

Łukasz Mach

Opole University of Technology, Narodowy Bank Polski, Regional Branch in Opole
e-mail: l.mach@po.edu.pl
ORCID:0000-0002-8200-4261

Dariusz Zmarzły

Opole University of Technology, Narodowy Bank Polski, Regional Branch in Opole
e-mail: d.zmarzly@gmail.com
ORCID:0000-0001-9421-4277

Ireneusz Dąbrowski

SGH Warsaw School of Economics, Narodowy Bank Polski
e-mail: ireneusz.dabrowski@sgh.waw.pl
ORCID:0000-0001-5353-7985

Paweł Frącz

Narodowy Bank Polski, Regional Branch in Opole
e-mail: pawel.fracz@nbp.pl
ORCID:0000-0003-1677-6084

A TIME-FREQUENCY ANALYSIS OF THE HOUSING CONSTRUCTION TIME AS THE BASIS FOR MAKING DECISIONS ON THE CONSTRUCTION MARKET (THE CASE STUDY OF POLAND)*

DOI: 10.15611/pn.2020.8.05

JEL Classification: R11, R15

© 2020 Łukasz Mach, Dariusz Zmarzły, Ireneusz Dąbrowski, Paweł Frącz

This work is licensed under the Creative Commons Attribution-ShareAlike 4.0 International License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-sa/4.0/>

Quote as: Mach, Ł., Zmarzły, D., Dąbrowski I., and Frącz, P. (2020). A time-frequency analysis of the housing construction time as the basis for making decisions on the construction market (the case study of Poland). *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 64(8).

* The paper presents the personal opinions of the authors and does not necessarily reflect the official position of the Narodowy Bank Polski or the Warsaw School of Economics or the Opole University of Technology.

Abstract: Due to the increasingly complex market situation characterized by the growing variability of its determinants, making accurate decisions is riddled with an increasing risk of error. Widely used economic methods for analyzing market phenomena with a trajectory of time series has proved insufficient in many cases. Hence, it becomes necessary to seek more precise analytic methods, based on which it is possible to obtain more precise mapping and relations in real-life activities. The goal of the present study is to apply the time-frequency analysis in the domain of real estate. Based on the application of, among others, Savitzky-Golay filtering, spectral density analysis, or cross-correlation, the time-frequency analysis will render it possible to precisely identify the parameters that selectively determine the housing market. The obtained results will make it possible to decrease the informational gap in the investment decision-making process in the housing market.

Keywords: housing construction, time-frequency analysis, the Savitzky-Golay filter, spectral density, cross-correlation.

1. Introduction

A time-frequency analysis of the process of housing construction in Poland is an extremely important issue. As a multidimensional research category, the real estate sector may be analysed from technical, spatial, or economic perspective. Considering the economic perspective, the sector should be understood as an opportunity to allocate resources with concurrent interaction between supply and demand, where market mechanisms ensure its proper functioning. The current and expected parameters of the market's supply and demand aspects significantly influence the creation of market potential for investment and rental on the real estate market (Zheng, Xia, Hui, and Zheng, 2018). The potential of the investment market and the rental market has direct implications on the construction market, which, combined with the real estate market creates a coherent whole, known as the real estate sector. Construction and the real estate markets form a kind of a connection between the end-clients and the developers and construction sector investors. This is why the precise examination of selected time-frequency relations of the construction market is crucially significant for satisfying future optimal housing needs. The use of time-frequency analysis for the parametrization of selected stages of the construction process renders it possible to examine and directly determine the relations between the number of building permits, the number of initiated housing investment projects, the number of new apartments released for use, as well as, indirectly, the purchasing capabilities on the demand side of the equation. This time-frequency analysis may form the basis for optimizing the decision-making processes undertaken by the demand and supply sides of this very market. Such an optimization is necessary for achieving the balanced development of the real estate sector. As a result, it will be possible to precisely attend to maintaining market balance on this market and to prevent the creation of speculative bubbles.

2. A literature review on the time-frequency analysis within the framework of the real estate market

In conducting a literature review of the examined research domain, the authors attempted to describe the current state of knowledge, with a special emphasis on analysing the process of how the examined phenomena develop over time (time series) on the real estate market. Publications describing the topic of investing in real estate became one of the thematic groups identified among the analysed academic output. The first such article undertook to assess whether foreign capital is responsible for real estate price changes in such global cities as London and New York, especially in crisis situations. In its analytical framework, the paper used large data sets of housing transactions and determined that foreign risk significantly influences housing prices. The effects are of a long-term character and are associated with the outcome of secure investment in real estate as well as migration, which significantly influences the price of housing stock in global cities (Badarinza and Ramadorai, 2018). Later studies analysed the justification of investing in various options while considering whether returns on investment in real estate stock reflect trends on the stock market. The relations between real estate stock were examined in correlation with private real estate investments (Devaney and Xiao, 2017).

A presentation of the opportunities for diversifying the investment portfolio through investment funds in real estate was the next important research topic (REIT) (La and Mei, 2015; Piao, Mei, and Xue, 2016). The paper by (Taderera and Akinsomi, 2020) attempted to answer the question of whether investing in commercial property is a good safeguard against inflation. Using the vector error correction (VEC) model for coordinated time series, the authors scrutinized the long-term interaction between return on real estate and inflation, and examined whether inflation fuels the return rate of investment in real estate.

