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Determinants of Yield Rate on the Office Market in Warsaw

Krzysztof Nowak[1]

[1] University of Rzeszów, Poland, ORCID: https://orcid.org/0000-0003-0543-1670, krnowak@ur.edu.pl

ABSTRACT

Purpose – In the article, we attempt to check whether polish monetary aggregate and PLN exchange rate determine yield rate in the main office market in CEE. We look for GFC and beginning of Covid-19 impact on the Warsaw office yield rate. Moreover, we investigate if structural breaks can be found in the time series of the yield rate on the Warsaw office market.

Design/methodology/approach – The error-correction model approach is used to determine factors affecting yield rate on the Warsaw office market. Based on the analysis of the literature we set three groups of possible factors i.e. endogenous (market), macroeconomic and regional (international). Moreover, we formulated dummy variables to check impact of the global financial crisis and beginning of the covid-19 pandemic on the yield rate. Also, structural breaks in the yield rate time series representing changes in market conditions were used to define subsequent dummy variables.

Findings – The results of the study indicate that yield rate on the office market in Warsaw, in the long and the short term, was determined by monetary liquidity (M2 aggregate) and by exchange rate (EUR/PLN). No clear dependence of yield rate on dummy variables of GFC and Covid-19 was detected. Furthermore, the obtained results indicate that certain changes of market conditions, which influenced the yield rate, can actually be identified after the first quarters of 2010 and 2015. The dependence of the office yield rate in Warsaw on the Vacancy rate was found only in long term. The risk premium variable in short-term also was statistically insignificant.

Research limitations – Limitations of the study are related to the time span of available time series. Time range of the data did not allow for the comprehensive verification of the impact of GFC and Covid-19 on the local office market yield.

Research implications – The obtained results may be substantial information for commercial real estate practitioners, as they indicate drivers of the local office market yield.

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INTRODUCTION

The office market in Warsaw has been developing rapidly over the last three decades, especially since Poland joined the EU. Warsaw is the biggest office market in Poland. At the end of 2020 stock of the modern office space in the city was 5.9 million sq. m., which is more than next eight polish regional markets together (Colliers, 2021). However, there is still a long way to catch up with primary Western European markets. The aim of the article is to verify determinants that affect yield rate in the office market in Warsaw, i.e. the main office market in CEE (Colliers, 2020). The goal is fulfilled by building two econometric models, formulated based on the Error Correction Model (ECM) approach.

The Literature review presents analysis of main papers as for modeling of yield rate on commercial real estate market. Examples of use of the ECM approach for this purpose were recalled. Further, the main groups of factors that were used so far to explain yield rate on commercial real estate market, are summarized. In the end of the section three hypotheses were indicated. In Research methodology the ECM approach was depicted along with the tests used to verify the econometric quality of the model. Moreover, in this section the consecutive steps of the study were characterized. Also, the time series applied in the model were presented. In Results and discussion, long-term equations along with the short-term equations were formulated. We reported results of the short-term equations including dummy variables representing the impact of global financial crisis (GFC), Covid-19 and structural breakpoints of yield rate time series. Finally, the Conclusion section contains a summary of the study along with the limitations and proposals of possible directions of extending the study in future.

LITERATURE REVIEW

In literature the terms capitalization (cap) rate and yield rate are usually used alternatively, as the cap rate equals the initial yield rate. In that case, initial yield is equal to the initial net operating income of the real estate divided by price or value of the real estate asset. Referring to Gordon-Shapiro's constant dividend growth model the property value can be stated as net income divided by difference between required rate of return and the constant rate of the income growth. Required rate of return consists of two elements: risk free interest rate and risk premium. So finally we get (Bruneau & Cherfouh, 2018):

$$Y_t = r_{F,t} + \pi_t^e - g_t^e \quad (1)$$

where:
Y_t – yield rate,
$r_{F,t}$ – risk free interest rate,
π_t^e – risk premium,
g_t^e – cash flow growth.

