Should we include rental prices in housing-macro VAR models?*

Radoslaw Trojanek[a] and Michał Rubaszek[b]

[a] *Poznań University of Economics and Business, Department of Microeconomics, Poland*
[b] *SGH Warsaw School of Economics, Collegium of Economic Analysis, Poland*

Abstract

We contribute to the macro-housing literature by incorporating rental prices into the structural VAR framework. With a unique quarterly dataset covering nine major Polish cities and years from 2000 to 2024, we find that rental prices are driven by labour market and house price shocks, while the impact of rental price shocks on unemployment, wages, and house prices is small or negligible. Consequently, rental prices can be treated as a post-recursive variable in macro-housing VAR models. This implies that policymakers might appreciate the rental market's role in housing affordability but need not be concerned about potential spillover effects from rental prices on the broader economy. These results may be specific to Poland's housing market, whose tenure structure is strongly tilted towards home ownership.

Keywords: Panel Vector Autoregression, Macro-housing VAR, Rental prices, Impulse-response function.

JEL classification: C33, J23, R30.

*Correspondence should be directed to `Radoslaw.Trojanek@ue.poznan.pl`. This article was realized thanks to the financial support from the National Science Centre (Poland) within grant No. 2021/43/B/HS4/01213.

1 Introduction

Until the Great Financial Crisis (GFC), the macroeconomic literature had paid little attention to the role of housing in the dynamics of the real sector of the economy. The article of Leamer (2007), who points out that eight out of ten US recessions between 1945 and 2006 were preceded by substantial problems in the housing sector, is a rare exception.[1] This earlier lack of interest in housing by macroeconomists can be illustrated by the fact that the Handbook of Macroeconomics from 1999 contains no references to housing. Housing was perceived as a capital, consumption good, or household wealth component that does not deserve special attention. After the GFC, the importance of housing for the economy has received more recognition in the economic literature, which is well described in the comprehensive review by Piazzesi and Schneider (2016).

The increased interest in the housing sector in the macroeconomic literature has been predominantly focused on the home-ownership segment of the market. On the contrary, the role of the rental market, including the level of rents, has gathered relatively little attention. As noticed by Leung (2022), the rental market is typically assumed away in classical macro-housing papers. Theoretical studies based on the DSGE framework are usually based on the seminal setup of Iacoviello (2005), in which households are solely allowed to own a house.[2] In the macro-housing VAR studies the housing sector is usually represented by house prices and, sometimes, investment in residential investment (e.g., Iacoviello, 2002; Musso et al., 2011; Calza et al., 2013; Rahal, 2016; Nocera and Roma, 2017; Zhu et al., 2017; Rosenberg, 2019; Rubaszek et al., 2025). The dynamics of rental prices are hardly considered in these studies, with the article of Dias and Duarte (2019) being the rare exception. In this case, however, the authors include housing rents in the set of endogenous variables to analyse rental prices as a component of the consumer price index in transmitting US monetary policy shocks.[3] As a result,

[1]It can be noticed, however, that Leamer emphasises that he is not a macroeconomist, hence was not constrained by theories that neglect the role of housing in modern US recessions.

[2]The studies of Rubio (2019); Rubaszek and Rubio (2020) are the exceptions as they propose a DSGE model with the rental market.

[3]The main finding is that, in contrast to house prices, housing rents increase in response to contractionary monetary policy shocks, which helps to understand inflation dynamics, including the existence of the "price puzzle".

it can be stated that the effects of rental price shock on the economy have been insufficiently explored in the macro-housing literature.

This lack of rental market dynamics in the macro-housing studies should be contrasted with the fact that about one-quarter of the OECD population lives in rental housing (see OECD Affordable Housing database). For that reason, several studies point to the high importance of the rental market for the joint dynamics of the housing sector and the macroeconomy and for reducing housing market shocks. They show that a developed rental market attenuates the effect of macroeconomic shocks on the housing market and simultaneously causes the strength of shocks originating in the housing sector to be lower. The main explanation of these findings is that a developed rental market causes that changes in credit availability do not lead to substantial swings in housing demand (e.g., Maclennan et al., 1998; van der Heijden et al., 2011; Kofner, 2014). Cuerpo et al. (2014) and Czerniak and Rubaszek (2018) confirm this mechanism with panel regressions by showing that housing sector volatility over the business cycle is negatively related to the size of the rental market. In turn, Rubaszek et al. (2025), who use the size of the rental market as an interaction variable in the PVAR model, indicate that the tenure structure significantly affects the economy's response to monetary and financial shocks.

A key question in this article is whether including rental prices in the housing-macro VAR model affects the joint dynamics of the remaining variables in the system. In the above context, we should refer to an ongoing debate on the dynamic relationship between house and rental prices in the housing literature. As discussed in the recent contribution by Fama and French (2024), house prices should equal the discounted value of rents the house will deliver in the future. This implies that past house price changes should not help predict future changes in the level of rents, whereas unexpected rent changes should instantaneously affect house prices. Regarding empirical evidence, Fama and French (2024) show that this model is not confirmed by the data for US cities, in which past house price changes help forecast rents. Other studies confirm this result within a bivariate VAR framework for house and rental prices. For the Italian market, Manganelli et al. (2014) show that housing prices affect rental prices, but the reverse causality is absent. Guancen et al. (2021) focus on the relationship between housing and rental prices in Chinese cities using a panel VAR model to show that both variables move independently or are interlinked depending on the housing policy. Chen and Chiang (2021) applies the time-varying Granger-causality test to conclude that the causal relationships between housing rents and housing prices in four Chinese cities are time-varying.

Our paper contributes to the above discussions by investigating the joint dynamics of four variables representing the housing sector and the labour market. We use a unique quarterly database for nine Polish cities over 2000:1-2024:1 to explore the joint dynamics of the unemployment rate, real wages, and real house and rental prices. We do it by estimating and simulating a panel VAR model. We present new evidence on how rental prices react to structural shocks and the macroeconomic effects of rental price shocks. Our main findings are that, at the three-year forecast horizon, labour market shocks are responsible for about a quarter of rental price variance, and the contribution of house price shocks is about 30%. In contrast, the remaining 45% of variance is related to shocks idiosyncratic to the rental market. Next, we show that rental market shocks' contribution to the variance of the remaining variables is small or negligible. This indicates that renal prices can be treated as a post-recursive variable in the housing-macro VAR framework. As a result, omitting this variable from the system is partially justified.

