IMPACT OF THE VOLUME OF DEVELOPER HOUSING UNITS ON REAL ESTATE PRICES IN POLAND: CORRELATION AND COHERENCE ANALYSIS

Daria Wotzka[1], Łukasz Mach[2], Paweł Frącz[2], Bartosz Chorkowy[2]
Marzena Stec[3] and Ireneusz Dąbrowski[4]

[1]Faculty of Electrical Engineering Automatic Control and Informatics,
Opole University of Technology, e-mail: d.wotzka@po.edu.pl
[2]Faculty of Economics, University of Opole,
e-mail: {lmach@uni.opole.pl, p.fracz@gmail.com, bchorkowy@uni.opole.pl}
[3]Narodowy Bank Polski, Regional Branch in Opole, e-mail: 7m.stec@gmail.com
[4]Collegium of Management and Finance, Warsaw School of Economics,
e-mail: ireneusz.dabrowski@sgh.waw.pl

KEYWORDS

Real estate market, seasonality, price volatility, market equilibrium, wavelet coherence, correlation

ABSTRACT

This article conducts a comprehensive correlation analysis to explore the relationship between the development volume by developers and average market prices in Poland's housing sector from 2010 to 2023, utilizing quarterly data on the number of apartments released and their average prices. It employs both linear and nonlinear correlation analysis alongside wavelet coherence analysis. Preliminary correlational analysis offered insights into the basic interdependency patterns, highlighting how developer-supplied apartment numbers impact average prices. Wavelet coherence analysis, a more sophisticated approach, decomposed the data across various frequencies to uncover complex, nonlinear relationship patterns potentially missed by conventional correlation methods. The findings of the study highlight significant connections between the variables that vary over time and space, emphasizing the complexity of the housing market and underscoring the necessity for thorough analysis. These results carry important implications for developers, investors, and housing policy formulation, contributing significantly to understanding Poland's residential real estate market dynamics and supporting further research and strategic real estate industry planning.

INTRODUCTION

The residential real estate market is one of the key markets significantly impacting a country's economic situation. The condition of the real estate market directly influences the macroeconomic and financial stability of the economic system as well as the financial situation of the entities operating within it (Wang, 2021; Mach, 2019; Mach and Rącka, 2018). The condition of the real estate market is undoubtedly affected by the phenomenon of cyclicality, which occurs in the economy (Ben Zeev et al., 2017; Caunedo, 2020; Mandler and Scharnagl, 2022) as well as in the real estate market itself (Pyhrr et al., 1999; Jones & Trevillion, 2022; Devaney and Xiao, 2017). Depending on the phase of the business cycle, we can assess the real estate market as being in a boom or a bust. If there is a boom in the real estate market, it leads to increased activity of its users, whereas a bust decreases user activity (Łaszek and Olszewski, 2018; Łaszek et al., 2017; Chang, 2019; Devaney and Xiao, 2017; Gabrovski and Ortego-Marti, 2019). Prices of mixed-use properties undoubtedly also affect this market (Ghysels et al., 2013; Tsai, 2019; Wang, 2021). According to economic theory, the price level is the result of the actions of the demand and supply sides operating in the market. Market players' actions, over a long period, lead to the achievement of an equilibrium point in the real estate market, which, at least from a theoretical point of view, establishes the market equilibrium price (Fan et al., 2019; Ionașcu et al., 2019; Łaszek et al., 2016; Tsai, 2019). In economic theory, the issue seems simple and easy to model; however, due to its key role in the economy, the residential real estate market is often monitored by the government. State interventionism in the real estate market aims to minimize the risk of crisis on the one hand, but on the other hand can contribute to the disruption of economic laws. (Fernández Muñoz and Collado Cueto, 2017; Tomal, 2019). In Poland, such an example was the government's subsidies for taking out mortgages (the so-called 2% safe mortgage), which, on the one hand, avoid stagnation in the real estate market, while artificially stimulating the demand side of the market.
It is therefore crucial to study the impact of the volume of sales of developer apartments on the sales prices appearing on the market. Investigating and identifying the relationship between the volume of sales of apartments on the primary market and their price will yield knowledge useful to developers for, among other

things, estimating the profit margin they are able to earn on their planned development projects for sale or rent.