Literature on cap rate of commercial real estate indicate real estate fundamentals (usually rent) and financial markets (usually bond yields), as it main determinants. Frequently cited article by Sivitanides, Torto and Wheaton (2003) revealed a strong influence of interest rates and systematic effects of market fundamentals on the cap rate. Sivitanidou and Sivitanides (1999) previously reported that the impact of local office market indicators was substantially stronger than the national capital market impact. Opposite conclusions were drawn by D'Argensio and Laurin (2008). Conducting an extensive study of office markets in 52 countries allowed them to state that bond yield was the main determinant of capitalization rates, even more important than real estate indicators. Jones, Dunse and Cutsforth (2015) signalized that the relationships between property cap/yield rates and bond yields are not stable. They found structural breaks in such relations during GFC in USA, UK and Australia. Based on the bond yield – real estate yield relationships, Morawski and De Francesco (2019), in the study of key centres in Europe and Australia, confirmed that the shape of the yield curve (representing the term structure of interest rates) affects office yields.

Henneberry and Mouzakis (2014) stated that office investment yields should follow spatial variation. Nonetheless, the UK study showed that yield in London was highly correlated with yields in regions, what can cause mispricing of properties. Devaney et al. (2019) examined the office market in 33 cities in 16 countries and along with previous studies indicated that government bond yields, yield spreads and real estate rents were the driving variables of the capitalization rates. Moreover, they indicated that there was a negative relationship between market size and cap rate.

The real estate market is increasingly becoming a global market, what is reflected in the growing importance of foreign investors. The development of commercial real estate market in Poland highly depends on foreign investors (NBP, 2020). An interesting finding, in this context, was reported by McAllister and Nanda (2016). They verified dependency of office market capitalization rates on local-sector specific and macroeconomic factors, in 28 European cities. Conclusions indicated a statistically significant negative effect of foreign real estate investment on capitalization rates. The negative impact of international investment flows on capitalization rate was confirmed by Oikarinen and Falkenbach (2017) for the office market in Helsinki.

Chervachidze and Wheaton (2013) conducted study of determinants of commercial real estate cap rates in 30 metropolitan in USA. They found that the model based on typically used local market fundamentals and treasury rates improved significantly, when two additional variables were included, i.e. risk premium operating in the economy, and the growth rate of debt relative to GDP.

As far as the method is concerned, in papers regarding cap/yield rates on commercial real estate market one can find both linear and nonlinear OLS models. We use ECM approach. To the best of our knowledge Hendershott, MacGregor and Tse (2002) and Hendershott, MacGregor and White (2002), were first to implement ECM to model commercial real estate market. However, the articles concerned the rent adjustments. In this paper we employ ECM to indicate determinants of yield rate on the Warsaw office market. The ECM framework was already used before for this purpose. Hendershott and MacGregor (2005) used ECM approach in the study of the office and the retail cap rates in UK, which revealed, among others, clear links to capital market. Peyton (2009) used ECM to determine relationships between cap rate of commercial real estate and four groups of factors: macroeconomic and interest rate fundamentals, credit risk pricing, investor risk aversion and commercial real estate performance. Findings indicated that in short term commercial real estate pricing was predicted by macroeconomic, financial market and real estate fundamental factors. Bruneau and Cherfouh (2018) used the ECM approach and non-linear approach of the Smooth Transition Regression, to model office market yield in UK. They stated that besides risk-free interest rate and expected rental growth, money supply was the main factor influencing the office market yields.

Literature analysis indicates that so far various sets of explanatory variables were used. For instance, Kohlert (2010) used ECM approach to regress total return in regional office markets in UK on GDP, total investment and also unemployment. However, the most frequently used time series can be assigned to one of the following main groups: market or endogenous (rent and rent ratios), macroeconomic (inflation, GDP, interest rates), monetary liquidity (money supply, debt), measures of investment (total investment), financial (bond yields, dividend), and time series reflecting the dependence to foreign investments. Some variables were specified on local, some on national level.

