IDENTIFICATION OF CAUSE-AND-EFFECT RELATIONSHIPS IN THE REAL ESTATE MARKET USING THE VAR MODEL AND THE GRANGER TEST

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Abstract

The real estate market, as an open, complex and dynamic system, responds to changes in the environment of economic, legal or social conditions, although the pace and direction of these changes depends on the level of inertia of this system. At the same time, this market stimulates the market environment through prices. This study attempts to identify cause-and-effect relationships in the scope of the impact of selected economic and social indicators on prices of residential premises, as well as to identify the effects of price changes on these indicators. The time horizon of the study covered the years from 2008 to 2018. In the studies, to assess the stationarity of time series, an extended Dickey-Fuller test was used for the model with a free expression and linear trend, a vector autoregression model (VAR) was then constructed and Granger tests and impulse response analysis were performed using the Impulse Response Function (IRF). As a result, it was demonstrated that the response of real estate prices to the impulse from explanatory variables appears between the first and the fourth quarters, and expires after about three years.

Keywords: *real estate market, VAR, causality.*

JEL Classification: *C10, E31, E37, R32.*

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1. Introduction

The real estate market is a well-established collection of interrelated participants in the process of offering and exchanging real estate, consisting in the transfer of ownership rights and rights to use real estate, and the conditions in which these processes are carried out (BELNIAK 2001, KAŁKOWSKI 2003; BRYX 2006; KUCHARSKA-STASIAK 2016). It is an open system, connected to the economic and social environment (FORYŚ 2011), which means that it is capable of exchanging signals with other open systems (OTT 1997). Although the real estate market receives signals generated by changes in its environment, it transmits signals that may affect this environment. As a result, mutual signal coupling may occur. This process is dynamic, which means that, with the passage of time, there is a change in the type and strength of signals and the response of the real estate market or its surroundings. In this sense, the real estate market should be treated as a complex adaptive system with properties of open, dynamic and nonlinear systems, which, subject to the influence of the market environment, evolves in a way that is appropriate for itself between various equilibrium states (BEŁEJ 2016). Therefore, there are adaptation processes on the real estate market and its pace and direction of changes depends on the degree of inertia of this system. Although these processes stimulate real estate prices, they may cause changes in economic, legal or social conditions. In this case, the key issue is determining the cause-and-effect relationship, taking into account the dynamic nature of price-making processes.

The study attempts to identify cause-and-effect relationships, including the response of prices of residential premises to changes in the market environment, as well as the effects of price changes on the economic and social environment. The main objective of the study is to determine causality in Granger's sense (GRANGER 1969) on the housing market, based on a time series including housing prices and selected economic and social indicators. The concept of causality testing formalized using vector autoregression (VAR) models was used for this purpose.

2. Literature review

In the leading trend of real estate market research, particular attention is paid to the multilateral nature of the links between the real estate market and its surroundings. LU and SO (2005) underline the necessity of making a cycle analysis in the real estate sector with the inclusion of a comprehensive analysis of aspects, such as: demography, economics, law, politics and religion. FISHER and GERVAIS (2007) analyzed the impact of changes in the structure of the domestic economy (intensification of availability of mortgages) on the stability of housing investments, as a result of which they demonstrated that demographic changes (reduced pace of household formation, late marriages and stratification of earnings) affect the instability of real estate markets. TROJANEK (2008) made the consumption of households dependent on expectations regarding the future level of income, to which, at the same time, prices of residential real estate react. NOWAK (2014), using autoregressive vector-autocorrelation models, showed the relationship between changes in the price of residential premises and changes in the number of unemployed people, as well as changes in average wages, consequently showing that changes in average wages have a greater impact on housing prices than changes in unemployment levels.

