CHARLES UNIVERSITY
FACULTY OF SOCIAL SCIENCES
Institute of Economic Studies

Inflation hedging properties of investment into real estate: evidence from countries of Visegrad Group

Master's thesis

Author: Daniel Matoušek
Study program: Economy and Finance
Supervisor: PhDr. Michal Hlaváček, Ph.D.
Year of defense: 2024

Declaration of Authorship

The author hereby declares that he or she compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain any other academic title.

The author grants to Charles University permission to reproduce and to distribute copies of this thesis in whole or in part and agrees with the thesis being used for study and scientific purposes.

Prague, July 31, 2024

Daniel Matoušek

Abstract

This thesis investigates the properties of real estate as a potential tool for protecting the purchasing power of money. The study focuses on the Visegrad Group countries, which are historically and geographically closely connected, making them suitable for comparative analysis. This work provides a comprehensive summary of the historical development of the real estate market in relation to inflation trends across these countries.Readers are given a detailed overview of publicly available data sources, their limitations, and the specific characteristics of real estate data that must be considered. The empirical analysis is conducted using the Fama and Schwert model, followed by the ARDL model and its ECM specification to estimate short-term dynamics. The analysis is performed at both the national level and with a focus on comparing major cities with national averages and distinguishing between new and existing properties. Although the statistical power of the interpreted models is limited and the results should be taken with caution, the findings suggest that real estate in Hungary offers the best protection against inflation, followed by properties in Slovakia. While major cities do not show a clear distinction from national averages, existing properties have been found to be a better hedge against inflation than new properties.

JEL Classification	F12, F21, F23, H25, H71, H87
Keywords	real estate, inflation, investment, inflation hedge, Visegrad Group, empirical analysis

Title	Inflation hedging properties of investment into real estate: evidence from countries of Visegrad Group

Author's e-mail	88952997@fsv.cuni.cz
Supervisor's e-mail	michal.hlavacek@unrr.cz

Abstrakt

Tato práce se zabývá vlastnostmi nemovitostí jakožto potenciálního nástroje pro ochranu kupní síly peněz. Tyto vlastnosti byly sledovány v zemích Visegrádské čtyřky, které k sobě mají historicky i geograficky velmi blízko a proto jsou považovány za vhodné pro porovnání. Tato práce přináší do existující literatury rozsáhlé shrnutí historického vývoje trhu s nemovitostmi s vazbou na vývoj inflace napříč zeměmi. ČtenářĹŻm je poskytnut detailní přehled o veřejně dostupných datových zdrojích, jejich nedostatcích a specifikách, která s sebou data o nemovitostech nesou a která musí být zohledněna. Empirická analýza je provedena na modelu Fama and Schwert, následována modelem ARDL a jeho ECM specifikací pro účely odhadu krátkodobé dynamiky. V obou případech jak na národní úrovni, tak v detailu zaměřujícím se na porovnání hlavních měst s národními prĹŻměry a rozdílu mezi novými a existujícími nemovitostmi. Přestože statistická síla interpretovaných modelĹŻ je omezená a výsledky proto musí být brány s rozvahou, nejlepší ochranu proti inflaci vykazují nemovitosti v MaÄŹarsku, následované nemovitostmi na Slovensku. Zatímco hlavní města nevykazují jednoznačnou odlišnost od národních prĹŻměrĹŻ, existující nemovitosti se ukázaly být jako lepší ochrana před inflací než nemovitosti nové.

Klasifikace JEL	F12, F21, F23, H25, H71, H87
Klíčová slova	nemovitosti, inflace, investice, ochrana před inflací, Visegrádská čtyřka, empirická analýza

Název práce	Investice do nemovitostí jako ochrana proti inflaci v zemích Visegrádské čtyřky

E-mail autora	`88952997@fsv.cuni.cz`
E-mail vedoucího práce	`michal.hlavacek@unrr.cz`

Acknowledgments

The author would like to express his great thanks to the supervisor of the thesis PhDr. Michal Hlaváček, Ph.D. for his time, guidance, endless support and helpful feedbacks.
Furthermore, the author would like to thank his family and schoolmates for their support during the studies.

Typeset in FSV LaTeX template with great thanks to prof. Zuzana Havránková and prof. Tomáš Havránek of Institute of Economic Studies, Faculty of Social Sciences, Charles University.

Bibliographic Record

Matoušek, Daniel: *Inflation hedging properties of investment into real estate: evidence from countries of Visegrad Group.* Master's thesis. Charles University, Faculty of Social Sciences, Institute of Economic Studies, Prague. 2024, pages 94. Advisor: PhDr. Michal Hlaváček, Ph.D.

Contents

List of Tables

List of Figures

Acronyms

ARDL Autoregressive Distribution Lag

ARMA Autoregresive Moving Average

BIS Bank of International Settlement

CEE Central and Eastern Europe

CB Central Bank

CPI Consumer Price Index

CZSO Czech Statistical Office

ECB European Central Bank

ECM Error Correction model

ECT Error Correction term

EU European Union

FDI Foreign Direct Investment

GFC Global Financial Crises

GDP Gross Domestic Product

GUS Polish Statistical Office

IMF International Monetary Fund

KSH Hungarian Statistical Office

MNB Hungarian National Bank

NBP National Bank of Poland

NBS National Bank of Slovakia

NSO National Statistical Office

OECD Organisation for Economic Co-operation and Development

RE Real estate

RPPI Residential property price index

Chapter 1

Introduction

Following the Global Financial Crisis (GFC) and subsequent implementation of loose monetary policies aimed at economic stimulus, an economic environment marked by elevated price levels has flourished. This introduced a considerable pressure on traditional investment instruments (Koniarski & Sebastian, 2015). As these instruments failed to deliver historical returns, investors sought for alternative asset classes that will be capable to provide sufficient yields to mitigate inflation-related investment risks, and preserve purchasing power of investors (Shepard *et al.*, 2015). This shift led to an increased interest in tangible assets, particularly real estate.

From the theoretical perspective, the robustness of real estate as hedge against inflation is motivated by its inherent value maintenance, healthy income returns and long-term benefits related to portfolio diversification. However, the effectiveness of real estate as an inflation hedge has been inconsistent across existing research. This inconsistency is mainly attributed to the varying characteristics of different properties, market exposures, and economic conditions, highlighting the need for country-specific research. In the context of the CEE region, research on inflation-hedging has been historically limited due to constraints in data availability and comparability that have been extensively addressed after the accession of V4 countries to the European Union and subsequent requirements for data collection and market monitoring. These drawbacks further accelerated during periods of unprecedented housing price booms that underscored the importance of real estate for market stability.

In recent economic turbulence marked with heightened inflation rates and market's uncertainty, driven by the COVID-19 pandemic, the energy crisis, and the ongoing conflict in Ukraine, the topic of real estate's inflation-hedging properties has become more relevant than ever. This period of high inflation necessitates an in-depth exploration of how real estate investments can serve as a hedge against inflation within the V4 countries.

Consequently, this thesis aims to explore the inflation-hedging properties of real estate within the Visegrad Group. By examining the interplay between real estate returns and inflation, this research seeks to provide insights into the viability of real estate as a protective investment in an inflationary environment, focusing on both cross-country and national differences. These findings will contribute to a broader understanding of real estate asset behavior in response to inflation and provide answers on potential real estate market synergies within the V4. The subsequent analysis on a national level will shed the light on the specific position of real estate markets in capital cities as well as disparities across different property types.

The thesis is organized as follows: the second chapter defines key terms utilized across the thesis, followed by the extensive description of real estate market developments across V4 countries after the fall of communist regimes. Chapter four provides evidence on research conducted and methods used for inflation-hedging analysis both in worldwide and European context. Section five and six are devoted to description of data and methodology utilized within this study, followed by the interpretation of results and discussion on potential shortcomings.

Chapter 2

Definition of key terms

In order to deep dive into the topic of inflation-hedging characteristics of the real estate, there is an urge to understand notion of key terms such as real estate, inflation, hedging strategy and their interconnections.

2.1 Real estate

Real estate market is a key driver of economic development and a substantial contributor to a nation's GDP (Ametefe, 2018). It affects overall financial stability of any economy through its strong linkages to financial market and wealth of individual economic subjects. The market itself is characterized by a cyclical and highly localized nature, inelastic demand and diversity of individual assets requiring need for local market knowledge. As a heterogeneous asset class, real estate has a specific nature of being both consumption good and investment vehicle. As a consumption good, the evidence from the Visegrad Group shows that a real estate represents the largest expenditure on the household's balance sheet ranging from 52% share in Hungary, 33% share in Poland, 31% share in the Czech Republic to 29% share in Slovakia.[1] (Eurostat, 2020)

From the perspective of an investment vehicle, real estate is a tangible and non-transferable asset associated with low liquidity due to the absence of exchange traded market place. Its acquisition is connected with high initial fund outlays and

[1] individual shares calculated based on COICOP methodology

transaction costs followed by significant maintenance expenditures and management requirements. There is also a risk of asset valuation inaccuracies and greater potential losses incurred during a fall in prices when the acquisition is funded with the use of debt instruments (Wilson & Zurbruegg, 2003)(Ruhmann & Woolston, 2011). On the other hand, it provides long-term investment benefits such as improvement of risk-return characteristics of an investment portfolio and further portfolio diversification (Zhou & Clements, 2010). Real estate also benefits from two streams of cash-flow, income and capital return. While income stream is usually generated on regular basis through monthly payments of rent according to a lease agreement, the capital return stems from the change of real estate's intrinsic value in time.

2.2 Inflation

Inflation is generally considered as the rate of increase in prices of goods and services over given period in time (Oner, 2010). It is one of the leading macroeconomic indicator whose evolution in time affects overall performance of financial markets. According to Lintner (1975): "only a few matters are of more serious concerns to students of finance and members of the financial community than the impact of inflation on our financial institutions and markets and its implications for investment policy". In today's highly competitive world where many central banks of western countries use liquidity operations, low prime rate regimes and currency weakening to keep up with the developing world, the fulfilment of the goal of stable and low inflation and the ability to predict its evolution have become more demanding than ever before (Kelleher, 2011). This holds not only for state institutions but also for every person and investor. As rational investors want to maintain the same, positive level of real returns, inflation has become a significant determinant of their decision making and a serious risk for their purchasing power and wealth erosion in the long term (Antolin *et al.*, 2012).

2.3 Inflation hedging

Hedging in general is an investment strategy used to reduce risk exposure to a certain situation in a market. Relating to inflation, hedging represents an effort to reach at least a certain degree of immunization against price level changes over a period of time and thereby maintain investor's purchasing power (Fama & Schwert, 1977; Zhou & Clements, 2010). Slightly wider description of inflation hedging was formulated by Bodie (1976) who came up with three possible definitions. Firstly, an asset is said to be an inflation hedge if it mitigates or fully eliminates the possibility of negative real returns on a given security. Secondly, an asset is perceived to be an inflation hedge if it in combination with other assets minimizes real return's variance. The last and the most frequently used definition of inflation hedging across empirical research is that the real rate of asset's return must be independent on the inflation rate. This implies presence of positive correlation between asset's nominal returns and inflation rate. It is the last definition tracking nominal and real returns separately that will further serve us as a baseline for introduction of theoretical framework for testing inflation hedging properties of real estate.

2.4 Real estate as a hedge

The period of loose monetary policies after the Global Financial Crises resulted in an economic environment with elevated price levels that created a pressure on the bond yields (Koniarski & Sebastian, 2015). With bond markets being unable to deliver past returns, investors started to explore alternative asset classes that could provide improved yields and mitigate inflation related investment risks (Shepard *et al.*, 2015). This resulted in an expanding interest in tangible assets, especially real estate whose real nature and income characteristics make strong intuition about its ability to provide investors healthy returns and inflation-hedging properties. As already described, real estate is both consumption and investment good giving itself an advantage of two channels through which price level changes can be transmitted to the real estate returns. From the perspective of a consumption good, inflation exerts an upward pressure on construction costs associated with the development of new properties. Higher expenses related to purchase of building material and financial compensation of construction labour project to the prices of newly constructed properties. Since existing properties are close substitutes to newly built ones, their price appreciates simultaneously providing investors with a capital return that should to a certain level keep up with inflation (Anari & Kolari, 2002). A similar perception on the interaction between construction prices and value of real estate provided Benjamin Friedman who underpinned the intuition by the Tobin's q. He argued that changes in inflation stimulate demand for housing and push prices of existing properties upward. Consequently, the Tobin's q for housing, defined as the ratio of existing real estate prices to the cost of constructing new real estate, rises above unity, prompting a reallocation of resources toward the construction of new real estate. Connected growing demand for construction material will push its prices up and elevate overall construction costs, which in turn would reduce Tobin's q back to unity and enhance prices of newly built properties (Hendershott *et al.*, 1980).

From the perspective of investment good on a competitive market, the value of real estate can be retrieved from the present value of future stream of cash flows, in this case actual or imputed net rent. Given the typically short-term nature of tenancy contracts with periodic renewals, there is a sufficient space for landlords or investors to react to evolving price levels. In practice, lease agreements often include inflation clauses that index rental rates year-on-year increases to the Consumer Price Index (CPI), a common indicator of inflation, ensuring the stabilization of real income derived from rent over time (Steinke, 2011; Anari & Kolari, 2002). Moreover, if a credit with fixed interest rate is used for the acquisition of real estate, rising inflation will speed up devaluation of the loan making the acquisition cheaper in real terms over time.

The link between inflation and real estate can also be retrieved from the definition of the CPI, the most commonly used indicator of inflation tracking. Within the European Union, its methodology is regularly and uniformly adjusted to allow comparison of price levels across EU countries. The index consists of 12 categories of household consumption expenditures according to the ECOICOP classification. Each category has a weight within index based on the average household expenditures according to national accounts statistics. Looking at the Czech Republic as an example, as of January 2022, housing represented by rent (imputed rent) accounts for 15.6% share within the CPI index (Český statistický úřad, 2022). Given such a significant representation of housing expenditures in the index, it can be noted that some degree of correlation between the inflation and real estate should come from the definition itself. This fact will need to be taken into account in the analytical part in order to avoid bias in the results.

Chapter 3

Real estate markets and inflation in Visegrad Group

The prevailing academic research concludes that the ability of real estate to hedge against inflation is inconclusive Arnason & Persson (2012). attributed this discrepancy to distinctive characteristics of real estate markets. Diverse attributes of real estate assets, supply dynamics, geographical location and associated economic potential are only a subset of factors contributing to the disparate performance of real estate across geographic regions and temporal periods. Consequently, it appears reasonable to examine the real estate market and inflation trends in each country of V4 individually (Steinke, 2011; Fiorilla & Halle, 2011). Nevertheless, owing to the interdependence among these economies, stemming from the collaborative alliance within the V4 and the comparable impact of communist regimes on their subsequent development, transformation, and liberalization processes, we have opted to briefly outline the evolution of real estate markets concurrently while highlighting key distinctions.

The initial paragraph of this section will cover the communist era and the early years of transformation, followed by a description of the period characterized by a property market boom culminating in the Global Financial Crises. The final paragraph will focus on recent years of development after the GFC.

3.1 From communism to early years of transformation

The consolidation of communist power in the V4 countries traces its roots to the late 1950s. During that time, the Czech Republic and Slovakia formed one state, Czechoslovakia, with significant socio-economic disparities between the Czech and Slovak regions. As a result, significant efforts were focused on implementing equalization incentives, which led to a reduction in the disparity between the two regions. Over the period spanning from 1948 to 1989, the per capita national income in Slovakia witnessed a growth from 61.2% to 85.7% of the Czech level, accompanied by comparable catch-up effects in other economic indicators (Becker, 2018). While the Czechoslovakian socialist regime adhered to relatively orthodox decisions aimed at socio-economic equality until its dissolution in 1989, regimes in Hungary and Poland initiated preliminary reforms already during the 1970s and 1980s. These reforms exerted considerable pressure on inflation, government debt and unemployment, but at the same time enabled Hungarian and Polish economies to enhance readiness for the transition to a market-oriented environment and exposure to Western competition (Spirkova & Ivanicka, 2006). To accelerate the transformation to democratic, market-led economies, Czechoslovakia, Poland and Hungary established a Visegrad Triangle by the joint declaration in 1991. The Visegrad Triagle, extended to V4 after the dissolution of Czechoslovakia, linked together countries of similar geopolitical conditions, shared history and the same goal of accession to the European Union (Błaszczyk *et al.*, 2022).

Even though the transformation target of V4 countries was similar, the process itself starting after the demise of communist regimes in 1989 was captured by each country differently. Poland pursued a rapid transition to a market-oriented economy through a strategy known as "shock therapy". This approach resulted in a substantial contraction in production, with a GDP drop of around 7% in 1990 and 1991, and an extraordinary hyperinflation peaking at 585.8% in 1990. Even though Poland witnessed double-digit inflation for several consecutive years thereafter, the economic transition was perceived successful, evidenced by a reversal trend towards positive GDP growth as early as 1992 (see Appendix, table A.1). In contrast, to minimize social and economic impact of transition, Czechoslovakia and Hungary adopted a gradual implementation of economic reforms. Moreover, in Czechoslovakia, despite the equalization efforts of the preceding regime, the divergent impact of economic reforms and varying attitude towards transformation became apparent. Notably, Slovaks expressed a preference for some degree of state support necessary for the maintenance of their industrial sector, contrasting with Czechs inclination towards pure liberalization and a market-oriented economy. These disparities in perspectives on future development ultimately culminated in the dissolution of Czechoslovakia into two sovereign countries on January 1, 1993. Although both countries exhibited increasing price levels, negative consequences of transformation and dissolution were more pronounced in Slovakia. Slovak economy faced its reliance on contracting Eastern markets and almost four times higher unemployment. With the end of financial support from the Czech Republic, Slovak state budget felt into deficit and economic reforms had to be slew-down to avoid higher economic and social losses. On the other hand, the Czech Republic successfully emerged from the recession already in 1993, thanks to the trade with Western countries and positive development of private sector that was able to create ten times more jobs than in Slovakia (Blazek, 1995).

