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THE POTENTIAL OF RESIDENTIAL PROPERTY IN POLAND AS AN INFLATION HEDGE INVESTMENT

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ABSTRACT

The research objective of the article was to assess the potential of residential property in Poland as an inflation hedge investment. The study was conducted using innovative measures of the level of inflation hedging. The study was made for Poland's six largest local residential markets, for two types of investments, for different investment horizons (from 6 to 15 years). The research period adopted was: 3Q2006-4Q2022. In all cities, investments providing only capital gains allowed an attractive inflation hedging level to be achieved. Investments that additionally included rental offered a high inflation hedging level. The variation in the six cities studied in terms of inflation hedging through housing investment was found to be very low. The question of how extending the investment horizon affected the inflation hedging ability was not firmly answered. Frequently, the extension of the investment horizon has been accompanied by an increase in the level of hedging.

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1. Introduction

The research problem of protecting capital against loss of purchasing power is always essential and topical, and is particularly interesting in a situation of rising and high inflation. It is international, with investors from different countries seeking financial instruments to protect the real value of capital.

Bodie (1976) discusses various definitions of inflation hedging (pointing to researchers who have adopted them in their research). The first has to do with investment portfolio optimization. The inflation hedging instrument minimizes the variance of a portfolio consisting of fixed-rate government bonds (as instruments free of credit risk but subject to inflation risk) and the hedging instrument[1]. The second definition reads: "A security is an inflation hedge if and only if its real return is independent of the inflation rate". According to Bodie, this means that ceteris paribus, a change in the inflation rate, should be accompanied by an equal change in the nominal return on the hedge. In simple terms, the condition of a positive correlation between the nominal return on the hedge and the rate of inflation is assumed. According to Arnold and Auer (2015), this definition is adopted in almost all empirical studies on inflation hedge instruments, usually testing for cointegration. According to the third definition provided by Bodie, "A security is an inflation hedge if it offers »protection« against inflation, which in turn means the elimination or at least the reduction of the possibility that the real rate of return on the security will fall below some specified »floor« value such as zero". The research carried out in this paper reflects the latter definition of the inflation hedge instrument.

The literature states that an effective hedge against inflation is when there is a stable positive relationship between inflation and the return of the hedging instrument, and a perfect hedge is when housing price increases can fully offset price increases (measured by the CPI, among others) (Tang et al., 2019; Arnold & Auer, 2015; Bodie, 1976). The terms “partial hedge” and “total hedge” are also used (e.g., Wahab et al., 2018).

Investors usually consider real estate to be an

[1] Bodie refers to equities as an instrument of inflation hedge.

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inflation hedge investment. However, the results of academic research are not conclusive. Researchers have come to different conclusions; these have varied depending on the country (developed as well as emerging markets have been studied), the research period (short, long), the type of real estate (commercial, industrial, land, residential), the type of investment (direct, indirect - REIT), the data source, and the research method used.

This paper focuses on residential real estate. Essafi Zouari and Nasreddine (2023) underline that, although several types of research raise the question of the hedging property of real estate, only some concentrate on physical residential assets (direct investment). At the same time, this is the most popular segment of the real estate market. Residential properties are commonly purchased for consumption purposes (in this case, it is also desirable to maintain the real value of the invested capital, e.g., regarding potential later sale and purchase of another) or for investment purposes, e.g., property for rent. It is worth adding that, according to Lee's research (2013), residential property is the only property type providing an effective hedge against actual, expected, and unexpected inflation.

Real estate hedging ability studies conducted in mature housing markets can be considered "evergreen". For example, the first US market studies were conducted from the 1970s onwards. Fama and Schwert (1977) proved that the US residential market was a complete inflation hedge against expected and unexpected inflation in 1953–1971. Bond and Seiler (2008) showed that in the 1969-94 period in the USA, residential real estate was a significant hedge against both, expected and unexpected inflation. Wu and Pandey (2012) stated that, in the USA, during 1987 - 2010, residential real estate provided only a moderate hedge against expected and unexpected inflation. Christou et al. (2018) considered nonlinearity in the relationship between house prices and non-housing CPI. Using a quantile cointegration analysis, they showed that, during 1953 – 2016, house prices in the USA acted as an inflation hedge when the former was relatively lower and the latter was comparatively higher. Nguyen (2023), based on the housing index for Japan and the USA from 2000 to 2020, showed that housing investments hedged against inflation in these countries.