Tests of the causality of macroeconomic conditions and housing prices have been noted in many scientific studies. The determination of causality between housing prices and selected determinants of the housing market (e.g. total household income, short-term interest rates, stock price index, construction costs and renovation costs) was postulated by CHEN and PATEL (1998). Their research resulted in the confirmation (using the Granger causality test, the variance decomposition and impulse response function (IRF) based on the vector error correction model) that all adopted determinants affect the changes in real estate prices, however, a bilateral return effect was only demonstrated between housing prices and the stock exchange index. These studies were continued by CHEN (2001) who, on the basis of changes in housing prices and stock exchange indices in Taiwan in 1973-1992, confirmed the synergy of stock market increases with increases in housing prices, showing that predicting price movements of these assets requires an increase in the role of mortgage rates more than the level of basic interest rates. FORYŚ (2011) showed that both the economic determinants (including GDP, unemployment rate, number of flats handed over, availability of loans, state budget expenditure on housing) and social determinants (including demography, marital rate, divorce rate, birth rate, migration balance) have a significant impact on the development of the real estate market. Through the construction of a multi-sectoral growth model, taking into account construction, industry and services, DAVIS and HEATHCOTE (2005) showed that housing investments are twice as volatile as other investments and are ahead of cyclical fluctuations, while non-residential investments constitute a lagging variable. Having conducted a process of logarithmisation, cleaning up for seasonality, analyzing the cyclicality of the time series from 1963-2012 in the USA using the Hodrick-Prescott filter and with the use of a cross-correlation graph, LIS (2012) showed that the number of new apartments is a factor preceding housing price increases. Based on housing investments, housing prices and housing loans in comparison to cyclical fluctuations of economies in 27 countries of the European Union, LIS (2012) also showed that housing investments are ahead of changes taking place in the economy, and that housing price changes follow the turning points of housing investments. Similarly, LEAMER (2007) indicates that price changes in the real estate market precede recession. Using the VAR models based on the largest Polish cities, DRACHAL (2018) showed that prices in a given city may also react to price changes in other cities. Seeking factors stimulating or destimulating the development of the real estate market, BAUMOHL (2007) carried out an analysis between the offer and transaction price of real estate and the index of real estate availability, the number of sold and offered properties, expenditure on construction, commenced construction and housing market index. CLAYTON et al. (2010) conducted an analysis of housing markets in 114 metropolitan areas in the United States in 1992-2002, where they analyzed both the prices and volume of trade as endogenous variables, as well as examining whether, and how, exogenous shocks cause price movements. In these studies, it was shown that both housing prices and the volume of trade depend on the conditions prevailing in the labor markets, the mortgage market and the stock market, and the effects differ between markets with low and high elasticity of supply.

The presented considerations regarding the relationship between the real estate market and the social and economic environment, as well as methods of testing causality in these relations, may also be supplemented by other studies: ENG (1994); GUO AND HUANG (2010); JINJARAK and SHEFFRIN (2011); KUETHE and PEDE (2011); JANIGA-ĆMIEL (2013); DING et al. (2014); URBANOVSKÝ (2017).

2. Methodology

2.1. Vector-autoregressive models (VAR)

The vector-autoregressive (VAR) models popularized by SIMS (1980) are multi-equation models in which each variable is explained by its own delays and delays of the other explained variables. The basic form of the VAR model can be presented as follows:

$$y_t = A_0 D_t + A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_k y_{t-k} + e_t \qquad (1)$$

where:

y_t - vector of endogenous variables $y_t = \left[y_{1t}\ y_{2t}\ y_{3t}\ \ldots\ y_{nt} \right]^T$,

D_t - vector of deterministic components of equations (constant, trend, binary variables, etc.),

A_0 - parameter matrix with deterministic variables,

A_i - matrix of parameters at i-th delays of the y_t vector,

e_t - vector of random components $e_t = \left[e_{t1}\ e_{t2}\ e_{t3}\ \ldots\ e_{tn} \right]^T$.

Vectors of the residuals should follow classical assumptions (null mean, constant variance, lack of autocorrelation), while simultaneous covariance between the rest of individual equations can be different from null. The order of k delay should be chosen so that it reflects natural interactions and, at the same time, guarantees the lack of autocorrelation of random components.

In model (1), the A_i matrices, by definition, do not contain null elements, so the number of variables on the right of each equation can be quite significant. The estimation of such a model may then be impossible due to the small number of supernumerary observations. The length of the delay should ensure the lowest possible autocorrelation of the components of random equations and, at the same time, guarantee an appropriate number of degrees of freedom (KILIAN, LÜTKEPOHL 2017). Information criteria, such as AIC (Akaike criterion), BIC (Schwartz-Bayesian criterion) and HQC (Hannan-Quinn criterion) can be used to determine the optimal delay length (ENDERS 1995).

When estimating the VAR model, the least squares method is used most often separately for all equations, since explanatory variables are predetermined and thus independent of the random component (lack of endogeneity of explanatory variables). Diagnostics of the VAR model is most often based on LR restriction tests, residual distribution tests and model stability studies (ENDERS 1995; KILIAN, LÜTKEPOHL 2017).

The estimators of the VAR model obtained with the least squares method retain the desired properties only when the time series of observations on variables are stationary (SIMS 1980). Since statistical properties of statistics obtained for non-stationary time series are generally questionable, the essential stage of vector-autoregressive modelling is to examine the stationarity of variables (KILIAN, LÜTKEPOHL 2017). The stochastic process is stationary if the total distribution of random variables is constant. For the analysis of stationarity, the extended ADR Dickey-Fuller test (Augmented Dickey-Fuller test) is most often used (DICKEY, FULLER 1981), which is based on the estimation of the following equation:

$$\Delta y_t = a_0 + bt + \delta y_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta y_t + \varepsilon_t \tag{2}$$

where a_0 is a constant, b is a trend factor, Δy_t is an operator of the first differences. The ADF test checks the existence of a unit root. This means that the rejection of the null hypothesis assuming the existence of the unit element H_0: $\delta=0$ in favor of the alternative stationary y_t process, i.e., H_1: $\delta<0$, allows for the statement that the x_t variable is integrated in the null order or is stationary. If the time series is not stationary, it is necessary to use the methodology typical for studying the dependencies of non-stationary time series in order to avoid the dangers resulting from spurious regression (GRANGER, NEWBOLD 1974).

