

Lukasz 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

APPLICATION OF FFT TRANSFORMATION AND COHERENCE ANALYSIS TO IDENTIFY THE SLOW-CHANGING CYCLICAL COMPONENT ON THE HOUSING MARKET*

DOI: 10.15611/pn.2020.10.05

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). Application of FFT transformation and coherence analysis to identify the slow-changing cyclical component on the housing market. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, 64(10).

Abstract: The paper reports the results of a study concerned with the identification and definition of time and frequency parameters regarding the cyclical phenomenon on the housing construction market. The cyclical component analysis in the frequency domain was identified

* 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.

using fast Fourier transformation, while the identification of the cyclical component and the interdependence of variables was performed by application of coherence analysis. The research provided answers to the questions regarding active cyclical characteristics that form determinants affecting the condition of the housing market. The resulting knowledge can be useful in decision-making processes that take place in the housing construction market, both on the demand and supply side of this market, as well as helpful in assessing the anticipated prices on the housing market and the formation of speculative bubbles.

Keywords: dwellings construction market, housing market, periodic component, cyclicity, financial stability, macroeconomic stability, coherence analysis, Fourier transformation.

1. Introduction

The housing market in the market economy is one of the fundamental categories affecting the financial and macroeconomic stability of the economic system (Bisht and Kumar, 2016; Cesa-Bianchi and Rebucci, 2017; Crowe, Dell’Ariccia, Igan, and Rabanal, 2013; Liu and Molise, 2019). The parameters of the housing market directly reflect the condition of the economy and allow it to be positioned in the economic cycle. The analysis of the condition of the economy and identifying the current phase of the economic cycle makes it possible to reduce the risk associated with the allocation of financial resources on both the demand and supply sides of this market (Lee, Liu, and Stebunovs, 2019; Shahzad, Lu, and Fareed, 2019). If it can be concluded from the analysis of the housing construction market that it is in the phase of growth in the economic cycle, it is likely that this will result in an increase in investment activities in this market. On the other hand, if the economy experiences a period of recession, this will also be reflected in the decline of investment activity on the housing market. The degree of investor activity on the housing market has a direct impact on the price formation on it and may be a signal to any speculative bubbles that may occur in it.

Considering the above, knowledge of the parameters regarding the stage of the cycle corresponding to the economic activity and in particular inputs concerning the housing construction market form extremely complex issues in terms of the economic activity. Knowledge of the cyclical characteristics will enable stakeholders of this market to make decisions that are appropriate to the phase of the cycle in which the market experiences. Taking into account the importance of cyclicity taking place on the housing construction market, the research reported in this paper was concerned with the identification of cyclical phenomena between determinants affecting the condition of this market and the economy as a whole. This relation was quantified using selected components of the construction process, which for the purposes of the research included the number of granted building permits and data on the completed construction of housing. The study with regard to the cyclical dependence for each variable and relations between them was performed by the application of the

fast Fourier transformation and coherence analysis, aimed at identifying the slow-varying cyclical characteristics separately for each of the investigated variables, whereas the use of coherence analysis was applied for the purposes of determining whether there is a relationship of collinearity in the frequency domain between the investigated variables. The research process was carried out in four stages. In the first of these, a presentation and basic analysis of data was conducted with regard to the number of granted building permits and the data on the completed construction of new housing. The data for analysis were extracted from the main statistical office databases using the API. For this purpose, the data from the period between 2005 and 2017 were utilized, and the analysis applied a monthly measurement interval. In the second stage, long-term periodicity was determined independently for the examined variables using the Fourier transformation. The third stage involved the use of coherence analysis to examine the cross-correlation of the investigated variables in the frequency domain. Next, in the fourth stage, the process of interpretation of the results and presentation of their utilitarian application in economic processes is provided. The research can provide answers to questions regarding the formation of cyclical periodicity in the individual stages of the housing construction process that offers the means to indicate similarities in the frequency domain of the examined cyclical variations of data. This information should allow decision-makers to obtain a more comprehensive view of the market situation in the housing construction market, and thus reduce decision risk.

