DOI: 10.52950/ES.2024.13.2.006

# EVIDENCE OF THE RIPPLE EFFECT ACROSS THE CZECH HOUSING MARKET

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## Abstract:

Czech regional housing markets have exhibited significant price co-movements over the last two decades. While part of this dynamic may be explained by traditional housing market fundamentals, some regions appear to be influenced by other variables. One possible explanation lies in the ripple effect, a phenomenon where house price shocks in one region influence prices in others. This study examines possible occurrence of the ripple effect using Toda-Yamamoto Granger causality. Results indicate statistically significant occurrence of lead-lag effect in eight out of 13 regions. Such price interconnectivity might be important factor for policymakers as study suggests that regional submarkets are not isolated and should be approached on macro level.

## Keywords:

House price spillovers, Regional housing market, Granger causality

**JEL Classification:** R15, R30, R31

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## Citation:

MARTIN SLANÝ, FILIP EMMER (2024). Evidence of the ripple effect across the Czech housing market. International Journal of Economic Sciences, Vol. XIII(2), pp. 104-115., 10.52950/ES.2024.13.2.006

## 1 Introduction

Over the past two decades, Czech regional housing markets have exhibited significant price co-movements. Although factors such as mortgage interest rates and regional economic disparities, as documented by Hromada (2024), affect these dynamics, some price movements appear to occur independently of traditional drivers of demand, such as demographics. One plausible explanation for this phenomenon is in ripple effect theory. Originating in the UK, the ripple effect describes a market phenomenon where house price shocks in one region affect house prices in other parts of the country (Nanda and Yeh, 2014). A defining characteristic of the ripple effect is the time lag observed in the spillover of house prices across regions.

The literature identifies several factors that may contribute to causal links between residential sub-markets. The first, and perhaps most widely discussed, transmission mechanism is migration flow. Alexander and Barrow (1994) argue that households often capitalize on regional differences in house prices. However, as noted by Meen (1999), migration flows tend to be relatively weak in many countries, including the Czech Republic. Notable exceptions include the influx of refugees following the outbreak of war in Yugoslavia in 1990 and the more recent wave of migrants from Ukraine after Russia's invasion in 2022. A second theoretical mechanism underlying house price connections is equity transfer. Households in regions experiencing price spillovers may benefit from greater house price appreciation, thereby increasing their purchasing power either in the form of collateral or liquidity and enabling properties to be purchased elsewhere. Boelhouwer et al. (2004) also discuss the role of homeowner expectations in amplifying house price spillovers.

Although the mechanisms driving house price spillovers may vary at regional and national levels, ripple effects remain an important yet underexplored topic for policymakers. Given the diverse characteristics of housing submarkets, implementing effective measures requires tailored policies (Kim and Seo, 2021). The ripple effect highlights the need for such tailored approaches, as it indicates the interdependence between regional housing markets.

The present study investigates the existence of a ripple effect from Prague to regional markets in the Czech Republic in the period Q1 2000 to Q4 2022. Methodologically, the study builds on the earlier work of Teye et al. (2017), applying the Toda-Yamamoto Granger causality approach to test for lead-lag effects. To mitigate potential confounding factors, the model incorporates controls for interest rates and real GDP growth. An analysis of quarterly regional house price time series reveals a pronounced north-south division in the timing of house price spillovers from Prague to other regions, with the exception of the South Moravia region.

The remainder of the article is structured as follows. Following the introduction, Section 2 briefly reviews related work. Section 3 describes the Czech housing submarkets and their evolution.

Section 4 outlines the methodological framework and presents empirical results. Section 5 concludes the paper and summarizes the study's key findings.