2.2. Research on causality

Traditional models make it possible to determine the relationships between variables which are not always cause-and-effect relationships. Before estimating the equation, in this case, it should be decided *a priori* which of the variables should be considered as the explanatory variable and which as the explained variable. This problem can be solved using the concept of causality testing, formalized using the VAR models (ENDERS 1995). These concepts assume that, given the two-dimensional VAR model, X is the cause in the sense of Granger's Y, if the current Y values can be predicted with greater accuracy by the past X and Y values than just the past Y values, observing the *ceteris paribus* principle (ENGLE, GRANGER 1987; CHAREMZA, DEADMAN 1992). If X_t and Y_t are stationary stochastic processes, the X_t variable is the cause of Y_t variable when the variance of the prediction error calculated based on the set of all available information at time t is less than the variance of the prediction error calculated based on the set, excluding those contained in the X_t process. The idea of the causality test consists in checking whether the introduction of a given variable to the model together with all delays significantly reduces the residual variance. The most commonly used variant of the Granger test is the Wald variant (OOMS 1994; KILIAN, LÜTKEPOHL 2017). Causality is tested by comparing a model with full information:

$$y_t = \sum_{k=1}^{m} \alpha_{0k} + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{i=1}^{p} \beta_i x_{t-i} + \varepsilon_t \tag{3}$$

with a model with restrictions:

$$y_t = \sum_{k=1}^{m} \alpha_{0k} + \sum_{i=1}^{p} \alpha_i y_{t-i} + \eta_t \tag{4}$$

where y_t is the value of variable Y in period t, while y_{t-i} and x_{t-i} are delayed values of variables Y and X respectively. The null hypothesis then has the following form:

$$H_0:\ \beta_1 = \beta_2 = \ldots = \beta_p = 0 \tag{5}$$

And, in this case, it shows the lack of causality. The test statistics are expressed as follows:

$$G = \frac{N\left[S^2(\eta_t) - S^2(\varepsilon_t)\right]}{S^2(\varepsilon_t)} \tag{6}$$

where: N – sample size, $S^2(\eta_t)$ – model residual variance, in which the variable whose causality is examined does not occur, $S^2(\varepsilon_t)$ – model residual variance, in which there is a variable whose causality is examined. The G statistic is asymptotically coincident with the *chi-square* distribution with the number of degrees of freedom corresponding to the order of delays. For a small sample, multiplication by the number of observations should be replaced with multiplication by $(N-k)/q$, where k is the number of all model parameters, while q is the order of delays. This way, the G statistic is reduced to a figure having a *Fisher-Snedecor F* distribution, with *q* and *N-k* degrees of freedom (CHAREMZA, DEADMAN 1992).

3. Characteristics of the data accepted for analysis

The analysis uses information on the average transaction price of 1m² of residential premises in Poland from the seven largest Polish cities (Gdańsk, Gdynia, Łódź, Kraków, Poznań, Warsaw, Wrocław) and a set of eight macroeconomic indices. Data came from 2008-2018 and related to quarterly observations; its source were databases maintained by the National Bank of Poland (www.nbp.pl), Statistics Poland (www.stat.gov.pl) and www.money.pl. The adoption of such a time horizon resulted, among others, from the fact that, before 2008, the real estate market in Poland was in a period of turbulent changes that would hinder the interpretation of the results of the causality test. A summary of the data presented above is shown in Table 1.