2. Multi-faceted analysis of the housing construction market and its effects on economy

When taking into account the relevance of the aspects raised in the introduction part of this paper, the presentation will report on the past research in the areas focusing on the issues related to prices on the real housing market, speculative bubbles, investment risk and the parameterization of cycles. The first dimension of the analysis carried out in the area of the housing construction market is concerned with the study of the variations of housing prices on it and their impact on this market and the economy as a whole. The current research (Tsai, 2019) explores the relations between the price of apartments on the housing market and the volume of their sales. The author of the study discussed these relations in terms of signals informing about the condition of the housing market, and indirectly, the economy as a whole. One of the interesting facts about the price-sales ratio is provided by the discussion of various models applied in studying this relationship. One can note here that the model of the impact of prices on sales volume known as the Downpayment model (Clayton, Miller, and Peng, 2010) as well as the loss-aversion model (Engelhardt, 2003) and the new search model (Huang, Leung, and Tse, 2018; Leung and Tse, 2017). The reports on price dependence and their exact convergence for various markets can be found in (Tsai, 2018), and focuses on the paper on the phenomenon of price convergence

in the eurozone and non-eurozone. The latest study by Lyons (Lyons, 2018) raises a very important issue regarding the housing market, involving the relationship between the terms of lending for the purpose of housing construction and the price of housing on this market. This study was performed for conditions in Ireland with regard to the periods of development of this market, and at the time when it was in crisis. Other studies in the area of lending explore the relations between the price of real estate and the choice of the length of its lending are also reported in the studies in this area (Park, 2019). With regard to the second aspect of analysis, i.e. the formation of speculative bubbles, an attempt was made in the study (Gazzani, 2020) to examine the effect of news about the condition of the housing market and the influence of the information regarding the emergence of a speculative bubble on the reactions and state of this market. In the aforementioned studies, the decomposition of information on speculative bubbles emerging on the housing market was analysed from the point of view of its effect on the stability of the economy. Research into the effect of unpredictable economic shocks on the housing market was also discussed in (Christou, Gupta, and Nyakabawo, 2019). These studies proved that every shock on the market negatively affects all parameters of the housing construction market. Other studies on emerging unpredictable circumstances on the housing market include (Silva, da Nóbrega Besarria, and Baerlocher, 2019), in which the relations between the shocks occurring on it and the dynamic characteristics of the housing market are explored. This comprehensive research was concerned with determining the effect of economic shocks on the value of aggregate production and the implementation of monetary policy. These studies also demonstrated that the behaviour of housing prices is dependent on market shocks, which in turn are orthogonal in regard to business cycles. Another important issue, in particular from the point of view of the subject of this article, are business cycles and their impact on the real estate market. The analysis of the effect of the business cycle on the housing market started with the important question: are the cyclical patterns of international housing markets interdependent? The conducted research, which involved the American, British and Canadian market demonstrates that the American and Canadian markets respond similarly, in contrast to the British market, whose relations are different from the North American housing markets (Chang, 2019). In later studies (Gabrowski and Ortego-Martí, 2019) the cyclical behaviour of the Beveridge curve on the housing market is described in the housing market along with the cycles occurring in it. It was demonstrated that the housing market is characterized by well-established cyclical components and demonstrates the relationship represented by price volatility that takes on the same direction as the volatility of the sales volume, but responds in the opposite direction to the duration that it takes to sell a property. A very important issue in identifying and predicting the phases of the business cycle on the real estate market is associated with the correct identification of the determinants affecting this market. The study by Tupenaite et al. reports on a comprehensive study concerned with the determinants affecting the volatility of the housing market (Tupenaite,

Kanapeckiene, and Naimaviciene, 2017). Another very interesting approach, indirectly dealing with cyclicalities, is the problem of the effectiveness of influencing it through government intervention (Zhou, 2018) and a presentation of how economic policy uncertainty affects the real estate market (Huang, Lin, and Ning, 2018). The final important issue raised with regard to the housing market is concerned with the risk associated with investing in it. In the research reported in (Damianov and Elsayed, 2018), an important aspect of the area of risk was raised, namely the transfer of indirect risk between the housing market, mortgage and capital REIT markets, and the stock market. The estimation of the loan risk and financial investment in real estate formed some of the important issues. In another study (Bessler, Kurmann, and Nohel, 2015), it was demonstrated that during the period of crises the credit risk and the risk of financing real estate increase very much. Another risk analysis involves its estimation in the process of investing in the housing market, in the private and public sector housing real estate. This study applied an asset valuation approach to assess the exposure of private real estate funds to risk factors in both the private and public markets. The analysis involves creating specific performance indicators and applying methods to address some of the inherent problems of private real estate fund data, such as the high degree of serial correlation of observed total returns (Farrelly and Stevenson, 2019). Another aspect of the analysis of the issue in the area of risk assessment concerns the examination of the occurrence of crisis situations in conjunction with political changes. This article presents wavelet analysis with the minimax threshold, is a comprehensive and powerful approach to the analysis of market data in the housing sector (Hui, Liang, Zhong, and Ip, 2016). Other studies concerned with the analysis of time series and the housing market deal with detection of sudden change points using empirical distributions and show their effects on the economy. (Lam, Yu, Choy, and Leung, 2016), examined the effect of location on the price of real estate (Fernandez, Marrón, and Rodríguez, 2016; Fernandez, Mukherjee, and Scott, 2018), and conducted research of the relationship between the cycle in the housing market and the population by the application of a dynamic model (Fernández et al., 2016).