One crucial issue is the importance of the investment horizon in hedging capital against inflation. Studies consider the long-term and short-term as a standard (Nguyen, 2023). Most studies have found the hedging ability of housing markets in the long term but not in the short term. Anari and Kolari (2002), based on house prices in the USA from 1968 to 2000, found that house prices were a stable inflation hedge in the long run. Li and Ge (2008) showed that residential properties in Shanghai from 1997 to 2005 did not provide a good hedge against inflation in the short run but could offer a partial hedge against inflation in the long run. Wahab et al. (2015) analyzed five residential housing zones in the capital of Nigeria. They stated that housing markets failed to provide a complete hedge across all the markets against inflation in the short run but provided a complete hedge across all the markets in the long run. Similarly, Gunasekarage et al. (2008) found a solid long-term relationship between the returns offered by the New Zealand residential market and the inflation rate during 1979 - 2003. Also, Inglesi-Lotz and Gupta (2013) stated long-run cointegration between house prices and the CPI in South Africa during 1970-2011. Aqsha and Mansur (2018) concluded that residential property in Malaysia during 1986-2018 could act as a good hedge against inflation in the long run. Lee (2021) compared the hedging ability of the residential market in China, Russia (2003-2019) and India (2010 - 2019). He stated that: 1) only residential properties in China and Russia provided a short-term hedge against expected inflation; 2) the residential properties in these three countries provided a long-term hedge against inflation; 3) the long-term hedging ability of residential properties as an investment in China was at least twofold stronger than that of India and Russia.

Surprisingly, Glascock et al. (2008) stated that residential properties in Hong Kong during 1998-2006 hedged against expected and unexpected inflation in the short but not the long term. Similarly, Chen and Foo (2006), when comparing five residential property markets in 1970 – 2003, for the short term, stated that: 1) the Singapore market was a perfect hedge against inflation, 2) London residential properties exhibited a partial hedge, and 3) Hong Kong, Taipei, and Tokyo markets performed poorly against inflation. In the long term, only the Taipei market offered a partial hedge.

Brounen et al. (2014) considered more horizons in the study of the housing market in Amsterdam between 1814 and 2008. They considered total housing returns (house price dynamics and rents). They used OLS, Granger causality and hedge ratio as alternative methodologies when examining horizons

from 1 year to 30 years, and stated that residential protection against actual and expected inflation increased with the investment horizon. The effect of the time horizon was evident up to horizons of approximately ten years (after which the used hedge ratio flattened).

Another issue is the differentiation of local housing markets regarding their inflation-hedging ability. Stevenson (1999), examining British regional housing markets from 1983 to 1995 (using the OLS regression and cointegration technique), stated that all the regional markets provided a hedge, but found substantial differences. Ma and Liu (2010) detected that inflation-hedging characteristics of Australian residential properties in eight capital cities varied strongly across cities in the long run (not every local market hedged against inflation) in 1998 – 2008. Umeh and Oluwasore (2015) examined the inflation-hedging capacities of returns on residential property investments during 2002-2014 in four selected Ibadan (Nigeria) areas. They found that the inflation hedging capacities of real estate investments varied across geographical sub-markets, and generally, residential properties did not hedge against actual inflation in all the considered areas. They also underline that their result does not agree with that of Dabara (2014) in Gombe, which may be due to the differences in geographical locations of the analyzed housing markets in Nigeria. Wu and Tidwell (2015) examined housing price dynamics and inflation relations in 35 Chinese cities from 2000 to 2010. They found that Chinese real estate markets provided a limited hedging possibility against expected and unexpected inflation. Central Chinese real estate markets outperformed western and eastern regions, which they explained by supply and demand factors.

Different results were obtained by Tang et al. (2019), who conducted a study of 29 cities in China using an Autoregressive Distributive Lag (ARDL) model and a bound test. Despite the differences in the patterns of the cumulative growth rate of the housing price index and cumulative inflation for individual cities, they generally found that there was no long-term relationship between housing prices and different types of inflation (actual, expected, unexpected) in first-tier and second-tier cities in China from 2003 to 2013. At the same time, they showed that the aggregate growth rate of the housing price index was much higher than the inflation rate, which they point out in their conclusions for investors.

Essafi Zouari and Nasreddine (2023) conducted in-depth research. They analyzed physical residential markets in 127 communes in Paris and the Parisian first-ring suburbs (clustered into five homogenous groups) from 1996 to 2017. They stated, among others: 1) the existence of positive and significant correlations between actual inflation and housing group returns; 2) the difference in hedging ability among groups. They concluded that investors seeking protection from inflation erosion should invest in direct housing, particularly within areas experiencing an effective metropolization process.

Some researchers have pointed out the diversity of residential properties. Lee (2012) examined the different types of residential properties in Hong Kong over the period 1980-2011 and stated that small and medium size residential properties in Hong Kong are better short-term and long-term inflation hedges than large and luxury residential properties. Ekemode (2021) compared the hedging abilities of three residential property types (bungalows, blocks of flats and detached houses) in 3 Nigerian cities during 1999–2018. He stated that, despite the variations in hedging abilities across property types, residential property assets significantly (completely or partially) protect from inflation. In turn, Yaep and Lean (2017) analyzed four house categories: detached, high-rise, semi-detached and terraced houses in Malaysia. They found that only investments in terraced houses hedge against consumer inflation in the long run.

A growing number of studies are looking at emerging markets. In addition to the previously mentioned studies on Malaysia and selected metropolitan areas in Africa, it is worth mentioning the Dabar study (2015), which showed that, in 2003 - 2012, the inflation-hedging performance of residential property investments in Gombe (Nigeria) vis-à-vis the actual inflation provided a partial hedge and vis-à-vis the expected inflation provided a complete hedge. On the contrary, Peunghuer (2006) stated that, during 1998-2004, housing markets in Thailand did not hedge against inflation. Similarly, Nguyen and Wang (2010) and Fang et al. (2008) demonstrate the ineffectiveness of inflation hedging in Taiwan's housing during 1991–2006.