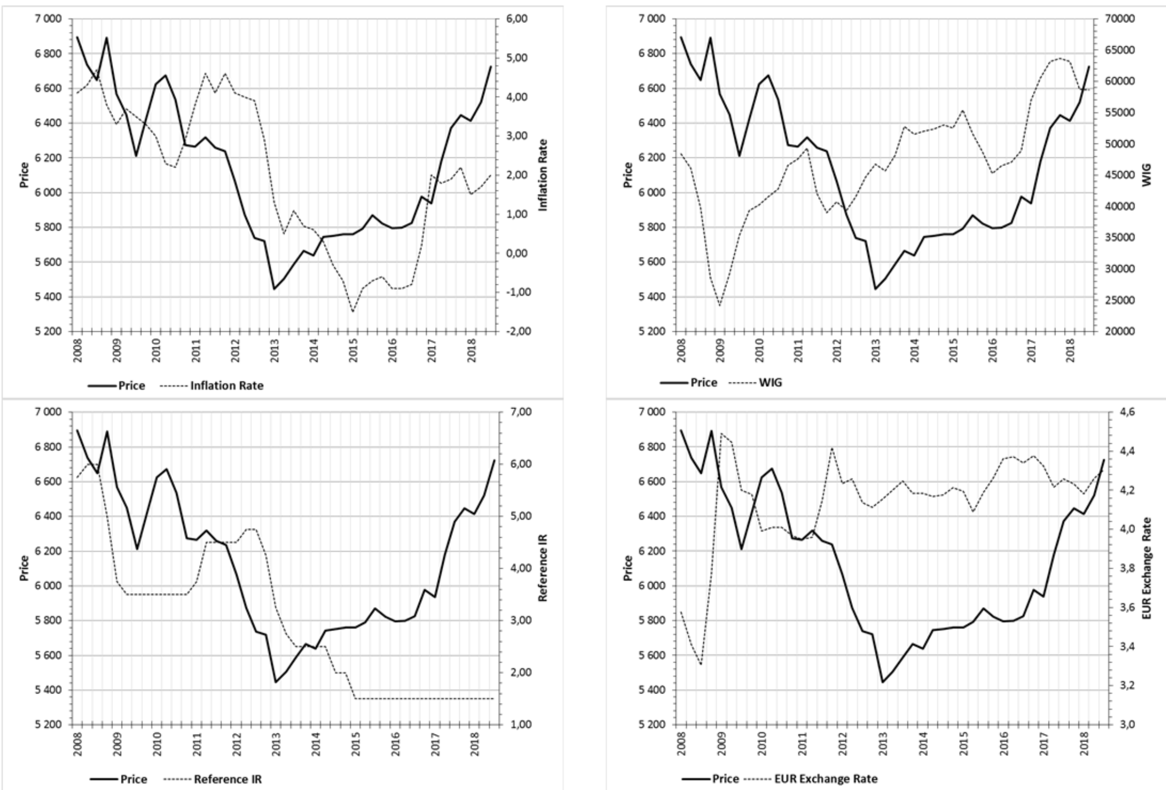
Table 1

List of variables accepted for analysis

Symbol	Description
P	The average price of 1 m² of residential premises on the secondary market from the seven largest cities in Poland
IR	Inflation rate in relation to the same period last year
WIG	Average quarterly WIG index according to the closing rate
RR	Reference rate determined by the National Bank of Poland
EUR	Average EUR exchange rate in relation to PLN
GDP	Gross Domestic Product
UR	Registered unemployment rate
E	Average monthly gross nominal wage in the national economy
ND	Number of new residential premises that have been handed over

Source: own study.

Figure 1 shows the correlation between the average price and the adopted macroeconomic indices.