DATA USED IN THE RESEARCH

The data subjected to analysis in this article were obtained from the Local Data Bank website, made available by the Statistical Information Center of the Central Statistical Office in Poland. The variables under consideration included: the quantity of apartments released for occupancy by developers, the volume of apartments sold in the primary market, and the mean price of apartments within the primary market, all in form of quarterly time-series from 2010 to 2023. To enhance comparability and facilitate the exploration of interrelations, the data underwent normalization utilizing the Z-score methodology. The Z-score methodology is a statistical technique that quantifies the distance of a data point from the mean of a data-set, in terms of standard deviations. It essentially measures how much a data point differs from the average, considering the variability of the data-set. This method transforms the data into a standardized form, making it possible to compare observations from different scales or distributions. The calculation involves subtracting the mean from the data point and then dividing this difference by the standard deviation of the data-set. By doing so, it facilitates the identification of outliers and the comparison of data across different contexts, providing insights into the relative position of each data point within its distribution. The dynamic behavior of the Z-scored data-sets was graphically depicted across Figures 1 to 3 as blue line.

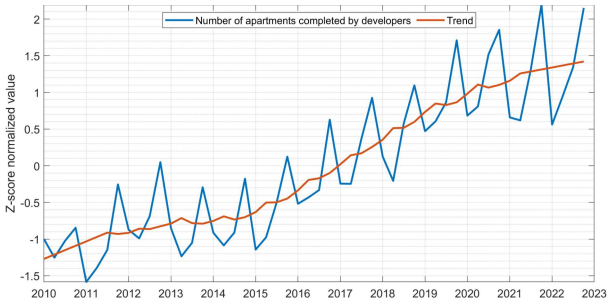

Figure 1: The quantity of apartments released for occupancy by developers and its trend

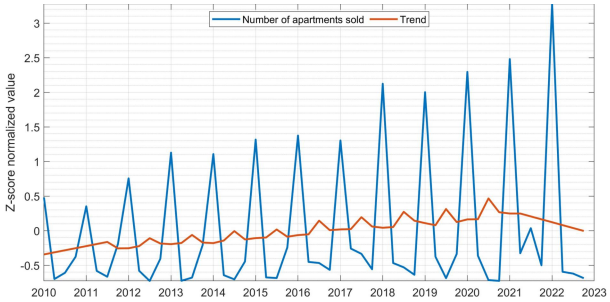

Figure 2: The quantity of apartments sold within the primary market and its trend

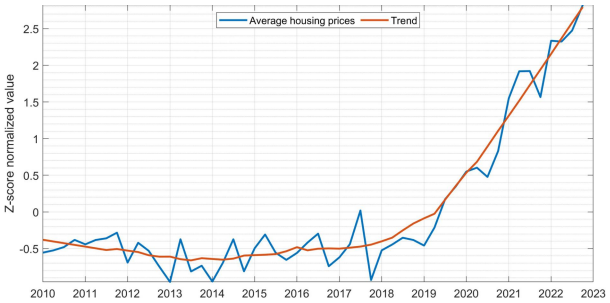

Figure 3: The prise of apartments sold within the primary market and its trend

Following the normalization process, the trend was delineated and the cyclical component extracted employing Sawitzky-Golay digital filters. The trend is indicated as red line in Figures 1-3. In Figure 4, the seasonal components of these variables are juxtaposed for their direct comparison, revealing a similar character in their dynamics. Savitzky-Golay filtration is a technique for smoothing numerical data, used to reduce noise while preserving the shape of the signal. The method involves fitting low-degree polynomials to subsets of data points in a moving window. This allows for the precise determination of local trends and signal characteristics without significantly distorting the data.
Based on the conducted signal processing procedure, the following variables were determined: the number of apartments made available for occupancy (completed) (V3), the number of apartments sold (V2), the average price of apartments (V1), and derivatives: the trend of the number of apartments made available, trend for the average price, and trend for the number of apartments sold, as well as, correspondingly: the seasonal component of the number of apartments made available for occupancy, the seasonal component of the average price, and the seasonal component of the number of apartments sold.

