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INSTITUTO COPPEAD DE ADMINISTRAÇÃO

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OFFICE RENT DYNAMICS:
A Panel Data Analysis of São Paulo, Rio de Janeiro and Oslo

Rio de Janeiro

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Master's dissertation presented to the COPPEAD Graduate School of Business, Universidade Federal do Rio de Janeiro, as part of the mandatory requirements in order to obtain the title of Master in Business Administration (M.Sc.).

Supervisor: Otavio Henrique dos Santos Figueiredo, D.Sc.

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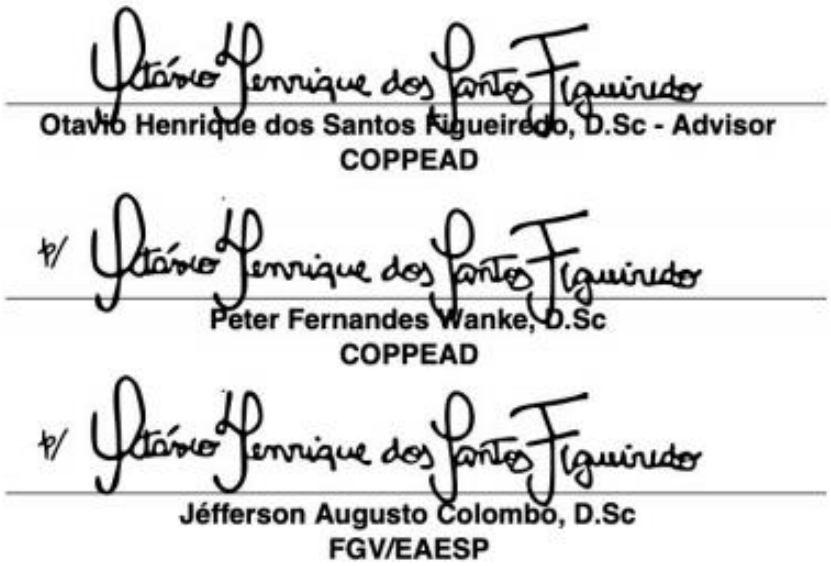

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RESUMO

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Nas últimas décadas, muitos artigos estudaram a dinâmica do aluguel de escritórios, com foco principalmente, nos Estados Unidos, Europa e Ásia, Enquanto isso, os países da América Latina não vêm sendo explorados em igual proporção. Este estudo visa preencher essa lacuna da literatura latino-americana e explorar fatores que ajudem a explicar a dinâmica de preços de aluguel de escritórios nos mercados brasileiros das cidades de São Paulo e Rio de Janeiro, comparando-os ao mercado norueguês da cidade Oslo.

A metodologia aplicada é um modelo de correção de erros, no qual as dinâmicas de longo e curto prazo dos mercados de escritórios são exploradas pelos diferentes modelos. Com base em estudos anteriores, são examinadas as significâncias das variáveis de demanda, produto interno bruto, taxa de desemprego, efeito do emprego sobre o nível de aluguel, oferta de demanda, taxa de vacância e estoque de área. O período estudado é compreendido entre 2005 a 2018 para São Paulo e Rio de Janeiro, e 2011 a 2019 para Oslo.

O principal achado neste estudo é que a maioria das variáveis explicativas estabelecidas em estudos anteriores também apresentaram significância neste estudo. Em particular, as variações nas variáveis de demanda mostraram ter uma conexão significativa com os preços de aluguel de escritórios no longo e no curto prazo. Uma diferença interessante entre os resultados do mercado brasileiro e do mercado norueguês investigado é que o poder explicativo dos modelos de longo prazo é maior no caso das cidades de São Paulo e Rio de Janeiro, enquanto para a cidade de Oslo, observa-se a situação oposta, onde os modelos de curto prazo têm o maior poder explicativo.

Palavras chave:
Dinâmica do aluguel de escritórios
Determinantes de aluguel
Mercado de escritórios brasileiro
Mercado de escritórios de Oslo
Análise de dados de painel
Modelo de correção de erros (ECM)

ABSTRACT

WENG, Jørgen. OFFICE RENT DYNAMICS: A Panel Data Analysis of São Paulo, Rio de Janeiro and Oslo. Rio de Janeiro, 2021. 45 pp. Thesis (Masters Degree in Business Administration) - COPPEAD Graduate School of Business, Federal University of Rio de Janeiro, Rio de Janeiro, 2021.

Many published papers have studied office rent dynamics during recent decades, where the focus has been mainly on the United States, Europe and Asia, while Latin America is less exploreed. This study aims to fill a part of Latin American gap in literature and explore which factors explain the dynamics of office rental prices in the Brazilian markets of São Paulo and Rio de Janeiro, and in the Norwegian market of Oslo.

The methodology that is applied is an error correction model, where both long-term and short-term dynamics of the office markets are explored through different models. Based on previous studies, the significance of the demand variables, gross domestic product, unemployment rate and employment effect on rent level is examined, as well as the demand supply variables, vacancy rate and stock of floor space. The period of time studied ranges from 2005 to 2018 for São Paulo and Rio de Janeiro, and from 2011 to 2019 for Oslo.

The key finding in this study is that most of the established explanatory variables from previous studies are also found in this study. In particular, fluctuations in the demand variables turned out to have a significant connection to the office rent prices on moth long-term and short-term. An interesting difference between the results from the Brazilian markets and the Norwegian market investigated is that the explanatory power of the long-term models is higher for the markets of São Paulo and Rio de Janeiro than for the market of Oslo, while the situation is opposite for the short-term models where the Oslo market has the highest explanatory power.

Keywords:
Office rent dynamics
Rent determinants
Brazilian office market
Oslo office market
Panel data analysis
Error correction model (ECM)

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LIST OF ABREVIATIONS

EA	Economic Activity
GDP	Gross Domestic Product
SSB	Norway Statistics (Statistisk sentralbyrå)
IBGE	Instituto Brasileiro de Geografia e Estatística
IPAE	Instituto de Pesquisa Econômica Aplicada
JLL	Jones Lang LaSalle
v	Vacancy Rate
s	Stock of Floor Space
R	Real Office Rent
D	Demand
OS	Occupied Supply of Space

CONTENTS

1. INTRODUCTION

Many published papers have studied the office rent dynamics in recent decades, where the focus has been mainly on the United States (Brounen & Jennen, 2009; Ibanez & Pennington-Cross, 2013) Europe (Mouzakis & Richards, 2007; Brounen & Jennen, 2008) and Asia (De Wit & Van Dijk, 2003). Latin American countries have not been researched and published in recognized English journals in the same extent regarding this field. This study builds on theories and findings from previous studies including Hendershott et al. (2002a, b) and it aims to explore which factors that can explain the dynamics of office rental prices in the Brazilian markets of São Paulo and Rio de Janeiro and the Norwegian market of Oslo, from 2005 to 2019.

The key finding of this study is that most of the established explanatory variables from previous studies are also found in this study. In particular, fluctuations in the demand variables turned out to have a significant connection to the office rent prices on month, long-term and short-term. An interesting difference between the results from the Brazilian markets and the Norwegian market investigated is that the explanatory power of the long-term models is higher for the markets of São Paulo and Rio de Janeiro than for the market of Oslo, while the situation is opposite for the short-term models where the Oslo market has the highest explanatory power.

In the following chapters of this paper, the contextual settings will be described. Then, the relevant literature in this paper is summarized. Thereafter, the methodology and data applied are described before the results of the analysis are presented. At the end of the paper, conclusions are stated, and future research studies are suggested.

2. CONTEXTUAL SETTINGS

In the early 2000s, the world economy was recovering from the crisis in 2001. Global GDP reached all-time highs, before the sub-prime-loan crisis struck the market in 2008. This crisis had a significant effect on the real estate prices in many countries, and in particular the residential real estate prices. In the following years, global GDP grew steadily, until the data series ended in 2019. The global GDP growth throughout the period of time examined in this study is illustrated in the graph below.

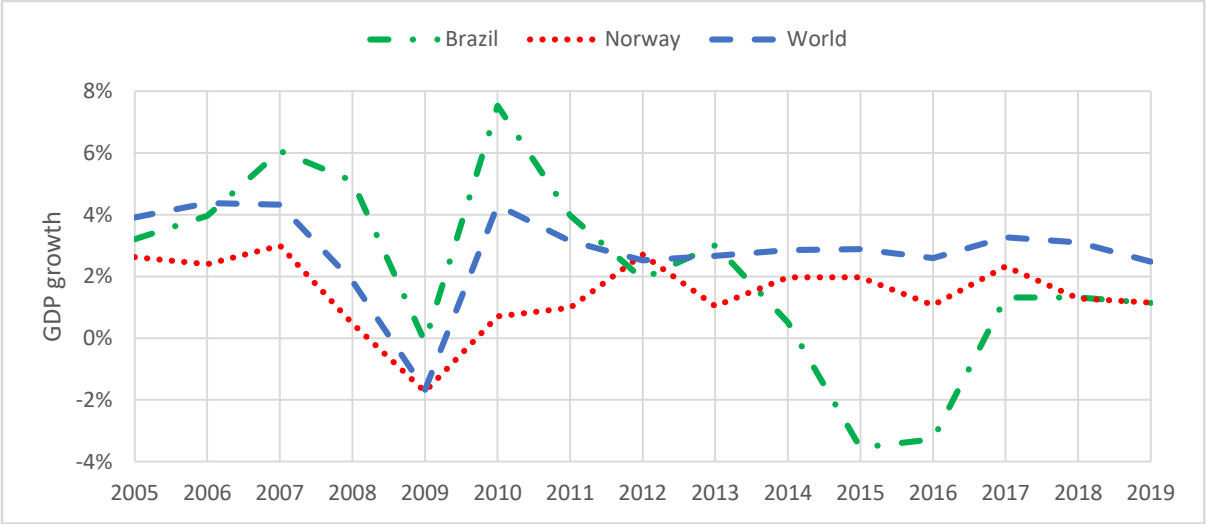

Figure 1: Yearly GDP Growth.

Note: Researcher-constructed, based on information from the World Bank - World Development Indicators.

The markets examined in this study are located in Brazil and Norway, both countries where oil and gas are major contributors to economic activity, significantly controlled by large state-owned companies in the respective countries. For this reason, changes in oil prices have an important impact on economic activity in both countries. The price of oil has varied significantly throughout the period from 2005 to 2019, ranging from 26 USD to 144 USD per barrel of brent spot oil. The graph below illustrates the history of oil prices throughout the period.

Figure 2: Oil price - Europe Brent spot price

Note: Researcher-constructed, based on information from the U.S. Energy Information Administration

In addition, the public sector accounts for a relatively high share of employment in both countries, with consequential implications on job stability and flexibility.

In Brazil, other factors have impacted domestic economic performance, in addition to the variations mentioned above. Brazil's economy was growing rapidly when the country was named host of the 2014 World Cup, and Rio de Janeiro the 2016 Olympics. Growth and optimism turned into trouble with allegations of corruption in key government positions, in the "Lava Jato" (Car Wash) scandal. The real-estate market in Brazil was heavily impacted, where the average office rent prices in São Paulo and Rio de Janeiro started falling in 2013 and 2014 and only stabilized in 2017, with increasing vacancy rates.

In Norway, the national economy has experienced fewer variations than that of Brazil. The average office rental price in Oslo has been increasing throughout the period of time studied, while the vacancy rate has decreased. Further, the office market in Oslo has been professionalized in the same period, and international investors have taken a more important role.