Regarding foreign markets, it is also worth mentioning Onder's research (2000) on Ankara's (Turkey) residential market, which showed that real estate investment does not provide a hedge against inflation in a high-inflationary environment.

Most studies in this area consider only capital gains. However, Li and Ge (2008) highlighted the

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limited nature of their research due to the unavailability of rental data and the need to rely solely on the housing price index. Few researchers have analyzed both capital return and rental return. Ojo et al. (2021) showed the greater importance of capital return than income (rent) returns in the inflation-hedging ability of residential properties in Nigeria. Similarly, Essafi Zouari and Nasreddine (2023) stated that residential assets in Paris are confirmed to be a hedge against inflation thanks to their capital appreciation rather than income. In turn, Umeh and Oluwasore (2015) detected that property investment return components (rent and capital returns) perform differently against inflation in different geographical sub-markets.

Research on the Polish housing market is sporadic. Trojanek (2007) studied the residential real estate market in Poznan from 1996 to 2004 using a regression model. Analyzing three groups of flats of different sizes separately, he found that investments in residential real estate in Poznan market provided an effective hedge against expected and unexpected inflation. Melnychenko et al. (2022), using regression analysis, showed that, in the years 2009 - 2021, in seven of the eight largest local housing markets in Poland, the real estate prices were positively related with the inflation rate. Wolski (2023) conducted a cointegration analysis for 2009-2021. Using three aggregated hedonic price indices of residential real estate (for 6, 7 and 10 of the biggest Polish cities), he stated that residential property prices and inflation rates (actual and expected) were not cointegrated, so Polish housing markets do not effectively hedge against inflation. For the same period, he also showed (2022), similarly to Melnychenko et al. (2022), that the housing price index was positively correlated with inflation and concluded by raising the question of an appropriate method of assessing the hedging properties of assets.

The dependence of the result on the method used has also been noted by other researchers. It has been found that regression or cointegration analyses can give a negative result regarding hedging ability, while the real return on investment over the study period is positive (Hin Li, & Lin Ge, 2008; Tang et al., 2019). This encourages a search for alternative methods to assess hedging ability.

Based on the search, a **methodological research gap** was identified: the commonly used methods for assessing inflation-hedging ability based on housing prices and inflation rate co-movement are not sufficient.

An **empirical research gap** was identified in relation to the Polish market. Firstly, a lack of comparative studies of the potential of local housing markets in inflation-hedging was identified. Secondly, a lack of research considering different investment horizons was identified. Thirdly, there is a lack of research taking into account two types of investment (investment yielding only capital gains, i.e. resulting from the appreciation of real estate, and investment yielding also rental income). Fourthly, studies to date have not indicated the level of capital protection against inflation.

The **research objective** of this article is to assess the potential of residential properties in Poland as an inflation hedge investment.

The following research questions were formulated:

1) What level of actual inflation hedging did housing investments offer?
2) Were investments in different local housing markets characterized by significantly different levels of capital protection against actual inflation?
3) Did extending the investment horizon affect the level of capital protection against actual inflation?

This study contributes to the existing literature in several important ways. Responding to the methodological research gap is the proposal of 4 original inflation hedge ratios (IHR) that measure the level of inflation-hedging ability of investments. They are based on real holding period yield distributions. The response to the empirical research gap is:

1) assessment of the level of inflation hedging-ability of two types of investments in the largest local housing markets in Poland,
2) comparative assessment of the largest housing markets in Poland in terms of the level of inflation-hedging ability,
3) determining of the relationship between the length of the investment horizon and the level of inflation-hedging ability of residential investments.

2. Material and methods

The study was conducted for the six largest residential markets in Poland: Warsaw, Tri-City, Krakow, Wroclaw, Poznan, and Lodz. It covered two types of investments: 1) based solely on capital gain, i.e. property appreciation (investment A); 2) taking into account the sum of capital gain and rental return

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(investment B).

For investment A, investment horizons from 6 years[2] to 15 years (extendable by a quarter, 37 horizons in total) were used. For investment B, investment horizons from 6 years to 15 years (extended by one year, 10 in total) were used.

Quarterly data from the National Bank of Poland (nbp.pl) was used: (1) hedonic price indices of 1m^2 of flats on the secondary market; (2) hedonic prices of 1m2 of flats on the secondary market; (3) average flat rents based on transactions (excluding service charges and utility charges)[3]. The quarterly (QoQ) consumer price index (CPI) (retrieved from NBP database[4]) was used as a proxy for actual inflation[5]. Study period adopted: 3Q2006 - 4Q2022.

For investment A, the nominal HPY was calculated based on hedonic price indices of 1m^2 of flats. For investment B, nominal HPY was calculated as the sum of capital yield (calculated as nominal HPY for investment A) and the rental yield (calculated as the sum of rental returns gained in the holding period divided by the hedonic purchase price) (cf. Essafi Zouari and Nasreddine (2023)).

