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Yield rate in the Warsaw office market and its determinants. Further studies

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Abstract: This article is a continuation and extension of a previous study which, to the best of the author's knowledge, was the first scientific attempt to identify determinants of the yield rate in the Warsaw office market. The paper is based on the Gordon growth model. In this approach, the yield rate of buildings offering office space to let is a function of the risk-free interest rate, the risk premium and a constant rate of growth of generated cash flows. In the article, five different elements of the risk premium were identified (term structure, alternative investments', market (country) specific, monetary and local office market capacity risk premium). The Error Correction Model was formulated based on quarterly time series data from 2007Q1 to 2021Q2. Most investors in the office market in Poland are financial institutions representing foreign capital. Therefore, the innovation of the paper and its main goal was to define which factors play key roles in determining yield rates in the Warsaw office space market – national or regional/international. However, the selected group of Polish determinants were indicated as having prevailing an impact on the yield rate in the Warsaw office market than the corresponding determinants from the European Monetary Union and the USA. Based on the model, the lead-lag, as well as asymmetric relations, were depicted. Moreover, the use of dummy variables checks, the Chow test and the Markov switching model indicated the presence of structural breaks and the existence of the two regimes in the model.

Keywords: office market, yield rate, capitalization rate, error correction model, Markov switching model

1. Introduction

Warsaw dominates the office market in Poland. At the end of 2021, the office stock in Warsaw stood at 6.15 million sq.m., which was a little more than the total stock in the next eight regional markets in Poland put together (BNP Paribas 2022a; 2022b). Another specificity of the Polish office space market (which applies to the entire Polish commercial real estate market) is that foreign investors play a dominant role (NBP 2022). Moreover, buy-sell transactions in Poland's commercial real estate and leasing contracts are normally settled in euros. Considering that, in recent years, it was profitable for foreign investors to borrow money at home at a rate close to zero and invest the capital in commercial real estate in Poland, and in this context the question is whether the interest rates from the European Monetary Union and the USA are transferred to the Warsaw office market. Furthermore, in this case, is the National Bank of Poland's monetary policy a factor determining the Warsaw office market's yield rate? Or is it the monetary policy of the European Central Bank or the Fed?

In accordance with the Gordon growth model, risk-free interest rate, together with the risk premium and the cash flow growth, are the default variables explaining the yield rate in the commercial real estate market. The conceptualisation of the first and the last is quite unambiguous; however, when it comes to risk premium range of options is quite large. However, most of this type of research concerns markets in developed countries such as the USA or members of the euro area, whereas there is nosimilar research on markets which, for historical reasons, started developing later and are at an earlier stage of development. The study of the office market in Warsaw in this approach is a novelty of the paper.

The research period starts in 2007Q1 and ends in 2021Q2, which provides a few implications for the study. First, it includes the Global Financial Crises and the Covid-19 pandemic. These, together with the two opposite directions of the course of the yield rate during the study and the influence of extremely low-interest rates, indicate verifying the presence of potential structural breaks in the model. The initially derived linear dependencies may vary significantly within rapidly changed market conditions – furthermore, changes in the financial markets and in monetary policies validate asymmetric relations in the model.

Based on the above, the following research questions should be posed:

1) Which factors play key roles in determining the yield rate in the office market in Warsaw – national or regional/international?
2) What is the character of the relations between the yield rate in the office market in Warsaw and its determinants (lead-lag, asymmetric)?
3) Are there clear structural breaks in these relations?

Determining answers to these questions is the main goal of the article, they also serve as the basis for hypotheses formulated in Section 3.

This article is a continuation and extension of a previous study (Nowak 2021), which to the best of the author's knowledge, was the first scientific attempt to identify determinants of the yield rate in the Warsaw office market. In this study, risk premium is attributed to the following groups of variables: term structure, alternative investments, market (country) specific, monetary liquidity and local office market capacity. The econometric model was built using the Error Correction Model (ECM) econometric approach. In order to verify which national or regional/international determinants are better in explaining fluctuations of the yield rate in the Warsaw office market, six models were built based on Polish variables as well as those of the EMU and the USA. The lead-lag relationships were tested on the final short-term equation within the ECM, along with asymmetric dependencies. Dummy variables together with the Chow test were used to detect potential structural breaks within the model, while the Markov switching model approach was employed to check for different regimes reflecting changing influence of particular variables in different market conditions.

The remainder of the paper is organised as follows: the next section analyses the relevant literature regarding the risk premium in the commercial real estate market with special attention to monetary liquidity and internationalisation process. Section 3 considers the selection of the variables used in the study and states four hypotheses to be tested. Section 4 specifies the data and the method, and Section 5 provides results and discussion. Finally, Section 6 outlines concluding remarks and implications.

2. Literature review

The motivation and purpose of the study indicates the need to concentrate on the explanatory variables – with a major focus on the elements of the risk premium - that impact on the yield rate on the office market. The initial yield rate is synonymous with specifying the capitalisation (cap) rate, and these two terms are usually used interchangeably in the literature when it comes to commercial real estate. The initial yield rate is defined as the yield rate on a building with a completed commercialisation process that can be subject to a buy-sell transaction. The yield rate in the office space market, understood in this way, is usually modelled as a result of the variables representing the local office markets' fundamentals such as rent or its increase and discount rate. This is commonly derived from the Gordon growth model:

$$Y_t = \frac{NOI_t}{V_t}, \tag{1}$$

$$V_t = \frac{NOI_t}{r_t - g_t}, \tag{2}$$

$$Y_t = r_t - g_t = r_{F,t} + r_{P,t} - g_t, \tag{3}$$

where: Y_t – initial yield rate (cap rate), NOI_t – net operating income, V_t – value of the property, r_t – discount rate (risk adjusted), $r_{F,t}$ – risk-free interest rate, $r_{P,t}$ – risk premium, g_t – cash flow growth.

Equation (3) is usually the starting point in the studies of cap rate (see e.g. Bruneau and Cherfouh 2018; Crosby et al. 2016; Chichernea et al. 2008; Hendershott and MacGregor 2005). The discount rate consists of a risk-free interest rate and a required risk premium. A risk-free interest rate is usually specified as interest on long-term (10 or 20 years) government bonds. It is worth mentioning that the dependencies signalised by the equation are not stable but can vary over time (Jones 2015). Additionally, in equation (3), the positive effect of the inflation rate is sometimes specified.

The risk premium is the main issue of the model formulated in the above manner. Risk premium may be diverse depending on the level at which it is analysed. Equation (3) suggests that it results from the financial market conditions and state of the local office market. However, the risk in the commercial real estate market may be understood much more broadly. Clayton et al. (2009) claimed that the risk premium depends on property, market and time. Then, it is determined by particular property characteristics, local market state/development, and the changing value of money over time. The latter is attributed not only to inflation but, as is common in the literature, to the treasury securities' yield curve.

The studies dealing with risk premiums in commercial real estate markets can be generally divided into two types: those that focus on modelling the yield/cap rate, and those in which the explained variable is the risk premium itself. In both, the variables reflecting risk premium are the main field of analysis. At macro-financial level, a risk premium in the commercial real estate market can be imputed as the term structure of interest rate, monetary policy, and capital flows both at international and national level (Szweizer 2019), interdependencies to the risk premium of investment in stocks and bonds (interest/rate of return spread) and their cyclicality (McGough and Berry 2020; Liow 2016). It also can be assigned to characteristics of the country/commercial real estate market specific risk such as

national economic prosperity, i.e. GDP (Ho et al. 2015), debt (Chervachidze and Wheaton 2013), structure and cyclicality of the economy at urban level (Orr and Jones 2003), lack of liquidity (Cheng et al. 2013), political risk (Jones 2019), financial regulations (Duca and Ling 2015), institutional issues and transparency (Sadayuki et al. 2019; Zhang et al. 2019; Farzanegan and Fereidouni 2014; Newell 2008; McGreal et al. 2001). In terms of a single building, risk can arise from location (Couts 2022; Gunnelin et al. 2004), neighbourhood, even environmental contamination (Jackson and Yost-Bremm 2018), the building itself as well as tenant credit risk (Peyton 2009). A growing amount of literature is devoted to the risk of a lack of sustainability/green building solutions in particular buildings (Fuerst and McAllister 2011). As to behavioural aspects, the required risk premium is related to the investor's self-perception of particular risk factors and investor sentiment (Beracha et al. 2019) and may also be affected by the composition of the investor's investment portfolio.

This research focuses on selected risk factors in the office market, however most attention is directed to those based on equation (3). In many publications based on (3) debt and/or monetary liquidity were stated as essential explanatory variables. Ling and Naranjo (2003) emphasised the importance of capital flows when it comes to REITs (Real Estate Investment Trusts) and commercial real estate returns. Ling et al. (2007) argued that capital flows are notably crucial in private markets, and insisted that a low level of supply elasticity subsistent in commercial real estate markets may be subject to exogenous capital flow shocks; both being relevant to the formation of speculative bubbles.

The commercial real estate market has become more global due to financialisation in recent decades. From that point of view, capital flows are key factors in understanding cyclicality at local level. Fadeyi et al. (2021) explored the interaction of international real estate capital flows in London, New York and Tokyo. Interestingly, the level of involvement of international capital differed in the three international financial centres, and it was higher in London, and lower in the other two cities. In this context, Falkenbach and Toivonen (2010) pointed to the positive effects of the rapid internationalisation of the Finnish commercial real estate market. However, it should be recalled that the inflow of foreign capital ceteris paribus causes a fall in the market cap rate – this applies to the USA (McAllister and Nanda 2015) and any other market in the world.