Publications dealing with a wide range of risks formed the next group of reviewed papers. Assessing crediting risks and real estate financial investment risks is important in decision-making. The study by (Bessler, Kurmann, and Nohel, 2015) showed that in a period of crisis, credit risk and the risk of real estate financing are very high and are often detrimental to the business of the company. Another undertaken risk analysis relates to its appraisal in the real estate investment process, in both the private and public sectors. The study used an asset valuation approach to estimate the exposure of private property funds to risk factors both in the private and public markets. The analysis included the creation of specific performance indicators and the use of methods to address some of the inherent problems with data coming from private property funds, such as the high degree of serial correlations observed in total reimbursements (Farrelly and Stevenson, 2019). Another analysis of the issue under discussion in the area of risk assessment concerns the examination of the occurrence of crisis situations in combination with political changes. The paper presents a wavelet analysis with minimax threshold, which is a widely used and

effective approach to analysing residential property data (Hui, Liang, Zhong, and Ip, 2016). Other studies in time series and real estate market analyses refer to identifying points of sudden shifts with the use of empirical distributions and reveal their influence on the economy as a whole (Lam, Yu, Choy, and Leung, 2016), while the influence of location on real estate pricing was examined by (Fernandez, Mukherjee, and Scott, 2018). Some studies examine the relations (with the use of dynamic modelling) between real estate cycles and population numbers (Fernández, Marrón, and Rodríguez, 2016). The next study shows multidimensionality of changes in the sustainability of the dividend and the price to change in the NASDAQ composite indicator (Leone and de Medeiros, 2015). The main goal of a recent study (Li, Sun, and Boersma, 2019) is to determine the side effect of regulatory politics with regard to real estate, imposed by main cities upon surrounding towns in various urban agglomerations on the basis of regional connections characteristic to the Chinese real estate market. The referred to range of studies that used time series analysis also included papers describing shaping of the value of land (McAllister, Shepherd, and Wyatt, 2018) as well as those that identified the determinants of city development in terms of real estate market development (Zhang and Su, 2016).

A precise analysis of the real estate market is also possible with the use of time-frequency analysis. The literature review of the real estate market from the perspective of time-frequency analysis confirms its significance in the decision-making processes.

3. Validity of the analysis of housing construction process in terms of time-frequency

Taking account of the time criterion for real estate management is very important. In the case of time-frequency studies of the housing construction process, it is equated with the period, during which changes in the examined resource occur. This assumption implies considering the demand and supply side as stream variables, meaning that it will directly affect developer activity on this market. This is why a precise analysis of the relations between the number of completed dwellings, the number of initiated investment projects, and the number of the newly completed dwellings is important in order to maintain the logic that characterizes the mechanism of cyclicity on this market. Many studies describe the economic, social, geographic, or technical situation on the real estate market by means of analysing stages of the construction process, hence examining the influence of such factors as the number of building permits, the number of started construction projects, and the number of completed new dwellings on this market, among others. Based on the findings identified in urban economics and public finance literature, it is possible to state that local politicians exert an influence on creating a number of building permits, which then translates onto balanced development of the real estate market and optimizing migration processes (De Witte, Geys, and Schönhage, 2018). Other studies revealed

that the significance of building permits as well as the complicated legal situation of obtaining them resulted in developing a cloud-based framework for activities supporting inhabitants as well as clerks in the process of issuing building permits (Eirinaki, Dhar, Mathur, Kaley, Patel, Joshi, and Shah, 2018). Another important study determined the relation between land price and administrative processes in the domain of the real estate market (such as decisions about the number of granted building permits) (Gluszek and Zygmunt, 2018), while (van Vuuren, Kjellander, and Nilsson, 2019) discuss another important issue, i.e. that of the proven influence of positive decisions in terms of issuing building permits for refugee accommodation on the decrease of house prices in their most immediate vicinity. The above examples of studies that examined the influence of the number of granted building permits on the region's economic or social situation prove that precise time-frequency analysis of the number of building permits is justifiable and makes it possible to conduct precise analyses of this issue. One can also observe an analogous situation on the two remaining stages of the construction process, i.e. started construction projects and completed new housing. In this situation, an analysis of their value was a condition for the parameterization of the economic situation of the region as a whole.

To sum up, the time-frequency analysis conducted in this renders it possible to clarify the various relations and relationships in the real estate market, examples of which are set out above.

4. A time-frequency analysis of housing construction time in Poland

A time-frequency analysis was conducted for three variables that reflect components of the stages of the construction process, i.e.:

- granted building permits,
- started construction projects,
- completed new housing.

The time-frequency analysis was carried out for the above variables in a number of key analytical stages. The first one was a graphic presentation of time series for each of the analysed variables. Stage two applied Savitzky-Golay filtering in order to smooth the examined time series. Then, the authors identified the periodical components with the use of spectral density analysis of the examined time series, and in the next stage created spectrograms for the examined variables, whose purpose was to smooth the occurring periodicity. Finally, cross-correlation was used in order to examine significant correlations between the examined variables.

From a macroeconomic development perspective, data shown in Figure 1 can be broken down into three distinct periods of time. The first was between 2005 and 2009, when the real estate market grew very dynamically in Poland. This dynamic (increase in the number of building permits) was caused by many factors, two of which were key from the economic perspective, namely the relative ease in obtaining

finance for house purchase by means of credit, as well as the stability or even the progressive improvement in economic prosperity.

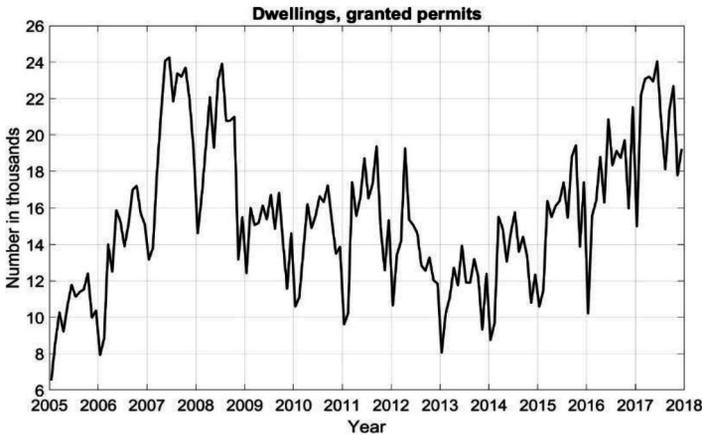


Fig. 1. Granted building permits in Poland

Source: own study based on the Central Statistical Office data.