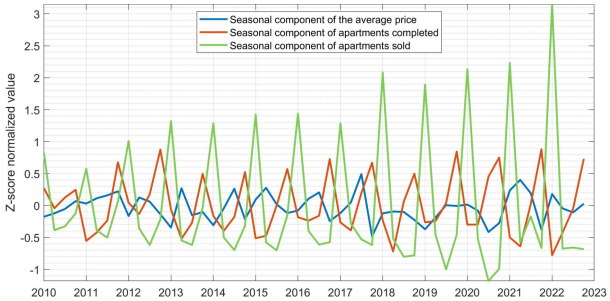

Figure 4: The seasonal components of the three considered market parameters

CORRELATION ANALYSIS RESULTS

In Figures 5 to 7, the scatter of values in three dimensions is depicted, showcasing the relationships among the three considered market parameters. The original data, although normalized, as well as the determined seasonal components and trends, are illustrated separately. Figure 5 displays the original data,

Figure 6 presents the deseasonalized data (trend), and Figure 7 shows the data in the form of the seasonal component. This three-dimensional visualization facilitates a comprehensive understanding of the intricate interdependencies between the variables, highlighting both their individual and combined effects. Through separating the original normalized data from the seasonal components and trends, the analysis provides a nuanced view of the data's underlying patterns and dynamics.

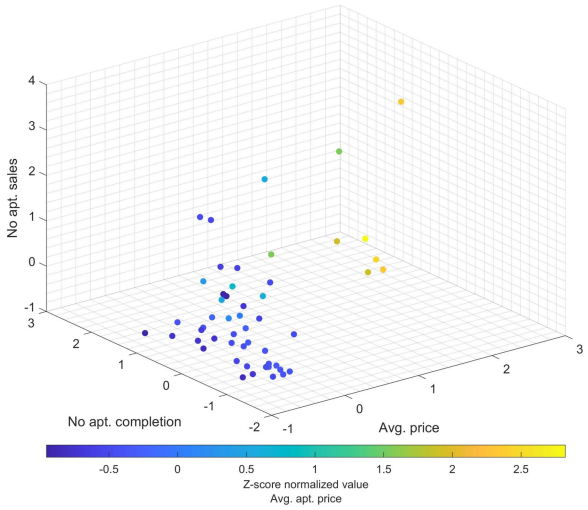

Figure 5: Scatter plot illustrating the dynamics between variables. Concerns to original data

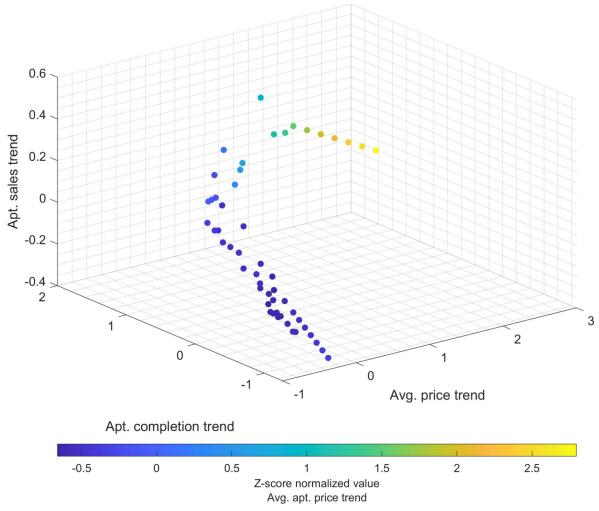

Figure 6: Scatter plot illustrating the dynamics between variables. Relates to the trend

