

SUPPLY, DEMAND AND ASYMMETRIC ADJUSTMENT OF HOUSE PRICES IN POLAND

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ARTICLE INFO	ABSTRACT
<p>Keywords: asymmetric adjustment, house prices, demand shock, supply shock</p> <p>JEL Classification: C32, R15, R21, R31</p>	<p>In recent years, a lot of empirical effort has been made to search for potential nonlinear responses of house prices to various demand and supply factors. This paper examines Poland's heterogeneous regional housing market reactions to key economic variables from 2000 to 2022. The study raises two research questions related to the asymmetric adjustment of housing markets to selected demand and supply shocks. Firstly, we ask whether the house price adjustments to negative shocks are relatively minor (for example, during an economic downturn) when compared to positive shocks (prevalent in booming markets), mainly due to the loss aversion behavior theory and nominal rigidity of house prices. In particular, we test the hypothesis that house prices react more to positive impulses from supply and demand than negative ones. Secondly, we investigate whether market reactions are similar for large and small metropolitan markets. The second hypothesis posits that metropolitan housing markets adjust asymmetrically to demand and supply shocks based on the city size (population and housing stock in a given city). The study uses a nonlinear ARDL model to test the research hypotheses empirically. This paper provides new insights into the nonlinear reactions of house prices to exogenous shocks and adds to the limited empirical evidence from less developed economies.</p>
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1. Introduction

The paper estimated dynamic adjustments of regional housing markets in Poland in the recent years. Since 2000, the housing market in Poland has been subject to turbulent changes caused by institutional and economic factors. Several economic papers addressed critical drivers of house price dynamics, rational bubbles and spill-over effects, much in line with ongoing research in the US, Western Europe and China.

The paper contributes to understanding housing market dynamics by addressing potential heterogeneous regional market responses. In particular, the paper aims to evaluate whether prices responded asymmetrically to changes in key economic variables. To achieve the research objective, we test

two hypotheses related to the heterogeneous housing responses.

Firstly, we hypothesize that the response of housing markets to demand and supply shocks varied over the analyzed sub-periods. The reaction varied depending on the market regime. The rationale for that is straightforward and derived from the loss aversion behavior theory and the nominal rigidity of house prices. We suspect house price adjustments in the down market will be smaller than when the market is booming.

The second hypothesis states that metropolitan housing markets asymmetrically adjust to demand and supply shocks subject to market size. The variation in responses depends on the housing stock in a given city. We believe that housing inventory may be linked to the size of the rental market

(unobservable in Poland). Thus, house price responses to the changes in economic conditions in bigger cities will be moderated by the substitution effect between owner-occupied and rental housing.

We use a panel of 18 regional housing markets observed at the metropolitan level in Poland. We examine market dynamics from 2000 to 2022 and investigate the house price reaction to supply and demand shocks. We use a panel VAR approach with induced asymmetries and a nonlinear ARDL model to test the research hypothesis empirically. It is a premiere study in Poland that applies this particular approach to address asymmetric housing market dynamics. The paper contributes to understanding the nonlinear reactions of house prices to exogenous shocks. It adds the slowly growing empirical evidence from less developed economies, where the issue has been relatively under-researched.

The rest of the paper is organized as follows. Section 2 reviews the links between various fundamental factors and house price dynamics. Additionally, we examine the reasons and consequences of asymmetric adjustments of supply and demand shocks on house price adjustments. In section 3, we discuss empirical data and the econometric approach used in the empirical part of the paper. Section 4 focuses on the empirical results and implications of the research and discusses prior economic research in the field. The last section highlights the major findings and identifies further research directions.

2. Literature review

Economic models of house price dynamics use a variety of fundamental variables that explain the demand and supply side of the market. On the demand side, the selection includes a broad hierarchy of demographic, economic and financial factors at the local, national and international levels. There is evidence that housing demand is driven by population growth dynamics (Borowiecki, 2009; Capozza, et al., 2002; Plakandaras et al., 2015) and migrations (Han et al., 2018; Laurinavičius, et al., 2021; Taltavull de La Paz & White, 2012). Other demand factors include households' incomes (Abelson, et al., 2005; Mikhed & Zemčík, 2009; Oikarinen, et al., 2018) and employment rate (Engerstam, 2021; Mikhed & Zemčík, 2009; Mohan, et al., 2019; Plakandaras et al., 2015). Furthermore, both mortgage costs (Bork & Møller, 2015; Cuestas, 2017; Jarociński & Smets, 2008; Mian & Sufi, 2011; Mikhed & Zemčík, 2009; Oikarinen, 2009;

Tsatsaronis & Zhu, 2004), and inflation rate (Alpha Kabine, 2023; Bagliano & Morana, 2012; Mohan et al., 2019; Plakandaras et al., 2015) have a significant impact on investment demand.

The hierarchy of factors also drives the supply of housing. Based on the economic literature, major factors affecting housing supply are land supply (Glaeser, et al., 2008; Han et al., 2018), physical and geographical constraints related to new development (Saiz, 2010), and construction costs (Capozza et al., 2002; Oikarinen, 2010).

There is solid economic evidence that real estate prices and rents do not react swiftly and consistently to exogenous shocks, both on the supply and demand side. In general, the housing market reaction asymmetry may be linked with the timing of exogenous shock. House prices seem to adjust differently in market downturns and upturns.

The downward rigidity of prices, a concept developed by J.M. Keynes in his "The General Theory of Employment, Interest and Money", has been investigated in economic literature and, to a large extent, focused rigidity of wages (Fallick, et al., 2022; Schaefer & Singleton, 2022), stocks (Chen, 2007) and commodity prices (Chen & Sun, 2021; Giulietti, et al., 2020). The sluggish response of prices to exogenous shocks, a property also referred to as sticky pricing, has also been addressed theoretically and empirically in housing literature and is typically linked to loss aversion behavior (Genesove & Mayer, 2001, 1997). The results from other studies reveal that sticky house prices may exacerbate housing market fluctuations and delay housing market convergence (Fan, 2022), with both properties having profound policy implications. Understanding the asymmetric responses of house prices to exogenous shocks may contribute to better forecasting and more effective policymaking (Katrakilidis & Trachanas, 2012).