The research period (2007Q1 – 2021Q2) can be regarded as a specific moment in economic history. Much of it falls in the post-GFC time and covers the onset of the COVID-19 pandemic, a period of low and in some cases negative interest rates, and quantitative easing process (QE). These issues certainly took their toll on the functioning of the financial markets during that time and should also be visible in the model trying to reflect relations between particular elements of financial markets, as seen, e.g. in the QE implications. Fratzscher et al. (2013) stated that as a result of QE1, capital flew into the US equity and bonds from emerging markets, whilst under QE2, the direction was the opposite.

The fluctuations of financial market conditions in the last two decades may provide a reason of the assumption of possible breaks in linear models of commercial real estate. There is a growing number of articles including that topic, yet still not as numerous as the studies dedicated to the housing market. Maitland-Smith and Brooks (1999), based on modelling value indices of commercial real estate in the US and the UK, claimed that the MSM approach was better able to capture the non-stationary features of the data than the Threshold Autoregressive model. Chervarchidze et al. (2009) found structural changes in the model of real estate cap rates in the USA using the CUSUM test. They argued that the changes reflect the changing sentiments of investors in consecutive business cycle phases. Hutchison et al. (2012), based on the Markov switching model, estimated on the UK's office, industrial and retail real estate sectors, stated that the risk premium on the last two exhibited regime shifting behaviour. Beracha et al. (2019), using the same model, indicated that the ex-ante risk premium in commercial real estate was affected by fundamental and non-fundamental determinants. Nonetheless, the impact was of an asymmetric nature, depending on the increasing and decreasing course of risk premium.

3. Selection of variables

The potential determinants of yield rate in the Warsaw office market were identified based on the above Gordon growth model (equation (3)). Thus, they were divided into risk-free interest rate, risk premium and cash flow growth.

Knowing that in many papers regarding the office market, interest rate of ten- or even twenty-year government bonds is selected as a risk-free interest rate, the author introduced interest rates of Wibor3M, Euribor3M, TBills3M and five-year government bonds in Poland, the European Monetary Union and the USA, respectively. First, the interbank interest rate is commonly used in finance articles as the one not bearing risk. Ling and Naranjo (1997) is an example of a commercial real estate study using short-term TBills3M as a risk-free interest rate. Secondly, the definition of the initial yield rate (in the literature review) suggests that it should be rather considered as a short-term not a long-term yield as it reflects cap rate on the office buildings in a particular point of time, with a lasting particular number of lease agreements, with particular terms of the agreements, and in particular market conditions. Thirdly, quarterly time series were employed, which again indicates the need of using short-term risk-free interest rate (three-month). Furthermore, the author leans towards Hagen and Hansen (2018), who acknowledged that ten-year government bond yields are not entirely risk-free as they capture government risk and inflation risk. Moreover, the author also believes that the duration of the risk-free interest rate should be coherent with the duration of lease contracts. As five years is the standard duration of an office space lease agreement in Warsaw, the choice of interest of the five-year government bonds seems rational. Interestingly, even in mature markets where typical lease contracts are usually concluded for longer periods, investors in fact often shorten the time of holding the investment in offices (Gardner and Matysiak 2005; Farragher and Kleiman 1996).

On the basis of the discussion in the previous section, the author decided to take into account the time series representing various types of risk premiums. Table 1 presents the time series used to derive adopted types of risk premiums. The aforementioned interbank interest rates and government bonds are often recognised as providing risk-free interest rates. In this case, comparing the two characterised by different maturity should allow to separate the term risk premiums. Therefore, in the study the term-structure risk premium is represented by the gap between interest on five-year government bonds and risk-free interest rates in Poland, the European Monetary Union and the USA, respectively.

Dunse et al. (2007) argued that risk premium should be a function of the local property market's characteristics and alternative investments in the stock market. Alternative investments risk premium here is also related to rates of return which can be exercised by investments in other types of financial assets/instruments rather than buildings offering office space to let. In the study, this kind of risk premiums is represented by the rate of return from leading blue chip stock indices in Poland, the EMU and the USA minus short-term risk-free interest rates (Wibor3M, Euribor3M, TBills3M), as well as interest on five-year government bonds. The approach is based on the fact that financial markets in diverse countries (economic areas) may show different profitability, which results from the different characteristics of these markets and various levels of systematic risk. This way of formulation of the variables was also motivated by the fact that despite several announcements (initially, REITs were indicated to function only in the housing market) in Poland, there are still no legal solutions enabling the functioning of REITs. While using REITs' rates of return is very popular in literature (e.g. Chiang et al. 2017), yet one can find some attempts at veryfing rate of returns in Poland regarding real estate development companies traded on the Warsaw Stock Exchange, e.g. Dittmann (2016).

Table 1. Characteristics of variables applied in the study (2007Q1 – 2021Q2)

Type of variables	Time series	Area	Variable name	Min.	Max.	Mean	St.dev.
Explained variable	Yield rate	Poland	Yield	0.0448	0.0703	0.0569	0.0073
Risk free interest rate	WIBOR3M	Poland	WIBOR	0.0020	0.0691	0.0296	0.0171
	EURIBOR3M	European Monetary Union	EURIBOR	-0.0054	0.0528	0.0075	0.0159
	TBILLS3M	USA	TBILLS	2.9929E-05	0.0487	0.0076	0.0115
	5YR government bonds	Poland	5YRPL	0.0046	0.0691	0.0350	0.0173
	5YR government bonds	European Monetary Union	5YREMU	-0.0078	0.0456	0.0085	0.0155
	5YR government bonds	USA	5YRUSA	0.0026	0.0473	0.0179	0.0095
Term-structure risk premium	5YR government bonds – Wibor3M	Poland	5YRWIB	-0.009	0.0161	0.0054	0.0058
	5YR government bonds – Euribor3M	European Monetary Union	5YREUR	-0.0151	0.0172	0.0009	0.0061
	5YR government Bonds – Tbills3M	USA	5YRTBI	-0.0048	0.0264	0.0103	0.0072
Alternative investments' risk premium	WIG20-Wibor3M*	Poland	W20WIB	-0.2839	0.1942	-0.0279	0.1039
	WIG20-5yr government bonds*	Poland	W205YR	-0.2838	0.1806	-0.0333	0.1019
	XetraDAX-Euribor3M*	European Monetary Union	XDEUR	-0.2696	0.2432	0.0129	0.1082
	XetraDAX-5yr government bonds*	European Monetary Union	XD5YR	-0.2646	0.2460	0.0119	0.1062
	S&P500-TBills3M*	USA	SNPTBIL	-0.2291	0.1930	0.0139	0.0848
	S&P500-5yr government bonds*	USA	SNP5YR	-0.2439	0.1917	0.0037	0.0847
Market (country) specific risk premium	Wibor3M-Euribor3M	Poland/European Monetary Union	WIBEUR	0.0024	0.0491	0.0222	0.0101
	5yr PL government bonds – 5yr EMU government bonds	Poland/European Monetary Union	PL5YREMU	0.0082	0.0446	0.0265	0.0082
	WIG20-XetraDAX*	Poland/ European Monetary Union	W20XD	-0.2120	0.1468	-0.0187	0.0774
	Wibor3M-TBills3M	Poland/ USA	WIBTBI	-0.0073	0.0556	0.0221	0.0190
	5yr PL government bonds – 5yr US government bonds	Poland/ USA	PL5YRUSA	-0.0051	0.0438	0.0171	0.0149
	WIG20-S&P500*	Poland/ USA	W20SNP	-0.1819	0.1345	-0.0199	0.0703
Monetary risk premium	M3/GDP	Poland	M3GDPPL	1.7787	3.1789	2.3538	0.3324
	M3/GDP	European Monetary Union	M3GDPEMU	3.5000	5.3526	4.1022	0.3519
	M3/GDP	USA	M3GDPUSA	2.0300	3.7536	2.6276	0.3989
Local office market capacity risk premium	Stock x (1–vacancy rate)/average employment in enterprise sector	Poland	OSAE	2799.71	4927.41	3887.36	637.58
Cash flow growth	Rent	Poland	Rent	21.8685	31.0312	24.9910	1.8726

Note: Units of the time series used to produce variables are as follows: percentage (Yield, WIBOR, EURIBOR, TBILLS, 5YRPL, 5YREMU, 5YRUSA, 5YRWIB, 5YREUR, 5YRTBI, W20WIB, W205YR, XDEUR, XD5YR, SNPTBIL, SNP5YR, WIBEUR, PL5YREMU, W20XD, WIBTBI, PL5YRUSA, W20SNP, Vacancy), PLN, EUR and USD (M3, GDP in Poland, EMU and USA), sqm (Stock), thousands of employees (average employment in enterprise sector in Warsaw), euro/sqm per month (Rent). *Stationarity issue.

Source: own study.