The transformation processes brought significant challenges also in the real estate markets. Up to 1989, real estate markets in V4 were subject to regulation and central planning. Substantial state ownership, housing subsidies and excessively low regulated rents served as supportive policies to mitigate disparities in the accessibility of real estate across different regions and social classes. With market liberalization, high inflation and only bank deposits being one of a few investment alternatives to real estate, real estate prices started to rise sharply. The pressure on real estate prices was additionally supported by the rigidity of banking sector, where high interest rates on loans made them largely inaccessible for both individuals and developers, leading to a substantial downturn in residential construction in the early 1990s and significant under-supply (Ciupek & Cheetham, 2010). The downturn in construction activity was the most apparent in Hungary, where new construction decreased by 80% compared to 1980s, resulting in a deep housing crises (Hegedüs & Varhegyi, 2000).

To support recovery of real estate market and its transition to market-based system, all V4 countries had to enact laws ensuring the protection of private property rights, previously very limited and at that time essential for reduction of public ownership. Following the legal anchoring of private ownership through appropriate legal reforms, the transfer of state-owned real estate to private entities with the aim to stimulate activity on the market and motivate individuals to invest and renovate their newly acquired real estate assets has started. The ownership transition occurred mainly through two channels, restitution and privatization, both considered as the most important driver of real estate business recovery after 1989 (Sỳkora & Šimoníčková, 1994). In the course of restitutions, properties collectivized after 1948 in Czechoslovakia and Poland were restored to their original owners. In Hungary, where restitution did not occur, individuals received financial compensation in the form of vouchers, limited to a maximum value, which enabled them to participate on the property market (Ghanbari-Parsa & Moatazed-Keivani, 1999). The effect of restitutions on market activity and subsequent restoration incentives was remarkable especially in large cities with historical centers such as Prague, where 70% of buildings were returned to their original owners. On the other hand, urban and industrial areas formed on the socialist prefabricated housing estate did not experience similarly apparent changes in ownership structure (Sỳkora & Šimoníčková, 1994). As a result, the quality and price of real estate started to differentiate between large cities and urban locations. The same holds also for Hungary and Poland, where the capital cities of Warsaw and Budapest have begun to build their country's dominance in terms of economic strength and price of real estate (Ghanbari-Parsa & Moatazed-Keivani, 1999).

Real estate assets that have not undergone restitution were transferred from the control of the state and municipalities to private ownership through multiple phases of privatization programs, a cheap sale of state-owned enterprises and their assets. In Hungary and Poland, privatization processes were initially slow due to political instability and public fear of high unemployment and high inflation. On the other hand, in the Czech Republic and Slovakia, privatization was broadly successful benefiting from more stable macroeconomic condition. By 1995, the private sector's share on overall GDP in the Czech Republic grew from 11% to 60% and in Slovakia from 27% to 62% (Ghanbari-Parsa & Moatazed-Keivani, 1999). The shift toward private ownership was notably evident also in the real estate market. In the Czech Republic, the proportion of privately owned apartments within the total housing stock rose from 10.2% in 1991 to 46.8% by 2001. In Slovakia, by the end of 1998, an average of 38% of apartments were privately owned. This contrasts sharply with Bratislava, where 68% of apartments were privately owned, underscoring the growing disparities in post-communist development between major cities and other urban areas (UN, 1998).

The success of privatization can be considerably attributed to foreign investors, whose interest shifted to the CEE region following the establishment of private ownership and gradual transition to market system since 1989. The engagement of foreign investors in privatization programs and new development plans was primarily driven by the perception of potentially higher rental and capital returns compared to mature markets in developed countries. Subsequently, an extensive amount of development initiatives resulted in the origination of large number of development projects between 1991 and 1993, predominantly in the office and retail sectors. Majority of related capital inflow was concentrated to capital cities of Prague, Warsaw and Budapest that have soon established themselves as political and economic centers of their countries. During 1990s, this phenomenon was boosted by a notable portion of FDI to the build-up of shopping centers, logistic centers and other industrial spaces nearby large cities of the Czech Republic, Hungary and Poland[1]. In Slovakia, the FDI inflow and subsequent build-up financed from foreign resources was delayed by approximately 5 years as a result of a transformational slow-down explained earlier.

3.2 From the Czechoslovakia split to the GFC

Apart from the growing foreign investment into real estate market in the V4 region, the expansion was further facilitated by the gradual privatization of the banking sector and the establishment of new housing finance models. Specialized mortgage banks were instituted in Poland and Hungary, complemented by legislative support for mortgage lending in the Czech Republic and Slovakia during the mid-1990s. However, the initially elevated interest rates, averaging around 8% per annum, significantly constrained loan accessibility and limited their effectiveness in the

[1]FDI to the Czech Republic, Hungary and Poland accounted for 76% of the total FDI to the CEE region in 1994 (Martin, 1998)

real estate investment support (Horvatova, 2020). Consequently, a large scale of public support schemes were introduced to enhance affordability of real estate and to boost the activity on the market. To facilitate the modernization of existing real estate assets, new contract saving schemes were introduced in the Czech Republic and Slovakia. These schemes became the main instrument of the housing policy, supporting over 100 000 housing modernization projects and consuming over 50% of the total housing policy budget (Dübel, 2003).

Beyond contract saving schemes, Slovakia housing policy focused on the renewal of housing stock and enhanced overall housing availability through direct interest rate subsidies for mortgage borrowers and income tax exemptions for mortgage bond investors (Rentkova & Gejdos, 2019; Dübel, 2003). Similar approach was utilized in the Czech Republic but with stronger focus on mortgage interest deductibility and tax exemptions as a part of home ownership programs. In the Czech Republic, special interest rate subsidy was targeted to young first-time buyers, who purchased property on the secondary market, resulting in one of the lowest recorded lending rates in Europe in 2002. In Poland, housing policy was dedicated to direct support of housing investment. However, the level of fiscal support of owner-occupied housing through construction grants, national fund loans and tax exceptions was the lowest in the region and lasted only until the end of 2001 (Dübel, 2003). Subsequently, the Polish government shifted focus towards building social housing under the program launched in 1996 by National Housing fund (Heldak & Pluciennik, 2019). In Hungary, housing policy was significantly affected by severe budgetary pressures caused by extensive interest rate subsidies of the previous regime[2]. Even though subsidy and tax credit deduction ceilings were set to reduce overall state budget burden, the government fiscal support of mortgage sector was still the most generous across V4 region[3]. As a result, swift expansion of the real estate market and revival of supply side occurred after 2000, manifested especially by 50% year-on-year escalation in construction activity in Hungary (Vadas *et al.*, 2005).

The convergence of developing economies of V4 countries toward developed

[2]accounted to nearly 2.5% of GDP in 1989 (Sagari *et al.*, 1992)

[3]for example, tax credit deductions of the debt service payment reached up to 40% (Harnos, 2018)

nations, alongside a positive macroeconomic outlook marked by increasing household purchasing power and diminishing inflation rates, fostered activity on both supply and demand side. In this favourable environment, the announcement of V4 countries' accession to the European Union in 2004 acted as a pivotal catalyst for a spike in real estate prices between 2001 and 2003. Speculation regarding a substantial price escalation enhanced interest of foreign investors in local markets and fueled demand for real estate, resulting in an unprecedented surge in prices. In the Czech Republic, a notable price bubble was documented during 2002-2003 by (Hlaváček & Komárek, 2009). Similarly, real estate prices in Hungary increased on average by 60% over three years and in Slovakia, the residential property price growth reached 61% in a two-year period between 2002-2004 (Trojanek, 2021; Nagy, 2013). Only in Poland, the initial price growth exhibited a gradual trajectory with no sustained surge.

Beyond the price boom on real estate markets, the EU accession of V4 countries strengthened and stabilized their economies. Post-accession, inflation rates in the Visegrad Group countries declined to single-digit levels, mainly in Hungary and Slovakia (Molendowski, 2015). The labor markets in Poland and Slovakia experienced notable improvements, with unemployment rates dramatically decreasing from 19.1% to 7.1% and from 18.4% to 9.6% by 2008, respectively. The unemployment in the Czech Republic also reduced, albeit less dramatically due to a lower initial rate (Molendowski, 2015). EU membership also expanded the economic openness of the V4, enhancing competitiveness and deeper integration into EU trade. This was evidenced by a sharp increase in exports, contributing to a reduction in economic disparities with older EU members[4]. An important aspect of V4 countries convergence towards EU was the generous EU financial aid, averaging to 2-3% of annual GDP of V4 and predominantly supporting infrastructure and regional disparity mitigation under the EU's Cohesion Policy (Jedlička *et al.*, 2014; Égert *et al.*, 2008). Foreign investors activity in the region also flourished with a threefold increase in FDI in the V4 during the initial decade of the 21st century. Interestingly, the proportionate allocation of FDI to Poland across V4 exhibited a declining trend over time, potentially explaining its milder real estate

[4]V4 GDP per capita rose from 48.5% of the EU-15 average in 2000 to 78% of the EU-28 average in 2019 (Błaszczyk *et al.*, 2022)

price increases compared to its V4 counterparts (Błaszczyk *et al.*, 2022).

Except for the positive stimulus of V4 economies, the EU accession required adoption of numerous EU directives and implementation of a broad range of reforms to align with the EU legal framework. Across all V4 countries, excessive and considerably untargeted interest rate and tax subsidies were subject to termination (Dübel, 2003). A pivotal milestone in the transition to a market-driven real estate systems in V4 was the deregulation of rentals, a significant barrier to real estate modernization and willingness to invest into owner-occupied housing sector. This deregulation led to rental prices approaching market levels, making home ownership a more attractive and economical alternative for solution of housing needs, thereby increasing the demand for real estate purchases and boosting home ownership rates.

The substitution effect towards home ownership was the most apparent in the Czech Republic, with symbolic rent levels originally set at the 1964 price per square meter across the country (Sỳkora & Šimoníčková, 1994). These nominal rents were insufficient for maintaining the housing stock and discouraged investment in real estate. However, given the low national wage levels, a rapid increase in rents was unfeasible. Consequently, rent deregulation started gradually in 1992 to minimize the impact on households reliant on the rental market. After the period of slow rent adjustments, a critical step towards rent deregulation emerged with the adoption of Deregulation law no. 107/2006 Sb. By the end of the validity of the law in 2013, household rents had increased by nearly 58%, reducing the proportion of regulated rentals by 17% (Jahoda & Špalková, 2009). This gradual deregulation led to a noticeable substitution for home ownership, which rose from 74.1% in 2006 to 80.4% in 2012 (Špalek & Špalková, 2015).

The Slovakian housing market suffered a more pronounced decline in quality than the Czech Republic, largely due to prolonged state ownership and extended period of rent regulation (Cempírek, 2014). Nevertheless, the impact of rent ceilings was relatively minor as they affected less than 6% of the total housing stock (Jahoda & Špalková, 2009). Consequently, no adjustments were made to the regulated rent levels until January 2000, when regulated rents were increased by 70 percent (Lux, 2001). Together with extensive privatization, comparable substitution from rental housing to home ownership as in the Czech Republic occurred.

From 2005 to 2012, the rate of home ownership in Slovakia increased from 82.1% to 90.4%, demonstrating a substantial move towards private property ownership (Špalek & Špalková, 2015).

Unlike the Czech Republic and Slovakia, Poland had a private rental sector even before the collapse of the communist regime, albeit under stringent state control and with restrictive tenant protection measures that were unfavorable for landlords. The Tenant Protection Act, adopted in 2001, reduced the state control only partially. The Act allowed rents in new contracts to be set freely but with subsequent increases at government-defined levels, limiting landlord's ability to adjust rent in time based on market conditions. Nevertheless, the transition to market-led determination of new contract rentals in Poland had a more pronounced impact on the occupational structure than the changes observed in the Czech Republic or Slovakia. Between 2007 and 2012, the home ownership share in Poland increased dramatically from 62.5% to 82.2%, while the share of tenancies at reduced prices declined by over 21% (O' Sullivan & De Decker, 2007; Lux, 2001).

In contrast to the strict tenant protections in the Czech Republic, Slovakia and Poland, the Hungarian rental market operated under a less regulated and more liberal legal framework. Following the Housing Act of 1993, the rental market was governed by civil law principles emphasizing contractual freedom, which did not provide a structured approach for resolving conflicts. This lack of regulation exposed landlords to substantial investment risks and, combined with the government's strong preference for home ownership, made the market rentals relatively more expensive due to the absence of any subsidy. With 85% of state-owned rentals privatized by the mid-2000s, there was little incentive to develop a robust public rental market. Despite the introduction of a private rent subsidy scheme in 2003 designed to improve attractiveness of market rentals for investors, the rental sector experienced only a limited growth, continued to occupy a minor role in Hungary's overall housing tenure structure and did not lead to a significant change in the share of home ownership on the market (Hegedüs *et al.*, 2014).

However, the overall rising demand for home ownership, combined with the ongoing expansion of the real estate financing sector, positive economic development linked to the convergence of V4 economies to developed nations in the EU, and the increasing interest of foreign investors, has generated a new wave of pressure on real estate prices.

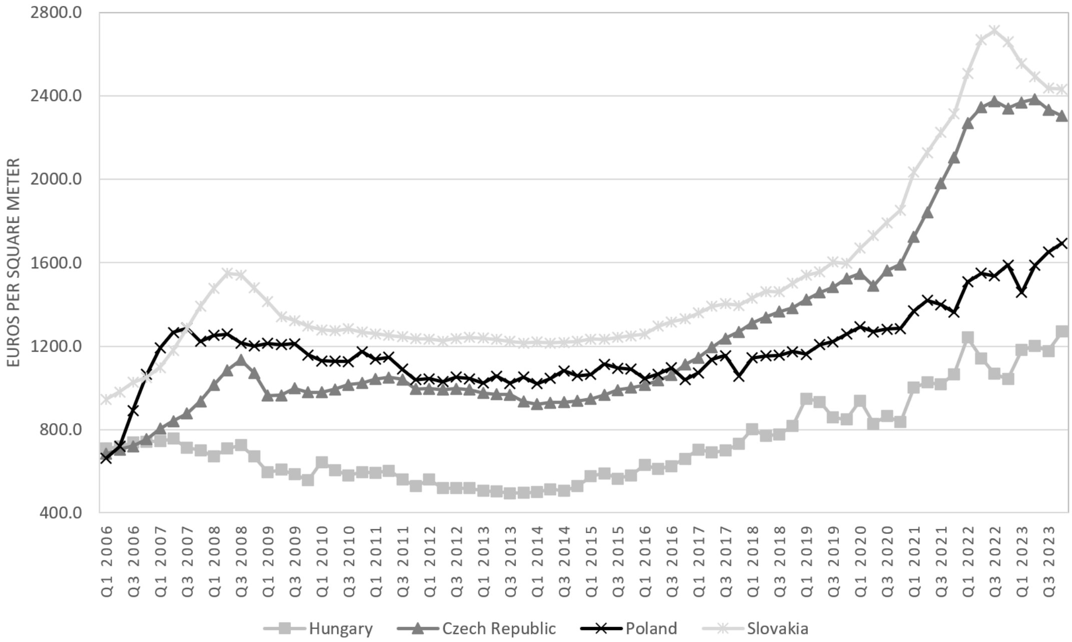

Figure 3.1: Price of all dwellings per square meter in EUR

Source: National Statistical Offices, Central Banks
Note: Data collected from BIS Detailed dataset database to ensure comparability of information on dataset dimensions

At the beginning of 2006, the price per square meter in the Czech Republic was the lowest across V4 countries. However, factors such as the substitution effect towards home-ownership stemming from the rent deregulation or anticipation of VAT increase on construction works pushed prices up. Figure 3.1 indicates that from the beginning of 2006 to the end of 2008, real estate prices across the whole country grew by 66%, almost reaching the price in Poland.

Slovakia experienced the fastest economic growth within V4 and was also perceived as the fastest growing economy in EU after the accession. This was attributed to a comprehensive set of reforms and improvements in the labor market (Horvatova, 2020). Positive and stable economic growth since 2000, increasing FDI and declining inflation and interest rates contributed to optimistic household expectations. Legislative changes in late 2006, offering interest rate subsidies to young lower-income families, fueled lending activity and projected to a more than 60% property price growth peaking in the third quarter of 2008 (see Figure 3.1) (Krcmar & Rychtarik, 2013).

In Poland, real estate market experienced remarkable activity in 2006, reaching a record transaction volume exceeding 5 Billion Euros. The housing boom was particularly noticeable in Warsaw with the highest number of new residential projects and the highest market prices across country. However, the supply shortage in Warsaw prompted interest and investment funds to other cities, namely Krakow, Tri-City, Wroclaw and Poznan. In Poland, the real estate boom was substantiated by positive demographic growth and development of the banking sector. Transition to cheaper Swiss franc-denominated loans, coupled with liquidity surplus, gradually decreasing interest rates and the introduction of new preferential mortgage loans program Rodzina na Swoim[5], fuelled a credit boom. Looking at the Figure 3.1, Poland encountered shorter period of a steeper real estate price growth compared to the Czech Republic and Slovakia. The peak can be observed already at the end of 2007 with prices being by more than 90% higher than in the first quarter of 2006 (Jedlička *et al.*, 2014).

In Hungary, the growth potential a speed of convergence were significantly limited by unstable public finances, fiscal imbalances and a high level of public debt. The financing of interest rate subsidies and other housing support tools posed an unsustainable burden on the financial budget (Vadas *et al.*, 2005). As a result, the overall subsidy system underwent tightening measures and tax increases, placing pressure on household's disposable income and negatively impacting aggregated real estate demand (Tvrdoň *et al.*, 2012). Moreover, a runaway exchange rate of the Forint in late 2008 required substantial interventions and led to elevated rates on foreign currency-based credit. This exerted immense pressure on repayments, causing new real estate projects to halt and a slowdown in demand for new housing (Balló, 2016). Consequently, Hungary stood out as the only country in V4 where real estate prices stagnated in the period between EU accession and the Global Financial Crises (see Figure 3.1).

[5]Financial support for families purchasing their own apartments, applicable between 2007-2012

3.3 From the GFC to these days

The onset of the GFC in 2008 had profound implications also for the Visegrad Group. As interconnected economies within the European Union, V4 countries faced immediate challenges from reduced export demand and shrinking foreign investment. Financial instability in global markets led to decreased consumer confidence, tighter credit conditions and a slowdown in economic performance. However, the overall negative impact of the GFC was less severe than in other Western and more developed countries, primarily due to the less developed financial sector in V4, which had minimal exposure to risky investments and in most cases avoided the need for capital support from public authorities.