For investment B, the following assumptions were made when estimating the holding period rental return: no vacancies, annual contracts, i.e., a change in the rental rate after each consecutive year of rental (the new average rate on the local market in the quarter in which the rent was updated was assumed), lump-sum tax (8.5%)[6].

As Essafi Zouari and Nasreddine (2023) underline that, because of the time-varying relationship between house prices and inflation, an investor needs to examine the hedging effectiveness of an asset in different subperiods. Therefore, time series of hypothetical nominal investment yields (HPY) were constructed for each local market using a moving observation window method with overlapping sub-periods (overlapping with quarterly steps). A total of 222 time series of nominal HPY for investment A (6 cities, 37 horizons) and 60 time series for investment B (6 cities, 10 horizons) were produced. The nominal HPY series were transformed into real HPY series using the Fisher equation.

Four characteristics were then calculated for each time series of real HPY: percentage of non-negative real HPY, minimum value, median, and maximum value.

To answer the first research question, four original measures of the level of inflation hedging-ability of investments (named inflation hedge ratios, IHR) were calculated (for each local market and each investment horizon):

1) the chance of a non-negative real HPY, CH (Formula 1)[7],
2) minimum inflation hedge ratio, minIHR (Formula 2),
3) average inflation hedge ratio, MeIHR (Formula 3),
4) maximum inflation hedge ratio, maxIHR (Formula 4).

$$CH = percentage\ of\ non-negative\ HPY_{real} \quad (1)$$

$$minIHR = 1 + minHPY_{real} \quad (2)$$

$$MeIHR = 1 + MeHPY_{real} \quad (3)$$

$$maxIHR = 1 + maxHPY_{real} \quad (4)$$

where: min/Me/max HPY_{real} – minimum/average/maximum value of the real HPY series.

Each measure communicates different information. CH informs about the chance of minimum total capital protection against inflation. MinIHR, MeIHR and maxIHR show the real value of capital at the end of a hypothetical investment relative to the real value of capital at the beginning of the investment. MinIHR indicates the lowest historical level of capital protection against inflation (the minimum level of inflation hedging), MeIHR indicates the average historical level of capital protection against inflation (the average level of inflation hedging), and maxIHR indicates the maximum historical level of capital protection against inflation (the maximum level of

[2] If the sale of the residential property takes place after the fifth tax year of the acquisition, no income tax must be paid.

[3] Rents and hedonic prices data was retrieved from NBP report series titled „Raport o sytuacji na rynku nieruchomości mieszkaniowych i komercyjnych w Polsce" (Report on the situation on the residential and commercial real estate market in Poland), while hedonic price indices were retrieved from the NBP database (nbp.pl/publikacje/cykliczne-materialy-analityczne-nbp/rynek-nieruchomosci/).

[4] Available at: nbp.pl/statystyka-i-sprawozdawczosc/inflacja-bazowa/

[5] The CPI is the most adopted in such studies; see Arnold and Auer (2015).

[6] The author assumed the analysis for non-large investors. Large investors (i.e., institutional investors and those investing in multiple rental flats) are subject to different tax arrangements in Poland.

[7] This measure was previously used by the Author in financial investment research. The other measures are novel.

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inflation hedging).

The higher the value of the (min, Me, max) IHR, the higher the level of inflation hedging:

a) IHR ⩾ 1 stands for total inflation hedging, including:
   - IHR =1 means that the real value of the capital invested has not changed,
   - IHR>1 means an increase in the real value of invested capital,
b) 0 < IHR < 1 stands for incomplete inflation hedging (a fall in the real value of invested capital),
c) IHR ≤ 0 means zero inflation hedging.

Next, to answer the second research question, the variation in inflation hedge ratios for individual cities, was examined. The coefficient of variation and the range were used.

For the third research question, the following hypothesis was formulated: lengthening the investment horizon increased the inflation hedging level. To test it, graphs were drawn, regression functions were estimated (with independent variable: length of investment horizon and dependent variable: the value of IHR), and the significance of the slope of the regression function was tested.

3. Results

3.1. Inflation hedge ratio values

Table 1 shows the values of inflation hedge ratios for investment A (considering capital gain only).

For investment A, for each city, significant differences were observed between the minIHR, MeIHR and maxIHR values. For Warsaw, minIHR ranged from 0.68 to 0,9 (which can be interpreted as the investment having secured at least 68% - 90% of the real value of the capital, depending on the length of the investment horizon), MeIHR ranged from 0.94 to 1.04 (which can be interpreted as the investment having secured, on average, 68% - 100% of the real value of the capital, depending on the length of the investment horizon), maxIHR ranged from 1.15 to 1.38 (which can be interpreted as the investment having secured maximally 100% of real value of the capital), and that CH ranged from 0.3 to 0.61. For Krakow, minIHR ranged from 0.66 to 1.01, MeIHR ranged from 0.97 to 1.19, maxIHR ranged from 1.21 to 1.54, and CH ranged from 0.44 to 1. For Tri-City, minIHR ranged from 0.62 to 0.97, MeIHR ranged from 1 to 1.15, maxIHR ranged from 1.27 to 1.61, and CH ranged from 0,5 to 0,87. For Wroclaw, minIHR ranged from 0.6 to 0.92, MeIHR ranged from 0.95 to 1.11, maxIHR ranged from 1.14 to 1.53, and CH ranged from 0.44 to 0.9. For Poznan, minIHR ranged from 0.64 to 0.85, MeIHR ranged from 0.88 to 1.02, maxIHR ranged from 1.2 to 1.43, and CH ranged from 0.27 to 0.58. For Lodz, minIHR ranged from 0.68 to 1.03, MeIHR ranged from 1.02 to 1.2, maxIHR ranged from 1.46 to 2.15, and CH ranged from 0.5 to 1.

