SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 231

WIG REAL ESTATE INDEX – MORE A STOCK OR A REAL ESTATE?

Krzysztof Adam NOWAK[1*], Jana PŘÍLUČÍKOVÁ[2], Krystian ŚWIERCZEK[3]

[1] University of Rzeszów, Department of Financial Markets and Consumer Finance; krnowak@ur.edu.pl, ORCID: 0000-0003-0543-1670

[2] Univerzita Tomáše Bati ve Zlíně, Faculty of Management and Economics; prilucikova@utb.cz, ORCID: 0000-0003-0204-187X

[3]University of Rzeszów, Faculty of Economics and Finance; swierczekkrystian226@gmail.com, ORCID: 0009-0005-0742-9584

* Correspondence author

Purpose: The primary purpose of the paper is to verify if the WIG Real Estate index is determined by direct real estate market or the stock market.
Design/methodology/approach: The methodology is based on the Autoregressive Distributed Lag models, explaining quotations of the WIG Real Estate index. The independent variables represent influence of stock exchange (the WSE indexes), economy (monetary variables), real estate market (demand, supply and construction costs variables), and direct real estate prices (residential transaction prices). The time range of the data comprises 2007 Q2 - 2025 Q1.
Findings: The findings suggest that in the long-term these are WIBOR3M, value of mortgage loans and number of building permits that cause the WIG Real Estate index fluctuations. While in the short-term there is an influence of WIG index, WIBOR3M and number of building permits evident. The direction of the dependencies may be surprising though. Moreover, the study proves impact of government subsidy housing programs and COVID-19 on the index.
Research limitations/implications: The time series used applied make more in-depth analysis of impact of the GFC and the COVID-19 on the model infeasible. The future studies should expand the time span and depict the impacts more thoroughly. Furthermore, it would be desirable to verify if similar relationships between private real estate, public real estate and stocks hold in other CEE countries.
Practical implications: The results reflect character of relationships between securitized real estate, direct real estate and stocks. The findings of the study should be exploited by investors in portfolio management process.
Originality/value: The relationships between direct real estate, securitized real estate, stocks and economic variables are quite well documented in literature for the U.S., Western Europe and Asia. However, there are very few such publications for the CEE countries, including Poland. The paper aims to shed light on the topic with a use of more suited variables, longer time series and more robust methodology compared to previous studies. The article points out that long-term and short-term dependencies may differ from one another. Also, the external factors, that may distort the regular relationships described by the model, are counted in.
Keywords: securitized real estate, real estate stocks, relationships between real estate and stocks, Autoregressive Distributed Lag (ARDL).
Category of the paper: Research paper.

http://dx.doi.org/10.29119/1641-3466.2025.231.21 http://managementpapers.polsl.pl/

1. Introduction

The residential real estate nowadays not only fulfil the social function of a shelter but increasingly act as an individual assets class. The direct investments in residential real estate have become very popular among polish households in recent years. Nevertheless, the capital-intensity still limits availability of such savings allocation. However, securitized real estate is answer to this disadvantage. There is a vast amount of literature worldwide on the question, if the public real estate is more like private real estate or it should be regarded as regular securities. However, there are very few such publications for the CEE countries, including Poland. Because of lack of the Real Estate Investments Trusts (REITs) on polish financial market, we address this question to the WIG Real Estate Index quoted at the Warsaw Stock Exchange (WSE). In that context, the paper is an attempt to clarify if the index is more under pressure from housing market or stock market. For this purpose we extend previous research by Nowak (2020) and use variables that represent various impacts on the WIG Real Estate index: stock exchange (the WSE indexes), economic (monetary variables), real estate market (demand, supply and construction costs variables) and direct real estate prices (residential transaction prices). We formulate three research questions which are answered based on the built Autoregressive Distributed Lag models (ARDL).

We found that in the long-term these are WIBOR3M, the value of mortgage loans and number of building permits that cause the WIG Real Estate index fluctuations. While in the short-term there is an influence of WIG index, WIBOR3M and number of building permits evident. The direction of the dependencies are not always in line with stylized facts though. Moreover, we report indication of statistically significant impact of government subsidy housing programs and COVID-19 on the index.

The article consists of six main sections. In the introduction we provide context of the study, basics of time series and methodology used as well as general findings. In the next section the literature background of the study is presented, followed by the section devoted to selection of the variables. In the fourth section the ARDL model is introduced together with step by step procedure applied. The section five of results and discussion is divided into three sub-sections delineating the primary ARDL model and its modifications including impacts of government subsidy housing programs and COVID-19, respectively. The conclusions section includes findings, limitations and suggestions for further research.

2. Literature review

There are many papers which, based on econometric models, indicate the bounds between real estate (residential) market and stock market. Most of the studies imply that the markets, at least in some way, are integrated (Gokmenoglu, Hesami, 2019; Lin, Lin, 2011; Yousaf, Ali, 2020; Yunus, 2012). However, there are also records indicating that the two are segmented (Wilson, Okunev, 1996). The difference is actually crucial. Basically, considering real estate and stock markets as two separate, not cointegrated submarkets in the world of finance, can lead to the point that the two asset classes may be used to diversify investment portfolio. On the other hand, if the markets are closely integrated one should choose between the two assets, instead of mixing them in the investment strategy. Interestingly, the distinction between these two conditions very often is not straightforward, even for countries from one region. Lin and Fuerst (2014) noted linear cointegration of stock and property markets in Taiwan, only signs of fractional cointegration in Singapore and Hong Kong and no evidence of cointegration in China, Japan, Thailand, Malaysia, Indonesia and South Korea. The integration/segmentation can vary based on time perspective and level of real estate market under analysis. Su et al. (2019) concluded that in China the two markets are generally segmented in the short run but are integrated in the long run. Adcock, Hua and Huang (2013) revealed integration at the national level. However, in the case of property markets at the city level the segmentation was visible.

Moreover, the relationships between the two markets indicated in the empirical literature may be of a twofold character. First, as per the wealth effect, unexpected gains in stock market increase the amount of housing consumed by households. This means increased shares' prices raise the residential prices. On the flip side, the credit-price effect claims that housing prices' growth, through stimulation of economic activity, can in effect transform to stocks bull market. There are papers that affirm first (Coelho, Gomes, Ramos, 2023; Jud, Winkler, 2002; Kapopoulos, Siokis, 2005) as well as papers that acknowledge the second concept (Su et al., 2019; Yousaf, Ali, 2020). However, thirdly Bahmani-Oskooee and Ghodsi (2018) argued that at the state level in the US the causal effect is evidently bidirectional. Lou (2016) also attests that for the returns in the PIGS countries.

Many papers which are focused on studying relationships between stock and real estate are based on securitized real estate. The latter most of the time covers the Real Estate Investment Trusts (REITs). The reason for this, first and foremost, is easy access to data. The issue that arises here, is if the securitized real estate (REITs) are still more close to direct real estate or they can be treated as another class of regular securities? This can be answered in the context of aforementioned integration/ segmentation to the last two. Again, the empirical results are not homogeneous in that manner. Wilson and Okunev (1996) provided evidence that that securitized property markets and equity markets in the USA, the UK and Australia, are segmented internationally. According to the study on Canadian time series, securitized property and stocks can be considered for diversification purposes in the short-run. However, this does not hold for the long-term perspective, since the fractional cointegration was detected (Assaf, 2006). Hoesli and Moreno (2007), based on the study of sixteen countries within years 1990-2004, found securitized real estate returns positively linked with stock and direct real estate returns, but negatively linked to bond returns. Based on the VECM model on returns in the U.S., the U.K. and Australia, Hoesli and Oikarinen (2012) asserted that in the long-term view, REIT market performance is much more closely related to the direct real estate market than to stock market. Nneji, Brooks and Ward (2013) found an interesting relationship regarding speculative bubbles i.e. stock market bubble works more heavily on the securitized real estate bubble, than that of direct property market does. Curiously enough, Kiohos, Babalos and Koulakiotis (2017) applied the ECM-ARFIMA methodology and similarly as for private real estate, provided support for the wealth effect (together with fractional integration) between stock and securitized real estate markets, in Germany and the UK. Wu and Wang (2024), with the use of Bootstrap Fourier Granger Causality in Quantiles test, found negative relationship between the stock price index and REITs' returns in the U.S. The paper of Olaleye and Ekemode (2014) is one example of the few in which quarterly time series of returns on the property listed stock, instead of REITs, are used against all share index. However, based on the integration with common/non-real estate stock in Nigeria, 1999-2011, they found real estate equity more like REITs. Moreover, upfront they denied integration of property listed stock to direct real estate market and returns of underlying direct real estate portfolio. Holcman and Prostejovská (2022) proved negative correlation between residential house price index and the Prague's all stock index in 2020. Liu et al. (2023) claimed that the Hong Kong REITs market consistently receives return and volatility spillover effects from the stock market and real estate market.