The empirical results suggest that house prices react asymmetrically to changes in money supply. Based on evidence from the UK, Tsai argues that house prices seem to change excessively in upturns and only moderately adjust in downturns in response to shifts in monetary policy (Tsai, 2013). The US study also documented the evidence of downward house price rigidity (Yuming Li, 2015). The authors confirmed that house prices respond asymmetrically depending on the current market cycle phase. A sticky response to demand shocks has been identified in the downturns, but the results reveal significant discrepancies between market responses in different

regions (coastal vs. inland). A long-run housing study confirmed downward nominal house price rigidity (Erlandsen & Juelsrud, 2023). Based on housing data from 1850 to 2019 in Norway, the authors identified a substantial fraction of repeat-sales housing transactions with a zero nominal price change. The study revealed that the share of that fraction of sales typically increases in housing market downturns. Xie, Chen and Wu (2019) examined housing dynamics in OECD countries and provided further evidence for the asymmetric adjustment of property prices in several markets. They found that the speed of mean reversion is positively linked to the discrepancy between the actual and fundamental price-rent ratios.

Financial factors also seem to have an asymmetric effect on house price dynamics, as proven by Armstrong, Skilling and Yao (2019). The study investigated the impact of mortgage lending regulations on house prices. The results indicate that, although the LTV policy can generally be used to cool the decreased housing demand, the instrument's effectiveness depends on the housing market dynamics when introduced. They demonstrated that under the regime of quickly increasing house prices, the cooling effect of LTV policies is weaker and temporal. Chatziantoniou, Filis, and Floros (2017) investigated the role of house prices and household credit in the transmission mechanism of the ECB monetary policy using a panel of 12 Eurozone countries. The results show that the impact of nominal money on house prices is asymmetric across the Eurozone. The effectiveness of this transmission mechanism differed between countries with different average house price growth rates. A recent Chinese study has also reported the asymmetric property of housing market adjustment to exogenous shocks in booming and cooling market regimes (Fan, 2022).

On the other hand, the asymmetric reaction may be linked to the direction of the shock itself. The strength and length of the adjustment may vary between negative and positive shocks.

An empirical study explored the impact of several macroeconomic variables on house prices in Greece (Katrakilidis & Trachanas, 2012). Based on an asymmetric ARDL cointegration approach, the study reveals substantial variation in the reaction of house prices to positive or negative exogenous shocks, both in the short and long run.

A Chinese study examined the asymmetric effects of the rental housing supply scale on house prices caused by the differences in substitutability between

self-owned housing and rental housing. The results revealed that the housing market reaction to rental supply increases depended on the city-level substitutability between owning and renting (Yaoyao Li, et al., 2022).

Another factor that exhibits asymmetric relations with house price dynamics is land supply. A recent study shows that a decrease in land availability has a weaker impact on house prices in the long run than an increase in land availability (Yii, et al., 2022).

This rigidity in the rents and house prices has drawn both theoretical and empirical interest from scholars. Nonetheless, the research was not limited to housing markets. Prior research on commercial property markets suggests that, for various reasons, rents exhibit asymmetric adjustments to demand and supply shocks (Englund, et al., 2008; Hendershott, et al., 2010; Ibanez & Pennington-Cross, 2013; McCartney, 2012; Nowak, et al., 2020).

Based on the existing body of knowledge, we conclude that empirical research on asymmetric adjustments of house prices in emerging and transitional markets is still underdeveloped. The paper's novelty stems from the fact that house price dynamics have not been fully addressed within this framework in CEE countries. There is a reason to believe that these markets do not behave analogously to their mature counterparts, and no direct conclusions can be made based on previous US or UK studies research.

2. Material and methods

Previous studies investigating regional house price dynamics relied on data from the National Bank of Poland (NBP) or the Central Statistical Office (CSO). The NBP house price indices have been a longstanding and widely recognized source of information on residential price dynamics in Poland, with quarterly publications since 2010 (data from the 3rd quarter of 2006) and inclusion in the Public Statistical Research Program since 2013.

However, the NBP data did not meet the objectives of this study for two main reasons. Firstly, there were significant disparities in recorded transaction volume and average house prices between the NBP data and the available comprehensive housing transaction information (Gluszak, et al., 2018; Hill, et al., 2023; Konowalczyk, 2014). Secondly, the NBP dataset did not cover the early 2000s, a period of particular interest for the investigation. The alternative CSO dataset on house prices was unsuitable for this

research, mainly due to its limited time series, encompassing only the dynamics of residential house prices in regional areas since 2015.

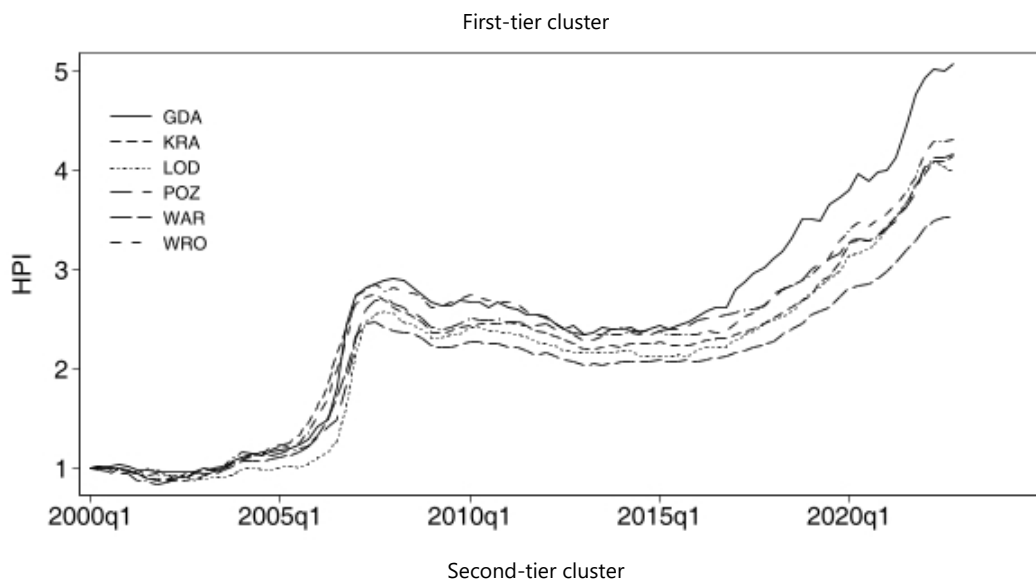
To address these limitations in NBP and CSO data, this study employed a unique dataset focusing on asking house price dynamics. Hedonic price indices are based on a unique housing offers database (more than 4.5 million observations) developed by Trojanek (2021). Using asking prices as a source for computing housing price indexes is not novel (Pollakowski, 1995). However, few research articles compare asking and transaction price indexes, primarily due to the requirement of accessing two different datasets often held by different institutions, which researchers may not have access to (Trojanek, 2018). Nonetheless, several studies suggest that offer data can provide valuable insight into property market changes and may serve as a suitable substitute when transaction data is unavailable (Anenberg & Laufer, 2017; Kolbe, et al., 2021; Lyons, 2019; Shimizu, et al., 2016). Moreover, in the case of new construction, listings can provide more reliable information on the housing market than transactions (Hill, et al., 2023).