## 2 Related work

House price co-movements have been a major focus of housing market literature. Historically, much of the early research concentrated on statistical analyses of the ripple effect in the UK during the late 1980s. Giussani and Hadjimatheou (1991) identified the relationship between price developments in London and the Southeast, which, after certain time lags, spilled over to northern regions. Building on those results, subsequent studies explored not only on the identification of the ripple effect and the establishment of long-run relationships between British regions but also examined the possible determinants of these interrelations (Alexander and Barrow, 1994; MacDonald and Taylor, 1993; Meen, 1999). Specifically, the ripple effect is theorized to occur between regions that are economically interconnected through mechanisms such as migration flows, capital transfers or spatial arbitrage (Meen, 1999). Kim and Seo (2021) offer a different interpretation that departs from previous conclusions and focuses on direct spatial spillovers, defining the ripple effect as a phenomenon where “house prices from one area are transferred to neighbouring areas.”

Recent studies are more geographically diverse. For example, in European countries, Teye et al. (2017), analysed regional housing markets in the Netherlands; Buyst and Helgers (2013) concluded that in Belgium, “house price shocks are likely to ripple from Antwerp to the rest of the country.” Similarly, Żelazowski (2019) tested for house price convergence between polish regions (voivodships), identifying long run convergence in about a quarter of these regions.

The strategies used to identify the ripple effect in housing markets vary across studies. A common approach involves testing for stationarity, using various methods. For example, augmented Dickey–Fuller tests are used to assess the stationarity of regional to national housing-price ratios (Meen, 1999; Cook, 2003). Tsai (2014) employed panel root tests to demonstrate the existence of a long-run equilibrium between national and regional housing markets in the UK. Advanced stationarity testing methods, such as SURADF and half-life analysis, were used by Holmes and Grimes (2008), Lee and Chien (2011) and Żelazowski (2019).

A large body of research also employs dynamic econometric models that control for potential confounding factors and effectively capture the propagation of price shocks. For example, Kim and Seo (2021) applied Granger causality and impulse response techniques to analyse house price relationships in the Seoul metropolitan area. Similarly, Shih, Li and Qin (2014) applied a vector error correction model to investigate spillover effects from core to peripheral Chinese provinces between 2000 and 2012. An earlier study by Riddle (2011) also applied an error correction model to explore how house prices in Los Angeles affected those in other submarkets.

For purposes of the present study, the lead-lag identification method applied by Teye et al. (2017) in their analysis of house prices in the Netherlands serves as a crucial reference. Using the Toda–