The second period, characterized by decline in the number of granted building permits was between 2009 and 2013. The change in the developmental tendency for the number of granted building permits in 2009 was dictated by the global economic crisis that originated from the American real estate market in 2008 (Coombs and Laufer, 2018; Degl’Innocenti, Grant, Šević, and Tzeremes, 2018; Gallegati and Delli Gatti, 2018; Makin, 2019; Manjunath, Baghel, and Kumar, 2019). Starting from 2013, one can note the period of time when the phenomenon under discussion saw growth again. Assuming that the number of granted building permits reflects investor sentiment in the real estate market, one may assume that in the opinion of investors, the economic crisis ended in 2013.

On the other hand, from the perspective of seasonality, one can note that the 2nd and 3rd quarter of each examined annual period is characterized by a larger number of granted building permits, in comparison with the 1st and 4th quarters.

Figure 2 presents the number of dwellings built in Poland between 2005 and 2018. Analogously to the first analysed variable (granted building permits), the authors noted three characteristics of the developmental tendency in started construction projects. Between 2005 and 2009, as well as in 2013-2018, there was a growing trend, and between 2009 and 2012 decreasing characteristics were observed. The period of negative change dynamics was caused by the effects of the global economic crisis.

Figure 3 regarding completed dwellings, shows a single outlier value obtained in December 2008. It is important to note that this value is real despite departing significantly from the expected value. The significant increase in the number

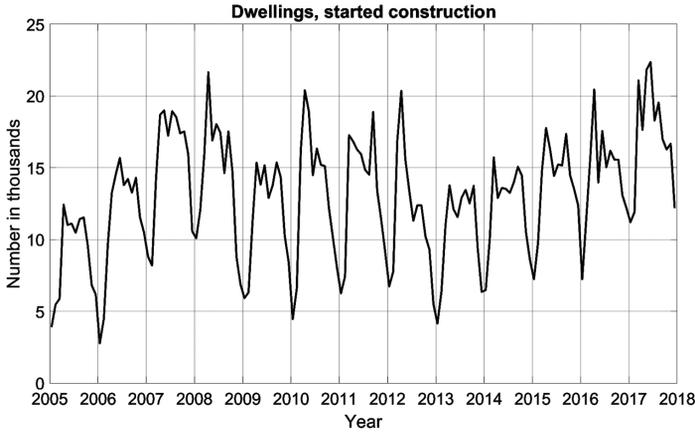


Fig. 2. Number of started construction projects in Poland

Source: own study based on the Central Statistical Office data.

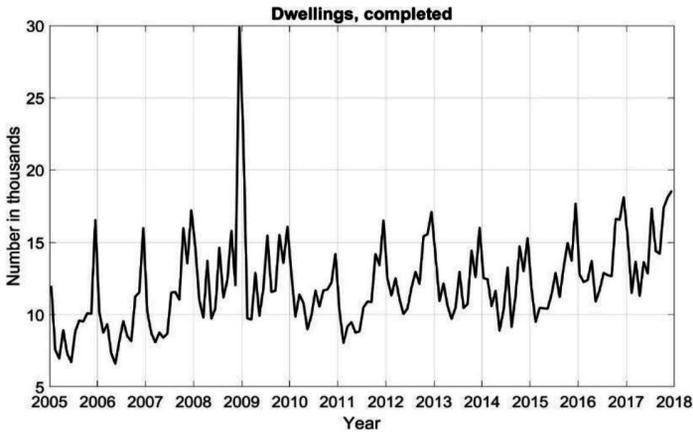


Fig. 3. Completed new dwellings in Poland

Source: own study based on the Central Statistical Office data.

of completed dwellings results from two coherent and co-existing factors, namely the legal changes that took place in the described period, as well as from of the constructed dwellings themselves. Starting from January 2009 it became obligatory to present a document known as an “energy performance certificate” when releasing a newly constructed dwelling for use. Considering the fact that in 2008 in Poland the majority of completed housing was released by individual investors, the new law resulted in two aspects for these investors, namely cost and investment uncertainty, which brought about a significant increase in the number of completed dwellings.

In attempting to define whether periodical or seasonal variations took place in the examined time series, the authors performed two transformations of those time series. The first was based on applying the Savitzky-Golay filter whose aim was to initially determine seasonal and periodical variations, and the authors applied the Savitzky-Golay filter with the smooth constant at $k = 5$, whereas for identifying periodical variations the Savitzky-Golay filter with the smooth constant at $k = 35$ was used.

While interpreting seasonal variations, one can note that each examined variable in each examined year is characterized by a similar characteristic of monthly variations. Two of three examined variables, namely granted building permits and started construction projects are characterized by nearly identical phases of monthly changes (see Figures 4 and 5 for comparison). Their values are the lowest in the beginning and at the end of the year.

When describing the observed seasonality in individual years for the third variable, namely completed new dwellings, the authors noted that the character of changes is similar to previously described variables, but the observed seasonality is characterized by a shift with regard to the previously described variables. This makes it possible to state that in an annual framework, the largest number of completed dwellings is released close to the end of the year (Figure 6).