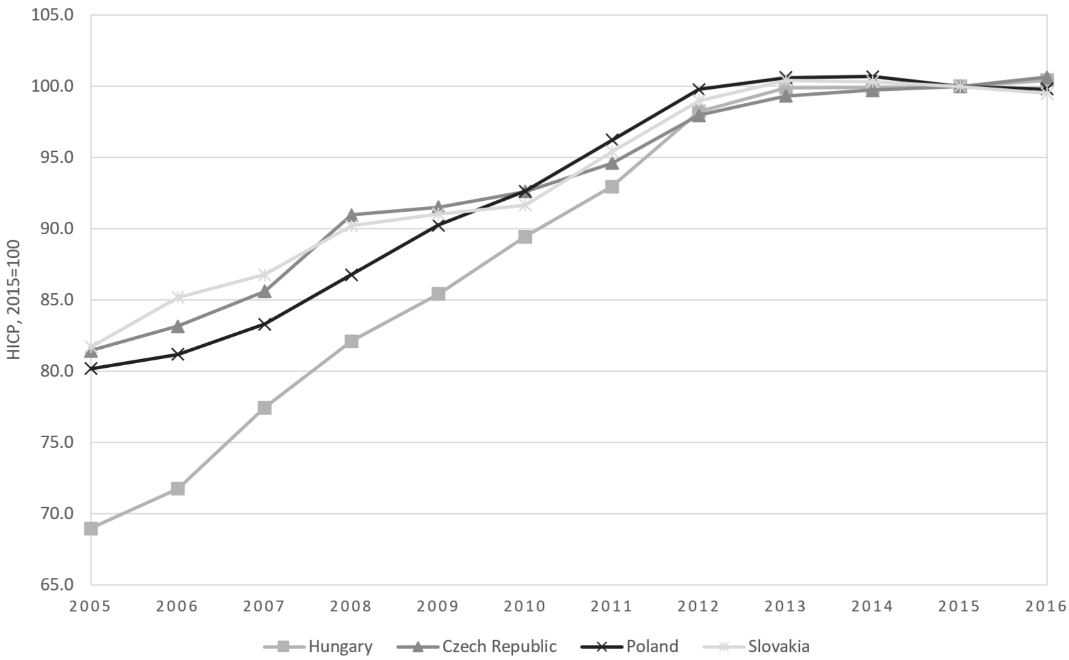

Figure 3.2: Harmonized Consumer Price Index (2005-2016)

Source: European Central Bank

In the Czech Republic, the reduction in export, shrinking FDI and capital outflows resulted in GDP contraction of 4.7% in 2009 according to Eurostat data. In order to stimulate the economy, stabilizing and growth stimulating measures such as interest rate cuts from 3.75% in 2008 to the level below 1% were adopted by the Czech National Bank. A little help towards Czech exporters was provided by a depreciation of the Czech koruna, fluctuating between 25.0 and 26.5 CZK/EUR at the peak of the crises. Interestingly, the fiscal stimulus of 2.1% of GDP did not lead to inflationary pressures as it did not overweight lower demand and falling commodity prices. According to Figure 3.2, the inflation rate measured by HICP remained relatively low and stable, averaging around 1% in 2009-2010 and fluctuating close to inflation target of 2% from 2010 to 2014. The real estate market, influenced by reduced investment and consumer spending, saw a sharp price decline of 15% in just two quarters. Since then, with reference to Figure 3.1, real estate prices stabilized and stagnated until the turn of 2016 and 2017 when they caught up pre-crises levels. This can be mainly attributed to the CNB's expansionary monetary policy of interest rate cuts and subsequent stimulus of lending (Somotogyi, 2019; Gregor, 2010).

Slovakia, a country with the fastest pace of growth before the GFC, was the second most impacted country by the GFC out of V4. Apart from the GDP contraction of 7%, it faced almost twice higher unemployment compared to the rest of V4 (Paweta, 2018). This was to some extent caused by inflexible monetary policy since the adoption of Euro on January 2009. The exchange rate inflexibility disabled currency to depreciate and to absorb some of the shocks from GFC like in other V4 countries. Consequently, Slovakia lost about 10-15% in price competitiveness against V4 countries and most of the shock projected to the labor market (Erste Group, 2014). Similar to the Czech Republic, inflation rates remained low in subsequent years, averaging around 1.5% from 2010 to 2014 and turning negative for next two consecutive years. The real estate market underwent a prolonged and more moderate decline compared to the Czech Republic. After the major price drop of over 19% between 2008 and 2009, the price per square meter continued to decline with only a slow pace until the end of 2014 (Hrachovec, 2012).

Unlike other V4 countries, Poland's larger domestic market and lower economic openness provided some resilience against the impact of the GFC. The significant depreciation of the zloty from an average of 3.52 PLN/EUR in 2008 to 4.33 PLN/EUR in 2009 enhanced the competitiveness of domestic products, supported local suppliers, and helped stabilize the labor market. With a interest rate cuts by the National Bank of Poland from 6.0% in 2008 to 3.5% in 2009 and slightly higher inflation rates compared to the Czech Republic and Slovakia in post-crises years, Poland was the only country in V4 that experienced an economic slowdown but avoided a recession (Hrachovec, 2012). Milder impacts of the GFC were observed also on the real estate market where prices mainly cooled down in the middle of 2007 and have reduced slowly until the fourth quarter of 2016 afterwards, without a dramatic drop. This can be attributed to regulation of mortgage lending practices by Polish Financial Supervision Authority since 2006 and housing policy programs "Family's own housing" (Rodzina na Swoim) and "Homes for the Young" (Mieszkanie dla Mlodych) that supported home-ownership and stimulated activity on residential market until 2018. Additionally, a positive impact can be seen also in construction activities carried out in connection with the football European Championship in 2012 (of Poland, 2010).

Despite successful fiscal consolidation before the crisis between 2006 and 2008, Hungary experienced one of the most severe recessions among OECD countries (OECD, 2010). It was the only country among V4 that required a financial aid from European institutions for economy stabilization as its government's response options were constrained by large government debt of 72.7% of GDP in 2008 and comparably higher inflation rates[6]. The financial aid was primarily targeted against markets that forced Hungarian forint to downward spiral (Hrachovec, 2012). Overall downgrade of economic situation in Hungary substantiated by a significant 14.5% fall in GDP between 2008 and 2009 transmitted also to the real estate market. Starting in 2008, real estate prices were decreasing for five consecutive years ending at the lowest average price per square meter in the European Union (see Figure 3.1). With high rates on foreign currency loans presented in Hungary in high volumes and considerable decline in disposable income of households, activity on the market participants felt and new construction reached its historical bottom in 2013 (Nagy, 2013; Balló, 2016).

Even though the Visegrad Group began to show signs of economic recovery after the GFC by the early 2010s, the turnaround towards increasing activity in real estate markets and subsequent rebound of prices was delayed by approximately four years. This can be attributed to the prolonged implementation of structural

[6]public debt in the Czech Republic, Poland and Slovakia was below 50% of GDP in 2008

reforms, slow resumption of development activities and a precautionary approach in terms of household expectations.

In the Czech Republic, factors such as low-interest rates, increasing money supply, and improvement in household wealth boosted lending activity. This, combined with a limited housing supply due to rigid construction laws and extensive bureaucracy regarding building permits, contributed to the steady increase in real estate prices.

Apart from very similar patterns to the Czech Republic, the Figure 3.2) suggest that the period between 2013 and 2014 in Slovakia and Poland was marked by strong stagflation, culminating in deflation between 2015 and 2016. In response to deflation, the European Central Bank (ECB) launched a quantitative easing program as an unconventional monetary policy tool designed to ease market conditions and boost the economy in an environment of low interest rates (Bank, 2015). Moreover, the Slovak parliament amended housing development laws in 2016 to streamline construction permits and reduce bureaucracy, boosting residential construction and real estate market activity (Council, 2016).

In Hungary, the financial affordability of housing measured by Price-to-Income ratio of square meter was at its highest in 13 years, accompanied by the lowest central bank rate in 25 years at 3% (Nagy, 2013). These favourable conditions were further supported by Hungarian government that introduced the Family Housing Allowance Program (CSOK) in the second half of 2015, providing significant financial support for the purchase or construction of new flats or houses. This program, combined with amendment of the building code a year later, were designed to increase prices of newly built properties, simplify the construction permit process and encourage new residential construction projects. (Balló, 2016; Parliament, 2017)

From 2014 onwards, Poland maintained relatively stable economic growth, driven by robust domestic demand and EU funding. Real estate prices were accelerated by increasing demand resulting from positive economic development, supportive housing policy programs "Family's own housing" (Rodzina na Swoim) and "Homes for the Young" (Mieszkanie dla Mlodych), low-interest rates, and the development of Poland's residential rental market including Airbnb. Apart from that, a decrease in bank deposit interest rates, long regarded as a good inflation hedge, attracted new individual investors to the housing market (Hrachovec, 2012).

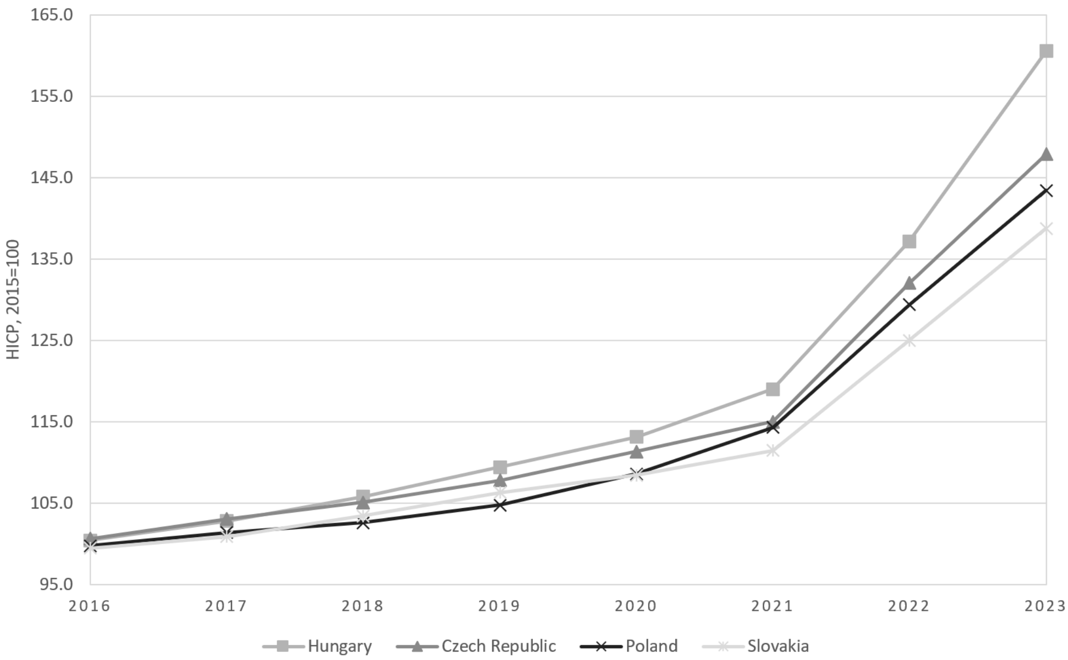

Figure 3.3: Harmonized Consumer Price Index (2016-2023)

Source: European Central Bank

An important milestone for the development of price levels in Visegrad Group was the emergence of COVID-19 pandemic, initially leading to an economic slowdown due to large set of restrictions imposed by government in order to reduce the spread of infection. In a response to restrictions on economic activity, central banks reacted with fiscal and monetary intervention to prevent economies from collapsing.

These restrictions led to accumulation of savings as spending possibilities were notably limited. Low interest rates on deposit accounts combined with uncertainty about further economic development and gradually increasing inflation forced households to search for new investment tools for allocation of their savings (Hromada, 2021). The interest of investors shifted towards real estate as it appeared to be a safe investment with attractive rates of return and favourable conditions for debt financing[7]. Excessive demand, shortage in construction activities and limited resources due to pandemic restrictions elevated property prices to historically unprecedented levels (ČNB, 2022). Based on Figure 3.1, major increase in prices was reported in Slovakia, where a 62% price surge between 2020 and 2022 pushed prices to 2 714 EUR per square meter. Quite similar price escalation was observed in the Czech Republic, where the average prices at national level peaked after a 59% increase. The positive real estate price trend was recorded also in Poland and Hungary, but the rate of price increase was approximately halved compared to the Czech Republic and Slovakia. Consequently, the gaps between nominal prices of real estate across Visegrad Group expanded. Supported by Figure 5.1, the phenomemon of divergent real estate prices appeared not only across countries but also on national levels where the prices in capital cities moved out from the national averages.

As the economy began to recover from the pandemic and governments started to ease pandemic-related restrictions, inflationary pressures between 2021 and 2023 emerged. These pressures were linked to resurgence of consumer spending and external factors such as global supply chain disruptions connected to the War in Ukraine and subsequent migration crises. Exacerbated geopolitical situation escalated into energy crises in 2022 leading to a sudden surge in energy prices, impacting household budgets and both inflation and real estate market dynamics (OECD, 2022). The erosion of inflation is documented by Figure 3.3, with double-digit inflation being reported across all V4 countries in 2022 and in 2023. In order to squeeze the inflation down back to inflation targets and stabilize economies, central banks strengthened monetary policies, raising interest rates up and tightening lending standards (European Economic Review, 2021). As a result of less accessible debt financing and stronger household's budgets constraints due to increasing prices on operating expenses, real estate prices in the Czech Republic and Slovakia fell. According to Figure 3.1), downward price adjustment in the Czech Republic was rather symbolic compared to Slovakia, where prices dropped by 281 Euros per sqm to 2021 price level.

[7]for example, in Slovakia interest rates on loans between 2019 and 2020 went below 1% with the possibility of arranging a housing loan online (Horvatova, 2020)

Chapter 4

Literature review

4.1 Worldwide research

Understanding key terminology applied in the thesis and being acquainted with the overview of real estate market and inflation development in all four countries of the Visegrad Group, we will proceed to the description of existing empirical evidence highlighting concepts utilized, results concluded and their limitations.

The theoretical framework for the relationship between asset returns and inflation was formally established by Irving Fisher in his famous book The Theory of Interest. The author claimed that the expected nominal return on asset is equal to its expected real return plus the expected inflation rate, implying that the investor should be compensated for the loss of purchasing power caused by inflation (Fisher, 1930). His approach to the relationship between inflation and asset returns, the so-called Fisher effect, was later utilized by Fama & Schwert (1977) in their article Asset Returns and Inflation, where the authors formulated the earliest and probably the most extensively applied regression framework for testing the inflation-hedging characteristics of assets (Dabara *et al.*, 2016). Fama and Schwert argued that if the information available in the previous period is processed efficiently, the market will price any asset so that the expected nominal return of the asset is the sum of the appropriate equilibrium expected real return and the best possible estimate of the expected inflation rate at that time (Fama & Schwert, 1977). With reference to Fama (1975), they extended Fisher's model by introduction of estimates for expected and unexpected inflation components. Using standard OLS framework, they argued that an asset is a complete hedge against either expected or unexpected inflation, if its nominal return co-moves in one-to-one correspondence with the given component of the inflation. They tested the inflation hedging properties of a wide range of U.S. assets using data at different frequencies over the period 1953-1971. They concluded that real estate is the only asset class with the ability to hedge against both expected and unexpected inflation predominantly over longer time horizon.

The same methodological approach was applied by Liu (2010). In order to conduct a three-dimensional level study, Liu collected transaction-based data of different frequencies for four types of real estate (private, office, retail, flatted factory) and observed the inflation-hedging properties of real estate rental income and capital returns. While rental income from private and office properties turned out to be nearly complete hedge against both expected and unexpected inflation, the same was not true for retail and flatter factory supporting the evidence from Hoesli *et al.* (2008) or Le Moigne & Viveiros (2008) that different property types may lead to distinct results. The coefficients of capital returns for all property types had positive sign, but were not significantly different from zero implying that rental income from leasing properties out contributes more to inflation-hedging than the price differential obtained from buy-and-sell strategy. Similar to findings of Fama & Schwert (1977) for hedging against unexpected inflation, the hedging abilities appear to strengthen as the time frequency of the data increases indicating that relationship is not stable in the short run.

Perhaps the most comprehensive application of the Fama & Schwert (1977) framework on U.S. data was published by Salisu *et al.* (2020). They investigated the inflation-hedging properties of gold, stock and real estate investment trusts (REIT) using monthly data. Instead of decomposing inflation into expected and unexpected, they controlled for potentially asymmetric response of returns to positive and negative changes in inflation and for the presence of structural breaks that were identified using multiple break-point test. Furthermore, as they were aware of the importance of the Global Financial Crisis on the asset returns, they partitioned their dataset into pre-GFC and post-GFC period to investigate potential time-variation in the inflation-return relationship. Their results suggested heterogeneous inflation hedging tendencies across assets with only stocks and real estate being good hedging instruments. Moreover, inflation beta coefficients of real estate were strikingly greater than one suggesting a more than proportionate growth with inflation rate. Interestingly, the asymmetric response of returns to inflation changes, structural breaks and portioning of the sample did affect the results. This is in contradiction to the findings of Grimes *et al.* (2004) who explained presence of an asymmetric response of asset returns to inflation by the reluctance of buyers to realize capital loss in situations of real estate price declines or of Yeap & Lean (2017) who found evidence of an asymmetric reaction of house prices especially in the short-run.

A further extension of the Fama & Schwert (1977) model to multiple regression was presented by Wu & Pandey (2012) with reference to Newell (1996), who noted that the ability of real estate to hedge against inflation is related to at least some macro-economic factors. Wu and his team expanded the model by three dummy variables that controlled for the presence of recession in the U.S. economy, a bull market and a potential real estate bubble. They inspected realized sales-based data of 20 cities and 2 composite indexes over more than 20 years and compared them with financial assets. Although they did not find any appreciable effect of equity market sentiment on the overall hedging ability of real estate, residential real estate was found to be at best only a modest hedge against inflation.