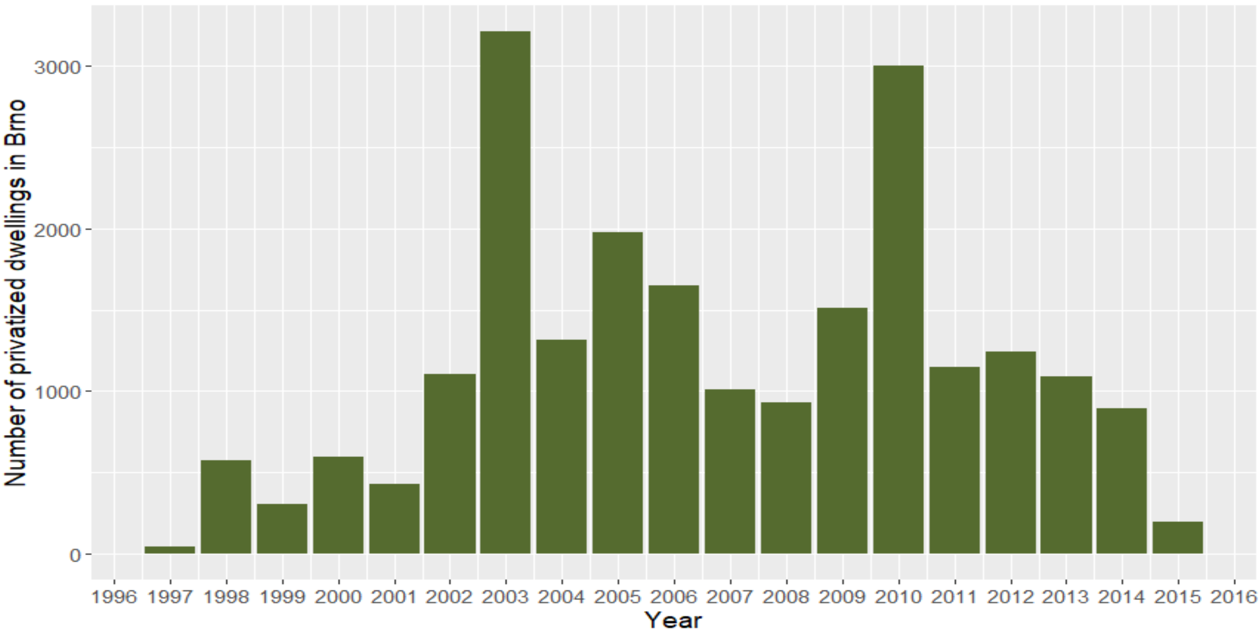
 

Yamamoto Granger causality test, Teye et al. (2017) determined that all but two regions demonstrated price dependencies on developments in Amsterdam, with varying time lags.

## 3 Regional housing submarkets in the Czech Republic

The contemporary Czech housing market structure was primarily shaped during privatization, occurring after the fall of the communist regime in the late 1980s. A defining feature of Czech privatization was the prominent role of municipal governments, which oversaw the restitution and privatization processes (Grabmüllerová, 2005). Decentralization resulted in considerable variability in both the timeline and the transaction prices associated with privatization. The legal framework enabling the transformation of properties from state to private ownership came into effect in 1994. However, by 2022, only half of the housing stock had been privatized (Broulíková and Montag, 2020). Using the housing stock in the city of Brno as an example, Figure 1 illustrates that the transition of ownership has been a prolonged and gradual process. This decentralization process, stemming from the municipal-level control of privatization, led to not only regional differences in sale prices but also individual privatization waves. Sýkora (2003) noted discounts as high as 80% off market prices during privatization; Mikula and Montag (2019), in their study of the privatization process in Brno, the second largest city in the Czech Republic, estimated that discounts varied between 30% and 60%. Although not empirically verified, such disparities in privatization pricing likely contributed to significant variations in price development post-privatization when supply and demand started exhibiting a more dominant role in shaping house prices.

**Figure 1: Number of privatized dwellings in Brno by year.**




*Source: City of Brno council records, 2023, modified by the author.*

Since the fall of Communism, house price dynamics across regions in the Czech Republic have varied significantly. The differences in house price trends can be partly attributed to variations in economic and demographic structures, which consequently affect housing supply and demand in these regions. Table 1 presents a statistical summary of house prices in the Czech Republic according to region for the period Q1 2000 to Q4 2022. Figure 2 illustrates the detailed evolution of house prices according to region during this period. Both Table 1 and Figure 2 indicate that the highest prices occurred in Prague and the South Moravia region, whereas the lowest prices occurred in the Ústecký and Moravia-Silesia regions. These descriptive statistics align with the disparities in economic development between the regions: Prague, as the core economic hub, experiences the highest levels of absolute migration, while regions with lower house prices typically suffer from migration outflows and lagging GDP per capita.

**Table 1: Statistical summary of average regional house prices in the Czech Republic between 2000 and 2022.**

| Region | Minimum | Median | Mean | Maximum | St. dev |
|---|---|---|---|---|---|
| JMK | 9.36 | 10.34 | 10.29 | 11.35 | 0.51 |
| PRG | 9.74 | 10.83 | 10.79 | 11.71 | 0.48 |
| STC | 9.08 | 10.13 | 10.11 | 11.21 | 0.52 |
| PLZ | 9.13 | 10.04 | 10.04 | 11.06 | 0.47 |
| VYS | 8.78 | 9.73 | 9.74 | 10.89 | 0.53 |
| ÚST | 8.44 | 9.08 | 9.12 | 10.41 | 0.45 |
| HK | 8.91 | 9.95 | 9.91 | 11.02 | 0.54 |
| PCE | 9.06 | 9.97 | 9.94 | 11.03 | 0.50 |
| KVK | 8.68 | 9.64 | 9.59 | 10.62 | 0.40 |
| JHC | 7.74 | 9.44 | 9.38 | 11.01 | 0.93 |
| OLM | 8.81 | 9.95 | 9.90 | 11.00 | 0.53 |
| MSZ | 8.46 | 9.63 | 9.51 | 10.71 | 0.59 |
| ZLN | 8.87 | 9.87 | 9.84 | 10.91 | 0.52 |
| LIB | 8.93 | 9.85 | 9.84 | 10.99 | 0.49 |

