replace BuildingCompletionYear_2008 = 1 if BuildingCompletionYear == 2008
gen BuildingCompletionYear_2010 = 0
replace BuildingCompletionYear_2010 = 1 if BuildingCompletionYear == 2010


*generating interaction variables**

gen Int1 = Treatment*BETWEEN
gen Int2 = Treatment*AFTER
gen Int3 = Treatment*TREND_BEFORE
gen Int4 = Treatment*TREND_AFTER

gen IntDist = Treatment*Dist
gen IntDist1 = Treatment*BETWEEN*Dist
gen IntDist2 = Treatment*AFTER*Dist
gen IntDist3 = Treatment*TREND_BEFORE*Dist
gen IntDist4 = Treatment*TREND_AFTER*Dist

**Droping outliers**

summarize LogR, detail
keep if inrange(LogR, r(p1), r(p99))
summarize GLA, detail
keep if inrange(GLA, r(p1), r(p99))
summarize LeaseDuration, detail
keep if inrange(LeaseDuration, r(p1), r(p99))
drop if Distance > 1500

**Deleting singleton dummy variables**

drop if LeasestartYEAR == 1999
drop if LeasestartYEAR == 2020
drop if LeasestartYEAR == 2021
drop if BuildingCompletionYear == 2009
drop if Zone == "East"

**Desriptive statistics**

summarize LogR Distance GLA LeaseDuration BuildingAge BuildingGLA if Distance
summarize LogR Distance GLA LeaseDuration BuildingAge BuildingGLA if Distance <= 400
summarize LogR Distance GLA LeaseDuration BuildingAge BuildingGLA if Distance > 400

**Correlation matrix**

correlate LogR Treatment Distance AFTER BETWEEN TREND_BEFORE LogGLA LeaseDuration LeasestartYEAR_2003
LeasestartYEAR_2004 LeasestartYEAR_2005 LeasestartYEAR_2006 LeasestartYEAR_2007 LeasestartYEAR_2008
```

```
LeasestartYEAR_2009 LeasestartYEAR_2010 LeasestartYEAR_2011 LeasestartYEAR_2012 LeasestartYEAR_2013
LeasestartYEAR_2014 LeasestartYEAR_2015 LeasestartYEAR_2016 LeasestartYEAR_2017 LeasestartYEAR_2018
LeasestartYEAR_2019 LogBGLA BuildingAge ClassAplus ClassA ClassB BuildingCompletionYear_1993
BuildingCompletionYear_1995 BuildingCompletionYear_1996 BuildingCompletionYear_1997 BuildingCompletionYear_1998
BuildingCompletionYear_1999 BuildingCompletionYear_2000 BuildingCompletionYear_2001 BuildingCompletionYear_2002
BuildingCompletionYear_2003 BuildingCompletionYear_2004 BuildingCompletionYear_2006 BuildingCompletionYear_2007
BuildingCompletionYear_2008 BuildingCompletionYear_2010 Zone_CBD Zone_CCW Zone_CCE Zone_JcU

** Model 1 **

reg LogR Treatment BETWEEN AFTER Int1 Int2 Int3 IntDist IntDist1 IntDist2 IntDist3 i.LeasestartYEAR, robust
estat ic

** Model 2 **

reg LogR Treatment BETWEEN AFTER Int1 Int2 IntDist IntDist1 IntDist2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA
BuildingAge i.Class i.BuildingCompletionYear i.Zoning, robust
estat ic

** Model 3 **

reg LogR Treatment BETWEEN AFTER Int1 Int2 Int3 Int4 IntDist IntDist1 IntDist2 IntDist3 IntDist4 LogGLA LeaseDuration
i.LeasestartYEAR LogBGLA BuildingAge i.Class i.BuildingCompletionYear i.Zoning, robust
estat ic

**Model 4**

gen IntDistPower = Treatment*Dist*Dist
gen IntDist1Power = Treatment*BETWEEN*Dist*Dist
gen IntDist2Power = Treatment*AFTER*Dist*Dist

reg LogR Treatment BETWEEN AFTER Int1 Int2 IntDist IntDistPower IntDist1 IntDist1Power IntDist2 IntDist2Power LogGLA
LeaseDuration i.LeasestartYEAR LogBGLA BuildingAge i.Class i.BuildingCompletionYear i.Zoning, robust
estat ic

**OLS assumptions testing**

reg LogR Treatment BETWEEN AFTER Int1 Int2 IntDist IntDist1 IntDist2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA
BuildingAge i.Class i.BuildingCompletionYear i.Zoning

** Error term has a population mean of zero**

predict res, residuals
sum res

**Autocorrelation - no time series**

**Homoscedasticity - heteroskedasticity present**
estat hettest

**Multicollinearity - high VIF due to interaction variables, however correlation matrix does not show anything
worrying**
```

```
vif

**Normal distribution of error term - no normal distribution of error term**
swilk res

**Exogeneity**
**Durbin-Wu-Hausman test*
reg Distance Treatment BETWEEN AFTER Int1 Int2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA BuildingAge i.Class
i.BuildingCompletionYear i.Zoning
predict Dist_res, res
reg LogR Treatment Dist Dist_res Int1 Int2 IntDist1 IntDist2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA BuildingAge
i.Class i.BuildingCompletionYear i.Zoning
test Dist_res
** Durbin-Wu-Hausman test -> no rejection of H0, endogeneity not a problem of Distance variable **


**Chow test**
reg LogR Treatment BETWEEN AFTER Int1 Int2 IntDist IntDist1 IntDist2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA
BuildingAge i.Class i.BuildingCompletionYear i.Zoning if Treatment == 1

reg LogR Treatment BETWEEN AFTER Int1 Int2 IntDist IntDist1 IntDist2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA
BuildingAge i.Class i.BuildingCompletionYear i.Zoning if Treatment == 1 & AFTER == 1

reg LogR Treatment BETWEEN AFTER Int1 Int2 IntDist IntDist1 IntDist2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA
BuildingAge i.Class i.BuildingCompletionYear i.Zoning if Treatment == 1 & BETWEEN == 1

reg LogR Treatment BETWEEN AFTER Int1 Int2 IntDist IntDist1 IntDist2 LogGLA LeaseDuration i.LeasestartYEAR LogBGLA
BuildingAge i.Class i.BuildingCompletionYear i.Zoning if Treatment == 1 & AFTER == 0 & BETWEEN == 0

**Chow test = ((RSSp - (RSS1 + RSS2 + RSS3))/(k1+k2+k3 - kp)/((RSS1 + RSS2 + RSSS3)/(Np-(k1+k2+k3)))**
**Chow test = ((3.6335789 - (0.297382927 + 0.535584435 + 2.33640123))/(9+14+16 - 32))/((0.297382927 + 0.535584435 +
2.33640123)/(205-(9+14+16))) = 3.47337823162 -> rejection of H0**
```