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ASSESSMENT OF THE POSSIBILITIES OF USING ALTERNATIVE FUELS IN THE CEMENT INDUSTRY

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ABSTRACT: This study examines property price trends in Czech cities (2018-2023) with more than 40,000 inhabitants using EVAL software, focusing on changes from 2018 to 2023. The methodology involves automated data collection from property listings, which are analysed to shed light on market dynamics and investment returns. The results show significant price increases, particularly in economically weaker cities, with variations influenced by economic and demographic factors. In this analysis, the environmental sustainability of urban development was additionally considered, highlighting the need for integrating sustainable practices into future urban growth. Practical implications include insights for policymakers and investors regarding the sustainability of urban property markets. Social implications reflect the ethical concerns of investment strategies that exploit economic disparities. The originality of the study lies in the use of advanced software to provide granular micro-level analysis within the Czech real estate market, providing valuable insights into localised economic impacts and investment opportunities.

KEYWORDS: Czech real estate, environmental sustainability, property price trends, market dynamics, investment strategies

Introduction

Unequal spatial distribution of economic opportunities is a resonant topic across all political parties in the EU structures, thus generating vast research aimed at regional development, change in the poverty status of regions, including the fiscal role of municipalities or economic development, infrastructure and energy from a macro perspective (Filenta & Kydros, 2022; Luczak & Kalinowski, 2022; Grzebyk & Stec, 2023; Bernat et al., 2023) as well as research aiming at micro level, particularly at key particular markets and industries among which labour market conditions, business conduct and structure and property market prevail (Lukavec & Kaderabkova, 2017; Kaderabkova & Rezabek, 2023; Jasova & Kaderabkova, 2021; Macek, 2023).

Within the context of regional differentiation, this study focuses on the dynamics of the real estate market, a key variable, we believe, for sustainable environmental and economic development.

The real estate market in the Czech Republic, like in the whole CEE region, has undergone significant changes over the past decade, influenced by a variety of economic, demographic and technological factors. Understanding these changes is crucial for policymakers, investors and academics who wish to grasp the nuances of market dynamics and make informed decisions. This study aims to provide a comprehensive analysis of property price trends in Czech cities with a population of over 40,000, using the advanced capabilities of EVAL software. The focus on these urban centres is particularly relevant as they represent significant centres of economic activity and population density, factors that typically influence property market behaviour.

This research is based on data mined by EVAL software from online property listings. EVAL's ability to drill down into the smallest detail has enabled a deeper understanding of the property market in different regions. By meticulously tracking price changes and identifying trends between 2018 and 2023, the tool has provided invaluable insights into shifts in market demand, the impact of economic policies, and the changing preferences of homebuyers and renters alike.

Our findings highlight the complexity of the real estate market in the Czech Republic, paving the way for more targeted and effective interventions in housing policy and market strategies. Our results can be generalised for the identification of universal principles existing in the real estate market. This study thus not only enriches our understanding of Czech real estate dynamics but also presents some interesting insights into responses of real estate markets to exogenous and endogenous factors and shocks. We examine property price trends in Czech cities and follow a structured approach. First, it establishes a theoretical basis by reviewing literature focusing on real estate dynamics and valuation. Subsequently, the research methods are outlined, detailing the software used for data collection and the underlying model assumptions. In the results and discussion section, the analyses conducted are presented and discussed in depth. Finally, the study concludes with a summary of the findings and recommendations for policymakers.

This study contributes uniquely to the understanding of the Czech real estate market in several ways. First, it provides a comprehensive analysis of property price trends across cities with varying economic strengths, offering insights into regional disparities and potential convergence. Second, the use of EVAL software allows for a more granular, street-level analysis that has not been previously available in studies of the Czech real estate market. Finally, by focusing on the period from 2018 to 2023, this research captures the impact of significant economic events, including the COVID-19 pandemic, providing valuable insights into market resilience and adaptability. By addressing these aspects, this study fills a gap in the current literature and offers a novel perspective on the dynamics of the Czech property market.

Within the context of decreasing housing affordability and the resonant topic of housing poverty, this study is motivated by the pressing need pronounced by government agencies to understand the dynamics of real estate markets across economically diverse regions, particularly in the context of recent global events. By analysing property trends in Czech cities from 2018 to 2023, we aim to provide valuable insights for policymakers, investors, and urban planners. Our research addresses a significant gap in the literature by offering a comprehensive, granular analysis of property trends across economically differentiated cities, utilising innovative data collection methods. The findings of this study have important economic implications, potentially informing housing policies, investment strategies, and our understanding of urban development patterns in the face of changing economic landscapes.

DOI: 10.34659/eis.2025.92.1.859

Literature review

To establish a broader context for understanding property price dynamics, the insightful findings of Hoxha et al. (2022) indicate that factors such as location, size, and building amenities continue to significantly influence apartment prices in Prishtina, Kosovo, mirroring trends observed in other regions (Hoxha et al., 2022). This aligns with the observed shifts in property prices in the Czech Republic, suggesting common determinant factors across different geographical landscapes.

To further enhance our comprehension of the housing market dynamics, Nguyen et al. (2023) have conducted a crucial study comparing factors influencing apartment price volatility in Hanoi and Ho Chi Minh City, Vietnam. This study identifies key variables such as GDP, inflation rate, lending interest rates, and construction costs, providing strategic insight for investors and policymakers (Nguyen et al., 2023). Such insights are essential for understanding the comparative dynamics of housing markets in different urban contexts, similar to the trends observed in our current review of the Czech Republic.

A recent study by Nguyen et al. (2020) employs the Hedonic pricing method to unravel the multifaceted factors affecting apartment prices in Ho Chi Minh City. The study illustrates significant variables such as apartment area and interior features positively influencing the prices, while factors like distance to the city centre have a negative impact (Nguyen et al., 2020). These findings provide a more nuanced understanding of how various attributes contribute to real estate valuations, similar to patterns seen in European markets such as Prague or Berlin.

In the evolving field of real estate valuation, Kim et al. (2020) present an innovative procedure integrating the Comparable Sales Method (CSM) with automated systems for estimating apartment prices, particularly in urban Korean contexts. This approach employs extensive real transaction data to compare with traditional methods, evidencing considerable advancements in the accuracy and efficiency of property valuations (Kim et al., 2020). The adaptation of such technology-driven methodologies provides a compelling parallel to manual valuation techniques discussed in this review, suggesting a significant shift towards more data-driven decision-making processes in the real estate sector.