There are few polish studies regarding dependencies between direct/securitized real estate and stock market. Kołtuniak (2016a) based on polish data for 2005-2014, found evidence of a long-term co-integration and the credit-price effect between public and private real estate. Kołtuniak (2016b) applied wavelet analysis method and proved structural changes over the period 2004 Q4 and 2014 Q4. Ergo, no constant relationships in terms of both frequency and direction when it comes to the direct real estate, real estate company stocks and stock market indices in Poland. Noteworthy, Wolski (2018) based on the cross-sectional regression analysis, argued that rates of return on investments in real estate companies, quoted at the WSE, explain the price changes in the secondary housing market in Poland. Accordingly, Wolski (2020) using the Engle - Granger method on the secondary market cumulative average residential prices in seven largest voivodeship cities, found co-integration only with the WIG Real Estate index and no relationships with other three implemented the WSE's indexes.

The studies closest to ours are Cellmer, Bełej and Cichulska (2019) and Nowak (2020). Both of the articles are based on application of the VAR model and the Granger causality on differenced log time series. They express only short-term dependencies though, for periods 2008 Q1 - 2018 Q4 and 2007 Q2 - 2020 Q1 respectively. Cellmer, Bełej and Cichulska (2019) found that WIG index statistically significantly Granger-caused the residential cumulative transaction price at secondary market in seven main cities in Poland. They did not point out the opposite dependency. Noteworthily, Nowak (2020) revealed that cumulative prices of new residentials in ten secondary voivodeship cities as well as indexes WIG and WIG20, were affecting the WIG Real Estate index in a negative manner.

Regarding the explanatory variables being exploited, Serrano and Hoesli (2009) argued that not only economic but also financial and real estate variables shall be used to forecast securitized real estate returns. In the study returns of the REIT indexes were explained by two sets of variables. First, they used variables proposed by Chan, Hendershott and Sanders (1990), i.e. change in term structure, change in risk premium, expected inflation and its changes, unexpected inflation; and these deployed by Liu and Mei (1992), i.e. T-bill rate, yield spread (corporate bonds minus T-bill rate), stocks dividend yield and REITs capitalization rate. Then they input set of financial and real estate factors – total return stock index, 10-year total return government bond index and property prices indexes. They used Fractionally Integrated ECM model on data for the U.S., the U.K., and Australia and found that financial and real estate factors generally outperformed economic variables. In accordance with this approach, Akinsomi et al. (2016) pointed that monetary policy instruments, economy-wide and sentiment indicators are these which are the most efficient in predicting REITs returns. They made a use of inflation rate, the industrial production growth, the relative 3-month treasury bill, the lagged real US stock market returns, the S&P dividend price ratio, interest rate factor, the real REITs returns volatility, together with time series of sentiment and uncertainty indicators. The potential determinants of securitized real estate should also depend on the specific features of national economy and financial market. Arora, Killins and Gangineni (2019) next to REITs' characteristics, hired macroeconomic conditions, out of which GDP, inflation rate, exchange rate, and money supply turned to be significantly related to the returns of the REITs in Singapore, in the period 2004-2013. Cohen and Burinskas (2020; 2023) examined over a dozen Eurozone macroeconomic variables on the European listed real estate companies and REITs, with a use of dynamic linear model, Granger causality and the ARDL. Apart from the variables that have been mentioned so far, they found the relevant impact of time series reflecting supply side of real estate market (e.g. construction and residential building permits, the inflation of producers' prices). Wu and Wang (2024) added to the current state of knowledge, the positive impact of unemployment rate on REITs' returns.

Despite a fairly extensive literature on the determinants of private real estate in Poland, there is a deficiency with regard to papers on factors acting on the public real estate market. The reason might be that the latter is relatively underdeveloped, since no REITs are available in Poland. Cellmer, Bełej and Cichulska (2019) focused on the one-to-one relationships between residential cumulative transaction price at secondary market in seven main cities in Poland, number of new residential premises handed over, the WIG index quotations and several macroeconomic variables (inflation, reference rate determined by the National Bank of Poland, average EUR/PLN exchange rate, GDP, unemployment rate, average gross nominal wage). Nowak (2020) hired cumulative average transaction price of new housing in ten voivodeship cities, the number of apartments with the official permit to inhabit, value and number of new mortgage loans and the WSE indexes: WIG, WIG20, WIG Real Estate.

In our study we follow the question stated in the title by Hoesli and Oikarinen (2012) - Are REITs real estate? However, considering the fact that on Polish financial market REITs are not available, we treat the WIG Real Estate index as the representative of securitized real estate. Then, we refer to the determinants of public real estate market and formulate the following first research question:

1. Which types of the explanatory variables influence the quotations of the WIG Real Estate index the most?

Based on the above literature analysis as well as taking into consideration the fact that the index is dominated by residential developing companies, we used four groups of variables: stock exchange (the WSE indexes), economic (monetary variables), real estate market (demand, supply and construction costs variables) and direct real estate prices (residential transaction prices).

At the beginning of XXI century Clayton and MacKinnon (2001) claimed, which we believe to be true by definition, that links between returns of REITs and bonds, stocks and unsecuritized real estate are of time-varying nature. Many authors acknowledge that by writing that the relationships among stocks, public and private real estate may be different in a long- and in a short-term (e.g. Assaf, 2006). This, to some point is a resultant of the exploited modelling approach. Many papers utilize the VAR, the VECM models or variants of the two. The first provides short-run estimations, while the second gives the long-run equilibrium and its short-run error corrections. The two approaches are based on the bi-directional dependencies between the employed variables. Unlike, instead of mutual relationships, we seek to verify impact of the particular independent variables on the WIG Real Estate index, in the long- and in the short-term. We use the ARDL model which helps to verify the one-side relationships in the two time frames. This brings on the second research question:

2. Is there evidence of different relationships among the dependent and independent variables in the long-term and in the short-term?

The aforementioned variations of the dependencies may be effects of changing conditions of the external environment. There may be many examples of such. However, there is a great amount of literature on the influence of shocks in the economy impacting public as well as on private real estate. Yuksel et al. (2017) prompted that the GFC and the European insolvency problems caused significant changes in cointegration between REITs and stock markets in ten developed countries. Caporin, Gupta and Ravazzolo (2021) proved spillover effects from the US REITs on-to the equity market. Furthermore, they insisted that the contagion was stronger during the GFC and in the period of the European sovereign debt crisis. Ewing and Payne (2005) found that macroeconomic shocks (monetary policy, economic growth, and inflation) led to REITs returns in the U.S. being lower than expected returns. Many authors demonstrated impact of shocks on REITs' volatility. Ajmi et al. (2014) used the US Equity Market Uncertainty Index and the US Economic Policy Uncertainty Index, instead of employing stock and macroeconomic variables. They documented the US REITs conditional volatility being rather responsive to different historical shocks. In line with that, Hoesli, Johner and Kraiouchkina (2025) with a use of the GARCH models found synchronous volatility shocks of European listed real estate returns, across sectors and countries. However, they noted differences in magnitude, based on investigation of the GFC and the COVID-19 pandemic. There are also other studies expressing the substantial importance of financial stress on REIT market's volatility (Ozcelebi, Yoon, 2025) and returns (Armah, Amewu, 2024).

Lee (2020) shed light on possible different causes of unstable relationships. The paper insisted high variations of integration between REITs and stock market was attributed to economic conditions (1990 recession, start and then burst of the dotcom bubble, the GFC), but also to tax reforms. Lee and Chiang (2010) conjured the structural change noticed in the early 1990s as a reason for the fact that the U.S. REITs were more like stock during 1973-1993 period and more like private real estate in years 1994-2008.

In this context one may treat government housing subsidy programs as plausible cause of structural changes on direct real estate market, and also on securitized real estate afterwards. Egan and Bergin (2023) - based on a COSMO model of Irish economy - stated that, in the case of social and economic goals i.e. increase affordable housing availability, government housing programs may be preferable to an economy-wide stimulus. On the other hand, Hilber and Schöni (2022) insist that the programs may not always be effective to beneficiaries, in a desired way. We aim the two issues – economy shocks and government subsidy housing programs – as potential sources of external impacts that may distort the basic equilibrium relationships between the WIG Real Estate index and its explanatory variables. In that context we formulate the third research question:

3. Are there signs of external impact on the emerged dependencies, in the time range of the study?

We ascribe the external impact to government housing programs and the GFC and the COVID-19 pandemic. This selection stems from the time span of the data. In the time period of the study there were four government housing programs run in Poland, which are believed to have a great impact on the direct real estate market (Marona, Tomasik, 2023; Radzimski, 2014). Moreover, the time series under research start five quarters before the GFC took off, and end twenty quarters after the COVID-19 launched. This may provide us with a room for potential checks, if the initially set dependencies were on pressure during these external impacts.