3. Presentation of current data

When an analysis was performed of the data on the housing construction market, first of all, the characteristics of waveforms for two variables representing the first and last components in the stages of the construction process were investigated.

The first component is associated with the variable describing the number of granted building permits, whereas the second represents the data on the completed construction of dwellings. This analysis involved the development of graphical presentation of waveforms representing each of the considered variables along with a synthetic description explaining the courses of the analysed time series. Figure 1 developed for the description was made of the first variable, i.e. the number of granted

building permits. From the macroeconomic development perspective, three periods can be identified from the data in Figure 1. The first period lasted from 2005 to 2009, and in this period the housing market in Poland was developing very dynamically. In the opinion of the authors of this study, the increase in the number of granted building permits in the investigated period resulted from a number of factors of which two played a key economic role, i.e. the relative ease of raising funds for the purchase of dwellings through credit, and the stable and even continuous improvement of the economic situation.

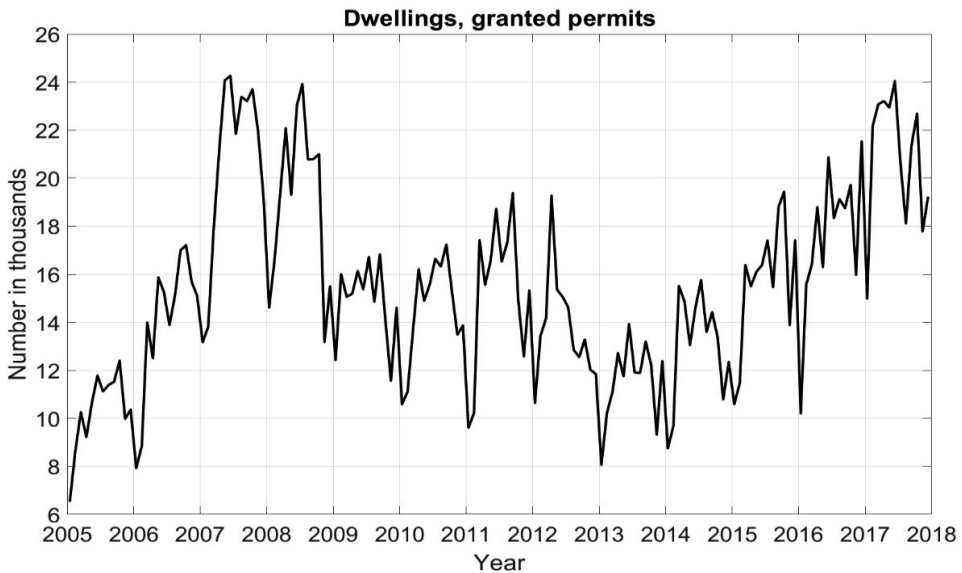


Fig. 1. Granted building permits in Poland

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

The second period was characterized by a decrease in the number of building permits between 2009 and 2013. The change in the developmental trend represented by the number of granted building permits in 2009 resulted from the global economic crisis that began on the American housing 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). Since 2013, in the third time period which has lasted until the present, the magnitude of the investigated phenomenon took on greater dynamic characteristics. Assuming that the number of building permits issued reflects the mood of investors on the real estate market, one can assume that according to the views of investors, the period of the economic crisis ended in 2013.