In a pivotal study examining the apartment market in Belo Horizonte, Brazil, Paixao (2023) explores multiple hedonic pricing methodologies to derive quarterly real estate price indices from 2004 to 2015. This research is particularly significant in the absence of an official real estate price index in Brazil, highlighting the urgent need and potential approach for such a framework. The study's findings underscore a substantial increase in apartment prices, especially noted between 2007 and 2011, thereby providing key insights into the dynamics of the housing market during that period (Paixao, 2023). The implementation of these hedonic methods could serve as a benchmark for developing standardised real estate indices in other emerging markets. A similar approach is applied by Rotschedl (2022), who investigates the impact of intertemporal discounting across different income, savings, and debt cohorts within the Czech Republic, particularly focusing on its implications for real estate investment decisions. The study involved 599 participants and explored their preferences using scenarios involving immediate versus delayed financial rewards. The analysis revealed a significant relationship between financial patience and participants' economic conditions, such as income levels, presence of savings, and debt burden, which are crucial factors in making prudent real estate investment choices. Rotschedl's (2022) findings elucidate how economic stability influences decision-making related to property investments, demonstrating that those with higher income and savings are not only more likely to delay gratification but are also potentially better positioned to engage in real estate markets. This translates to real estate investors needing to consider the socioeconomic profiles of regions when evaluating market potentials, as areas with higher income and savings levels may exhibit more robust and stable housing demand. The study's nuanced insights into financial behaviour underscore the need for targeted financial literacy programs that could enhance individuals' understanding of real estate investment benefits and risks, particularly in economically diverse settings (Rotschedl, 2022).

Continuing to advance the field of real estate valuation, Deaconu et al. (2022) evaluate the effectiveness of Artificial Neural Networks (ANN) over Generalized Linear Models (GLM) in predicting apartment prices based on a study conducted in Cluj-Napoca, Romania. Their research, utilising data from 900 apartment sales, demonstrates the superiority of ANN in providing stable and accurate

DOI: 10.34659/eis.2025.92.1.859

price predictions while effectively illustrating the importance of various property attributes. This work further emphasises the growing relevance of machine learning methodologies in the real estate sector, bridging the gap between traditional statistical models and more dynamic, adaptive systems (Deaconu et al., 2022).

In their investigative study on the Kenyan real estate market, Kieti and Ogolla (2021) apply a hedonic pricing model to effectively identify and analyse critical determinants of apartment values in Nyali estate, Mombasa. Their findings reveal significant factors such as the number of parking lots, the presence of a swimming pool, the age of the apartment, and the provision of a balcony, which all play substantial roles in shaping property values. This approach not only enhances the precision and reliability of apartment valuations in this region but also contributes a novel methodology to the broader field of real estate valuation (Kieti & Ogolla, 2021).

Similarly, Krolage (2023) extensively analyses the effects of real estate purchase subsidies on property prices within Bavaria, Germany. Utilising a detailed micro-dataset and employing a difference-in-difference methodology, she discovers that the introduction of new subsidy schemes led to an approximate 10,000-euro increase in the prices of single-family homes near the Bavarian border. Interestingly, this price increase did not extend to apartments, likely because their buyers often did not qualify for the subsidies. Krolage's findings suggest a full capitalisation of the subsidies into single-family home prices and a modest boost in construction activities, ultimately benefiting property sellers more than the intended homebuyers. This study contributes valuable insights into the unintended consequences of government subsidy policies on real estate markets (Krolage, 2023).

De Graaff and Zietz (2022) explore the intricate relationship between crime and apartment prices in Hamburg, Germany, over the period from 2012 to 2017. Utilising a panel data model with fixed effects, they aim to mitigate endogeneity concerns associated with crime data. Their findings reveal that apartment prices react to changes in crime rates with a delay of two to three years and that the type of crime – whether total, property, or violent – significantly influences these price adjustments. Notably, properties in areas with high crime rates and low income are disproportionately affected. Their study is pioneering in providing detailed empirical evidence on the tangential effects of crime on property prices in Germany, highlighting significant policy implications for prioritising resources in crime prevention, especially concerning property crimes (de Graaff & Zietz, 2022). On the other hand, Sviatlana Engerstam focuses her research on the long-term impacts of macroeconomic fundamentals on apartment price dynamics in major cities across Sweden and Germany. Utilising panel cointegration analysis, Engerstam addresses challenges like spatial heterogeneity and cross-sectional dependence, which are common in real estate data. Her findings reveal more pronounced reactions to these economic fundamentals in Swedish cities compared to German ones, suggesting potential market overreactions in Sweden that may indicate the building of price bubbles. This study stands out for its focus on the apartment market segment, providing a unique long-term perspective on price elasticities and how various institutional housing market arrangements in Sweden and Germany might influence these effects (Engerstam, 2021).

In their innovative study, Chikhmous and Rahman (2024) explore how various attributes affect apartment sale prices in Riyadh, Saudi Arabia, using hedonic regression analysis. By examining a sample of 592 apartments listed online, they meticulously recorded both internal characteristics, such as age and floor area, along with external factors, including proximity to key urban facilities. Their findings underscore the importance of both internal amenities and strategic location to higher pricing, with profitable proximity to commercial centres, educational institutions, and planned metro stations. A notable discovery was the differential impact of proximity to Riyadh's distinct business districts, with the Olaya district and the King Abdullah Financial District enhancing property values, in contrast to the traditional downtown area, which surprisingly had a negative effect. This study not only provides detailed insights into the Riyadh real estate market but also contributes to the broader understanding of urban economics and property valuation techniques (Chikhmous & Rahman, 2024).

Real estate markets have been found to suffer from bounded rationality and agents' sentiment. Isler et al. (2021) investigate how market news and media credibility influence non-professional participants' house price predictions. Using an experimental setup, they analysed the behaviours of participants who were exposed to varying levels of market news authenticity and media credibility. Their findings corroborate the hypothesis that more credible news sources significantly enhance the accuracy of price predictions. Additionally, the visibility of the news brand was found to augment this

DOI: 10.34659/eis.2025.92.1.859

effect, detailing a nuanced interaction between content credibility and brand recognition in influencing economic decisions. This study not only contributes to the understanding of consumer behaviour in real estate markets but also emphasises the critical role of credible information dissemination in enhancing market efficiency (Isler et al., 2021). Vasileiou et al. (2024b) confirmed a strong role of sentiment in real estate market trends, making house prices not always consistent with what price models based on purely economic variables would predict. The Greek housing market is also investigated by Nikitidou et al. (2021) to analyse the effects of structural characteristics and economic factors on residential property prices in Athens during the financial crisis. Utilising an extensive dataset of 13,835 valuation reports from 2006 to 2016, the researchers employ econometric models to dissect the influence of property attributes and macroeconomic variables on real estate prices. Their analysis reveals that factors such as apartment size, age, and amenities significantly impact prices, alongside macroeconomic indicators like average wage and unemployment rates. The study is noteworthy for its depth, especially in its use of spatial analysis to examine the varied impact of these factors across different sub-regions of Athens. By highlighting the resilience of house prices in response to economic fluctuations and demographic shifts, this research provides valuable insights for stakeholders navigating the complex landscape of real estate investment during economic downturns (Nikitidou et al., 2021).

Grybauskas et al. (2021) leverage big data analytics to understand the dynamics of the real estate market in Vilnius during the initial wave of the COVID-19 pandemic. Utilising a web-scraping algorithm to collect data from 18,992 property listings, they apply fifteen different machine learning models to predict revisions in apartment prices. The study highlights that despite expectations of a crash similar to 2007, the real estate market exhibited resilience, with price drops less severe than anticipated. The findings underscore the importance of time-on-market (TOM) as the most influential factor affecting price predictions, displaying an inverse U-shaped behaviour, which underscores its predictive power in real estate valuation. This research not only demonstrates the robustness of the real estate market in the face of a pandemic but also illustrates the potential of advanced analytics in enhancing market predictions (Grybauskas et al., 2021).