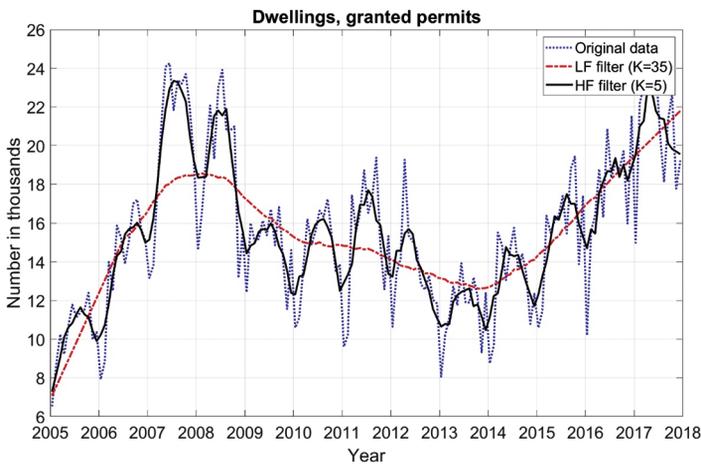


Fig. 4. Granted permits; low and high frequency Savitzky-Golay filter applied

Source: own study.

When analysing the next harmonics, namely the periodical component, one can observe cyclical fluctuations, as illustrated by Figures 4 to 6. Those cyclical fluctuations for two variables in particular, namely the number of granted building permits and dwellings under construction, have identical characteristics, whereby the local minimum is observed in 2012-2013 and the local maximum in 2008-2009. Interpreting the observed local maximums, they can be justified by real estate market

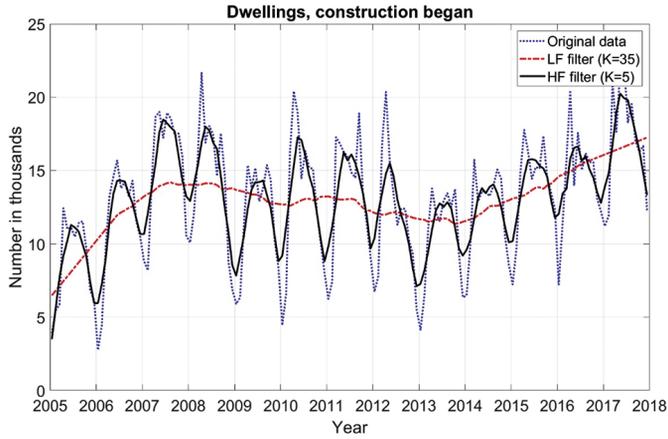


Fig. 5. Data for started construction projects; low and high frequency Savitzky-Golay filter applied
Source: own study.

boom, and the minimums observed for the period 2014-2014 can be interpreted through the neutralization of the influence of the global economic crisis on the condition of the real estate sector.

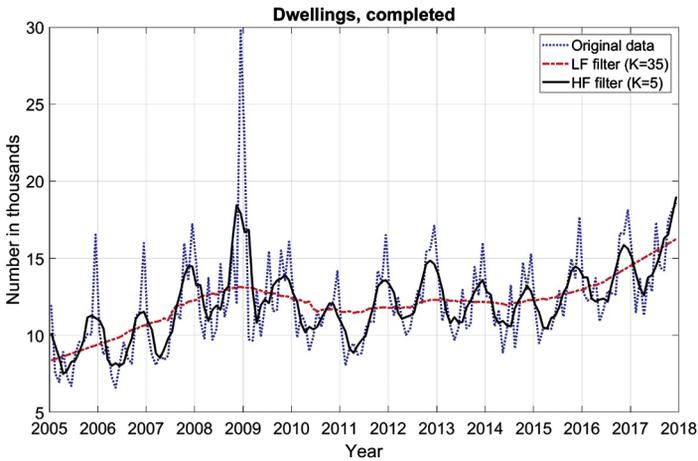


Fig. 6. Data for completed new dwellings; low and high frequency Savitzky-Golay filter applied
Source: own study.

Describing the third variable, namely completed dwellings, one can note a certain time shift in comparison with the previously described variables as well as a lower

amplitude of observed cyclical fluctuations. Figure 7 shows the economic cycles and their phase shift.

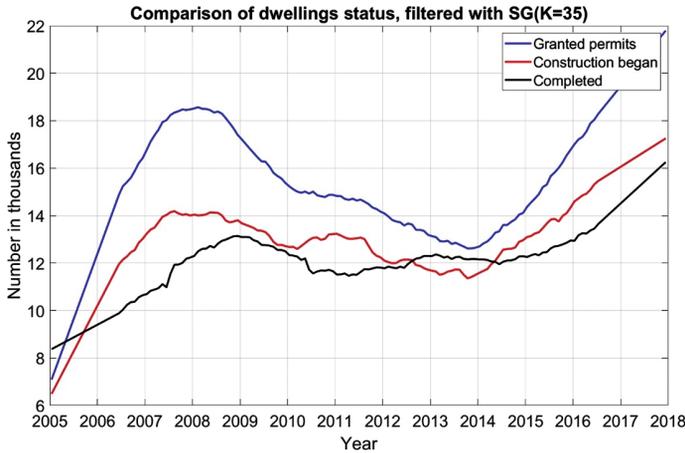


Fig. 7. Comparison of dwellings status, filtered with S-G ($k = 35$)

Source: own study.

In attempting to parametrize the observed periodical (cyclical) fluctuations, the authors created power spectral density charts that show leading periodicities. When analysing the variable that describes granted building permits, one can note two leading delays. The first is a $\frac{1}{4}$ -year (quarter) delay, and the other is a $\frac{1}{2}$ -year (half-year) delay. In summary, one can state that investors intensify their activity in half-year time periods, with greater quarterly intensification (see Figure 8). Half a year is the leading periodicity that results from the power spectral density conducted for the started construction projects variable (Figure 9).