In our study, we follow the path set by Nowak (2020) and to lesser extent Cellmer, Bełej and Cichulska (2019). There are several advantages of our study over that ones. In the first place, we use broaden and more disciplined approach with longer time series and more suited variables. Furthermore, we deploy the ARDL model, rather than the VAR, which is suited to generate both the long- and short-run relationships. Last but not least, we also examine possible workings of external impacts on the dependencies (government housing programs, the GFC and the COVID-19).

3. Data and methodology

3.1. Selection of the variables and data characteristics

The dependent variable in the study represents fluctuations of the WIG Real Estate Index, which is quoted on the Warsaw Stock Exchange (WSE). The index is a total return index, thus its calculation takes into account both the prices of the included shares and income from dividends and subscription rights. The index is composed of companies classified in the real estate sector. As of the 8th of August 2025 there were 23 companies included in the index. The ten biggest companies comprise 96,14% of the index portfolio. Six out of the ten companies are focused entirely on developing business in residential sector (74.464% weight in the index). One company runs a development business in residential, office and retail real estate (6.452%). Two companies are mainly concentrated in commercial real estate but also invest in portfolio of apartments for rent (9.087%). There is only one company out of ten that is solely focused on commercial real estate (6.137%). On the one hand, composition of the index indicates its strong dependence on the economic situation in the residential market in Poland. On the other hand, fluctuation of the WIG Real Estate Index shall be also a product of present conditions on the WSE. In other words, the WIG Real Estate Index is located somewhere in between the housing market and the stock market. Taking this into account the study aims to verify what kind of determinants influence the index. The six types of variables that may impact the index are characterized in the Table 1.

Table 1.
Characteristics and descriptive statistics of time series applied in the study

Variables' characteristics	Time series	Variables' codes	Variables' roles	Unit	Min.	Max.	Mean	S.D.
Stock exchange variables	WIG Real Estate	WRE	Dependent variable	Quotation points	1237	6463	2443	1082
	WIG	WIG	Independent variable		24036	95953	53935	13423
	WIG Construction	WCO			1602	11686	4091	2278
	WIG Banks	WBA			2799	16030	7157	2272
Monetary variables	CPI inflation rate	CPI		p.p. (%)	-1.500	17.300	3.603	3.946
	WIBOR3M interest rate	W3M			0.210	7.210	3.509	2.043
Demand variables	Average salary	ASA		PLN	2644	8962	4621	1551
	Value of newly granted mortgages	MVA		bn PLN	6.169	28.148	13.170	4.520
Supply variable	Number of building permits for apartments	BPE		No.	29382	93295	57199	14934
Construction costs' variables	Price index of construction and assembly production	ICA		p.p. (%)	-2.000	14.800	2.907	4.081
	Production cost of an apartment	CPR		PLN per sq. m	2650	7612	4495	1021
Average transaction price of apartment	In 7 first tier voivodeships cities (primary market)	P7			5931	14347	8052	2337
	In 10 second tier voivodeships cities (primary market)	P10			3923	10675	5884	1835
	In 7 first tier voivodeships cities (secondary market)	S7			5445	13529	7581	2228
	In 10 second tier voivodeships cities (secondary market)	S10			3767	8793	4979	1476

Note: The time series of following variables represent value/numbers as of the end of the quarter: WRE, WIG, WCO, WBA, W3M. The time series of following variables represent cumulative value/numbers for the whole quarter: CPI, ASA, MVA, BPE, ICA, CPR, P7, P10, S7, S10. The sources of the time series are as follows: the Central Statistical Office (GUS) - CPI, ASA, BPE, ICA, CPR; the National Bank of Poland - P7, P10, S7, S10; The Warsaw Stock Exchange - WRE, WIG, WCO, WBA; the AMRON-SARFiN reports – MVA; the bankier.pl - W3M.

Source: Own elaboration.

The selection of explanatory variables was based in some way on the general classification provided by Serrano and Hoesli (2009). However, we also took into account local specifics, the nature of the explanatory variable (Real Estate stocks index, not REITs), and the data availability. As well as the fact that unlike the authors, we use time series of WIG Real Estate quotations rather than returns. Furthermore, we follow Cohen and Burinskas (2020; 2023) to some point, as we use determinants capturing particular facets of direct real estate market. Some of the applied variables were used by Cellmer, Bełej and Cichulska (2019) and Nowak (2020), however, we extend spectrum of the explanatory variables and scope of examined dependencies.

As far as the stock exchange variables are concerned, we included the WIG index together with two sectoral indexes, the WIG Construction and the WIG Banks. The first is the main index traded on the WSE, which includes all the stocks available on the market. Hence, this is the best mirror of current market conditions on the WSE. Another two indexes represent sectors closely connected to the residential market. The changes in the construction sector may affect the residential development branch by costs of construction and by that can work on profitability of housing projects. The impact of banking sector is twofold. Firstly, number and value of mortgage loans granted represent a vast part of a housing demand. Secondly, many residential projects are financed with bank loans. All the three indexes are income-based, meaning that their calculation takes into account both the prices of the shares and income from dividends and subscription rights.

The monetary group of independent variables includes CPI and WIBOR3M. It is well documented that real estate prices tend to follow dynamics of inflation and are even called an inflation hedge (Fehrle, 2023; Muckenhaupt, Hoesli, Zhu, 2025). Moreover, inflation triggers reactions from central bank regarding interest rates. The WIBOR3M variable represents time series of Warsaw Interbank Offer Rate for three months, which is the interest rate at which banks lend money to each other. The WIBOR3M is informally bound with reference interest rate set by Monetary Policy Council (Rada Polityki Pieniężnej). An increase / decrease of the reference interest rate causes, ceteris paribus, similar effect on the WIBOR3M. In that way, one should expect negative impact of WIBOR3M on stock market but also on residential market. Since in Poland interest rate of adjustable rate mortgages is equal to, most often, WIBOR3M plus a bank's margin. In that way variations of WIBOR3M reflect changes in the cost of mortgage repayment. Besides, oscillations of WIBOR3M also induce changes in households' borrowing power, which affects housing demand.

We also applied independent variables representing demand on residential market. The quarterly-cumulative average wage in Poland, on a monthly basis, reflects the ability of households to satisfy their housing needs. In the context of mortgage loans, the variable influences the borrowing power of polish households. The time series of the value of newly granted mortgages expresses households' ability to purchase housing. The last may be an outcome of various determinants e.g. households' financial situation, changes in the mortgage repayment costs but also influence of legal acts or clauses of Recommendation S[1] of the Polish Financial Supervision Authority (Komisja Nadzoru Finansowego).

The number of building permits for apartments conveys the supply side of the housing market. One has to bear in mind that in the nomenclature of the Central Statistical Office (Główny Urząd Statystyczny) the word "apartment" relates to apartment as well as house.

The construction costs which cover the changes in the economic environment in which housing development companies operate, are carried by two variables. The price index of construction and assembly production gives the quarterly year-on-year dynamics of the costs bore by housing development companies. The production cost of an apartment variable represents a nominal expenditures of building one sq. m of a usable area of a residential building put into use in Poland.

The last four time series represent average transaction prices of one sq. m of brand new apartments and the ones sold on the secondary market. The variables are of a cumulative character, delineating two groups i.e. primary seven and secondary ten residential markets in Poland collectively. Most of the cities are the capitals of the sixteen polish voivodeships.

The variables' codes, units and basic descriptive statistics are presented in the Table 1. All the time series are quarterly data, however depending on the specificity, the method of their calculation may vary (details are provided in Table 1). The quotations of the WIG Real Estate index started in the second quarter of 2007, which limits the time range of the data to 2007 Q2 - 2025 Q1. The time span provides 72 periods. The data are of a nominal form as inflation rate was planned as a separate explanatory variable (this refers to variables W3M, ASA, MVA, ICA, CPR, P7, P10, S7, S10). Figure 1 presents oscillations of the variables used in the primary ARDL model.