This study employed a unique database of over 4

million apartment listings in 18 Polish provincial cities from 2000 to 2022. A detailed description of dataset formation can be found in Trojanek (Trojanek, 2021). The hedonic HPI for each city was constructed with the rolling time-dummy method (Trojanek, 2023).

We investigate house price adjustments to supply and demand shocks in 18 regional housing markets that vary in size (Figure 1). To test whether market response differs based on the size of the city (GUS, 2021), we divided the sample into three clusters:

1. First-tier cluster (largest cities with a population from 0.49 to 1.86 mln people): Gdansk (GDA), Krakow (KRA), Łódz (LOD), Poznan (POZ), Warsaw (WAR), Wrocław (WRO).
2. Second-tier cluster (medium cities with a population from 0.2 to 0.39 mln people): Białystok (BIA), Bydgoszcz (BYD), Katowice (KAT), Lublin (LUB), Szczecin (SZC), Torun (TOR).
3. Third-tier cluster (smallest cities with a population from 0.12 to 0.19 mln people): Gorzów Wielkopolski (GOW), Kielce (KIE), Olsztyn (OLS), Opole (OPO), Rzeszów (RZE), and Zielona Góra (ZGO).



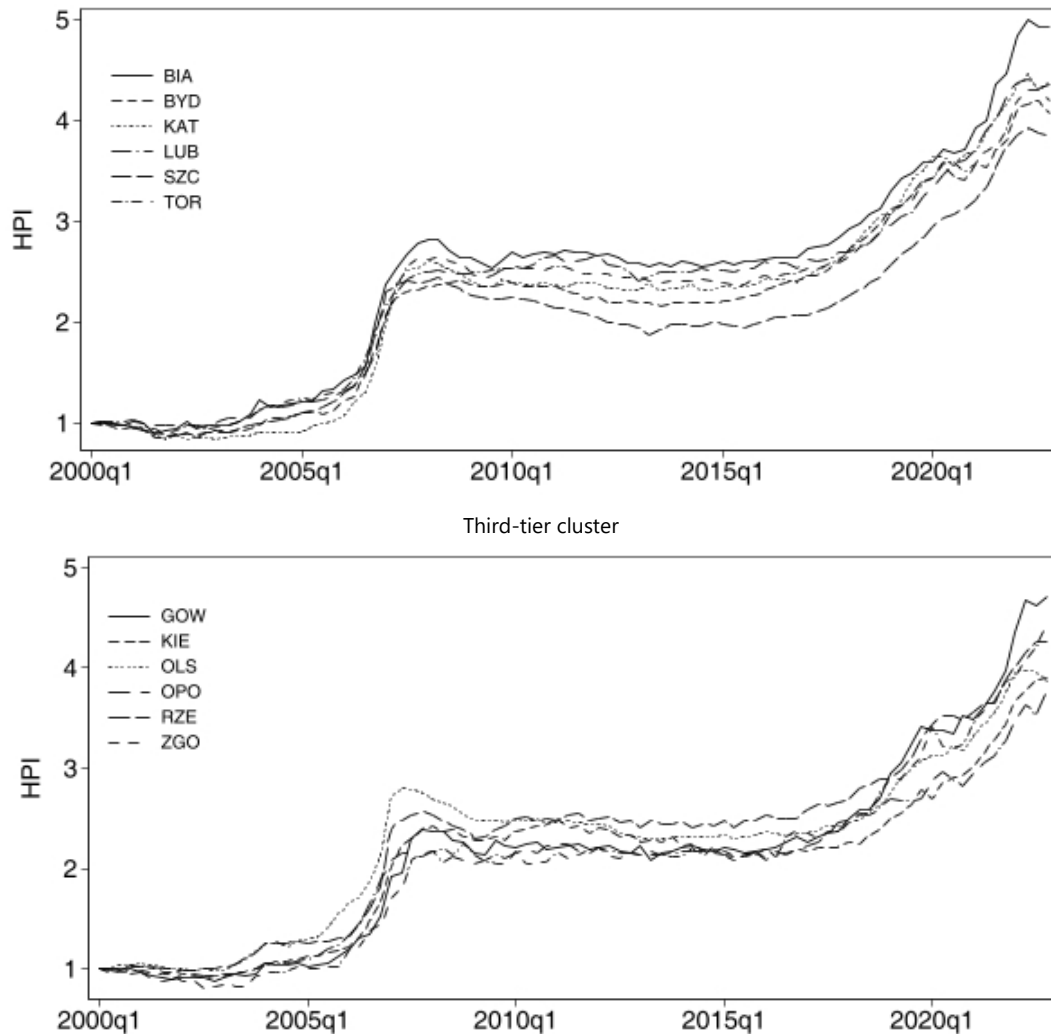


Fig. 1. Hedonic house price indices in selected cities in Poland (2000-2022). *Source:* Own elaboration.

Table 1

Variables definitions and data sources								
Variable	Definition	Frequency/ Level	Data source	Mean	SD	Min	Max	Obs
CON	New houses built	Quarterly, city	SOP	0.070	0.037	0.028	0.206	N = 1656; n=18; T=92
MIR	Interest rate for mortgage borrowing	Quarterly, country	NBP	328.018	261.814	1.00	1932.00	N = 1656; n=18; T=92
HPI	Hedonic price index	Quarterly, city	TR21	2.183	0.891	0.803	4.997	N = 1656; n=18; T=92

Note: SOP – Statistical Office of Poland; NBP – National Bank of Poland; TR21 (Trojanek, 2021).

Source: own elaboration.

Explanatory variables used in the research were selected based on the literature and availability in the Polish context. Variables available for the entire analysis period were adopted for further analysis, as well as no change in the methodology for their determination. We incorporated three groups of variables. There are many economic, financial and demographic variables potentially affecting the

dynamics of house prices that have been used in prior research, both on a country (Risse & Kern, 2016) and city level (Wei & Cao, 2017): industrial production, economic growth, (un)employment rate, salaries, stock prices, migration rates, birth rates. In the paper, we used two exogenous variables for supply and demand factors affecting house prices: new housing construction (CON) and mortgage interest rate (MIR).

A brief overview of the data is presented in Table 1.

In the paper, we use the nonlinear ARDL method introduced by Shin, Yu and Greenwood-Nimmo (2011), who argued that overlooking the salient nonlinearities leads to biased estimates and subpar inference. The NARDL framework allows for evaluating the asymmetric impact of key economic, financial and demographic variables on house prices, both in the short- and long run. In the following years, several papers adopted the nonlinear ARDL models to assess the asymmetric responses of house prices to changes in economic fundamentals (Katrakilidis & Trachanas, 2012; Zhao & Park, 2023). A recent Indian study investigated the purpose of this paper to assess the asymmetric impact of the COVID-19 pandemic on housing prices (Mehta, et al., 2023).