Both Brazil and Norway have been affected by some of the same global occurrences, but there have also been differences in how the economic activity and office rent levels have behaved in the different cities. While the Brazilian cities, and Rio de Janeiro in particular, have had high volatility in the office rent level and vacancy ratios, Oslo has had lower volatility throughout the observed time periods. Potential impacts of the COVID-19 pandemic, which began in 2020, are not considered in this paper, as the data only covers activity until the end of 2019.

3. LITERATURE REVIEW

Two main research directions that explain the determinants of office rental prices have evolved in recent decades. De Wit & Van Dijk (2003) described one direction as determinants of a single equation model, focusing on demand variables. Brounen & Jennen (2008) referred to this perspective as the focus of European literature. The other is described as a structural model where both supply and demand variables are included by looking at the market dynamics, where there is a natural vacancy rate and the rent is explained by the deviation from this. US literature focuses on this direction, according to Brounen & Jennen (2008). In the following sections, the development of these two paths and their merge will be described.

To understand the development of the office rent literature, it is worthwhile to consider some early residential rent literature, as this area of research started to evolve before the area of

office rent. In the US literature, Blank & Winnick (1959) introduce a framework for residential markets for what later evolved into being applied in office markets. They study how vacancy rates impact rent in their study of the US residential market from 1918 to 1944. Rosen (1984) builds on this study, applying the theory in an office market study of San Francisco from 1963 to 1983. Rosen develops a structural office model, where rent levels are explained by the difference between actual and natural vacancy rate. The study found that the rise or fall of rent increased the further the actual rent was from the optimal vacancy rent. Hekman (1985) included vacancy rate directly as a cause for rent in the office market. Schilling et al. (1987) used a structural framework to explain local office rents in the United States, while Wheaton and Torto (1988) used the framework for aggregated office market in the United States. Further, Hendershott (1996) explained in his study of the Sydney office market the changes of real rents by vacancy and deviations in rent from the equilibrium level.

In the European literature, most of the first studies on office rent were done of markets in the UK. Gardiner and Henneberry (1988, 1991) study the UK office market from 1977 to 1984 and explain the rent changes by including GDP, employment, unemployment and average income as demand variables and office stock as a supply variable. Dobson and Goddard (1992) find in their studies of the UK from 1972 to 1987, that employment is not a significant determinant of office rent. In this study they also found support for real interest rates' positive effect on real office rents. Giussani and Tsolacos (1993) apply a multiple linear regression when investigating determinants of the UK office market from 1977 to 1991. They find that national office rents are significantly impacted by GDP and service employment.

Giussani and Tsolacos (1993) widened the study area to 10 major European cities in their study of data from 1983 to 1992. They found that GDP is the most important determinant of rental values. Supply side variables were left out because of data constraints. In their study of 22 European cities, D'Arcy et al. (1997) explains office change rates with changes in GDP and short-term interest rates. Inclusion of office market size, economic growth and change in the local economy did not increase the explanatory power of the model. Due to increased data availability, also European studies started to include supply side variables in their studies. The same researchers, D'Arcy et al. (1999), explains the Dublin office market from 1970 to 1997 with stock of office floor space as a supply side variable, and GDP and service sector employment as demand side variables. Changes in real GDP lagged one period and changes in stock of office space lagged three periods were exploreed as the two most important determinants of changes in rents. De Wit and van Dijk (2003) study 46 office districts in Asia, Europe and the United States from 1986 to 1999 in order to explore determinants of direct office

investment returns. They examine rent determinants and use changes in GDP (or gross metropolitan product), unemployment rates and inflation as demand side variables. Change in office stocks and change in vacancy rates as supply side as supply side variables. All of the markets are studied using values in the local currencies of the respective countries.

The two paths of office rent literature were combined in an Error Correction Model (ECM) in the studies of office markets in Australia, the UK and the US (Hendershott et al., 2002a, b). This methodology is based on a Cobb-Douglas function and became popular among other researchers within the area, and a significant part of the studies after this apply ECM. All of the following studies mentioned in this chapter apply ECM.

Mouzakis and Richards (2007) investigate 12 major European office markets from 1980 to 2001 and find that market service output and stock of floor space are mostly significant, and the significance increases when looking at data lagged one leg. Brounen and Jennen (2008) had a closer look at ten European cities in their study of data from 1990 to 2006. Five of the cities were considered as premier tier markets (Amsterdam, Frankfurt, London, Madrid and Paris) and five as second tier markets (Barcelona, Düsseldorf, Glasgow, Lyon and Rotterdam). They find only marginal differences between data of demand variables at local and national level. All the economic variables are expressed in the local currency in the respective markets (Euro and GBP). In a study of 15 metropolitan areas in the US from 1990 to 2007, Brounen and Jennen (2009) find that rents are affected by office employment and that this is stronger when the vacancy rates are below the long-time average vacancy. They also find that lagged rents have explanatory power of rents. Hendershott et al. (2010) find matching results in their study of the office market in London from 1977 to 2006, as do Ibanez and Pennington-Cross (2013) in their study of 36 metropolitan office areas in the US from 1990 to 2009.

A study of the Dublin office market over a 33-year period from 1978 to 2010 and find that GNP has explanatory power in both the short- and long-term (McCartney, 2012). Vacancy rate and lagged rent are significant determinants in short-term variations, while stock of floor-space is significant in the long-term. The Bruneau and Cherfouh (2015) study of the greater Paris office market in 1990 to 2013 finds similar short- and long-term determinants as McCartney (2012). In addition, they find that employment is both a short- and long-term determinant of office rent. Nowak (2019) also observes that stock of floor space and employment are significant factors of changes in office rent in his study of the office rental market in four Polish cities from 2005 to 2016. Matching results were found in a study of the office market in Oslo from 2004 to 2019 (Bjørland and Hagen, 2019).

Recent research seems to have reached a relative consensus regarding methods and which main variables affect changes in the office rental prices. The ECM method divided in a short-term and a long-term model with the explanatory variables vacancy rate, stock of floor space, GDP and employment in addition to lagged rent levels. As shown above, a significant number of studies have been conducted in Asia, Europe and the United States, but less in South American markets. This study attempts to fill a part of this gap in the literature by investigating the Brazilian office markets in São Paulo and Rio de Janeiro, by applying the current accepted methodology. In addition, this study investigates the office market in Oslo, Norway, and puts the results from the three markets in a broader context by comparing them to findings from previous studies.

Relevant findings of explanatory variables in previous studies are organised in the

Table 1.

Table 1: Key findings From the Literature Review

Author	Year	Location	Lagged rent	Demand variables			Supply variables	
				GDP	Unemployment rate	Employment	Vacancy rate	Stock of floor space
Blank & Winnick	1953	The United States					Yes	
Rosen	1984	San Francisco, The United States					Yes	
Hekman	1985	The United States		Yes	Yes		Yes	
Shilling et al.	1987	17 cities in the United States					Yes	
Gardiner & Henneberry	1988	United Kingdom		Yes	Yes	Yes		Yes
Wheaton & Torto	1988	The United States					Yes	
Gardiner & Henneberry	1991	United Kingdom		Yes	Yes	Yes		Yes
Dobson & Goddard	1992	United Kingdom			No			
Giussani et al.	1992	10 European cities		Yes	No	Yes, service sector		
Giussani & Tsolacos	1993	United Kingdom		Yes		Yes, service sector		
Hendershott	1996	Sydney, Australia					Yes	
D'Arcy et al.	1997	22 European cities		Yes				
D'Arcy et al.	1999	Dublind, Ireland		Yes		Yes, service sector		Yes
Hendershott	1999	London, United Kingdom	Yes			Yes	Yes	
Hendershott et al.	2002	US, UK and Australia	Yes, short-run			Yes, service sector	Yes, short-run	Yes, long-run
Hendershott et al.	2002	United Kingdom	Yes, short-run			Yes, service sector		Yes, long-run
De Wit & Van Dijk	2003	46 cities in Asia, Europe and the US		Yes	Yes		Yes	Yes
Mouzakis & Richards	2007	12 European cities	Yes	Yes				Yes
Brounen & Jennen	2008	10 European cities		Yes		Yes, service sector		
Brounen & Jennen	2009	The United States	Yes			Yes, service sector	Yes	
Hendershott et al.	2010	London, United Kingdom	Yes, short-run				Yes, lagged	Yes, long-run
McCartney	2012	Dublin, Ireland	Yes, short-run	Yes (GNP)			Yes, short-run	Yes, long-run
Ibanez & Pennington-Cross	2013	36 Metropolitan areas in the United States	Yes		Yes	Service sector		Yes
Bruneau & Cherfouh	2015	Paris, France	Yes, short-run			Yes	Yes, short-run	Yes, long-run
Nowak	2019	4 cities in Poland				Yes		Yes
Bjørland & Hagen	2019	Oslo, Norway	Yes, short-run	Yes		Yes		Yes

The findings from the literature review suggest the following model to explain changes in rent levels in São Paulo, Rio de Janeiro and Oslo:

$$Rent = f(supply, demand)$$

More specifically, we can assess the following model:

$$Rent = f(economic\ activity, stock\ of\ floor\ space, vacancy, lagged\ rent)$$

For economic activity there are a few indicators that have been frequently applied in the literature review, including GDP, unemployment rate and employment.

4. METHODOLOGY

First, the data is tested for co-integration

Aligned with the literature review, the methodology applied in this study is based on the Error Correction Model (ECM) from Hendershott et al. (2002). The ECM usually contains two equations. The first equation describes relationships between variables in the long run, implicitly in the state of equilibrium. The second equation represents short-term adjustments, when dynamics of the variables in the system are influenced by deviations from equilibrium. The model is based on the following Cobb-Douglas function, where demand for space (D) is expressed as a function of real office rent (R) and a measure of economic activity (EA).

$$D_t = \lambda_0 R_t^{\lambda_1} EA_t^{\lambda_2}$$

where λ_1 the price (rent) elasticity is expected to be negative, and λ_2 the income elasticity should be positive. The occupied supply of space (OS) can be expressed as the product of the supply of available office space (s) and the occupancy rate, $(1 - v)$, where v is the vacancy rate.

$$OS_t = (1 - v_t)s_t$$

By definition, at equilibrium, the demand of space equals the occupied stock (OS):

$$OS_t = D_t$$

$$\Leftrightarrow$$

$$(1 - v_t)s_t = \lambda_0 R_t^{\lambda_1} EA_t^{\lambda_2}$$

By adding taking logs on both sides and solving the equation for log of rent, leaves us the reduced-form long-run model[1]:

$$lnR_{it} = \beta_0 + \beta_1 lnEA_{it} + \beta_2' \ln[(1 - v_{it}) \times s_{it}] + u_{it}$$

which also can be written as follows where the supply variables appear separated:

[1] Long-run model: A model that tries to explain the dependent variable's movements over time (years).

$$lnR_{it} = \beta_0 + \beta_1 lnEA_{it} + \beta_2 \ln(1 - v_{it}) + \beta_3 lns_{it} + u_{it}$$

This equation shows long run price (rent) as a function of supply and demand. The i subscript identifies the city or area, while the t subscript stands for time and denotes the observation for the particular panel. The error term is expressed through u_{it}. The implied price and income elasticity are λ1 = 1/β2' and λ2 = −β1'/β2', respectively. Under this specification, rents are associated with contemporaneous demand and supply variables. The contemporaneous vacancy rate is likely to be endogenous, as higher unemployment leads to lower commercial occupancies and declining rents.