IHRs (min, Me, max) can be interpreted as scenarios in investment analysis that reflect differences in the level of inflation hedging due to the timing of the start and end of the investment. MinIHR can be considered a highly pessimistic timing scenario, MeIHR can be interpreted as a moderate timing scenario, and maxIHR can be found as a highly optimistic timing scenario. The apparent differences between the three scenarios identified for all cities demonstrate the importance of the timing of the purchase and sale of the dwelling.

Table 2 shows the inflation hedge ratios for investment B (considering capital gain and rental income).

Table 1

The values of inflation hedge ratios for investment A

Investment horizon (in years)	inflation hedge ratios																							
	Warsaw				Krakow				Tri-City				Wroclaw				Poznan				Lodz			
	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH
6	0.69	0.99	1.29	0.50	0.69	0.98	1.45	0.48	0.62	1.09	1.52	0.55	0.61	0.97	1.45	0.48	0.65	1.02	1.27	0.50	0.68	1.05	1.57	0.52
6.25	0.69	0.99	1.32	0.49	0.70	0.98	1.45	0.44	0.62	1.06	1.51	0.59	0.60	0.95	1.46	0.49	0.64	0.99	1.27	0.49	0.69	1.02	1.52	0.51
6.5	0.68	0.97	1.31	0.48	0.68	0.98	1.45	0.48	0.64	1.06	1.55	0.55	0.61	0.96	1.49	0.48	0.66	1.00	1.30	0.50	0.70	1.04	1.52	0.50
6.75	0.68	0.97	1.31	0.46	0.66	0.97	1.44	0.46	0.64	1.05	1.54	0.56	0.64	0.97	1.50	0.49	0.67	1.02	1.31	0.51	0.69	1.06	1.54	0.51
7	0.70	0.97	1.30	0.47	0.71	0.98	1.47	0.47	0.64	1.06	1.55	0.58	0.62	0.98	1.51	0.50	0.69	0.99	1.31	0.47	0.69	1.07	1.57	0.53
7.25	0.71	0.98	1.32	0.49	0.70	1.02	1.51	0.51	0.66	1.10	1.58	0.57	0.61	0.99	1.50	0.46	0.67	1.00	1.29	0.51	0.70	1.09	1.53	0.51
7.5	0.71	0.99	1.34	0.50	0.70	1.01	1.54	0.56	0.65	1.10	1.56	0.56	0.64	0.99	1.51	0.44	0.69	1.01	1.31	0.50	0.68	1.07	1.55	0.53
7.75	0.71	1.01	1.34	0.51	0.70	1.03	1.53	0.54	0.68	1.11	1.58	0.57	0.63	0.97	1.51	0.49	0.68	1.02	1.33	0.54	0.69	1.05	1.55	0.57
8	0.70	1.00	1.34	0.50	0.72	1.02	1.49	0.56	0.67	1.10	1.56	0.59	0.65	0.97	1.53	0.44	0.70	1.02	1.33	0.53	0.70	1.07	1.53	0.56
8.25	0.72	0.98	1.35	0.48	0.69	1.01	1.47	0.55	0.65	1.08	1.54	0.61	0.66	0.97	1.51	0.45	0.70	1.01	1.34	0.52	0.71	1.08	1.54	0.58
8.5	0.72	0.98	1.38	0.47	0.70	1.01	1.51	0.53	0.68	1.08	1.61	0.63	0.64	0.97	1.53	0.44	0.71	0.98	1.30	0.47	0.72	1.10	1.56	0.59
8.75	0.73	0.97	1.37	0.48	0.70	1.03	1.48	0.55	0.70	1.06	1.59	0.65	0.66	0.99	1.52	0.45	0.71	1.00	1.31	0.52	0.70	1.11	1.57	0.61
9	0.74	0.98	1.32	0.50	0.72	1.05	1.44	0.60	0.73	1.11	1.57	0.63	0.65	1.01	1.51	0.53	0.70	1.00	1.31	0.50	0.70	1.10	1.55	0.63
9.25	0.73	0.99	1.29	0.48	0.76	1.08	1.44	0.66	0.73	1.10	1.55	0.66	0.69	1.00	1.52	0.48	0.71	1.02	1.27	0.52	0.71	1.12	1.54	0.66
9.5	0.74	1.00	1.25	0.50	0.75	1.09	1.46	0.64	0.74	1.12	1.53	0.64	0.67	1.01	1.48	0.54	0.71	1.00	1.28	0.50	0.71	1.11	1.50	0.64
9.75	0.74	1.01	1.25	0.56	0.77	1.10	1.42	0.63	0.78	1.13	1.46	0.63	0.67	1.02	1.51	0.59	0.72	1.00	1.28	0.52	0.72	1.11	1.50	0.67
10	0.74	1.01	1.21	0.58	0.77	1.12	1.42	0.62	0.78	1.14	1.43	0.65	0.70	1.05	1.41	0.58	0.72	1.01	1.22	0.58	0.76	1.14	1.48	0.69
10.25	0.75	1.02	1.19	0.56	0.74	1.15	1.39	0.60	0.78	1.14	1.41	0.64	0.71	1.07	1.39	0.56	0.72	1.00	1.23	0.48	0.77	1.14	1.46	0.68