The boost in capital inflow to the commercial real estate market can find its origin in increased monetary liquidity what can result in the growing interest of foreign and domestic investors. Examples of variables used in the literature are, in this case, money aggregates alone and in relation to the GDP (Bruneau and Cherfouh 2018), as well as the number and value of transactions made by foreign actors. The inflow of foreign capital is not applied in the study directly. To verify the resulting risk premium between the three studied economic areas, the author defined the variables representing gaps in the interest rate and rate of return gained on the same classes of financial instruments (short-term risk-free interest, five-year government bonds, stock indices) in Poland and the EMU as well as in Poland and the USA. The variables can play roles of country-specific risk premiums. The premium is a factor that investors in EUR and USD should be aware of willing to place financial resources in Poland. An increase in the difference should enhance the pipeline of the eurozone and American investments. Most of the time span of the research falls on quantitative easing, low and even negative risk-free interest rates in the USA, European countries, Japan, etc. This stays not without significance on the office yields and requires inclusion in the study. Regarding the influence of the monetary liquidity factor, it is mirrored by the variable representing the M3 aggregate divided by the GDP.

Last but not least, Sivitanidou and Sivitanides (1999) insisted that national and local indicators should be of interest when determining the office yield rate. In accordance with that, the level of development of the local office market should also be regarded as a part of the risk premium. This matter can be crucial in terms of rent, vacancy rate, demand and supply in a particular market. Maturation of the market may entail a change in the yield rate, for instance, the growing amount of stock available in the office market, with stable demand, may ceteris paribus imply a lowering of rent, an ever-increasing vacancy rate and, in that way, decreasing the yield rate (assuming the denominator remains unchanged). However, one can also imagine the growing office market working as a cluster attracting new tenants, also from new industries and building up a local labour market. This should not necessarily lead to a fall in rent and an increase in the vacancy rate. Indeed, some studies insist that due to reduced office space occupation risk at clusters, vacancy rates tend to be lower and rental growth rates tend to be higher, which conversely may mean higher prices and/or valuations of properties, and thus lower yield rates (van der Vlist et al. 2021; Cheng et al. 2013; Jennen and Brounen 2009). Devaney et al. (2019), based on a study of office markets in 16 countries, proved that mature markets with a comparatively large total stock tend to have lower cap rates and, thus, higher asset prices. In this context two trends have been evident in the Warsaw office market since the 1990s; these are systematic growth of stock accompanied by decreasing levels of nominal rent. During the time span of the study, stock in the Warsaw office market rose from 2.5 million sqm to 6.1 million sqm. FIRE (finance, insurance and real estate) employment – which is regarded as primarily responsible for office space demand – certainly is still a growing element of the local labour market in Warsaw. However, statistical data regarding the labour market in Poland provided by the Central Statistical Office (GUS) does not allow the extraction of figures for pure FIRE employment in Warsaw in the first years of the study. Hence, the author decided to use occupied stock divided by average employment in the enterprise sector as a factor representing risk premium attributed to local office market development. This variable is similar to those used by D'Argensio and Laurin (2008), who determined office capitalisation rates by, among others, variables representing office market stock divided by the city's total population and stock divided by city area, whereas Laurin et al. (2010) used variables obtained by dividing the city's total annual occupied space by its respective annual office-using employment figures.

Rent increase or various forms of rent are in use in literature as representing the cash flow growth. Since the ADF test detected a stationarity issue regarding the rental growth rate (at the long-term equation level), the study opted for the rent time series for the cash flow growth variable.

The author decided to verify determinants from the euro zone, with Poland being an EU member since 2004, hence the influence of capital flows from the EMU countries seems self-explanatory. The USA

variables were considered in the study as the USA serves as a main global source of investment capital flows (Fadeyi et al. 2021).

Based on the analysis of the literature and the specificity of the Warsaw office market the following hypotheses were tested in the study:

Hypothesis 1: The selected group of determinants from the European Monetary Union explains better the yield rate in the Warsaw office market than the group of corresponding Polish variables.

Hypothesis 2: The formulated ECM model's short-term equation indicates lead-lag relationships between the Warsaw office market yield rate and selected explaining variables.

Hypothesis 3: In the Warsaw office market, asymmetric relations between the yield rate and the selected explaining variables can be indicated.

Hypothesis 4: Changes in the market environment led to structural breaks in the formulated model, namely changes in the impact of the selected determinants on the Warsaw office market yield rate.

4. Data and method

4.1. Data

The period of quarterly data employed in the study covers 2007Q1 – 2021Q2. Figure 1 depicts nominal rent, yield rate, and supply as a percentage of a lagged one-period stock, Wibor3M, Euribor3M and TBills3M. The yield rate after an increase in 2008 was slightly decreasing until 2014Q3, then the short-term rise was followed by a more evident systematic fall.

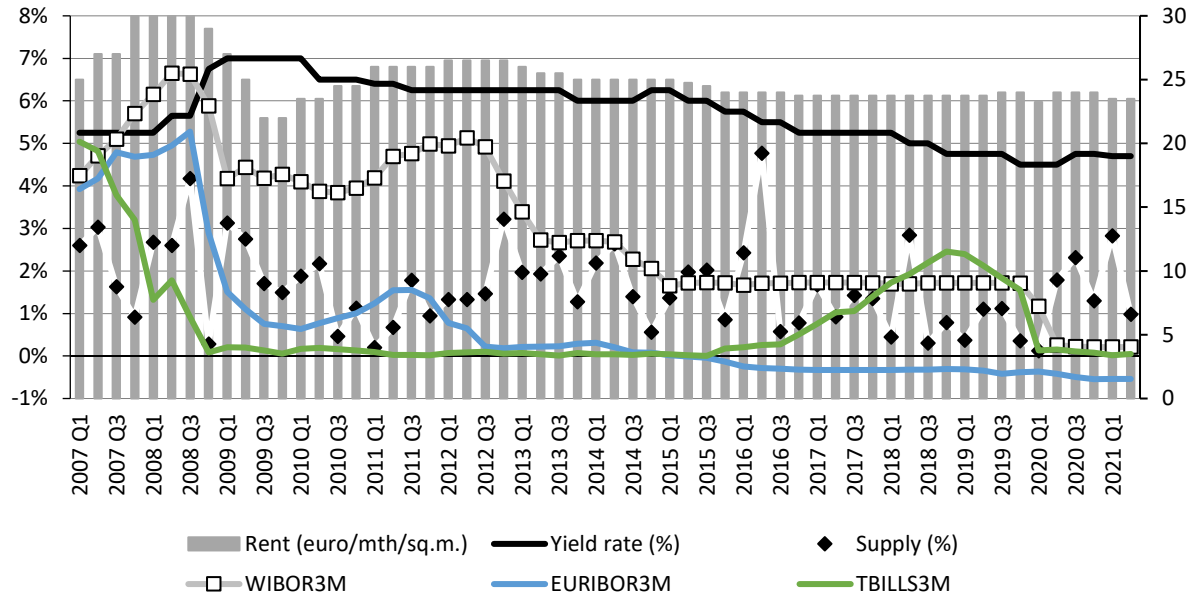

Fig. 1. Rent, yield rate, supply in the office market in Warsaw and Wibor3M, Euribor3M, TBills3M, 2007Q1 – 2021Q2

Source: own study.

All the variables used in the study representing cash flow (rent, office yield rate, diverse interest rates and rates of return) are inflation adjusted. Moreover, the risk premium attributed to the exchange rate was not included in Table 1 as the cash flow variables were adjusted to represent values in euros. This was done because rent in buildings offering modern office space in Poland is charged in euros, buy-sell

transactions of modern commercial real estate in Poland are also processed in euros, i.e. the yield rate represents values in euros. Accordingly, the time series in PLN and USD were divided by 1 plus the rate of change time series of the EURPLN and EURUSD exchange rates, respectively, and thus one obtained, e.g. rate of return on index WIG20 adjusted by the rate of return of EURPLN. The returns of stock indices WIG20, XetraDax and S&P500 were calculated as follows:

$$\left(\frac{WIG20_t - WIG20_{t-1}}{WIG20_{t-1}}\right) \tag{4}$$

Diverse variables used in the study resulted in several of data sources. The Warsaw office market data regarding yield rate, rent, stock, supply and vacancy rate were obtained from Newmark Polska. The rent and yield rate time series apply to prime office buildings in Warsaw's Central Business District. Data regarding the interest rate of government bonds in Poland, the EMU and the USA came from Thomson Reuters and the FED. The time series of Wibor3M, Euribor3M and quotations of the indexes WIG20, Xetra Dax, and S&P500 were obtained from https://stooq.com. The interest rates of TBills3M were acquired from https://www.marketwatch.com. The Eurostat was the source of monthly HICP inflation rates in Poland and the EMU, which were later transformed into quarterly time series. The US HICP inflation rate was collected from the International Financial Statistics. The Polish M3 money aggregate came from the National Bank of Poland, while M3 for the EMU and the USA were obtained from the FED, while the GDP of Poland, the EMU and the USA from the International Money Fund. The Central Statistical Office (GUS) provided average employment figures in the enterprise sector in Warsaw.

4.2. Methodology issues

The study was based on the error correction model (ECM) approach (Engle and Granger 1987). The ECM normally consists of two equations (Enders 2004). The first depicts the long-term relationship between the dependent variable and explanatory variables, and is usually based on level or log time series, while the second is based on the time series representing changes in the long-term variables. Additionally, lagged one period of long-term residuals in the second equation work as an explanatory variable, reflecting the short-term deviations from the long-term equilibrium. The OLS of the ECM approach takes the following form (Kośko et al. 2007: 356):

$$Y_t = \alpha_0 + \alpha_1 X_t + u_t \tag{5}$$

$$\Delta Y_t = \beta_0 + \beta_1 \Delta X_t + \gamma\, u_{t-1} + \eta_t, \tag{6}$$

where: Y_t, X_t – explained and explanatory variables respectively (cointegrated nonstationary time series); ΔY_t, ΔX_t – changes of Y_t and X_t (stationary time series); u_t – white noise error term, u_{t-1} – the error correction term (one period lagged residuals of (5)), η_t – white noise error term.