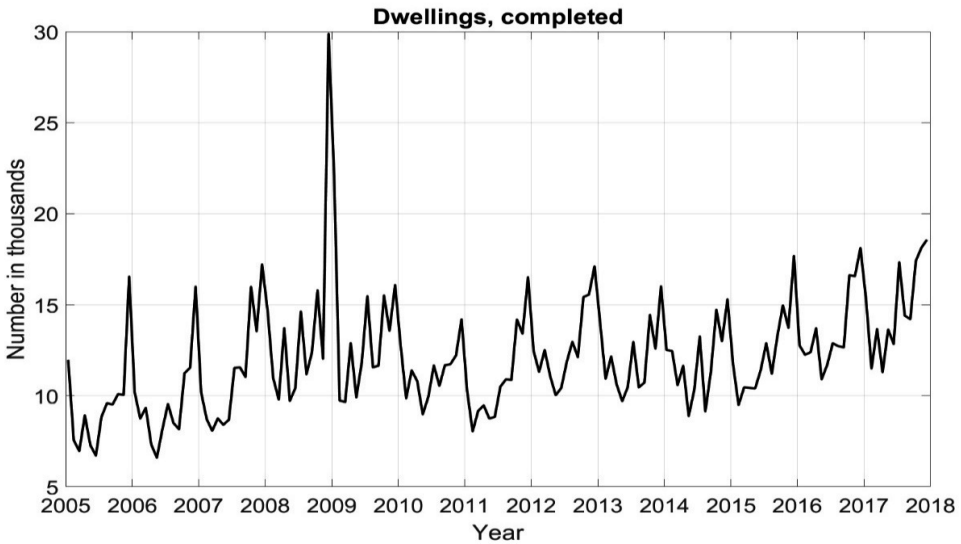


Fig. 2. Completed construction of dwellings in Poland

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

However, in terms of seasonality, one can see that Q2 and Q3 in each of the analysed annual periods is characterized by a greater number of granted building permits in comparison to Q1 and Q4.

Figure 2 shows the data regarding the completed construction of dwellings, and contains a single outlier along its course, which was recorded in December 2008. One can note that the value that significantly deviates from the forecast is associated with the actual value which took place on the market. The significant increase in the number of dwellings completed was attributable to two coherent factors at the same time, i.e. legal changes that took place in the analysed period and the form of the housing being built. From January 2019, there is an obligation of investors to obtain a document called the energy performance certificate for the purpose of concluding the purchase contract. Considering the fact that in Poland in 2008 the vast majority of flats that were completed were commissioned by individual investors, the new legal provision generated two aspects for them, i.e. cost and investment uncertainty. These aspects caused a significant increase in the number of dwellings completed.

The above general characteristics of the formation of variables affecting the condition of the housing construction market in Poland reflected the implementation of their time-frequency variations. This provided basis for the preliminary identification of sub-annual, seasonal and long-term fluctuations. The first stage of the descriptive research offered grounds to determine the directions taking the form of the variables in question.

4. Application of the Fourier transformation with the purpose of demonstrating long-term periodicity

In the second research stage, using the fast Fourier transformation with an averaging window equal to 8192, low-frequency spectra were obtained with the purpose of identifying long-term components. At this stage, two long-term spectra components of granted permits data and of construction completed data were prepared using the zero padding method.

Figures 3 to 4 contains spectrograms with a slow-frequency component, where long-term spectra components of granted permits data and long-term spectra components of the completed constructions are listed, respectively. The analysis of individual charts was applied to identify the occurrence of cycles and sub-cycles in the housing construction market.