We test the dynamic relations between (i) the hedonic price index (HPI); (2) the mortgage interest rate (MIR), a key determinant of investment demand and (3) the new housing construction (CON), as a proxy of housing supply (see Table 1). All variables were transformed into natural logarithms.

Similarly to Katrakilidis and Trachanas (2012, p. 1066), our nonlinear ARDL model follows general empirical specification:

$$\ln HPI_t = f(\ln MIR_t^+, \ln MIR_t^-, \ln CON_t^+, \ln CON_t^-) \quad (1)$$

Where: $\ln MIR_t^+$, $\ln MIR_t^-$, $\ln CON_t^+$ and $\ln CON_t^-$ denote partial sums of positive and negative changes in $\ln MIR$ and $\ln CON$.

Considering long-run and short-run effects, as well as lags structure, our NARDL empirical nonlinear error correction specification (Katrakilidis & Trachanas, 2012, p. 1067) is given by:

$$\begin{aligned} \Delta \ln HPI_t = & \alpha + \rho \ln HPI_{t-1} + \theta_1^+ \ln MIR_{t-1}^+ + \theta_1^- \ln MIR_{t-1}^- + \theta_2^+ \ln CON_{t-1}^+ + \theta_2^- \ln CON_{t-1}^- + \\ & \sum_{i=1}^{p-1} \gamma \Delta \ln HPI_{t-i} + \sum_{i=1}^q \varphi_{1,i}^+ \Delta \ln MIR_{t-i}^+ + \sum_{i=1}^q \varphi_{1,i}^- \Delta \ln MIR_{t-i}^- + \sum_{i=1}^q \varphi_{2,i}^+ \Delta \ln CON_{t-i}^+ + \sum_{i=1}^q \varphi_{2,i}^- \Delta \ln CON_{t-i}^- + \varepsilon_t \end{aligned} \quad (2)$$

There are some alternatives to our approach. For one, several papers applied a regime-switching approach. The use of non-linear models set within

regime switching methodology is validated by unstable data-generating processes typical to emerging and changing market environments. Growing evidence suggests that models that assume economic processes' stability and apply constant parameter techniques are not robust (Brown, et al., 1997). Theoretical advantages and better forecast performance of non-linear error-correction models with multiple regimes have been discussed in the literature and tested using simulation methodology (Psaradakis & Spagnolo, 2005). Error-correction, in which the adjustment coefficient switches stochastically between a stable and unstable regime, was employed to address housing dynamics in the UK (Hall, et al., 1997). A recent study used the Markov regime-switching modeling approach to address the discrepancy between regional housing market dynamics in the UK during different regimes - recession and boom periods (Azad Chowdhury & Maclennan, 2014). In another paper, Markov regime switching modeling was applied to assess the impact of monetary policy shocks on house prices in changing economic and institutional environments (Chatziantoniou, et al., 2017). The conditions of using the Markov-switching VAR model and the benefits of regime-dependent impulse response functions are discussed in another paper that examines asymmetries in the dynamics of house prices in South Africa about monetary policy (Simo-Kengne, et al., 2013).

3. Results

3.1. Basic research premises

In the first step of the analysis, we applied the ADF unit root test. The variables used are nonstationary in levels. However, the first differences of variables are stationary. Thus we conclude that the basic requirement for the ARDL model is met. The estimations were performed in STATA 17 using the `nardl` module by Shin, Yu and Greenwood-Nimmo (2014). The estimation results for the largest cities in Poland (first-tier) are presented in Table 2.

Table 2

Vars	Nonlinear ARDL estimation results (first tier cluster)					
	Gdansk	Krakow	Lodz	Poznan	Warsaw	Wroclaw
$\ln HPI (-1)$	-0.035	-0.022**	-0.041	-0.057**	-0.043***	-0.028
$\ln MIR^+ (-1)$	-0.038	-0.001	-0.014	-0.011	-0.001	-0.034
$\ln MIR^- (-1)$	-0.065**	-0.059**	-0.053**	-0.069***	-0.066***	-0.037

InCON+(-1)	-0.004	0.019**	0.005	0.026	0.022*	0.000
InCON ⁻ (-1)	-0.002	0.027***	0.008	0.031	0.032**	0.002
$\Delta \ln \text{HPI} (-1)$	0.562***	0.557***	0.814***	0.616***	0.782***	0.246**
$\Delta \ln \text{HPI} (-2)$	-0.007	0.181*	-0.171	-0.027	-0.091	0.421***
$\Delta \ln \text{MIR}^+$	-0.053	0.023	-0.030	-0.075	-0.027	-0.036
$\Delta \ln \text{MIR}^+ (-1)$	0.043	-0.081*	0.020	0.050	0.057	0.082
$\Delta \ln \text{MIR}^+ (-2)$	0.057	0.019	0.014	-0.013	0.007	0.019
$\Delta \ln \text{MIR}^-$	-0.072	0.101***	-0.009	-0.007	0.035	0.155**
$\Delta \ln \text{MIR}^- (-1)$	0.168**	0.047	0.051	0.146**	-0.007	-0.019
$\Delta \ln \text{MIR}^- (-2)$	-0.088	-0.015	-0.024	-0.020	0.013	-0.050
$\Delta \ln \text{CON}^+$	0.014	0.016*	0.023*	0.005	-0.001	0.012
$\Delta \ln \text{CON}^+ (-1)$	-0.015	0.007	0.016	0.014	-0.013	-0.009
$\Delta \ln \text{CON}^+ (-2)$	-0.018	0.017**	-0.006	-0.013	-0.014	-0.011
$\Delta \ln \text{CON}^-$	0.007	0.000	0.002	0.006	-0.001	0.001
$\Delta \ln \text{CON}^- (-1)$	0.016	-0.025**	0.011	-0.024	-0.007	0.028
$\Delta \ln \text{CON}^- (-2)$	0.015	-0.005	0.028**	0.018	-0.019	0.022
Constant	-0.010	-0.025***	-0.027	-0.040*	-0.017	0.012
R2	0.574	0.848	0.658	0.629	0.771	0.586
A _{SR} MIR	.0615	2.847*	0.006	0.860	0.000	0.021
A _{SR} CON	2.345	14.040***	0.095	0.018	0.002	1.747
A _{LR} MIR	.548	1.620	1.421	4.182**	6.288**	0.005
A _{LR} CON	.854	1.487	1.334	3.605*	5.787**	0.0797

Note: A_{SR} is an F-stat for short-run asymmetry, and A_{LR} is an F-stat for long-run asymmetry; the superscripts "+" and "-" denote positive and negative partial sums, respectively; statistical significance * p<0.10, ** p<0.05, *** p<0.01.