The study was conducted in the following order. Firstly, the time series employed in the study were checked for stationarity with the ADF test. Next, six long-term equations were formulated (two representing each geographic area – Poland, the EMU and the USA). Then, the Johansen cointegration tests validated the relationship between the variables used in the equations, and then, a short-term equations were constructed. Next, one short-term equation (out of six) was picked based on the econometric fit used to conduct the following steps of the study. The basic form of the short-term equation was reformulated by adding explanatory variables lagged 1 to 4 periods, as well as lagged dependent variables. The variable with the highest t-value and above 0.1 was excluded from the equation, which was then regressed again. This procedure was repeated until only statistically significant variables stayed in the equation. The above adjustment process was meant to include possible lead-lag relationships which can occur among the variables. The number of lags results from the fact that the time series are on a quarterly basis. The finally obtained equation was

checked using econometric tests: the Shapiro-Wilk test, the Breusch-Pagan test, and the Breusch-Godfrey test.

Next, the asymmetric relationships between the dependent and explanatory variables were tested. Seventeen asymmetric variables based on the primary short-term equation were formulated, along with variables reflecting factors not directly included in the model. The final equation was used to test the potential changes in the model structure, i.e. changes in the relation between the dependent variable and the explanatory variables. First, 0-1 dummy variables (DV) representing the start of the Global Financial Crisis (GFC) and COVID-19 were added to the equation. The same procedure was carried out for 2010Q2 and 2015Q2, which were the first quarters of the declining trends of the yield rate in the Warsaw office market. This corresponds to the author's previous study (Nowak 2021), in which the two periods were also tested. The equation with the best econometric fit (adjusted R^2, number of statistically significant variables) was re-run, with additional dummy variables being a product of previous 0-1 DV and primary short-term variables. Next, the Chow test of the basic short-term equation was used to confirm the structural break.

After that, the Markov switching autoregression model was established. The approach was developed by Hamilton (1989, 1990). The MSM can prove the presence of two or more separate regimes in the model. The regime of the current moment is not known; nevertheless, one can estimate the probability of changing the regime in the next period. Moreover, the coefficients of the variables used in the model may be allowed to change between model states. In this study, the MSM was used to verify if there were two regimes of the final short-term equation and later if, in the regimes, the elements of risk premium affected the yield rate on the Warsaw office market in a different manner. Therefore, two MSM equations were constructed. The MSM models were formulated in the form proposed by Stata (2022: 15):

$$y_t = \mu_{St} + x_t\alpha + z_t\beta_{St} + \emptyset_{1,St}(y_{t-1} - \mu_{St-1} - x_{t-1}\alpha - z_{t-1}\beta_{St-1}) + \emptyset_{2,St}(y_{t-2} - \mu_{St-2} - x_{t-2}\alpha - z_{t-2}\beta_{St-2}) + \varepsilon_{St} \quad (7)$$

where: y_t – dependent variable; μ_{St} – state-dependent intercept; x_t – covariates whose coefficients α are state-invariant; z_t – covariates whose coefficients β_{St} are state-dependent (risk premium's variables in the second equation); $\Phi_{1,St}$ – the first AR term in state s_t; $\Phi_{2,St}$ – the second AR term in state s_t (added in the second equation).

The study proceeded with the use of the STATA software.

5. Results and discussion

Tables 11 and 12 in the Appendix present the results of the ADF stationarity test. At this stage of the study the following variables were excluded: W20WIB, W205YR, XDEUR, XD5YR, SNPTBIL, and SNP5YR. These time series are stationary in levels. The ECM implies that all series used in the long-term equation must be of the same order. For this reason, the above variables could not be used to formulate the long-term equation together with non-stationary variables. With the rest of the variables, the author built six ECM models: two were developed representing the variables from each geographic area – Poland, the EMU and the USA. This should provide an answer to the question of whether the yield rate on the Warsaw office market is determined more by domestic factors or those derived from the EMU or the USA.

In every two models, different variables were used for risk-free interest, i.e. Wibor3M/Euribor3M/ TBills3M and five-year government bonds, respectively, for each area. Risk premium in most publications is usually expressed by, e.g. the spread between interest on short and long-term treasury securities or the spread between interest on ten or twenty-year government bonds and corporate

bonds of the same maturity. Some studies add selectively chosen variables, whilst the author believes that it seems appropriate to take into account all separated types of risk premiums together, since each risk premium type plays a role in relation to others. For instance, institutional investors do not focus on analysing a single risk factor and do not estimate the risk premium based only on that one-kind risk. The investor tries to take into account all aspects that, on the one hand, form a comprehensive level of risk and, on the other, translate into risk premium which should be included in the yield rate. Therefore, each model consists of the variables from Table 1 representing the different types of risk premiums together. However, the risk premium connected with alternative investments could not be included because of the stationarity issue mentioned. Moreover, in models 2, 4 and 6, the term-structure risk premium is not stated as the five-year government bonds play a role of the risk-free interest. The time series of rent was used as cash flow growth in each model.

5.1. The basic long-term and short-term equations

The long-term equations of models 1 to 6 are presented in Table 2. Adjusted R^2 were quite high, between 0.7327 and 0.8904. As far as the first two models – including Polish determinants – are concerned, 5YRWIB and M3GDPPL were not statistically significant. In models 3 and 4, WIBEUR and 5YREUR, while in models 5 and 6, variables 5YRTBI, WIBTBI and PL5YRUSA were not statistically significant. It should be noted that not all the variables have signs according to the equation (3), e.g. the coefficient of Rent is positive in two equations, while some risk premium variables are negative. This issue is discussed next to the final short-term equation. The coefficients' magnitude of the variables is related to the numbers of the time series used, e.g. the coefficient of WIBEUR is 0.64724, while the mean value of the series is 0.02216. At the same time, the coefficient of Rent is 0.00116, and the mean value of the series stays at 24.99. The cointegration within variables used in each model was confirmed by the Johansen tests (Table 13).

The short-term equations are introduced in Table 3. In models 5 and 6, two variables are statistically insignificant, while in model 3, as many as five variables are insignificant. The adjusted R^2 in short-term equations dropped significantly. Both equations based on the US variables (models 5 and 6) have a relatively low match to the data. Moreover, equations with the risk-free interest rate determined by the short-term Interbank interest rate in Poland and the EMU as well as Tbills3M in the USA (i.e. equations 1, 3 and 5) are marked by a higher R^2 value than those with five-year government bonds.

Based on adjusted R^2, model 1 is the most adequate to explain fluctuations in yield rate on the office market in Warsaw. The better econometric fit of model 1 than model 3 serves as the basis for the rejection of the first hypothesis which says that the selected group of determinants from the European Monetary Union explains better the yield rate on the Warsaw office market than the group of corresponding Polish variables. Additionally, the number of statistically significant variables in the short-term equation of model 1 is higher than in the equation of model 3. The variables that affect the yield rate on the office market in Warsaw (in model 1) are the changes in the Wibor3M rate and the variable reflecting the changes in the difference between the Wibor3M rate and the Euribor3M rate, along with long-term residuals.

Table 2. The long-term equations of models 1 to 6

Variable	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t
Constant	0.09705	0.01365	7.11***	0.14783	0.01876	7.88***	0.09423	0.01266	7.44***	0.14424	0.01783	8.09***	0.14579	0.01061	13.74***	0.18070	0.01918	9.42***
Rent	0.00116	0.00041	2.85***	-0.00108	0.00036	-2.96**	0.00123	0.00039	3.17***	-0.00102	0.00035	-2.92***	-0.00109	0.00027	-4.08***	-0.00197	0.00036	-5.44***
WIBOR	-0.61138	0.08206	-7.45***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
OSAE	-0.00002	2.55e-06	-8.26***	-0.00002	3.88e-06	-6.12***	-0.00002	2.04e-06	-9.92***	-0.00002	2.99e-06	-7.70***	-7.25e-06	1.65e-06	-4.39***	-0.00001	2.76e-06	-3.82***
5YRWIB	0.11182	0.08739	1.28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
M3GDPPL	0.00681	0.00475	1.43	0.01139	0.00684	1.67	–	–	–	–	–	–	–	–	–	–	–	–
WIBEUR	0.64724	0.04894	13.23***	–	–	–	-0.01346	0.05396	-0.25	–	–	–	–	–	–	–	–	–
5YRPL	–	–	–	-0.40500	0.10842	-3.74***	–	–	–	–	–	–	–	–	–	–	–	–
PL5YREMU	–	–	–	0.59379	0.08334	7.12***	–	–	–	0.16588	0.08197	2.02**	–	–	–	–	–	–
EURIBOR	–	–	–	–	–	–	-0.65615	0.07524	-8.72***	–	–	–	–	–	–	–	–	–
5YREMU	–	–	–	–	–	–	0.09139	0.10046	0.91	-0.49804	0.10164	-4.90***	–	–	–	–	–	–
M3GDPEMU	–	–	–	–	–	–	0.00391	0.00169	2.30**	0.00672	0.00249	2.70***	–	–	–	–	–	–
TBILL	–	–	–	–	–	–	–	–	–	–	–	–	-0.53072	0.08300	-6.39***	–	–	–
5YRTBI	–	–	–	–	–	–	–	–	–	–	–	–	0.00071	0.07832	0.01	–	–	–
M3GDPUSA	–	–	–	–	–	–	–	–	–	–	–	–	-0.01041	0.00227	-4.59***	-0.00903	0.00338	-2.67**
WIBTBI	–	–	–	–	–	–	–	–	–	–	–	–	-0.09325	0.05758	-1.62	–	–	–
5YRUSA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-0.52358	0.11391	-4.60***
PL5YRUSA	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-0.02728	0.08576	-0.32
Adj. R^2	0.8812			0.7384			0.8904			0.7583			0.8883			0.7327		

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

Source: own study.