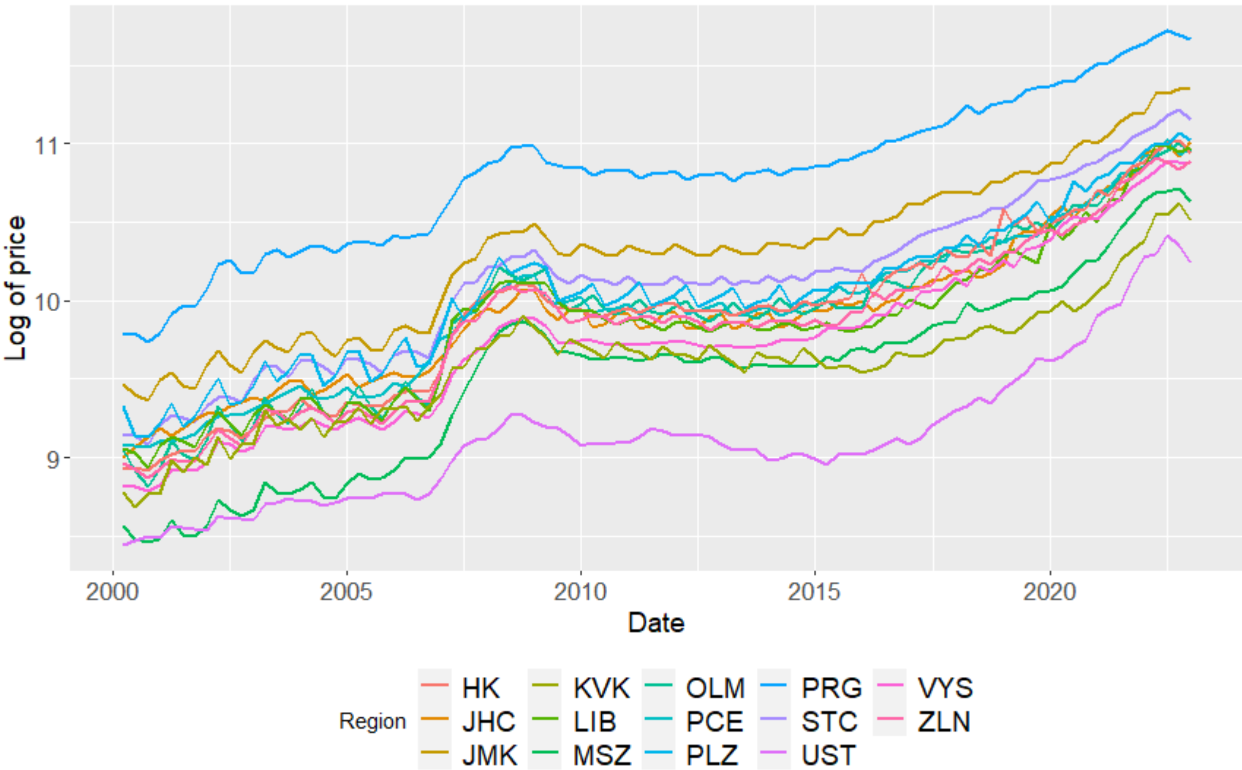
**Note**: All values are in logarithmic form. JMK = South Moravia Region; PRG = Capital city Prague; STC = Central Bohemia; PLZ = Pilsen region; VYS = Vysočina; ÚST = Ústecký region; HK = Hradec Králové region; PCE = Pardubický region; KVK = Karlovy Vary region; JHC = Southern Bohemia; OLM; Olomouc region; MSZ = Moravia-Silesia region; ZLN = Zlínský region; LIB = Liberecký region