The periodogram obtained for the completed new housing variable needs attentive interpretation. It shows the three leading periods, namely a quarter of a year, a third of a year, as well as half a year. These three periodicities with various frequencies for this variable can be explained by the fact that the characteristic of this variable absorbs investor activities from the two previous phases of the construction process, i.e. the phase of granted building permits and the phase of started construction projects (Figure 10).

An indication of time periods during which leading periodicities were characterized by activity forms further specification of this research. In the case of the number of granted building permits variable, the 2011-2012 period of highest activity can be interpreted as the increase of business activity of construction market investors that followed the global crisis of 2008. Quarterly periodicity can also be observed for 2014-2017. The second leading periodicity is a half-year, identified for 2007-2008 (see Figure 11).

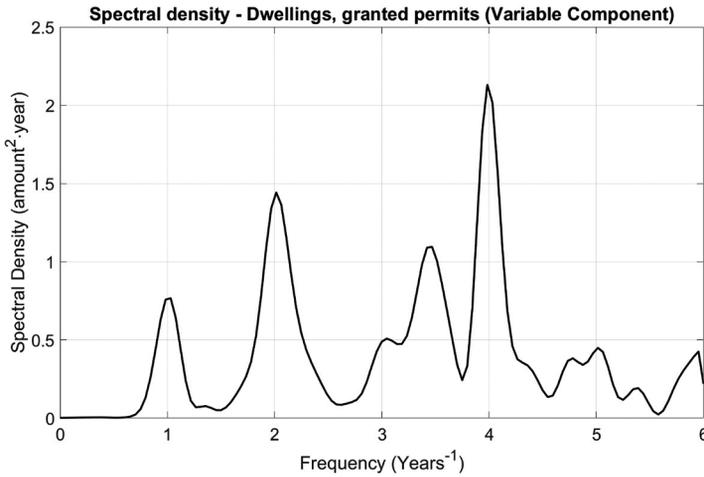


Fig. 8. Power spectral density of the granted building permits variable component

Source: own study.

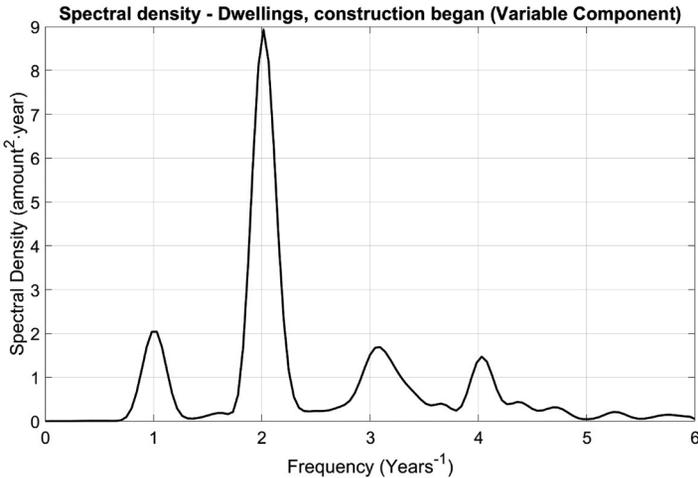


Fig. 9. Power spectral density of the started construction projects variable component

Source: own study.

When analysing the spectrogram obtained for the started construction projects variable, one can note a leading half-year periodicity, with highest activity between 2009 and 2013 (see Figure 12). However, in the case of the completed new dwellings variable, the period of 2008-2009 is significant primarily for quarterly, but also the four-month and half-year periodicities (see Figure 13).

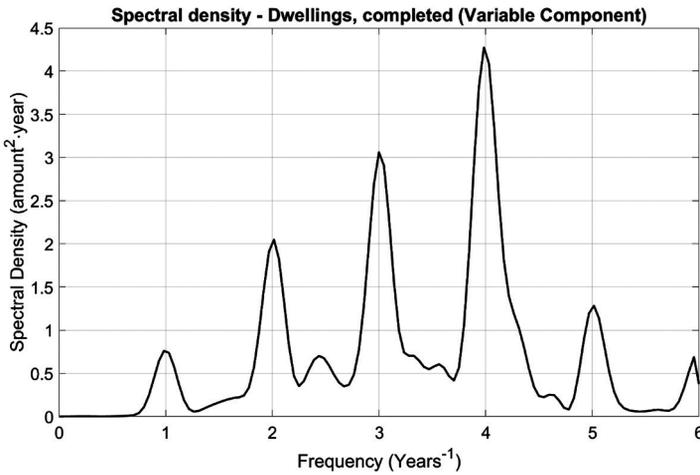


Fig. 10. Power spectral density of the completed new dwellings variable component

Source: own study.

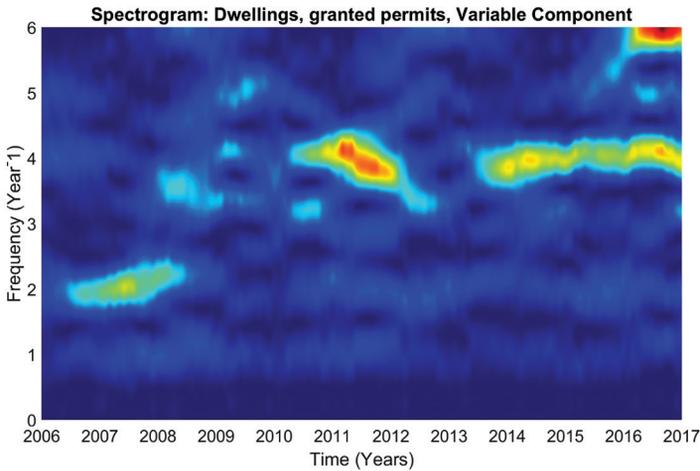


Fig. 11. Spectrogram of the granted building permits variable component

Source: own study.