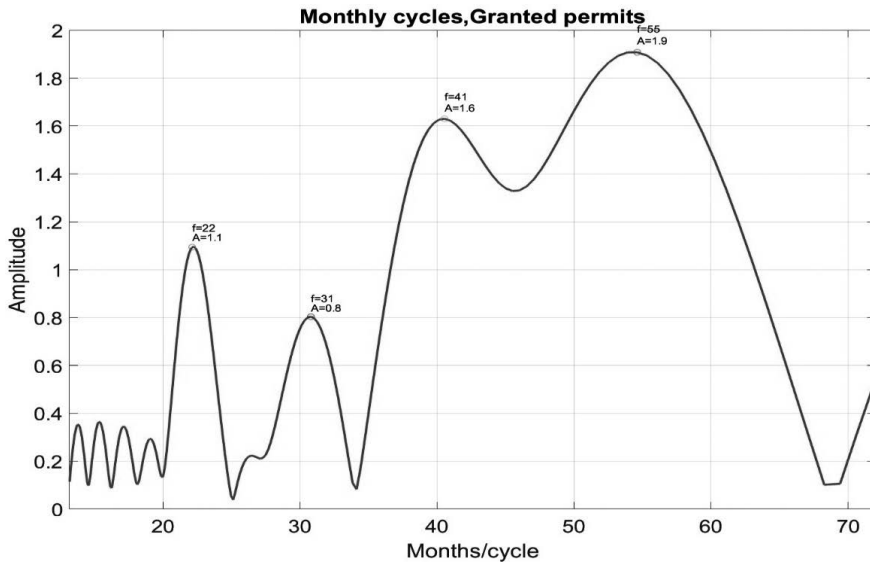


Fig. 3. Long-term spectra components of granted permits data (low frequency component)

Source: own study.

When the analysis was performed with regard to the first examined variable describing the number of granted permits and data on completed constructions, one can see that cyclicity over the periods lasting 55, 41, 31 and 22 months is significant (see Figure 3). For the variable applied to describe completed constructions data, there is a single clear leading cyclicity lasting 53 months. (cf. Figure 4). However, the spectrogram results obtained for the variable for new dwellings completed, despite the spectrogram being derived on the basis of market data, may not be

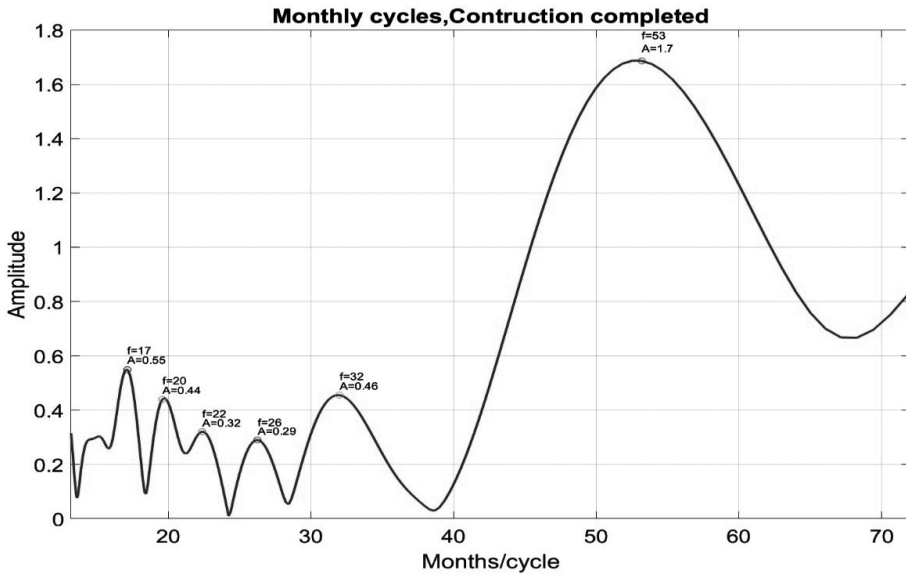


Fig. 4. Long-term spectra components of construction completed data (low frequency component)

Source: own study.

entirely accurate, since the data contains a single significant outlier (at the end of 2008). The occurrence of the outlier could have caused that other significant cyclical periods were not identified distinctly. With the purpose of the accurate examination of cyclicity, additional analysis using the phenomenon of coherence was employed, which will allow for the synchronization of the frequency variability with regard to the variables describing the number of building granted permits and data on completed constructions. This synchronization will provide information regarding the existence of cyclicity for the variable describing construction completed data, which may have been omitted due to the occurrence of outliers in these data. Performing the process of cyclical synchronization for the examined variables is feasible under the assumption that the variable regarding the number of building permits and the variable describing completed constructions will be considered as components of the construction process with the additional assumption of cascading consequences of their implementation.

5. Calculation of coherence between investigated variables

With the purpose of comparing individual slow-varying components for the variables of granted building permits issued and completed construction of dwellings, the relations of coherence between the above variables were examined. The study of

the coherence relations leads to the determination of the level of correlation of the investigated relation in the frequency domain. The research process involved the calculation of the value of spectral coherence on the basis of formula 1. The coherence between granted permits and construction completed is presented in Figure 5.

$$C_{xy}(freq) = \frac{abs(G_{xy}(freq))^2}{G_{xx}(freq)G_{yy}(freq)} \tag{1}$$

where: G_{xx} is auto-spectral density of number of granted building permits, G_{yy} is auto-spectral density of dwellings completed construction data, G_{xy} is cross-spectral density between analysed data.