Lorenz et al. (2023) examine the potential of interpretable machine learning (IML) to enhance the understanding of real estate market dynamics, particularly focusing on the rental sector. Their study adopts a model-agnostic interpretation approach to deconstruct the "black box" nature of sophisticated algorithms used in predicting real estate prices, specifically through hedonic models. The research highlights how certain property attributes, such as size, age, and specific location features, significantly influence rental values. Notably, IML techniques helped reveal the nuanced interactions of these attributes, demonstrating their varying impacts across different market segments and over time (Lorenz et al., 2023).

Another comprehensive data paper by Skribans et al. (2020) presents a dataset collated from the leading Latvian real estate advertisement website, www.ss.com, throughout the year 2018. This dataset, which captured the dynamics of real estate advertisements over 12 months, comprises 238,000 observations with 24 distinct dimensions. These dimensions include prices, deal types, location specifics, and detailed characteristics of various types of real estate, such as land and apartments. Hosted in the Data Archiving and Networked Services (DANS) repository, this dataset is pivotal for researchers and practitioners in the field of econometrics and data mining, offering a unique insight into the Latvian real estate market during this period. This substantial dataset not only supports advanced analytical approaches like data mining but also serves as a critical resource for understanding market trends and consumer behaviour in real estate (Skribans et al., 2020).

In his comprehensive analysis, Venhoda (2022) examines the pivotal role of macroprudential policy instruments, specifically the Debt Service-to-Income (DSTI) and Debt-to-Income (DTI) ratios, in shaping the mortgage market landscape in the Czech Republic during 2022. This study is particularly significant given the heightened economic uncertainty brought about by rising mortgage interest rates following successive base rate hikes by the Czech National Bank. Venhoda's research meticulously assesses how these financial measures impact the affordability and accessibility of mortgages for potential buyers within the Czech real estate market. His findings underline the critical influence of these macroprudential limits in moderating the borrowing capacity of individuals, thereby indirectly influencing property demand and pricing dynamics in the residential sector (Venhoda, 2022).

DOI: 10.34659/eis.2025.92.1.859

In their research, Pozdílková and Marek (2022) delve into web-based real estate data to analyse market trends across Czech municipalities, utilising a unique method involving elasticity and a modified price-volume indicator. Their study, conducted from June 2019 to March 2021, not only collected vast amounts of data but also applied cluster analysis to compare regional market developments effectively. This methodology offers new insights into the dynamic changes in the Czech real estate market, making it possible to discern patterns and trends that are crucial for investors, policymakers, and researchers (Pozdílková & Marek, 2022). Similarly, Hromada (2024) found that the elasticity of demand positively correlated with the elasticity of supply, indicating that in Czech big cities that lacking supply most manifested the elasticity of demand is lower compared to regions with more robust construction. Also, Kalabiska et al. (2022) delve into the dynamics of housing prices across regions of the Czech Republic from 2000 to 2019, utilising a robust panel dynamic OLS estimator to examine the influence of various macroeconomic factors on apartment prices. They employ an error correction model to ascertain the long-term equilibrium of apartment prices and quantify the speed at which prices adjust in the short term. Their findings highlight significant regional disparities: factors such as wages, unemployment rates, and migration predominantly drive apartment prices. Particularly in high-income areas, the cost of building plots significantly affects prices, while labour market conditions such as wages and demographic factors hold more sway in low-income regions. The study's innovative use of regional exclusion to test the robustness of their model adds depth to their findings, offering valuable insights for policymakers and real estate developers on the regional determinants of housing prices (Kalabiska et al., 2022).

In their study, Srivastava and Rezábek (2022) critically evaluate the evolving dynamics of payment systems, scrutinising the potential long-term impacts of digital payment adoption on the Czech Republic's economic growth. Their research, spanning from 2015 to 2020, employs sophisticated econometric models, including linear and multiple regression analyses, to unpack the relationship between emerging cashless payment systems and economic indicators. While their findings suggest a tangible but moderate impact of digital payments on the economy, they expose a potential for growth limited by current data constraints, which, if overcome, may reveal more profound economic implications (Srivastava & Rezábek, 2022). The adaptation to digital payment platforms is positioned as a catalyst for more streamlined, efficient economic transactions, which could fundamentally support real estate transactions by simplifying processes, reducing costs, and potentially increasing transactional volumes in the real estate sector. As such, the shift towards more robust digital payment systems could serve as a significant driver of activity within the Czech real estate market, highlighting a critical area for future studies focusing on the intersection of technological innovation and real estate economics.

Research methods

Overview of EVAL Software

The results presented in this article are based on the outputs of the EVAL software. EVAL is an advanced software application designed to systematically collect, analyse and evaluate property price data extracted from online real estate listings in the Czech Republic.

EVAL is developed and refined by one of the authors of this study. EVAL has been in use since 2007. The software plays a crucial role in aggregating data, which is then used for academic and governmental analysis, including during the COVID-19 pandemic when data collection intervals were adjusted to meet the urgent analytical needs of the Ministry of Regional Development.

EVAL operates through an automated mechanism with periodic data collection. For optimal performance, it requires stable high-speed internet access, Microsoft Windows 10 or higher, large storage capacity (in the order of TB), a high-performance processor and at least 32 GB of RAM. Data collection has taken place on a monthly basis, capturing complex details of property listings, including but not limited to location, price and property features.

EVAL is divided into several interrelated modules:

- Link Collection Module: Harvests internet links from property websites to property sales and rental listings.

DOI: 10.34659/eis.2025.92.1.859

- Full-text download and data export module: Extracts detailed information from listings for robust statistical analysis.
- Data Filtering Module: Ensures accuracy and reliability of data by filtering out anomalies or duplicates.
- Data Evaluation Module: Provides the source data for the production of statistical reports showing trends in the property market.

EVAL is able to perform detailed analyses of property price trends over time for all municipalities in the Czech Republic. Its database contained over 300,000 records in the first half of 2023 alone, demonstrating its extensive data-handling capabilities. In addition, EVAL can perform high-resolution local analysis down to street level if such details are provided in the listings.

EVAL is a key tool for analysing the real estate market in the Czech Republic. Its development has adapted to technological advances and changing market needs, providing reliable, detailed and actionable property market data. This has significant implications for policy-making and economic analysis in the real estate sector, proving indispensable for both academic research and government operational strategies.

EVAL is software owned by one of the authors of this article, and as such, the program itself is not publicly available. However, the outputs generated by EVAL, which provide valuable insights into property price trends and market dynamics, are available for academic and research purposes. These outputs are detailed data analyses that can significantly contribute to studies and discussions related to the real estate market in the Czech Republic.

Model assumptions

Two categories of apartments were selected based on floor area: Smaller apartments – 20 to 50 m^2 and larger apartments – 51 to 80 m^2. These categories were chosen because the unit prices of smaller apartments tend to be higher. This pricing pattern can be attributed to factors such as higher demand for more affordable, smaller apartments in densely populated urban areas and the premium paid for more conveniently located, compact apartments that are often more desirable in city centres.