Source: own elaboration.

We estimated short-run and long-run coefficients of the asymmetric ARDL model. Generally, models were reasonably well-fit to empirical data (R2 ranged from 0.57 to 0.85), and the signs were relatively intuitive. With few exceptions, long-run coefficients were also relatively similar in all cities. The short-run adjustments were also similar. These differences, however, were not notable. Moreover, based on the Wald test for both long- (ALR) and short-run (ASR), we

were able to prove either short-run or long-run asymmetric house price reaction to changes in new housing construction (lnCON) or mortgage interest rates (lnMIR) only for half of the first-tier housing market in Poland. Asymmetric short-run reactions were observed in Krakow, while long-run adjustments were confirmed in Warsaw and Poznan.

The estimation results for medium size cities (second-tier) are presented in Table 3.

Table 3

Nonlinear ARDL estimation results (second tier cluster)						
Vars	Bialystok	Bydgoszcz	Katowice	Lublin	Torun	Szczecin
InHPI (-1)	-0.060**	-0.031	-0.031	-0.018	-0.050**	-0.023
InMIR ⁺ (-1)	-0.031	-0.055*	-0.043	-0.042	-0.008	-0.092**
InMIR ⁻ (-1)	-0.081**	-0.044*	-0.064**	-0.068***	-0.042**	-0.026
InCON+(-1)	0.007	0.006	-0.004	0.020	0.019	-0.025
InCON ⁻ (-1)	0.010	0.006	-0.002	0.024	0.022	-0.030*

$\Delta \ln \text{HPI} (-1)$	0.265**	0.455***	0.542***	0.355***	0.552***	0.456***
$\Delta \ln \text{HPI} (-2)$	0.296**	0.074	0.073	0.095	0.072	0.056
$\Delta \ln \text{MIR}^+$	-0.065	-0.080	-0.048	0.040	0.070	-0.019
$\Delta \ln \text{MIR}^+ (-1)$	0.059	0.157**	-0.019	-0.022	0.027	0.035
$\Delta \ln \text{MIR}^+ (-2)$	0.105	-0.021	0.098	-0.036	-0.134*	0.159**
$\Delta \ln \text{MIR}$	-0.086	0.048	-0.081	-0.013	0.029	0.012
$\Delta \ln \text{MIR} (-1)$	-0.056	0.135**	0.183**	0.000	0.071	0.061
$\Delta \ln \text{MIR} (-2)$	0.187**	-0.035	-0.060	0.055	0.028	0.016
$\Delta \ln \text{CON}^+$	0.057***	0.010	-0.008	0.035***	0.010	-0.012
$\Delta \ln \text{CON}^+ (-1)$	0.027	-0.001	0.008	0.020**	0.002	-0.007
$\Delta \ln \text{CON}^+ (-2)$	-0.018	0.013	-0.006	0.014**	0.005	-0.003
$\Delta \ln \text{CON}^-$	-0.008	-0.001	0.008	0.004	-0.001	0.018
$\Delta \ln \text{CON}^- (-1)$	0.038*	0.002	-0.010	-0.012	0.004	0.011
$\Delta \ln \text{CON}^- (-2)$	0.039**	-0.006	0.008	-0.004	0.015	-0.018
Constant	-0.021	-0.023	-0.021	-0.044***	-0.028	0.008
R ²	0.502	0.572	0.576	0.624	0.624	0.660
A _{SR} MIR	0.093	0.477	0.004	0.231	1.469	0.399
A _{SR} CON	0.010	1.091	0.245	12.08***	0.004	0.954
A _{LR} MIR	0.996	0.086	0.247	0.455	1.497	0.665
A _{LR} CON	0.826	0.013	0.373	0.515	0.939	0.723

Note: ASR is an F-stat for short-run asymmetry, and ALR is an F-stat for long-run asymmetry; the superscripts "+" and "-" denote positive and negative partial sums, respectively; statistical significance * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: own elaboration.

We estimated short-run and long-run coefficients of the asymmetric ARDL model. Generally, we note that the signs align with the reported literature; for example, increases in mortgage interest rates were linked to house price decreases. The results were relatively similar in all of the cities in the subsample.

Additionally, we could prove short-run asymmetric

house price reaction to changes in new housing construction (lnCON) only in the case of Lublin. Apart from this singular case, the effects reported in other medium-sized cities were generally symmetrical.

The estimation results for smaller cities (third-tier) in Poland are presented in Table 4.

Table 4

Vars	Nonlinear ARDL estimation results (third tier cluster)					
	Gorzow	Kielce	Olsztyn	Opole	Rzeszow	ZGora
$\ln \text{HPI} (-1)$	-0.035	-0.037	-0.040	-0.040	-0.048	-0.032
$\ln \text{MIR}^+ (-1)$	-0.086	-0.040	-0.064*	-0.012	-0.024	-0.067
$\ln \text{MIR}^- (-1)$	-0.068**	-0.032*	-0.070***	-0.067	-0.029	-0.055*
$\ln \text{CON}^+ (-1)$	0.007	-0.020	0.003	0.005	0.017	0.022
$\ln \text{CON}^- (-1)$	0.007	-0.021	0.005	0.008	0.018	0.023
$\Delta \ln \text{HPI} (-1)$	0.085	0.224*	0.378***	0.357***	0.273**	-0.045
$\Delta \ln \text{HPI} (-2)$	0.202	0.358***	0.046	0.128	0.218*	0.275**
$\Delta \ln \text{MIR}^+$	0.034	-0.040	-0.019	0.026	0.045	-0.034

$\Delta \ln \text{MIR}^+ (-1)$	0.121	0.059	0.081	-0.029	0.029	0.011
$\Delta \ln \text{MIR}^+ (-2)$	0.071	0.021	0.016	0.040	0.021	0.153
$\Delta \ln \text{MIR}$	0.038	-0.016	0.027	0.019	0.044	0.207**
$\Delta \ln \text{MIR}^- (-1)$	0.066	0.014	-0.050	0.050	0.051	0.117
$\Delta \ln \text{MIR}^- (-2)$	-0.049	0.024	0.018	-0.012	0.053	0.085
$\Delta \ln \text{CON}^+$	0.005	-0.003	0.001	0.007	0.001	0.028**
$\Delta \ln \text{CON}^+ (-1)$	0.011	0.002	0.011	-0.001	-0.020	0.004
$\Delta \ln \text{CON}^+ (-2)$	-0.013	-0.006	0.012	0.004	-0.006	0.007
$\Delta \ln \text{CON}^-$	-0.010	-0.004	0.014	-0.004	0.000	-0.016
$\Delta \ln \text{CON}^- (-1)$	-0.010	0.020	0.004	0.003	-0.006	0.010
$\Delta \ln \text{CON}^- (-2)$	0.007	0.011	0.014	0.002	0.013	-0.008
Constant	-0.043	0.002	-0.025	-0.009	0.002	-0.035
<hr/>						
R ²	0.319	0.514	0.484	0.399	0.384	0.449
A _{SR} MIR	0.612	0.016	0.215	0.017	0.091	2.136
A _{SR} CON	0.303	2.426	0.142	0.273	1.278	2.114
A _{LR} MIR	0.092	0.043	0.024	1.117	0.009	0.046
A _{LR} CON	0.003	0.417	0.866	0.701	0.136	0.129

Note: ASR is an F-stat for short-run asymmetry, and ALR is an F-stat for long-run asymmetry; the superscripts "+" and "-" denote positive and negative partial sums, respectively; statistical significance * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Source: own elaboration.