To quantify the similarity in the considered market parameters, correlational analyses were employed, including Pearson's linear correlation analysis as well as Kendall's and Spearman's nonlinear correlation analyses. Pearson's correlation coefficient is a measure of the linear relationship between two variables, quantifying the degree to which they move together. It ranges from -1 to 1, where 1 means a perfect positive linear relationship, -1 means a perfect negative linear relationship, and 0 indicates no linear relationship. The calculation involves the covariance of the variables divided by the product of their standard deviations, essentially assessing how well a linear equation can describe the relationship between the two variables. Kendall's tau is a non-parametric measure used to assess the ordinal association between two measured quantities. It evaluates the strength and direction of the relationship between two variables by comparing the ranks of their data points. Kendall's tau considers the number of concordant and discordant pairs of data points, focusing on the consistency of the ordering in the data pairs across the entire dataset. Spearman's rank correlation coefficient, also a non-parametric measure, assesses how well the relationship between two variables can be described using a monotonic function. It ranks the data points for each variable and then calculates Pearson's correlation coefficient on these ranks. This method is particularly useful when the relationship between variables is not linear but still increases or decreases consistently. Both Kendall's and Spearman's methods do not require normality of the data distributions and are more robust against outliers than Pearson's correlation, making them suitable for ordinal data or when the assumptions of Pearson's correlation are not met.
In Tables 1 to 3, the values of both linear and nonlinear correlation coefficients are presented, calculated separately for the original data, trends, and cycles, across combinations of the variables under consideration.

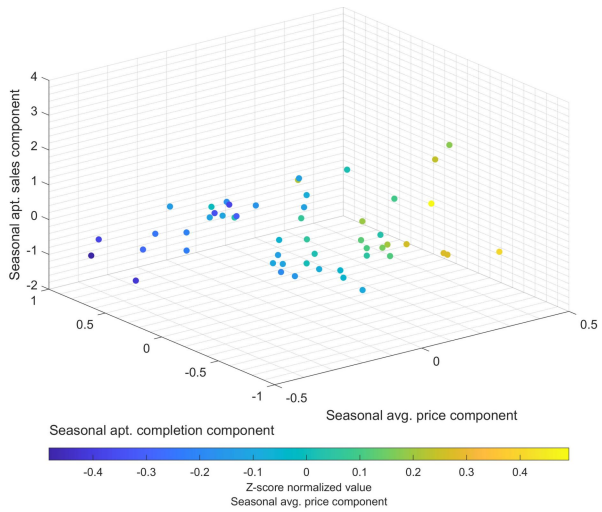

Figure 7: Scatter plot illustrating the dynamics between variables. Concerns seasonal components

It is apparent that the number of apartments completed and theirs average price (variables V1 and V3), when analyzed as original time series, exhibit statistically significant correlations (with a significance level set at 5%), evidenced by a Pearson correlation coefficient of 0.66 and a Spearman correlation coefficient of 0.54. However, these variables demonstrate considerably

weaker correlations, approximately 0.4, when only their seasonal components are analyzed. A strong correlation is observed between number of apartments completed and price (variables V1 and V3), as well as the number of apartments sold and theirs price (variables V2 and V3), when only their trends are considered, with Pearson correlation coefficients exceeding 0.8. Conversely, no correlation is evident between the number of apartments completed and sold (variables V2 and V1) in both the original and seasonal data, and between he number of apartments sold and theirs price (variables V2 and V3) in the original and seasonal data, as determined by the Spearman and Kendall methods.