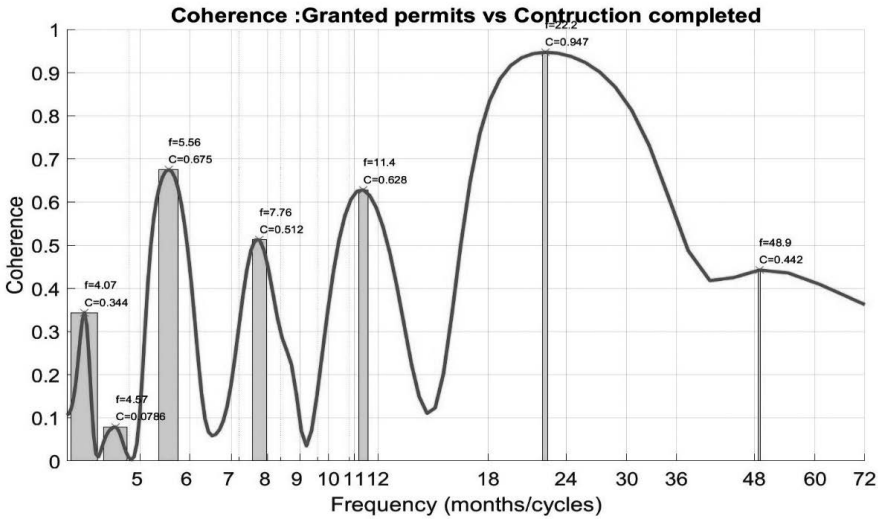


Fig. 5. Cross coherence between granted permits and completed construction of dwellings

Source: own study.

On the basis of the conducted research one can conclude that the largest linear dependence in the frequency domain between the examined variables applies for a period lasting 22 months. This period defines almost two years of cyclical activity in the housing construction process. The co-occurrence of the coherence level of $C = 0.947$, over a period of 22 months demonstrates a linear relation between the investigated cycles for variables representing the number of granted building permits and the data on the completed construction of dwellings. It should also be noted that the conducted research confirmed the results published by the Central Statistical Office.

6. Results

To summarise the analysis, one can see that the calculated (resulting) value of active cyclicity equal to nearly two years can be applied in the business decision process to provide information to define a common and, more importantly, identical cyclical activity. This knowledge, in the decision-making sphere, can be exceptionally useful since it demonstrates an active cycle for the investigated variables and indirectly identifies the standard construction period, which takes 22 months from the decision to grant a building permit to the actual commissioning of the dwellings. This assumption seems to be correct as was previously stated, assuming the cascade process of implementation of the examined variables. An additional conclusion noted during the implementation of the study is the fact that the analysis of spectrograms developed for slow-varying periodicity, for the variable: completed construction of dwellings, does not indicate the occurrence of a cyclicity lasting 22 months. This only indicates the leading cyclicity lasting for 53 months. This unexpected outcome may be due to the observation in the current data regarding completed constructions that are significantly different from the expected value for the examined variable. This observation may affect other key cyclicity in the examined process. By analysing each of the examined variables separately, one can see that in the case of the variable concerning issued building permits, the existence of cyclical activity was identified for the 22nd, 31st, 41st and 55th month, whereas for the variable: completed construction of dwellings, it is 53 months.

7. Conclusion

The housing construction market forms one of key determinants affecting the condition of the economy and plays an important role from the point of view of its adequate parameterization. Such parameterization can be performed by taking into account a variety of socio-economic and economic dimensions. However, it is necessary to bear in mind that the dimension involving the description of the time-frequency parameters forms the basic and also the initial dimension of the analysis. These characteristics can be applied to identify the time and frequency variability of the determinants that determine the level of development of the housing construction market. Such knowledge can provide the basis for determining the components of the investigated variables, in which one can, among others, include the periodic component identified as the long-term cyclical variable. The identification of the cyclical characteristics of the phenomena occurring on the housing construction market can provide criteria for an accurate decision-making process with regard to investment on this market, both on the demand and supply sides. Taking into account the above, an attempt was made in this study to identify and analyse the cyclical component in terms of the number of granted building permits and data on the completed construction of dwellings. Regarding the tools of applied computational

engineering, the parameterization of the cyclic component was carried out in two stages. The first stage involved the determination of the leading cyclic activities for the variables using the fast Fourier transformation. In the second stage, using the coherence analysis, cross-correlation of the examined variables was carried out in the frequency domain. This resulted in the determination of the actual leading cyclicity, such that are feasible in making decisions regarding investment in this market. This knowledge will allow to describe more precisely the characteristics of variations on the housing market and thus to minimize the risk of business decisions made on this market.