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10.5	0.76	1.03	1.17	0.58	0.76	1.16	1.35	0.63	0.82	1.14	1.35	0.71	0.72	1.09	1.40	0.58	0.73	1.01	1.22	0.54	0.78	1.14	1.48	0.67
10.75	0.76	1.03	1.17	0.61	0.74	1.17	1.32	0.65	0.84	1.15	1.31	0.74	0.75	1.09	1.28	0.57	0.75	1.02	1.20	0.57	0.79	1.15	1.49	0.70
11	0.77	1.03	1.16	0.59	0.77	1.18	1.29	0.64	0.86	1.13	1.27	0.73	0.77	1.09	1.29	0.59	0.76	1.01	1.20	0.55	0.85	1.15	1.59	0.73
11.25	0.80	1.02	1.15	0.57	0.81	1.19	1.28	0.62	0.86	1.13	1.27	0.76	0.74	1.09	1.23	0.62	0.78	1.02	1.21	0.57	0.87	1.16	1.58	0.67
11.5	0.81	1.04	1.16	0.55	0.82	1.15	1.27	0.60	0.92	1.12	1.27	0.75	0.74	1.08	1.24	0.65	0.78	1.00	1.22	0.45	0.90	1.13	1.62	0.75
11.75	0.80	1.04	1.16	0.53	0.82	1.16	1.29	0.63	0.90	1.14	1.33	0.74	0.76	1.06	1.21	0.68	0.79	1.00	1.26	0.53	0.92	1.11	1.63	0.84
12	0.84	1.01	1.17	0.50	0.85	1.13	1.32	0.72	0.93	1.11	1.37	0.72	0.79	1.07	1.25	0.78	0.80	0.98	1.28	0.44	0.93	1.15	1.75	0.89
12.25	0.85	1.00	1.21	0.53	0.87	1.12	1.36	0.71	0.93	1.09	1.39	0.71	0.86	1.08	1.26	0.65	0.81	0.98	1.31	0.47	0.94	1.12	1.80	0.88
12.5	0.85	0.98	1.23	0.44	0.89	1.11	1.35	0.81	0.93	1.07	1.39	0.81	0.82	1.07	1.27	0.69	0.81	0.98	1.31	0.44	0.96	1.10	1.85	0.88
12.75	0.86	0.98	1.23	0.40	0.91	1.09	1.32	0.80	0.95	1.06	1.49	0.87	0.86	1.07	1.26	0.87	0.83	1.00	1.32	0.47	0.99	1.11	1.90	0.93
13	0.85	0.99	1.27	0.50	0.95	1.11	1.29	0.79	0.94	1.05	1.46	0.86	0.85	1.10	1.27	0.79	0.82	0.98	1.34	0.50	0.96	1.11	1.91	0.93
13.25	0.89	0.99	1.30	0.38	0.95	1.12	1.33	0.77	0.95	1.05	1.52	0.77	0.88	1.11	1.23	0.85	0.83	0.96	1.37	0.38	0.98	1.12	1.97	0.85
13.5	0.88	0.98	1.30	0.33	0.94	1.12	1.31	0.83	0.93	1.03	1.51	0.83	0.88	1.11	1.26	0.83	0.82	0.92	1.36	0.33	0.99	1.11	1.97	0.83
13.75	0.89	0.97	1.31	0.36	0.96	1.09	1.27	0.91	0.93	1.03	1.52	0.64	0.90	1.11	1.16	0.82	0.84	0.90	1.40	0.27	1.01	1.10	2.04	1.00
14	0.90	0.95	1.30	0.30	0.99	1.09	1.22	0.90	0.97	1.00	1.55	0.50	0.91	1.10	1.14	0.90	0.85	0.89	1.40	0.30	1.00	1.13	2.14	1.00
14.25	0.89	0.94	1.36	0.33	1.01	1.08	1.21	1.00	0.93	1.01	1.53	0.56	0.92	1.09	1.17	0.89	0.83	0.88	1.41	0.33	1.02	1.13	2.01	1.00
14.5	0.90	0.94	1.34	0.38	1.01	1.08	1.23	1.00	0.90	1.02	1.55	0.50	0.91	1.09	1.17	0.88	0.83	0.88	1.39	0.38	1.03	1.11	2.04	1.00
14.75	0.88	0.97	1.35	0.43	0.98	1.08	1.27	0.71	0.89	1.01	1.52	0.71	0.92	1.11	1.20	0.86	0.83	0.89	1.41	0.43	1.00	1.16	2.09	1.00
15	0.85	0.99	1.37	0.50	0.96	1.06	1.30	0.83	0.86	1.10	1.51	0.67	0.89	1.09	1.21	0.83	0.84	1.02	1.43	0.50	0.95	1.20	2.15	0.83

Source: own calculation.