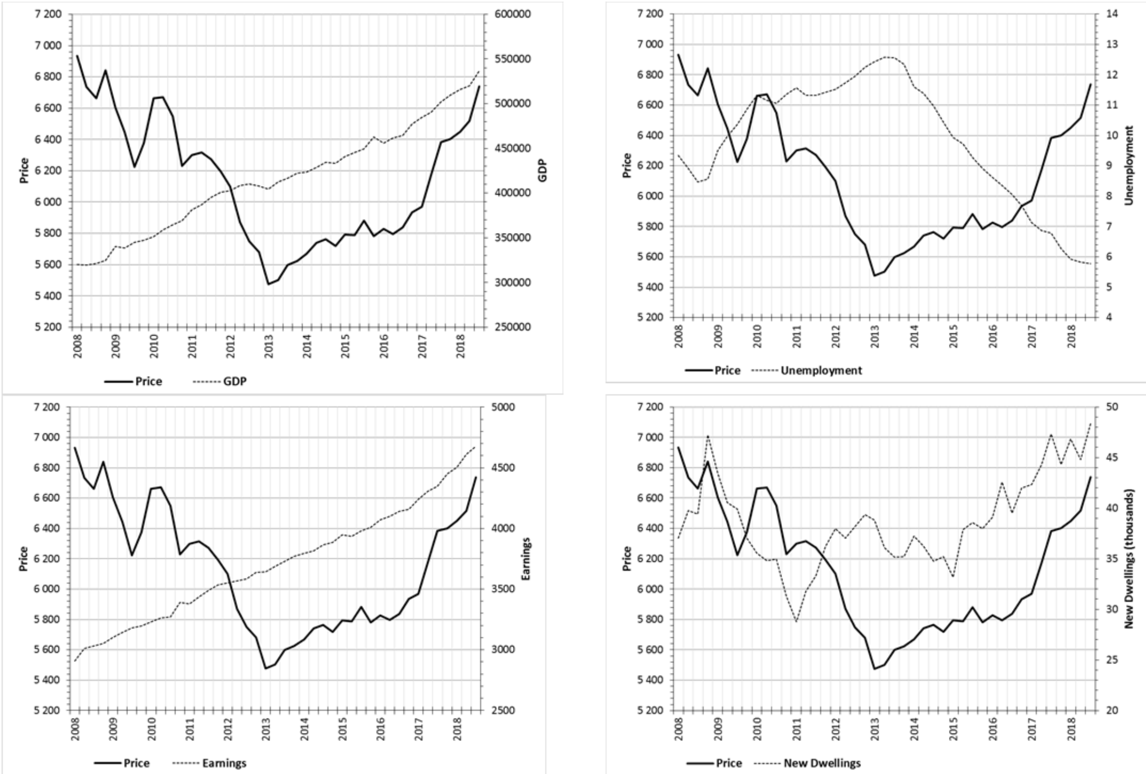


Fig. 1. Macroeconomic indices vs. average apartment prices. *Source*: own study.

In 2008 – 2013, there was a clear drop in average prices. The next five years brought a systematic increase that allowed prices to rise to the level of 2008. The macroeconomic indices, especially GDP, unemployment and wages, indicate the development of the economic situation accompanying the growing housing prices. The cyclical nature of changes in GDP, average salary and the number of new residential premises that have been handed over is noteworthy. Positive correlation with prices can be observed in the case of inflation rate and the number of apartments. For the unemployment rate level, there is a negative correlation with prices, which means that the price increase is accompanied by a drop in the value of this index.

4. Results and discussion

Prior to the analysis, according to the recommendations OF CANOVA (1999) logarithms of variables that represent absolute values were determined. This is particularly important when the first differences are included in the study (increases are then relative). Research aimed at determining causality was carried out in several stages in which the stationary variables were analyzed and a series of two-equation VAR models was then built. In each of them, the average price of 1 m^2 of residential premises was a variable. In the next step, causality was tested using the Granger test and the impulse response analysis was performed.

The extended Dickey-Fuller test for the model with the constant was used for the stationary analysis. This test was carried out for the variable value and for the first differences. The test results are presented in Table 2.

Table 2

Study of stationarity of variables with the extended Dickey-Fuller test

Variable	Test for the variable value		Test for the first differences	
	ADF	p-value	ADF	p-value
lnP	-0.1614	0.9919	-5.8144	0.0001
IR	-1.5490	0.8127	-4.7269	0.0025
lnWIG	-4.7573	<0.0001	-5.0275	0.0001
RR	-3.3384	0.0601	-3.8462	0.0239
lnEUR	-1.8737	0.6681	-6.3891	<0.0001

lnGDP	-1.7483	0.7116	-7.1893	<0.0001
UR	-1.2416	0.9010	-2.9343	0.1515
lnE	-0.4476	0.9859	-9.6742	<0.0001
lnND	-1.7276	0.7212	-7.0888	<0.0001

Source: own study.

P-values lower than the assumed significance level (0.05) indicate that the null hypothesis (lack of stationarity) should be rejected in favor of an alternative hypothesis. The test for the variable value showed that the time series turned out to be stationary only for the lnWIG variable. In the case of other variables, there is no reason to reject the null hypothesis. In the vast majority, the time series for the first differences turned out to be stationary. Therefore, first variable differences were used for further research.

Building a VAR model based on all variables is difficult in this case, due to the rapidly decreasing number of degrees of freedom, taking into account subsequent delays. The number of variables (9) and the adopted units of time (43) allows for the use of maximum third-order delays. Given the low flexibility of the real estate market and its slow response to external stimuli (BEŁEJ, CELLMER 2014), one should consider delays of at least one year. Therefore, causality tests were carried out based on two-equation VAR models which, in this case, allow for the application of higher-order delays. In each of the analyzed models, ΔlnP variable (the first difference in logarithms of average prices) appeared both as the explanatory variable and the explained variable. These models were built on the basis of formula (1), without a trend, taking free expression into account. Tests of delay lengths in individual models indicated that the minimum values of information criteria (AIC, BIC, HQC) correspond to relatively low-order delays (usually 1 or 2). Given the low flexibility of the real estate market, it can be assumed that causality should not be reduced to only such a short period of time. Hence, higher-order delays, i.e. from 1 to 8, are also taken into account. For each of the obtained models, the G statistic was calculated according to formula (7) reduced to the form having the distribution of F statistic. In this case, the null hypothesis reflects the lack of causality. This means that, for significance level values greater than the assumed value of $p = 0.05$, there is no reason to reject the null hypothesis. A significance level lower than 0.05 means that we reject the null hypothesis for an alternative hypothesis (causality occurs). Table 3 presents the values of F statistic together with information on the level of significance for individual models.