References

- 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. <https://doi.org/10.1016/j.intfin.2014.11.009>
- Bisht, K., and Kumar, S. (2016). Fuzzy time series forecasting method based on hesitant fuzzy sets. *Expert Systems with Applications*, 64, 557-568. <https://doi.org/10.1016/j.eswa.2016.07.044>
- Cesa-Bianchi, A., and Rebucci, A. (2017). Does easing monetary policy increase financial instability? *Journal of Financial Stability*, 30, 111-125. <https://doi.org/10.1016/j.jfs.2017.04.001>
- Chang, K. L. (2019). Are cyclical patterns of international housing markets interdependent? *Economic Modelling*, 88, 14-24. <https://doi.org/10.1016/j.econmod.2019.09.002>
- Christou, C., Gupta, R., and Nyakabawo, W. (2019). Time-varying impact of uncertainty shocks on the US housing market. *Economics Letters*, 180(c), 15-20. <https://doi.org/10.1016/j.econlet.2019.03.029>
- Clayton, J., Miller, N., and Peng, L. (2010). Price-volume correlation in the housing market: Causality and co-movements. *Journal of Real Estate Finance and Economics*, 40(1), 14-40. <https://doi.org/10.1007/s11146-008-9128-0>
- Coombs, W. T., and Laufer, D. (2018). Global crisis management – current research and future directions. *Journal of International Management*, 24(3), 199-203. <https://doi.org/10.1016/j.intman.2017.12.003>
- Crowe, C., Dell’Ariccia, G., Igan, D., and Rabanal, P. (2013). How to deal with real estate booms: Lessons from country experiences. *Journal of Financial Stability*, 9(3), 300-319. <https://doi.org/10.1016/j.jfs.2013.05.003>
- Damianov, D. S., and Elsayed, A. H. (2018). On the transmission of spillover risks between the housing market, the mortgage and equity REITs markets, and the stock market. *Finance Research Letters*, 27, 193-200. <https://doi.org/10.1016/j.frl.2018.03.001>
- 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. <https://doi.org/10.1016/j.irfa.2018.07.009>
- Engelhardt, G. V. (2003). Nominal loss aversion, housing equity constraints, and household mobility: Evidence from the United States. *Journal of Urban Economics*, 53(1), 171-195. [https://doi.org/10.1016/S0094-1190\(02\)00511-9](https://doi.org/10.1016/S0094-1190(02)00511-9)
- Farrelly, K., and Stevenson, S. (2019). The risk and return of private equity real estate funds. *Global Finance Journal*, 42, 100471. <https://doi.org/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.