Table 2

The values of inflation hedge ratios for investment B

Investment horizon (in years)	inflation hedge ratios																							
	Warsaw				Krakow				Tri-City				Wroclaw				Poznan				Lodz			
	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH	min	Me	max	CH
6	0.79	1.20	1.54	0.79	0.73	1.25	1.71	0.81	0.71	1.29	1.90	0.74	0.75	1.27	1.76	0.79	0.76	1.20	1.51	0.79	0.82	1.35	1.84	0.81
7	0.85	1.23	1.62	0.79	0.79	1.27	1.99	0.82	0.77	1.37	1.99	0.76	0.81	1.30	1.84	0.79	0.84	1.26	1.58	0.84	0.88	1.38	1.90	0.87
8	0.90	1.25	1.65	0.91	0.84	1.35	2.04	0.85	0.86	1.39	2.04	0.85	0.90	1.30	1.88	0.91	0.89	1.27	1.60	0.88	0.96	1.43	1.90	0.94
9	1.00	1.28	1.64	1.00	0.89	1.37	2.01	0.90	0.96	1.39	2.01	0.90	0.97	1.37	1.86	0.97	0.94	1.28	1.59	0.90	1.01	1.49	1.92	1.00
10	1.03	1.35	1.51	1.00	0.96	1.47	1.78	0.92	1.02	1.44	1.78	1.00	1.05	1.43	1.72	1.00	0.99	1.33	1.50	0.92	1.11	1.56	1.84	1.00
11	1.07	1.31	1.44	1.00	0.97	1.49	1.65	0.95	1.14	1.44	1.65	1.00	1.14	1.47	1.58	1.00	1.07	1.31	1.51	1.00	1.23	1.60	1.96	1.00
12	1.16	1.31	1.49	1.00	1.07	1.43	1.78	1.00	1.23	1.40	1.78	1.00	1.19	1.45	1.65	1.00	1.11	1.24	1.61	1.00	1.34	1.57	2.15	1.00
13	1.16	1.29	1.61	1.00	1.18	1.41	1.91	1.00	1.23	1.36	1.91	1.00	1.28	1.50	1.56	1.00	1.15	1.23	1.68	1.00	1.45	1.55	2.34	1.00
14	1.05	1.24	1.64	1.00	1.21	1.34	2.02	1.00	1.12	1.29	2.02	1.00	1.33	1.45	1.62	1.00	1.08	1.19	1.77	1.00	1.32	1.53	2.61	1.00
15	1.01	1.23	1.69	1.00	1.08	1.28	1.97	1.00	0.99	1.40	1.97	0.83	1.17	1.39	1.69	1.00	1.03	1.26	1.78	1.00	1.27	1.59	2.61	1.00

Source: own calculation.

For investment B, the IHR values are substantially higher than for investment A, which was to be expected.

Similarly, significant differences were observed between the minIHR, MeIHR and maxIHR values for each city. For Warsaw, minIHR ranged from 0.79 to 1.16, MeIHR ranged from 1.2 to 1.35, maxIHR ranged from 1.44 to 1.69, and CH ranged from 0.79 to 1. For Tri-City, minIHR ranged from 0.71 to 1.23, MeIHR ranged from 1.29 to 1.44, maxIHR ranged from 1.65 to 2.04, and CH ranged from 0.74 to 1. For Wroclaw, minIHR ranged from 0.75 to 1.33, MeIHR ranged from 1.27 to 1.47, maxIHR ranged from 1.56 to 1.88, and CH ranged from 0.79 to 1. For Poznan, minIHR ranged from 0.76 to 1.15, MeIHR ranged from 1.19 to 1.33, maxIHR ranged from 1.51 to 1.78, and CH ranged from 0.79 to 1. For Lodz, minIHR ranged from 0.82 to 1.45, MeIHR ranged from 1.35 to 1.6, maxIHR ranged from 1.84 to 2.61, and CH ranged from 0.81 to 1.

The identified differences in minIHR, MeIHR and maxIHR values can be again analyzed in the context of differences in three timing scenarios.

More detailed research on IHR values was carried out in the following sections.

3.2. Differentiation of local housing markets in terms of the level of inflation hedging

The calculated coefficient of variation and range values are shown in Table 3 (for investment A) and Table 4 (for investment B).