*Source: Czech Statistical Office, Deloitte, 2023, the author's own calculations.*

Figure 2 also reveals dynamic patterns in house price trends across regions. Prices in the South Moravia region (JMK) and Prague remain consistently higher than those in other regions, and price movements across locations exhibit similarities, particularly during periods of upswings and downturns. The main periods of growth are associated with economic expansions during 2005–2008 and 2015–2019. The first period of house price stagnation corresponds to the aftermath of the global financial and economic crisis, which impacted the Czech economy from 2009 to 2014. Notably, the Czech economy, along with some Southern European countries, experienced one of the slowest recoveries to pre-crisis levels and saw labour market deterioration. During this period, property prices tended to stagnate rather than decline dramatically. This observation is consistent with the findings of Čermáková et al. (2024), which suggest that property prices exhibit downward rigidity; a reduction in property demand is more likely to manifest as a decrease in transaction volumes rather than a decline in property prices. The second downturn illustrated in Figure 2 is linked to the effects of a restrictive monetary policy implemented in response to inflationary pressures caused by major COVID-19-related government spending as well as supply chain disruptions, which contributed to rising consumer prices. The general co-movement in house price trends may be partially attributed to underlying economic fundamentals, such as changes in borrowing costs or economic welfare. However, it could also suggest the presence of a ripple effect.

Another notable insight from Figure 2 concerns the dynamics between Prague and other regions. Changes in house price cycles appear to originate in Prague and the JMK region before spreading to other submarkets. This pattern is clearly evident towards the end of the time series, where a slight price correction occurred in response to changes in monetary policy. A possible explanation is that house prices in Prague are more volatile, and that the decline in house prices in other regions might have been a direct response to earlier price reductions in Prague.

**Figure 2: Regional house prices in the Czech Republic, Q1 2000–Q4 2022.**




*Source: Czech Statistical Office, Deloitte, 2023.*

## 4 Methodology and results

The present study applied the Toda–Yamamoto Granger causality test to examine the lead-lag relationship between Prague, as a core region, and other regional housing submarkets and to explore the spillover effects of house prices. This methodology is consistent with the approach used by Teye et al. (2017).

Among the methods commonly used to study the ripple effect in house prices, Granger causality offers significant advantages, specifically in controlling the effect of economic fundamentals on the observed relationships between house price series. Toda–Yamamoto Granger causality (Toda and Yamamoto, 1995) also enables the detection of cumulative effects over time.

Let us assume two house price series, $p_{1t}$ and $p_{2t}$, which follow the model VAR($k$):

$$p_{1t}=c_{10}+a_1^{11}p_{1t-1}+a_2^{11}p_{1t-2}+\cdots+ap^{11}p_{1t-p}+a_1^{12}p_{2t-1}+a_2^{12}p_{2t-2}+\cdots+a_k^{12}p_{2t-k}+\epsilon_{1t}, \quad (1)$$

$$p_{2t}=c_{20}+a_1 21p1t-1+a_2^{21}p_{1t-2}+\cdots+a_p^{21}p_{1t-p}+a_1^{22}p_{2t-1}+a_2^{22}p_{2t-2}+\cdots+a_k^{22}p_{2t-k}+\epsilon_{2t}. \quad (2)$$

Times series $p_{2t}$ is said to Granger-cause $p_{1t}$ if the historical values of $p_{2t}$ contribute to predicting $p_{1t}$ in Equation (1). Alternatively, this relationship can be tested by evaluating the null hypothesis $H_0$: $a^1_{12}=a^2_{12}=\cdots=a^k_{12}=0$. To test this hypothesis, a standard Wald test can be applied to the coefficient matrices. An important assumption of the Granger causality test is the stationarity of the time series. The final form of the VAR model with control variables is defined as:

$$\begin{bmatrix} y_{it} \\ x_t \end{bmatrix} = \begin{bmatrix} \alpha_0 + & \gamma_1 z_{t-1} + \cdots + & \gamma_q z_{t-q} \\ \beta_0 + & \delta_1 z_{t-1} + \cdots + & \gamma_q z_{t-q} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \beta_{11} \\ \alpha_{21} & \beta_{21} \end{bmatrix} \begin{bmatrix} y_{it-1} \\ x_{t-1} \end{bmatrix} + \cdots + \begin{bmatrix} \alpha_{1p} & \beta_{1p} \\ \alpha_{2p} & \beta_{2p} \end{bmatrix} \begin{bmatrix} y_{it-p} \\ x_{t-p} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (3)$$

where $x_t$ and $y_{it}$ are the house price series for Prague and region $i$, where p, q ≥ 1 and $x_t$ and $y_{it}$ are stationary.

To test for stationarity in the time series, we apply the widely used augmented Dickey–Fuller test. The Dickey-Fuller test is a statistical procedure for determining whether a given time series is non-stationary and contains a unit root. The null hypothesis of the test asserts that the time series has a unit root, indicating non-stationarity. Formally, it proposes that the autoregressive parameter $\rho$ equals one in the following autoregressive model of order one (AR(1)):

$$y_t=\rho_{yt-1}+\epsilon_t, \quad (4)$$

where $y_t$ represents the time series at time $t$, $y_{t-1}$ is the lagged value of the series, and $\epsilon_t$ is the white noise error term. An alternative hypothesis proposes that the time series is stationary, implying that the autoregressive parameter is less than one ($\rho < 1$). To test the null hypothesis, the Dickey–Fuller test reformulates the above model into the following regression equation:

$$\Delta y_t=\alpha+\beta_t+\gamma y_{t-1}+\epsilon_t. \quad (5)$$

In this equation, $\gamma y_{t-1}$ denotes the first difference of the time series, $\alpha$ is a constant term, $\beta_t$ is a time trend, and $\gamma$ is the coefficient tested for stationarity. Table 2 summarizes the results of the augmented Dickey–Fuller test applied to the original time series and the log-transformed series for each variable.

**Table 2: Unit root tests for the time series used in the VAR model.**

| | Levels | | First difference | |
|---|---|---|---|---|
| Series | Test statistics | *P*-value | Test statistics | *P*-value |
| JMK | 0.58 | 0.5 | -6.2 | 0.01*** |
| PRG | -0.398 | 0.7 | -5.2 | 0.003*** |
| STC | -0.6 | 0.3 | -4.7321 | 0.00*** |
| PLZ | -0.5 | 0.1 | -6.675 | 0.04*** |
| VYS | -0.1 | 0.17 | -6.9 | 0.00*** |
| ÚST | -0.81 | 0 | -11.8 | 0.02*** |
| HK | -0.27 | 0.015 | -8.3 | 0.00*** |
| PCE | -0.38 | 0.8 | -5.5511 | 0.00*** |
| KVK | -0.22 | 0.93 | -9.9 | 0.00*** |
| JHC | -0.7 | 0.089 | -6.06 | 0.03*** |
| OLM | -0.474 | 0.1 | -4.7986 | 0.04*** |
| MSZ | -0.231 | 0.24 | -8.1 | 0.00*** |
| ZLN | 0.51 | 0.23 | -7.5 | 0.00*** |
| LIB | -0.4 | 0.3 | -6.05 | 0.00*** |
| GDP | -2.77 | 0.21 | -6.5 | 0.00*** |
| R | -1.17 | 0.7 | -4.83 | 0.00*** |

**Note:** The real interest rate is denoted by *r*. The ADF test regression was estimated separately for each time series, without including a deterministic trend and intercept. Statistical significance at the 10%, 5%, and 1% intervals are indicated by *, ** and ***, respectively.