Our results should be interpreted with caution as they might be specific to the Polish market, especially as the tenancy structure and characteristics of this market resemble post-transition rather than mature economies (Priemus and Mandic, 2000; Rubaszek, 2019). First of all, Poland's market is strongly tilted towards home-ownership: Eurostat data indicate that with 87% home-ownership rate, Poland is ranked very high compared to other EU countries. The rental sector accounts for the remaining 13%, with the market-rate rentals amounting to merely 4%. This outcome can be attributed to two primary factors: the systematic privatisation initiatives implemented during the post-communist transition of the 1990s and deeply embedded socio-cultural preferences favouring property ownership over tenancy. Secondly, the private rental market is also different than in mature economies. It is characterised by high fragmentation and the dominance of individual landlords, managing portfolios ranging from a single to a few units rather than bigger institutional investors. Individual landlords constitute approximately 98% of the market share. This means that the share of professional, institutional investors remains well below the levels observed in mature markets. For the above reasons, further investigation into mature housing markets is warranted.

The rest of this paper is organised as follows. Section 2 presents the panel VAR methodology. Section 3 discusses the data used in this paper. Section 4 presents the empirical results. The last section concludes.

2 Econometric methodology

Our methodology is based on a panel vector autoregression (PVAR) model describing the dynamics of the following set of variables: the unemployment rate (*unemp*), log real wages (*wage*), log real house prices (*hpi*), and log real rental prices (*rent*). This choice of endogenous variables allows us to investigate the interaction between the macroeconomy, represented by labour market variables, and the housing sector.

The vector of endogenous variables is $\mathbf{x}_{it} = (unemp_{it}, wage_{it}, hpi_{it}, rent_{it})'$, where i stands for city index and t refers to time period. Its dynamics are given by:

$$\mathbf{x}_{it} = \mu_i + \sum_{l=1}^{L} A_l \mathbf{x}_{i,t-l} + D\epsilon_{it}, \tag{1}$$

where $\epsilon_{it} = (\epsilon_{it}^U, \epsilon_{it}^W, \epsilon_{it}^H, \epsilon_{it}^R)'$ is the vector of uncorrelated structural shocks. In the above notation μ_i stands for fixed effects, A_l are matrices of parameters describing the dynamics of the model, and D is a recursive identification matrix. The maximum lag length L is set to four quarters to account for the use of quarterly data. The PVAR model is specified for seasonally adjusted variables in levels, which follows the dominant part of the macro-housing VAR studies that use models specified in levels rather than growth rates (e.g., Musso et al., 2011; Calza et al., 2013; Sa et al., 2014; Rahal, 2016; Rosenberg, 2019; Rubaszek et al., 2025). As regards the technical details, the PVAR model is estimated using the mean group estimator of Pesaran and Smith (1995) using the `panelvar` package in `R`.

The PVAR model described in equation (1) assumes that the system dynamics are the same in all units i, i.e. Polish cities. We test this assumption in the sensitivity analysis by estimating the heterogenous PVAR model:

$$\mathbf{x}_{it} = \mu_i + \sum_{l=1}^{L} A_{li}\mathbf{x}_{i,t-l} + D_i\epsilon_{it}, \tag{2}$$

in which all model parameters depend on index i and endogenous variables response to structural shocks can vary across cities. The simplest way to explore this heterogeneous response would be to consider separate VAR models for each unit (in our case city). This kind of strategy has been applied in several papers investigating the dynamics of the housing market in a multi-country context (e.g., Iacoviello, 2002; Giuliodori, 2005; Calza et al., 2013; Nocera and Roma, 2017). The alternative is to estimate an interacted PVAR model, introduced to the literature by Towbin and Weber (2013), in which the parameters are allowed to vary with city characteristics z_i, so that:

$$\begin{aligned} A_{li} &= A_{l,0} + A_{l,1}z_i \\ D_i &= D_0 + D_1 z_i \end{aligned} \tag{3}$$

for $l = 1, \ldots, L$. In our study, we use two kinds of interaction variables, which, in our opinion, are relevant to the functioning of the rental market: the number of students per 10k inhabitants (demand characteristic) and the number of apartments (supply characteristic) per 1000 inhabitants.[4]

It can be noted that in the housing-macro VAR literature, the interacted PVAR framework was applied by Zhu et al. (2017), who show that the housing market response to monetary policy innovations depends on the mortgage market structure, and by Rubaszek et al. (2025), who show that the rental market structure affects the response of the economy to interest rate shock. This method has also been successfully applied to analyse fiscal policy shocks (Amendola et al., 2020; Huidrom et al., 2020), the dynamic of the labour market (Abbritti and Weber, 2018) or the response of the economy to commodity prices (Dabrowski et al., 2022).

[4]Both variables are taken from Local Data Bank of Polish Central Statistical Office, tickers: P2383 and P2430.

3 Data

Our dataset describes the joint dynamics of the labour and housing markets in five of the largest Polish cities (Warszawa, Krakow, Wroclaw, Lodz, Poznan) and four other voivodship capitals (Gdansk, Bydgoszcz, Szczecin, and Lublin). The time coverage for the five largest cities is from 2000:1 to 2024:1, whereas for the last four, the sample starts in 2008:4. The starting period is chosen based on the availability of house and rent price data.

For house and rental prices, we use a unique database compiled and described by (Trojanek, 2021; **?**), which we updated for the purpose of this study. It is based on over 4 million apartment listings for rent and sale from the analysed cities from 2000:1 to 2024:1. The data for the five largest cities over the initial periods (2000:1-2008:3) are collected and digitalised from numerous advertisements in local newspapers. The data for all cities from 2008:4 onwards are gathered from advertising portals using web-scraping techniques. For each city, the listing data are used to calculate the hedonic house price index and hedonic rental price index with the rolling time-dummy method. The set of explanatory variables in these hedonic models varies depending on the data source. Listings from 2008:4 onwards include district/estate, area, age, technology, and apartment quality. The variables for listings up to 2008:3 are limited to district/estate and area.[5]

Our database is unique because it is based on the hedonic house and rental price indices for the same geographical units (in our case, cities), and these kinds of data are hardly available. The last aspect related to our database worth discussing is that we use listings and not transaction data. The use of this kind of data as a source of information for computing housing price indexes, which dates back to (Pollakowski, 1995), has been justified by several studies that compared housing price indices derived from listings with those based on actual sales transactions.

[5] There are alternative, official house price indices, which are published by the Polish Central Statistical Office (CSO) and the National Bank of Poland (NBP). The NBP house price indices have been published since 2010, with quarterly data dating back to 2006:3. The CSO offers alternative house price indices for provincial cities, limited to full property ownership and years after 2015. We don't use these data as their sample length is shorter than ours, and they don't incorporate hedonic indices for rental prices. Even though the NBP publishes information on the rent level, it is based on simple averages. Additionally, the initial observations in the NBP dataset might not be representative of the entire market (see Głuszak et al., 2018; Hill and Trojanek, 2022, for details).