Based on the literature analysis we stated following hypotheses:

1. Monetary factors as well as exchange rate EUR/PLN determine yield rate on the Warsaw office market.
2. The global financial crisis and Covid-19 pandemic impacted fluctuations of yield rate on the Warsaw office market.
3. Within the time range of the study there can be indicated points in time when relations between the office market yield in Warsaw and explanatory variables have modified.

RESEARCH METHODOLOGY

The study is based on the ECM approach. The ECM usually consists of two equations[1]. The first one, which depicts a long-term relation, works as a cointegrating relation of non-stationary time series, usually on levels. This equation depicts the long-term market equilibrium. The second step in the ECM procedure is to build equation dedicated to short term fluctuations. It is formulated on variables based on stationary changes of time series used in the long-term equation. Moreover, in the short-term equation, lagged residuals from the first equation are included to accommodate deviations from the equilibrium. Both equations which can be estimated by OLS, take the following form (Kośko, Osińska & Stempińska, 2007, p. 356):

$$Y_t = \alpha_0 + \alpha_1 X_t + u_t \tag{2}$$

$$\Delta Y_t = \beta_0 + \beta_1 \Delta X_t + \gamma ECM_{t-1} + \eta_t \tag{3}$$

where:
Y_t, X_t – cointegrated nonstationary time series,
ΔY_t, ΔX_t – stationary time series of Y_t and X_t differences,
ECM_{t-1}- one period lagged residuals of (2), the error correction mechanism.

The study was conducted in few consecutive steps. The first is estimation of stationarity of the time series that are to be used in the study. This is done via the ADF test. Next, the long-term equation is formulated. Then, cointegration of the time series used in the long-term equation is verified via the Johansen test. After that, the short-term equation is built. The short-term equation is then tested for normality distribution of residuals (the Shapiro-Wilk test), autocorrelation (the Breusch-Godfrey test) and heteroscedasticity (the White test).

To cope with heteroscedasticity in the model, two often used approaches were applied, i.e. Weighted Least Squares (WLS) and OLS model

[1] Some studies join the two equations into one.

with heteroscedasticity robust standard errors. The WLS equations were obtained by weighting each term of the basic short-term equation by each of the variables in the equation. Under the robust OLS version of the short-term equation the coefficients of the variables stay unchanged, only the standard errors are re-estimated (Kufel, 2013, p. 136).

Thereafter, dummy variables were added to short-term equation to verify impact of the GFC and beginning of the Covid-19 pandemic. In addition, two changes in market conditions reflected by changes of trend in yield rate time series were also verified. This was done by implementing two dummy variables. The Chow test was used to confirm the structural breaks in yield rate time series in two chosen periods.

As far as time series are concerned, first, three groups of potential determinants of yield rate were identified:

1. Endogenous (market) factors: rent, vacancy rate.
2. Macroeconomic factors: interest rates of long term government bonds (polish and EMU), monetary aggregate M2, M2/GDP ratio, WIG20 index.
3. Regional (international) factors: liabilities of portfolio investment in national balance of payments, exchange rates EUR/PLN and USD/PLN.

All the time series are inflation adjusted, on quarterly basis of Q1 2007 – Q4 2020 time period. Time series of yield rate and rent represent values for prime buildings in Central Business District in Warsaw. The time series of yield rate comprise estimates of the market yield rate based on market transactions for the prime office buildings in Warsaw CBD.

First, model 1 is based on the equation (1). The risk premium variable is reflected by the time series of the difference between interest rates on long-term treasury bonds in Poland and in the European monetary union (EMU), multiplied by the EURPLN exchange rate. Subsequently, it reflects the difference in the level of market risk between Poland and the EMU countries, which generally can be regarded as developed countries.