We estimated short-run and long-run coefficients of the asymmetric ARDL model. Generally, we note that the signs along long-run coefficients are in line with expectations and relatively similar in most cities.

Based on statistical tests, we could not prove asymmetric house price reaction to changes in new housing construction (lnCON) or mortgage interest

rates (lnMIR) in the case of any third-tier housing market in Poland. Again, the effects were generally symmetrical within this subgroup of cities.

The overall overview of the long-run effects of mortgage interest rates and new housing construction on house prices is presented in Table 5.

Table 5

(A)symmetric long-run effects on house prices

Cities	Mortgage interest rate (lnMIR)		New housing construction (lnCON)	
	Long-run effect [+]	Long-run effect [-]	Long-run effect [+]	Long-run effect [-]
First-tier cluster				
Gdansk	-1.106	1.859	-0.114	0.057
Krakow	-0.048	2.712	0.888	-1.251*
Lodz	-0.352	1.294	0.122	-0.188
Poznan	-0.197	1.213**	0.449	-0.537
Warsaw	-0.031	1.531***	0.514**	-0.757***
Wroclaw	-1.208	1.329	-1.208	1.329
Second-tier cities				
Białystok	-0.512	1.345**	0.116	-0.175
Bydgoszcz	-1.799	1.425	0.188	-0.196
Katowice	-1.372	2.044	-0.124	0.074
Lublin	-2.266	3.698	1.108	-1.311
Szczecin	-3.928	1.128	-1.054	1.276

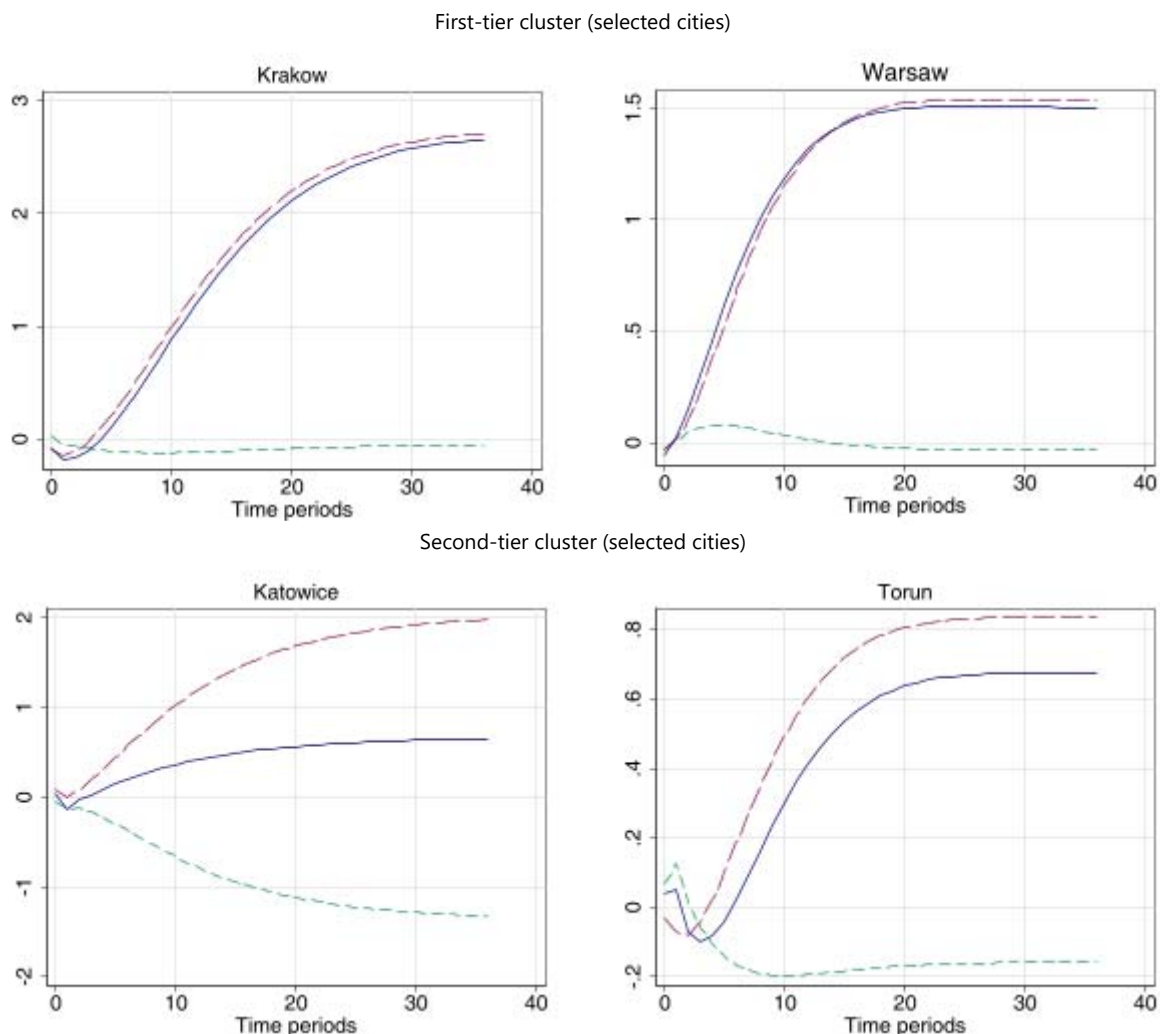
Toruń	-0.158	0.833*	0.380	-0.430*
Third-tier cities				
Gorzow Wielkopolski	-2.468	1.941	0.202	-0.205
Kielce	-1.089	0.868	-0.545	0.576
Olsztyn	-1.615	1.768	0.081	-0.116
Opole	-0.311	1.701	0.124	-0.196
Rzeszów	-0.502	0.597	0.355	-0.382
Zielona Gora	-2.111	1.746	0.691	-0.726

Note: Long-run effect [+] refers to a permanent change in an exogenous variable by +1; Long-run effect [-] refers to a permanent change in an exogenous variable by -1.
 Source: Own elaboration.