These studies highlight the high accuracy of listings-based price indices and present evidence that they often predict future transaction data changes (e.g. Anenberg and Laufer, 2017; Shimizu et al., 2016; Wang et al., 2020; Ardila et al., 2021). This implies that analysing listing data can be valuable for understanding housing market dynamics, especially when transaction data is limited or unavailable.

In the empirical analysis, we deflate house and rental prices by the country-wide consumer price index (CPI) to be expressed in real terms. These series are presented in the upper panel of Figure 1, and the descriptive statistics for their growth rates are summarised in Table 1. The upper left panel of the figure illustrates the rapid increase in house prices before the GFC, their gradual decline afterwards, and subsequent rebound from 2015 onward. The right upper panel indicates that rental prices exhibited a broadly horizontal trend. This is confirmed by the figures about the annualised growth rates reported in the table, which ranged between 2.94% (Bydgoszcz) and 4.19% (Gdansk) for real house prices and merely between -0.47% (Warszawa) to 0.90% (Wroclaw) for real rents. The table also shows that the volatility of house and rental prices is comparable, with an annualised standard deviation amounting to around 7-8%. Finally, the table reports that growth rates of house prices are characterised by highly positive skewness, strongly fat tails, and high autocorrelation. At the same time, these characteristics are less pronounced for rental prices.

The labour market data are downloaded from the Local Data Bank provided of the CSO (tickers: P2392 and P2497). Both series are seasonally adjusted using `seasonal` package in `R`, and wages are deflated by the CPI. The bottom-left panel of Figure 1 shows that real wages were increasing steadily over the investigated period, with the average growth rate amounting to between 1.97% in Warsaw and 3.66% in Krakow (see bottom panel of Table 1). In turn, the bottom-right panel outlines the spectacular decline of the unemployment rate from double-digit levels observed in the early 2000s to below 5% at the end of the sample.

4 Results

In the first part of this section, we describe the results of simulations with the homogeneous PVAR model (see equation 1). Our main focus is concentrated on two aspects: the response of rental prices to structural shocks and the effects of the rental price shock on wages, the unemployment rate and house prices. Next, we investigate if incorporating rental prices in the model affects the joint dynamics of the remaining variables. We compare the impulse-response functions from four-variate (with rental prices) and three-variate (without rental prices) VAR models. Finally, we check if the homogeneity assumption of the PVAR model from equation (1) is justified. We simulate the interacted PVAR model described in equations (2)–(3).

Response of rental prices to shocks. We start our investigation by analysing the response of rental prices to the four structural shocks. The left panels of the Figure 2 indicate that the labour supply shock, which leads to higher unemployment and lower wages, suppresses real house and rental prices. In the latter case, the decline hits its low of about 1.5% two years after the shock. The panels in the next column illustrate that labour demand shock, defined as a permanent upward shift in real wages and a gradual decline in unemployment, leads to a rise in house and rental prices, where real rents are about 1% higher three years after the shock. It should be noted that the pattern of house and rental prices responses to both labour market shocks is similar, which means that rent-to-price ratios are relatively stable. The panels in the third column show that the house price shock, which augments real house prices by 3% on impact and 6% at a two-year horizon, also increases rents by about 2% within three years. This means that rental prices are gradually adjusting to changes in house prices. Finally, the bottom-right panel illustrates that the rental price shock is defined as a quick increase in real rental prices by about 3% and their gradual return to the initial level.

Regarding the contribution of the above four shocks to rental price variance, Table 2 shows that at the shortest horizon, rental price shocks are responsible for over 95% of rental price fluctuations. On the contrary, at the three-year horizon, this share drops to about 45%, as the contributions of house price shocks (30%), unemployment shocks (20%) and wage shocks (5%) are increasing.

Dynamic effects of rental price shocks. We continue the analysis by looking at the effects of the rental price shock on the remaining variables, describing the labour and housing market. The results are presented in the right panels of Figure 2. As mentioned above, the rental price shock is defined as an immediate increase in real rental prices by about 3% and their gradual return to the initial level. This increase in rental prices does not affect real house prices in a significant way, which is not consistent with the model that links house prices with expected rents (see Fama and French, 2024). The figure also shows that the response of real wages is insignificant. Finally, there is a significant albeit small increase in the unemployment rate at longer horizons, consistent with the notion that high rents are detrimental to labour mobility, negatively affecting employment.

In general, the analysis of Figure 2 indicates that the effects of the rental price shock on the unemployment rate, wages and real house prices is small or negligible. This is confirmed by the forecast error variance decomposition results reported in Table 2. It shows that the contribution of rental price shocks to real wage variance and real house prices is below 0.5%. As regards the unemployment rate, the role of rental price shocks is negligible for shorter horizons, but amounts to 3% at the three-year horizon.

Including rental prices to macro-housing SVAR model. We continue our investigation by checking if including rental prices in the macro-housing VAR affects the joint dynamics of the remaining variables. For that purpose, we estimate and simulate PVAR model for the vector of three variables ($\mathbf{x}_{it} = (unemp_{it}, wage_{it}, hpi_{it})'$), i.e. the full model without rental prices. Next, we compare the response of these three variables to unemployment, wage and house price shocks in full and restricted models.

Figure 3 illustrates that removing rental prices from the VAR model does not meaningfully affects the shape of IRFs. This implies that rental prices can be considered as a post-recursive variable in a macro-housing VAR model. However, it should be added that this result might be related to the fact that the tenure structure in Poland is heavily tilted toward home-ownership, hence rental prices might be less important than in other developed countries.

Identification scheme. In the baseline specification, we have identified structural shocks by applying a recursive scheme with house prices leading to rental prices.

This scheme might be questioned as the theoretical model linking house prices with expected rents implies reverse ordering. In Figure 4, we present the impulse response function from this alternative recursive identification scheme, in which rental price shocks affect house prices instantaneously. It can be seen that our benchmark results are broadly robust in response to this change.

Homogeneity issues Finally, we check whether the homogeneity assumption of the PVAR model is justified. We do it by simulating the Interacted PVAR model described in equations (2)–(3). If the response to shocks in this interacted PVAR model would vary across cities, this would indicate that the homogeneity assumption is violated. As a result, the use of interacted PVAR might be treated as a test for the homogeneity assumption in PVAR.

We have decided to use the number of students, who comprise the main tenants (demand characteristic), and the number of apartments (supply characteristic) as interaction variables. In both cases, the variables are scaled by the number of inhabitants. In Figures 5 and 6, we compare the response of two cities with the highest (black colour) and lowest (red colour) values of these interaction variables. In general, differences in the response to all shocks in both cities are insignificant. These simulations show this informal test does not reject the PVAR homogeneity assumption.