In order to complete the previously conducted time-frequency analysis, the authors verified the relations that exist between and among the examined variables. These relations were examined with the use of cross-correlation of two time series (Figures 14 and 15).

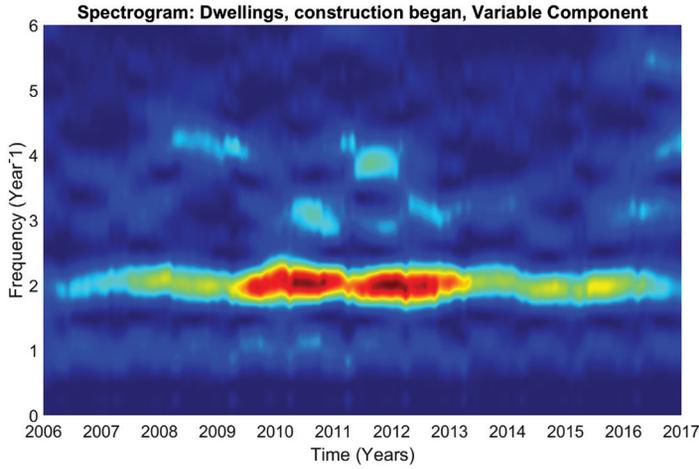


Fig. 12. Spectrogram of the started construction projects variable component

Source: own study.

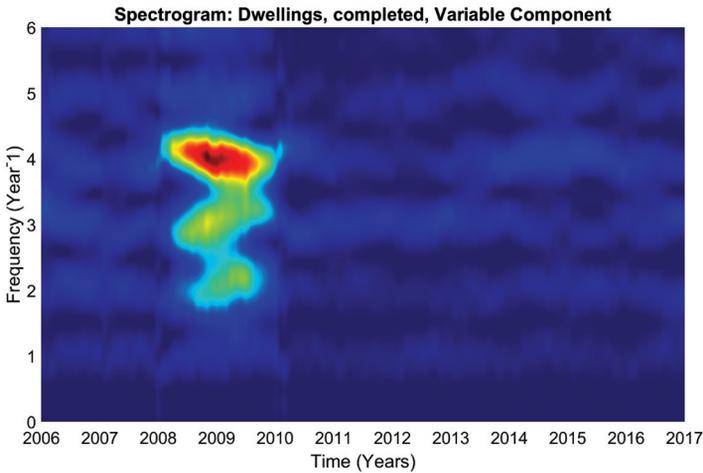


Fig. 13. Spectrogram of the completed new dwellings variable components

Source: own study.

The first relation under examination is the influence of the number of granted building permits on completed new housing projects. It is important to note that almost all cross-correlations between the variables under examination are characterized by the time interval of 12 months. This shift shows a ‘significant’ delay of the examined variables by a value of yearly multiplicity. On considering data obtained from multi-family real estate investors, the authors were able to formulate the thesis that

the most probable shift that takes place in the case of a single investment between granted building permits and completed new dwellings amounts to 27 or 40 months.

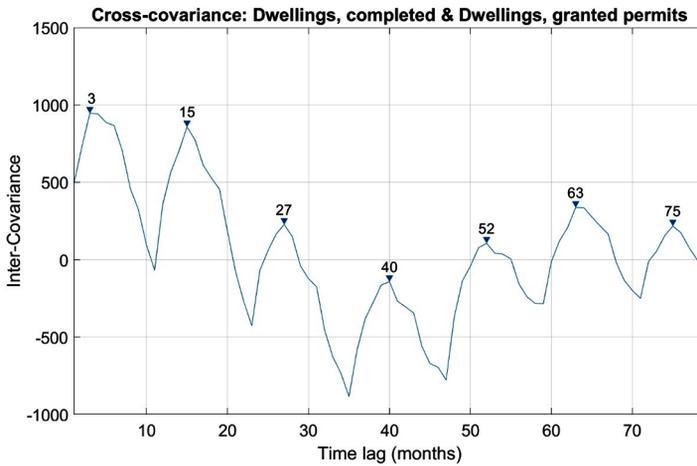


Fig. 14. Cross-correlation between granted building permits and completed new dwellings

Source: own study.

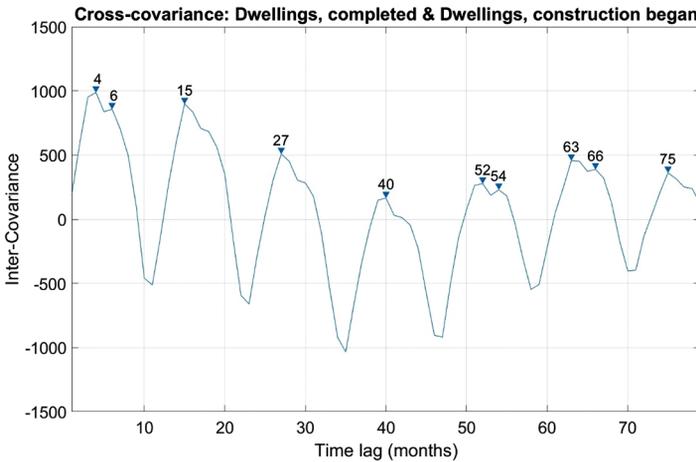


Fig. 15. Cross-correlation between started construction projects and completed new dwellings

Source: own study.

A more complex situation takes place in the case of a cross-correlation between the variables of started construction projects and completed new dwellings. This complexity results from the fact that the started construction projects category is not anchored in a single time point, but rather is blurred over time. Assuming the logic of

vigorous activities one may assume that since there are determinants in the economy that promote developer activity, a significant majority of investors start to construct new housing. Thus the closely concomitant time correlations (i.e. 4 and 6; 52 and 54; 63 and 66) may confirm two or three-month investment time shifts between and among developers.