The model 2 is formulated to verify the first hypothesis. The second and third hypotheses were tested in both models. In case of model 2, all possible versions of the long-term equation were built following the principle that each equation must contain one variable from each group. Based on the stationarity analysis of individual time series and econometric fit (results of the Johansen test, level of Adjusted R^2, the number of statistically significant variables), three long term equations were then selected to continue the study. The goal was to obtain the valid short-term equation i.e. such in which yield rate will be explained only by statistically significant explanatory variables, with relatively high adjusted R^2. Therefore, the first form of the three short-term equations consisted of current time series of the explanatory variables, as well as their four lagged time series. Furthermore, the right side of the equations included lags of the dependent variable, together with the long-term one period lagged residuals. Next, the variable which was most of all, over the significance level of 0.1, was eliminated, and the equation was rerun. This descending, a posteriori elimination step was repeated until only significant explanatory variables remained in the equation. The final short-term equation out of three, was chosen based on the econometric fit. Table 1 presents descriptive statistics of the time series which were used in the finally chosen form of the models 1 and 2. Figure 1 plots graph of the yield rate time series.

Table 1. Descriptive statistics of the time series used in the study

Time series	Source	Mean	S.d.	Min.	Max.
Yield rate (%)	Cresa Polska	5.76	0.73	4.5	7.0
Rent (EUR/mth/s.q. m.	Cresa Polska	25.00	1.88	21.91	30.97
Vacancy rate (%)	Cresa Polska	8.96	3.71	1.87	15.19
Government bonds' interest rate in EMU (%)	Eurostat	2.43	1.57	-0.18	4.56
Aggregate M2 (M PLN)	The National Bank of Poland	1 023 195	344 364	497 295	1 814 671
EUR/PLN (PLN)	The National Bank of Poland	4.170	0.272	3.354	4.701

Source: own study.

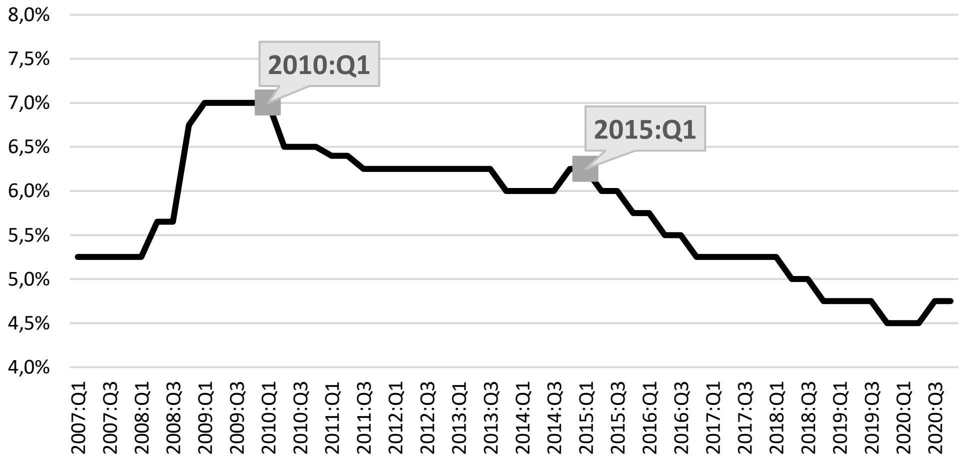

Figure 1. Time series of yield rate on the Warsaw office market
Source: own study.

Visual analysis of the figure 1 implies that the graph of the yield rate can be divided into three parts. First, increase of yield rate is evident, followed by stabilization at 7%. This path takes place until the first quarter of 2010. Then, within time range of Q2 2010 - Q1 2015, the yield rate slightly fell to 6.25%. Finally, in period Q2 2015 - Q4 2020, yield rate dropped to 4.75%.

RESULTS & DISCUSSION

The results of the ADF test (Table 7 in Appendix) indicate that the time series used to formulate the long-term equation of the models 1 and 2 are nonstationary. While changes of the respective time series, used in the short-term equations are stationary. Table 8 in Appendix reports results of the Johansen test, which indicate one cointegrating vector between variables used in the long-term equations. The dependent variable represents time series of yield rate. The long-term equation of model 1 is presented in Table 2. It is of quite good econometric fit. R^2 stays above 50%, however, the risk premium variable is not statistically significant. All coefficients are of appropriate signs.