*Source: Author's own calculations.*

Log-transformed house prices were used in the following analysis of the lead-lag effect, which requires that *k* must be set to one in each region-specific VAR model. To estimate the lead-lag relationship, the Toda–Yamamoto Granger causality test was applied, using a VAR($p+1$) model to evaluate the lead-lag effect between regional and Prague house prices. Consistent with previous studies, GDP and interest rates on new mortgage loans were included as control variables. As regional GDP data were unavailable, a national aggregate was used. For interest rates, the financial market in the Czech Republic is uniform across all regions. The lag order for each region was estimated according to the Akaike Information Criterion. To ensure the validity of the results, the Breusch-Godfrey LM serial correlation test was applied to detect serial correlation. If the residuals of the model exhibit serial correlation, *p* is incremented by one until serial independence is achieved at the 5% significance level.

The null hypothesis (H0) of the Toda–Yamamoto Granger causality test is defined as follows: *Prague house prices do not Granger-cause house prices in the specified region*.

To confirm the lead-lag effect and the time lag over which prices spill over from Prague to other regions, the null hypothesis must be rejected at least at the 5% significance level. Table 3 summarizes the results for each region. The results indicate that the lead-lag effect is observable in 9 out of 13 regions. However, the null hypothesis cannot be rejected for the Pilsen (PLZ), Vysočina (VYS) and Zlín (ZLN) regions. Granger causality at a level of significance below 10% was detected in the Liberec region. The shortest time lag was observed between Prague and the Jihomoravský (JMK) region, which includes Brno, the second-largest city in the Czech Republic and a hub of significant house price dynamics. The transmission mechanism for house price spillovers may be hidden in the combination of fully competitive labour markets and a well-developed transport infrastructure, both of which both support migration trends between cities and may thus contribute to the ripple effect occurring over relatively short periods.

**Table 3: Summary of the results of TY-GC and serial correlation tests.**

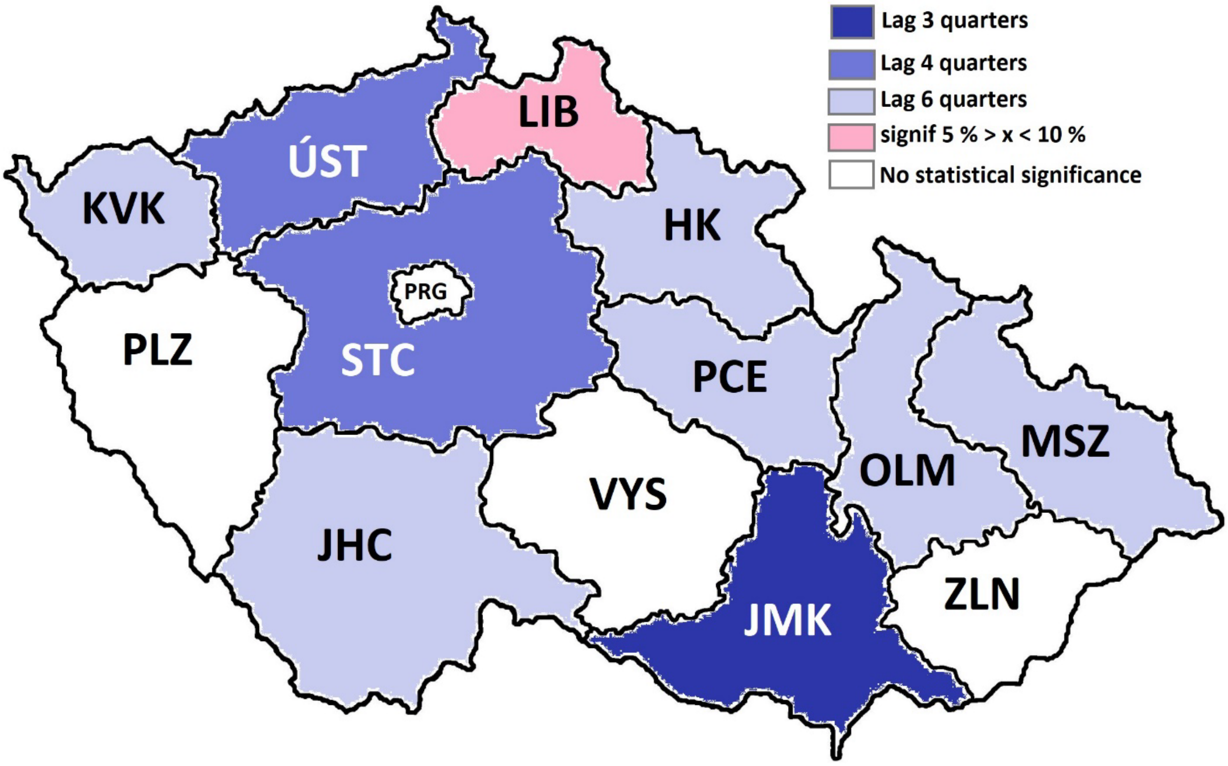
| | LM test statistics | *P*-value bg test | Optimal lag length | *p*-value Wald test | Significance |
|---|---|---|---|---|---|
| *a) Toda–Yamamoto GC Test* | | | | | |
| JMK | 0.00 | 0.980 | 3 | 0.010 | *** |
| STC | 2.30 | 0.130 | 4 | 0.005 | *** |
| PLZ | 2.58 | 0.110 | 6 | 0.130 | |
| VYS | 1.89 | 0.170 | 4 | 0.270 | |
| ÚST | 2.72 | 0.120 | 4 | 0.000 | *** |
| HK | 5.04 | 0.080 | 6 | 0.000 | *** |
| PCE | 0.10 | 0.740 | 6 | 0.001 | *** |
| KVK | 0.79 | 0.370 | 6 | 0.000 | *** |
| JHC | 0.96 | 0.320 | 6 | 0.031 | ** |
| OLM | 0.17 | 0.670 | 6 | 0.000 | *** |
| MSZ | 0.32 | 0.570 | 6 | 0.001 | *** |
| ZLN | 2.58 | 0.108 | 6 | 0.130 | |
| LIB | 0.01 | 0.930 | 4 | 0.075 | * |