To make the price and income elasticity have the correct sign in the long-run model, the coefficient on occupied space must be negative. This implies that higher vacancy rates, which must decrease the amount of occupied space, $((1 - v_{it}) \times s_{it})$, should be associated with higher rent rates. This relationship seems problematic. One approach taken in the literature is to break occupied space or supply into its two components, the occupancy rate and total space.

The ECM requires the variables in the level equation to be cointegrated, or the error correction term to be stationary. Taking differences of the level equation and adding the error correction term yields the short-run rent adjustment model[2]:

$$\Delta lnR_{it} = \alpha_0 + \alpha_1 \Delta lnEA_{it} + \alpha_2' \Delta \ln[(1 - v_{it}) \times s_{it}] + \alpha_3' u_{i(t-1)} + \alpha_4' \Delta lnR_{i(t-1)} + \varepsilon_{it}$$

which also can be written as follows where the supply variables appear separated:

$$\Delta lnR_{it} = \alpha_0 + \alpha_1 \Delta lnEA_{it} + \alpha_2 \Delta \ln(1 - v_{it}) + \alpha_3 \Delta s_{it} + \alpha_4 u_{i(t-1)} + \alpha_5 \Delta lnR_{i(t-1)} + \varepsilon_{it}$$

Here Δ is the differencing operator, such that $\Delta y_{i,t} = y_{i,t} - y_{i,t-1}$, $u_{i(t-1)}$ is the error correction term estimated from the long-run model, and ε_{it} is the error term. The ECM requires the variables in the level equation to be cointegrated, or the error correction term to be stationary, so a preliminary step is to perform unit root test on the error term. The rents adjust to short run changes in the state of the economy, the vacancy rate, the supply of space, deviations of rents from their long run values (error correction term or lagged error term from the long-run model), and the lagged rent changes. The lagged endogenous variable, $\Delta \ln R_{(t-1)}$, allows for partial short run adjustment in the rents or sticky rents (De Wit and Van Dijk, 2003). Assuming that there is no drift in rents, α_0 should be zero. If rents are sticky, then changes in demand, measured by

[2] Short-run model: A model that tries to explain the dependent variable's movement from one period to the next (quarter of a year)

employment or sales, should lead to an increase in rents. The impact of changes in occupied stock is indeterminate. The coefficient on the error correction model is expected to be negative, and it indicates whether there is no adjustment ($\alpha'_3=0$), partial adjustment ($-1<\alpha'_3<0$), complete adjustment ($\alpha'_3=-1$), or over-adjustment ($\alpha'_3<-1$). If the variables are cointegrated, ECM is considered as a suitable method to be applied.

By inserting the data in the long-run model described in Chapter 3, we get the following equation:

$$lnRent_{it} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 \ln(1 - vacancy\ rate_{it}) + \beta_3 Stock + u_{it} \quad (1a)$$

where GDP is substituted a proxy for economic activity (EA). Similar equations for unemployment rate (1b) and employment (1c) are proxies for economic activity are also applied, which leaves us three different equations for long-run rent, where the economic activity proxy the only one that is different among the three of them.

$$lnRent_{it} = \beta_0 + \beta_1 lnUnemployment\ rate_{it} + \beta_2 \ln(1 - vacancy\ rate_{it}) + \beta_3 Stock + u_{it} \quad (1b)$$

$$lnRent_{it} = \beta_0 + \beta_1 lnEmployment_{it} + \beta_2 \ln(1 - vacancy\ rate_{it}) + \beta_3 Stock + u_{it} \quad (1c)$$

By doing the same for the short-run model, we get the following equation:

$$\Delta lnRent_{it} = \alpha_0 + \alpha_1 \Delta lnGDP_{it} + \alpha_2 \Delta \ln(1 - vacancy\ rate_{it}) + \alpha_3 \Delta Stock_{it} + \alpha_4 u_{i(t-1)} + \alpha_5 \Delta lnRent_{i(t-1)} + \varepsilon_{it} \quad (2a)$$

For the long-run model, unemployment rate (2b) and employment (2c) are other proxies for economic activities, which also leave us with three short-run models.

$$\Delta lnRent_{it} = \alpha_0 + \alpha_1 \Delta lnUnemplyment\ rate_{it} + \alpha_2 \Delta \ln(1 - vacancy\ rate_{it}) + \alpha_3 \Delta Stock_{it} + \alpha_4 u_{i(t-1)} + \alpha_5 \Delta lnRent_{i(t-1)} + \varepsilon_{it} \quad (2b)$$

$$\Delta lnRent_{it} = \alpha_0 + \alpha_1 \Delta lnUnemplyment\ rate_{it} + \alpha_2 \Delta \ln(1 - vacancy\ rate_{it}) + \alpha_3 \Delta Stock_{it} + \alpha_4 u_{i(t-1)} + \alpha_5 \Delta lnRent_{i(t-1)} + \varepsilon_{it}$$

(2c)

The models are applied on each of the markets separately, as they are all expected to have specific characteristics, such as different currencies, importance of industries, public companies etc. Previous studies have been conducted in this manner, according to De Wit and van Dijk (2003) and Brounen & Jennen (2008), granting greater alignment of the results of this study to the existing structure of literature in the research area.

In order to control for autocorrelation, the Durbin-Watson test (DW) is performed. The software "R" was applied operationalize the equations models presented above. The "PLM" package was applied. The dependent variable was Rent in all the models, and the independent variables changed according to the equations specified above.

A cointegration test for panel data is applied to explore potential cointegration among the variables. Pedroni (1999) critical values for cointegration is used to measure presence of cointegration.

5. DATA

As concluded in the literature review, studies of the dynamics of South American office markets are rarely published in global journals. As this study is conducted at a Brazilian university (UFRJ – COPPEAD), it was a logical consequence to examine Brazilian office markets. Knowledge from professors at the Brazilian university and local network, was helpful to promote availability of data. The two largest office markets of Brazil, São Paulo and Rio de Janeiro, are also the markets which have the highest quality of available historical data. They were therefore chosen as markets to be examined in this study to expand knowledge of South American office market dynamics.

In order to compare the results from markets in developing countries, the office market in Oslo was chosen because of the Norwegian origin of this paper's author. Personal experience and local network and knowledge were helpful to locate relevant data for the Oslo office market to this study.

The variables in this study are based on the findings in the literature review. The data is secondary data gathered from a several sources in order to serve the issue of this study.

Due to data availability, the time period of this study is a 14-year period starting in 2005 and ending 2018 for the office markets São Paulo and Rio de Janeiro, while it is a 9-year period from 2011 to 2019 for the Oslo office market. The data provided and analyzed on a quarterly basis. This implies that the total number of periods studied in the Brazilian office markets is 56

periods and the total number of periods studied in the Oslo office market is 36 periods. The rent prices are expressed as Brazilian reais per square meter per month (BRL/sqm/month) in Brazil, and Norwegian kroner per square meter per year (NOK/sqm/year) in Norway, as these are the way they normally are expressed in the respective countries. This is also how the currencies are treated in the studies in the literature review. For Rio de Janeiro, the rent data is provided semi-annually from 2005 to 2009 and is interpolated to quarterly data for this time period. This is done by substituting the missing point by middle point of the observation before and after. While this can reduce the quality of the data, the benefits from getting a longer data series are considered as more beneficial.

To study the office rent dynamics in São Paulo and Rio de Janeiro, Jones Lang LaSalle Brazil provides historical data for rent and vacancy. The data is gathered from a significant number of office buildings in different neighborhoods (submarkets) and is considered to be very relevant for the purpose of this study, even though it does not cover all the office buildings in the markets. Rent level is based on asking price and is average for the total market in the city is as well as divided in neighborhoods as submarkets. This implies limitations as the varieties in the different contracts are not considered. There are breaks in 2009 by how the data is gathered and organized. Data for stock of floor space and vacancy rate are applied at market level, because this the submarkets are very linked for these two variables. Data for economic activity, GDP, is from the public available data provided by IBGE and concerns Brazil as a country. Data for unemployment rate and employment are on metropolitan level for São Paulo and Rio de Janeiro respectively, and gathered from IBGE. Because of limited availability of continuous data series throughout the period, data series from 2005 to 2016 are continued by other data series from 2012 to 2018. In order to make a continuous data series, there was made a regression of the overlapping observations, and the points from 2005 to 2011 were adjusted according to this. This adjustment might lead to a little lower accuracy, but the advantage of a continuous data series is considered as greater. The data for GDP, unemployment rate and employment are all seasonally adjusted in order to remove seasonally effects on the data set. The inflation data set for Brazil is provided by the Central Bank of Brazil (Banco Central do Brasíl), while the inflation data for Norway is provided by Norway Statistics (Statistisk sentralbyrå).

Rent data for the office market in Oslo provided by Arealstatistikk. The data is gathered from a significant number of office buildings in different neighborhoods of Oslo and is considered to be very relevant for the purpose of this study, even though it does not cover all the office buildings in the market. The provided rent data is based on the actual price on the

signing date. As for São Paulo and Rio de Janeiro, the rent data is provided as average for the total market in the city is, as well as divided in neighborhoods as submarkets. Data for stock of floor space and vacancy rate are provided by Malling & Co. and is applied at market level like in the Brazilian markets. Data for the GDP, unemployment rate and employment are provided by public data on Statistics Norway (Statistisk sentralbyrå), all concerning Norway as a country. According to Brounen & Jennen (2008), there are just marginal differences between national and regional data for the prime-tier cities, which Oslo is considered to be in Norway. The data applied is listed in

Table 2.

Table 2: Variables and the Sources of the Data Applied in the Model

Variable		São Paulo and Rio de Janeiro	Oslo
R	Rent	Jones Lang LaSalle	Arealstatistikk
EA	GDP	IPEA, IBGE	Statistisk sentralbyrå
EA	Unemployment rate	IBGE	Statistisk sentralbyrå
EA	Employment	IBGE	Statistisk sentralbyrå
S	Stock of Floor Space	Jones Lang LaSalle	Malling & Co
V	Vacancy rate	Jones Lang LaSalle	Malling & Co

EA = Economic activity

The different submarkets that provide data applied in the analyzes were chosen based on the continuity if rental data. Submarkets where a significant amount of data are missing are excluded. Data from the submarkets listed in

Table 3 are applied in order to analyze the respective markets:

Table 3: Submarkets in the Markets Explored

Market	São Paulo	Rio de Janeiro	Oslo
Submarket	Alpaville	Barra	Bryn/Helsfyr
	Barra Funda	Centro	CBD (Vika og Aker Brygge)
	Berrini	Orla	City Center
	Faria Lima		Inner City
	Itaim		Lysaker
	Paulista		Nydalen
			Outer East
			Outer South
			Outer West
			Skøyen

6. RESULTS AND ANALYSIS

First some descriptive statistics will be presented. Further, the results from the different models are divided into sections of the long-term models and the short-term models.

6.1 DESCRIPTIVE STATISTICS

In order to understand the data set applied in this study, the data is illustrated in the following figures and key information is tables for descriptive statistics and correlation. All the following information presented is separated by market.

The office rent level in the different submarkets in São Paulo throughout the studied time period are illustrated in Figure 3. There is a general trend that rent levels peaked around 2012 and declined the following years before stabilizing the last few years. The submarket of Faria Lima has had the highest rent level throughout the period. In 2017, the submarket of Alphaville has one observation the variates dramatically from the rest. This observation has been controlled with the supplier of the data series and is confirmed to be correct.