[1] The Recommendation S, set by the Polish Financial Supervision Authority, concerns the scope of lending by banking sector in the mortgage loans segment in Poland.

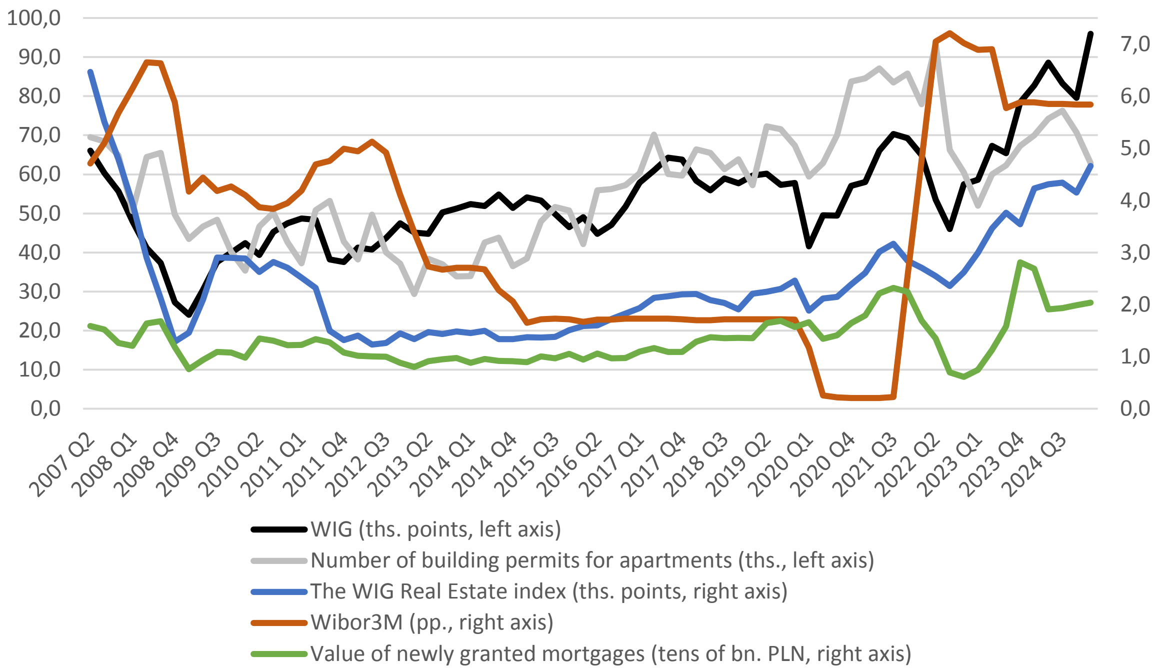

Figure 1. The oscillations of the variables used in the primary ARDL model.

Source: own elaboration.

3.2. Method

Many papers regarding the relationships between direct/securitized real estate and stocks are based on the VAR or VECM frameworks. The two allow to verify bidirectional dependencies. We chose the ARDL methodology (Pesaran, Shin, 1999; Pesaran, Shin, Smith, 2001) as we are looking for strictly examination of the impact of explanatory variables on the WIG Real Estate index alone. Moreover, the ARDL model enables to work out the long-term as well as the short-term relationships. Further, in the ARDL model one can exploit time series stationary at order [0] and at [1]. This broadens the range of potential independent variables as we use the raw time series in our study. The error-correction form of the ARDL model is conveyed by equation (1).

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta X_{t-j} + \delta_1 Y_{t-1} + \delta_2 X_{t-1} + u_t \quad (1)$$

where:

ΔY_t, ΔY_{t-i}, ΔX_{t-j} - dependent and explanatory variables on first-differenced time series,

Y_{t-1}, X_{t-1} – lagged dependent and explanatory variables on time series on levels,

α_0 – constant,

β_i, γ_j – coefficients indicating the short-run relationship between the dependent and explanatory variables,

δ_1 – a coefficient reflecting the speed of the adjustment process,

δ_2 – a coefficient indicating the long-run relationship between the dependent and explanatory variables,

u_t – error term.

The study was conducted in the STATA software. We pretty much followed the procedure provided by Kripfganz and Schneider (2023). The first step of the study involved verifying stationarity of particular variables, which was conducted with a use of the ADF test. Then, we formulated set of possible models, each including one explanatory variable from each type presented in Table 1. Hence, at the beginning each equation consisted of six independent variables. To avoid possible multicollinearity we formed the correlation matrices. If correlation with magnitude higher than 0.7 was detected, one variable was dismissed from the model. Subsequently, the ARDL models were built based on the remaining variables with number of lags served by the Bayesian (Schwarz) information criterion (BIC). We applied the Variance inflation factor (VIF) to inspect the magnitude of linkages between kept independent variables. Afterwards, we chose the best model out of the set of the basic ARDL models by using a three-step approach. First, as we seek for long- and short-run relationships, thereupon we dropped models with no cointegration indicated according to the Bounds test. Next, we dismissed models with inappropriate results of other postestimation tests: the Breusch-Godfrey test (autocorrelation); the White and the Breusch-Pagan tests (heteroskedasticity); the Jarque-Bera and the Shapiro-Wilk tests (normal distribution of residuals), Cumulative sum test for parameter stability (stability of the model). At that point, the primary ARDL model was chosen based on the magnitude of Adj. R^2.

The second part of the study includes examination of possible external impact on the established primary ARDL model. First, we verified if the four government subsidy housing programs influenced quotations of the WIG Real Estate index. These are: The Family on their own (Rodzina na Swoim), Apartment for young people (Mieszkanie dla Młodych), The Apartment plus (Mieszkanie plus), The Safe mortgage 2% (Bezpieczny kredyt 2%). If the programs improved the economic conditions in the residential market, they should also influence of stocks' prices of companies operating in this sector and the WIG Real Estate index. We formulated binary dummy variables for each of the programs, which take 1 in the quarters the programs took place in and 0 in remaining quarters. Also, we formed one time series for all the programs together, in the same way. Moreover, we formulated dummy variables by multiplying the binary dummies with each of the explanatory variables' time series. The dummy variables were input to the primary ARDL model according to the following scenarios: 1. the binary dummy alone; 2. the binary dummy and WIBOR3M dummy; 3. the binary dummy and value of the mortgages dummy; 4. the binary dummy, WIBOR3M dummy and value of the mortgages dummy; 5. the binary dummy and dummies of all explanatory variables. The time series of WIBOR3M and value of the mortgages reflect conditions of households' creditworthiness in order to purchase residential real estate. We decided to pay a special attention to dummy variables of the two time series, as three out of four government housing programs concerned subsidies in taking on mortgage loans (the scenarios 2, 3 and 4).

The impact of the GFC and the COVID-19 was estimated in similar approach. However, there are six scenarios of dummy variables' injections to the primary ARDL model, in each case: the binary dummy variable alone; the binary dummy and dummy of each of the explanatory variable separately (four scenarios); the binary dummy and dummies of all independent variables together.

We built independent model based on each of the dummy variables scenarios. We acknowledge the impact of the housing program/ the GFC/ the COVID-19 if the model passes postestimation tests (the Bounds test, the Breusch-Godfrey test, the White test, the Breusch-Pagan test, the Jarque-Bera, the Shapiro-Wilk test, Cumulative sum test for parameter stability) and coefficients of the dummy variables are statistically significant.

4. Results and discussion

The following section is divided into three parts. The first presents results of the regular ARDL model. The another two sub-sections serve models including impact of government housing subsidy programs and the COVID-19.

4.1. The primary ARDL model

Table 2 provides results of the ADF test, which works as a verification of the stationarity of the variables employed. Most of the variables are stationary at first differences, however few of them (i.e. CPI, MVA, PICA) are stationary on levels. In order to use all the variables, we chose the ARDL model as the study approach.

Table 2.
Results of the ADF stationarity test of time series applied in the study

Variable		**WRE**	**WIG**	**WCO**	**WBA**	**CPI**
Levels	Test statistic	-2.312	-0.650	-2.152	-0.764	-2.818*
First differences	Test statistic	-3.910***	-4.619***	-4.491***	-4.926***	-3.810***
Variable		**W3M**	**ASA**	**MVA**	**BPE**	**ICA**
Levels	Test statistic	-2.343	3.310	-3.511**	-2.032	-3.827***
First differences	Test statistic	-4.136***	-8.235***	-6.486***	-7.655***	-3.649***
Variable		**CPR**	**P7**	**P10**	**S7**	**S10**
Levels	Test statistic	1.011	2.349	4.010	1.350	2.431
First differences	Test statistic	-6.250***	-5.651***	-3.386**	-3.433**	-3.399**

Note: *p < 0.1; **p < 0.05; ***p < 0.01. The ADF test conducted with 1 lag.