Table 1: Comprehensive compilation of correlation coefficient values for the original data

Parameters	Correlation coefficients		
	Pearson	Spearman	Kendall
V1&V3	0.67	0.54	0.36
V2&V1	0.09	-0.12	-0.08
V2&V3	-0.02	0.03	0.01

Table 2: Comprehensive compilation of correlation coefficient values for the trend

Parameters	Correlation coefficients		
	Pearson	Spearman	Kendall
V1&V3	0.82	0.74	0.59
V2&V1	0.52	0.63	0.40
V2&V3	0.86	0.88	0.72

Table 3: Comprehensive compilation of correlation coefficient values for the seasonal components

Parameters	Correlation coefficients		
	Pearson	Spearman	Kendall
V1&V3	-0.42	-0.43	-0.31
V2&V1	-0.02	0.03	0.02
V2&V3	-0.37	-0.28	-0.19

WAVELET COHERENCE ANALYSIS RESULTS

As part of the research, wavelet coherence analysis (Grinsted et al., 2004) was performed on a combination of the considered real estate parameters. Wavelet coherence is an advanced data analysis method that enables the understanding of complex relationships between two signals or time series in the time and frequency domains. It facilitates the investigation of how the interdependence between variables changes over time and identifies periods in which the signals exhibit strong synchronization within specific frequency bands. This method is based on wavelet transformation, which decomposes the signal into frequency components over various time periods, allowing for the analysis of local signal properties. Wavelet coherence is expressed as a value between 0 and 1, where values close to 1 indicate strong coherence, denoting a high degree of interdependence between the time series in a given frequency range, while values close to 0 suggest a lack of such relationship. One of the key advantages of wavelet coherence is its ability to detect and illustrate phase and amplitude relationships between time series that may not be visible using traditional statistical methods. This enables a more detailed interpretation of the dynamics of relationships between variables, providing insight not only into whether variables are correlated but also how and when these correlations occur.

Scalograms depicting the outcomes for all nine variable combinations are presented in Figures 8 to 16. The arrows and colors on the charts are instrumental in interpreting the relationships between signals. The arrows indicate the phase relationship direction and nature between two signals. Arrows pointing to the right suggest the signals are in phase, implying synchronous movements of the variables. Conversely, arrows pointing to the left indicate the signals are in antiphase, where one variable reaches peaks as the other reaches troughs. Vertically oriented arrows show that one variable leads or lags the other by a quarter of a cycle. The colors on the chart reflect the coherence degree between signals across different frequency bands; warm colors denote high coherence, signifying a strong dependency between the time series, while cool colors imply low coherence, indicating a weak or absent dependency. Areas of statistical significance are marked on the chart, highlighted by outlines within the color areas, indicating statistically significant coherence between the signals and affirming the reliability of the detected relationships. Areas outside these demarcated boundaries may not be statistically significant, suggesting caution should be taken in interpretation.

Within the here considered data, a period of one quarter signifies fluctuations that recur on a quarterly basis. A period of four quarters, equivalent to one year, indicates annual cycles within the data. Larger period values suggest longer cycles, which may manifest over several years, revealing patterns of change that extend beyond the immediate temporal frame.

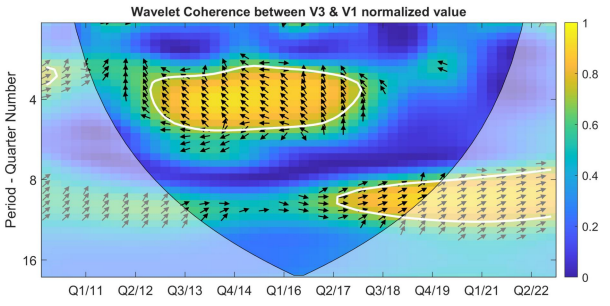

Figure 8: Wavelet coherence scalogram for V1 and V3 original data

The coherence scalogram analysis concerning the relationship between the number of apartments completed and theirs average price (variables V1 and V3, see Figures 8-10), taking into account the seasonal