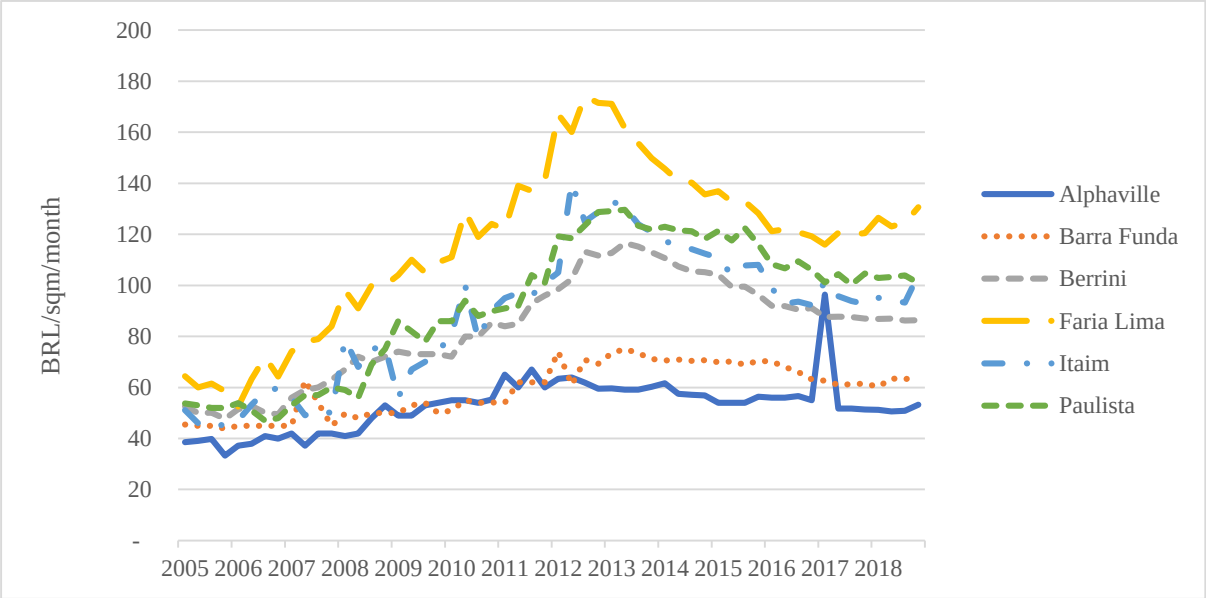

Figure 3: Office Rent Levels in São Paulo

Correlation and descriptive statistics for the data of the São Paulo market is presented in

Table 4. Rent has the highest correlation with unemployment rate (-0.48), and observation that coherent with the findings from the literature review. The correlations between GDP and employment (0.93) and stock of floor space (0.78) are high, while the correlation between unemployment rate and employment is surprisingly low (-0.21) in relation to the findings of significance in the literature review.

The median of the rent level is 74.00, the mean is 82.28 and the standard deviation is 30.83. The employment is most stable and has the lowest relative standard deviation (9 %), while stock of floor space (35 %) and rent (33 %) have the highest volatility.

Table 4: Correlation and Descriptive Statistics of Data for the São Paulo Market

	Rent	GDP	Unemploy	Employ	Vacancy	Stock
Rent	1.00					
GDP	0.16	1.00				
Unemploy	-0.48	-0.38	1.00			
Employment	0.08	0.93	-0.21	1,00		
Vacancy	-0.28	0.36	0,39	0,37	1,00	
Stock	-0.18	0.78	0,26	0,81	0,73	1,00
Min.	33.28	1 048 470	0.074	5 477	0.060	1 967 502
1st Q	55.14	1 329 113	0.078	9 088	0.098	2 315 122
Median	74.00	1 634 288	0.105	9 786	0.180	2 867 586
Mean	82.28	1 515 253	0.105	9 583	0.165	3 291 707
3rd Q	104.73	1 697 379	0.125	10 289	0.230	4 135 252
Max	174.19	1 808 903	0.147	10 560	0.260	5 422 631
SD	30.83	233 159	0.025	864	0.068	1 138 011
Relative SD	33 %	15 %	24 %	9 %	41 %	35 %

The development of office rent prices in the submarkets of Rio de Janeiro is illustrated in Figure 4. The rental prices were increasing until they peaked in 2013 and decreased for the remaining period of time studied. Orla is the submarket that has had the highest rent levels during the period. Centro had a peak in 2015 that stands out from the rest of the observations. In order to control that the observation is correct, it has been doublechecked with the data series from the data provider.

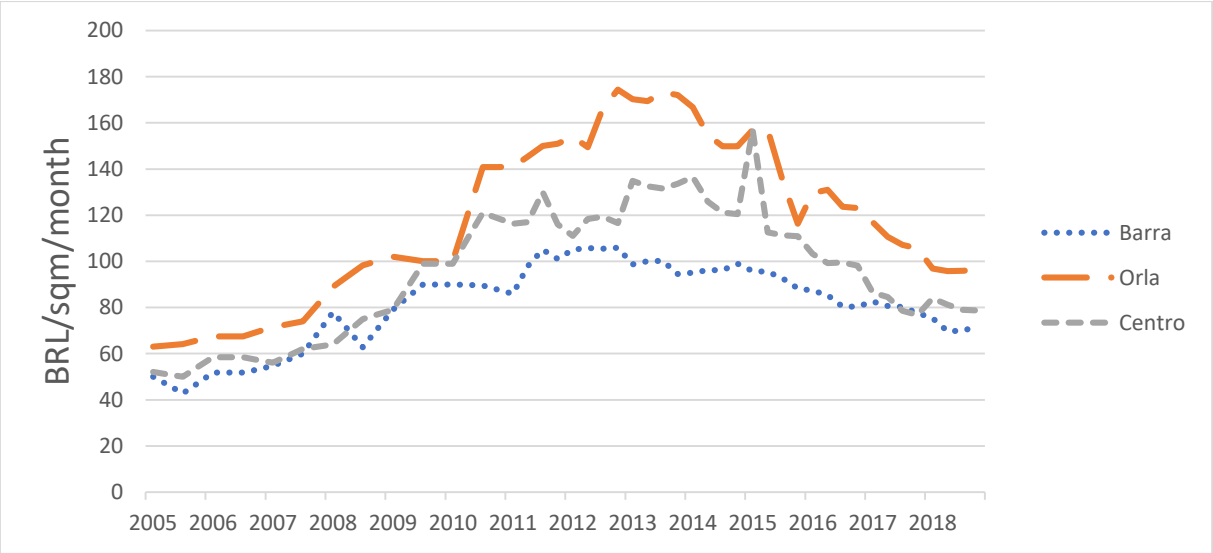

Figure 4: Office Rent Levels in Rio de Janeiro

Correlation and descriptive statistics for the data of the Rio de Janeiro market is presented in

Table 5Table 6. The correlation between rent and unemployment rate (-0.56) and vacancy rate (-0.44) are the strongest and matches the findings in the literature studies. Further, as for São Paulo, there are strong correlations between GDP and employment (0.82) and stock of floor space (0.75), which also is coherent with the findings in previous studies.

The rent level reaches from 42.75 to 174.42, with a median of 95.82 and a mean of 97.48. The relative standard deviations for the different variables are comparable to the values for the São Paulo market.

Table 5: Correlation and Descriptive Statistics of Data for the Rio de Janeiro market

	Rent	GDP	Unemploy	Employ	Vacancy	Stock
Rent	1.00					
GDP	0.34	1.00				
Unemploy	-0.56	-0.35	1.00			
Employment	0.34	0.82	-0.30	1.00		
Vacancy rate	-0.44	0.35	0.48	0.01	1.00	
Stock	-0.20	0.75	0.16	0.48	0.82	1.00
Min.	42.75	1 048 470	0.060	4 857	0.034	722 245
1st Q	73.69	1 329 113	0.078	5 078	0.051	869 252
Median	95.82	1 634 288	0.096	5 371	0.101	1 261 434
Mean	97.48	1 515 253	0.098	5 277	0.152	1 435 983
3rd Q	116.66	1 697 379	0.114	5 507	0.243	1 885 500
Max	174.42	1 808 903	0.151	5 558	0.375	2 593 863
SD	31.51	233 508	0.027	240	0.113	628 062
Relative SD	30 %	15 %	27 %	5 %	74 %	44 %

The office rent levels in the different submarkets of Oslo are illustrated in Figure 5. In all the submarkets, the rent level has increased throughout the studied period of time. CDB has had the highest rent levels all the time.

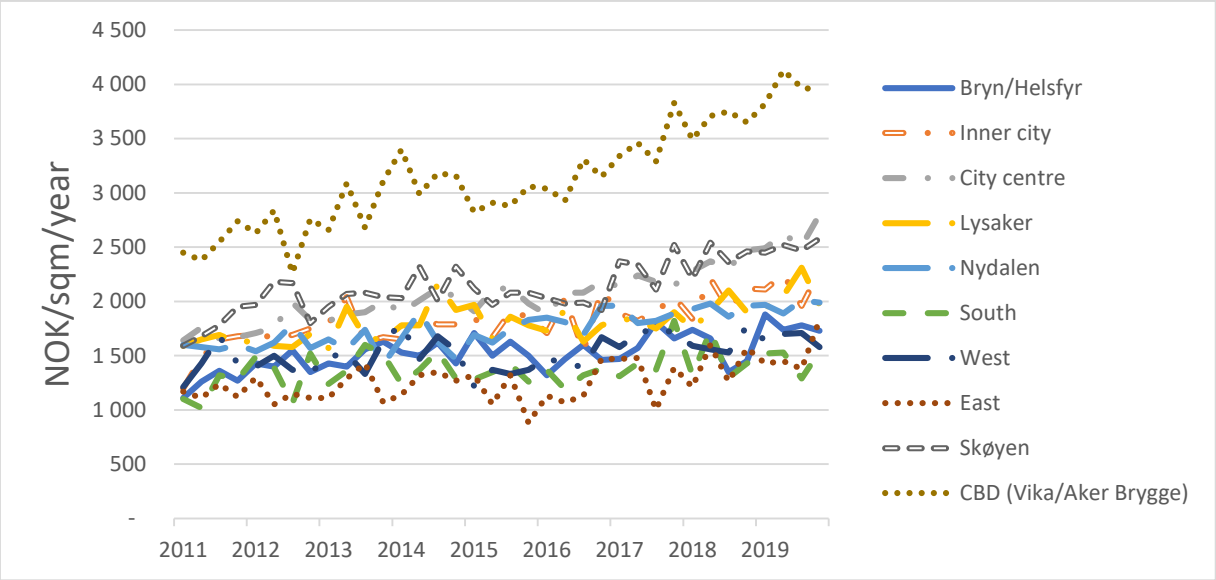

Figure 5: Office Rent Levels in Oslo

Correlation and descriptive statistics for data of the Oslo market is presented in Table 6. The correlations between rent and the other variables are surprisingly low compared to the findings from previous studies. GDP is highly correlated to all the other variables (0.46-0.97).

The rent levels reach from 880 to 4130, with a median of 1720 and a mean of 1845. The relative standard deviation is highest for the rent level (29 %), and lowest for employment (2 %), GDP (4 %) and stock of floor space (4 %).