Source: Own elaboration.

According to aforementioned methodology, initial models were predefined with six independent variables. In every model each type of variables stated in Table 1 was represented by only one explanatory variable. Table 3 brings on the correlation matrix for the primary ARDL model variables. The variables CPR and TS10 were dropped due to strong correlation (magnitude > 0.7). Accuracy of this method is proven by results of the VIF in Table 3. The numbers, well below 5.0, indicate a lack of strong relationships between the independent variables in the primary model.

Table 3.
The correlation matrix of the first choice independent variables and results of the variance inflation factor

Variable	**WIG**	**W3M**	**MVA**	**BPE**	**CPR**	**TS10**
WIG	1.0000					
W3M	0.0361	1.0000				
CVA	0.6463***	0.0210	1.0000			
BPE	0.5605***	-0.0544	0.6968***	1.0000		
CPR	0.7089***	0.2198*	0.5302***	0.4376***	1.0000	
TS10	0.7193***	0.3769***	0.6195***	0.6211***	0.9244***	1.0000

Variance inflation factor					
Variable	WIG	W3M	MVA	BPE	Mean
VIF	1.79	1.01	2.39	2.05	1.81

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

Source: Own elaboration.

The primary ARDL model is presented in Table 4. The adj. R^2 is pretty high (0.7195). Also, the adjustment variable is statistically significant and negative. This works as confirmation of non-explosive pattern of the model, as in each quarter 23% of previous WRE move is corrected.

Three out of four long-run variables turned out to be significant. W3M represents short-term interest rate, which one might expect to be negative. This is proved for REITs returns in Japan, Hong Kong, Singapore and Malaysia (Liow, Yang, 2005), and for REITs prices in Japan by Ito (2016). On the other hand there is also quite a number of studies reporting opposite direction of the relationships e.g. Bouchouicha and Ftiti (2012), Chaudhry et al. (2022) regarding US REITs. According to stylized facts, increase of interest rates should effect, ceteris paribus, in stock market declines. Consistently, increased cost of mortgages should effect in lower sales and by that lower prices of real estate on both primary and secondary markets. However, one has to bear in mind that within the time span of the study there were four housing programs implemented by government in Poland. Three of them, i.e. Family on their own (Rodzina na Swoim), Apartment for young people (Mieszkanie dla Młodych), Safe mortgage 2% (Bezpieczny kredyt 2%), were dedicated to support households taking on mortgage loans. The time range of the study comprises of 72 periods, out of which only 9 quarters were these without any housing program running. Besides, within the Family on their own and the Safe mortgage 2% programs, the government subsidies were directly aimed at lowering the interest rate paid on mortgage loans. This might have skewed the WIBOR3M default impact on residential market and on WIG Real Estate index as well. Another case is the fact that the study covers a very specific period of time. Firstly, in the sixth quarter of the study the Lehman Brothers went bankrupt and the GFC took off. Secondly, the first COVID-19 lockdown in Poland took place in the first quarter of 2020, which can be considered as the beginning of the pandemic's impact. Moreover, the surprisingly positive coefficient of W3M may be a result of factors which are not controlled for, in the model. An example of such may be an improvement of general financial conditions of polish households, which could inflate housing demand regardless of interest on mortgages. All in all, the external impacts on the WSE and on the residential market in Poland, and factors not included in the model may cause other than expected direction of influence of W3M on WRE (337.1872).

Also, the coefficient of MVA is other than expected i.e. negative. Again, it seems that the housing programs are first to be blamed for the fact that each additional PLN billion of sold mortgage loans decreases changes of WIG Real Estate by almost 116 points. This may be caused by the regulations of the programs. For instance, in three programs easing taking on mortgage loans, there were clauses setting maximum prices (either in PLN/ sq. m. or regarding total prices). Despite the conventional wisdom regarding the residential developers, next to the banking sectors, being main beneficiaries of the programs; such clauses might limit the developers' margin on the housing. Furthermore, the three housing programs, most of the time, were dedicated to both primary and secondary residential market. As residential developers drive the WIG Real Estate index the negative MVA suggests that the programs might have been more beneficiary to entities of secondary residential market. Moreover, the fourth program i.e. the Apartment plus (Mieszkanie plus) consisted in apartments being built by public authorities on public land, for rent or for rent with possible acquire in future. The last can be treated as the competition to private capital on residential market. Regardless the arguments, one would expect that the housing programs, in total positively influenced number of residential units sold. This should bring profits of residential developers as well as quotations of the WIG Real Estate index higher. However, another issue here is a specificity of the residential development process. The residential development act (Ustawa deweloperska) stands that when the agreement between residential developer and client is concluded the money from mortgage loan flow to the developer gradually, after each construction stage is finished. Hence, residential developers first bear the costs of construction and later receive (four to ten) instalments from the client's open escrow account. In that case, the value of mortgages may express promise of future profits burdened by today's costs, what can cause the WRE to fall. However, this should be true in a short-run. Unfortunately, in the primary model there is a lack of short-term MVA variable.

As expected, the coefficient of BPE variable is positive, which means that one additional building permit on residential real estate increases the WRE by 0.08 points. The coefficient of the WIG index is insignificant, insisting that there are no long-term relationships with WRE. Kołtuniak (2016b), in turn, proved causality between the WIG Real Estate index, the WIG index and the investment property fair value index but also unstable long-term dependencies at the same time.

As far as the short-term is concerned, coefficients of the variables DWREL1 and DWREL2 indicate trend continuation (0.2370 and 0.2226). A positive influence is also carried by DWIG and DWIGL3, 0.0286 and 0.0138 respectively. However, this contradicts findings of Nowak (2020) who reported negative short-term impact of indexes WIG and WIG20 on the WIG Real Estate. One should bear in mind that the study (Nowak, 2020) was based on time series that end in 2020 Q1. It essentially did not included the time of the COVID-19, what may impact the results. Naturally, one should expect the WRE to rather strongly follow short-run stock exchange (the WSE) conditions. This should be evident especially during stock market sharp overreactions, mostly in situations where systematic risk materializes. Nonetheless, literature on the impact of stock indexes on securitized real estate is ambiguous. One can find papers implying positive (on prices - Ito, 2016) and negative (on returns - Wu, Wang, 2024) effects on REITs.

Interestingly, statistically significant variables of WIBOR3M rate (DW3M and DW3ML2) are negative, -114.8398 and -311.9026. There is a clear difference of the Warsaw interbank offer rate's impact in the long- and short-term then. In the short-run the WRE responses to changes of W3M are consistent with economic theory. On the other hand, in the long-run the phrase "ceteris paribus" covers influence of all the external factors that may prevail and distort the standard relationships. Surprisingly, variables representing differenced time series of building permits (DBPE, DBPEL1) are negative (-0.0069 and -0.0084), what contradicts the long-term dependence. This, however, can be a result of the fact that in Poland there is still a problem of great amount of areas, within cities, which are not under local zoning plans. This means that residential developers often need to apply for land development conditions first, what may also make the process of obtaining the building permits more time consuming. The number of building permits is a derivative of a number of applications submitted few, usually 2-4 quarters before[2]. Therefore, the lag longer than just one quarter may be a reason of lack of positive coefficients in the short-term. Nowak (2020) noted lack of statistical significance of residential premises with permit to make use of, which is a close statistics to the building permits. It is worth to advert that Nowak (2020) obtained negative, so expected coefficients on value and number of mortgage loans handed over. In our study the MVA does not impact WRE in the short-run.

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[2] However, the process may last even for few years in the case of opposition from the owners of neighboring parcels.

Differences in magnitude between individual variables are related to the time series values. Taking into account mean values of the variables (Table 1), in the long-run the strongest impact is contributed to building permits. Albeit, in the short-term these are lagged changes of the WIG index which weigh the most, which are insignificant in the long-term. The above means that answer to the first research question depends on the time-frame. Moreover, there is obvious change of WIBOR3M, which coefficients are according to the stylized facts in the short-term (negative) and opposite in the long-term (positive). The change is also evident when it comes to the building permits. The results directly indicate positive answer to the second research question. There are distinctions between long- and short-term relationships patterns, which again insist heavy impact of time frame on the obtained results.

The average transaction prices of apartments were dismissed from the model due to high correlation issue. For that reason we were unable to prove direct relationships between time series of securitized real estate and direct real estate, which is demonstrated in many aforementioned papers (e.g. Hoesli, Oikarinen, 2012; Kołtuniak, 2016a; Wolski, 2018, 2020).