Table 3. The basic short-term equations of models 1 to 6

Variable	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t
Constant	-0.00038	0.00028	-1.37	-0.00010	0.00035	-0.30	-0.00034	0.00028	-1.19	-0.00006	0.00034	-0.18	-0.00014	0.00033	-0.44	-0.00011	0.00035	-0.31
RentC	0.00026	0.00029	0.88	-0.00091	0.00035	-2.59**	0.00041	0.00029	1.37	-0.00089	0.00034	-2.66**	-0.00085	0.00033	-2.55**	-0.00107	0.00038	-2.81***
WIBORC	-0.51177	0.07787	-6.57***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
OSAEC	-2.11e-06	5.33e-06	-0.40	-4.26e-06	6.58e-06	-0.65	-3.39e-06	5.26e-06	-0.64	-5.81e-06	6.31e-06	-0.92	-2.16e-07	6.08e-06	-0.04	-1.77e-06	6.47e-06	-0.27
5YRWIBC	-0.00904	0.05712	-1.58	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
M3GDPPLC	-0.00166	0.00328	-0.51	-0.00103	0.00408	-0.25	–	–	–	–	–	–	–	–	–	–	–	–
WIBEURC	0.44702	0.07159	6.24***	–	–	–	-0.01285	0.05838	-0.22	–	–	–	–	–	–	–	–	–
5YRPLC	–	–	–	-0.20059	0.07539	-2.66**	–	–	–	–	–	–	–	–	–	–	–	–
PL5YREMUC	–	–	–	0.10455	0.09360	1.12	–	–	–	-0.09722	0.07338	-1.32	–	–	–	–	–	–
EURIBORC	–	–	–	–	–	–	-0.49668	0.08328	-5.96***	–	–	–	–	–	–	–	–	–
5YREMUC	–	–	–	–	–	–	-0.02854	0.06474	-0.44	–	–	–	–	–	–	–	–	–
M3GDPEMUC	–	–	–	–	–	–	-0.00065	0.00185	-0.35	-0.00015	0.00224	-0.07	–	–	–	–	–	–
5YREMUC	–	–	–	–	–	–	–	–	–	-0.21085	0.07478	-2.82***	–	–	–	–	–	–
TBILLC	–	–	–	–	–	–	–	–	–	–	–	–	-0.29637	0.08659	-3.42***	–	–	–
5YRTBIC	–	–	–	–	–	–	–	–	–	–	–	–	-0.07929	0.06678	-1.19	–	–	–
M3GDPUSAC	–	–	–	–	–	–	–	–	–	–	–	–	-0.00667	0.00328	-2.03**	-0.00387	0.00343	-1.13
WIBTBIC	–	–	–	–	–	–	–	–	–	–	–	–	-0.13473	0.06260	-2.15**	–	–	–
5YRUSAC	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-0.22686	0.07247	-3.13***
PL5YRUSAC	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-0.11079	0.06496	-1.71*
M1R	-0.29762	0.10128	-2.94***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
M2R	–	–	–	-0.21652	0.08617	-2.51**	–	–	–	–	–	–	–	–	–	–	–	–
M3R	–	–	–	–	–	–	-0.34259	0.10746	-3.19***	–	–	–	–	–	–	–	–	–
M4R	–	–	–	–	–	–	–	–	–	-0.24239	0.08723	-2.78***			–	–	–	–
M5R	–	–	–	–	–	–	–	–	–	–	–	–	-0.45988	0.12625	-3.64***	–	–	–
M6R	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	-0.20347	0.09429	-2.16**
Adj. R^2	0.4529			0.1274			0.4363			0.1482			0.2583			0.1360		

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

Source: own study.

5.2. The lead-lag relationships

The lack of significance of four explanatory variables in the basic short-term equation of model 1 does not necessarily mean that there is no impact on the dependent variable, as the relations may be of a lead-lag character. For this reason, the short-term equation of model 1 was estimated again, this time on the right-hand side, all explanatory variables and their lags 1 to 4, lags of yield rate and long-term residuals were taken into account. The regression was re-run again each time after the variable that most exceeded the significance level of 0.1 was removed. The results are presented in Table 4. Adjusted R^2 improved to 0.6515. Significant explanatory variables include lags of yield rate changes (YieldCL2, YieldCL3), lagged changes of rent (RentCL4), changes of Wibor3M (WIBORC, WIBORCL2), long-term equation residuals as well as variables of three risk premium types – the local market capacity (OSAECL1), the term-structure (5YRWIBC) and the market risk premium (WIBEURC, WIBEURCL1, WIBEURCL2). Thus, the form of the final short-term equation confirmed hypothesis 2: the formulated ECM model's short-term equation indicates lead-lag relationships between the Warsaw office market yield rate and selected explaining variables.

Table 4. The final short-term equation of model 1 with lagged variables

Variable	Coefficient	Standard error	t
Constant	-0.00048	0.00028	-1.73*
YieldCL2	0.31439	0.13602	2.31**
YieldCL3	0.32785	0.12109	2.71**
RentCL4	0.00049	0.00024	2.08**
WIBORC	-0.38065	0.06812	-5.59***
WIBORCL2	0.26013	0.08987	2.89***
OSAECL1	0.00001	4.87e-06	2.09**
5YRWIBC	-0.15515	0.04998	-3.10***
WIBEURC	0.34761	0.06845	5.08***
WIBEURCL1	-0.12705	0.05085	-2.50**
WIBEURCL2	-0.18997	0.08790	-2.16**
M1R	-0.37039	0.10449	-3.54***
Adj. R^2		0.6515	

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

Source: own study.

The coefficients of lagged yield rate time series are positive, just as with rent. Equation (3) suggests that the rent should be negative. One should bear in mind that the variable in equation (3) represents expected rent growth which is most of the time expressed by time series of rental growth rate due to survey data scarcity. Let us suppose that the expected rental growth rate is relatively high, thus it should increase the value of office property and decrease the current yield rate (Hendershott and MacGregor 2005); note that in the study, the time series of rent was used. In this context, it is worth recalling Figure 1, where there is a clear downward trend of the yield rate mostly accompanied by a declining tendency of rent. A positive coefficient of Rent can be seen as a long-term process related to the maturation of the office market in Warsaw. In the 1990s and the beginning of the 21st century, due to intensive economic changes, the growing demand for office space in Warsaw encountered limited stock and a slowly growing supply. Therefore, it was a natural process for rent to decrease from the previous high as the stock increased, whereas due to stock growth, the Warsaw office market should also become subject to standard market fluctuations. Moreover, the reduction in the yield rate can be associated with the EU convergence process. As the Polish economy and the financial market are getting closer to those in developed European countries, the office space market is anticipated to follow the same path, which means a gradual decrease in the local market risk premium over time.

The two Wibor3M variables are of opposite signs, however, taken in total, the two are of negative overall coefficient. The impact of a risk-free interest rate was expected to be positive; Figure 1 can help find a meaningful interpretation. One can notice that changes in the yield rate are either directed toward another course or lagged to changes in Wibor3M. This was the case at the turn of 2008 and 2009 when Wibor3M was increasing at first. In contrast, the yield rate visibly increased only when Wibor3M started to decline. From 2011 until mid-2012, Wibor3M showed an upward trend, while the yield rate slightly decreased and stabilised later. Similar scenarios took place in the periods 2012Q3 – 2013Q2, 2014Q2 – 2015Q1 and 2019Q4 – 2020Q4. Therefore, the current changes of Wibor3M are negative, although lagged two periods are positive. Furthermore, one should bear in mind that the time series of the study started less than seven quarters before the bankruptcy of Lehman Brothers and ended in the middle of 2021. Thus, the time span encompasses a period of low, close to zero and, in the case of Euribor, even negative values of the risk-free interest rate. At the same time, the financial markets in most developed and developing countries world-wide witnessed a relatively low level of inflation rate. Stylised facts suggest that under standard macro conditions, the owner of financial resources chooses the way to invest based (among others) on the rate of interest/return offered. However, easy access to low-cost financial capital and no inflation may reverse standard financial market relationships. Since investors may assume the risk-free interest rate at a level close to zero, it may no longer be perceived as an important element of the yield rate. This is confirmed by the two Wibor3M coefficients' overall magnitude, which added together are of considerably lower absolute value.

The aforementioned macroeconomic conditions also affect the other financial market variables which are part of the risk premium. The first is 5YRWIBC, representing a term-structure risk premium whose coefficient is negative. It is worth mentioning that only in 7 out of 58 periods was Wibor3M greater than the interest on five-year government bonds in Poland. Accordingly, this result may be surprising as the increase in term-structure risk premium should also raise the yield rate in the Warsaw office market. The reason being that most of the time, the increase in differences between five-year government bonds and Wibor3M resulted from the decline of the second, but not the rise of the first. However, considering the mentioned lagging of the yield rate in relation to Wibor3M, primarily the negative value seems coherent as the lag is certainly impacting the 5YRWIBC coefficient.