Table 3

Research on causality. *F* statistic values for two-equation models with restrictions (p-value in parentheses)

	Order of delay							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
ΔIR→ΔlnP	2.242 (0.143)	1,114 (0.340)	0.568 (0.640)	0.357 (0.837)	0.564 (0.726)	0.587 (0.737)	0.539 (0.794)	0.624 (0.747)
ΔlnP→ΔIR	0.006 (0.937)	0.037 (0.964)	0.634 (0.598)	0.858 (0.500)	0.860 (0.521)	0.808 (0.574)	0.577 (0.766)	0.592 (0.771)
ΔlnWIG→ΔlnP	2.745 (0.106)	**5.023** **(0.012)**	**4.206** **(0.013)**	**2.846** **(0.042)**	2.318 (0.072)	1.634 (0.183)	1.004 (0.457)	0.756 (0.644)
ΔlnP→ΔlnWIG	0.348 (0.558)	0.042 (0.959)	0.058 (0.981)	0.055 (0.994)	2.324 (0.072)	1.711 (0.164)	1.543 (0.210)	0.647 (0.730)
ΔRR→ΔlnP	1.240 (0.272)	0.765 (0.473)	1.658 (0.196)	1.468 (0.237)	1.165 (0.353)	1.456 (0.237)	1.050 (0.429)	1.101 (0.409)
ΔlnP→ΔRR	1.057 (0.310)	2.110 (0.136)	1.651 (0.197)	0.425 (0.789)	0.382 (0.857)	0.306 (0.927)	0.494 (0.828)	0.986 (0.480)
ΔlnEUR→ΔlnP	**5.800** **(0.021)**	**4.181** **(0.023)**	2.262 (0.100)	1.462 (0.239)	1.075 (0.397)	0.786 (0.618)	0.765 (0.622)	0.473 (0.859)
ΔlnP→ΔlnEUR	1.471 (0.233)	0.225 (0.800)	0.595 (0.623)	0.833 (0.515)	0.860 (0.520)	1.164 (0.359)	1.171 (0.362)	0.820 (0.596)
ΔlnGDP→ΔlnP	0.024 (0.878)	0.832 (0.444)	0.198 (0.897)	0.931 (0.460)	1.622 (0.189)	1.822 (0.139)	1.523 (0.216)	1.165 (0.374)
ΔlnP→ΔlnGDP	**5.536** **(0.024)**	2.397 (0.106)	1.461 (0.243)	0.820 (0.523)	0.463 (0.800)	0.356 (0.899)	0.247 (0.967)	0.262 (0.970)

ΔUR→ΔlnP	2.084 (0.157)	1.278 (0.291)	0.988 (0.411)	0.589 (0.673)	0.971 (0.454)	1.569 (0.201)	1.243 (0.327)	1.197 (0.357)
ΔlnP→ΔUR	1.600 (0.214)	3.035 (0.061)	1.314 (0.287)	**4.409 (0.007)**	**4.023 (0.008)**	**2.638 (0.043)**	**3.125 (0.021)**	**3.393 (0.016)**
ΔlnE→ΔlnP	0.085 (0.772)	2.178 (0.128)	1.272 (0.301)	0.462 (0.763)	0.591 (0.707)	0.568 (0.751)	0.739 (0.642)	0.950 (0.503)
ΔlnP→ΔlnE	0.796 (0.378)	1.514 (0.234)	1.149 (0.344)	1.111 (0.370)	0.970 (0.454)	0.912 (0.504)	0.575 (0.767)	0.445 (0.877)
ΔlnND→ΔlnP	3.703 (0.062)	1.683 (0.200)	2.164 (0.112)	0.809 (0.529)	0.831 (0.539)	1.963 (0.113)	1.210 (0.342)	0.975 (0.487)
ΔlnP→ΔlnND	1.386 (0.246)	1.132 (0.334)	0.863 (0.470)	0.956 (0.446)	0.804 (0.557)	1.304 (0.295)	1.448 (0.242)	**2.685 (0.041)**

Source: own study.

Studies have shown that the relationship between the first differences in the inflation rate (ΔIR) and the first differences in transaction price logarithms (ΔlnP) are not causal. The apparent cointegration of IR and P variables (Fig. 1) results, inter alia, from the lack of their stationarity. Irrespective of the order of delay, there is no reason to reject the causality hypothesis. A slightly different situation occurs in the model that takes into account ΔlnWIG and ΔlnP variables. It turns out that, in models taking into account the delay of the second-, third- and fourth-order, there is a significant relationship indicating that the change in the WIG index is the cause of changes in the prices of residential premises. The volatility of asset prices on the securities market is much higher than price volatility in the real estate market, as confirmed, among others, by studies conducted by CHEN (2001) and DING ET AL. (2014). As a result, changes in the Polish WIG stock index react faster to changes in the Polish economy, while the delay of the real estate market reaction from 2 to 4 quarters results from the natural inertia of this market.