Based on a comparative analysis of long-run effects estimated in NARDL models, we observe that relatively strong asymmetry can be observed in the case of the permanent effect of mortgage interest rates in the first-tier cities (Gdansk, Krakow, Lodz, Poznan and Warsaw), where reactions to a decrease in MIR were much stronger than in case of increases. In other cases, the results were less conclusive, and there is less empirical evidence of asymmetry in market

adjustment in the long run.

A more in-depth analysis of the dynamic effects between all variables used in NARDL models is possible when examining the cumulative dynamic multipliers. Figure 2 plots the dynamic effects of positive and negative changes in mortgage interest rates on house prices in selected cities in Poland (Warsaw, Krakow, Katowice, Torun, Olsztyn and Rzeszow).



Third-tier cluster (selected cities)

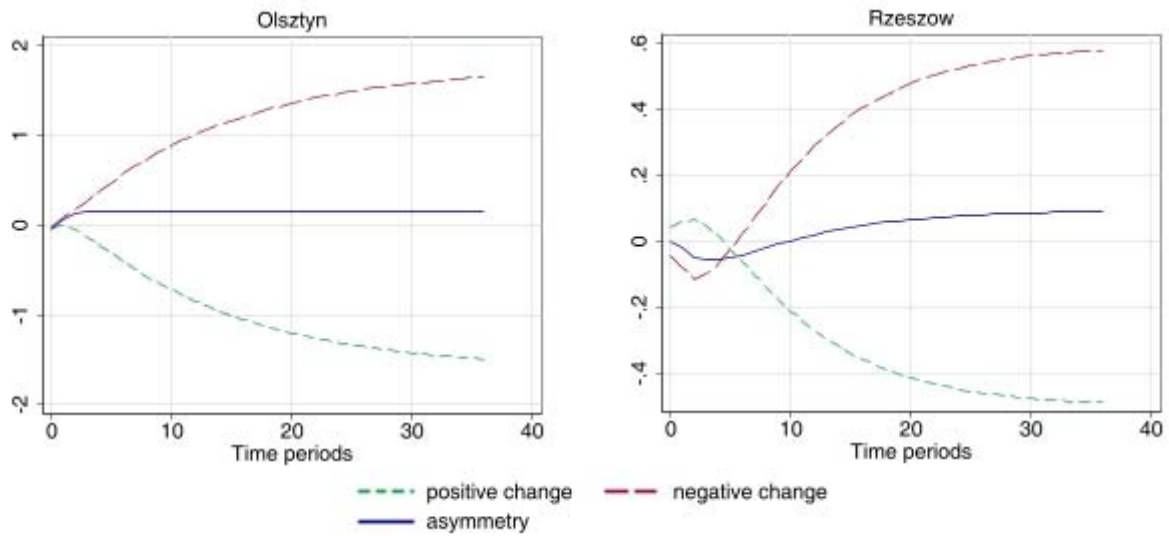


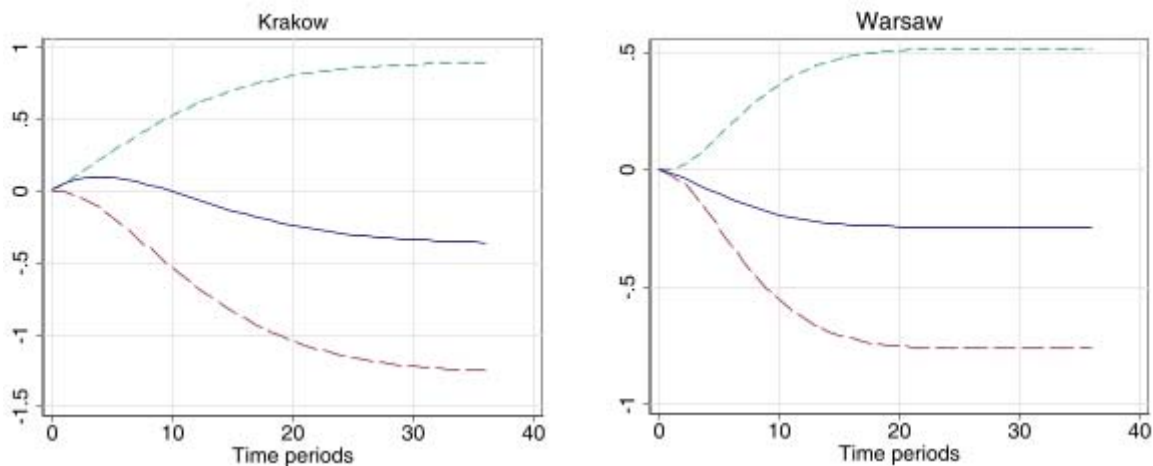
Fig. 2. The cumulative effect of Mortgage Interest Rates on House Prices in selected cities in Poland. Source: Own elaboration.

Based on Figure 2 we observe that house prices respond more to decreases in the mortgage rates than to increases in Warsaw, Krakow (and other large cities); however, the adjustment process is relatively similar. The house prices achieved equilibrium after four years. This asymmetric effect was weaker but still visible for the second-tier cluster (Katowice and Torun). The house price adjustment process to long-run equilibrium was considerably slower within this

group. Housing markets in smaller cities responded more symmetrically to positive and negative changes in mortgage interest rates. However, equilibrium was not achieved within the ten-year period.

Figure 3 illustrates the dynamic effects of positive and negative changes in new housing construction on house prices in selected cities in Poland (Warsaw, Krakow, Katowice, Torun, Olsztyn and Rzeszow).