Table 2. Long-term equation in model 1

Variable	Coefficient	Std. Err	t
Intercept	0.156	0.045	3.44***
RentLN	-0.034	0.014	-2.49**
IREMU	0.416	0.055	7.53***
RPremium	0.033	0.041	0.80
Adj. R^2	0.5086		

Note: *p < 0.1; **p < 0.05; ***p < 0.01. RentLN – log rent, IREMU – interest rates on long-term treasury bonds in EMU, RPremium - difference between interest rates on long-term treasury bonds in Poland and EMU, multiplied by exchange rate.
Source: own study.

Based on the long-term cointegration, the short-term equation was formulated. The span of the time series includes GFC, as well as, the beginning of the Covid-19 pandemic. We checked if occurrence of the two impact the model. Two dummy variables were formulated to reflect influence of GFC, taking 1 starting in third quarter and fourth quarter 2007 respectively. Another two dummies were to reflect Covid-19, taking 1 starting in first quarter and second quarter 2020 respectively. All the four dummies (included as additional explanatory variables) turned to be statistically insignificant. Therefore, based on the visual analysis of the Figure 1, we decided to anticipate the issue of changing market conditions from the other side. Two breakpoints of yield rate time series were picked out. After first quarter 2010 the time series starts to decline and never come back to 7%. Similar happened after first quarter of

2015[2]. Results of the Chow test, stored in Table 12, on one hand indicated the structural break in Q1 2010, on the other hand, did not point out the break in Q1 2015. The short term equation of model 1 was rerun with additional variables (the dummy variable itself - taking 1 in periods after the breakpoint - and variables representing products of dummy variable and basic variables). Tables 9, 10 and 11 in the appendix, present tests for normal distribution (the Shapiro-Wilk test), autocorrelation (the Breusch-Godfrey test) and heteroscedasticity (the White test), respectively. Results denote that rests follow normal distribution and there is no autocorrelation in the equation. However, the results of the White test indicate the presence of heteroscedasticity at 0.05. Therefore, equations based on the WLS and the robust standard errors OLS were developed. In the first case, the quality of the models (R^2, the number of statistically significant variables) deteriorated significantly. Thus, the equation with robust standard errors presented in Table 3 is the final form of the short-term equation in model 1. In the equation variable of lagged rent is positive. Risk premium variable was removed due to insignificancy. Coefficients of the variables, the one reflecting the interest rate on government bonds in EMU, and the one with interest rate starting in Q2 2010, are of the highest magnitude. The variables, however, act in the opposite way, which can be treated as a confirmation of the market condition change. Re-estimation of the standard errors led to the second variable to be insignificant, though.

Table 3. Short-term equation in model 1, with robust standard errors and structural break in Q1 2010

Variable	Coefficient	Std. Err	t
Intercept	0.002	0.001	2.45**
RentLNCL4	0.022	0.009	2.42**
IREMUC	-0.798	0.423	-1.88*
DVIREMUC	0.637	0.429	1.48
DVQ12010	-0.002	0.001	-3.14***
RM1_L	-0.110	0.045	-2.41**
R^2	0.5589		

Note: *p < 0.1; **p < 0.05; ***p < 0.01. RentLNCL4 – lagged 4 change of log rent, IREMUC – change of IREMU, DVIREMUC – the product of DVQ12010 and IREMUC, DVQ12010 – dummy variable taking 1 in periods after Q1 2010, RM1_L – lagged 1 residuals from long term equation.

Source: own study.

[2] It is worth to note that in first quarter of 2015 the reference interest rate was cut to 1.5% and stayed at this level till the first quarter of 2020.

Table 4 presents the long-term equation in model 2. It is characterized by well econometric fit, i.e. adjusted R^2 stays at 60,87% and all descriptive variables are statistically significant. Coefficients denote that an increase in the vacancy rate, as well as EUR/PLN exchange rate, translates into an increase in the yield rate. On the other hand, the increase in money supply causes a reduction in the yield rate. It is worth to note that in the case of model 2, vacancy rate not rent stays as an endogenous (local) factor, what is a result of adopted methodology.