The causality test for a model based on the pair of ΔRR and ΔlnP variables indicates that there are no grounds for rejecting the null hypothesis. At the same time, this means that there is no significant correlation between the change in the reference rate and the change in the level of prices. This may seem a bit surprising because interest rates are perceived as one of the most important factors stimulating demand, and as a result - prices. From the model built on the basis of ΔlnEUR and ΔlnP variables, it can be concluded that, in Granger's sense, there is a relationship between the change in the euro exchange rate and the change in prices with a delay of 1 and 2 quarters.

The analysis of the relationship between ΔlnGDP and ΔlnP variables indicates that a causal relationship can be observed at the first-order delay. Figure 1 shows that the GDP value grows in a systematic manner, while the price change is irregular. The analysis of the model taking into account ΔUR and ΔlnP variables, where the explanatory variable is ΔUR, indicates that there is no causality in Granger's sense, i.e. the change in the unemployment rate is not the cause of the price change (results of the causality test in Table 3). However, from the causality test for the equation in which ΔlnP is the explanatory variable, it can be concluded that this variable is the cause of changes in unemployment rates in Granger's sense. This applies to significant delays ranging from 4 to 8, which refers to inertia as an immanent feature of housing markets (BEŁEJ 2017; BRZEZICKA et al. 2018). It can therefore be assumed that price changes stimulate a change in the unemployment rate (UR) with some delay. The level of unemployment in Poland in 2008-2018 was highly volatile. Between 2008 and 2013, the unemployment rate increased from 10% to 13.4%, after which it dropped to 5.5% in 2018. For prices of residential premises, these increased in 2013-2018, which clearly indicates a mutual opposite relationship. The assumptions defined in such a manner are confirmed by LIU ET AL. (2016), who showed that real estate prices and unemployment changed in opposite directions depending on the business cycle. The housing sector, as an important element of the economy, reacts to increases in prices of residential premises by intensifying the supply of property development investments. The implementation of further housing investments requires an increase in employment in this area of the economy, which translates into a drop in the level of unemployment. The demonstrated causality (in Granger's sense) regarding the impact of prices of residential premises on the unemployment level for a series of delays (from 4 to 8) shows the stable, long-term correlation of these factors. Analyzing the relationship between ΔlnE and ΔlnP variables, it was found that there is no reason to reject the hypothesis of the lack of causality in the case of eighth-order delays. The level of remuneration changes, similar to GDP, in a systematic and periodic manner, which confirms its relationship with the economic situation, although it is difficult to demonstrate its direct impact on transaction prices. For relations between the ΔlnND and ΔlnP variables, the causality test indicates that the change in the number of newly handed-over apartments is not the cause of changes in average prices in Granger's sense. The causality test, however, indicates that the effect of ΔlnP on ΔlnND can be observed only at the eighth-order delay. This means that price changes stimulate the change in the number of apartments handed over with a longer time horizon. The analysis performed indicates that:

– ΔlnWIG is a cause of ΔlnP in the case of delays of quarters 2, 3 and 4,
– ΔlnEUR is a cause of ΔlnP in the case of delays of quarters 1 and 2,
– ΔlnP is a cause of ΔUR in the case of delays of 5-8,
– ΔlnP is a cause of ΔlnND in the case of delays of quarters 8.

The existence of links between random components of the VAR model, which is expressed by the non-null simultaneous covariance between the random components of particular equations that make up the model, allows for the creation of structural models [KILIAN, LÜTKEPOHL 2017]. Using this model, it is possible to construct an impulse response function (IRF), which determines the behavior of the j-th variable in response to disturbances in the remains of the k-th variable. The most common method of IRF presentation is a graph showing the change in time and the reaction of the explained variable to disturbances in the value of the explanatory variable. Graphs of the impulse response function are constructed in such a way that the magnitude of the response of the indicator to the change in the explained variable is set back on the ordinate axis, and the time of impact of the impulse, expressed in quarters on the abscissa axis, is set aside. This describes several important elements: the direction of the impact of the impulse, its strength and the distribution over time and the speed of extinction. Figure 2 presents IRF charts for pairs of variables between which the phenomenon of causality occurs.