Table 4.
The primary ARDL model explaining the differenced quotations of the WIG Real Estate

Independent variables	Coefficient	Std. Err.
Constant	-502.1992	139.6117***
Adjustment variable		
WREL1	-0.2278	0.0578***
Long-run variables		
WIG	0.0064	0.0126
W3M	337.1872	67.4224***
MVA	-115.9749	64.6887*
BPE	0.0793	0.0218***
Short-run variables		
DWREL1	0.2370	0.1029**
DWREL2	0.2226	0.1007**
DWIG	0.0286	0.0052***
DWIGL1	-0.0019	0.0061
DWIGL2	-0.0077	0.0057
DWIGL3	0.0138	0.0051***
DW3M	-114.8398	47.0447**
DW3ML1	42.1012	60.0075
DW3ML2	-311.9026	58.3945***
DBPE	-0.0070	0.0033**
DBPEL1	-0.0084	0.0031**
Adj. R^2	0.7195	

Note: *p < 0.1; **p < 0.05; ***p < 0.01. “D” at the beginning of variables’ codes indicates first-differenced time series. “L” at the end of the variables’ codes stands for lagged time series.

Source: Own elaboration.

Table 5 provides results of Bounds cointegration test. Results of the other postestimation tests, stored in table 6 and 7, indicate no autocorrelation (the Breusch-Godfrey test), heteroskedasticity (the White and the Breusch-Pagan tests) and normal distribution of residuals (the Jarque-Bera and the Shapiro-Wilk tests).

Table 5.
Results of the Bounds cointegration test (Case 3) of the primary ARDL model

p levels of critical values		10%		5%		1%		p-value	
Lower and upper bounds		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F-statistics	8.621***	2.475	3.720	2.956	4.341	4.054	5.735	0.000	0.000
t-statistics	-3.939*	-2.492	-3.581	-2.827	-3.963	-3.492	-4.708	0.003	0.052

Note: rejection of the null hypothesis of no long-run relationship at levels at *p < 0.1; **p < 0.05; ***p < 0.01.

Source: Own elaboration.

Table 6.
Results of the Breusch-Godfrey autocorrelation test of the primary ARDL model

Number of lags	chi2	df	Prob > chi2
1	0.002	1	0.9650*
2	1.198	2	0.5494*
3	1.701	3	0.6367*
4	2.028	4	0.7306*

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

Source: Own elaboration.

Table 7.
Results of heteroskedasticity tests (the White and the Breusch-Pagan tests) and normality tests (the Jarque-Bera and the Shapiro-Wilk tests) of the primary ARDL model

The White test	The Breusch-Pagan test	The Jarque-Bera test	The Shapiro-Wilk W test
chi2(67)	F(16, 51)	chi(2)	z
68.00	1.02	1.463	0.104
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.4514*	0.4812*	0.45844*

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

Source: Own elaboration.

We investigated the stability of the primary ARDL model with the Cumulative sum test for parameter stability. Based on the results provided by Table 8 the null hypothesis of no structural break stays on, in the case of both recursive as well as OLS statistics. This is also proved by Figure 2, both the recursive and the OLS cumulative sums stay within the 95% bands.

Table 8.
Results of the Cumulative sum tests for parameter stability of the primary ARDL model

Statistic	Test Statistic	1% Critical value	5% Critical value	10% Critical vale
Recursive	0.6825	1.1430	0.9479	0.850
OLS	0.4772	1.6276	1.3581	1.224

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

Source: Own elaboration.

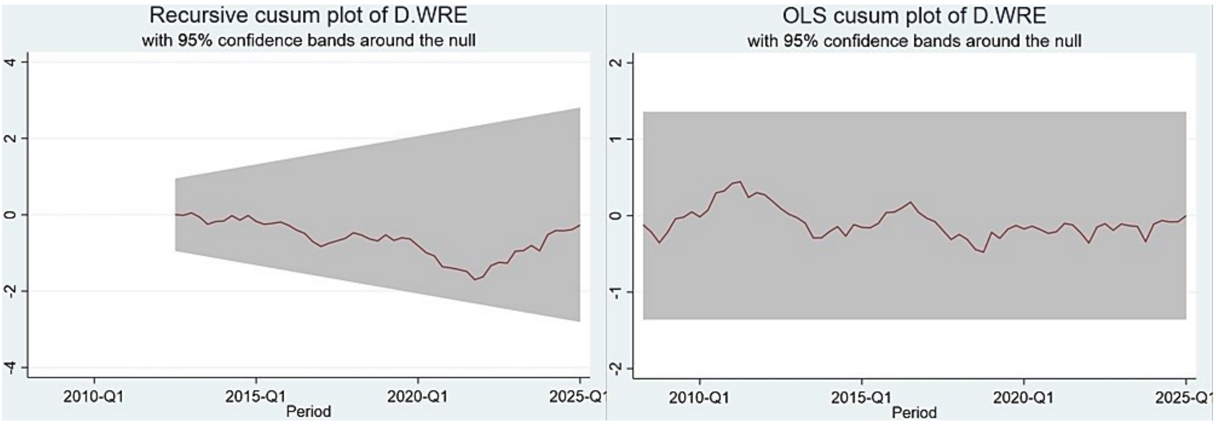

Figure 2. CUSUM test plots.

Source: Own elaboration.

The interpretation of the primary ARDL model, along with the ambiguous results of various studies recalled in this section, emphasize possible external impacts on the model that may result from the time span of the study, like economic situation, monetary, fiscal and even social policy (housing programs), and shocks arising from economic crises. In this context, and following the third research question, two major issues shall be examined: first, if the particular housing programs; second, if the GFC and the Covid-19; had impact on the WIG Real Estate.

4.2. The impact of government housing subsidy programs

As it was mentioned before, within the time span of the study (2007 Q2 – 2025 Q1) there were four government housing programs in Poland. Presenting the in-depth characteristics of the programs does not lie within the scope of the paper. However, short description may be crucial for understanding the impact they may have on residential market and on the WIG Real Estate index. The Family on their own (Rodzina na Swoim) housing program was aimed at young married couples and single parents and was in place in years 2007-2012. Under the program, the state paid half of the interest on the mortgage loan for the first eight years. The Apartment for young people (Mieszkanie dla Młodych) included subsidies for down payments while taking on the mortgage loan. The program was also dedicated to young adults and was running from 2014 to 2018. The Apartment plus (Mieszkanie plus) program which was in force from 2016 Q4 to 2023 Q2. The goal here was to build affordable rental apartments with the option of ownership in future. The Safe mortgage 2% (Bezpieczny kredyt 2%) housing program lasted only in two last quarters of 2023. According to this program young residential buyers could take on a mortgage loans with interest rate limited to 2% plus bank's margin. It is also worth to note that only people who did not own any residential real estate could become beneficiaries of all the four housing programs.

We formulated binary dummy variable of each housing program which take value 1 in the periods of running the program and 0 in others. We also formed such time series for all the programs altogether. Then, we formulated dummy variables as products of the binary dummy and two regular variables of the primary ARDL model i.e. W3M and MVA. Three out of four housing programs represent different kind of subsidies of mortgage loans. The variables W3M and MVA represent interbank interest rate and value of mortgage loans, thus they should reflect the impact of the programs the most. The verification was proceeded by adding the dummy variables to the primary ARDL model according to scenarios listed in the second column of Table 9. Again, the goal here was to specify a model with long- and short-term adjustments, so with detected cointegration.

Table 9.
List of housing programs dummy variables added to primary ARDL model in particular scenarios

No.	Variables added to primary ARDL model	Family on their own (RNS)	Apartment for young people (MDM)	Apartment plus (MPL)	Safe mortgage 2% (BK2)	Housing programs overall (HP)
1	Binary dummy	No cointegration	No cointegration	Cointegration	Cointegration, significant impact	No cointegration
2	Binary dummy, W3MDV	No cointegration	No cointegration	No cointegration	No cointegration	Cointegration, significant impact
3	Binary dummy, MVADV	No cointegration	No cointegration	No cointegration	No cointegration	Cointegration, significant impact
4	Binary dummy, W3MDV, MVADV	No cointegration	No cointegration	No cointegration	No cointegration	No cointegration
5	Binary dummy, all independent variables' DV	No cointegration	No cointegration	No cointegration	No cointegration	No cointegration

Source: Own elaboration.

The four models mirroring impact of housing programs, with cointegrated time series, are served in Table 10. There are moderate improvements of adj. R^2 in each of the four housing program models in comparison to the primary ARDL model.