Table 6: Correlation and Descriptive Statistics of Data for the Oslo Market

	Rent	GDP	Unemploy	Employ	Vacancy	Stock
Rent	1.00					
GDP	-0.03	1.00				
Unemploy	-0.13	0.46	1.00			
Employ	0.00	0.96	0.36	1.00		
Vacancy	0.01	-0.89	-0.27	-0.93	1.00	
Stock	-0.04	0.97	0.59	0.93	-0.87	1.00
Min.	880	778 250	0.031	2526	0.050	7 111 025
1st Q	1 470	808 935	0.035	2600	0.064	7 517 179
Median	1 720	846 448	0.039	2638	0.069	7 851 324
Mean	1 845	842 015	0.039	2635	0.069	7 729 954
3rd Q	2 030	875 879	0.042	2655	0.076	7 977 914
Max	4 130	898 657	0.050	2737	0.088	8 149 515
SD	566	36 578	0.005	53	0.010	314 714
Relative SD	29 %	4 %	13 %	2 %	15 %	4 %

6.2 LONG-TERM MODELS

In this section, we discuss the results from the long-term models. The regression outputs are provided in Table 7.

Table 7: Results of Long-term Models

Long-term models	Model 1a			Model 1b			Model 1c		
	SP	RJ	Oslo	SP	RJ	Oslo	SP	RJ	Oslo
Log (GDP_t)	1.90 ***	2.27 ***	0.46						
	(0.10)	(0.25)	(0.50)						
log ($Unemploy_t$)				-0.56 ***	-0.27 ***	-0.34 ***			
				(0.03)	(0.06)	(0.06)			
log ($Employment_t$)							0.80 ***	5.72 ***	2.78 **
							(0.20)	(0.82)	(0.86)
log ($1\text{-}Vacancy_t$)	-0.55 ***	0.59	1.72	0.54 ***	2.63 ***	-1.59	0.99 ***	1.71 ***	-0.28
	(0.15)	(0.37)	(0.95)	(0.13)	(0.25)	(1.05)	(0.20)	(0.31)	(1.12)
log ($Stock_t$)	-1.04 ***	-0.76 ***	-0.29	-0.05	0.59 ***	1.55 ***	-0.19 *	-0.21	-0.61
	(0.06)	(0.19)	(0.48)	(0.03)	(0.08)	(0.34)	(0.08)	(0.17)	(0.31)
N	336	168	360	336	168	360	336	168	360
R^2-adj	0.65	0.86	0.05	0.62	0.82	0.13	0.28	0.84	0.08
DW	0.7	0.6	1.8	0.7	0.6	1.9	0.4	0.6	1.8
Cointegration	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors are reported in parentheses below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%. For detailed results from cointegration test, see Appendix 2. The short-term model was adjusted with an EMC approach.

The results show that the adjusted R^2 ranges from 0.08 to 0.86, where the numbers for the São Paulo market (0.28-0.62) and the Rio de Janeiro market (0.82-0.86) are to be closer to each other, than to the Oslo market (0.05-0.13).

While the results from the Durbin-Watson tests for the Oslo market show no autocorrelation, the results for the markets of São Paulo and Rio de Janeiro show there is a

positive auto correlation for all three models for the two markets. In order to be comparable with the results from Oslo, there no corrections have been applied to handle the autocorrelation.

The first demand variable, GDP, is a positive significant explanatory variable only for the São Paulo and Rio de Janeiro markets, which means that a higher GDP leads to a higher office rent level. GDP as an explanatory variable with positive sign finds support from a broad consensus among the research in the area including findings from Hekman (1985), Gardiner & Henneberry (1988 & 1991), Giussani et al. (1992), D'Arcy et al. (1997 & 1999) Mouzakis & Richards (2007), Bruonen & Jennen (2008) in their studies. For Oslo, GDP is not found to be a significant long-term explanatory variable, differing from the findings of significance in the same market from Bjørland & Hagen (2019).

The second demand variable, unemployment rate, is found as a highly significant explanatory variable with negative sign for all of the markets, which corresponds well with the findings from Hekman (1985), Gardiner & Henneberry (1988 & 1991), De Wit & Van Dijk (2003) and Ibanez & Pennington-Cross (2013). This means that a higher unemployment rate has explanatory power to a lower long-term rent level, and that a lower unemployment rate leads to a higher long-term rent level.

The third variable representing economic activity, employment, shows also to be significant explanatory variable for the long-term rent level in all the three markets investigated. The variable is significantly higher than zero, which means that a higher employment has explanatory power to a higher rent level. This finding found broad support from previous studies including Gardiner & Henneberry (1988 & 1991), Hendershott (1999), Bruneau & Cherfouh (2015) and Nowak (2019). Also Bjørland & Hagen (2019) found similar results in their research of the market in Oslo.

Regarding the supply variables, the significances vary among the cities, again with greater similarities between São Paulo and Rio de Janeiro than with Oslo.

The first supply variable, occupancy rate, is modelled as “1-vacancy rate”. Occupancy rate is a significant explanatory variable for the São Paulo market in all of the models, but negative for Model 1a and positive for Model 1b. A negative sign means that a higher occupancy rate (lower vacancy rate) leads to a lower rent level, which is the opposite of the findings in the literature review. A positive sign means that a higher occupancy rate leads to a higher rent level. For Rio de Janeiro, the variable is significant positive in Model 1b and 1c. Occupancy rate is not found as a significant variable for the 0slo market in any of the models. In previous studies, vacancy rate has been found to have a negative significant correlation with the rent level by many, including Blank & Winnick (1953), Rosen (1984), Hendershott (1996),

De Wit & Van Dijk (2003) and Brounen & Jennen (2009), while other studies found this variable only significant on a short-term basis. This will be described further under the short-term models.

The second supply variable, stock of floor space, shows mixed results across the different markets and models. A positive correlation means that changes in stock of floor space and rent level will move in the same direction, while a negative correlation means that when the stock of floor space moves in one direction, the rent level will move the opposite direction. While the variable is significant negative for the São Paulo market in Models 1a and Model 1c, it is significant negative in Model 1a and significant positive in Model 1b for the Rio de Janeiro market. For the Oslo market, the variable is significant in Model 1b. The inconsistency of the results of the stock of floor space variable, makes it difficult to draw clear conclusions. However, a variety of previous studies have found this variable to be significantly positive on a long-term basis, including Hendershott et al. (2002a, 2002b & 2010), McCartney (2012) and Bruneau & Cherfouh (2015).

6.3 SHORT-TERM MODELS

This section presents the results from the short-term models. The regression outputs are shown in

Table 8.

Table 8: Results of Short-term Models

	Model 2a			Model 2b			Model 2c		
	SP	RJ	Oslo	SP	RJ	Oslo	SP	RJ	Oslo
△log (GDP_t)	2.02 ***	1.45 ***	3.44 *						
	(0.39)	(0.38)	(1.52)						
△log ($Unemploy_t$)				-0.43 ***	-0.37 ***	-0.19 *			
				(0.12)	(0.11)	(0.07)			
△log ($Employ_t$)							0.36	3.09 *	0.86
							(0.23)	(1.40)	(1.46)
△log (1-$Vacancy_t$)	0.04	0.23	-0.90	0.38	0.54	-2.30 *	-0.01	0.51 .	-1.62
	(0.35)	(0.28)	(1.12)	(0.35)	(0.30)	(1.09)	(0.37)	(0.29)	(1.13)
△log ($Stock_t$)	0.32	0.04	-1.70	0.45	0.27	-0.87	0.40	0.01	-2.52 *
	(0.32)	(0.27)	(1.25)	(0.33)	(0.29)	(1.24)	(0.34)	(0.28)	(1.27)
u_{t-1}	-0.30 ***	-0.31 ***	-0.77 ***	-0.29 ***	-0.25 ***	-0.83 ***	-0.20 ***	-0.25 ***	-0.76 **
	(0.04)	(0.05)	(0.07)	(0.04)	(0.05)	(0.07)	(0.03)	(0.05)	(0.07)
△log ($Rent_{t-1}$)	-0.16 **	0.13	-0.18 ***	-0.15 **	0.13	-0.16 **	-0.18 ***	0.17 *	-0.80 **
	(0.05)	(0.07)	0.05	(0.05)	(0.08)	(0.05)	(0.05)	(0.08)	(0.05)
N	324	162	340	324	162	340	324	162	340
R^2-adj	0.22	0.23	0.47	0.18	0.16	0.50	0.14	0.14	0.46
DW	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.0	2.0

Standard errors are reported in parenthesis below the point estimates. The asterisks denote significance levels: * = 10%, ** = 5% and *** = 1%.

Like for the long-term models, the results from the short-term models show some differences among the markets.

Adjusted R^2 is higher for the Oslo market (0.46-0.48) than for the São Paulo market (0.14-0.22) and the Rio de Janeiro market (0.14-0.23).

The results from the Durbin-Watson test shows there is no auto correlation in the results from the short-term models.

The demand variable GDP is significant positive explanatory variable on a short-term bases for all the three markets concerned by this research. This means that a positive change in GDP leads to a positive change on the rental price. This finding coincides with previous studies including Gardiner & Henneberry (1988; 1991), Giussani et al. (1992), Giussani & Tsolacos

(1993), D'Arcy et al. (1997; 1999) and Mouzakis & Richards (2007). Bjørland & Hagen (2019) also found supporting result for their study of the Oslo market.

The second demand variable, unemployment rate, also give consistent results with a significant negative effect on short-term rent level, even though the significancy for São Paulo and Rio de Janeiro are higher than for Oslo. The significant negative effect means that a positive change in unemployment rate leads to a negative change on rental price. Previous studies finding support for unemployment rate as a significant explanatory variable with a negative sign are Hekman (1985), Gardiner & Henneberry (1988; 1991), De Wit & Van Dijk (2003) and Ibanez & Pennington-Cross (2013).

The third demand variable, employment, turns out to be (positive) significant for the Rio de Janeiro market. This indicate that that a change in employment has a low level of explanatory power on the change of the office rent price in the same period. This is a contrast to other studies that have found significant positive connection between employment and rental price, including studies of Gardiner & Henneberry (1988; 1991), Hendershott (1999), Bruneau & Cherfouh (2015) Nowak (2019) and Bjørland & Hagen (2019).

Changing the focus to the supply variables, the results for occupancy rate show a low level of significancy throughout the markets and models. However, in Model 2b for the Oslo market, the explanatory variable is significant negative. A significant negative result means thar an increase in the occupancy rate leads to a decrease in the rental price, a finding which contrasts to the findings in the literature review. As this is the only significant result for occupancy rate, the support for significancy of this variable is weak. This contrast to findings in studies on short-term effect of this variable by Hendershott et al. (2002a), McCartney (2012) and Bruneau & Cherfouh (2015). Further, Hendershott et al. (2010) found a significant effect when applying lagged vacancy rate data.

The other tested supply variable, stock of floor space, has similar results as vacancy rate, with a general low level of significancy. Only Model 2c for the Oslo market shows a significant (negative) result. A significant negative variable means that a positive change in stock of floor space leads to a negative change in rental price, which is opposite of the findings from previous studies. The weak results impliy that there is a not a significant connection between a change in the stock on floor space on the change on office rent prices in the explored markets. Previous studies have found a significant connection, but Hendershott et al. (2002a; 2002b; 2010), McCartney (2012) and Bruneau and Cherfouh (2015) found this only on a long-term basis.

The error correction term is significant negative for all models in all the explored markets. A negative value means that the rents adjust down to the respective percentage value of coefficient of the disequilibrium from the quarter before. As all the error correction terms are between -1 and 0, the error corrections are partial.