component, reveals the presence of a strong and statistically significant anti-phase (observe arrows pointing to the left in Figures) correlation with an annual shift, but this is limited exclusively to the period from the second quarter of 2012 to the third quarter of 2018. After this period, a desynchronization was observed, which gave way, allowing for re-synchronization from the fourth quarter of 2019. In the context of classical correlation, the correlation coefficient did not exceed 0.44, whereas the scalogram highlights specific periods of intense coherence, approaching a value of 1. The reintegrated annual correlation observed after 2019 is not reflected in the original data, where a correlation with a mild two-year delay appears. Data corresponding to trends show phase-aligned (observe arrows pointing to the right in Figures) dependencies in biennial cycles starting from the first quarter of 2016 and annual cycles starting from the first quarter of 2021. Anti-phase consistency in the period from the third quarter of 2013 to the first quarter of 2016 is observed for annual cycles, regardless of the signal decomposition. It is noteworthy that the seasonal component has been in anti-phase since the end of 2019, while the trends and original data are in phase.

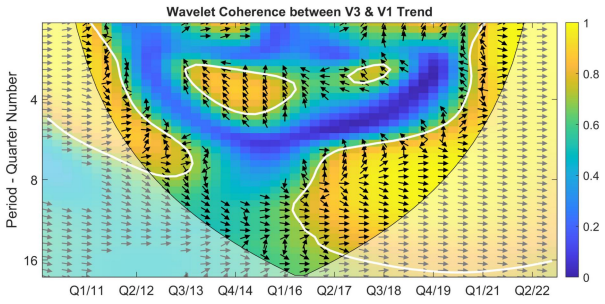

Figure 9: Wavelet coherence scalogram for V1 and V3 trend data

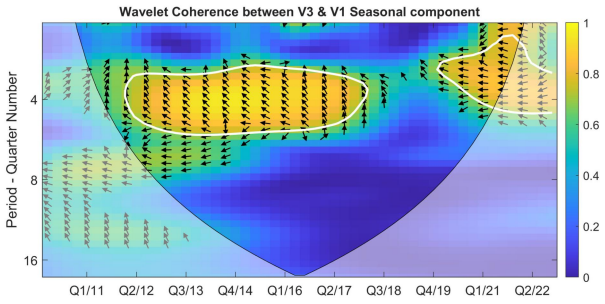

Figure 10: Wavelet coherence scalogram for V1 and V3 seasonal components

The correlational relationships for the pair of variables V1 and V2 (the number of apartments sold and theirs price, see Figures 11-13), when original data are considered, closely resemble the relationship between V3 and V1 (the number of apartments completed and theirs price). Differences in delays stem from the sequence of data processing, thus, these differences can be overlooked. The relationships for the seasonal components of these variables also show similarities. However, for the pair of variables V2 and V1, there exist slight correlations (about 0.6) within the biennial cycle in phase, post-Q2/17, yet they are not statistically significant. Conversely, the trends show significant differences. There is no strong correlation in phase starting from Q1/16 for the biennial cycle, nor in the annual cycle post-2019, as observed with variables V1 and V3. There is, however, a short period of correlation in 2013-2014 in anti-phase. Moreover, a quarter delay is observed around 2017-2018.