In the case of the first model (MPL model) the dummy variable does not represent statistically significant impact on WRE. The coefficients of long-term as well as short-term variables are pretty close to these of the primary ARDL model.

As far as BK2 model is concerned coefficient of the DVBK2 indicates that the housing program Safe mortgage 2% took away almost 1053 points of WIG Real Estate index in last two quarters of 2023. Moreover, constant became negative and MVA became insignificant. The coefficients representing short-run variables changed only slightly.

When it comes to the HP1 model influence of W3M on WRE increased by 2,5 times (838.4225), however, the boost is totally limited by negative value of W3MHP1 (-582.8846). The variable DVHP1 imply considerable positive effect of consecutive housing programs on the real estate stock index (2159.086). Again, there are no major changes in the short-run adjustments.

In the HP2 model the MVA variable turned to be statistically insignificant. It seems like its impact is included in the dummy MVAHP2 which coefficient is about 60% higher (-184.2183). The binary dummy DVHP2 once more reflects major positive impact on WRE (2221.435). The coefficient of W3M declined by about 40%. In the short-term part of the equation one can notice magnitudes drop of coefficients of DW3M and DW3ML2 to -85.1855 and -231.4869. Also, the total influence of building permits rose by over 60%, primarily thanks to new significant variable (DBPEL2).

All things considered, there are signs of strong positive influence of all the four housing programs taken altogether (models HP1 and HP2), what is indicated by the binary dummies. However, the impact of the Safe mortgage 2% (BK2) program alone is negative. Nevertheless, one has to bear in mind that the program lasted only for six months. Therefore, in this case the long-term conclusions should be drawn with caution. Moreover, in the HP1 model, taking together coefficients of W3M and its dummies, the effect on WRE is weaker than in the primary ARDL model.

The results of the postestimation tests obtained for the four housing programs' models allow for their interpretation and are stored in the Tables 13-16.

Table 10.
The ARDL models with housing programs' dummy variables

MPL model			BK2 model			HP1 model			HP2 model		
Independent variables	**Coeff.**	**Std. Err.**	**Independent variables**	**Coeff.**	**Std. Err.**	**Inde-pendent variables**	**Coeff.**	**Std. Err.**	**Inde-pendent variables**	**Coeff.**	**Std. Err.**
Constant	-569.6563	147.4737***	Constant	542.9562	139.4298***	Constant	-745.9784	211.4558***	Constant	-637.0546	187.1444***
Adjustment variable			Adjustment variable			Adjustment variable			Adjustment variable		
WREL1	-0.2329	0.0575***	WREL1	-0.2510	0.0585***	WREL1	-0.2665	0.0559***	WREL1	-0.2551	0.0517***
Long-run variables			Long-run variables			Long-run variables			Long-run variables		
WIG	0.0060	0.0122	WIG	0.0046	0.0113	WIG	-0.0125	0.0135	WIG	-0.0179	0.0136
W3M	290.3875	70.0789***	W3M	354.3408	62.7145***	W3M	838.4225	200.3793***	W3M	200.5232	60.2713***
MVA	-137.5918	68.8840*	MVA	-76.9380	55.4024	MVA	-95.5225	49.2235*	MVA	83.9408	53.8413
BPE	0.0952	0.0269***	BPE	0.0708	0.0186***	BPE	0.0686	0.0163***	BPE	0.0710	0.0162***
DVMPL	-504.4125	389.9154	DVBK2	-1052.935	622.2718*	DVHP1	2159.086	833.3081**	DVHP2	2221.435	755.3445***
Short-run variables			Short-run variables			W3MHP1	-582.8846	207.0785***	MVAHP2	-184.2183	56.2601***
DWREL1	0.2261	0.1024**	DWREL1	0.2847	0.1051***	Short-run variables			Short-run variables		
DWREL2	0.2397	0.1008**	DWREL2	0.2579	0.1013**	DWREL1	0.2476	0.0969**	DWREL1	0.2848	0.0921***
DWIG	0.0293	0.0052***	DWIG	0.0286	0.0051***	DWREL2	0.2600	0.0955***	DWREL2	0.2093	0.0894**
DWIGL1	-0.0002	0.0062	DWIGL1	-0.0033	0.0060	DWIG	0.0312	0.0052***	DWIG	0.0325	0.0049***
DWIGL2	-0.0076	0.0057	DWIGL2	-0.0084	0.0056	DWIGL1	-0.0003	0.0058	DWIGL1	-0.0013	0.0055
DWIGL3	0.0130	0.0051**	DWIGL3	0.0147	0.0051***	DWIGL2	-0.0064	0.0054	DWIGL2	-0.0011	0.0054
DW3M	-110.9709	46.7773**	DW3M	-137.4579	48.2108***	DWIGL3	0.0138	0.0048***	DWIGL3	0.0148	0.0046***
DW3ML1	39.7792	59.5774	DW3ML1	30.9249	59.3776	DW3M	-88.7952	45.1443*	DW3M	-85.1855	42.6062*
DW3ML2	-306.565	58.0889***	DW3ML2	-294.4172	58.3654***	DW3ML1	38.5282	56.8925	DW3ML1	28.8920	54.2163
DBPE	-0.0093	0.0037**	DBPE	-0.0060	0.0033*	DW3ML2	-281.0384	58.8264***	DW3ML2	-231.4869	58.4887***
DBPEL1	-0.0101	0.0034**	DBPEL1	-0.0076	0.0031**	DBPE	-0.0068	0.0031**	DBPE	-0.0090	0.0031***
-	-	-	-	-	-	DBPEL1	-0.0087	0.0030***	DBPEL1	-0.0107	0.0030***
-	-	-	-	-	-	-	-	-	DBPEL2	-0.0057	0.0029*
Adj. R^2	0.7238		Adj. R^2	0.7289		Adj. R^2	0.7519		Adj. R^2	0.7805	

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. "MPL", "BK2" and "HP" at the end of the variables' codes stay for programs Apartment plus, Safe mortgage 2% and Housing programs overall, respectively.

Source: Own elaboration.

4.3. The impact of the GFC and the COVID-19

The impact of the GFC and the COVID-19 on the WIG Real Estate index was verified with a use of a similar procedure as in the case of the housing programs. The examined scenarios are presented in second column in Table 11. The cointegration and significant impact of the dummies were found only in the case no. 3 for COVID-19.

Table 11.
List of the GFC and the COVID-19 dummy variables added to primary ARDL model in particular scenarios

No.	Variables added to primary ARDL model	GFC	COVID-19
1	Binary dummy	No cointegration	No cointegration
2	Binary dummy, WIGDV	No cointegration	No cointegration
3	Binary dummy, W3MDV	No cointegration	Cointegration, significant impact
4	Binary dummy, MVADV	No cointegration	No cointegration
5	Binary dummy, BPEDV	No cointegration	No cointegration
6	Binary dummy, all independent variables' DV	No cointegration	No cointegration

Source: Own elaboration.

The COVID model is presented in Table 12. The Adj. R^2 has slightly improved (0.8098). The constant represents a positive number with over 40% higher magnitude than in the primary ARDL model. Curiously enough, WIG is significant and has a negative effect on WRE. One point increase of the WIG index quotation produces 0.0975 point decline in the WIG Real Estate index. W3M turned negative. But again, taking the coefficients of W3M (-520.9804) and W3COV (1061.206) together gives positive impact about 60% stronger than in the primary model. The binary dummy variable COV itself implies that starting 2020 Q1, in each quarter the Real Estate index was lower by 2,579.902 points. The MVA is positive, showing that every additional PLN 1 billion in newly granted mortgage loans increases WRE by 239.8643 points. The magnitude of the BPE decreased by a half.

There are no lags of independent variable in the short-term part of the model. All the four WIG differenced variables are significant and reflect 120% stronger total effect on WRE than in primary ARDL model, the direction stays the same though. When it comes to WIBOR, only changes lagged two periods are significant (DW3ML2). The coefficient is still negative and 20% lower than in regular model (-253.7385). Then again, taking it together with coefficient of emerged DW3COV (-222.4872) gives the slightly greater number. Also, there is an evidence of short term dependency of differenced WRE on changes of value of newly granted mortgages. The WRE changes in reverse direction than all of the four differenced MVA variables (the sum of coefficients stays at -137.0620). Joint influence of DBPE and DBPEL1 is little bit weaker but remains negative. The results of the postestimation tests for the COVID model are stored in the tables 13 – 16.