5 Conclusion and policy implications

This study has provided new insights into the macro-housing literature by incorporating rental prices into the structural VAR framework. Using a unique quarterly dataset for nine Polish cities and years from 2000 to 2024, we have estimated and simulated a panel VAR model to reach several conclusions. We have shown that labour market conditions and house prices are significant drivers of rental price dynamics. On the contrary, the contribution of rental price shocks to the variance of wages and house prices turned out insignificant. For the unemployment rate, we have found that higher rents might lead to a slight deterioration in labour market conditions at longer horizons. Our results imply that rental prices can be treated as a post-recursive variable in macro-housing VAR models. However, it should be noted that this result may be specific to our sample, given the unique characteristics of Poland's housing market, such as the high home-ownership rate and the relatively small rental market.

Our findings have important policy implications. While macroeconomic and housing market conditions influence rental prices, they do not appear to have significant feedback effects on these variables. This suggests that policymakers should consider the rental market's role in housing affordability but may not be concerned about the potential spillover effects from rental prices on the broader economy, at least in the Polish context. Poland's unique market structure, dominated by individual landlords and low institutional involvement, serves as a case study for understanding how market-specific factors influence housing dynamics. This underscores the necessity for further research to generalise these findings across diverse housing markets and explore how rental market policies can be leveraged to enhance macroeconomic resilience.

References

Abbritti, M., Weber, S., 2018. Reassessing the role of labor market institutions for the business cycle. International Journal of Central Banking 14 (1), 1–34.

Amendola, A., Di Serio, M., Fragetta, M., Melina, G., 2020. The euro-area government spending multiplier at the effective lower bound. European Economic Review 127, 103480.

Anenberg, E., Laufer, S., 2017. A more timely house price index. Review of Economics and Statistics 99 (4), 722–734.

Ardila, D., Ahmed, A., Sornette, D., 2021. Comparing ask and transaction prices in the Swiss housing market. Quantitative Finance and Economics 5 (1), 67–93.

Calza, A., Monacelli, T., Stracca, L., 2013. Housing finance and monetary policy. Journal of the European Economic Association 11, 101–122.

Chen, C., Chiang, S., 2021. Time-varying causality in the price-rent relationship:

Revisiting housing bubble symptoms. Journal of Housing and the Built Environment 36, 539–558.

Cuerpo, C., Pontuch, P., Kalantaryan, S., 2014. Rental market regulation in the European Union. European Economy. Economic Papers 515, European Commission.

Czerniak, A., Rubaszek, M., 2018. The size of the rental market and housing market fluctuations. Open Economies Review 29 (2), 261–281.

Dabrowski, M. A., Papiez, M., Rubaszek, M., Smiech, S., 2022. The role of economic development for the effect of oil market shocks on oil-exporting countries. Evidence from the interacted panel VAR model. Energy Economics 110, 106017.

Dias, D. A., Duarte, J. B., 2019. Monetary policy, housing rents, and inflation dynamics. Journal of Applied Econometrics 34 (5), 673–687.

Fama, E. F., French, K. R., 10 2024. House prices and rents. The Review of Financial Studies, hhae065.

Giuliodori, M., 2005. The role of house prices in the monetary transmission mechanism across European countries. Scottish Journal of Political Economy 52 (4), 519–543.

Guancen, W., Chen, L., Xing, N., Ping, L., Li, T., 2021. Evolution of relationship between housing and rental prices and inter-urban differences in China under the context of the simultaneous rental and sales markets policy. Real Estate Management and Valuation 29 (3), 29–38.

Głuszak, M., Czerski, J., Zygmunt, R., 2018. Estimating repeat sales residential price indices for Krakow. Oeconomia Copernicana 9 (1), 55–69.

Hill, R. J., Trojanek, R., 2022. An evaluation of competing methods for constructing house price indexes: The case of Warsaw. Land Use Policy 120, 106226.

Huidrom, R., Kose, M. A., Lim, J. J., Ohnsorge, F. L., 2020. Why do fiscal multipliers depend on fiscal positions? Journal of Monetary Economics 114 (C), 109–125.

Iacoviello, M., 2002. House prices and business cycles in Europe: a VAR analysis. Working papers, Boston College Department of Economics Working papers.

Iacoviello, M., 2005. House prices, borrowing constraints, and monetary policy in the business cycle. American Economic Review 95 (3), 739–764.

Kofner, S., 2014. The German housing system: Fundamentally resilient? Journal of Housing and the Built Environment 29 (2), 255–275.

Leamer, E. E., 2007. Housing is the business cycle. Proceedings - Economic Policy Symposium - Jackson Hole, 149–233.

Leung, C. K. Y., 2022. Housing and Macroeconomics. ISER Discussion Paper 1197, Institute of Social and Economic Research, Osaka University.

Maclennan, D., Muellbauer, J., Stephens, M., 1998. Asymmetries in housing and financial market institutions and EMU. Oxford Review of Economic Policy 14, 54–80.

Manganelli, B., Morano, P., Tajani, F., 2014. House prices and rents. The Italian experience. WSEAS Transactions on Business and Economics 11, 219–226.

Musso, A., Neri, S., Stracca, L., 2011. Housing, consumption and monetary policy: How different are the US and the euro area? Journal of Banking & Finance 35 (11), 3019–3041.

Nocera, A., Roma, M., 2017. House prices and monetary policy in the euro area: Evidence from structural VARs. Working Paper Series 2073, European Central Bank.

Pesaran, M., Smith, R., 1995. Estimating long-run relationships from dynamic heterogeneous panels. Journal of Econometrics 68 (1), 79–113.

Piazzesi, M., Schneider, M., 2016. Housing and Macroeconomics. Vol. 2 of Handbook of Macroeconomics. Ch. 19, pp. 1547–1640.

Pollakowski, H., 1995. Data sources for measuring house price changes. Journal of Housing Research 6 (3), 37–53.

Priemus, H., Mandic, S., 2000. Rental housing in Central and Eastern Europe as no man's land. Journal of Housing and the Built Environment 15 (3), 205–215.

Rahal, C., 2016. Housing markets and unconventional monetary policy. Journal of Housing Economics 32, 67–80.

Rosenberg, S., 2019. The effects of conventional and unconventional monetary policy on house prices in the Scandinavian countries. Journal of Housing Economics 46, 101659.

Rubaszek, M., 2019. Private rental housing market underdevelopment: life cycle model simulations for Poland. Baltic Journal of Economics 19 (2), 334–358.

Rubaszek, M., Rubio, M., 2020. Does the rental housing market stabilize the economy? A micro and macro perspective. Empirical Economics 59 (1), 233–257.

Rubaszek, M., Stenvall, D., Uddin, G. S., 2025. Rental market structure and housing dynamics: An interacted panel VAR investigation. International Journal of Finance & Economics 30 (1), 781–802.

Rubio, M., 2019. Rented vs. owner-occupied housing and monetary policy. The B.E. Journal of Macroeconomics 19 (1), 1–16.