The three variables expressing the difference between Wibor3M and Euribor3M together give a positive coefficient of 0.03059. This means that an increase in the total WIBEURC and its two lagged variables causes an increment in the analysed yield rate. However, the positive influence of this variable is more clear-cut in the long-term equation and the basic short-term equation. This variable, in a way, expresses the transfer of interest rates from the euro area to the Warsaw office market. In regular market conditions, Wibor3M should be higher than Euribor3M, as Poland is still considered as developing and a less stable economy than those in the EMU. As already mentioned, most of the buy-sale transactions of buildings offering office space in Poland are conducted by foreign investors, and it can be assumed that a large part of them probably comes from the euro zone. Such investors consider the Euribor3M rate in their decisions as the risk-free interest rate and not the Wibor3M. Let us suppose that Wibor3M grows, or Euribor3M decreases in relation to Wibor3M, then from the point of view of a foreign investor, the part of the yield rate available in the Warsaw office market that is due to the risk-free interest rate may decrease. In turn, the share of the risk premium related to market specific risk in the yield rate may increase. In that case, the current attractiveness of the yield rate in the Warsaw office market rises.

Another risk premium element is the relation of occupied office stock to average employment in Warsaw. The coefficient of OSAECL1 is positive, as expected. The result can confirm that apart from determinants deriving strictly from the financial market, the development of the local office market also plays an important role in shaping the yield rate in Warsaw. The coefficient is negative in the long-term equation and positive in the short-term. This can be ascribed to the time-consuming investment process in the office market, causing a lag of supply adjustment to changes in demand. The latter is

the main characteristic of the real estate market resulting in relatively low supply elasticity. The time required for an investment process of constructing office space is usually estimated at 2-3 years. An increase in the value of the OSAE variable can occur for two reasons: either due to an increase in occupied leasing space or a decrease in the average employment in the enterprise sector. The average employment in Warsaw rose from 890.4 thousand in 2007Q1 to 1.0876 million in 2021Q2. Considering that, in the short run, when the total office stock is unchanged, an increase in the OSAE is an effect of the growth of the rented office square meters, therefore it is a result of growing demand, hence the impact of the variable on the yield rate is anticipated to be positive. However, in the long term, an increase in this ratio may result from a growth of the total stock of office space available in the market, accompanied by an increase in the vacancy rate and a declining rent. In that case, an increase in OSAE can be an effect of too high saturation of the local labour market with office buildings. This may mean increased competition for tenants, translated into a decreasing yield rate.

In both versions of the short-term equation, there is a lack of statistically significant M3GDPPLC variable. However, this is not surprising at all, and the author expected such a result. This variable was introduced into the model to check the strange outcome stated in the earlier paper (Nowak 2021), where a statistically significant influence of the variable representing the M2 aggregate in PLN was obtained. Such a result was not expected because the main currency in the office space market in Poland is the euro. The current study confirms that the monetary factor in PLN should not be considered a significant determinant of the yield rate in the Warsaw office market.

The last variable in the equation presented in Table 4 represents the residuals of the long-term equation. A negative coefficient was anticipated as M1R should be treated as a force pulling the explained variable to the long-term equilibrium.

The short-term equation of model 1 introduced in Table 4 was subject to the following econometric tests commonly used in the literature: the Shapiro-Wilk normality test for residuals (Table 14), the Breusch-Pagan heteroskedasticity test (Table 15) and the Breusch-Godfrey autocorrelation test (Table 16). The results of all the tests are correct and allow for the interpretation of the obtained equation.

5.3. Asymmetric relationships

In order to check for the asymmetric relationships, seventeen asymmetric variables were defined and added to the final short-term equation. According to Table 5, only AS8 and AS9 turned out to be statistically significant. A vast amount of literature argues that real estate appraisals are smoothed and may not keep up with the changing market conditions (Chaney and Hoesli 2012). In the case of a black swan, it usually turns out that commercial real estate was overvalued. In extreme changes of market conditions, it is rent that reacts first, which should lead to the decline of the office yield rate. The above-mentioned variables reflect the opposite: the periods when the rent decreased while the yield rate increased simultaneously. This means that the decline in the value of the sale prices or valuations of office buildings had to be greater than the rent drop. There were six such quarters over the entire period under the study (2008Q2, 2008Q4, 2009Q1, 2009Q3, 2013Q2 and 2020Q1). The first four can be assigned to GFC, while the last one to the pandemic. AS8 and AS9 are of opposite signs which seems consistent. AS8 reflects the influence of such specific situations on the yield rate, i.e. an increase as an effect of the definition of the variable. In turn, AS9 reflects the impact of the rent on the yield rate in such scenarios.

The asymmetric variables whose structure allowed it, were placed in the final short-term equation instead of the basic variables. The results are shown in Table 6. The four equations are of quite high adj. R^2. AS2 variable reflects the impact of the 5YRWIBC when Euribor3M is greater than the interest rate of five-year government bonds in the EMU. In this way, the negative impact of the term-structure risk premium in the euro zone on the size of the term-structure risk premium in Poland was verified; the coefficient is negative and of quite ordinary magnitude. AS3 mirrors the influence of Wibor3M on

the yield rate in the Warsaw office market if the term-structure premium in Poland is negative, and in this instance the coefficient is also negative and of considerable magnitude. AS2 and AS3 depict in a certain way the effect of a yield curve inversion when the short-term interest rate is higher than the long-term interest gained, therefore the negative impact on the office yield rate appears accurate. The next verified asymmetric variable was AS6. Including AS6 in the equation – which represents the impact of 5YRWIBC when Euribor3M is negative – did not change the direction of the effect on the yield rate; AS6 is also negative. Regarding AS2, AS3, and AS6, the impact on the yield rate remained negative, just as in the final short-term equation (5YRWIBC, WIBORC and WIBORCL2). However, each of the asymmetric variables can prove to have a stronger impact on the yield rate as the coefficients are of a higher number than in the final short-term equation (Table 4). AS9 is also negative and the coefficient is, as previously, of a higher magnitude than in the final short-term equation. In conclusion, the fourth hypothesis can be confirmed as there are evident examples of asymmetric variables significantly explaining the yield rate in the Warsaw office market.

Table 5. Asymmetric relationships checked by individual asymmetric variables

Asymmetric variable	Definition of the asymmetric variable	Coefficient	Adj. R^2 of the equation	Variables lacking statistical significance in the model
AS1	Product of 0-1 DV taking on 1 when Euribor3M<0 and WIBORC	0.09399	0.6466	AS1
AS2	Product of 0-1 DV taking on 1 when Euribor3M>5yr government bonds in EMU and 5YRWIBC	-0.13847	0.6549	AS2
AS3	Product of 0-1 DV taking on 1 when Wibor3M>5yr government bonds in Poland and WIBORC	-0.13208	0.6535	YieldCL2, AS3
AS4	Product of 0-1 DV taking on 1 when Wibor3M>5yr government bonds in Poland and 5YRWIBC	-0.01183	0.6429	AS4
AS5	Product of 0-1 DV taking on 1 when Wibor3M>WIG20 and W20WIBC	0.00125	0.6450	AS5
AS6	Product of 0-1 DV taking on 1 when Euribor3M<0 and 5YRWIBC	-0.12327	0.6530	AS6
AS7	Product of 0-1 DV taking on 1 when Euribor3M<0 and WIBEURC	0.12173	0.6490	AS7
AS8	Product of 0-1 DV taking on 1 when RentC<0 and 0-1 DV taking on 1 when change of Yield rate>0	0.00204**	0.6961	YieldCL3, RentCL4
AS9	Product of 0-1 DV taking on 1 when RentC<0 and 0-1 DV taking on 1 when change of Yield rate>0 and RentC	-0.00153**	0.6815	YieldCL3
AS10	Product of 0-1 DV taking on 1 when OSAEC>average of OSAEC and OSAEC	1.14e-06	0.6434	AS10
AS11	Product of 0-1 DV taking on 1 when M3GDPEMU>average of M3GDPEMU and M3GDPEMU	-0.00007	0.6486	AS11
AS12	Product of 0-1 DV taking on 1 when M3GDPEMU>average of M3GDPEMU and WIBEURC	0.12820	0.6495	AS12
AS13	Product of 0-1 DV taking on 1 when M3GDPUSA>average of M3GDPUSA and M3GDPUSA	-0.00015	0.6546	AS13
AS14	Product of 0-1 DV taking on 1 when XDEUR<average of XDEUR and XDEURC	0.00349	0.6613	AS14
AS15	Product of 0-1 DV taking on 1 when SNPTBIL<average of SNPTBIL and SNPTBILC	0.00512	0.6603	AS15
AS16	Product of 0-1 DV taking on 1 when 5YREURC<0 and 5YREURC	0.00591	0.6428	AS16
AS17	Product of 0-1 DV taking on 1 when 5YRTBIC<0 and 5YRTBIC	0.02929	0.6437	AS17

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

Source: own study.