Table 4. Long-term equation in model 2

Variable	Coefficient	Std. Err	t
Intercept	0.323	0.031	10.27***
VacancyR	0.075	0.022	3.40***
M2LN	-0.026	0.003	-9.29***
EURPLNLN	0.057	0.012	4.57***
Adj. R^2	0.6087		

Note: *p < 0.1; **p < 0.05; ***p < 0.01. VacancyR – vacancy rate, M2LN – log of monetary aggregate M2, EURPLNLN – log of EUR/PLN exchange rate.

Source: own study.

When it comes to the short-term equation of model 2 either the dummy variables of GFC and Covid-19 or residuals from long-term equation were statistically insignificant. The Chow test confirmed structural breaks in both aforementioned points of time, Q1 2010 and Q1 2015 (Tab. 12). Two versions of the equation was rerun with additional dummy variables appropriate for these periods. First one is presented in Table 5. Adjusted R^2 is at quite high level of 64.93%. The equation consists of the two lags (1 and 4) of M2 monetary aggregate, exchange rate and lagged (1) long term equation residuals, as well as, appropriate dummy variables. Dummy variables for money aggregate M2 and EUR/PLN exchange rate are all of opposite signs compared to the basic variables. Coefficient of the basic dummy variable is negative and of comparatively low value. Time series of vacancy rate turned to be insignificant in short-term. This may be due to the fact that vacancy rate changes from period to period may be of a relatively limited magnitude (especially changes quarter on quarter). One could list few possible reasons of that. First, lease contracts cover many periods (usually few years), during which tenants are unable to change the amount of space consumed. Moreover, change in the number of employees (decrease or increase) which should state as office space measure of demand, does not have to result immediately into the quantity of the rented space. The office area per employee (per desk) can change. Besides, the effects of supply shocks resulting from the sudden increase in office supply can also be limited. This is because the commercialization process of office buildings begins at a relatively early stage of their physical construction. When office buildings are put into use, i.e. when they start to be included in market statistics, a sizeable part of the space is already leased. Tables 9, 10 and 11 show correct results of tests for normal distribution of residuals, autocorrelation and heteroscedasticity.

Table 5. Short-term equation in model 2, with structural break in Q1 2010

Variable	Coefficient	Std. Err	t
Intercept	0.016	0.004	3.74***
M2LNCL1	-0.168	0.054	-3.13***
DVM2LNCL1	0.192	0.055	3.47***
M2LNCL4	-0.231	0.073	-3.15***
DVM2LNCL4	0.224	0.075	2.99***
EURPLNLNC	0.058	0.009	6.36***
DVEURPLNLNC	-0.063	0.012	-5.28***
DVQ12010	-0.017	0.004	-3.89***
RM2_L	-0.119	0.064	-1.86*
Adj. R^2	0.6493		

Note: *p < 0.1; **p < 0.05; ***p < 0.01. M2LNCL1 – lagged 1 change of M2LN, DVM2LNCL1 – the product of DVQ12010 and M2LNCL1, M2LNCL4 – lagged 4 change of M2LN, DVM2LNCL4 – the product of DVQ12010 and M2LNCL4, EURPLNLNC – change of EURPLNLN, DVEURPLNLNC – the product of DVQ12010 and EURPLNLNC, DVQ12010 – dummy variable taking 1 in periods after Q1 2010, RM2_L - lagged 1 residuals from long term equation.

Source: own study.