Even more contractionary results regarding the inflation-hedging ability of real estate were provided by Liu *et al.* (1997) who took into consideration potential geographical disparities and applied Fama & Schwert (1977) framework and its modification developed by Solnik (1983) on seven countries across the world. For U.S., UK, France, Switzerland, Australia and two Asian countries, they collected monthly data on real estate company stocks, country-specific property funds and REITs between 1980 and 1991. In most cases, the inflation-hedging betas for real estate securities were not statistically different from zero providing evidence in favour of no systematic economic relationship between real estate securities and inflationary expectations. Moreover, the authors utilized Geske & Roll (1983) reverse causality model to inspect hypothesis that stock returns are a catalyst for changes in fiscal and monetary policy and thus may lead inflation. Surprisingly, fluctuations in asset returns turned out to be a stimulus for changes in inflation expectations indicating that Fisher theory may not hold.

Dabara *et al.* (2016) explained the inconsistency of the results by the highly localized nature and dynamics associated with real estate markets claiming that empirical tests on the inflation-hedging characteristics need to be conducted on a country-by-country basis. This is in line with Fiorilla & Halle (2011) who added that local economic factors are also of crucial importance. According to research by Tenigbade (2011) on the inflation-hedging characteristics of office spaces in Lagos, the results may vary even on regional level. Apart from geographic reasons, Tarbert (1996) pointed out the inappropriateness of static regression models when examining real estate due to factors such as illiquidity, the absence of a central market and the uncertain lengthy transaction periods associated with the asset. He supported his claim with evidence of very low Durbin-Watson statistics of these models across the reviewed literature. From a methodological perspective, Dabara *et al.* (2016) and Christou *et al.* (2018) emphasized the inappropriate application and shortcomings of the Fama & Schwert (1977) model to be the predominant reason for inconsistent results of previous research. Specifically, they pointed out to the failure to account for orders of integration in the data and to the inability of the standard OLS framework to capture the time-varying relationship between house prices and inflation. The inability of Fama & Schwert (1977) model to capture the dynamic relationship was also addressed by Anari & Kolari (2002) and Bork & Møller (2015).

As a consequence, a new stream of literature, which have emerged around 1990s and have accelerated later on particularly in the wake of the housing bubble burst and the subsequent Global Financial Crisis, have begun to utilize various forms of cointegration approaches. These approaches are based on the intuition that variables may be correlated in the long run, regardless of whether there is any short-run relationship between them. These methods benefit not only from the ability to capture the time-varying relationship, but also from the fact that the majority of them do not rely on the stationarity of variables and the same order of integration.

To investigate the long-run relationship between real estate, expected inflation proxied by ARIMA estimates and the unexpected inflation component in China, Zhou & Clements (2010) utilized the autoregressive distribution lag (ARDL) cointegration technique. In order not to lose long-run information in the real estate data, they followed Granger & Joyeux (1980) or Johansen & Juselius (1990) and used real estate prices instead of returns. They were not able to reject the null hypothesis of no cointegration between real estate prices and inflation and subsequent Granger tests demonstrated the existence of several short-term causal relationships. While residential real estate granger-caused actual inflation, non-residential real estate granger-caused both actual and expected inflation.

Anari & Kolari (2002) employed an extension of the standard ARDL approach, the so called error-correction model of Pesaran *et al.* (2001). This method introduces first-differenced variables into the model allowing them to investigate both the short-run and long-run relationship in a single step estimation. Without necessity to conduct pre-unit-root testing, they observed the relationship between new and existing housing prices and inflation. Furthermore, recursive regression was applied to examine the variability of the relationship over time. Their results indicated perfect hedging ability of both new and existing housing prices that were, according to recursive regression, more or less stable over the entire sample period. Additionaly, cointegration implying existence of a long-run relationship was confirmed by the ARDL.

Except for utilization of an error-correction version of the ARDL model, Xi & Bahmani (2016) replaced the lagged level variables from the error-correction model with the so called error-correction term to determine the speed to which house prices adjust towards their equilibrium values. Moreover, they made use of a nonlinear version of the ARDL (NARDL) developed by Shin *et al.* (2014). This model allowed them to examine the pass-through effect of positive and negative inflation (asymmetry) into house prices in the short-run and long-run simultaneously while accounting for possible non-linearities. On quarterly data from 30 states of U.S. over almost 40-year time span, the effect of inflation on real estate prices was investigated indirectly by selecting income and mortgage rate as explanatory variables. While not much support for cointegration was found by standard ARDL, NARDL model revealed strong evidence in favour of both short run and long-run relationship between house prices and both explanatory variables. At the same time, asymmetric response of house prices to income and interest rate was confirmed.

Similarly, Yeap & Lean (2017) used NARDL to test the asymmetric response of house prices to inflation and their speed of adjustment to equilibrium in Malaysia. Four major types of real estate were analysed in relation to CPI inflation and energy inflation over the period 1999-2015. In the short-run, an asymmetric effect with larger magnitude of reaction to negative changes was reported while no hedging ability against CPI inflation was found. In the long-run, the response to energy and CPI inflation was symmetric with only terraced houses being an effective hedge against inflation as other housing types showed positive but not sufficiently large beta coefficients. These results are consistent with findings on the hedging abilities of house prices by Barkham *et al.* (1996) but diverge from the findings of Katrakilidis & Trachanas (2012) whose NARDL model on Greek house prices declared an asymmetric response to inflation in both the short and long-run.

Christou *et al.* (2018) provided a fairly exhaustive review of cointegration techniques applied to the topic of inflation-hedging while pointing out to their weaknesses that may cause the results to be unstable. They motivated their preference for quantile cointegration analysis over other methods by its ability to deal with potential non-linearity and the presence of structural breaks in the relationship between house prices and inflation. Specifically, they proposed the application of quantile cointegration analysis of Kuriyama (2015). The method allows cointegrating coefficients to vary over the conditional distribution of house prices and simultaneously tests for the existence of cointegration in each quantile, i.e. in specific housing market phases. They investigated the long-run relationship between US house prices and non-housing CPI using monthly data over 53 years, which to the author's knowledge is the longest time span ever used to the topic of inflation-hedging. Their results indicated always positive and significant response of house prices to the non-housing CPI. However, the non-housing CPI and house prices were cointegrated only at lower quantiles (0-20) of inflation and higher price levels (90+ quantile). Consequently, they concluded real estate to be a hedge against inflation only in environment of low inflation and high housing prices at which 1% change in inflation led to 1.1-1.6% change in nominal housing returns.

4.2 European research

European research on the topic of inflation-hedging emerged with a substantial lag especially due to limitations in the availability of sufficient data time span. The first ever published article on inflation-hedging of real estate applied to data from any European country was written by Limmack & Ward (1988). They followed the methodology of Fama & Schwert (1977) and conducted a sector level analysis on real estate appraisal based data series in the UK over 1976-1986. Contrary to the previous research, they utilized the UK retail price index (RPI) as a proxy for actual inflation as it was the official measure of inflation in the UK that time. After estimation of expected inflation by ARIMA and yields on T-bills, they concluded that the combined property and the three sub-sectors analysed (office, shops, industrial) were a hedge against expected inflation. However, only the industrial property sub-sector proved to be a hedge against unexpected inflation.

Probably the most comprehensive approach to applied data and the selection of proxy for expected inflation in the UK was published by Hoesli *et al.* (1997). He studied the short-term inflation hedging characteristics of real estate compared to other investments in the UK. He decomposed the gain from ownership of real estate into total return, capital value and income and observed their hedging features against total inflation and its expected and unexpected components. In contrast to Fama & Gibbons (1982), he argued that T-bills can be used as a proxy for expected inflation only if real interest rates are assumed to be constant. Therefore, three other procedures for estimation of expected inflation were adopted. Firstly, following Fama & Gibbons (1984), real interest rates were forecasted by moving average of past real interest rates for several sets of window sizes and the expected inflation was then obtained by subtracting these forecasts from T-bill rates. Secondly, forecasts of real interest rates were estimated by ARIMA model while keeping the rest of the procedure without change. Finally, the structural time-series approach suggested by Harvey (1990) where the unobserved component of inflation is modelled as a random walk plus noise was utilized. Hoesli claimed that real estate has poorer short term hedging characteristics for all profitability lines compared to stocks, but better than bonds. While real estate total return did not offer any protection against inflation, rental income reported some protection against expected but not unexpected inflation. The change in capital value was perceived as a partial hedge against both components of inflation but the very low R^2 suggested importance of other factors omitted in the regression. In accordance with Matysiak *et al.* (1996), such omission of relevant variables may lead to misspecification. Moreover, he noted that the relationship between real estate and inflation might not be linear and instantaneous. Inflation may lead or be lagged to real estate returns and therefore it would be beneficial to examine short and long-term effects jointly.

The drawbacks of Fama & Schwert (1977) model were later on discussed by Arnason & Persson (2012) who argued that property returns do not adjust immediately to changes in inflation and that the model is not capable to capture this lagging nature of adjustment. They also mentioned the necessity to distinguish between short and long-run equilibrium in order to obtain reliable results. Above Fama and Schwert model, they employed the rolling window approach to investigate behavioral changes in correlation of inflation with both lagged and non-lagged property returns. Residential, securitized and unsecuritized real estate were investigated over an 18-year period in Sweden with the conclusion that none of the real estate asset classes is a hedge against inflation.

A multi-national analysis of the inflation-hedging properties of direct investment in real estate with an augmented version of the Fama and Schwert model was conducted by Demary & Voigtländer (2009). They investigated panel data of six European countries including Sweden or Germany and concluded that only residential property provides hedge against expected and unexpected inflation. Other property types (offices and retail) were able to hedge only partially and against just a fraction of inflation. These mixed results across the components of inflation were in line with the findings of Dabara *et al.* (2016) and were explained by lower demand for offices in worsening economic conditions, the inability of retailers to shift inflation to customers completely and the greater market power of landlords in the negotiation of rent agreements with their occupants.

The approach to inflation hedging shifted to cointegration methods in European research as well with Stevenson & Murray (1999) being the first outside the UK research using cointegration methods. Their article, one of few examining both national and regional market, observed the hedging characteristics of returns of real estate, stocks and bonds in Ireland. None of the assets were found to be effective hedge with only real estate delivering positive significant results. Substantial differences in hedging abilities and no long-term cointegration were observed across regions. To infer more insights into the link between real estate and inflation, they separated the sample into high and low inflation scenarios. Similar to Hartzell & Webb (1988), their results suggested that hedging ability is high when inflation is high and diminishes in low inflation environment.

In order to shed the light on the distinct performance of methodologies commonly applied on the topic of inflation hedging of real estate, Stevenson (2000) analysed quarterly data for 11 regional markets in the UK using a set of four different models. As a proxy for actual inflation, the RPI and the Producer price index (PPI) were selected with lagged short term yield and the Fama & Gibbons (1982) correction being their respective estimates of expected inflation. Conventional OLS model developed by Solnik (1983) as an extension of the Fama & Schwert (1977) model reported only a little evidence of consistent and stable relationship with large variation across regions. Seven out of the eleven regions produced significant coefficients while only 5 of them designated as 'old industrial areas' provided a complete hedge. Cointegration using Engle & Granger (1987) procedure suggested strong evidence to support the hypothesis that housing and inflation are cointegrated for both RPI and PPI. Moreover, the cointegration tested by Johansen & Juselius (1990) method was stronger for the RPI proxy of inflation compared to the PPI proxy. These results highlighted the importance of data selection for the output of the analysis and potential instability of the relationship in short-term periods that may distort the results of OLS. Finally, Engle & Granger (1987) causality test revealed that housing leads inflation while the reverse causality was inconclusive.

Variety of methodological approaches were also applied by Ametefe (2018), who apart from the inflation hedging properties of real estate in the UK examined the portfolio structure and performance of pension funds when real estate is included. The author selected the ARDL of Pesaran *et al.* (2001) to test for long-run hedging and Toda & Yamamoto (1995) causality approach for short-run hedging. Real estate was found to be a complete hedge against inflation in the long-run with the retail and industrial sub-sector being also cointegrated with inflation. In the short-run, real estate was also found to be a good hedge as a bi-directional causal relationship was observed in most of the cases confirming the previous findings of Chu & Sing (2004). In line with Barber *et al.* (1997), the speed of adjustment to equilibrium following inflationary shocks took real estate some time as even after three years, less than 40% of erosion in real values caused by inflation was recaptured.

Geographically the nearest evidence to the Visegrad group was provided by Obereiner & Kurzrock (2012) using data from Germany. Their Fama & Schwert (1977) model tracked no hedging ability of indirect real estate investment against expected and unexpected inflation and almost no dependence of real estate returns on inflation in the short-run. On the other hand, cointegration tests, supported by the strong influence of German CPI on real estate fund performance derived from causality tests, indicated that real estate stocks, open-end funds and special funds do provide a hedge against inflation in the long term. This goes in hand with Dabara *et al.* (2016) who concluded that unlike in the long-run, investors can find better hedging opportunities than investment into real estate in the shorter horizon (6-12months).

Looking directly into the Visegrad Group, there is almost no existing research on the topic of inflation hedging. We can only consider Al-Nassar & Bhatti (2019) who investigated the inflation hedging properties of stock market indexes across 50 emerging markets or Lee & Lee (2012) who explored the inflation hedging ability of property stock index returns in European developed and emerging markets. They examined France, Germany, the UK, Poland and the Czech Republic on the time span of 1990-2011. However, data for Poland and the Czech Republic were available only since 1996 and 2005, respectively highlighting the aforementioned data shortage that European research suffers from. The authors employed Fama & Schwert (1977) model to test hedging ability of real estate stocks in the short run and the dynamic OLS (DOLS) model proposed by Stock & Watson (1993) for the long-run. They explained the choice of DOLS over other models by its less dispersed distribution with fewer outliers compared to Johansen cointegration test and by the allowance for the contemporaneous, lagged and lead values of differences of right-hand regressors (Wooldridge, 2008; Willem, 2006). Following Glascock *et al.* (2002) and Hoesli *et al.* (2008), they controlled for the real activity and monetary policy in the long-run by including industrial production and money supply into the regression. In the short-run, only a little inflation-hedging ability was reported in developed markets while in the long-run, real estate stocks of developed countries provided a positive hedge against expected inflation. In Poland and the Czech Republic, only marginal inflation-hedging effectiveness of real estate stocks was observed as beta coefficients were positive but insignificant. The author explained the discrepancy in results between developed and emerging markets by lower degree of institutional investor's involvement, less transparent information and different impact of money supply and monetary policies in emerging real estate markets.

Chapter 5

Data

According to Arthur (2005), quality data should meet six statistical criteria: regular availability, representativeness, homogeneous comparability, consistent data collection methodology, and sufficient length and frequency of the data series. Achieving data homogeneity and ensuring adequate length and frequency are usually main challenges when conducting real estate research (Hrachovec, 2012). The reasoning behind the difficulties of real estate data series collection arises from the unique characteristics of both housing market and real estate asset.

Consequently, before describing the data series used in the econometric part of this thesis, we will briefly highlight the specific characteristics and limitations of real estate data related to the V4 countries. We will also outline requirements for data quality and granularity that guided our data selection process. After this, we will provide a concise overview of the history of real estate data compilation framework in the EU and a review of publicly available real estate datasets that were considered during the data selection process.

5.1 Real estate data specifics and limitations

The issue of data homogeneity mentioned at the beginning of this chapter stems from the high geographic segregation of housing markets, which differ in construction activity, price levels, and their ability to attract foreign investments. These factors collectively contribute to significant variations in real estate market dynamics and price trends (Ahnert & Page, 2005). The Figure 3.1 indicates distinct price levels and magnitude of price adjustments across V4 countries, mainly around the Global Financial Crises and since the beginning of COVID-19 pandemic. The disparity in the rate of price adjustment is clearly illustrated in Figure B.1. For example, since 2015, real estate prices in Hungary have risen by over 50% more compared to other V4 countries, partially due to the convergence effect from significantly lower initial base. These disparities can be, apart from inconsistent financing structures, regulatory frameworks and tax policies, attributed to the distinct development paths of V4 economies. Based on Kijek (2017) research, the similarity of V4 economies, as measured by the correlation of average GDP growth, is relatively low given their highly comparable background[1] (corr. coef. = 0.68).

Variations are evident not only internationally, but also within individual countries. Ahnert & Page (2005) argue that especially capital cities, particularly in smaller economies, often follow distinct dynamics and volatility in economic indicators than the rest of the country due to their role of political and economic centers. The Figure 5.1 demonstrates the divergence of property prices in capital cities from their national averages in the Czech Republic and Hungary. Since 2015, prices in Prague and Budapest have almost doubled compared to their respective national averages. In Poland, following a period of price convergence lasting until 2016, Warsaw has gradually diverged from the national average. In contrast, Bratislava's price trajectory has closely mirrored the national trend.