First-tier cluster (selected cities)



Second-tier cluster (selected cities)

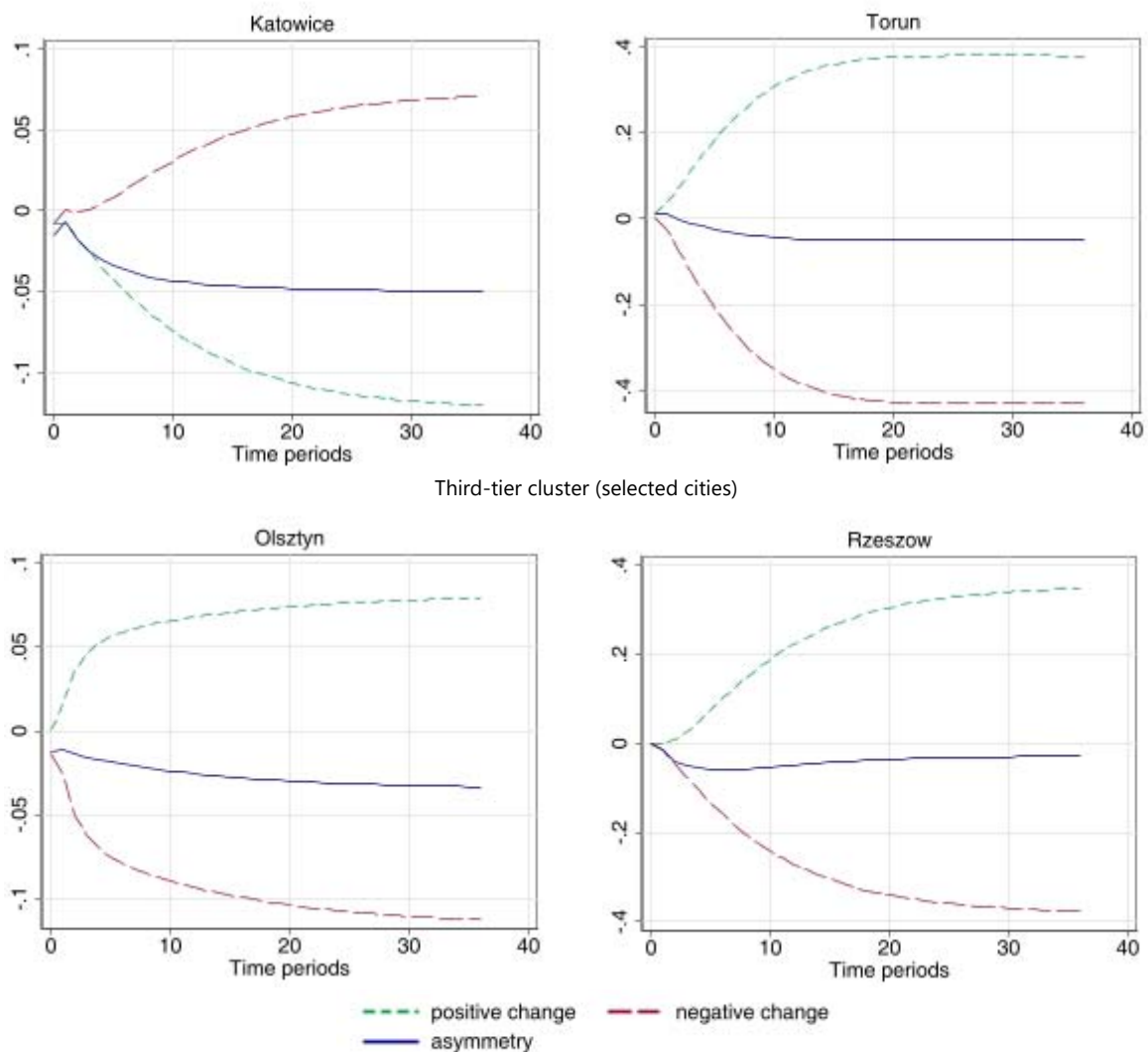


Fig. 3. The cumulative effect of New Housing Construction on House Prices in selected cities in Poland. *Source:* Own elaboration.

Examining Figure 3, we see that the dynamic response of house prices to changes in housing construction output was generally gradual and relatively symmetrical in all cities. Equilibrium correction was achieved after 4-5 years and was relatively quicker in larger cities.

4. Discussion

The results indicate that housing market reactions to positive and negative shocks may differ and generally align with the literature. We found that the reaction to exogenous shocks is not swift, as house prices were sticky in response to mortgage interest rate increases – results confirmed by several studies (Erlandsen & Juelsrud, 2023; Fan, 2022). The results also align with prior research suggesting that changes in lending conditions have an asymmetric effect on house prices (Armstrong, et al., 2019; Chatziantoniou et al., 2017).

Similarly to Katrakilidis and Trachenas (2012), we observed that house price adjustments in the short and long run differ substantially. However, on the city level, the adjustment process was longer than reported in the mentioned study. The results also indicate that market reactions may differ between different groups of regional housing markets, due to different convergence patterns (Trojanek, et al., 2023).

Finally, we add to the existing evidence on asymmetries in the residential (Brzezicka, et al., 2022) and commercial (Nowak et al., 2020) real estate market in Poland, as we contribute to the understanding of the dynamic adjustment of property prices to various demand and supply shocks.

Aside from being one of the few papers to analyze this topic in the Central Eastern European context, and Poland in particular, the paper contributes to the existing body of empirical evidence by providing

support for the presence of asymmetry in the long and short-run adjustments of house prices. We also found that market reactions differ depending on the direction of exogenous shocks, as house prices tend to display downward rigidity in response to negative demand impulses (for example, an increase in mortgage rates). The mechanism of regional housing market adjustment to the exogenous conditions is the key to the understanding of housing bubble formation (Trojanek, et al. 2023), especially when entering the new turbulent era of the climate crisis, mass-scale migration and military conflicts (Trojanek & Gluszak, 2022).

5. Conclusions

The paper investigated potential asymmetric responses of house prices to supply and demand shocks, both in the short and long run.

We used NARDL dynamic multipliers to assess the transition between the short- and long-run effects of changes in mortgage interest rates and housing construction output on house prices in regional markets in Poland. This is one of the first attempts to analyze asymmetric adjustment of house prices to positive and negative supply and demand shocks in Poland. The study used a nonlinear ARDL model to address this objective.

In particular, we tested whether house price adjustments displayed downward price rigidity exposed to negative demand shocks. Using the city-level data, we observed that house price reaction to the increases in mortgage interest rates is relatively weak and delayed, at least in most of the cities examined. We attribute that reaction to the loss aversion behavior theory. On the other hand, prices responded strongly to the decreases in mortgage interest rates in most of the cities studied. The market reactions differed substantially between cities, and only in the largest cities could we prove that the effect is statistically significant.

Secondly, the cities with high populations and housing inventory (first-tier) differed from cities with small populations and housing stock (third-tier). Reactions in the case of medium-sized cities were somewhere in between. We therefore found empirical support for the claim that at least some metropolitan housing markets adjust to demand and supply shocks based on the size of the city (population and housing stock inventory). This asymmetric effect is not universal and is predominant only in the biggest cities.

The research provides new insight into the

nonlinear reactions of house prices to exogenous shocks. It adds to the limited empirical evidence from less developed economies (most notably in Central Eastern Europe). The paper contributes to the limited empirical evidence on the asymmetric house price adjustment in regional cities in Poland, a topic that has long been understudied. Additionally, the results have important implications for housing policy, as they suggest that the effectiveness of different demand and supply incentives may differ depending on the housing market size.

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