5. Conclusion

The applied time-frequency analysis for the parametrization of select stages of the construction process made it possible to directly identify the relations between the number of granted building permits, the number of started construction projects, the number of completed new dwellings, and, indirectly, the purchasing ability appearing on the demand side of the equation. This may lead to optimizing decision-making processes undertaken by the supply and demand sides of the real estate market. In contemporary market realities, such optimization is necessary for the balanced development of the real estate sector, resulting in maintaining this market in balance. The above studies were preceded by the analysis of the current literature on time series, focusing on the real estate market. The authors concluded that economic entities draw up their operational, as well as strategic action plans, based on time series that reveal relations that exist on the real estate market. Hence it seems necessary to conduct time-frequency examinations of phenomena that occur on the real estate market. When conducting time series examinations, the authors used the Savitzky-Golay filter in order to identify seasonal and periodic fluctuations in the examined phenomena. To identify seasonal fluctuations, the low-frequency Savitzky-Golay filter was used and to identify periodic fluctuations, the high-frequency Savitzky-Golay filter. Undertaking a more detailed parametrization of the identified periodic (cyclical) fluctuations, the authors applied power spectral density, which identified periodic fluctuations and revealed leading periodicities. The analysis of the spectrograms deepened the analysis of the examined phenomena and indicated the time periods when leading periodicities were characterized by their highest activity. The determination of the correlational relations between the number of granted building permits, the number of started construction projects, and the number of completed new dwellings, concluded this study. The research described in this paper demonstrated the usefulness of applying spectral density when elaborating a precise model of how the examined variables were formed and showed the relations between and among them. The information obtained in conclusion of the above studies may be helpful in the process of making investment decisions in the supply, as well as the demand dimensions.

References

- Badarinza, C., and Ramadorai, T. (2018). Home away from home? Foreign demand and London house prices. *Journal of Financial Economics*, 130(3), 532-555. DOI: 10.1016/j.jfineco.2018.07.010
- Bessler, W., Kurmann, P., and Nohel, T. (2015). Time-varying systematic and idiosyncratic risk exposures of US bank holding companies. *Journal of International Financial Markets, Institutions and Money*, (35), 45-68. DOI: 10.1016/j.intfin.2014.11.009
- Cheung, S. O., Wong, P. S. P., Fung, A. S. Y., and Coffey, W. V. (2006). Predicting project performance through neural networks. *International Journal of Project Management*, 24(3), 207-215. <https://doi.org/10.1016/j.ijproman.2005.08.001>
- Coombs, W. T., and Laufer, D. (2018). Global crisis management – current research and future directions. *Journal of International Management*, 24(3), 199-203. DOI: 10.1016/j.intman.2017.12.003
- De Witte, K., Geys, B., and Schönhage, N. L. (2018). Strategic public policy around population thresholds. *Journal of Urban Economics*, (106), 46-58. DOI: 10.1016/j.jue.2018.06.001
- Degl'Innocenti, M., Grant, K., Šević, A., and Tzeremes, N. G. (2018). Financial stability, competitiveness and banks' innovation capacity: Evidence from the Global Financial Crisis. *International Review of Financial Analysis*, (59), 35-46. DOI: 10.1016/j.irfa.2018.07.009
- Devaney, S., and Xiao, Q. (2017). Cyclical co-movements of private real estate, public real estate and equity markets: A cross-continental spectrum. *Journal of Multinational Financial Management*, 42-43, 132-151. DOI: 10.1016/j.mulfin.2017.10.002
- Dineen, D., and Gallachóir, B. P. Ó. (2011). Modelling the impacts of building regulations and a property bubble on residential space and water heating. *Energy and Buildings*, 43(1), 166-178. DOI: 10.1016/j.enbuild.2010.09.004
- Eirinaki, M., Dhar, S., Mathur, S., Kaley, A., Patel, A., Joshi, A., and Shah, D. (2018). A building permit system for smart cities: A cloud-based framework. *Computers, Environment and Urban Systems*, (70), 175-188. DOI: 10.1016/j.compenvurbsys.2018.03.006
- Farrelly, K., and Stevenson, S. (2019). The risk and return of private equity real estate funds. *Global Finance Journal*, (42), 100471. DOI: 10.1016/j.gfj.2019.04.005
- Fernandez, L., Mukherjee, M., and Scott, T. (2018). The effect of conservation policy and varied open space on residential property values: A dynamic hedonic analysis. *Land Use Policy*, (73), 480-487. DOI: 10.1016/j.landusepol.2017.12.058
- Fernández, M. D., Marrón, M. L., and Rodríguez, P. M. (2016). Condiciona la población la dinámica de la actividad inmobiliaria? Un análisis de cointegración para el caso español. *Investigacion Economica*, 75(297), 103-124. DOI: 10.1016/j.inveco.2016.08.003
- Gallegati, M., and Delli Gatti, D. (2018). Macrofinancial imbalances in historical perspective: A global crisis index. *Journal of Economic Dynamics and Control*, (91), 190-205. DOI: 10.1016/j.jedc.2018.01.026
- Gluszak, M., and Zygmunt, R. (2018). Development density, administrative decisions, and land values: An empirical investigation. *Land Use Policy*, (70), 153-161. DOI: 10.1016/j.landusepol.2017.10.036
- Hui, E. C. M., Liang, C., Zhong, J., and Ip, W. C. (2016). Capture the abrupt changes in Asian residential property markets. *Habitat International*, (56), 235-244. DOI: 10.1016/j.habitatint.2016.06.005
- La, L., and Mei, B. (2015). Portfolio diversification through timber real estate investment trusts: A cointegration analysis. *Forest Policy and Economics*, (50), 269-274. DOI: 10.1016/j.forpol.2014.07.003
- Lam, B. S. Y., Yu, C. K. W., Choy, S. K., and Leung, J. K. T. (2016). Jump point detection using empirical mode decomposition. *Land Use Policy*, (58), 1-8. <https://doi.org/10.1016/j.landusepol.2016.07.006>