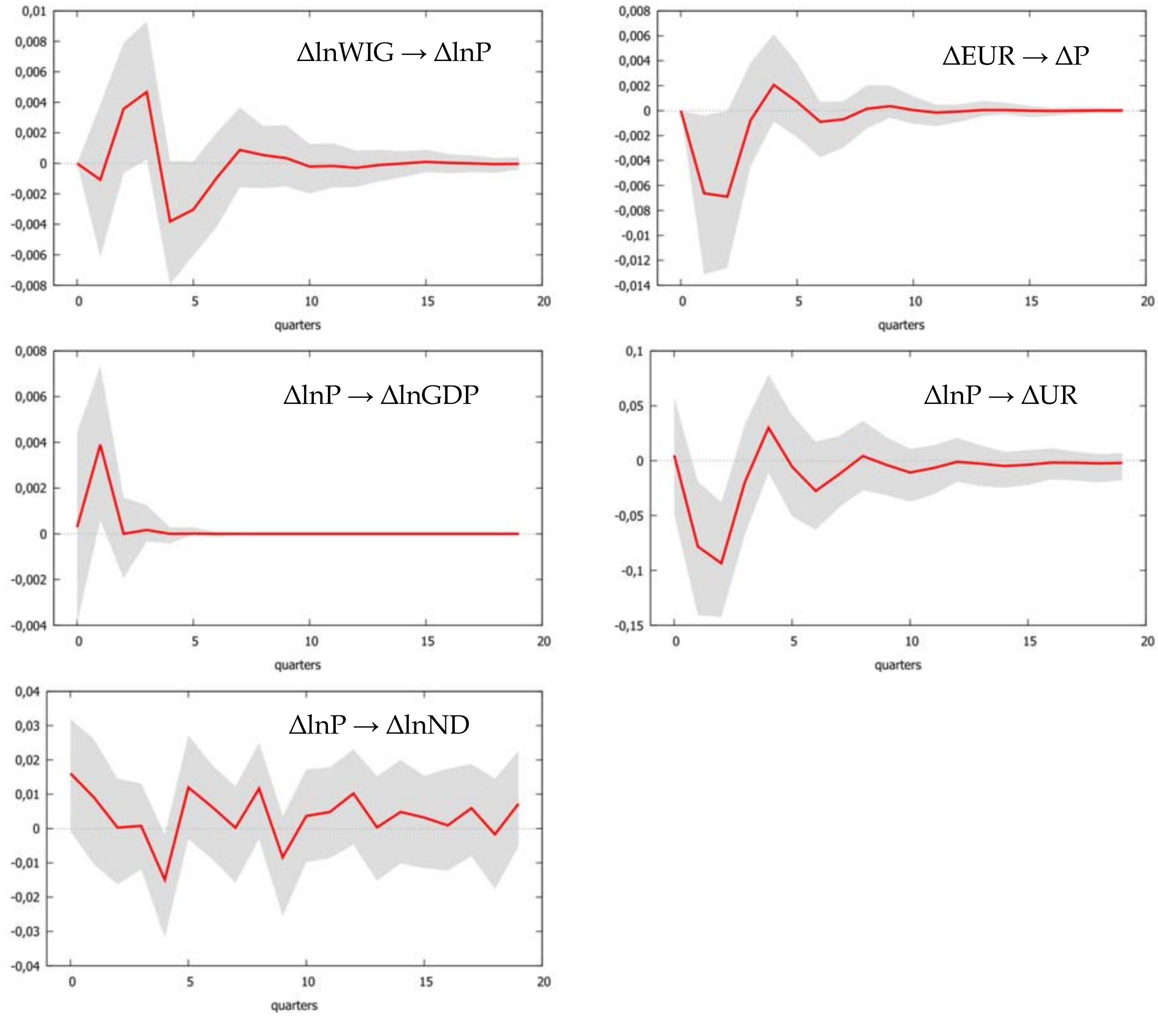


Fig. 2. Responses to the impulse. *Source*: own study.

The ΔlnP response to the ΔlnWIG impulse is not immediate. The reaction, initially negative, changes into a positive one after the second quarter and expires after about 10 quarters. The reaction of ΔlnP to the ΔlnEUR impulse takes place only in the first quarter; it takes the highest value in the third quarter, after which it stabilizes and expires after 10 quarters. The ΔlnGDP reaction to the ΔlnP impulse occurs immediately and is relatively quickly extinguished. Similarly, the ΔUR reaction to the ΔlnP impulse occurs immediately and the fluctuations only expire after a dozen or so quarters. The ΔlnND reaction to the ΔlnP impulse is extended over time. Fluctuations oscillate around null, but disappear only in a longer time horizon.

5. Conclusions

The analysis performed showed that the relationship between changes in prices and changes in the conditions of the real estate market environment can be of a cause-and-effect nature. The immanent feature of the real estate market is its low flexibility which, in effect, affects significant delays (from one to several quarters) between the time of occurrence of the cause and the effect. In the course of the studies, it was shown that changes in the WIG index and the euro exchange rate can be indicated as the reason for price changes. Moreover, it was found that the average change in real estate prices (in Granger's sense) is the cause of changes in the unemployment rate and, in the longer term, the number of newly commissioned apartments. The strongest reaction of changes in real estate prices to the impulse from explanatory variables occurs between the first and the fourth quarters and expires after about three years.

The complex nature of economic relationships in the real estate market makes the actual interdependencies between the level of transaction prices and macroeconomic factors to be of a possibly bi-directional, or even a feedback nature.

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