While a more detailed breakdown into additional size categories could provide more nuanced insights, such a breakdown would go beyond the recommended scope of this article and potentially clutter the analysis with excessive detail that may not provide proportionately valuable insights.

The analysis included all Czech cities with more than 40,000 inhabitants. This decision was based on the availability of comprehensive primary statistical data for these cities, which ensures the robustness and reliability of the research findings. Furthermore, limiting the scope of the article in this way maintains a manageable dataset and avoids dilution of key findings. While it would be possible to conduct this analysis for smaller cities, the statistical data available for smaller cities would not significantly alter the general trends observed in larger cities and could distract from the more significant dynamics of the urban rental market.

Results

Price Trends for Apartments in Selected Czech Cities

Table 1 shows the asking prices per square metre for apartments for sale between 20 and 50 square metres in Czech cities with more than 40,000 inhabitants from 2018 to 2023. The rows are organised according to the magnitude of the price change over this period.

Since 2018, average property prices in the Czech Republic have been rising steadily, with the exception of 2023, when there was a slight decline in prices. This trend can be attributed to many economic factors, including shifts in market demand, migration, changes in interest rates and general economic uncertainties. In addition, the initial surge in prices in recent years may have reached a saturation point, leading to the price adjustments observed in 2023. This period of price correction provides a new perspective on the sustainability of the housing market and may influence future investment decisions.

DOI: 10.34659/eis.2025.92.1.859

Table 1. Price Trends for Smaller Apartments in Czech Cities (2018-2023) [CZK/m^2]

City	2018	2019	2020	2021	2022	2023	Change from 2018 to 2023
Most	9 736	11 305	16 004	21 564	28 984	26 512	+172.30%
Děčín	15 641	16 869	24 550	34 156	43 534	37 761	+141.42%
Jablonec nad Nisou	33 592	33 547	37 273	88 682	86 527	80 713	+140.28%
Ústí nad Labem	16 217	17 919	23 852	36 580	43 298	37 908	+133.75%
Havířov	14 417	16 685	21 368	30 794	37 195	33 513	+132.45%
Teplice	13 283	16 623	17 588	24 170	32 033	30 026	+126.04%
Ostrava	20 780	23 078	30 585	42 689	48 719	45 425	+118.60%
Karviná	11 916	13 336	16 695	24 672	30 401	25 562	+114.51%
Chomutov	24 859	27 926	28 322	35 677	37 856	51 253	+106.17%
Olomouc	43 531	48 660	56 507	60 037	64 261	87 835	+101.78%
Kladno	41 474	50 786	60 247	70 622	84 482	80 535	+94.18%
Liberec	36 209	40 484	54 116	65 508	69 737	69 564	+92.12%
Pardubice	40 254	45 248	54 802	74 595	83 784	76 527	+90.11%
Přerov	26 278	27 247	30 653	38 151	46 261	49 700	+89.13%
Zlín	37 624	45 502	50 929	62 722	72 538	71 027	+88.78%
České Budějovice	43 252	46 841	56 667	78 660	87 098	78 713	+81.99%
Opava	29 748	28 582	38 101	48 568	51 863	53 301	+79.17%
Prostějov	28 781	31 480	36 419	43 091	51 989	51 432	+78.70%
Frýdek-Místek	32 015	34 626	37 748	54 578	60 702	53 918	+68.42%
Brno	65 201	69 316	82 633	99 810	113 911	106 171	+62.84%
Hradec Králové	47 495	47 843	58 217	82 041	88 156	77 198	+62.54%
Jihlava	38 087	41 180	44 657	53 171	62 790	60 694	+59.36%
Karlovy Vary	38 863	41 587	48 666	53 174	61 328	61 628	+58.58%
Plzeň	45 829	47 952	60 334	67 305	76 541	72 191	+57.52%
Mladá Boleslav	48 683	54 871	58 782	73 537	77 086	74 417	+52.86%
Prague	91 850	100 744	109 991	123 948	140 604	137 862	+50.10%

Source: authors' work based on software EVAL.

The data show that the largest price increases occurred in cities where the price level was very low in 2018. In these cities, there was significant room for growth due to the relatively low starting price points relative to income levels. As a result, investors in these locations saw the greatest returns on their investments.

It is particularly noteworthy that the cities of Jablonec and Nisou experienced a significant jump in prices between 2020 and 2021. This sharp increase is attributed to the COVID-19 lockdown, during which people sought properties close to nature, prioritising space and environmental quality as essential elements of living standards. Despite the easing of pandemic-related restrictions, price levels in Jablonec nad Nisou remained high, suggesting a sustained shift in residential preferences towards locations with better access to the natural environment.

DOI: 10.34659/eis.2025.92.1.859

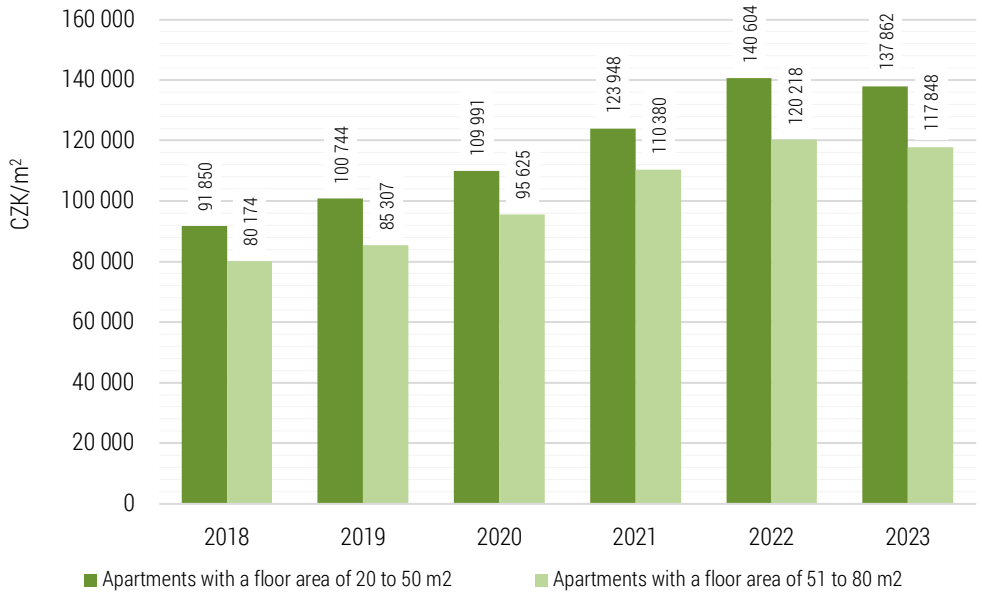

Figure 1. Dynamics of Listing Unit Prices for Smaller and Larger Apartments for Sale in Prague, 2018-2023
Source: author's work based on software EVAL.

In contrast, Prague experienced a relatively modest price increase of 50% over the same period (Figure 1). This lower rate of increase is largely due to the already high base price level in 2018, which left less room for growth compared to other cities. The capital, already characterised by high property values, faced natural limits on how much further prices could rise without reaching a tipping point that could significantly reduce demand. In addition, the high starting price levels in Prague may have discouraged the same level of speculative buying that smaller cities with more attractive starting prices experienced during the pandemic.