In case of the short-term equation of model 2 with structural break at Q1 2015 heteroscedasticity was detected. As previously, we developed WLS and OLS with robust standard errors versions of the equation. The last was characterized by best econometric fit. It is enclosed in Table 6. In this case dummy variable also has the opposite sign to the basic variable. It is worth noting that the coefficients of basic variables of aggregate M2 are positive, while in table 5 they are negative. Moreover, coefficients of monetary and exchange rate variables are of smaller magnitude, while the lagged one period residuals are of higher magnitude, as in the short-term equation stored in Table 5. R^2 stays at 58.63%

Table 6. Short-term equation in model 2, with robust standard errors and structural break in Q1 2015

Variable	Coefficient	Std. Err	t
Intercept	-0.001	0.001	-2.62**
M2LNCL1	0.042	0.013	3.37***
M2LNCL4	0.057	0.019	3.02***
DVM2LNCL4	-0.080	0.020	-4.07***
EURPLNLNC	0.020	0.010	2.01*
EURPLNLNCL2	-0.009	0.004	-2.18**
RM2_L	-0.318	0.092	-3.46***
R^2	0.5863		

Note: *p < 0.1; **p < 0.05; ***p < 0.01. M2LNCL1 – lagged 1 change of M2LN, M2LNCL4 – lagged 4 change of M2LN, DVM2LNCL4 - the product of DVQ12015 and M2LNCL4, EURPLNLNC – change of EURPLNLN, EURPLNLNCL2 – lagged 2 change of EURPLNLN, RM2_L - lagged 1 residuals from long term equation.

Source: own study.

Based on the study consisting of models 1 and 2, we can confirm the hypotheses 1 and 3. The hypothesis 2 is rejected. The study indicates that yield rate in the office market in Warsaw, in the long and short term is dependent on the money supply and the currency exchange rate. Monetary aggregate is mentioned in literature as useful determinant of the office yields, when it comes to global liquidity. However, one should bear in mind that buy-sell transactions on the office market in Poland are mostly denominated in euro. This also, in principle, applies to office space lease agreements. Thus, one could expect negative verification of the first part of hypothesis one (aggregate M2 in PLN). By contrast, exchange rate of PLN can be a proxy of the office market yield in Poland. Foreign investors, while considering capital investment in Poland, compare the possible returns on commercial (office) real estate with other assets available on the financial market. The final financial result from an investment in e.g. government bonds, depends also on the currency exchange rate. Thereby, there is an indirect relationship between the PLN exchange rate and office market yield in Poland. The first hypothesis is a conjunction of two distinct factors, so we expected it to be rejected. As far as second hypothesis is concerned, there is no clear dependence detected of yield rate on dummy variables of GFC and Covid-19. Furthermore, the obtained results indicate that certain changes of market conditions, which influenced the yield rate, can actually be identified after the first quarters of 2010 and 2015. Farther, in case of model 2, the vacancy rate is a factor explaining yield rate in the long but what unexpected, not in the short term.

CONCLUSION

The results of the study indicate that yield rate in the office market in Warsaw, in long and in short term, is determined by monetary liquidity (M2 aggregate) and by exchange rate (EUR/PLN). The dependence of the office market yield in Warsaw on the fundamental factor (Vacancy rate) was found only in long term. Its lack in the short term equation is incompatible with previous studies. Nonetheless, it is worth to note that other authors usually used the rent not the vacancy rate as a local office market factor. In the case of the model 1 the risk premium variable in short-term was found statistically insignificant. The obtained results may be substantial information for commercial real estate practitioners, as they indicate drivers of the office market yield.

The time span of available time series can be regarded as a limitation of the study. Time range of the data did not allow for a comprehensive verification of the impact of the GFC and Covid-19 on the office market yield. The time series start only few periods before occurrence of the GFC and end when covid-19 was still a threat.

In our opinion, further study should be conducted in following directions. Firstly, it seems advisable to verify impact of the local demand factors (number of employees in the FIRE sectors) and supply factors (stock, supply). So far, these were measured indirectly, through rent and vacancy rate. Application of other financial time series is also recommended (e.g. government bond yield rates in countries from which investment capital flows to the office market in Warsaw, as well as, other CEE countries). Furthermore, more detailed verification of the Covid-19 impact on yield rate on the office market in Warsaw, might be curious. Perhaps including time series of GDP or related in the model, would be suggested. In addition, a more detailed verification of found structural breaks is indicated, what suggests using a nonlinear model specification.