Table 6. The final short-term equation of model 1 with asymmetric variables

Variable	Model1AS2			Model1AS3			Model1AS6			Model1AS9		
	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t	Coefficient	Std. err	t
Constant	-0.00048	0.00029	-1.63	-0.00051	0.00029	-1.71*	-0.00038	0.00029	-1.33	-0.00076	0.00027	-2.78***
YieldCL2	0.19787	0.14568	1.36	-0.07500	0.11616	-0.65	0.31408	0.14321	2.19**	0.25675	0.13671	1.88*
YieldCL3	0.24463	0.12259	2.00*	0.13966	0.11126	1.26	0.25935	0.12298	2.11**	0.12616	0.14757	0.85
RentCL4	0.00049	0.00025	1.98*	0.00062	0.00027	2.30**	0.00052	0.00025	2.06**	–	–	–
WIBORC	-0.35079	0.06997	-5.01***	–	–	–	-0.29393	0.06812	-4.32***	-0.30048	0.08071	-3.72***
WIBORCL2	0.20234	0.09527	2.12**	–	–	–	0.26249	0.09462	2.77***	0.25662	0.08761	2.93***
OSAECL1	8.29e-06	5.09e-06	1.63	3.91e-06	5.13e-06	0.76	9.95e-06	5.12e-06	1.94*	0.00001	4.58e-06	2.66**
5YRWIBC	–	–	–	0.02321	0.05374	0.43	–	–	–	–0.18501	0.05016	-3.69***
WIBEURC	0.37374	0.07469	5.00***	0.18117	0.05991	3.02***	0.30457	0.07210	4.22***	0.30246	0.07353	4.11***
WIBEURCL1	-0.13782	0.05587	-2.47**	-0.12572	0.05747	-2.19**	-0.10516	0.05239	-2.01*	-0.13959	0.05060	-2.76***
WIBEURCL2	-0.11327	0.09154	-1.24	0.01412	0.04924	0.29	-0.16022	0.09103	-1.76*	-0.18364	0.08591	-2.14**
M1R	-0.37417	0.11006	-3.40***	-0.13646	0.10246	-1.33	-0.33922	0.10960	-3.10***	-0.38347	0.09989	-3.84***
AS2	-0.24970	0.11343	-2.20**	–	–	–	–	–	–	–	–	–
AS3	–	–	–	-0.45320	0.08564	-5.29***	–	–	–	–	–	–
AS6	–	–	–	–	–	–	-0.24017	0.10674	-2.25**	–	–	–
AS9	–	–	–	–	–	–	–	–	–	-0.00176	0.00069	-2.52**
Adj. R^2	0.6151			0.5550			0.6169			0.6664		

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

Source: own study.

5.4. Testing for structural breaks

In Figure 1, one can observe two modes of the yield rate. From 2007Q1 to 2010Q1, the yield rate is initially growing and stabilising later. The 2010Q2 is the starting point of the declining tendency on the graph. The two opposite directions of the course of the yield rate during the time span of the study as well as GFC, the COVID-19 pandemic and the influence of extremely low-interest rates, dictate the testing of whether a structural break can be detected in the functioning of the devised model. In order to achieve that first, the two 0-1 dummy variables were put into the short-term equation. The time series of the two dummy variables took on 1, starting in 2008Q4 and 2020Q2, respectively, and 0 in the preceding quarters. The same was used for the next two dummy variables introduced based on the fluctuations in the yield rate in the Warsaw office market in 2010 and 2015. Figure 1 suggests that there are two turning points within the Warsaw office market yield rate time series, after which the yield rate started to decline: at the turn of 2010Q1 and 2010Q2 and at the turn of 2015Q1 and 2015Q2. The first may be attributed to the post-GFC effect of easing monetary policy, while the second is the starting point of extremely low-interest rates. Therefore, the two dummy variables took the value of 1, starting in 2010Q2 and 2015Q2, respectively, and 0 in the preceding quarters.

Table *7*. Results of implementing 0-1 dummy variables into the final short-term equation of model 1

Dummy variables	Coefficient	Adj. R^2 of the equation	Variables lacking statistical significance in the model
GFCDV	-0.00321***	0.7119	RentCL4
CovidDV	0.00038	0.6458	CovidDV
2010DV	-0.00306***	0.7893	–
2015DV	-0.00057	0.6625	2015DV

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

Source: own study.

Table 7 shows that GFCDV and 2010DV are statistically significant, however the equation with the latter variable is of a better econometric fit. On this basis, additional dummy variables were formulated, namely the products of variables from the final short-term equation and the variable 2010DV. The additional dummy variables were added to the equation and estimated based on the a posteriori elimination regression, i.e. the variable which was most over the 0.1 significance level was excluded from the equation. The equation was re-run in that manner until only significant variables were left. The obtained short–term equation with five 2010 dummy variables is presented in Table 8. It should be emphasised that all dummy variables are of opposite signs compared to the corresponding basic variables. This can be treated as a validation of the changes in the market environment that have impacted the yield rate in the Warsaw office market since 2010Q2, hence the influence of particular determinants on the yield rate has changed since 2010Q2.

Table 8. The final short-term equation of model 1 with dummy variables of structural change in 2010Q1/Q2

Variable	Coefficient	Standard error	t
Constant	-0.00095	0.00024	-4.03***
YieldCL2	0.20085	0.11101	1.81*
WIBORC	-0.62644	0.07239	-8.65***
WIBORCL2	0.50738	0.10389	4.88***
OSAECL1	9.50e-06	3.92e-06	2.43**
5YRWIBC	-0.39521	0.09885	-4.00***
WIBEURC	0.87698	0.15006	5.84***
WIBEURCL1	0.47699	0.11735	4.06***
WIBEURCL2	-0.29946	0.10997	-2.72**
M1R	-0.44439	0.08608	-5.16***
WIBORCDV2010	0.30728	0.16322	1.88*
WIBORCL2DV2010	-0.24805	0.08697	-2.85***
5YRWIBCDV2010	0.25285	0.12257	2.06**
WIBEURCDV2010	-0.57485	0.17124	-3.36***
WIBEURCL1DV2010	-0.61393	0.13583	-4.52***
Adj. R^2	0.7600		

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

Source: own study.

The Chow test of the model 1 basic short-term equation shown in Table 17 confirmed the structural break in 2010Q2. The test was not carried out with the short-term equation enclosed in Table 4 because of limited degrees of freedom. Importantly, the previous study (Nowak 2021) also insisted on a significant impact of changes in market conditions on the yield rate in 2010 (dummy variables check, the Chow test).

The occurrence of the structural break in the model may mean that a regime switch behaviour can be identified. To investigate that, the Markov switching model was applied with the final short-term equation, including the autoregression term of lag four. As seen in Table 9, the mean values of the yield rate in the two states differ significantly from each other, which is reported by the magnitude and signs of the constants (-0.00099 vs 0.00355). This indicates the confirmation of the changes in the regime of the equation. The provided probabilities concern staying in the present state and transitioning to the next state in the following quarter. The decreasing process of the yield rate is very persistent, as the probability of staying at state 1 exceeds 98%, while the probability of staying at state 2 is lower than 0.01%.

Table 9. The Markov switching regression results with state–dependent constant

Variable	Coefficient	Standard error	z
YieldCL2	0.18783	0.07465	2.52**
YieldCL3	0.23347	0.06220	3.75***
RentCL4	0.00055	0.00013	4.12***
WIBORC	-0.15312	0.06700	-2.29**
WIBORCL2	0.138804	0.04799	2.89***
OSAECL1	0.00001	2.75e-06	3.82***
5YRWIBC	-0.17340	0.03101	-5.59***
WIBEURC	0.15378	0.06053	2.54**
WIBEURCL1	-0.11517	0.02942	-3.91***
WIBEURCL2	-0.16747	0.04747	-3.53***
M1R	-0.47208	0.05727	-8.24***
ARL4	0.41621	0.07747	5.37***
State1 Constant	-0.00099	0.00021	-4.65***
State2 Constant	0.00355	0.00069	5.18***
Sigma	0.00070	–	–
P11	0.98034	–	–
P22	2.1e-06	–	–

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

Source: own study.

Table 10. The Markov switching regression results with state–dependent constant, ARL4 and risk premium variables

Variable	Coefficient	Standard error	z
YieldCL2	0.32581	0.04330	7.52***
YieldCL3	0.18971	0.04014	4.73***
RentCL4	0.00019	0.00009	1.98**
WIBORC	-0.22429	0.04231	-5.30***
WIBORCL2	0.10957	0.03514	3.12***
M1R	-0.57576	0.03879	-14.84***
State1 OSAECL1	0.00003	3.65e-06	7.28***
State1 5YRWIBC	0.14165	0.04458	3.18***
State1 WIBEURC	0.16618	0.05687	2.92***
State1 WIBEURCL1	-0.18892	0.06183	-3.06***
State1 WIBEURCL2	-0.22620	0.05375	-4.21***
State1 ARL4	-1.25472	0.18090	-6.94***
State1 Constant	9.21e-06	0.00017	0.06
State2 OSAECL1	0.00002	1.66e-06	9.27***
State2 5YRWIBC	-0.15744	0.02093	-7.52***
State2 WIBEURC	0.18593	0.03346	5.56***
State2 WIBEURCL1	-0.08629	0.01675	-5.15***
State2 WIBEURCL2	-0.17391	0.03278	-5.31***
State2 ARL4	0.49723	0.04772	10.42***
State2 Constant	-0.00163	0.00011	-15.20***
Sigma	0.00036	–	–
P11	0.36452	–	–
P22	0.72708	–	–

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

Source: own study.