- <https://doi.org/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. <https://doi.org/10.1016/j.inveco.2016.08.003>
- Gabrovski, M., and Ortego-Martí, V. (2019). The cyclical behavior of the Beveridge Curve in the housing market. *Journal of Economic Theory*, 181, 361-381. <https://doi.org/10.1016/j.jet.2019.03.003>
- 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. <https://doi.org/10.1016/j.jedc.2018.01.026>
- Gazzani, A. (2020). News and noise bubbles in the housing market. *Review of Economic Dynamics*, 36, 46-72. <https://doi.org/10.1016/j.red.2019.08.001>
- Huang, D. J., Leung, C. K. Y., and Tse, C. Y. (2018). What accounts for the differences in rent-price ratio and turnover rate? A search-and-matching approach. *Journal of Real Estate Finance and Economics*, 57(3), 431-475. <https://doi.org/10.1007/s11146-017-9647-7>
- Huang, W. L., Lin, W. Y., and Ning, S. L. (2018). The effect of economic policy uncertainty on China's housing market. *North American Journal of Economics and Finance*, 100850. <https://doi.org/10.1016/j.najef.2018.09.008>
- 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. <https://doi.org/10.1016/j.habitatint.2016.06.005>
- 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>
- Lee, S. J., Liu, L. Q., and Stebunovs, V. (2019). Risk-taking spillovers of U.S. monetary policy in the global market for U.S. dollar corporate loans. *Journal of Banking and Finance*. <https://doi.org/10.1016/j.jbankfin.2019.05.006>
- Leung, C. K. Y., and Tse, C. Y. (2017). Flipping in the housing market. *Journal of Economic Dynamics and Control*, 76, 232-263. <https://doi.org/10.1016/j.jedc.2017.01.003>
- Liu, G. and Molise, T. (2019). Housing and credit market shocks: Exploring the role of rule-based Basel III counter-cyclical capital requirements. *Economic Modelling*, 82, 264-279. <https://doi.org/10.1016/j.econmod.2019.01.013>
- Lyons, R. C. (2018). Credit conditions and the housing price ratio: Evidence from Ireland's boom and bust. *Journal of Housing Economics*, (42), 84-94. doi.org/10.1016/j.jhe.2018.05.002
- Makin, A. J. (2019). Lessons for macroeconomic policy from the Global Financial Crisis. *Economic Analysis and Policy*, 64, 13-25. <https://doi.org/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. <https://doi.org/10.1016/j.eti.2019.100478>
- Park, K. A. (2019). An event study in relative prices and choice of loan term. *Journal of Housing Economics*, 46(February), 101637. <https://doi.org/10.1016/j.jhe.2019.101637>
- Shahzad, F., Lu, J., and Fareed, Z. (2019). Does firm life cycle impact corporate risk taking and performance? *Journal of Multinational Financial Management*, 51, 23-44. <https://doi.org/10.1016/j.mulfin.2019.05.001>
- Silva, M. E. A., da Nóbrega Besarria, C., and Baerlocher, D. (2019). Aggregate shocks and the Brazilian housing market dynamics. *Economía*, 20(2), 121-137. <https://doi.org/10.1016/j.econ.2019.08.001>
- Tsai, I. C. (2018). House price convergence in euro zone and non-euro zone countries. *Economic Systems*, 42(2), 269-281. <https://doi.org/10.1016/j.ecosys.2017.05.010>
- Tsai, I. C. (2019). Dynamic price-volume causality in the American housing market: A signal of market conditions. *North American Journal of Economics and Finance*, 48, 385-400. <https://doi.org/10.1016/j.najef.2019.03.010>

- Tupenaite, L., Kanapeckiene, L., and Naimaviciene, J. (2017). Determinants of housing market fluctuations: Case study of Lithuania. *Procedia Engineering*, 172, 1169-1175. <https://doi.org/10.1016/j.proeng.2017.02.136>
- Zhou, Z. (2018). Housing market sentiment and intervention effectiveness: Evidence from China. *Emerging Markets Review*, 35(10), 91-110. <https://doi.org/10.1016/j.ememar.2017.12.005>

ZASTOSOWANIE TRANSFORMACJI FTT ORAZ ANALIZY KOHERENCJI DO IDENTYFIKACJI SKŁADOWEJ CYKLICZNEJ WOLNOZMIENNEJ NA RYNKU BUDOWNICTWA MIESZKANIOWEGO

Streszczenie: Przeprowadzone badania pozwoliły na identyfikację oraz określenie cyklicznej zmienności czasowej i częstotliwościowej występującej na rynku budownictwa mieszkaniowego. Identyfikacji i analizy składowej cyklicznej w dziedzinie częstotliwości dokonano z wykorzystaniem szybkiej transformacji Fouriera. Badając natomiast współliniowość współwystępujących wahań cyklicznych dla poszczególnych etapów budowy mieszkań, wykorzystano analizę koherencji. Badania umożliwiły znalezienie odpowiedzi na pytanie, jakimi aktywnymi cyklami cechują się badane zjawiska. Uzyskana wiedza może być użyteczna w procesach decyzyjnych, jakie zachodzą na rynku nieruchomości mieszkaniowych po stronie zarówno popytowej, jak i podażowej tego rynku. Może być również pomocna w ocenie przewidywanych cen na rynku nieruchomości czy powstawania baniek spekulacyjnych.

Słowa kluczowe: rynek budownictwa mieszkaniowego, rynek nieruchomości, składowa okresowa, cykliczność, stabilność finansowa, stabilność makroekonomiczna, analiza koherencji, transformacja Fouriera.