Sa, F., Towbin, P., Wieladek, T., 2014. Capital inflows, financial structure and housing booms. Journal of the European Economic Association 12 (2), 522–546.

Shimizu, C., Nishimura, K. G., Watanabe, T., 2016. House prices at different stages of the buying/selling process. Regional Science and Urban Economics 59, 37–53.

Towbin, P., Weber, S., 2013. Limits of floating exchange rates: The role of foreign currency debt and import structure. Journal of Development Economics 101, 179–194.

Trojanek, R., 2021. Housing price cycles in poland – the case of 18 provincial capital cities in 2000–2020. International Journal of Strategic Property Management 25 (4), 332–345.

van der Heijden, H., Dol, K., Oxley, M., 2011. Western European housing systems and the impact of the international financial crisis. Journal of Housing and the Built Environment 26, 295–313.

Wang, X., Li, K., Wu, J., 2020. House price index based on online listing information: The case of China. Journal of Housing Economics 50, 101715.

Zhu, B., Betzinger, M., Sebastian, S., 2017. Housing market stability, mortgage market structure, and monetary policy: Evidence from the euro area. Journal of Housing Economics 37 (C), 1–21.

Figures and tables

Table 1: Descriptive Statistics

	Moments, annualized QoQ				*ACF(1)*	
	Mean	StDev	Skew	Kurt	level	diff
	Real rents					
Krakow	0.76	6.67	0.01	4.70	0.96	0.20
Lodz	0.60	9.07	0.53	5.40	0.94	-0.02
Poznan	0.43	7.37	0.26	8.17	0.94	0.11
Warszawa	-0.47	7.05	-0.85	4.47	0.94	0.29
Wroclaw	0.90	7.37	0.88	4.36	0.96	0.15
Bydgoszcz	-0.30	6.91	0.53	4.24	0.93	-0.19
Gdansk	0.24	7.77	1.01	6.19	0.93	0.17
Lublin	0.18	7.59	-0.31	2.65	0.85	-0.18
Szczecin	0.10	7.95	0.16	2.25	0.94	-0.08
	Real house prices					
Krakow	3.75	7.48	1.38	5.85	0.97	0.82
Lodz	3.24	9.50	3.25	18.26	0.97	0.70
Poznan	3.52	8.45	2.30	12.09	0.97	0.67
Warszawa	3.46	8.09	2.63	13.88	0.97	0.69
Wroclaw	3.70	8.33	1.55	6.94	0.97	0.56
Bydgoszcz	2.94	7.71	1.73	8.97	0.98	0.60
Gdansk	4.19	9.16	3.04	17.46	0.97	0.62
Lublin	3.54	6.96	2.07	11.68	0.97	0.61
Szczecin	3.02	8.07	2.20	11.28	0.98	0.67
	Real wages					
Krakow	3.66	2.16	-0.94	6.81	0.97	0.31
Lodz	2.88	1.93	-0.80	8.22	0.97	0.46
Poznan	2.62	2.17	-1.01	5.47	0.97	0.22
Warszawa	1.97	1.86	-0.82	5.20	0.97	0.37
Wroclaw	2.96	2.76	1.10	9.17	0.97	0.13
Bydgoszcz	2.74	2.98	2.40	20.41	0.97	0.17
Gdansk	3.01	2.91	-0.04	5.12	0.97	-0.02
Lublin	2.64	5.73	0.14	12.60	0.97	-0.30
Szczecin	2.57	2.89	0.80	6.49	0.97	0.07

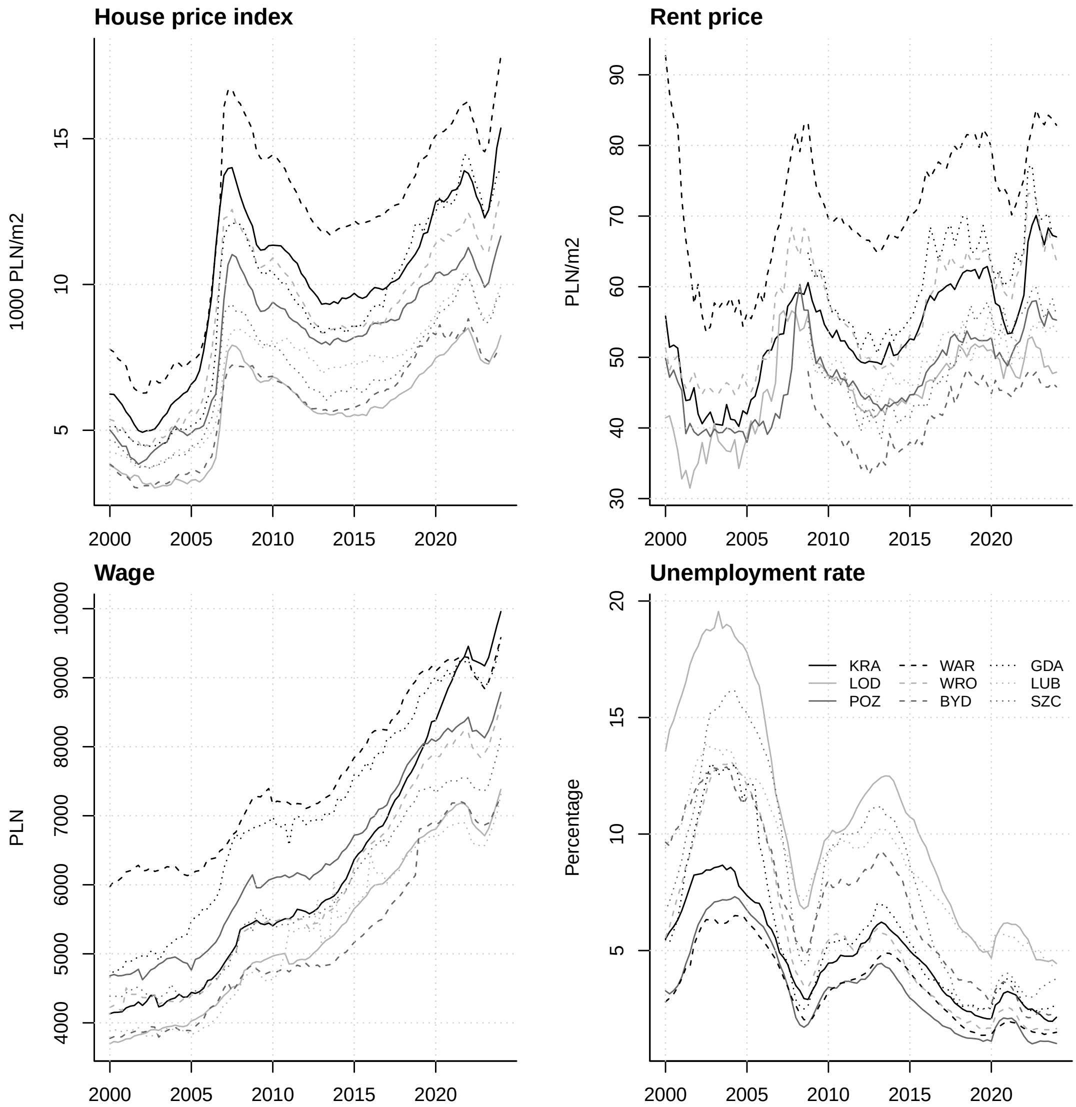
Notes: In the above table, the mean value and standard deviation have been rescaled so that they show annualised growth rates. All variables are expressed in logs.