In the context of the GFC and the COVID-19, we also formulated two additional models to check if the time span alter the relationships between WIG Real Estate index and the set of explanatory variables of the primary ARDL model. First model was built on the time series for a period 2009 Q1 – 2025 Q1, the second covered 2009 Q1 – 2019 Q4. However, in the both cases cointegration was not detected, so the models are not presented in the paper.

The impact of COVID-19 on economy and stock markets was negative at first. However, one shall recall the helicopter money and interest rates cuts as reactions of fiscal and monetary authorities, respectively. Then, expansion of inflation and its effect in elevated central bank rates later on, during restrictive monetary policy. All of this produced massive oscillations since 2020 on stock markets worldwide, also on the WSE. Eventually, the COVID model indicates the significant negative influence of the pandemic on WIG Real Estate index quotations in the long-term, conveyed by binary dummy (COV). Also, it pictures positive and negative impact of W3M's dummies in the long- (W3COV) and in the short-term (DW3COV), respectively.

Table 12.
The ARDL model with the COVID-19 dummy variables (the COVID model)

Independent variables	Coefficient	Std. Err.
Constant	719.3529	226.4888***
Adjustment variable		
WREL1	-0.2155	0.0528***
Long-run variables		
WIG	-0.0975	0.0309***
W3M	-520.9804	209.0767**
MVA	239.8643	81.3782***
BPE	0.0396	0.0175**
COV	-2579.902	843.969***
W3COV	1061.206	301.3015***
Short-run variables		
DWIG	0.0403	0.0051***
DWIGL1	0.0226	0.0048***
DWIGL2	0.0134	0.0046**
DWIGL3	0.0168	0.0042***
DW3M	-0.9187	66.5914
DW3ML1	42.6432	53.4153
DW3ML2	-253.7385	54.5753***
DMVA	-50.6590	12.6909***
DMVAL1	-31.9013	13.4205**
DMVAL2	-32.5153	9.9939***
DMVAL3	-21.9864	10.3504**
DBPE	-0.0038	0.0034
DBPEL1	-0.0090	0.0031***
DW3COV	-222.4872	83.4072**
Adj. R^2	0.8098	

Note: *p < 0.1; **p < 0.05; ***p < 0.01. "COV" at the end of the variables' codes indicate Covid-19 dummy variable.

Source: Own elaboration.

5. Conclusions

The study is based on the question if public real estate is more like private real estate or it should be treated as another class of securities. To examine that we verified impact on the WIG Real Estate index traded at the WSE, of variables representing stock exchange (the WSE indexes), economic (monetary variables), real estate market (demand, supply and construction costs variables), and direct real estate prices (residential transaction prices). Our findings insist that basically in the short-run the path of WIG Real Estate index is set by macroeconomic variables, real estate variables and the mostly by the WIG index. However, in the long-run the WIG index coefficient turns insignificant. This incline that the WIG Real Estate index captures the current stock market situation and follows its short-term shocks. While in the long-term view it traces the macroeconomic and sector based conditions. We also found that there is a statistically significant impact of government subsidy housing programs as well as the COVID-19 on the index.

The main limitation of the study springs from time range of available time series. The time frame is imposed by the quotations of the WIG Real Estate index which set out in 2007 Q2. This made more in-depth analysis of impact of the GFC on the model infeasible. Moreover, the data end in 2025 Q1, what again leave us with insufficient number of quarters to build reliable model starting at the beginning COVID-19. However, this constraint can be overcome in time.

The results indicate linkages between direct real estate market and stock market with the WIG Real Estate index. The implied character (direction and magnitude) of the relationships can be of service to investment portfolio management. The findings can be useful for investors building their portfolios with direct real estate, securitized real estate and stocks.

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Appendix

Table 13.
Results of the Bounds cointegration test (Case 3) for models with dummy variables (housing programs, the COVID-19)

p levels of critical values		**10%**		**5%**		**1%**		**p-value**	
MPL model									
Lower and upper bounds		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F-statistics	7.592***	2.306	3.580	2.736	4.150	3.716	5.430	0.000	0.001
t-statistics	-4.049*	-2.482	-3.774	-2.820	-4.167	-3.491	-4.936	0.002	0.062
BK2 model									
F-statistics	7.894***	2.306	3.580	2.736	4.150	3.716	5.430	0.000	0.000
t-statistics	-4.288**	-2.482	-3.774	-2.820	-4.167	-3.491	-4.936	0.001	0.040
HP1 model									
F-statistics	8.197***	2.184	3.478	2.579	4.013	3.476	5.214	0.000	0.000
t-statistics	-4.761**	-2.473	-3.945	-2.814	-4.348	-3.490	-5.138	0.000	0.022
HP2 model									
F-statistics	10.045***	2.178	3.483	2.572	4.020	3.469	5.228	0.000	0.000
t-statistics	-4.933**	-2.466	-3.935	-2.808	-4.340	-3.486	-5.134	0.000	0.015
COVID model									
F-statistics	12.070***	2.164	3.491	2.558	4.034	3.455	5.256	0.000	0.000
t-statistics	-4.083*	-2.451	-3.914	-2.796	-4.323	-3.479	-5.126	0.002	0.076

Note: rejection of the null hypothesis of no long-run relationship at levels at *p < 0.1; **p < 0.05; ***p < 0.01.

Source: Own elaboration.

Table 14.
Results of the Breusch-Godfrey autocorrelation test for models with dummy variables (housing programs, the COVID-19)

Number of lags	**chi2**	**df**	**Prob > chi2**	**Number of lags**	**chi2**	**df**	**Prob > chi2**
MPL model				**BK2 model**			
1	0.030	1	0.8632*	1	0.022	1	0.8809*
2	2.526	2	0.2828*	2	0.548	2	0.7603*
3	3.367	3	0.3384*	3	1.108	3	0.7750*
4	4.252	4	0.3729*	4	1.473	4	0.8315*
HP1 model				**HP2 model**			
1	0.014	1	0.9042*	1	0.136	1	0.7123*
2	0.850	2	0.6539*	2	1.206	2	0.5471*
3	1.660	3	0.6458*	3	1.232	3	0.7453*
4	1.979	4	0.7397*	4	1.490	4	0.8283*
COVID model				-			
1	2.631	1	0.1048*	-	-	-	-
2	4.358	2	0.1132*	-	-	-	-
3	8.572	3	0.0356***	-	-	-	-
4	8.666	4	0.0700**	-	-	-	-

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

Source: Own elaboration.

Table 15.
Results of heteroskedasticity tests (the White and the Breusch-Pagan tests) and normality tests (The Jarque-Bera and The Shapiro-Wilk tests) for models with dummy variables (housing programs, the COVID-19)

The White test	The Breusch-Pagan test	The Jarque-Bera test	The Shapiro-Wilk W test
MPL model			
chi2(67)	F(17, 50)	chi(2)	z
68.00	1.03	2.859	0.604
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.4431*	0.2394*	0.27303*
BK2 model			
chi2(67)	F(17, 50)	chi(2)	z
68.00	0.61	1.684	0.544
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.8695*	0.4308*	0.29337*
HP1 model			
chi2(67)	F(18, 49)	chi(2)	z
68.0	0.47	1.867	0.329
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.9573*	0.3931*	0.37116**
HP2 model			
chi2(67)	F(19, 48)	chi(2)	z
68.0	0.57	1.97	0.205
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.9096*	0.3734*	0.41883*
COVID model			
chi2(67)	F(21, 46)	chi(2)	z
68.0	0.78	0.6131	0.485
Prob > chi2	Prob > F	Prob > chi2	Prob>z
0.4429*	0.7226*	0.736*	0.3138*

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

Source: Own elaboration.

Table 16.
Results of the Cumulative sum tests for parameter stability for models with dummy variables (housing programs, the COVID-19)[3]

Statistic	Test Statistic	1% Critical value	5% Critical value	10% Critical vale
MPL model				
Recursive	0.3470	1.1430	0.9479	0.850
OLS	0.5504	1.6276	1.3581	1.224
BK2 model				
Recursive	0.0584	1.1430	0.9479	0.850
OLS	0.4862	1.6276	1.3581	1.224
HP1 model				
Recursive	0.7218	1.1430	0.9479	0.850
OLS	0.6209	1.6276	1.3581	1.224
HP2 model				
Recursive	0.6090	1.1430	0.9479	0.850
OLS	0.5385	1.6276	1.3581	1.224
COVID model				
Recursive	0.1640	1.1430	0.9479	0.850
OLS	0.3250	1.6276	1.3581	1.224

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

Source: Own elaboration.

[3] Graphs of Cumulative sum tests for parameter stability are available from author at a reasonable request.