In addition, the dynamics of the Prague property market are influenced by its status as an economic centre, which attracts both domestic and international investors and stabilises the market to a certain extent. However, these same factors also contribute to a high cost of living, which can deter first-time homebuyers and limit overall market growth in times of economic turbulence.

The research team similarly produced a table for apartments between 51 and 80 square metres, and the results were similar, with the difference that prices are around 12% lower within individual cities and years. The lower unit prices for larger apartments may be due to economies of scale, as larger spaces often have lower costs per square metre, making them more economically advantageous for both developers and buyers. In addition, another reason for lower unit prices is that the overall cost of larger properties is so high that many buyers find themselves unable to afford them.

Due to the limited scope of this article, we do not include this table for apartments between 51 and 80 square metres here. We present at least some of the most significant results from this table. The price increase between 2018 and 2023 is 46.99% for Prague and 61.66% for Brno. At the other end of the ranking are Most, with an increase of 137.11% and Ostrava, with an increase of 109.78%. In most cities, price increases are lower than for smaller dwellings, which we explain by the lower level of investment activity for larger dwellings. Investment flats are mainly bought for renting, while small flats are more likely to be rented and, therefore, traded.

The observed price increases, particularly in economically weaker cities, can be attributed to several economic factors. First, the low initial price points in these areas created opportunities for investors seeking higher returns, driving up demand and prices. Second, government policies aimed at regional development may have stimulated local economies, increasing housing demand. Finally, the trend of remote work, accelerated by the COVID-19 pandemic, has likely contributed to increased interest in previously less desirable locations, further pushing up prices in these areas.

DOI: 10.34659/eis.2025.92.1.859

Average Annual Return on Investment for Selected Czech Cities

Table 2 shows the average annual return on investment for selected cities and years in the Czech Republic, based on a conventionally maintained apartment with a floor area of 40 m^2, excluding newly built properties.

The calculation does not differentiate between the structural and material characteristics of the building, the age of the property or the state of maintenance of the apartment. It takes into account the average rental income achievable in each city. It also takes into account the initial purchase cost of the dwelling. Operating costs related to the functioning of the dwelling are also included. These include costs associated with the ownership of the property (management fees, remuneration of elected housing association bodies, repair fund), maintenance and renewal costs, taxes (income tax, property tax), insurance (household insurance, property insurance), advertising costs on real estate platforms and a risk reserve to cover potential losses such as unpaid rent, loss of income due to tenant turnover, damage to the property and legal services.

Table 2. Average Annual Return on Investment for Smaller Apartments in Czech Cities (2018-2023) [%]

City	2018	2019	2020	2021	2022	2023	Average
Most	7.08	7.04	5.18	3.89	3.37	4.03	5.10
Mladá Boleslav	4.56	4.00	4.19	3.04	2.89	3.04	3.62
Teplice	3.25	3.77	4.47	3.30	2.71	3.59	3.52
Ústí nad Labem	4.00	4.41	3.51	2.57	2.28	2.94	3.28
Zlín	3.74	3.57	3.26	2.95	2.95	2.98	3.24
Frýdek – Místek	3.85	3.46	3.22	2.65	2.57	3.19	3.16
Liberec	2.91	3.36	2.90	2.75	2.99	2.80	2.95
Jihlava	2.77	3.54	2.95	2.49	2.80	2.99	2.92
Chomutov	2.47	2.94	2.92	2.84	3.42	2.40	2.83
České Budějovice	5.82	2.57	2.25	1.77	2.00	2.37	2.80
Ostrava	3.24	3.49	2.98	2.09	2.25	2.72	2.80
Olomouc	3.20	2.94	2.72	2.55	2.71	2.16	2.71
Pardubice	3.05	3.19	2.83	2.10	2.15	2.66	2.66
Jablonec nad Nisou	3.21	3.13	3.18	1.89	2.16	2.41	2.66
Kladno	3.39	3.20	2.64	2.23	2.01	2.44	2.65
Prague	3.20	2.99	2.38	1.89	2.23	2.86	2.59
Brno	2.81	2.83	2.52	2.12	2.32	2.86	2.58
Přerov	2.42	3.20	2.39	2.52	2.27	2.60	2.57
Plzeň	2.87	2.96	2.34	2.00	2.08	2.56	2.47
Hradec Králové	2.60	3.02	2.63	1.89	2.05	2.40	2.43
Prostějov	2.83	2.14	2.89	1.78	1.88	2.22	2.29
Karlovy Vary	2.17	2.43	2.53	1.97	2.04	2.50	2.27
Děčín	1.89	3.05	2.00	1.81	2.11	2.19	2.17
Opava	2.52	2.30	1.97	1.78	1.85	2.32	2.12
Karviná	1.36	2.20	1.81	1.38	1.90	2.79	1.91
Havířov	0.52	0.94	1.28	1.43	1.62	2.49	1.38

Source: authors' work based on software EVAL.

DOI: 10.34659/eis.2025.92.1.859

Table 2 ranks cities on the basis of the average achievable return on property investment. Typically, the highest returns are found in economically deprived areas characterised by a variety of socio-economic challenges, such as high unemployment rates, high crime rates, low levels of resident education and an influx of unreliable tenants. Several factors contribute to this investment dynamic.

Property in these poorer areas is significantly cheaper than in wealthier regions, while wage differentials between regions are less pronounced. In addition, a significant proportion of the population in these regions benefits from various government welfare programmes.

The welfare system is often exploited by both tenants and landlords, leading to a phenomenon known as 'poverty trading'. This term describes a market strategy whereby investors target housing in deprived areas specifically because economic conditions artificially inflate returns. In these scenarios, government intervention in the housing market can lead to various market anomalies that affect the profitability of investments.

A specific group of investors focuses on exploiting these market inefficiencies through 'poverty trading'. While this investment strategy may offer high returns, it is fraught with risk. Not only is it ethically questionable, but it relies on the continuation of generous government support, which is uncertain in the face of significant budget deficits. This reliance on government policy makes such investments particularly volatile and potentially unsustainable in the long term. Such complexities in the housing market underline the need for a balanced approach to investment decisions, taking into account both economic benefits and ethical implications.

Table 2 shows a decrease in the achievable investment returns for most cities in 2021 and 2022. This decline can be attributed to several factors. First, the COVID-19 pandemic caused many tenants to terminate their leases, increasing the number of apartments available for rent. This oversupply led to a fall in rental prices (also see Figure 2). At the same time, the government implemented stimulus measures by distributing helicopter money to citizens. This influx of cash quickly contributed to inflationary pressures, which in turn pushed up the cost of housing. As a result, the profitability of property investments declined significantly.

This period highlights the vulnerability of property markets to sudden economic and socio-political changes. The simultaneous occurrence of reduced rental income and increased property costs squeezed investment margins, illustrating the interconnectedness of housing markets with broader economic policies and public health crises. These dynamics underline the need for investors to consider external economic factors and potential risks when assessing the stability and profitability of their property investments.