Table 2: Forecast error variance decomposition.

Horizon	u^U	u^W	u^H	u^R	u^U	u^W	u^H	u^R
	Housing market							
	Real house prices				Real rental prices			
1Q	0.9	3.1	95.5	0.5	1.5	0.0	0.5	98.0
2Q	2.3	3.2	93.8	0.7	3.0	0.0	1.3	95.7
1Y	4.9	3.9	90.9	0.3	9.1	0.1	6.5	84.3
2Y	7.8	6.2	85.8	0.2	16.9	1.5	23.1	58.5
3Y	9.6	8.6	81.5	0.3	18.1	5.2	30.4	46.3
	Labour market							
	Unemployment rate				Real wages			
1Q	96.9	0.7	0.9	1.5	0.7	96.1	3.1	0.0
2Q	95.0	1.5	2.2	1.4	2.1	91.2	6.7	0.0
1Y	89.8	2.6	6.5	1.1	3.9	86.2	9.8	0.1
2Y	76.2	5.8	17.7	0.4	7.0	80.2	12.7	0.1
3Y	66.7	10.1	22.5	0.7	9.1	76.8	14.1	0.1

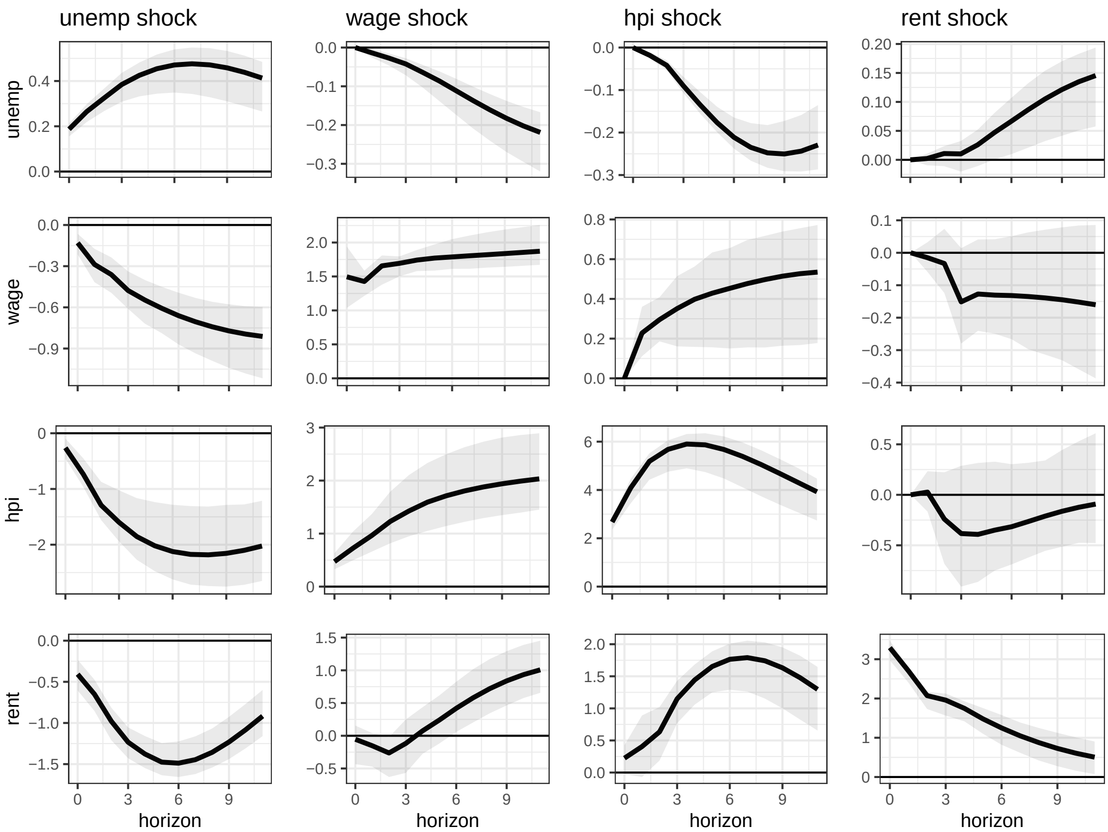
Notes: In the table u^U, u^W, u^H and u^R denote the % contributions of shocks to unemployment, wages, house prices and rental prices equations to the overall variability in endogenous variables.

Figure 1: Endogenous variables in the PVAR model.



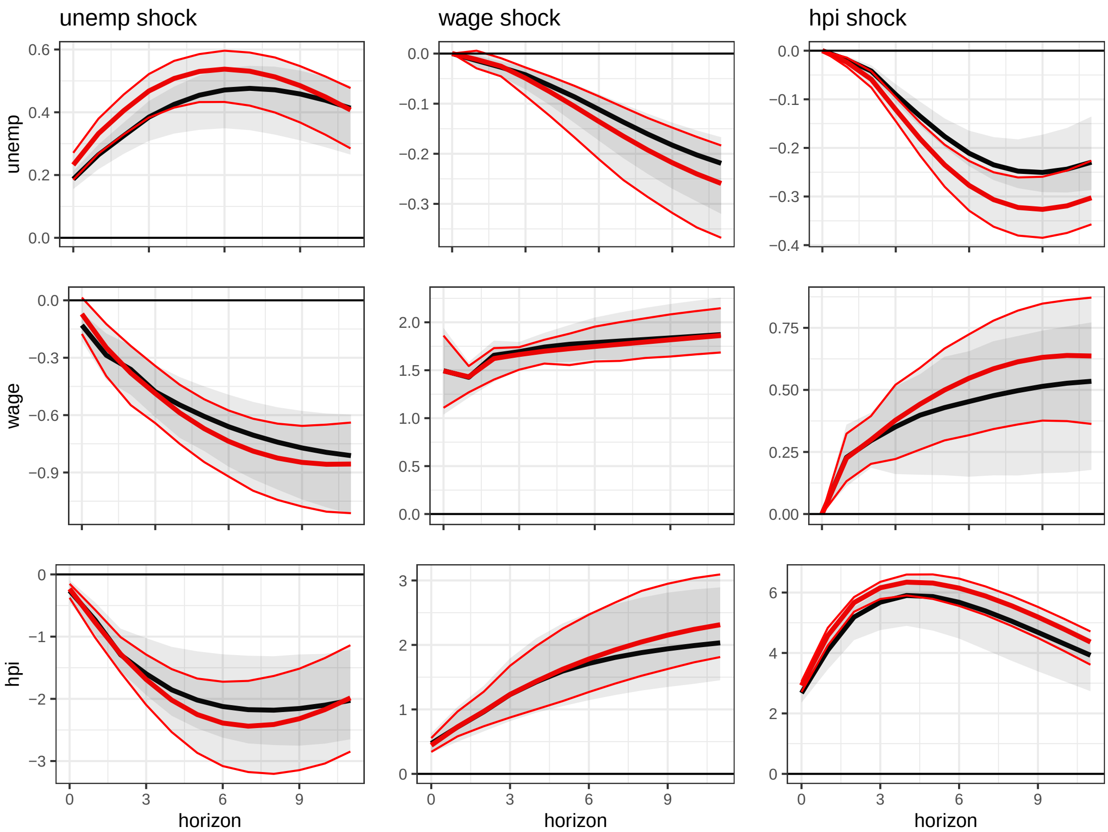
Notes: The figure presents endogenous variables in the model before log transformation.