## 5 Conclusion

The lead-lag effect analysis indicates that Prague has a statistically significant influence on house prices in other regions, with the exception of three regions, where no Granger causality was identified, and one region, which exhibited only a very weak lead-lag effect. Figure 3 illustrates the spatial distribution of these results.

**Figure 3: Time lags for house price spillovers in the Czech Republic.**




Three of the regions are border regions with strong economic centres in their respective regional capitals, where prices and purchasing power may be influenced by cross-border dynamics not captured by the applied model. In contrast, the Vysočina (VYS) region is characterized by a higher proportion of detached family houses and recreational properties, which are less likely to be affected by the house price dynamics of Prague's predominantly flat-based property market.

The strongest lead-lag relationship was observed in the Jihomoravský (JMK) region, which includes Brno, the second-largest economic centre in the Czech Republic. The mechanisms driving this price spillover require further investigation, but the strong economic ties between Brno and Prague, supported by highway and railway connections, likely play a significant role.

A one-year delay in price information transmission was identified in the Středočeský (STC) region, consistent with migration flows from Prague to adjacent cities offering more affordable housing. However, the relationship with the Ústecký (ÚST) region is less clear. Ústecký has consistently recorded the lowest house prices, lacks apparent economic ties with Prague, and experiences migration flows primarily towards Prague. Although the underlying determinants of this relationship remain unclear, it is important for housing policy recommendations. House price appreciation partially driven by the spillover of price information from another region could exacerbate housing affordability challenges in one of the least developed areas. Persistent house price appreciation deviating form real disposable income may also hamper convergention process. As examined before, lead lag effect was identified in Czech regions which are economically lagging behind and inaffordable housing may be significant factor which could contribute to slowing down regional economic convergention process (Rezabek et. al., 2022).

This study identifies a significant lead-lag effect across regions in the Czech Republic; however, the specific determinants of these relationships in each region warrant further research to better understand the underlying transmission mechanisms, which are beyond the scope of the current study. Understanding the spillover effects of house prices is essential to crafting precise policy interventions designed to address housing affordability. Evidence demonstrating that submarkets are interlinked would support the importance of considering the broader implications of local-level housing policy decisions, which, in targeting a specific housing market, may have unintended consequences on other regions.

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