The lagged rent is significant negative for all models for the São Paulo market and the Oslo market, while for Rio de Janeiro the variable is slightly positive significant only for model 2c. This means that rent level from previous period is a significant explanatory variable in São Paulo and Oslo, but more uncertain for Rio de Janeiro. Hendershott et al. (2002a; 2002b; 2010), McCartney (2012), Bruneau and Cherfouh (2015) and Bjørland and Hagen (2019) all found lagged rent to be a significant explanatory variable on a short-term basis.

7. CONCLUSION

7.1 FINDINGS

This study aims to contribute to the existing office market literature. While most of the prior literature has concerned North American, Asian and European markets, this study examines the Brazilian markets São Paulo and Rio de Janeiro, as well as the Norwegian market, Oslo. This study applies established models for short-term and long-term dynamics of the office rent market.

The results indicate partial support the existing literature, in particular for the demand variables in the long-term models, but also for the short-term models. Further, the importance of lagged variables on short-term changes in the rent level supports the findings from existing literature.

An interesting finding from this study is the difference in explanatory power among the markets in long-term and short-term models. While the explanatory power of the long-term models is higher for the markets of São Paulo and Rio de Janeiro than for the market of Oslo, the situation is the other way around for the short-term models where the Oslo market has a highest explanatory power. The differences between the findings from the Brazilian markets and the Norwegian market are difficult to determine what are caused by, but a possible reason can be that the Oslo market seems to be more transparent with a higher degree of public information, than the markets of São Paulo and Rio de Janeiro. This might lead to a more efficient market, where changes in factors that influence the rent level will be absorbed by the market quicker. To determine whether this is a random difference in this particular situation, or if it is a structural difference, a possibility is to compare more office markets in developing

countries with markets from developed countries. If the assumption of this quicker absorption of information in markets in developed countries holds, it may be easier to forecast the future rent levels in undeveloped markets. It is difficult to say whether this is a likely consequence.

Some of the findings in this study contradict previous studies, and are hard to understand. An example is that occupancy rate has a significant negative effect on the rental price in the long run in Rio de Janeiro in model 1a, while not in Model 1b and Model 1c. This means that a higher supply leads to a higher price, which contradicts both previous studies and fundamental economic theory. A possible explanation to this finding, might be that it is a random coincidence in this study. This has to be studied further to increase the confidence in the finding.

7.2 RESEARCH LIMITATIONS

A limitation in this study is the representativeness of the rent data from São Paulo and Rio de Janeiro. The data series had a several submarkets that with no continuous data throughout the studied time period, which led to an exclusion of the respective data. This may lead to results that are not representative for the markets. On the other hand, there is no reason to conclude that the submarkets that are excluded from the analysis are operating very differently from the included submarkets, in particular where the findings correspond with previous studies.

The research concerns only the Brazilian markets of São Paulo and Rio de Janeiro, and the results are valid only for these markets in Brazil. Other markets in Brazil may have different dynamics, but as the studied markets are the two cities with highest economic activity, they are also the most relevant markets in an international context.

This study has analyzed the effect of the independent explanatory variables on the rent level. By including lagged explanatory variables in the models, the results could have yielded other results both in significance and exploratory power.

7.3 FURTHER STUDIES

This study includes data compiled prior to the COVID-19 pandemic. A study of office rent dynamics post-COVID-19 could contribute useful information, that could differ substantially from existing knowledge.

This study has examined the São Paulo, Rio de Janeiro and Oslo markets, by applying data on submarket level, but only considering the results on a market level. A future study can examine the dynamics in the different submarkets.

As this study concerns São Paulo and Rio de Janeiro, the results provide information about the dynamics specific to those markets. In order to increase the knowledge of Brazilian office rent dynamics, future research could examine other markets such as Porto Alegre, Curitiba, Belo Horizonte and Salvador.

More studies concerning other South American office markets, like Argentina, Chile, Uruguay, will improve the knowledge of office rent dynamics in the continent. Studies comparing office rent dynamics in developing countries and developed countries can provide similarly interesting information.

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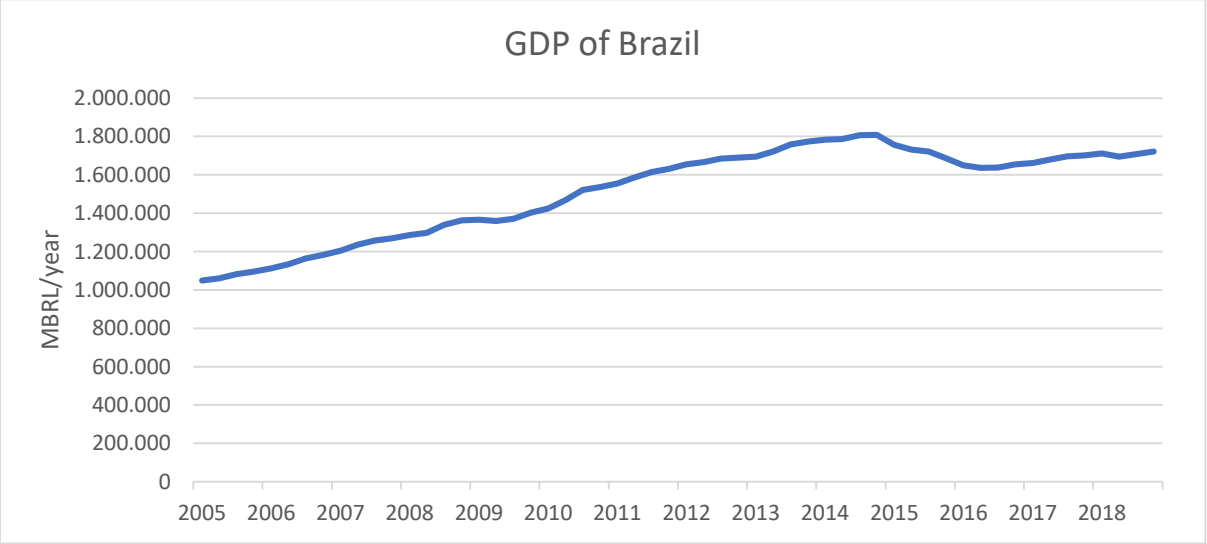
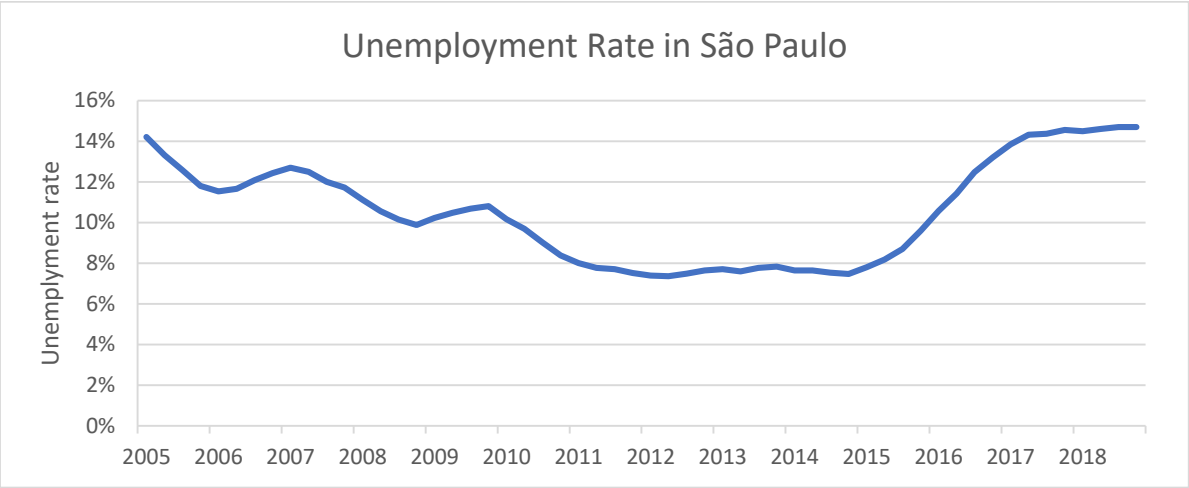
APPENDICES

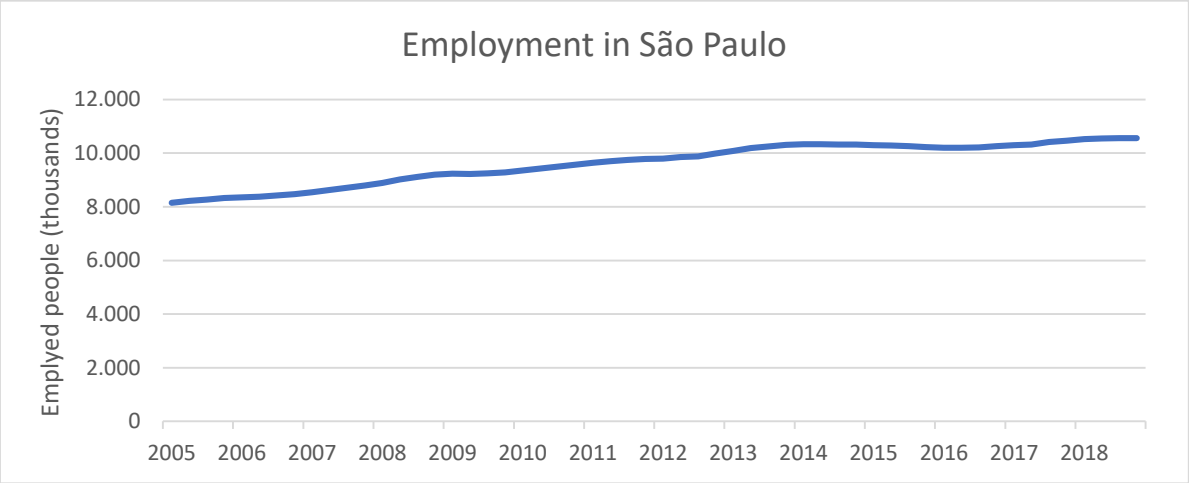
APPENDIX I

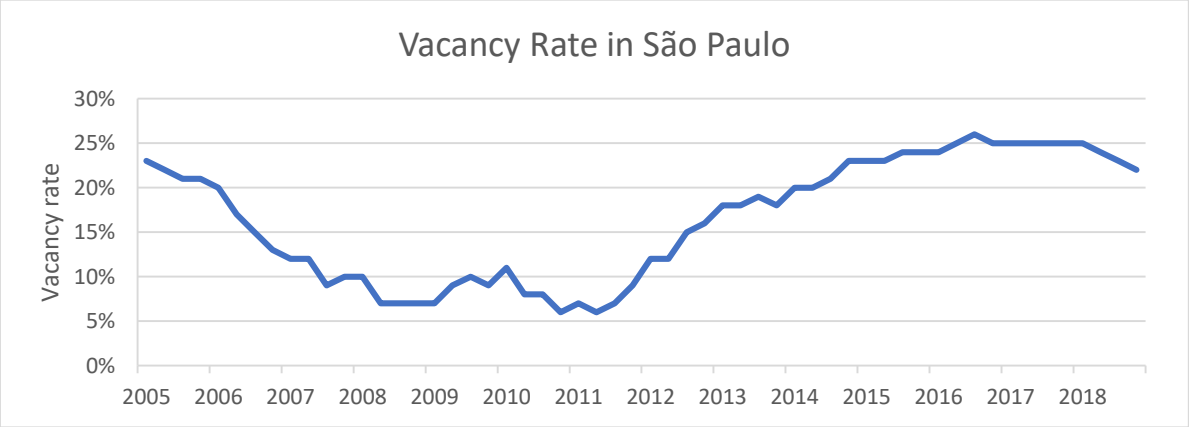
Graphs of the explanatory variables for:

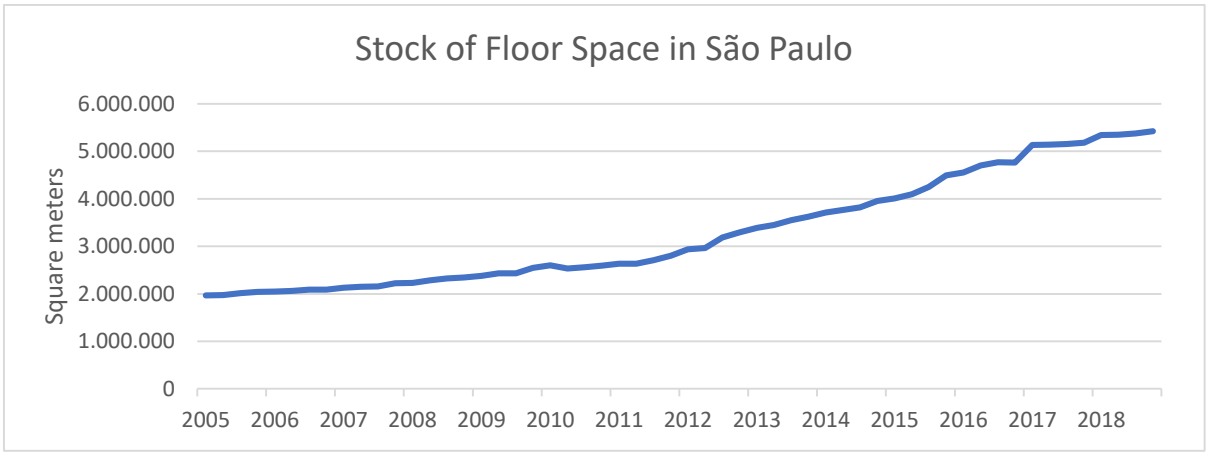
- GDP for Brazil
- Unemployment rate in São Paulo
- Employment in São Paulo
- Vacancy rate in São Paulo
- Stock of floor space in São Paulo
- Unemployment rate in Rio de Janeiro
- Employment in Rio de Janeiro
- Vacancy rate in Rio de Janeiro
- Stock of floor space in Rio de Janeiro
- GDP for Norway
- Unemployment rate in Norway
- Employment in Norway
- Vacancy rate in Oslo
- Stock of floor space in Oslo

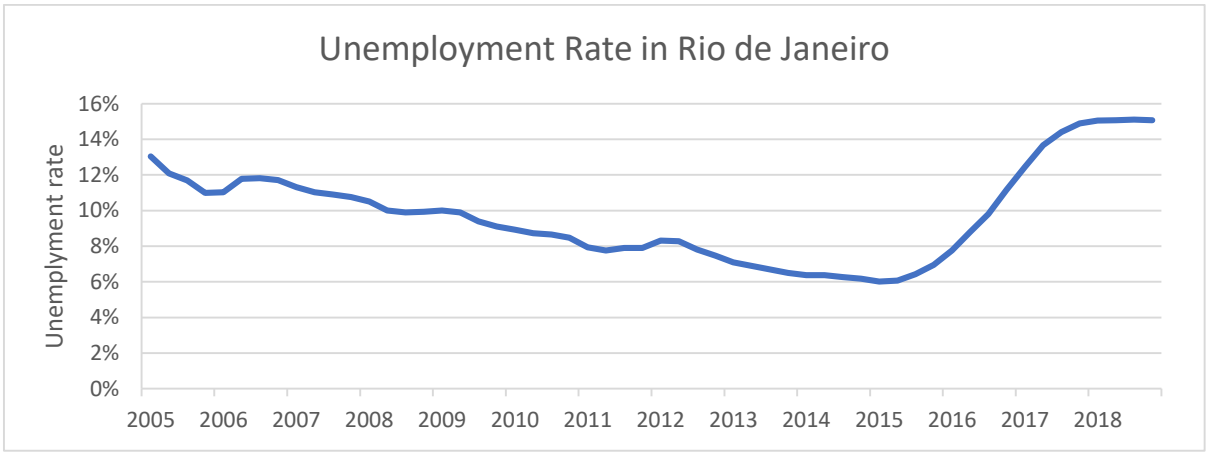


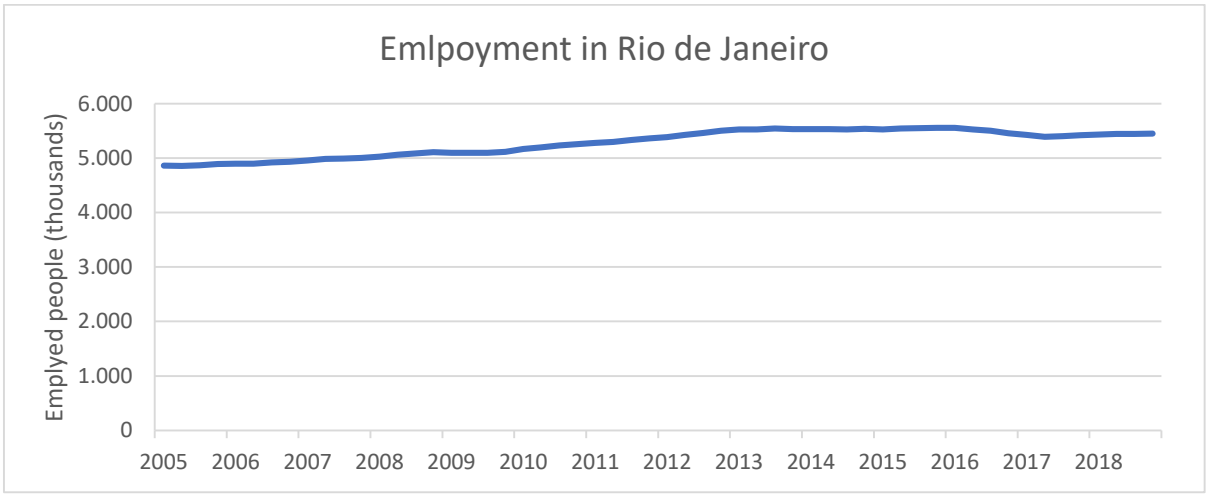

Unemployment Rate in São Paulo
Unemplyment rate
16%
14%
12%
10%
8%
6%
4%
2%
0%
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

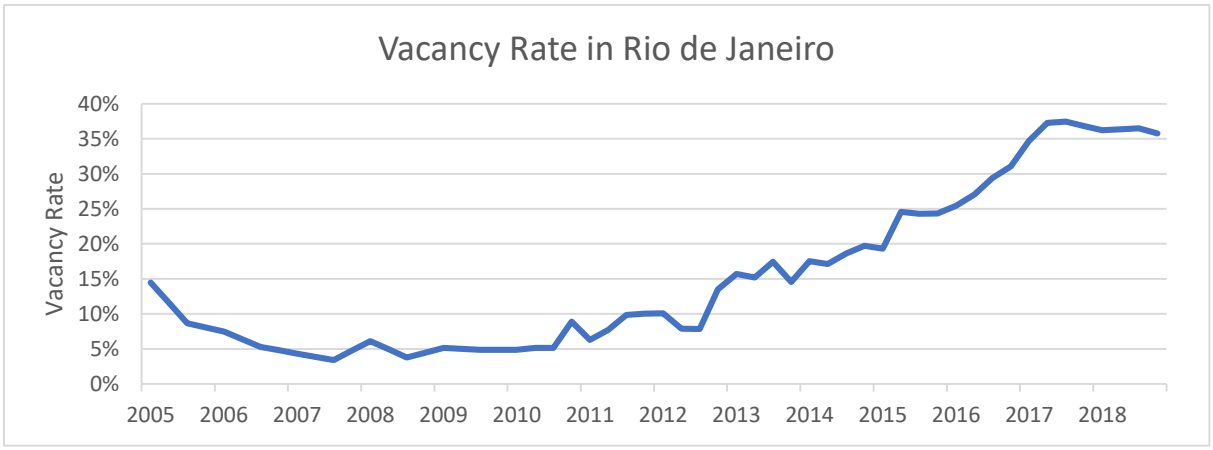

Employment in São Paulo
Emplyed people (thousands)
12.000
10.000
8.000
6.000
4.000
2.000
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

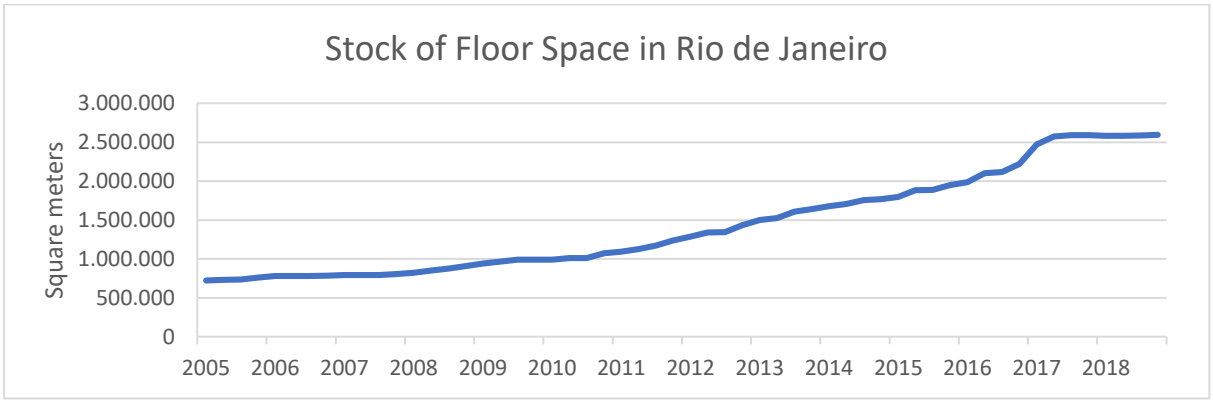

Vacancy Rate in São Paulo
Vacancy rate
30%
25%
20%
15%
10%
5%
0%
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