Figure 2: Benchmark impulse response functions.



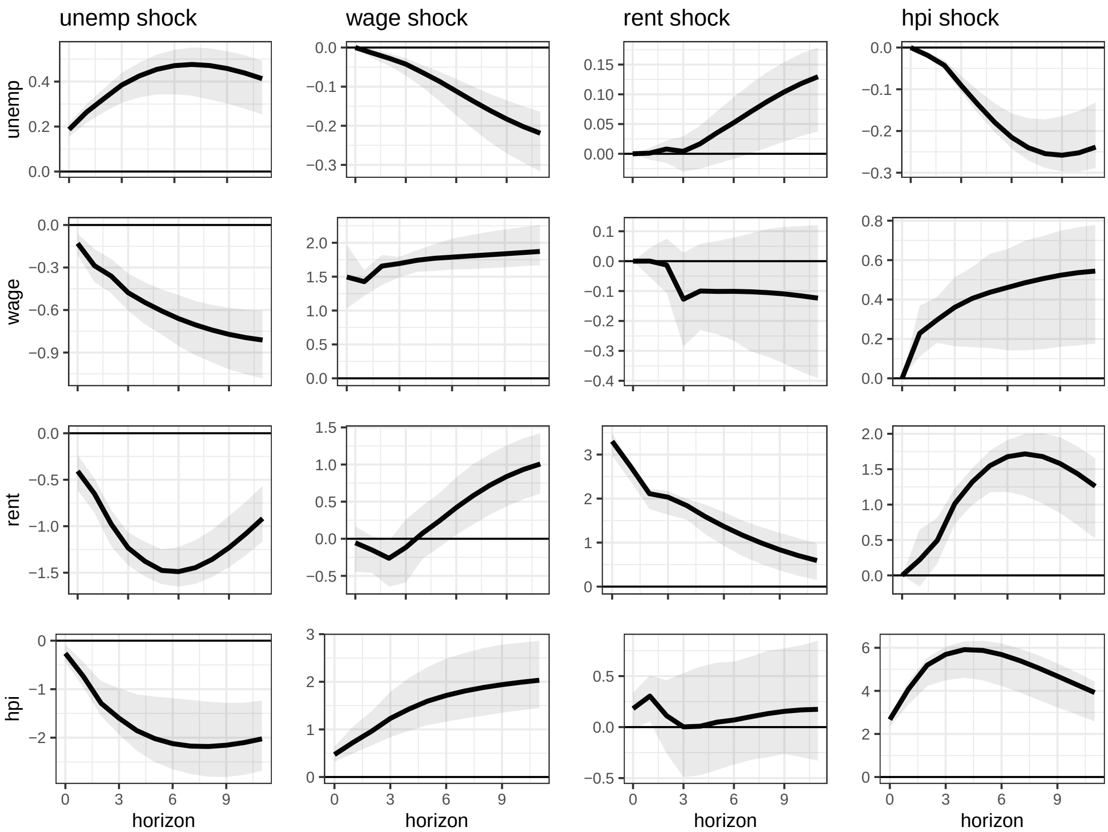
Notes: The shaded areas represent the 90% bootstrapped confidence interval. The horizon on the x-axis refers to quarters.

Figure 3: Impact of including rental prices on IRFs.



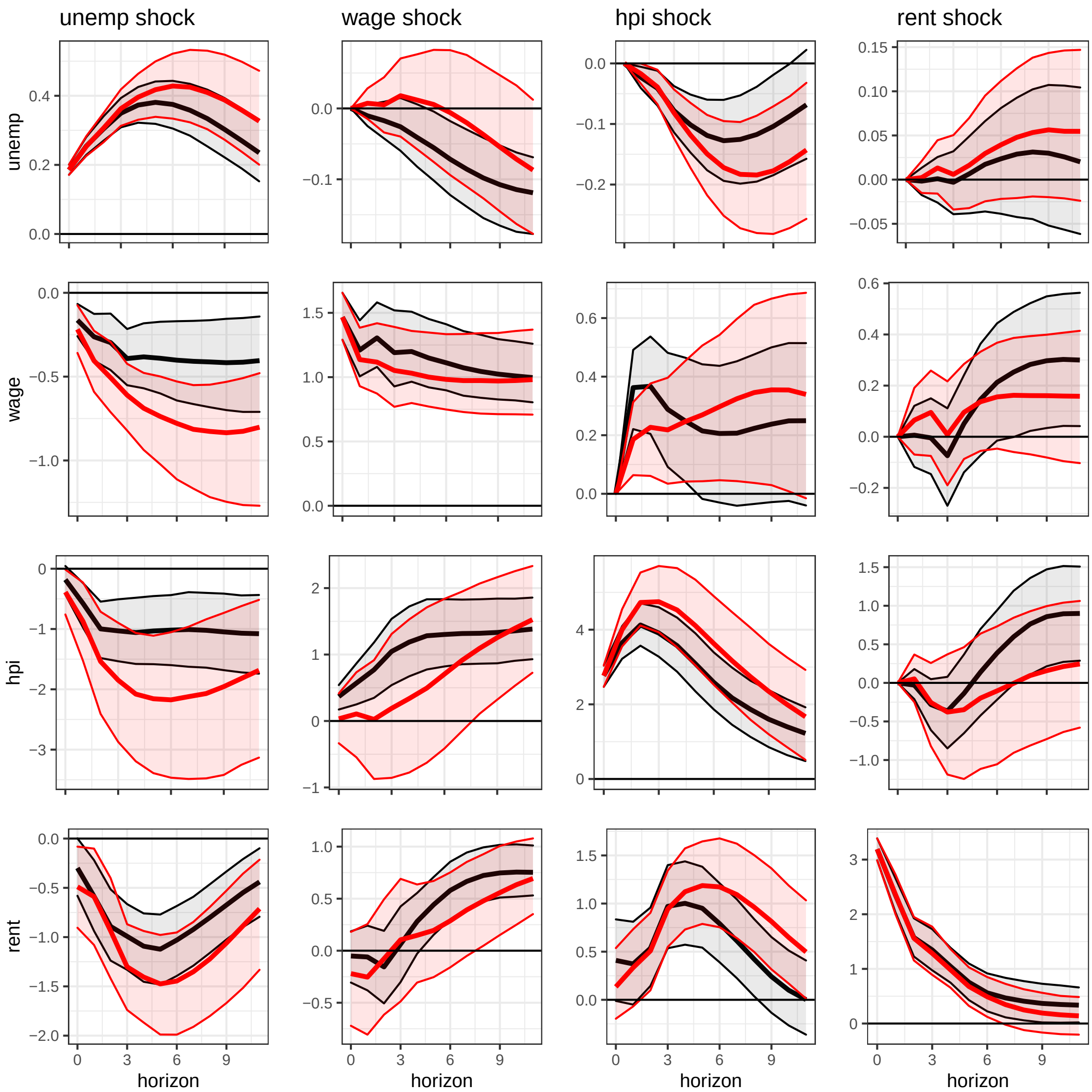
Notes: The figure presents a comparison of impulse response functions from three-variate (without $rent_{it}$, red color) and four-variate (with $rent_{it}$, black color) number of students per 10k inhabitants. The shaded areas represent the 90% bootstrapped confidence interval. The horizon on the x-axis refers to quarters. The shaded areas represent the 90% bootstrapped confidence interval. The horizon on the x-axis refers to quarters. The red shaded area represent IRFs from trivariate SVAR