Figure 2. Dynamics of Listing Unit Prices for Smaller and Larger Apartments for Rent in Prague, 2018-2023

Source: authors' work based on software EVAL.

DOI: 10.34659/eis.2025.92.1.859

Cities such as Opava, Karviná and Havířov, which are located in the Moravian-Silesian Region, consistently show the lowest return on investment. This trend is deeply rooted in the current economic transformation of the region, which is characterised by the gradual phasing out of heavy industry and significant migration of the population to other areas. Particularly notable is the emigration of people of working age, which has an irreversible negative impact on the potential future development of the region. Research conducted by Kurekova (2022) identifies regions experiencing such structural emigration and confirms a spillover effect on selected markets. The decline of traditional industries often leads to a reduction in local employment opportunities, which reduces the attractiveness of the area for both existing residents and potential newcomers. This demographic shift leads to reduced demand for housing, which reduces rental prices and, consequently, the return on property investment. The situation in these cities illustrates the broader challenges facing regions heavily dependent on declining industries and highlights the critical need for strategic economic planning aimed at diversifying and revitalising the economy to attract and retain the workforce needed for sustainable regional development.

For comparison, the authors of the study carried out a similar analysis for apartments with a floor area of 65 m^2 (Cermakova et al., 2023). It was observed a slightly lower rate of return than for smaller apartments. In addition, the fall in prices in 2021 and 2022 was less pronounced for these larger dwellings, and the annual results were more stable. This phenomenon is explained by the impact of the COVID-19 closures, which led to the vacancy of smaller dwellings in particular, which were mainly occupied by workers whose permanent residence was in other regions. In contrast, larger dwellings remained occupied during the pandemic, as they are typically used for long-term family housing.

This scenario highlights how different types of property were affected differently during the pandemic, depending on their use and the demographics of their occupants. While smaller units experienced rapid turnover and greater volatility due to their association with transient, nonlocal workers, larger units maintained their occupancy more consistently, reflecting their role as stable, family-oriented housing. This distinction highlights the importance of considering the size and intended use of housing when assessing property investment opportunities, particularly in the context of unprecedented events such as a global pandemic.

Analysing the Rental Market Dynamics in Czech Cities: Correlations, Influences, and Investment Implications

Table 3 examines the size of the rental market in different cities in the Czech Republic and correlates it with the population size of each city. The authors introduce a metric called the "rental coefficient", which represents the average number of rental offers that appeared per year from 2018 to 2023 per 1,000 inhabitants in each city. The higher the coefficient, the more developed the rental market is considered to be in that city. Cities with the highest values of this coefficient include Prague, Havířov, Olomouc, Brno, Most, Karviná and Ostrava. In particular, these cities are academic centres, with a consequent high demand for rental housing from university students. In addition, these cities have developed industrial sectors, attracting many individuals seeking rental accommodation due to employment opportunities. This analysis provides a comprehensive overview of the dynamics of the rental housing market, highlighting regional variations influenced by demographic and economic factors.

Investing in residential property is often seen as a conservative financial decision. The authors, therefore, suggest that investors focus their resources on cities where the rental market is already flourishing. In contrast, cities at the other end of the spectrum, such as Frýdek-Místek, Jihlava, Pardubice, Liberec and Přerov, have a high level of home ownership, an ageing population and a pattern of out-migration of the younger generation. As a result, these cities have underdeveloped rental markets. These factors are exacerbated by the lack of sufficient ancillary services to support landlords in running their businesses. These deficiencies further inhibit the development of a rental market and make these areas less attractive to property investors seeking dynamic markets with ongoing rental demand.

DOI: 10.34659/eis.2025.92.1.859

Table 3. Number of offers for rent for Smaller Apartments in Czech Cities (2018-2023)

City	Number of offers for rent							Population*	Rental coefficient
	2018	2019	2020	2021	2022	2023	Average (2018 to 2023)		
Prague	10 370	15 178	31 385	31 254	10 602	15 129	**18 986**	1 357 326	**13.99**
Havířov	782	579	456	728	939	1 319	**801**	70 245	**11.40**
Olomouc	561	933	1 399	1 466	1 195	1 225	**1 130**	101 825	**11.09**
Brno	2 942	3 175	5 046	5 629	3 547	5 433	**4 295**	396 101	**10.84**
Most	515	613	635	790	872	723	**691**	63 856	**10.83**
Karviná	555	501	438	459	564	592	**518**	50 172	**10.33**
Ostrava	2 482	2 458	2 627	2 890	2 749	3 519	**2 787**	283 504	**9.83**
Karlovy Vary	232	336	517	718	404	365	**429**	49 043	**8.74**
Chomutov	237	243	360	428	519	566	**392**	46 940	**8.35**
Plzeň	681	1 200	2 062	2 090	1 163	1 226	**1 404**	181 240	**7.74**
Teplice	284	252	395	405	350	621	**384**	50 843	**7.56**
Ústí nad Labem	519	486	511	606	776	1 087	**664**	91 963	**7.22**
Opava	205	313	376	439	497	491	**387**	55 512	**6.97**
Jablonec nad Nisou	110	114	270	399	436	548	**313**	45 830	**6.82**
Zlín	278	417	533	464	496	717	**484**	74 191	**6.52**
Kladno	215	390	576	650	384	453	**445**	68 436	**6.50**
Hradec Králové	345	585	571	698	724	700	**604**	93 506	**6.46**
Prostějov	136	140	325	281	304	358	**257**	43 551	**5.91**
Děčín	222	141	153	220	435	500	**278**	47 180	**5.90**
České Budějovice	335	488	718	632	518	651	**557**	96 417	**5.78**
Mladá Boleslav	97	174	290	197	274	358	**232**	45 000	**5.15**
Frýdek-Místek	228	235	229	263	298	408	**277**	54 188	**5.11**
Jihlava	79	167	418	323	248	344	**263**	52 548	**5.01**
Pardubice	263	308	541	483	411	622	**438**	92 149	**4.75**
Liberec	211	387	681	578	487	647	**498**	107 389	**4.64**
Přerov	83	105	181	135	212	230	**158**	41 634	**3.78**

Source: authors' work based on software EVAL and Czech Statistical Office (2023).

Figure 3 provides a fascinating insight into the evolution of the rental market in Prague, illustrating the changes in the availability of rental apartments over the years. In 2020 and 2021, there was a significant increase in the supply side due to the COVID-19 pandemic. This increase was characterised by an influx of temporary vacancies and a slowdown in housing demand as mobility restrictions and economic uncertainty took hold. By 2023, the situation appears comparable to that of 2019, suggesting that the rental market has normalised after the pandemic. However, it remains evident that demand for rental housing in Prague consistently outstrips supply.

A reasonably priced rental offer can be expected to attract more than 50 prospective tenants within a few days, reflecting the strong demand. This scenario represents a lucrative opportunity for investors in the residential property market, although it poses significant challenges for those seeking rental accommodation, exacerbated by complications such as competitive and rapidly changing market conditions.