In the two states/regimes, the impact of the risk premium on the yield rate in the Warsaw office market may alter. In order to account for that, the Markov switching regression was re-run with state-volatile variables of risk premium. The results are presented in Table 10. All the variables are statistically significant except for the constant in state 1. The impact of the OSAECL1 does not vary in the two states. The absolute value of the coefficient of the 5YRWIBC is similar in both states. However, there is an evidence of asymmetry as this is the direction of the impact that changes. In state 1, the impact of the term-structure risk premium is positive, whereas when the constant is negative (state 2), the impact of the term-structure risk premium turns around to be negative. Taking the effect of the three variables WIBEURC, WIBEURCL1 and WIBEURCL2 together, the influence on the yield rate in each state is negative even though the magnitude differs substantially (-0.24894 and -0.07427, respectively). When the intercept is positive, the influence of the market-specific risk premium on the yield rate is stronger, and when the mean value is negative, the influence is weaker. The probability of staying in the same state is high in the case of a decline of the yield rate (state 2) and relatively low in the case of increasing the yield rate (state 1), 0.72 and 0.36, respectively.

This section of the study made it clear that hypothesis four, stating that changes in the market environment led to structural breaks in the formulated model, i.e. changes in the impact of the selected determinants on the Warsaw office market yield rate, therefore can be confirmed.

6. Conclusions

The paper is first to check dependencies of the office yield rate in Warsaw on various variables from Poland, the EMU and the USA. The study's novelty is the range of variables that reflect the different nature of risk premiums, including the transfer of foreign interest rates to the Warsaw office market.

First, based on the ECM approach, the model based on Polish variables (model 1) explains the yield rate better than the models based on data from the euro area and the USA. However, this study proved that there are variables from the EMU and the USA that statistically significantly influence the yield rate in the Warsaw office market (Table 3), i.e. changes in Euribor3M, changes in TBills3M, changes in M3/GDP in the USA, just as the changes of differences in the interest rate on five-year government bonds between Poland and the EMU, as well as between Poland and the USA. This means that there is a certain impact of foreign risk-free interest rates in the EMU and the USA, as well as monetary liquidity in the USA, on the yield rate in the Warsaw office market. This, in fact, is a reflection of the dominant role of foreign capital in the market. In that context, the added value of the paper for practitioners of the commercial real estate market lies in the fields of market analysis and property valuation (e.g. calculating the discount and the capitalisation rate).

Secondly, three out of the four hypotheses were confirmed. According to the final short-term equation (Table 4), the relations between the yield rate and explanatory variables were, in fact, of lead-lag characteristics. This applied to risk-free interest rates, cash flow growth variable, elements of a risk premium and lags of changes in the yield rate. Furthermore, it has been demonstrated that the dependencies expressed by asymmetric variables based on Euribor3M, five-year government bonds in the EMU, Wibor3M, and five-year government bonds in Poland, and also relations between rent and the yield rate may affect the way the model works. Moreover, structural breaks in the functioning of the short-term dependencies were found using dummy variables at the beginning of the GFC and in 2010Q2. The second break was tested more in-depth using extended dummy variables check, the Chow test and the Markov switching model approach. The two Markov switching regression equations confirmed the occurrence of two model regimes and indicated an asymmetric impact of two risk premium elements (term-structure risk premium in Poland, market specific risk premium in Poland/the EMU) in the regimes. In both cases, there was a strong persistence in the states of negative intercept of changes in the yield rate. This can be seen as an evident reflection of the long-term decreasing trend of the yield rate in the Warsaw office market that started in 2010Q2.

Finally, further studies should include a longer time span of data which over time would allow for, e.g. an appropriate testing of the pandemic's impact on the Warsaw office market yield rate. Furthermore, the study used linear econometric modelling. Limitations of the linear regression (i.e. sensitivity to outliers, prone to underfitting, etc.) will prompt the use of the nonlinear regression in studies to come. This could allow for a more effective reflection of the impact of exogenous shocks and opposite monetary trends on the yield rate that may arise if the study covers a relatively long time range. This seems crucial as 2022 witnessed major changes in monetary policy worldwide.

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APPENDIX

Table 11. Results of the ADF stationarity test of time series used in the long-term equations (models 1 to 6)

Variable	Test statistic	Critical value 1%	Critical value 5%	Critical value 10%
Yield	-0.693	-3.570	-2.924	-2.597
WIBOR	-0.215	-3.570	-2.924	-2.597
EURIBOR	-1.851	-3.570	-2.924	-2.597
TBILLS	-4.230	-3.570	-2.924	-2.597
5YRPL	-0.670	-3.570	-2.924	-2.597
5YREMU	-1.852	-3.570	-2.924	-2.597
5YRUSA	-2.971**	-3.570	-2.924	-2.597
5YRWIB	-2.935**	-3.570	-2.924	-2.597
5YREUR	-2.841*	-3.570	-2.924	-2.597
5YRTBI	-2.670*	-3.570	-2.924	-2.597
W20WIB	-5.944***	-3.570	-2.924	-2.597
W205YR	-6.128***	-3.570	-2.924	-2.597
XDEUR	-7.378***	-3.570	-2.924	-2.597
XD5YR	-7.522***	-3.570	-2.924	-2.597
SNPTBIL	-6.982***	-3.570	-2.924	-2.597
SNP5YR	-6.912***	-3.570	-2.924	-2.597
WIBEUR	-1.959	-3.570	-2.924	-2.597
PL5YREMU	-2.309	-3.570	-2.924	-2.597
W20XD	-9.929***	-3.570	-2.924	-2.597
WIBTBI	-1.420	-3.570	-2.924	-2.597
PL5YRUSA	-1.255	-3.570	-2.924	-2.597
W20SNP	-8.047***	-3.570	-2.924	-2.597
M3GDPPL	-0.848	-3.570	-2.924	-2.597
M3GDPEMU	-0.698	-3.570	-2.924	-2.597
M3GDPUSA	0.278	-3.570	-2.924	-2.597
OSAE	-0.618	-3.570	-2.924	-2.597
Rent	-1.613	-3.570	-2.924	–2.597

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

Source: own study.

Table 12. Results of the ADF stationarity test of time series used in the short-term equations (models 1 to 6)

Variable	Test statistic	Critical value 1%	Critical value 5%	Critical value 10%
YieldC	-6.725***	-3.572	-2.925	-2.598
WIBORC	-4.841***	-3.572	-2.925	-2.598
EURIBORC	-5.053***	-3.572	-2.925	-2.598
TBILLSC	-5.904***	-3.572	-2.925	-2.598
5YRPLC	-6.829***	-3.572	-2.925	-2.598
5YREMUC	-7.013***	-3.572	-2.925	-2.598
5YRUSAC	-7.416***	-3.572	-2.925	-2.598
5YRWIBC	-6.525***	-3.572	-2.925	-2.598
5YREURC	-7.263***	-3.572	-2.925	-2.598
5YRTBIC	-7.130***	-3.572	-2.925	-2.598
W20WIBC	-12.018***	-3.572	-2.925	-2.598
W205YRC	-12.076***	-3.572	-2.925	-2.598
XDEURC	-12.618***	-3.572	-2.925	-2.598
XD5YRC	-12.676***	-3.572	-2.925	-2.598
SNPTBILC	-12.548***	-3.572	-2.925	-2.598
SNP5YRC	-12.596***	-3.572	-2.925	-2.598
WIBEURC	-7.004***	-3.572	-2.925	-2.598
PL5YREMUC	-5.590***	-3.572	-2.925	-2.598
W20XDC	-14.926***	-3.572	-2.925	-2.598
WIBTBIC	-5.180***	-3.572	-2.925	-2.598
PL5YRUSAC	-6.416***	-3.572	-2.925	-2.598

W20SNPC	-14.046***	-3.572	-2.925	-2.598
M3GDPPLC	-9.109***	-3.572	-2.925	-2.598
M3GDPEMUC	-8.424***	-3.572	-2.925	-2.598
M3GDPUSAC	-6.697***	-3.572	-2.925	-2.598
OSAEC	-9.291***	-3.572	-2.925	-2.598
RentC	-5.667***	-3.572	-2.925	-2.598

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

Source: own study.

Table 13. Results of the Johansen cointegration tests of time series used in the long–term equation model 1

Number of cointegrating vectors	Trace statistics	Critical value 5%	Maximum eigenvalue statistic	Critical value 5%
0	192.5475	124.24	65.2536	45.28
1	127.2939	94.15	40.1411	39.37
2	87.1528	68.52	34.1786	33.46
3	52.9742	47.21	23.4915*	27.07
4	29.4827*	29.68	21.0329	20.97
5	8.4499	15.41	7.9625	14.07
6	0.4874	3.76	0.4874	3.76

Note: cointegrating vectors at *p<0.05. Johansen tests for four lags.

Source: own study.

Table 14. Results of the Shapiro-Wilk normality test for residuals of the final short-term equation

W	0.98079
Prob>z	0.54745*

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

Source: own study.

Table 15. Results of the Breusch-Pagan heteroskedasticity test of the final short-term equation

F(11, 41)	0.32	chi2(11)	4.19
Prob > F	0.9767*	Prob > chi2	0.9642*

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

Source: own study.

Table 16. Results of the Breusch-Godfrey autocorrelation test of the final short-term equation

Number of lags	chi2	Prob > chi2
1	1.326	0.2495*
2	1.427	0.4899*
3	1.546	0.6717*
4	2.439	0.6556*

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

Source: own study.

Table 17. Results of the structural break Chow test of model 1 basic short-term equation

Chow F statistic	2.689781298
Critical F value	2.07

Note: results at p value 0.5.

Source: own study.