- Leone, V., and de Medeiros, O. R. (2015). Signalling the Dotcom bubble: multiple changes in persistence approach. *Quarterly Review of Economics and Finance*, (55), 77-86. DOI: 10.1016/j.qref.2014.08.006
- Li, X., Sun, M., and Boersma, K. (2019). Policy spillover and regional linkage characteristics of the real estate market in China's urban agglomerations. *Journal of Management Science and Engineering*, 4(3), 189-210. DOI: 10.1016/j.jmse.2019.05.004
- Makin, A. J. (2019). Lessons for macroeconomic policy from the global financial crisis. *Economic Analysis and Policy*, (64), 13-25. DOI: 10.1016/j.eap.2019.07.008
- Manjunath S.V., Baghel, R. S., and Kumar, M. (2019). Performance evaluation of cement-carbon composite for adsorptive removal of acidic and basic dyes from single and multi-component systems. *Environmental Technology and Innovation*, (16), 100478. DOI: 10.1016/j.eti.2019.100478
- McAllister, P., Shepherd, E., and Wyatt, P. (2018). Policy shifts, developer contributions and land value capture in London 2005–2017. *Land Use Policy*, (78), 316-326. DOI: 10.1016/j.landusepol.2018.06.047
- Murray, C. K. (2018). Developers pay developer charges. *Cities*, 74, 1-6. DOI: 10.1016/j.cities.2017.10.019
- Piao, X., Mei, B., and Xue, Y. (2016). Comparing the financial performance of timber REITs and other REITs. *Forest Policy and Economics*, (72), 115-121. DOI: 10.1016/j.forpol.2016.06.022
- Ranjan, P., Wardropper, C. B., Eanes, F. R., Reddy, S. M. W., Harden, S. C., Masuda, Y. J., and Prokopy, L. S. (2019). Understanding barriers and opportunities for adoption of conservation practices on rented farmland in the US. *Land Use Policy*, (80), 214-223. DOI: 10.1016/j.landusepol.2018.09.039
- Taderera, M., and Akinsomi, O. (2020). Is commercial real estate a good hedge against inflation? Evidence from South Africa. *Research in International Business and Finance*, (51), 101096. DOI: 10.1016/j.ribaf.2019.101096
- Vuuren, A. van, Kjellander, J., and Nilsson, V. (2019). Refugees and apartment prices: A case study to investigate the attitudes of home buyers. *Regional Science and Urban Economics*, (77), 20-37. DOI: 10.1016/j.regsciurbeco.2019.02.003
- Viggers, H., Keall, M., Wickens, K., and Howden-Chapman, P. (2017). Increased house size can cancel out the effect of improved insulation on overall heating energy requirements. *Energy Policy*, (107), 248-257. DOI: 10.1016/j.enpol.2017.04.045
- Yigitcanlar, T., Kamruzzaman, M., Buys, L., Ioppolo, G., Sabatini-Marques, J., da Costa, E. M., and Yun, J. H. J. (2018). Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework. *Cities*, (81), 145-160. DOI: 10.1016/j.cities.2018.04.003
- Zhang, Q., and Su, S. (2016). Determinants of urban expansion and their relative importance: A comparative analysis of 30 major metropolitans in China. *Habitat International*, (58), 89-107. DOI: 10.1016/j.habitatint.2016.10.003
- Zheng, X., Xia, Y., Hui, E. C. M., and Zheng, L. (2018). Urban housing demand, permanent income and uncertainty: Microdata analysis of Hong Kong's rental market. *Habitat International*, (74), 9-17. DOI: 10.1016/j.habitatint.2018.02.004

ANALIZA CZASOWO-CZĘSTOTLIWOŚCIOWA CZASU BUDOWY NIERUCHOMOŚCI MIESZKANIOWYCH JAKO PODSTAWA PODEJMOWANIA DECYZJI NA RYNKU BUDOWLANYM (STUDIUM PRZYPADKU POLSKI)

Streszczenie: Ze względu na coraz bardziej złożoną sytuację rynkową, charakteryzującą się rosnącą zmiennością determinantów ją określających, podejmowanie trafnych decyzji jest obciążone zwiększającym się ryzykiem popełnienia błędu. Metody stosowane w naukach ekonomicznych do analizy

zjawisk rynkowych mających przebiegi szeregów czasowych stają się niewystarczające do poprawnego modelowania zjawisk rynkowych. Konieczne staje się poszukiwanie precyzyjniejszych metod analitycznych, pozwalających uzyskać dokładniejsze odwzorowania i zależności występujące w sferze działań realnych. Celem badań jest zastosowanie analizy czasowo-częstotliwościowej w sektorze nieruchomości. Analiza ta, bazująca na wykorzystaniu m.in. filtracji Savitzky'ego-Golaya, analizy widmowej czy korelacji krzyżowej, pozwoli możliwie precyzyjnie sparametryzować wybrane determinanty wpływające na rynek nieruchomości mieszkaniowych. Otrzymane wyniki pozwolą na zmniejszenie luki informacyjnej w podejmowaniu decyzji inwestycyjnych na rynku nieruchomości mieszkaniowych.

Słowa kluczowe: rynek mieszkaniowy, analiza czasowo-częstotliwościowa, filtr Savitzky'ego-Golaya, gęstość widmowa, korelacja krzyżowa, podejmowanie decyzji.