DOI: 10.34659/eis.2025.92.1.859

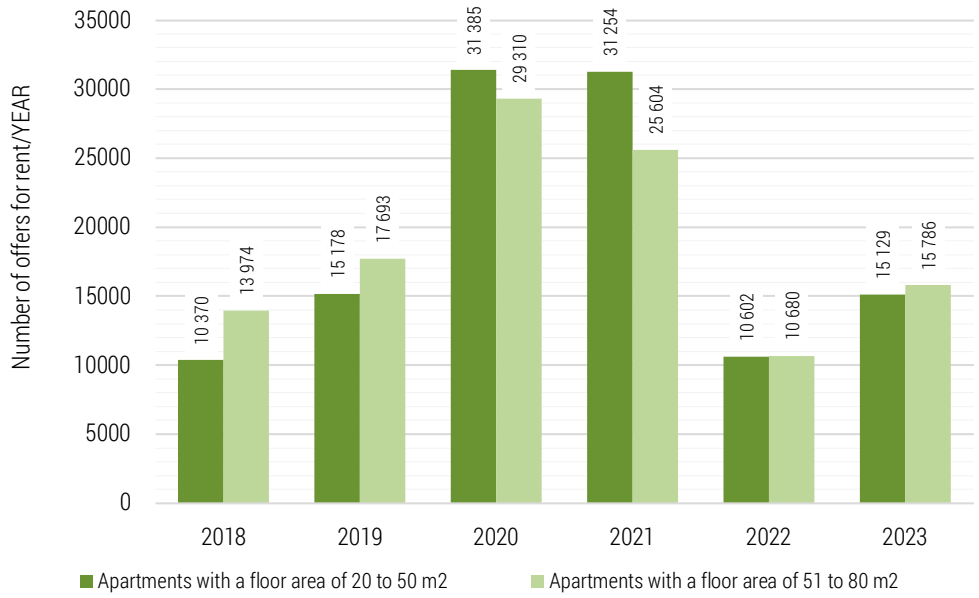

Figure 3. Number of offers for rent for Smaller and Larger Apartments in Prague, 2018-2023 Source: authors' work based on software EVAL.

A fundamental problem is the longstanding lack of a coherent national housing policy in the Czech Republic. This has had a particularly severe impact on young adults and families looking to settle. The state's piecemeal approach to addressing housing needs has failed to alleviate the pressures of an increasingly constrained rental market, leaving the younger population disproportionately affected by the challenges of finding affordable and suitable housing in urban centres such as Prague and Brno. This multifaceted problem underlines the urgent need for comprehensive housing policy reforms to ensure a more balanced and accessible market for all demographic groups.

Assessing Energy Efficiency and Environmental Protection Trends in the Czech Housing Market

Table 4 and Figure 4 provide a chronological illustration of the energy efficiency of apartments offered for sale. In the Czech Republic, the energy performance of buildings is classified into seven classes, ranging from class A (most efficient) to class G (least efficient). This classification is usually included in every sales listing to inform potential buyers. However, it has been observed that a proportion of estate agents omit this important information in contravention of the law. In such cases, it is highly likely that the apartments in question fall into the worst category, class G.

Table 4. Energy performance of the Apartments in Prague (2018-2023) [%]

Energy performance of the apartments	2018	2019	2020	2021	2022	2023
Class A	0.73	0.53	0.49	1.04	0.81	0.95
Class B	21.92	26.09	31.71	26.36	26.03	29.90
Class C	16.50	17.37	17.69	14.64	18.53	17.25
Class D	5.79	6.31	5.79	6.58	7.62	7.31
Class E	2.29	2.76	2.71	2.81	2.58	2.64
Class F	0.43	0.44	0.52	0.64	0.44	0.63
Class G	37.93	33.29	28.91	31.90	29.33	28.45
Class not determined	14.40	13.21	12.17	16.02	14.66	12.88
Total [%]	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: authors' work based on software EVAL.

DOI: 10.34659/eis.2025.92.1.859

The authors had expected that, over time, there would be a noticeable improvement in environmental standards in the construction sector, leading to a trend where more properties for sale would be classed as A or B. Unfortunately, the research did not confirm these expectations. The authors attribute this discrepancy to the fact that new construction represents only a small segment of the overall housing market. It will be many years before significant environmental progress is made in the market.

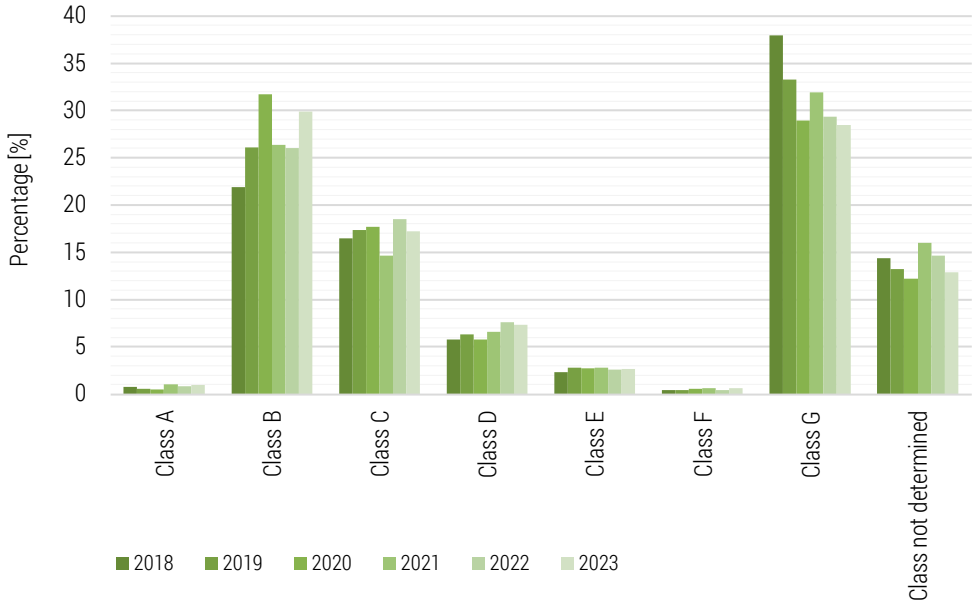

Figure 4. Energy performance of the Apartments in Prague (2018-2023) [%]

Source: authors' work based on software EVAL.

This research highlights the ongoing challenges in aligning the property market with environmental sustainability goals. Despite the regulatory framework requiring disclosure of energy performance, compliance issues persist, potentially hindering progress towards more energy-efficient housing. The findings underline the need for strict enforcement of existing legislation and possibly the introduction of incentives to accelerate the adoption of higher energy efficiency standards in residential buildings.

Discussion

Role of EVAL software and methodological considerations

EVAL software plays an important role in the aggregation and analysis of property data in this study. Designed and managed by one of the authors, its development and use in collecting large amounts of data effectively supports complex analyses of property price trends over time across the Czech Republic. However, the exclusivity of access to the EVAL could potentially limit the reproducibility of the results, as external researchers or parties cannot independently verify the processes. Future research could benefit from making the EVAL software or its methods more accessible for peer review and wider use in the academic community.