Figure 4: Identification scheme and IRFs.



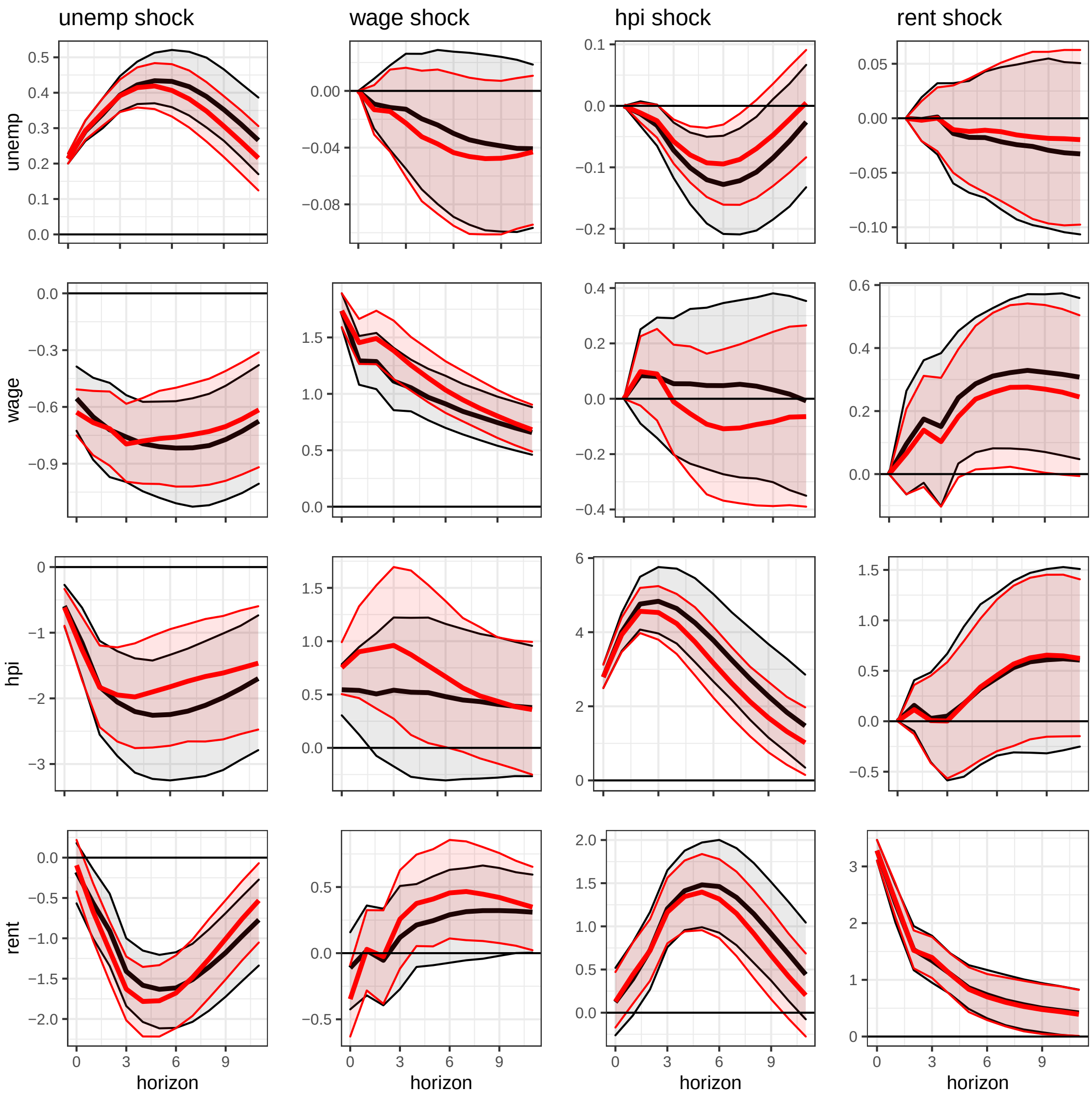
Notes: The shaded areas represent the 90% bootstrapped confidence interval. The horizon on the x-axis refers to quarters.

Figure 5: The number of students and impulse response function.



Notes: The figure presents a comparison of impulse response functions of two cities characterised by highest (Warsaw – 498.5, red color) and lowest (Bydgoszcz – 406.5, black color) number of students per 10k inhabitants. The shaded areas represent the 90% bootstrapped confidence interval. The horizon on the x-axis refers to quarters.

Figure 6: The number of houses and impulse response function.



Notes: The figure presents a comparison of impulse response functions of two cities characterised by highest (Warsaw – 576.7, red color) and lowest (Bydgoszcz – 347.9, black color) number of appartments per 1000 inhabitants. The shaded areas represent the 90% bootstrapped confidence interval. The horizon on the x-axis refers to quarters.