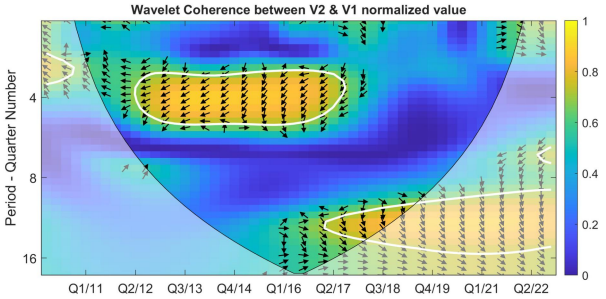

Figure 11: Wavelet coherence scalogram for V1 and V2 original data

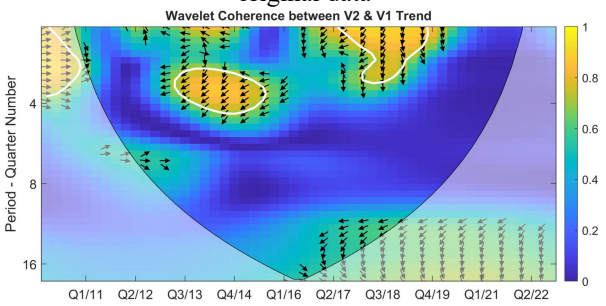

Figure 12: Wavelet coherence scalogram for V1 and V2 trend data

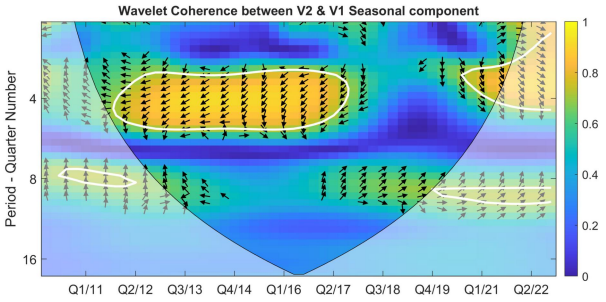

Figure 13: Wavelet coherence scalogram for V1 and V2 seasonal components

The relationships between the pair of variables V2 and V3 (the number of apartments completed and sold, see Figures 14-15) demonstrate a markedly different behavior. Wavelet analysis reveals strong annual correlations for both the original data and the seasonal components throughout the entire dataset. However, regarding trends, there is no annual correlation before the year 2013, but then biennial cycle correlations become apparent, and no correlations are observed post-Q3/2018. For this pair, the benefits of the wavelet method become particularly apparent, as Pearson,

Spearman, or Kendall correlations for the original data and cycles failed to identify any correlations, whereas the wavelet method enabled the detection of strong and statistically significant relationships shifted by a quarter period (observe downward arrows in Figures).