Real estate price development is influenced not only by different market conditions across countries or regions, but also by the unique characteristics of each property type. Properties differ immensely in many aspects such as location, size or age, all of which impact their valuation. Differences may also be uncovered in local conditions. For instance, limited land availability for new construction in urban areas or outdated land use plans can negatively affect supply and drive prices for new dwellings up. Further price differentiation, mainly pronounced in case of houses, results from variation in construction quality, including architectural and technical features, or facilities affiliated to the real estate. Unfortunately,

[1] all are post-soviet countries, formed Visegrad Group to support socio-economic cooperation in 1991, and joined EU together in 2004

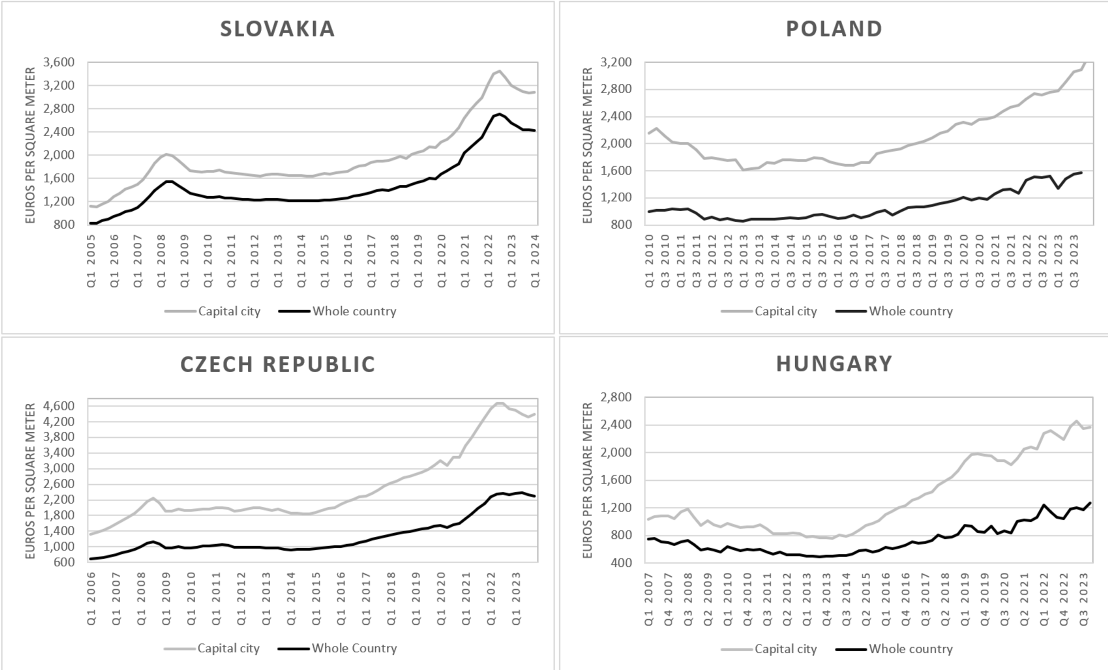

Figure 5.1: Price per sqm - Capital city vs. Whole country

Source: National Statistical Offices, Central Banks
Note: Not intended for cross-country comparison as Polish data represented by price of existing dwellings, while the rest of the countries by price of all types of dwellings

the low level of standardization and the limited number of transactions with insufficient detail complicate the compilation of reliable metrics for house prices. Consequently, majority of publicly available and trusted data sources provide data split for new and existing dwellings only, with "dwellings" covering together both flats and houses (Ahnert & Page, 2005).

Figure 5.2 highlights price evolution of these two categories. Until 2018, the price dynamics were comparable. Since then, the growth rate of prices for existing dwellings exceeded that of new dwellings in Slovakia and Poland. In the Czech Republic, prices for existing dwellings followed development of prices for new dwellings, but surpassed their peak and price correction with a short delay. In Hungary, prices for existing dwellings began to stagnate in 2022, whereas the growth rate for new dwellings continued unabated, leading to the initial formation of a price gap between existing and new dwellings.

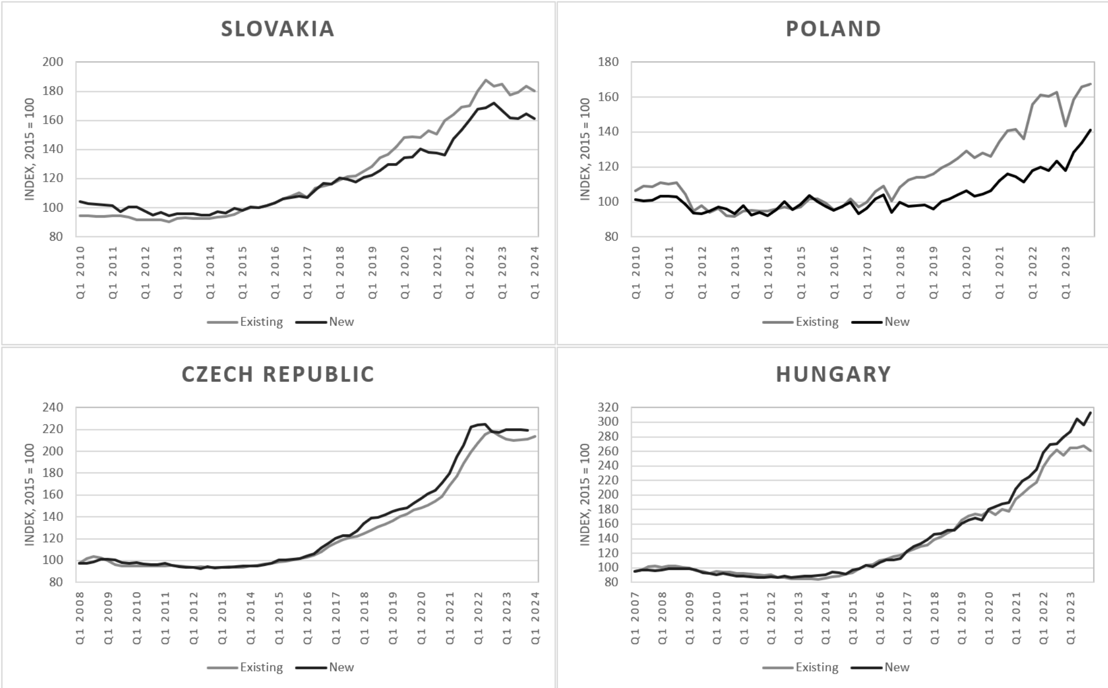

Figure 5.2: Whole country RPPI - Existing vs. New dwellings

Source: National Statistical Offices, Central Banks
Note: Data collected from BIS Detailed dataset database to ensure comparability of information on dataset dimensions

Reflecting the discussion on the specifics and limitations of real estate data, several considerations related to data collection have to be taken into account. Firstly, given the heterogeneity of real estate markets, it is essential to make quality adjustments to isolate price changes from variations in property characteristics over time. Generally, three main approaches can be used for quality adjustments and related prevention of long-term bias in the series. The simplest method, applied when detailed property characteristics beyond size are unavailable, relies on calculation of the average property price within a specific area. More sophisticated techniques, such as hedonic regression or stratification, consider a wider range of property attributes and are preferred when standardization of housing unit over time or control for cross-sectional differences in quality is needed (Ahnert & Page, 2005; Scatigna *et al.*, 2014). Secondly, to ensure sufficient length of data series in terms of number of observations, the analysis will be conducted purely on quarterly data. Thirdly, to utilize data representing the closest approximation of true market value of properties, transaction price based series will be preferred over supply price data that are generally of lower quality as they are biased by agent's provisions or unrealistic expectations of the sellers. We will also exclude analysis of rental price development in relation to inflation due to unavailability of reliable and comparable data source and the fact that rental prices are already incorporated in property prices as the discounted present value of the expected future cash flow stream (Hilbers, 2005). Finally, to eliminate potential data distortions connected to undetected changes in data collection methodology or compilation method, the author chooses to utilize only publicly available data published by reputable institutions such as national banks or national statistical offices that provide extensive methodology related to data collection and compilation.

To account for differences in dynamics of price development supported by figures and discussion in this section, the author will, apart from cross-country inflation-hedging properties of real estate, attempt to collect data series that will enable investigation of inflation-hedging characteristics on a national level and between different property types. To accomplish this, the analysis should involve a comparative examination of data for capital cities against their respective national averages, as well as a comparison between existing and new dwellings on a national level.

5.2 Real estate public data overview

Although the real estate market acts as a fundamental contributor to financial stability, systematic monitoring of this sector in Europe commenced relatively recently. The foundational efforts for the unified collection and compilation of real estate data traced back to a conference organized by the IMF and BIS in 2003. After the conference, the scope of Compilation Guide of Financial Soundness Indicators, a comprehensive manual that offers methodological guidance on the concepts, definitions and compilation methods for Financial Soundness Indicators, was extended for a topic of residential property price indices.

In response to the Global Financial Crisis, there was a significant increase in the demand for reliable and comparable real estate market statistics. Consequently, in

July 2010, the BIS was mandated to collect and publish residential property prices for the G20 countries (Scatigna *et al.*, 2014). Additionally, Eurostat issued the Handbook on Residential Property Prices Indices (HRPP) in 2013. The HRPP is a live document offering best practice recommendations for real estate data compilation with an emphasis on different requirements based on the purpose of further data utilization. These recommendations were formulated in cooperation with various international organizations, including BIS. Since initiating efforts to establish a reliable global real estate database in 1980, the BIS has collected and regularly reported data series for 61 countries. These series are collected from central banks that report to BIS all public and private residential property series available in their country. The data are by BIS controlled for quality, compiled following the HRPP recommendations and in most cases published with extensive descriptive information about the sources, geographical coverage and compilation methods. Consequently, BIS database can be perceived as the most comprehensive source of publicly available, reliable and comparable real estate data. The data are released in three distinct dataset types, each tailored for different uses. While the "Detailed" dataset includes almost all the original series collected for each country, the "Selected" series dataset consists of a single representative price series per country that is the most suitable for cross-country comparison. The "Long" series dataset aggregates the most extensive data series available that fulfill the minimum standards for cross-country comparison. The detailed overview of all data series covering V4 countries with quarterly frequency published by BIS, segmented by covered area, are available in Appendix 3.

In addition to the data series shared with BIS by central banks, there are several other real estate data publications that merit attention. In the Czech Republic, the Czech Statistical Office (CZSO) collects transaction prices of real estate from tax return data provided by the Ministry of Finance. This data series originates from Act No. 151/1997 Coll. on Asset Evaluation, which mandates tax authorities to relay data from tax declarations concerning real estate valuations and agreed sale prices to the Ministry of Finance and the CZSO (Hrachovec, 2012). These data have been compiled and published in "Prices of Observed Types of Real Estate" since 2002, with historical data dating back to 1995. The publication covers a wide range of property types, including flats, houses, and land in a regional breakdown.

However, due to changes in tax legislation in 2020, real estate transfer prices are no longer available from tax returns forcing CZSO to replace the data source by the data from the Czech Office for Surveying, Mapping and Cadastre (ČÚZK). Unfortunately, both data sources are not fully comparable leading to a distortion in data series consistency. Additionally, the CZSO publishes "Indices on realized prices of flats" with sub-national breakdowns for Prague, the entire country, and the country excluding Prague. These indices are constructed from transaction prices provided by real estate agencies that are prior to the index calculation adjusted for quality. While Prague data series for both new and second-hand flats are available since Q1 2008, nationwide data are published only for second-hand flats and with a 1.5 year delay in starting date.

In Hungary, the national bank (MNB) publishes House Price Index, sometimes also labelled as Other House Price Index. The index offers an overview with a geographical breakdown to cities in seven regions, aggregating all municipalities together, but without differentiation by property type or vintage. The index with a base in Q1 2001 is compiled from data on stamp duty receipts collected by the National Tax and Customs Administration (NTCA). It is controlled for quality adjustments in real estate using hedonic regression and is available in quarterly series for the whole country and the capital city since 1990 and 2001, respectively. However, the MNB advises utilization of the index data from 2008 onwards, due to significant changes in data structure following the unification of data collection and storage, as well as the inclusion of data from Budapest into the whole country series.

The National Bank of Slovakia (NBS) provides an extension of privately sourced real estate data published by BIS. The data collected from NARKS database are categorized by NBS based on property vintage into houses and flats, with detailed sub-categories of flats based on the number of rooms. The series offers regional breakdown of supply prices per square meter denominated in Euros for existing properties, collected from advertisement records and managed by the National Association of Real Estate Agencies. The dataset is available from 2002, with quarterly data accessible from 2005. Although the dataset does not fully satisfy some of the ECB's requirements for real estate data samples, it remains one of the few public sources that provides data at the regional level (Mikuláš, 2010).

The Polish National Statistical Office (GUS) provides data based solely on transaction prices per square meter of residential premises in multi-dwelling buildings. With no regional breakdown, data are split according to property vintage. The data are collected from Register of Real Estate Prices (RCiWN) and are available since Q1 2010 in national currency and price indices that are compiled using stratification method. Additionally, quite extensive BaRN database with a starting date in Q3 2006 is created by National Bank of Poland (NBP) from data shared by real estate agents and developers. The database covers price development of all housing stock on primary and secondary market separately for 16 biggest cities of Poland's voivodeships and Gdynia. The aggregated averages for big cities (7) and big and medium cities (10) are part of the BIS database. It covers both offer and transaction prices per square meter that are further converted to indices. While offer data are published by BIS, transaction data, corrected for quality changes by hedonic regression, are available only at the bank'websites.

5.3 Selected data description

5.3.1 Real estate data

For the analysis of cross-country inflation-hedging real estate properties, two types of datasets will be used. Firstly, nominal indices with a base year of 2010 from the BIS Selected series will be utilized. These indices provide the most homogeneous data series available, adhering to the BIS selection procedure based on criteria outlined in the Handbook on Residential Property Prices (HRPP) and metadata provided by central banks. These series cover all types of dwellings nationwide and aggregate both primary and secondary markets. The longest available time span considering potential methodological changes described in the previous paragraph will be selected for each country.

To account for the diverse dynamics of price development for each property vintage across countries, nationwide data series segmented into new and existing dwellings will be used. These data are predominantly sourced from the detailed

BIS dataset[2]. An index with a base year of 2015, seasonally non-adjusted and calculated from all home sales by private individuals, is selected. The index is calculated according to standardized Eurostat data transmission protocols, compiled in line with HRPPI recommendations and quality-adjusted using either regression (Hungary) or stratification (Czech Republic, Poland, Slovakia) methods. The availability of data ranges from the first quarter of 2007 in Hungary to the first quarter of 2010 in Poland and Slovakia.

The selection of data at the national level is more demanding, as the comparison of nationwide data with that of capital cities necessitates the availability of regional statistics. This requirement significantly limits the number of sources available for selection, as evidenced by the limited number of datasets related to capital cities published by BIS. Consequently, the data segmentation and granularity will vary from country to country to ensure the most homogeneous datasets within each country. For Hungary, Other House Price Index constructed by MNB will be selected to inspect potential distortions between capital city and whole country on data of all property types and all vintages together. Keeping in mind MNB's recommendation from Section 5.2, Q1 2008 will be set as a starting date. In case of the Czech Republic, Indices on realized prices of existing flats published by CZSO will be utilized as no other data series of required geographical coverage has consistent data collection and a starting date no later than in 2010. In Poland, differences in inflation-hedging characteristics of real estate between Warsaw and whole country will be due to the issue of comparable data availability analyzed on existing dwellings only. Whole country transaction prices from OECD will be compared against capital's transaction data from BaRN database. Finally, Slovakian market and potential distinctions of Bratislava from the country's average will be analyzed purely on the supply data from NARKS database.

To facilitate easier comparison of all real estate data series with each other and with country-specific inflation data, the data were converted to indices and adjusted to a base year of 2015.

[2]for Poland, the same data series was collected from OECD as BIS publishes only nationwide index without differentiation for existing and new dwellings

5.3.2 Inflation data

Inflation will be measured by Harmonized Consumer Price Index (HICP), regularly published by the Eurostat since January 1996. It fully satisfies criteria of cross-country comparability as it is calculated by the national statistical officess according to the same methodology and revised by Eurostat before publication. The methodological framework for its compilation was adopted in 1995 as a basis for consumer price indices compilation in the EU and further developed by currently valid Framework Regulation (EU) 2016/792. The framework addresses issues of common reference period, coverage and classification of consumer goods and services, as well as requirements on data quality and compilation. The HICP is a Laspeyres-type price index that is designed to measure a pure price change for goods and services over time. The quarterly data were derived by recalculating the monthly indices.

The Table 5.1 provides an overview of the correlation between the Harmonized Index of Consumer Prices (HICP) and the real estate data series selected for the analysis. In all cases, the coefficients exceed 0.833, indicating a very strong relationship between real estate market prices and inflation trends. The strongest correlation is observed in the Czech Republic, where differences in covered areas and real estate vintages are minimal, similar to the situation in Slovakia. Conversely, the most distinct correlations are in Poland, where the prices of existing dwellings follow the inflation trend more closely on a national average compared to Warsaw. Additionally, for new dwellings, the correlation with the inflation trend is on a national level stronger compared to existing dwellings.

	Country	Data type	Harmonized Consumer Price Index (HICP)			
			CZE	HUN	POL	SVK
Real estate indices	CZK	W, All, E	0.933			
		W, All, N	0.930			
		W, All, All	0.931			
		C, Flats, E	0.914			
		W, Flats, E	0.927			
	HUN	W, All, E		0.902		
		W, All, N		0.922		
		W, All, All		0.887		
		C, All, All		0.862		
		W, All, All		0.877		
	POL	W, All, E			0.909	
		W, All, N			0.944	
		W, All, All			0.871	
		C, All, E			0.833	
	SVK	W, All, E				0.900
		W, All, N				0.897
		W, All, All				0.887
		W, All, All				0.896
		C, All, All				0.898

Table 5.1: Correlation matrix of HICP and selected real estate data series
Note: Data type contains information on covered area (W = Whole country, C = Capital city), real estate type (All = All Dwellings, Flats, Houses) and real estate vintage (E = Existing, N = New)

Chapter 6

Methodology

In this section, we develop the methodology for analyzing the inflation-hedging properties of real estate. We discuss the three most commonly used econometric frameworks in inflation-hedging research, detailing their characteristics, requirements for input data structure, and the methods for testing them. Additionally, the model specifications chosen for the analysis are described within each framework.

6.1 Fama and Schwert framework

The framework established by Fama & Schwert (1977) can be perceived as the pioneering approach for testing the inflation-hedging properties of various assets, including real estate, and serves as a baseline for subsequent research in this area. This framework is built upon the Fisher hypothesis suggesting that asset returns must at least compensate investors for inflation to maintain the purchasing power of their investments. This implies that the real interest rate equals the nominal interest rate less the anticipated rate of inflation. Mathematically, the Fisher hypothesis can be described as:

$$1 + R = (1 + r)(1 + \pi)$$

where R is the nominal interest rate, r is the real interest rate, and π is the anticipated rate of inflation.