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APPENDIX

Table 7. The ADF test for stationarity of time series used in the models 1 and 2

Variable	Test statistic	Critical value 1%	Critical value 5%	Critical value 10%
Yields	-0.706	-3.573	-2.926	-2.598
RentLN	-1.728	-3.573	-2.926	-2.598
Vacancy	-1.564	-3.573	-2.926	-2.598
IREMU	0.132	-3.573	-2.926	-2.598
RPremium	-2.109	-3.573	-2.926	-2.598
M2LN	-0.713	-3.573	-2.926	-2.598
EURPLNLN	-2.495	-3.573	-2.926	-2.598
RM1_L	-2.658*	-3.574	-2.927	-2.598
RM2_L	-3.686***	-3.574	-2.927	-2.598
YieldsC	-6.419***	-3.574	-2.927	-2.598
RentLNC	-5.823***	-3.574	-2.927	-2.598
VacancyC	-5.119***	-3.574	-2.927	-2.598
IREMUC	-5.698***	-3.574	-2.927	-2.598
RPremiumC	-7.051***	-3.574	-2.927	-2.598
M2LNC	-7.688***	-3.574	-2.927	-2.598
EURPLNLNC	-6.591***	-3.574	-2.927	-2.598

Note: *p < 0.1; **p < 0.05; ***p < 0.01.

Source: own study.

Table 8. The Johansen test for cointegration of time series used in the long-term equations, models 1 and 2

Number of cointegrating vectors	Trace statistics	Critical value 5%	Maximum eigenvalue statistic	Critical value 5%
Model 1				
0	57.1954	47.21	32.2011	27.07
1	24.9943**	29.68	17.4747**	20.97
2	7.5195	15.41	7.5188	14.07
3	0.0008	3.76	0.0008	3.76
Model 2				
0	68.6838	47.21	41.5682	27.07
1	27.1157**	29.68	20.5068**	20.97
2	6.6088	15.41	5.7713	14.07
3	0.8375	3.76	0.8375	3.76

Note: one cointegrating vector at **p < 0.05. Johansen test for two lags.
Source: own study.

Table 9. The Shapiro-Wilk normality test for residuals in the short-term equations of models 1 and 2

Short-term equation of model 1		Short-term equation of model 2 with structural break in Q1 2010	
z	0.387	z	0.847
Prob>z	0.34951*	Prob>z	0.19844*
		Short-term equation of model 2 with structural break in Q1 2015	
		z	0.697
		Prob>z	0.24295*

Note: *p >0.1; **p >0.05; ***p >0.01.
Source: own study.

Table 10. The Breusch-Godfrey autocorrelation test for the short term equations of models 1 and 2

Short-term equation of model 1		
Number of lags	chi2	Prob > chi2
4	8.052	0.0897**
Short-term equation of model 2 with structural break in Q1 2010		
Number of lags	chi2	Prob > chi2
4	3.164	0.5307*
Short-term equation of model 2 with structural break in Q1 2015		

Number of lags	chi2	Prob > chi2
4	5.972	0.2013*

Note: *p >0.1; **p >0.05; ***p >0.01.
Source: own study.

Table 11. The White test for heteroscedasticity in short-term equations in models 1 and 2

Short-term equation of model 1	chi2(16)	Prob > chi2
	27.84	0.0330***
Short-term equation of model 2 with structural break in Q1 2010	chi2(22)	Prob > chi2
	24.68	0.3128*
Short-term equation of model 2 with structural break in Q1 2015	chi2(26)	Prob > chi2
	46.05	0.0090

Note: *p >0.1; **p >0.05; ***p >0.01.
Source: own study.

Table 12. The Chow test for structural break in yield rate time series

Model 1		
	Breakpoint Q1 2010	Breakpoint Q1 2015
Chow F statistic	4.001	0.665
Critical F value	2.342	2.342
Model 2		
	Breakpoint Q1 2010	Breakpoint Q1 2015
Chow F statistic	5.831	3.319
Critical F value	2.270	2.270

Note: results at p value 0.5.
Source: own study.