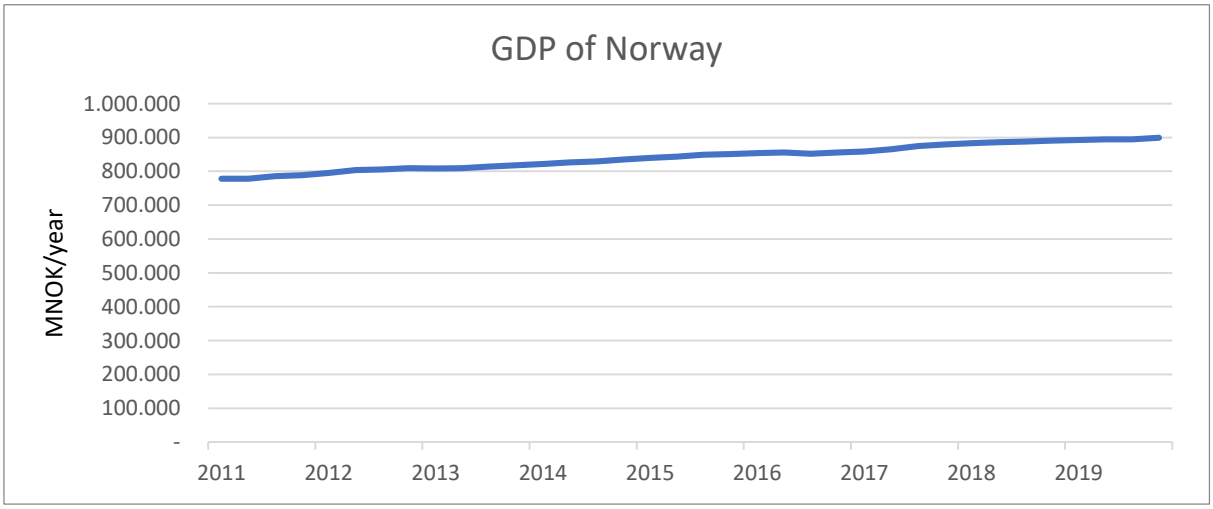

Stock of Floor Space in São Paulo
Square meters
6.000.000
5.000.000
4.000.000
3.000.000
2.000.000
1.000.000
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

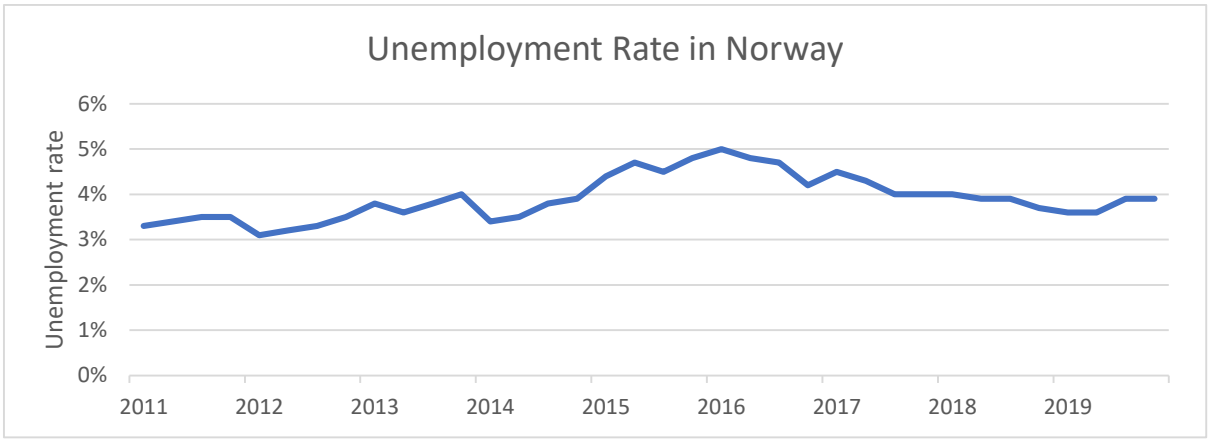

Unemployment Rate in Rio de Janeiro
Unemplyment rate
16%
14%
12%
10%
8%
6%
4%
2%
0%
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


Emlpoyment in Rio de Janeiro
Emplyed people (thousands)
6.000
5.000
4.000
3.000
2.000
1.000
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

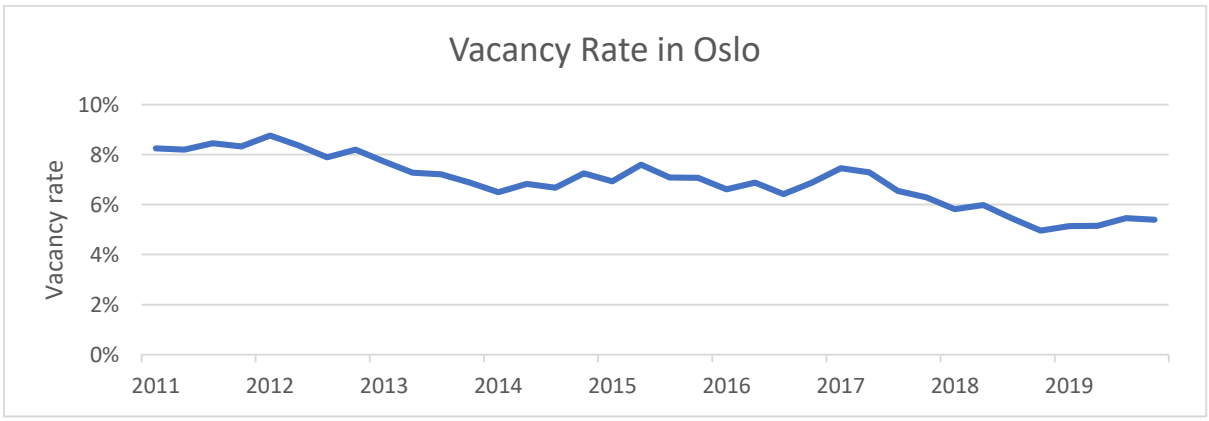

Vacancy Rate in Rio de Janeiro
Vacancy Rate
40%
35%
30%
25%
20%
15%
10%
5%
0%
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

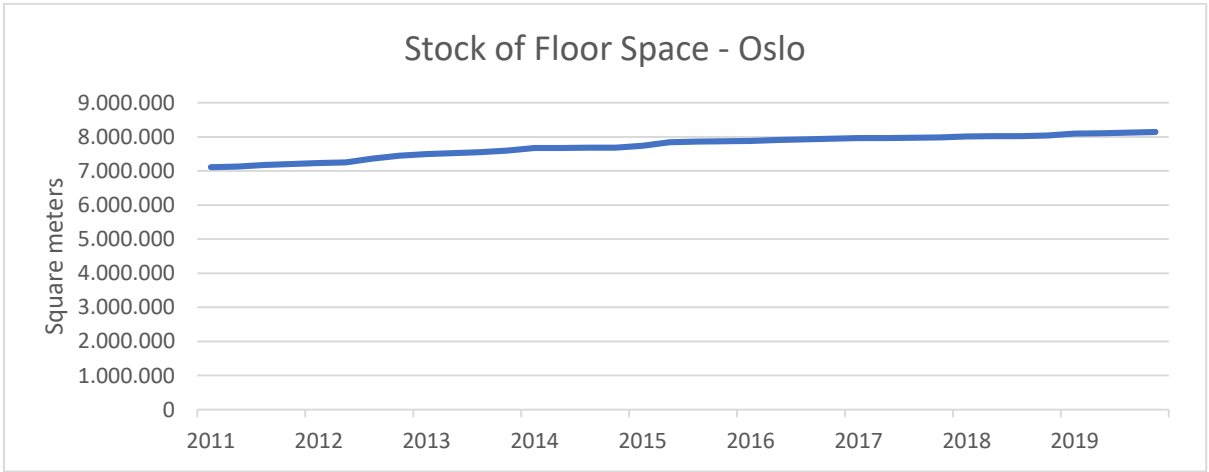

Stock of Floor Space in Rio de Janeiro
Square meters
3.000.000
2.500.000
2.000.000
1.500.000
1.000.000
500.000
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018


GDP of Norway
MNOK/year
1.000.000
900.000
800.000
700.000
600.000
500.000
400.000
300.000
200.000
100.000
-
2011 2012 2013 2014 2015 2016 2017 2018 2019


Unemployment Rate in Norway
Unemployment rate
6%
5%
4%
3%
2%
1%
0%
2011
2012
2013
2014
2015
2016
2017
2018
2019


Employment in Norway
Employed people (thousands)
3000
2500
2000
1500
1000
500
0
2011
2012
2013
2014
2015
2016
2017
2018
2019


Vacancy Rate in Oslo
Vacancy rate
10%
8%
6%
4%
2%
0%
2011
2012
2013
2014
2015
2016
2017
2018
2019


Stock of Floor Space - Oslo
Square meters
9.000.000
8.000.000
7.000.000
6.000.000
5.000.000
4.000.000
3.000.000
2.000.000
1.000.000
0
2011
2012
2013
2014
2015
2016
2017
2018
2019

APPENDIX II

Results from cointegration tests (Pedroni99m)

The results contain the following measures:

- Panel v-Statistic
- Panel p-Statistic
- Panel t-Statistic (non-parametric)
- Panel t-Statistic (parametric)
- Group p-Statistic
- Group t-Statistic (non-parametric)
- Group t-Statistic (parametric)

Test results for the São Paulo market

Model 1a	Empirical	Standardized
nipanel	4.86E-02	-3.02
nhopanel	-9.43E+00	3.16
tpanelnonpar	-2.88E+00	4.45
tpanelpar	-1.03E+03	-1060.87
rhogroup	-1.12E+01	4.49
tgroupnonpar	-2.69E+00	6.73
tgrouppar	-2.42E+00	7.09

Model 1b	Empirical	Standardized
nipanel	0.16	-3.01
nhopanel	-24.75	1.77
tpanelnonpar	-4.49	2.78
tpanelpar	-1397.20	-1442.95
rhogroup	-23.26	3.20
tgroupnonpar	-4.09	4.85
tgrouppar	-3.69	5.38

Model 1c	Empirical	Standardized
nipanel	0.06	-3.02
nhopanel	-9.14	3.19
tpanelnonpar	-2.69	4.65
tpanelpar	-787.79	-810.34
rhogroup	-9.36	4.68
tgroupnonpar	-2.40	7.12
tgrouppar	-2.02	7.62

Test results for the Rio de Janeiro market

Model 1a	Empirical	Standardized
nipanel	4.26E-02	-2.13
nhopanel	-2.23E+01	0.81
tpanelnonpar	-4.40E+00	0.69
tpanelpar	-1.80E+03	-1861.58
rhogroup	-2.33E+01	1.54
tgroupnonpar	-4.48E+00	1.31
tgrouppar	-4.15E+00	1.75

Model 1b	Empirical	Standardized
nipanel	0.09	-2.13
nhopanel	-16.58	1.33
tpanelnonpar	-3.96	1.15
tpanelpar	-1581.67	-1636.62
rhogroup	-17.97	2.10
tgroupnonpar	-4.31	1.54
tgrouppar	-4.25	1.61

Model 1c	Empirical	Standardized
nipanel	0.11	-2.13
nhopanel	-31.77	-0.05
tpanelnonpar	-5.58	-0.53
tpanelpar	-1939.95	-2008.54
rhogroup	-33.72	0.43
tgroupnonpar	-5.73	-0.36
tgrouppar	-5.38	0.11

Test results for the Oslo market

Model 1a	Empirical	Standardized
nipanel	1.83E-01	-3.89
nhopanel	-6.76E+00	5.05
tpanelnonpar	-2.69E-01	9.33
tpanelpar	-4.88E+02	-496.99
rhogroup	2.52E+00	7.59
tgroupnonpar	4.58E-01	13.94
tgrouppar	2.22E-01	13.62

Model 1b	Empirical	Standardized
nipanel	0.16	-3.89
nhopanel	-1.45	5.06
tpanelnonpar	-0.26	9.34
tpanelpar	-733.54	-751.86
rhogroup	6.99	8.07
tgroupnonpar	1.46	15.28
tgrouppar	0.25	13.66

Model 1c	Empirical	Standardized
nipanel	0.21	-3.89
nhopanel	-2.69	4.95
tpanelnonpar	-0.48	9.11
tpanelpar	-656.45	-671.84
rhogroup	6.21	7.98
tgroupnonpar	1.20	14.94
tgrouppar	0.64	14.19