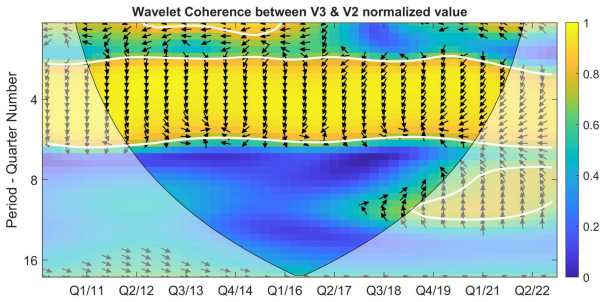

Figure 14: Wavelet coherence scalogram for V2 and V3 original data

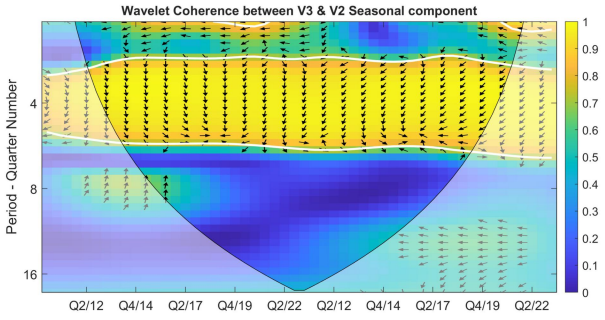

Figure 15: Wavelet coherence scalogram for V2 and V3 seasonal components

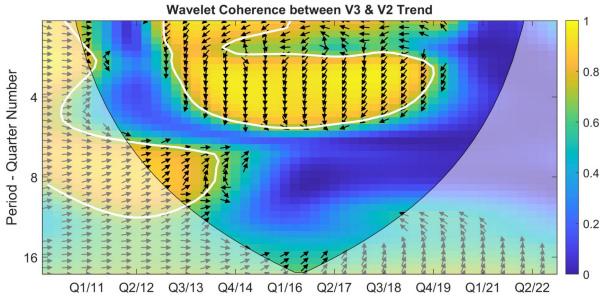

Figure 16: Wavelet coherence scalogram for V2 and V3 trend data

SUMMARY

Wavelet coherence analysis facilitates the identification of intervals during which a strong correlation exists between time series at distinct frequencies, thereby uncovering regular patterns or market trends. This approach allows for the monitoring of how fluctuations in the supply of new apartments impact their prices, an essential aspect of grasping the dynamics within the real estate market. Consequently, investors and analysts are equipped to more accurately interpret current market dynamics and forecast future pricing trends for apartments in the primary market.

The research undertaken has not only validated the utility of wavelet analysis in examining the interrelations among the price, availability, and sales volume of apartments in the primary market but has also highlighted the variability in correlation occurrences. Notably, these correlations were predominantly observed between 2012 and 2017, during which cyclical patterns were analyzed and found to be in anti-phase between the number of apartments made available for occupancy (V3) and the average price of apartments (V1). A notable cessation of correlation was detected from the end of 2017 through the beginning of 2019, particularly when price was a factor. Conversely, the relationship between the volume of apartments made available and those sold demonstrated consistent correlation throughout the entire period under review, trend exclusions notwithstanding.

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AUTHOR BIOGRAPHIES

DARIA WOTZKA received M.Sc. degree in Computer Science from the Technische Universität Berlin, Germany, the Ph.D. and habilitation degree in Electrical Engineering from the Opole University of Technology, Poland. She is a lecturer and research fellow at the Opole University of Technology, Poland. Her research interests include data mining, modeling, and simulation. Her e-mail address is d.wotzka@po.edu.pl.

ŁUKASZ MACH received Ph.D. and habilitation degree in Economics and Finance from the Warsaw School of Economics, Poland. He is a Professor, researcher, and lecturer at the Faculty of Economics and Management at the Opole University of Technology, Poland. His research interests include quantitative methods in economic research, time series analysis, modeling of the residential real estate market, and the analysis of its cyclicality. His e-mail address is lmach@uni.opole.pl

PAWEŁ FRĄCZ is a full Professor, researcher, and lecturer at the Faculty of Economics at the University of Opole, Poland. His research interests include methods of time series analysis, issues in the area of modeling real estate markets, and applications of signal analysis methods in the time and frequency domain in economic sciences. His e-mail address is p.fracz@gmail.com.

MARZENA STEC received M.Sc. Degrees from University of Opole, Poland in the field of social sciences. She is an employee of the Narodowy Bank Polski. Her area of research interest is related to the real estate market. Her e-mail address is 7m.stec@gmail.com.

BARTOSZ CHORKOWY, M.Sc., Ph.D., earned his Master's degree in Economics and a Doctoral degree in Economics from the University of Opole. He is also a graduate of postgraduate studies in Information Systems Management at the Wrocław University of Science and Technology. Presently, he holds the position of Assistant Professor at the Institute of Economics and Finance at the University of Opole. His research interests encompass the determinants and effectiveness of the Polish pension system, analysis of the investment fund market, application of technical analysis methods for mitigating investment risk in the capital market, and the employment of quantitative methods in forecasting financial instrument prices. His contact email is bchorkowy@uni.opole.pl.

IRENEUSZ DĄBROWSKI is a Polish economist and lawyer, holder of a habilitation degree in economic sciences, and associate professor at the Warsaw School of Economics (Szkoła Główna Handlowa) in Warsaw, Poland. He serves as a professor, researcher, and lecturer at the Collegium of Management and Finance, within the Department of Applied Economics at the Warsaw School of Economics. His research interests are focused on the stability of systems, general equilibrium, and evolutionary economics. His e-mail address is ireneusz.dabrowski@sgh.waw.pl.