Although the Fisher hypothesis provides a theoretical foundation for a positive relationship between interest rates and inflation, empirical studies have often failed to confirm it in its strictest form. Various studies have attempted to reconcile these deviations, including Fama & Schwert (1977), who proposed a generalization of the Fisher hypothesis framework for evaluation of the inflation-hedging properties of a particular asset, as follows:

$$r_t = \alpha + \beta\pi_t + \epsilon_i; \quad \epsilon_t \sim N(0, \sigma_\epsilon^2) \tag{6.1}$$

Equation 6.1 will serve as our baseline model for Fama and Schwert framework, with r_t being represented by a simple return from real estate index and π by the inflation rate. The coefficient β serves as an indicator of inflation-hedge ability of real estate. An asset is considered to be a perfect hedge against inflation if $\beta = 1$ and a partial hedge if it satisfies the condition $0 < \beta < 1$. Conversely, real estate has no inflation-hedging abilities if $\beta \leq 0$. In such a case, it is referred to as a perverse hedge.

Before the estimation of a baseline model, we check for potential presence of a unit-root in the data. For the verification of stationarity, Dickey & Fuller (1979) is utilized and further validated by Phillips & Perron (1988) and Zivot & Andrews (2002) tests. While the second is robust to serial correlation and heteroskedasticity in errors, the third controls for potential endogenous structural breaks that frequently occur in real estate prices and inflation and may reduce the power of the ADF test (Christou *et al.*, 2018). As the unit root tests uniformly indicated that time series are integrated of order one, several techniques generally utilized for unit-root elimination such as transformation or trend removal were considered. We also consider calculation of log-returns to improve distribution of the data, but neither of these techniques provided satisfactory results. Consequently, we relied on simple return's first-differencing. After confirming the stationarity of the first-differenced data, the potential presence of heteroskedasticity is examined by Engle's ARCH test[1]. As the null hypothesis of no ARCH effect was rejected on 5% significance level in five cases, we recalculated the results of all models with heteroskedasticity-robust standard errors.

[1] results of the tests are available in Appendix 4

After testing for the main statistical properties of the data and estimation of a baseline model, we proceed to the formulation of additional Fama & Schwert (1977) model specifications, motivated by both prior research and the nature of the data under analysis discussed in Chapter 5. Following the suggestion of Yeap & Lean (2017), we first incorporate the possibility of an asymmetric response of real estate returns to inflation changes by decomposing the inflation rate into positive (π_t^+) and negative (π_t^-) components, such that:

$$\pi_t^+ = \sum_{j=1}^{t} \Delta\pi_j^+ = \sum_{j=1}^{t} \max(\Delta\pi_j, 0)$$
$$\pi_t^- = \sum_{j=1}^{t} \Delta\pi_j^- = \sum_{j=1}^{t} \min(\Delta\pi_j, 0)$$

The extended model controlling for an asymmetric response is than defined as:

$$r_t = \alpha + \beta^+\pi_t^+ + \beta^-\pi_t^- + \epsilon_i; \quad \epsilon_t \sim N(0, \sigma_\epsilon^2) \tag{6.2}$$

where β^+ represents effects to positive changes in inflation rate and β^- represents negative changes. Both coefficients are expected to be positive for real estate to be classified as an inflation hedge.

Finally, considering the unprecedented fluctuations in real estate prices and inflation during the GFC and the COVID-19 pandemic, detailed in Section 3, the baseline model defined in Equation 6.1 is tested for structural breaks using the multiple break-point test by Bai & Perron (1998). If structural breaks are identified, the third model specification, which includes dummy variable to the model to represent the structural shift, is analyzed[2]. The model is defined as follows:

$$r_t = \alpha + \beta\pi_t + \sum_{i=1}^{k} \varphi_i D_{i,t} + \epsilon_t \tag{6.3}$$

For the clarity of result's synthesis, extended models described in Equations 6.2 and 6.3 are constructed for each country using the most comparable whole-country data series from "Selected" dataset only. Furthermore, we do not decompose inflation into expected and unexpected components as proposed by research papers

[2] number of dummy variables depends on number of breaks identified by the test

described in Section 4. Firstly, the utilization of T-bill rates or ARMA forecasts as commonly used proxies for expected inflation might not be sufficiently precise, especially with the reference to inflationary pressures present in the V4 countries in recent years. Secondly, investors are primarily interested in actual inflation, as their main goal is to achieve ex-post real returns (Arnason & Persson, 2012).

6.2 ARDL framework

As argued by Arnason & Persson (2012), a limitation of static regressions, such as the Fama & Schwert (1977) model, is their inability to capture the delayed adjustments of real estate returns to changes in inflation. Furthermore, static regressions can only capture long-term relationships while overlooking both ongoing deviations from equilibrium and the dynamics of the adjustment process. These limitations can be addressed by the Autoregressive Distributed Lag (ARDL) model, an approach for examination of cointegration relationships. The ARDL framework incorporates lagged values of both the dependent and independent variables into the equation which enables to capture both short-term and long-term dynamics in the relationship between real estate returns and inflation rate, effectively addressing the issue of delayed adjustments in real estate returns to changes in inflation. In contrast to conventional cointegration approaches such as Engle and Granger (1987) or Johansen (1995), ARDL is less strict on the data structure. It provides robust results even when the orders of integration of relevant variables are missspecified, which might be our case as quite small sample size utilized for the empirical part of the thesis may significantly reduce the power of most of the unit root tests (Perron & Ng, 1996).

To estimate the long-term equilibrium relationship, we proceed to so called post-regression derivation of long-run dynamics. Even though stationarity might be under ARDL approach more relaxed, we refer to results of already conducted unit root tests to ensure that data series are not integrated of order two or higher, which is the restriction for ARDL. The estimated model for long-run relationship is defined as:

$$r_t = \alpha + \sum_{i=1}^{p} \beta_i r_{t-i} + \sum_{j=0}^{q} \gamma_j \pi_{t-j} + \epsilon_t \tag{6.4}$$

A parameter α is the intercept and r_t is a dependent variable regressed simultaneously on its own lags and current and lagged values of independent variable π. ϵ_t is the error term and p and q represent number of lags of dependent and independent variable introduced into the equation, respectively.

The optimum number of lags for both variables is selected based on Akaike (AIC) Information Criterion, with an upper bound being set to four as the analysis is conducted on quarterly data. Adequate selection of lag length is further verified by Breusch-Godfrey test and Breusch-Pagan test that inspect potential presence of serrial correlation and heteroskedasticity in residuals. In case the null hypothesis of no serial correlation was rejected, we corrected the model by inclusion of additional lags in both dependent and independent variables.

Once the final specification of the model with optimal lag structure is estimated, the long-run effect is with the reference to Blackburne & Frank (2007) retrieved from the model using following formula:

$$LR = \frac{\sum_{j=0}^{q} \gamma_j}{1 - \sum_{i=1}^{p} \beta_i} \tag{6.5}$$

To evaluate the short-run inflation-hedging ability of real estate, we employ the error-correction model (ECM) form of the ARDL. The ECM specification allows us to examine how deviations from long-term equilibrium, calculated in 6.5, adjust in the short term. Specifically, it enables us to determine the number of observation periods required for the long-run equilibrium relationship to be restored when real estate return and inflation rate diverge in a response to an unexpected market event.

Before estimating the ECM, it is essential to test for the presence of cointegration, as a cointegrating relationship between the dependent and independent variables is crucial for construction of ECM model. Cointegration is based on the premise that certain variables may be associated in the long run, despite potential short-run divergences. If variables are cointegrated, they tend to "move together" and converge towards equilibrium in the long run due to the similarity in their stochastic trends (Ametefe, 2018).

The cointegration relationship between real estate returns and the inflation rate is assessed using the Bounds test developed by Pesaran *et al.* (2001). This test is based on a standard F-test, wherein the computed test statistic is compared against two sets of critical values. The lower bound is relevant when the variables are stationary, i.e., purely I(0), while the upper bound applies when the variables are integrated of order one, I(1). The null hypothesis of no cointegration is rejected if the F-statistic exceeds the upper bound and is not rejected if it falls below the lower bound. However, if the F-statistic lies between the upper and lower bounds, the results are deemed inconclusive. In all model specifications across countries and property types, p-value was notably below 1% threshold enabling us to reject no cointegration between variables with a strong level of confidence.

After cointegration is confirmed, we proceed to test for the short-run dynamics of the relationship between real estate returns and inflation rate. As investment into real estate usually has a longer horizon, partly due to high transaction costs and limited liquidity, we are not predominantly interested in a short-run relationship but rather concentrate our focus on its dynamics. The speed of adjustmet towards long-run equilibrium is captured by the error-correction term (ECT) that can be derived from the Equation 6.4 by saving its residuals, such that:

$$\mathrm{ECT}_t = Y_t - \beta_0 - \beta_1 X_t \tag{6.6}$$

The ECT is further incorporated into short-run dynamic model, which is a differenced form of ARDL model:

$$\Delta r_t = \alpha + \theta \mathrm{ECT}_{t-1} + \sum_{i=1}^{p} \beta_i \Delta r_{t-i} + \sum_{j=1}^{q} \gamma_j \Delta \pi_{t-j} + \epsilon_t \tag{6.7}$$

In this model specification, we are mainly interested in parameter θ, the coefficient of speed of adjustment. Its value is expected to range between -1 and 0 driven by the intuition that the closer the value is to -1, the faster the adjustment towards equilibrium is. If the parameter values exceed this threshold, we may conclude that the relationship between real estate returns and inflation exhibits oscillatory behavior rather than following a steady adjustment process

Chapter 7

Results

7.1 Fama and Schwert framework

From the general perspective, Fama and Schwert framework provided notably weak results related to inflation hedging properties of real estate both on national and cross-country level. All model specifications reported considerably low R-squared that in most of the cases were not able to overcome 0.1 threshold. This can be interpreted in two dimensions. Firstly, Fama and Schwert OLS framework might not fit current nature of real estate market and price levels development within V4 countries as determination of simple linear trend might not fit to the dynamic environment of economic development in the CEE region in last two decades. Secondly, low statistical power of the models might be attributed to the time span under analysis. As most of the series started at the beginning of the GFC and ended in the last quarter of 2023, there is a sharp decline around the starting period in real estate prices followed by a gradual increase after 2012 that peaks around 2021[1]. Such U shape path of the real estate development does not correspond with a gradual evolution of price levels across countries until 2021. Moreover, recent years of COVID-19 pandemic and energetic crises, that bring with double-digit inflation levels and a stagnation of real estate prices, might serve as another hint why the results are not sufficiently satisfactory. These remarks can be supported be regression results of baseline models with structural breaks and on a subset

[1] for details see Figures 3.2, 3.3 and B.1

with a cutting date in Q4 2021.While the first model provides multiply higher R-squared and strongly significant coefficients for structural breaks, the model on a data sample generates notably higher β coefficients that indicate at least partial hedge.

From more quantitative perspective, only 8 inflation βs were identified statistically significant with 10 out 36 estimated parameters being reported with a counterintuitive negative coefficient. Overall, existing properties seem to provide a better hedge against inflation than new properties as their coefficients are more towards inflation-hedge in all model specifications. Interesting finding can be also retrieved from the data sets used. While data sets selected for national comparisons provide mixed results, the BIS Selected data used for a different model specifications and cross-country comparison seem to be consistent both in sign and magnitude.

Table 7.1: Czech Republic - Fama & Schwert different model specifications

	Real estate returns				
	Baseline	**with SB**	**with Asymmetry**		**Subset**
			positive	negative	
HICP rate	0.103	0.125	0.103	0.102	0.201
	(0.104)	(0.082)	(0.102)	(0.232)	(0.188)
Constant	-0.001	-0.0006	-0.001		0.0003
	(0.001)	(0.001)	(0.002)		(0.001)
Observations	62	62	62		54
R2	0.025	0.028	0.025		0.030
Adjusted R2	0.009	0.009	-0.008		0.011
Residual SE	0.011	0.011	0.011		0.010
F Statistic	1.560	1.560	0.767		1.593

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Additional notes: Baseline model is defined by Equation 6.1, model with SB (structural breaks) is defined by Equation 6.2, model with asymmetry is defined by Equation 6.3, model Subset is a model on a time span ending in Q4 2021

Moving on specifically to the results for the Czech Republic, we can observe quite clear consistency across all model specifications on national level - excluding the model regressed on a subset data, all coefficients reach values around 0.1, indicating almost no hedge. The Table E.1 available in the Appendix indicates statistically significant coefficients for new dwellings on a Country level and existing flats on a Capital level. While the first is associated with positive sign indicating partial hedge, the other has a negative sign of -0.296. This might be explained generally higher price base in the capital city that becomes, in case of general increase in price level, not financially attainable for the households resulting in a decreased demand for housing and corresponding slowdown or decrease of a price trend.

Table 7.2: Hungary - Fama & Schwert different model specifications

	Real estate returns				
	Baseline	**with SB**	**with Asymmetry**		**Subset**
			positive	negative	
HICP rate	0.382	0.441	0.306	0.452	0.460
	(0.317)	(0.447)	(0.706)	(0.461)	(0.361)
Constant	-0.001	0.363	0.0002		-0.0002
	(0.003)	(0.436)	(0.005)		(0.003)
Observations	90	91	90		82
R2	0.022	0.268	0.022		0.029
Adjusted R2	0.011	0.252	-0.0003		0.017
Residual SE	0.032	3.706	0.032		0.031
F Statistic	1.969	16.135***	0.985		2.401

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Additional notes: Baseline model is defined by Equation 6.1, model with SB (structural breaks) is defined by Equation 6.2, model with asymmetry is defined by Equation 6.3, model Subset is a model on a time span ending in Q4 2021

In Hungary, the results obtained be different model specifications provide overall the best inflation-hedging characteristics across all countries as βs exceed the magnitude of 0.3 in all cases indicating a partial hedging ability. This seems to be strongly driven by existing properties with a statistically significant coefficient of 0.679[2]. Interestingly, Hungary reports 1.5 times stronger relationship to negative changes in inflation than to positive ones.

Poland seems to be a very specific case as the results indicate a reverse hedge in almost all cases, no matter of the model specification, geographic area or property

[2]see E.2 in the Appendix

Table 7.3: Poland - Fama & Schwert different model specifications

	Real estate returns				
	Baseline	**with SB**	**with Asymmetry**		**Subset**
			positive	negative	
HICP rate	0.139	-0.183	-0.144	-0.135	0.089
	(0.340)	(0.223)	(0.619)	(0.517)	(0.478)
Constant	0.001	5.024***	0.001		0.001
	(0.004)	(1.876	(0.005)		(0.004)
Observations	74	75	74		66
R2	0.002	0.344	0.002		0.0005
Adjusted R2	-0.012	0.317	-0.026		-0.015
Residual SE	0.030	3.031	0.031		0.032
F Statistic	0.123	12.436***	0.061		0.032

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Additional notes: Baseline model is defined by Equation 6.1, model with SB (structural breaks) is defined by Equation 6.2, model with asymmetry is defined by Equation 6.3, model Subset is a model on a time span ending in Q4 2021

type. Out of these findings stems a positive and statistically significant coefficient of 0.586 for existing dwellings on a national data. This positive coefficient is followed by a positive zero for existing dwellings in Warsaw, compared to two negative coefficients of new dwellings. The author argues that these differences between negative and positive coefficients might be a result of slower slower (lagged) price adjustments of new dwellings as the elasticity of real estate supply side is very limited due to long interval between commencement of construction and supply of the new dwellings for sale.

The Slovakian real estate market exhibits the second best inflation hedging characteristics after Hungary as 7/8 coefficients are positive and in 3 cases close to 0.5, indicating partial hedging features. The asymmetric model reported quite interesting results as negative coefficient for positive shocks is accompanied be 1.451 statistically significant and positive coefficient. This will indicate that while real estate prices cannot keep up with positive inflation trends, they surpass the negative trends in terms of a magnitude.

Table 7.4: Slovakia - Fama & Schwert different model specifications

	Real estate returns				
	Baseline	**with SB**	**with Asymmetry**		**Subset**
			positive	negative	
HICP rate	0.277	0.268	-0.767	1.451*	0.429
	(0.344)	(0.360)	(0.402)	(0.755)	(0.361)
Constant	-0.0003**	4.142***	0.0007**		-0.0001*
	(0.004)	(1.273)	(0.005)		(0.004)
Observations	70	71	70		62
R2	0.007	0.291	0.058		0.010
Adjusted R2	-0.008	0.259	0.030		-0.006
Residual SE	0.030	2.937	0.029		0.030
F Statistic	0.453	9.149***	2.051		0.617

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Additional notes: Baseline model is defined by Equation 6.1, model with SB (structural breaks) is defined by Equation 6.2, model with asymmetry is defined by Equation 6.3, model Subset is a model on a time span ending in Q4 2021

7.2 ARDL framework

The results of the ARDL model for long-run effects presented together with the dynamics of adjustment towards equilibrium, presented in 7.5, provide quite unexpected results. Even though speed of adjustment towards equilibrium expressed as coefficients for the ECT variable are strongly statistically significance, their magnitude is exceeding the border -1 and 0 expected by the theory. The estimated values higher than -1 may lead us to the conclusion that the relationship between real estate returns and inflation rates rather diverge than converge to equilibrium. On the other hand, this might be to some extent attributed to potentially specific nature of the data and time span used, as discussed in the presentation of results for Fama and Schwert model. Idea of potential specificity of the data arises from Loayza & Ranciere (2006) who argued that for some relationships between two variables, ECT term lying in the interval (-2,1) are sufficient for oscillatory convergence. With respect to these findings, several adjustments related to lag structure or input data were tested, none of which provides any significant changes in the results. Consequently, to retrieve further insights, we argue that it will be necessary to test the relationship on a larger dataset, which is, unfortunately, not possible due to limited data availability. Moving on from the ECT term to long-run equilibrium, the magnitude of the positive coefficients seem to be generally slightly higher compared to the results of the Fama and Schwert framework which may indicate that ARDL model was successful to identify stronger relationship between the variables that is in favor of better real estate inflation-hedging features. However, as in the case of OLS models, 6 coefficients are estimated with negative sign, indicating a reverse hedge. The existing dwellings seem to outperform inflation-hedging properties of the new dwellings, supporting the finding listed in the previous section. Slovakian real estate market seem to capture the inflation risk the best as its coefficients have all positive signs. Finally, ARDL model indicated existing dwellings on a national average in Hungary to be the only specification that can be, due to its proximity to 1, labelled as a perfect hedge.