Geographical limitations and wider implications

Integrating additional types of data could greatly enhance the utility and accuracy of the EVAL software's outputs. For instance, incorporating data from social media platforms could provide real-time insights into consumer sentiment and emerging market trends, which are increasingly influential in today's digital age. Social media data might reveal early shifts in the attractiveness of certain

DOI: 10.34659/eis.2025.92.1.859

areas or changes in consumer preferences toward housing features, which are not immediately evident through traditional data sources.

The inclusion of international data could also be valuable, particularly for comparative studies or for understanding the impact of global economic movements on local markets. This could be critical for regions like the Czech Republic, where foreign investment plays a significant role in the real estate sector. Analysing cross-border market dynamics and investment flows can provide a deeper understanding of how international events and trends influence local property markets.

Expanding the scope of data collection and analysis in these ways could substantially broaden the implications of the research, providing a richer, more detailed understanding of the real estate market that is both timely and geographically comprehensive. Additionally, these enhancements could support more targeted and effective policymaking, ultimately contributing to more sustainable and equitable market development.

Market saturation and economic factors

The observed saturation point of property prices in 2023 suggests an adjustment phase in the market dynamics of the Czech Republic. This phenomenon provides an opportunity for future studies to explore the long-term sustainability of the property market. In addition, the impact of external economic factors such as global crises, changes in interest rates and demographic shifts on property markets could be studied in more detail, providing insights for forecasting models and risk assessments.

Ethical considerations and investment strategies

The concept of 'poverty trading' identified in certain investment practices raises ethical questions about the exploitation of economic inequality for financial gain. Future research could explore the ethical implications of investment strategies in real estate markets, with a particular focus on the sustainability of such practices and their impact on local communities. This could also lead to discussions on regulatory frameworks that balance investment returns with community well-being and housing affordability.

The trends observed in this study have significant economic implications. The rapid price appreciation in economically weaker cities may lead to improved local economic conditions through increased property tax revenues and construction activity. However, it also raises concerns about housing affordability for local residents. From an investment perspective, these trends suggest a potential convergence in property values across different regions, which could impact future investment strategies and urban development patterns.

Conclusion

The aim of the study was to conduct a comprehensive analysis of property price trends in Czech cities. The results presented in this article were derived from the EVAL software and analysed property price trends in Czech cities with more than 40,000 inhabitants from 2018 to 2023. The analysis focused on presenting the average annual return on investment in different cities, as well as examining the correlation between the rental market and population size. The results showed that cities with thriving rental markets tend to have high rental coefficients, indicating a developed rental market. The paper also examined trends in environmental sustainability in the Czech housing market, with a particular focus on the energy efficiency of homes for sale. In conclusion, the assessment of energy efficiency and environmental protection trends in the Czech housing market reveals significant challenges in aligning the market with sustainability goals. Contrary to expectations, the research did not observe a significant improvement in environmental standards over time, attributed to the dominance of existing housing stock and slow progress in new construction.

The following paragraphs highlight the significant benefits of using EVAL software for detailed data collection and analysis of the Czech property market, providing valuable insights down to street level. It stresses the importance of recognising the limitations of relying on a non-publicly available tool for wider scrutiny. In addition, the study highlights rising property prices in economically weaker

DOI: 10.34659/eis.2025.92.1.859

cities. This underlines the need for continuous market monitoring and nuanced housing policies to address different regional needs. It also suggests directions for future research, including a deeper exploration of the socio-economic implications, the role of technology and ethical considerations in real estate investment strategies.

This study benefits significantly from the detailed data collection and analysis enabled by EVAL software, which provides insightful trends in the Czech property market. EVAL's ability to analyse data down to the street level provides a unique vantage point that could be crucial for both policymakers and investors in making informed decisions. However, it is important to recognise the reliance on a tool that is not publicly available, which may limit wider scrutiny and validation of the research findings.

The research highlights a clear trend of rising property prices in the Czech Republic, especially in economically weaker cities. This upward trend offers an investment opportunity but also carries potential risks associated with market corrections and economic volatility. These findings underscore the need for continuous market monitoring and adjustment of investment strategies based on evolving economic conditions.

The analysis of rental market dynamics reveals significant differences between cities, influenced by demographic, economic and social factors. The strong rental market in major academic and industrial cities contrasts sharply with the stagnant markets in regions facing demographic decline and industrial decline. These findings underscore the importance of nuanced housing policies that address the diverse needs of populations in different regions.

This study lays the groundwork for future research, including a deeper dive into the socio-economic implications of property market trends and the role of technology in property analysis. Further studies could also explore the impact of international economic trends on local markets and develop more sophisticated models for predicting market behaviour under different economic scenarios. The integration of ethical considerations into real estate investment strategies also provides fertile ground for future academic research aimed at balancing profitability with social responsibility.

From an economic standpoint, our findings highlight the complex interplay between property markets and broader economic factors such as regional development policies, demographic shifts, and changing work patterns. These insights can inform more effective policy-making and investment strategies, potentially leading to more balanced and sustainable urban development across economically differentiated regions.

The economic significance of our findings is substantial for both real estate investors and policymakers. For investors, the observed price increases in economically weaker cities suggest potential opportunities for higher returns, albeit with increased risk. This trend may lead to a shift in investment strategies, potentially redirecting capital from traditionally favoured locations to emerging markets within the Czech Republic. For policymakers, our findings highlight the need for targeted interventions to manage the effects of rapid price appreciation in economically weaker regions. This may include implementing measures to ensure housing affordability for local residents, developing infrastructure to support growing demand, and creating policies to promote sustainable urban development. Moreover, the observed trends in energy efficiency underscore the importance of incentivising green building practices and renovations to align the real estate sector with broader environmental goals. These insights can inform more effective and nuanced approaches to both investment strategies and policy formulation, potentially leading to more balanced and sustainable urban development across economically differentiated regions.

While this study provides valuable insights into the Czech real estate market, it is important to acknowledge its limitations. Firstly, our analysis is confined to cities with populations over 40,000, potentially overlooking trends in smaller urban or rural areas. Secondly, the reliance on listing prices rather than actual transaction data may not fully capture market realities. Lastly, the focus on a specific time frame (2018-2023) may not account for longer-term cyclical patterns in the real estate market.

These limitations present opportunities for future research. Expanding the analysis to include smaller cities and rural areas could provide a more comprehensive picture of the Czech real estate landscape. Additionally, incorporating actual transaction data, when available, could enhance the accuracy of price trend analyses.

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Furthermore, while this study focuses on the Czech market, many of the observed trends may have relevance for other EU markets, particularly in Central and Eastern Europe. Countries like Poland, Hungary, or Slovakia, which share similar historical and economic contexts, might exhibit comparable patterns in terms of regional price disparities and the impact of economic events on real estate markets. Future studies could explore these potential parallels, contributing to a broader understanding of real estate dynamics across the EU.

Acknowledgements

This research has been supported by Academia aurea Grant Agency (GA AA) within the framework of project No. GAAA/2024/5, project title: A multidisciplinary approach to housing investments.

The contribution of the authors

Conceptualisation, E.H., L.K. and K.Č.; literature review, B.K.; methodology, E.H.; formal analysis, L.K. and K.Č.; writing, K.Č., E.H., L.K. and B.K.; conclusions and discussion, B.K. and K.Č.

The authors have read and agreed to the published version of the manuscript.

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