Table 7.5: Country comparison - ARDL regression results

		Real estate returns			
		CZE	**HUN**	**POL**	**SVK**
Capital Exist. flats	LR	-0.294			
		(0.001)			
	ECT	-1.253***			
		(0.180)			
Country Exist. flats	LR	0.464			
		(0.865)			
	ECT	-1.146***			
		(0.199)			
Capital Existing	LR			-0.084	
				(0.675)	
	ECT			-1.111***	
				(0.190)	
Capital New	LR			-0.346	
				(0.621)	
	ECT			-1.078***	
				(0.163)	
Capital All	LR		0.081		0.411
			(0.274)		(0.245)
	ECT		-1.156***		-0.954***
			(0.140)		(1.539)
Country All	LR		-0.463		0.381
			(0.232)		(0.248)
	ECT		-0.984***		-0.933***
			(0.159)		(0.155)
Country Existing	LR	0.766	0.917	-0.222	0.067
		(0.563)	(0.090)	(0.342)	(0.230)
	ECT	-1.333***	-1.022***	-1.054***	-1.366***
		(1.936)	(0.214)	(0.216)	(0.159)
Country New	LR	0.616	0.166	-0.133	0.684
		(0.114)	(0.146)	(0.189)	(0.378)
	ECT	-1.020***	-1.052***	-1.126***	-1.173***
		(0.162)	(0.158)	(0.181)	(0.161)
Country all (BIS)	LR	0.207	0.119	0.128	0.180
		(0.601)	(0.076)	(0.409)	(0.268)
	ECT	-1.326***	-1.237***	-1.146***	-1.154***
		(1.887)	(0.166)	(0.166)	(0.149)

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Chapter 8

Discussion

To sum up, the analysis provides us with following findings. Firstly, we cannot state a clear and unified conclusion related to inflation-hedging characteristics of real estate within and across countries. Even though Hungarian real estate market seem to provide the best inflation-hedging characteristics closely followed by Slovakian market, the magnitude and statistical significance of the results are not strong enough and need to be taken with a caution. In the same manner we can conclude that existing properties provide better hedge against inflation, without being able to to come up with a similarly differentiating conclusion related to country versus capital case. Secondly, the issue of data comparability seem to be of a considerable importance as different data sources provide highly distinct results. Here we succeeded to answer the question which dataset is the most consistent across publicly available data sources. For subsequent research, the author recommend to use BIS Selected dataset that consists of country-level indices and that was the only one under analysis that provide consistently positive estimation results across all model specifications. Using data sources provided by national statistical offices or banks seem to be appropriate for a within-country analysis at most. A time span or data frequency might be other open points for further consideration.

As the author of the thesis is fully aware of some limitations of the presented analysis, several concluding remarks that may improve the empirical results will be provided. Fist, selection of different data transformation might be considered to deal with a presence of unit-root. When working with indices, calculation of log-returns might be more appropriate than utilization of simple returns, even though it was not suitable in our case as we were not able to fully remove non-stationarity from the logarithmic representation of returns. Secondly, inclusion of additional variables into the regressions might be a solution of low R-squared of presented models and may lead to an increase of statistical power. However, as the goal of the thesis was to examine pure relationship between real estate and inflation, we decided not to included into the thesis scope. Thirdly, a detailed inspection of potential reverse causality within V4 might provide additional insight into the relationship between real estate and inflation. Here it is necessary to state that Granger causality test for potential reverse relationship was executed as a response to quite non-standard ARDL regression results. However, the Granger causality test provided us with inconclusive results so that we decided not to include it into the presentation of our findings and let this question open for further researchers. Fourthly, the author is fully aware of the fact that only one stream of possible cash-flow from investment into real estate was tested, while all costs connected to holding the asset were omitted. Incorporation of rental income on one side and transaction costs, maintenance costs and tax liabilities might provide more precise overview on real estate returns. However, for such analysis, a significantly narrower scope would have to be selected as these variables will add additional disparities into the data. Finally, even though all statistical tests and calculations were executed to the author's best knowledge in accordance with correct methodology, the ARDL model and its ECM form seem to be misspecified. Even though wide range of lag selection criteria, datasets etc. were tested in order to improve the model performance and obtain results that are more in light with the theory, the effort was not successful.

Bibliography

Ahnert, H. & A. Page (2005): "Euro area residential property prices: the aggregation of non-harmonised national data." **21**: pp. 288–307.

Al-Nassar, N. S. & R. H. Bhatti (2019): "Are common stocks a hedge against inflation in emerging markets?" *Journal of Economics and Finance* **43(3)**: pp. 421–455.

Ametefe, F. K. (2018): "Portfolio structure, real estate investment and the performance of defined contribution pension funds."

Anari, A. & J. Kolari (2002): "House prices and inflation." *Real Estate Economics* **30(1)**: pp. 67–84.

Antolin, P., S. Payet, & J. Yermo (2012): "Coverage of private pension systems: evidence and policy options." .

Arnason, O. & K. Persson (2012): "Swedish real estate as a hedge against inflation - with comparison to stocks, bonds and gold."

Arthur, S. (2005): "Obtaining real estate data: criteria, difficulties and limitations." .

Bai, J. & P. Perron (1998): "Estimating and testing linear models with multiple structural changes." *Econometrica* pp. 47–78.

Balló, Z. (2016): "Dwellings and housing market in hungary, 1990-2015." *Procedia engineering* **161**: pp. 2079–2087.

Bank, E. C. (2015): "Ecb announces expanded asset purchase programme." Accessed: 2024-07-07.

Barber, C., D. Robertson, & A. Scott (1997): "Property and Inflation: The Hedging Characteristics of U.K. Commercial Property, 1967-1994." *The Journal of Real Estate Finance and Economics* **15(1)**: pp. 59–76.

Barkham, R., C. Ward, & O. Henry (1996): "The inflation-hedging characteristics of uk property." *Journal of Property Finance* **7(1)**: pp. 62–76.

Becker, J. (2018): "Uneven development and a new approach to regional development in slovakia." pp. 63 – 72.

Blackburne, E. F. & M. W. Frank (2007): "Estimation of nonstationary heterogeneous panels." *The Stata Journal* **7(2)**: pp. 197–208.

Błaszczyk, M. C. *et al.* (2022): "Selected aspects of european integration of the visegrad group countries." *Comparative Economic Research. Central and Eastern Europe* **25(2)**: pp. 81–98.

Blazek, J. (1995): "Break up of czechoslovakia: roots, 1989, and consequences." *Treballs de la Societat Catalana de Geografia* pp. 143–149.

Bodie, Z. (1976): "Common stocks as a hedge against inflation." *The journal of finance* **31(2)**: pp. 459–470.

Bork, L. & S. V. Møller (2015): "Forecasting house prices in the 50 states using dynamic model averaging and dynamic model selection." *International Journal of Forecasting* **31(1)**: pp. 63–78.

Cempírek, P. (2014): "Housing prices in the czech republic and slovakia: Regional comparison." .

Christou, C., R. Gupta, W. Nyakabawo, & M. E. Wohar (2018): "Do house prices hedge inflation in the us? a quantile cointegration approach." *International Review of Economics Finance* **54**: pp. 15–26.

Chu, Y. & T. Sing (2004): "Inflation hedging characteristics of chinese real estate market." *Journal of Real Estate Portfolio Management* **10**.

Ciupek, P. & T. Cheetham (2010): "The prospects for new investment vehicles based on real estate in poland: a review of the market and demand from potential investors." *Sheffield Hallam University Built Environment Research Transactions* **2(Spec.)**: pp. 5–19.

Council, S. N. (2016): "Amendment to the act on housing development." Accessed: 2024-07-07.

Dabara, D., O. Omotehinshe, O. Adewuyi, A. Ankeli, & L. Adaranijo (2016): "Real estate investments and the inflation-hedging question: A review." *International Journal of Business and Management Studies* **05**: pp. 187–196.

Demary, M. & M. Voigtlånder (2009): "The inflation hedging properties of real estate: A comparison between direct investments and equity returns." .

Dickey, D. A. & W. A. Fuller (1979): "Distribution of the estimators for autoregressive time series with a unit root." *Journal of the American statistical association* **74(366a)**: pp. 427–431.

Dübel, H.-J. (2003): "Housing policy in central european countries in transition: Czech republic, hungary, poland, and slovakia." *Centre for Legal Competency, Vienna* .

Égert, B., R. Martin *et al.* (2008): "Real estate, construction and growth in central and eastern europe: Impact on competitiveness." *Focus on European economic integration* **2**: pp. 52–72.

Engle, R. F. & C. W. J. Granger (1987): "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* **55(2)**: pp. 251–276.

Erste Group (2014): "Czech republic economic outlook." Accessed: 2024-07-07.

European Economic Review (2021): "Real estate market dynamics in the czech republic." *European Economic Review* **135**: pp. 103–120. Accessed: 2024-07-07.

Eurostat (2020): "Household budget survey." .

Fama, E. F. (1975): "Multiperiod consumption-investment decisions." *Stochastic optimization models in finance* pp. 389–400.

Fama, E. F. & M. R. Gibbons (1982): "Inflation, real returns and capital investment." *Journal of Monetary Economics* **9(3)**: pp. 297–323.

Fama, E. F. & M. R. Gibbons (1984): "A comparison of inflation forecasts." *Journal of Monetary Economics* **13(3)**: pp. 327–348.

Fama, E. F. & G. Schwert (1977): "Asset returns and inflation." *Journal of Financial Economics* **5(2)**: pp. 115–146.

Fiorilla, P. & M. Halle (2011): "Market opportunities in global real estate securities." .

Fisher, I. (1930): "The theory of interest." *MacMillan* p. 43.

Geske, R. & R. Roll (1983): "The fiscal and monetary linkage between stock returns and inflation." *The Journal of Finance* **38(1)**: pp. 1–33.

Ghanbari-Parsa, A. R. & R. Moatazed-Keivani (1999): "Development of real estate markets in central europe: the case of prague, warsaw, and budapest." *Environment and Planning A* **31(8)**: pp. 1383–1399.

Glascock, J. L., C. Lu, & R. W. So (2002): "REIT Returns and Inflation: Perverse or Reverse Causality Effects?" *The Journal of Real Estate Finance and Economics* **24(3)**: pp. 301–317.

Granger, C. W. J. & R. Joyeux (1980): "An introduction to long-memory time series models and fractional differencing." *Journal of Time Series Analysis* **1(1)**: pp. 15–29.

Gregor, T. (2010): *The Impact of the Global Financial Crisis on the Czech Economy.* Ph.D. thesis, University of Economic Studies. Accessed: 2024-07-07.

Grimes, A., A. Aitken, & S. Kerr (2004): "House price efficiency: Expectations, sales, symmetry." *Urban/Regional 0408001*, University Library of Munich, Germany.

Harnos, L. (2018): "Cycles of the housing market in hungary from the economic crisis until today." *Naše gospodarstvo/Our economy* **64(2)**: pp. 3–14.

Hartzell, D. & J. Webb (1988): "Real estate risk and return expectations: Recent survey results." *Journal of Real Estate Research* **3(3)**: pp. 31–37.

Harvey, A. C. (1990): *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge University Press.

Hegedüs, J., V. Horváth, & N. Tosics (2014): "Economic and legal conflicts between landlords and tenants in the hungarian private rental sector." *international Journal of Housing policy* **14(2)**: pp. 141–163.

Hegedüs, J. & E. Varhegyi (2000): "The crisis in housing financing in hungary in the 1990s." *Urban Studies* **37(9)**: pp. 1619–1641.

Heldak, M. & M. Pluciennik (2019): "Financing housing support programs in poland in the light of national housing resources." In "IOP Conference Series: Materials Science and Engineering," volume 471, p. 112031. IOP Publishing.

Hendershott, P. H., B. P. Bosworth, & D. M. Jaffee (1980): "Real user costs and the demand for single-family housing." *Brookings Papers on Economic Activity* **1980(2)**: pp. 401–452.

Hilbers, P. (2005): "Methodological issues regarding residential real estate prices." .

Hlaváček, M. & L. Komárek (2009): "Housing price bubbles and their determinants in the czech republic and its regions." *CNB WP* **12**: p. 2009.

Hoesli, M., C. Lizieri, & B. MacGregor (2008): "The Inflation Hedging Characteristics of US and UK Investments: A Multi-Factor Error Correction Approach." *The Journal of Real Estate Finance and Economics* **36(2)**: pp. 183–206.

Hoesli, M., B. D. MacGregor, G. Matysiak, & N. Nanthakumaran (1997): "The Short-Term Inflation-Hedging Characteristics of U.K. Real Estate." *The Journal of Real Estate Finance and Economics* **15(1)**: pp. 27–57.

Horvatova, E. (2020): "Twenty years of mortgage banking in slovakia." *International Journal of Financial Studies* **8(3)**: p. 56.

Hrachovec, M. (2012): *The Impact of the Global Financial Crisis on the Czech Economy.* Ph.D. thesis, Charles University. Accessed: 2024-07-07.

Hromada, E. (2021): "Development of the real estate market in the czech republic in connection with the covid-19 pandemic."

Jahoda, R. & D. Špalková (2009): "Analỳza distribučních aspekt regulace/deregulace nájemného v čr." *Urbanismus a územní rozvoj* **12**.

Jedlička, J., J. Kotian, & R. Münz (2014): "Visegrad four-10 years of eu membership." *Erste Group Research CEE Special Report* **23**: pp. 1–23.

Johansen, S. & K. Juselius (1990): "Maximum likelihood estimation and inference on cointegration â€" with applications to the demand for money." *Oxford Bulletin of Economics and Statistics* **52(2)**: pp. 169–210.

Katrakilidis, C. & E. Trachanas (2012): "What drives housing price dynamics in greece: New evidence from asymmetric ardl cointegration." *Economic Modelling* **29**: pp. 1064–1069.

Kelleher, E. (2011): "How best to tackle the threat of rising costs?" *Financial Times* .

Kijek, A. (2017): "Spectral analysis of business cycles in the visegrad group countries." *Comparative Economic Research* **20**.

Koniarski, T. & S. Sebastian (2015): "Inflation-protecting asset allocation: A downside risk analysis." *The Journal of Portfolio Management* **41(2)**: pp. 57–70.

KRCMAR, M. & S. RYCHTARIK (2013): "Dynamics of housing affordability in slovakia and its regions on the background of macroeconomic development." *Biatec* **21(9)**: pp. 18–21.

KURIYAMA, N. (2015): "Testing cointegration in quantile regressions with an application to the term structure of interest rates." *Studies in Nonlinear Dynamics Econometrics* **20**.

LE MOIGNE, C. & Ă. VIVEIROS (2008): "The inflation-hedging ability of canadian direct real estate return and its components, income, and appreciation." *Journal of Real Estate Portfolio Management* **14(2)**: pp. 141–154.

LEE, C. L. & M.-L. LEE (2012): "Do European real estate stocks hedge inflation? Evidence from developed and emerging markets." *ERES* *eres2012*$_155, European Real Estate Society (ERES)$.

LIMMACK, R. & C. WARD (1988): "Property returns and inflation." *Land Development Studies* **5(1)**: pp. 47–55.

LINTNER, J. (1975): "Inflation and security returns." *The journal of finance* **30(2)**: pp. 259–280.

LIU, C. H., D. J. HARTZELL, & M. E. HOESLI (1997): "International evidence on real estate securities as an inflation hedge." *Real Estate Economics* **25(2)**: pp. 193–221.

LIU, Z. (2010): "Short-term inflation-hedging characteristics of real estate in hong kong."

LOAYZA, N. V. & R. RANCIERE (2006): "Financial development, financial fragility, and growth." *Journal of money, credit and banking* pp. 1051–1076.

LUX, M. (2001): "Social housing in the czech republic, poland and slovakia." *European Journal of Housing Policy* **1(2)**: pp. 189–209.

MARTIN, R. (1998): "Central and eastern europe and the international economy: The limits to globalisation." *Europe-Asia Studies* **50(1)**: pp. 7–26.

Matysiak, G., M. Hoesli, B. MacGregor, & N. Nanthakumaran (1996): "The long-term inflation-hedging characteristics of uk commercial property." *Journal of Property Finance* **7**: pp. 50–61.

Mikuláš, C. (2010): "Monitoring residential property prices in slovakia." .

Molendowski, E. (2015): "10 years of membership in the european union-poland in comparison with the visegrad group countries." *Central European Review of Economics & Finance* **10(4)**: pp. 5–18.

Nagy, G. (2013): "Monitoring 15 years of residential house price development in hungary with the help of the fhb house price index." In "The Narodowy Bank Polski Workshop: Recent Trends in the Real Estate Market And its Analysis," .

Newell, G. (1996): "The inflationâ€hedging characteristics of australian commercial property: 1984â€1995." *Journal of Property Finance* **7**: pp. 6–20.

O' Sullivan, E. & P. De Decker (2007): "Regulating the private rental housing market in europe." *European Journal of Homelessness* **1**.

Obereiner, D. & B.-M. Kurzrock (2012): "Inflation-hedging properties of indirect real estate investments in Germany." *Journal of Property Investment & Finance* **30(3)**: pp. 218–240.

OECD (2010): *OECD Economic Surveys: Hungary 2010*.

OECD (2022): *Economic Recovery and Inflation Trends*. Paris: OECD Publishing. Accessed: 2024-07-07.

Oner, C. (2010): "What is inflation." *Finance & Development* **47(1)**: p. 44.

Parliament, H. (2017): "Amendment to the building code." Accessed: 2024-07-07.

Paweta, B. (2018): "Impact of the global financial crisis on the business cycle in the visegrad group." *Entrepreneurial Business and Economics Review* **6**: pp. 43–58.

Perron, P. & S. Ng (1996): "Useful modifications to some unit root tests with dependent errors and their local asymptotic properties." *The Review of Economic Studies* **63(3)**: pp. 435–463.

Pesaran, M. H., Y. Shin, & R. J. Smith (2001): "Bounds testing approaches to the analysis of level relationships." *Journal of Applied Econometrics* **16(3)**: pp. 289–326.

Phillips, P. C. & P. Perron (1988): "Testing for a unit root in time series regression." *biometrika* **75(2)**: pp. 335–346.

of Poland, N. B. (2010): "Annual report 2010." Accessed: 2024-07-07.

Rentkova, K. & P. Gejdos (2019): "Housing policy in slovakia." In "IOP Conference Series: Materials Science and Engineering," volume 603, p. 042026. IOP Publishing.

Ruhmann, S. & C. Woolston (2011): "Us private core real estate investing."

Sagari, S. B., L. Chiquier, & B. Mundial (1992): *Coping with the legacies of subsidized mortgage credit in Hungary*, volume 847. Citeseer.

Salisu, A. A., I. D. Raheem, & U. B. Ndako (2020): "The inflation hedging properties of gold, stocks and real estate: A comparative analysis." *Resources Policy* **66**.

Scatigna, M., R. Szemere, & K. Tsatsaronis (2014): "Residential property price statistics across the globe." *BIS Quarterly Review* .

Shepard, P., P. Hobbs, & Y. Liu (2015): "Is real estate bond-like?" *MSCI* **7**.

Shin, Y., B. Yu, & M. Greenwood-Nimmo (2014): *Modelling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL Framework*, pp. 281–314. Springer New York.

Solnik, B. (1983): "The relation between stock prices and inflationary expectations: The international evidence." *The Journal of Finance* **38(1)**: pp. 35–48.

Somotogyi, T. (2019): "Analýza vývoje cen nemovitostí v Čr." p. 45.

Špalek, J. & D. Špalková (2015): "Impacts of rent deregulation process on household behavior: Lessons from the czech and slovak republics." *Theoretical and Practical Aspects of Public Finance 2015* p. 256.

Spirkova, D. & K. Ivanicka (2006): "15 years of real estate markets in visegrad countries and beyond." .

Steinke, C. (2011): "Analysis of different dimensions for property allocation process within real estate investment companies."

Stevenson, S. (2000): "A Long-Term Analysis of Regional Housing Markets and Inflation." *Journal of Housing Economics* **9(1-2)**: pp. 24–39.

Stevenson, S. & L. Murray (1999): "An examination of the inflation hedging ability of irish real estate." *Journal of Real Estate Portfolio Management* **5(1)**: pp. 59–69.

Stock, J. H. & M. W. Watson (1993): "A simple estimator of cointegrating vectors in higher order integrated systems." *Econometrica* **61(4)**: pp. 783–820.

Sỳkora, L. & I. Šimoníčková (1994): "From totalitarian urban managerialism to a liberalized real estate market: Pragueâ€™s transformations in the early 1990s." *Development and administration of Prague* pp. 47–72.

Tarbert, H. (1996): "Is commercial property a hedge against inflation? a cointegration approach." *Journal of Property Finance* **7(1)**: pp. 77–98.

Tenigbade, O. (2011): "An analysis of relative inflation hedging capacities of prime commercial properties in lagos." *Global Journal of Human-Social Science Research* **11**.

Toda, H. Y. & T. Yamamoto (1995): "Statistical inference in vector autoregressions with possibly integrated processes." *Journal of Econometrics* **66(1)**: pp. 225–250.

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)**: pp. 332–345.

TVRDOŇ, M., P. TULEJA, & T. VERNER (2012): "Ekonomická vỳkonnost a trh práce v kontextu ekonomické krize: zkušenosti ze zemí visegradské čtyřky." .

UN (1998): "Implementation of human settlements policies on urban renewal and housing modernization: Vienna case study." *(No Title)* .

ČESKÝ STATISTICKÝ ÚŘAD (2022): *Indexy spotřebitelských cen (metodická příručka pro uživatele) 2022*.

VADAS, G., G. KISS *et al.* (2005): "The role of the housing market in monetary transmission." *Technical report*, University Library of Munich, Germany.

ČNB (2022): "Annual financial stability report." Accessed: 2024-07-07.

WILLEM, T. (2006): "How Would an Appreciation of the Renminbi Affect the U.S. Trade Deficit with China?" *The B.E. Journal of Macroeconomics* **6(3)**: pp. 1–17.

WILSON, P. & R. ZURBRUEGG (2003): "International diversification of real estate assets: Is it worth it? evidence from the literature." *Journal of Real Estate Literature* **11(3)**: pp. 257–278.

WOOLDRIDGE, J. (2008): *Introductory Econometrics: A Modern Approach*. ISE - International Student Edition. Cengage Learning.

WU, C. Y. & V. K. PANDEY (2012): "The impact of housing on a homeowner's investment portfolio." *Financial Services Review* **21**: p. 177.

XI, D. & S. BAHMANI (2016): "Asymmetric effects of exchange rate changes on the demand for money in china." *Applied Economics Letters* **23**: pp. 1–6.

YEAP, G. P. & H. H. LEAN (2017): "Asymmetric inflation hedge properties of housing in malaysia: New evidence from nonlinear ardl approach." *Habitat International* **62**: pp. 11–21.

ZHOU, X. & S. CLEMENTS (2010): "The inflation hedging ability of real estate in china." *Journal of Real Estate Portfolio Management* **16(3)**: pp. 267–277.

Zivot, E. & D. W. K. Andrews (2002): "Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis." *Journal of business & economic statistics* **20(1)**: pp. 25–44.

Appendix A

Appendix 1

Country	**Variable**	**1989**	**1990**	**1991**	**1992**
Czechoslovakia	GDP growth	4.5%	-0.4%	-15.9%	-8.5%
	CPI	1.4%	10.8%	59.0%	11.0%
Hungary	GDP growth	0.7%	-3.5%	-11.9%	-3.1%
	CPI	16.9%	28.6%	34.8%	22.8%
Poland	GDP growth	3.8%	-7.2%	-7.0%	2.6%
	CPI	251.1%	585.8%	70.3%	43.0%

Table A.1: Annual growth of GDP and Consumer Price index
Source: IMF (1999)

Appendix B

Appendix 2

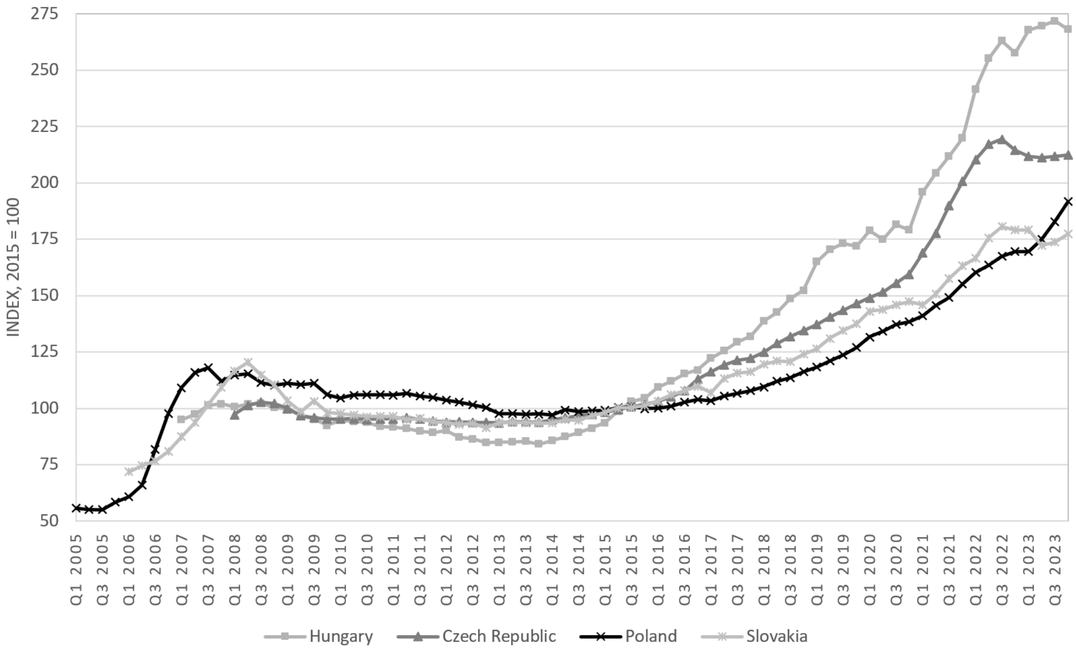

Figure B.1: House Price Index 2005 - 2023

Source: BIS - Selected data series

Appendix C

Appendix 3

Covered area	Property type	Property vintage	Unit of measurement	Starting date	Source
Country	Flats	Existing	Index, 2015=100	Q1 2015	NSO
	Houses	Existing	Index, 2015=100	Q1 2015	NSO
	Multi-dwell.	Existing	Index, 2010=100	Q1 2009	NSO
	Land	-	Index, 2010=100	Q1 2009	NSO
	All	Existing	Index, 2015=100	Q1 2008	NSO
	All	New	Index, 2015=100	Q1 2008	NSO
	All	All	Index, 2015=100	Q1 2008	NSO
	All	All	Index, 2010=100	Q1 2008	BIS
	All	All	YoY % change	Q1 2009	BIS
Capital	Flats	Existing	Index, 2015=100	Q1 2015	NSO
	Houses	Existing	Index, 2015=100	Q1 2015	NSO

Table C.1: Czech Republic - BIS RPP quarterly datasets overview

Covered area	Property type	Property vintage	Unit of measurement	Starting date	Source
Country	All	All	Index, Q1 2001=100	Q1 1990	CB
Country	All	All	Index, 2015=100	Q1 2007	NSO
Country	All	All	Forints	Q1 2007	NSO
Country	All	Existing	Index, 2015=100	Q1 2007	NSO
Country	All	New	Index, 2015=100	Q1 2007	NSO
Country	All	All	Index, 2010=100	Q1 1990	BIS
Country	All	All	YoY % change	Q1 1991	BIS
Capital	All	All	Forints	Q1 2007	NSO

Table C.2: Hungary - BIS RPP quarterly datasets overview

Covered area	Property type	Property vintage	Unit of measurement	Starting date	Source
Country	All	All	Index, 2015=100	Q1 2010	NSO
Country	All	All	Index, 2010=100	Q1 2010	BIS
Country	All	All	YoY % change	Q1 2011	BIS
Capital	All	Existing	Zloty	Q3 2006	Private
Capital	All	New	Zloty	Q3 2006	Private
Big cities	All	Existing	Zloty	Q3 2006	Private
Big cities	All	New	Zloty	Q3 2006	Private
Big cities	All	Existing	Index, Q3 2006=100	Q3 2006	CB
Big cities	All	New	Zloty	Q3 2006	CB
Big and medium cities	All	Existing	Zloty	Q3 2006	Private
Big and medium cities	All	New	Zloty	Q3 2006	Private

Table C.3: Poland - BIS RPP quarterly datasets overview

Covered area	Property type	Property vintage	Unit of measurement	Starting date	Source
Country	All	All	Index, 2002=100	Q1 2005	Private
Country	All	All	Index, 2015=100	Q1 2006	NSO
Country	All	All	Index, 2010=100	Q1 2006	BIS
Country	All	All	YoY % change	Q1 2007	BIS
Country	All	New	Index, 2015=100	Q1 2010	NSO
Country	All	Existing	Index, 2015=100	Q1 2010	NSO
Capital	All	All	Euro	Q1 2005	Private

Table C.4: Slovakia - BIS RPP quarterly datasets overview

Appendix D

Appendix 4

Table D.1: Czech Republic - results of unit-root tests

Time Series	ADF		Phillips Perron		Zivot Andrews	
	Stat	**P-value**	**Stat**	**P-value**	**Stat**	**P-value**
Country_All_Exist	-5.955	0.010	-54.704	0.010	-7.741	-4.800
Country_All_New	-5.232	0.010	-66.022	0.010	-10.344	-4.800
Country_All_All	-5.661	0.010	-53.241	0.010	-7.639	-4.800
Capital_Flats_Exist	-4.495	0.010	-53.436	0.010	-9.259	-4.800
Country_Flats_Exist	-4.110	0.010	-37.675	0.010	-6.099	-4.800
HICP	-4.413	0.010	-70.522	0.010	-13.419	-4.800

Note: printed p-values correspond to 5% significance level

Table D.2: Hungary - results of unit-root tests

Time Series	**ADF**		**Phillips Perron**		**Zivot Andrews**	
	Stat	**P-value**	**Stat**	**P-value**	**Stat**	**P-value**
Country_All_Exist	-3.732	0.028	-99.064	0.010	-17.472	-4.800
Country_All_New	-4.115	0.010	-78.481	0.010	-13.627	-4.800
Country_All_All	-4.799	0.010	-95.342	0.010	-16.639	-4.800
Capital_All_All	-4.410	0.010	-76.056	0.010	-11.936	-4.800
Country_All_All	-5.088	0.010	-76.395	0.010	-12.702	-4.800
HICP	-3.884	0.018	-57.908	0.010	-9.638	-4.800

Note: printed p-values correspond to 5% significance level

Table D.3: Poland - results of unit-root tests

Time Series	**ADF**		**Phillips Perron**		**Zivot Andrews**	
	Stat	**P-value**	**Stat**	**P-value**	**Stat**	**P-value**
Country_All_Exist	-3.776	0.026	-50.400	0.010	-8.864	-4.800
Country_All_New	-4.656	0.010	-69.794	0.010	-13.237	-4.800
Country_All_All	-9.990	0.010	-67.896	0.010	-11.564	-4.800
Capital_All_New	-4.795	0.010	-77.294	0.010	-16.118	-4.800
Capital_All_Exist	-6.094	0.010	-68.155	0.010	-14.277	-4.800
HICP	-3.524	0.044	-57.756	0.010	-10.690	-4.800

Note: printed p-values correspond to 5% significance level

Table D.4: Slovakia - results of unit-root tests

Time Series	**ADF**		**Phillips Perron**		**Zivot Andrews**	
	Stat	**P-value**	**Stat**	**P-value**	**Stat**	**P-value**
Country_All_Exist	-5.728	0.010	-74.891	0.010	-14.459	-4.800
Country_All_New	-5.163	0.010	-75.795	0.010	-14.015	-4.800
Country_All_All	-5.092	0.010	-71.282	0.010	-12.995	-4.800
Country_All_All	-4.433	0.010	-61.296	0.010	-10.153	-4.800
Capital_All_All	-4.999	0.010	-65.545	0.010	-10.747	-4.800
HICP	-3.776	0.023	-48.447	0.010	-9.352	-4.800

Note: printed p-values correspond to 5% significance level

Table D.5: Engle's ARCH test for heteroskedasticity

Time Series	**CZE**		**HUN**	
	Statistic	**P-value**	**Statistic**	**P-value**
Country_All_Exist	17.052	0.147	22.296	0.034
Country_All_New	10.519	0.570	15.929	0.194
Country_All_All	15.297	0.225	23.341	0.024
Capital_Flats_Exist	9.000	0.702		
Country_Flats_Exist	14.487	0.270		
Capital_All_All			35.708	0.0003
Country_All_All			10.221	0.596
HICP	55.788	0.306	15.681	0.206

Note: printed p-values correspond to 5% significance level

Table D.6: Engle's ARCH test for heteroskedasticity

Time Series	**SVK**		**POL**	
	Statistic	**P-value**	**Statistic**	**P-value**
Country_All_Exist	7.334	0.834	12.563	0.401
Country_All_New	9.019	0.701	13.465	0.336
Country_All_All	20.144	0.064	40.197	6.667
Capital_All_New	22.218	0.035		
Capital_All_Exist	15.026	0.240		
Country_All_All			21.950	0.038
Capital_All_All			12.635	0.396
HICP	4.015	0.983	18.500	0.101

Note: printed p-values correspond to 5% significance level

Appendix E

Appendix 5

Table E.1: Czech Republic - Fama & Schwert fundamental model

	Real estate returns			
Covered area	**Capital**	**Country**	**Country**	**Country**
Dwelling type	**Exist. flats**	**Exist. flats**	**Existing**	**New**
HICP rate	-0.296**	-0.062	0.055	0.320*
	(0.127)	(0.109)	(0.107)	(0.166)
Constant	0.00005	0.0004	-0.001	-0.001
	(0.002)	(0.002)	(0.001)	(0.002)
Observations	62	56	62	62
R2	0.101	0.008	0.007	0.083
Adjusted R2	0.086	-0.010	-0.010	0.067
Residual SE	0.016	0.013	0.012	0.019
F Statistic	6.707**	0.433	0.418	5.410**

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table E.2: Hungary - Fama & Schwert fundamental model

	Real estate returns			
Covered area	**Capital**	**Country**	**Country**	**Country**
Dwelling type	**All**	**All**	**Existing**	**New**
HICP rate	0.095	-0.195	0.679*	0.074
	(0.471)	(0.319)	(0.370)	(0.337)
Constant	0.0003	-0.001	-0.001	0.001
	(0.005)	(0.003)	(0.004)	(0.005)
Observations	90	90	66	66
R2	0.001	0.007	0.063	0.001
Adjusted R2	-0.011	-0.005	0.048	-0.015
Residual SE	0.044	0.030	0.034	0.039
F Statistic	0.065	0.583	4.272**	0.037

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table E.3: Poland - Fama & Schwert fundamental model

	Real estate returns			
Covered area	**Capital**	**Country**	**Capital**	**Country**
Dwelling type	**New**	**New**	**Existing**	**Existing**
HICP rate	-0.160	-0.224	0.084	0.586**
	(0.544)	(0.307)	(0.435)	(0.235)
Constant	0.0005	0.001	-0.002	0.0001
	(0.006)	(0.003)	(0.005)	(0.002)
Observations	68	52	68	52
R2	0.022	0.044	0.0003	0.144
Adjusted R2	0.008	0.025	-0.015	0.126
Residual SE	0.053	0.018	0.042	0.013
F Statistic	1.515	2.315	0.023	8.380***

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table E.4: Slovakia - Fama & Schwert fundamental model

	Real estate returns			
Covered area	**Capital**	**Country**	**Country**	**Country**
Dwelling type	**All**	**All**	**Existing**	**New**
HICP rate	0.454	0.426	0.293	0.093
	(0.318)	(0.309)	(0.444)	(0.375)
Constant	0.0001	-0.00004	0.0004	0.001
	(0.003)	(0.003)	(0.004)	(0.005)
Observations	74	74	54	54
R2	0.032	0.029	0.008	0.001
Adjusted R2	0.019	0.016	-0.011	-0.019
Residual SE	0.022	0.022	0.031	0.034
F Statistic	2.417	2.150*	0.438	0.036

Notes: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1