Table 3

The coefficient of variation and range values for investment A

investment horizon (in years)	variation coefficient (%)				range			
	minIHR	MeIHR	maxIHR	CH	minIHR	MeIHR	maxIHR	CH
6	4.7	4.1	7.7	5.0	0.08	0.12	0.29	0.07
6.25	5.8	3.5	6.8	8.8	0.09	0.11	0.25	0.15
6.5	4.1	3.6	6.8	5.4	0.08	0.10	0.25	0.08
6.75	2.8	3.8	6.9	7.1	0.05	0.09	0.24	0.10
7	4.8	4.0	7.4	7.6	0.09	0.10	0.27	0.11
7.25	5.1	4.5	7.5	6.4	0.10	0.12	0.29	0.11
7.5	3.9	3.9	7.0	7.5	0.07	0.11	0.25	0.11
7.75	4.0	4.0	6.8	5.7	0.09	0.13	0.25	0.09
8	3.2	4.1	6.4	9.1	0.07	0.13	0.23	0.15
8.25	3.7	4.4	5.7	9.8	0.07	0.12	0.20	0.15

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8.5	4.0	5.0	7.2	13.3	0.08	0.12	0.30	0.19
8.75	3.1	4.6	6.9	12.6	0.07	0.14	0.28	0.19
9	4.2	4.7	7.2	10.2	0.09	0.13	0.26	0.13
9.25	3.2	4.9	8.0	14.1	0.07	0.13	0.28	0.17
9.5	3.8	4.9	7.6	11.5	0.08	0.12	0.27	0.14
9.75	4.9	4.9	7.3	8.3	0.11	0.13	0.26	0.15
10	3.7	5.2	7.7	7.2	0.08	0.13	0.27	0.12
10.25	3.5	5.6	7.5	10.9	0.08	0.15	0.28	0.20
10.5	4.4	5.3	7.8	9.1	0.10	0.15	0.31	0.17
10.75	4.6	5.5	8.0	10.2	0.10	0.15	0.32	0.17
11	5.2	5.6	10.7	10.9	0.09	0.17	0.43	0.18
11.25	5.7	5.9	10.9	10.3	0.14	0.17	0.44	0.19
11.5	7.6	5.1	11.6	17.1	0.18	0.16	0.46	0.30
11.75	6.8	5.1	11.8	17.1	0.15	0.16	0.48	0.32
12	6.6	5.7	13.7	23.0	0.14	0.16	0.58	0.44
12.25	5.0	5.1	13.9	20.3	0.13	0.14	0.58	0.41
12.5	6.1	4.9	14.8	**26.3**	0.15	0.13	0.62	0.44
12.75	6.3	4.5	16.3	**28.9**	0.16	0.13	0.68	0.53
13	6.2	5.2	15.9	23.0	0.14	0.13	0.64	0.43
13.25	5.5	6.1	17.0	**30.3**	0.14	0.16	0.74	0.46
13.5	6.0	7.2	16.8	**35.4**	0.17	0.20	0.71	0.50
13.75	6.0	7.5	19.8	**40.7**	0.18	0.21	0.88	0.73
14	5.7	8.4	22.7	**45.1**	0.15	0.24	1.00	0.70
14.25	7.1	8.7	19.2	**42.3**	0.19	0.25	0.84	0.67
14.5	7.2	8.3	19.9	**40.3**	0.19	0.23	0.87	0.63
14.75	6.4	8.9	19.8	**30.3**	0.17	0.28	0.88	0.57
15	5.3	6.2	20.5	21.5	0.12	0.21	0.94	0.33

Source: own calculation.

Table 4

The coefficient of variation and range values for investment B

investment horizon (in years)	variation coefficient (%)				range			
	minIHR	MeIHR	maxIHR	CH	minIHR	MeIHR	maxIHR	CH
6	4.7	4.1	8.5	3.0	0.11	0.15	0.39	0.07
7	4.6	4.1	8.1	4.4	0.11	0.15	0.41	0.11
8	4.2	4.9	8.3	3.6	0.12	0.18	0.44	0.09
9	4.1	5.2	8.3	4.9	0.12	0.21	0.42	0.10
10	4.7	5.5	7.7	3.7	0.16	0.24	0.33	0.08
11	7.3	7.1	10.0	1.7	0.26	0.29	0.52	0.05
12	7.4	7.5	12.1	0.0	0.27	0.33	0.67	0.00
13	8.2	8.1	15.3	0.0	0.30	0.32	0.78	0.00
14	9.2	8.8	18.6	0.0	0.28	0.34	0.99	0.00
15	9.0	9.0	17.1	6.4	0.28	0.36	0.92	0.17

Source: own calculation.

For both investments (A and B), the coefficient of variation generally indicates very low variation in local housing markets regarding the level of inflation hedging. The lowest variation is characteristic of minIHR and MeIHR. Only in the case of investment A, for several horizons, was an average variation in the CH measure detected (bold font in Table 3).

Considering the range values, it can be subjectively concluded that there are apparent differences in IHR values between the best and worst cities. The exception is the lack of variation in CH values for some horizons in the case of investment B. It is worth adding that the obtained results do not allow to unambiguously indicate the best and the worst cities in terms of the level of protection against inflation. Cities occupying extreme positions differ depending on the measure used and the length of the investment horizon.

3.3. Investment horizon and the level of inflation hedging

After formulating the null hypothesis (H_0: lengthening the investment horizon increased the inflation hedging level) and the alternative hypothesis (H_1: lengthening the investment horizon did not increase the inflation hedging level), graphs were drawn (sample graphs are provided in Figures 1 and 2). Then the parameters and fitting of the regression functions were estimated. The regression function's slope with its significance (p-value=0.05) have been presented in Table 5.

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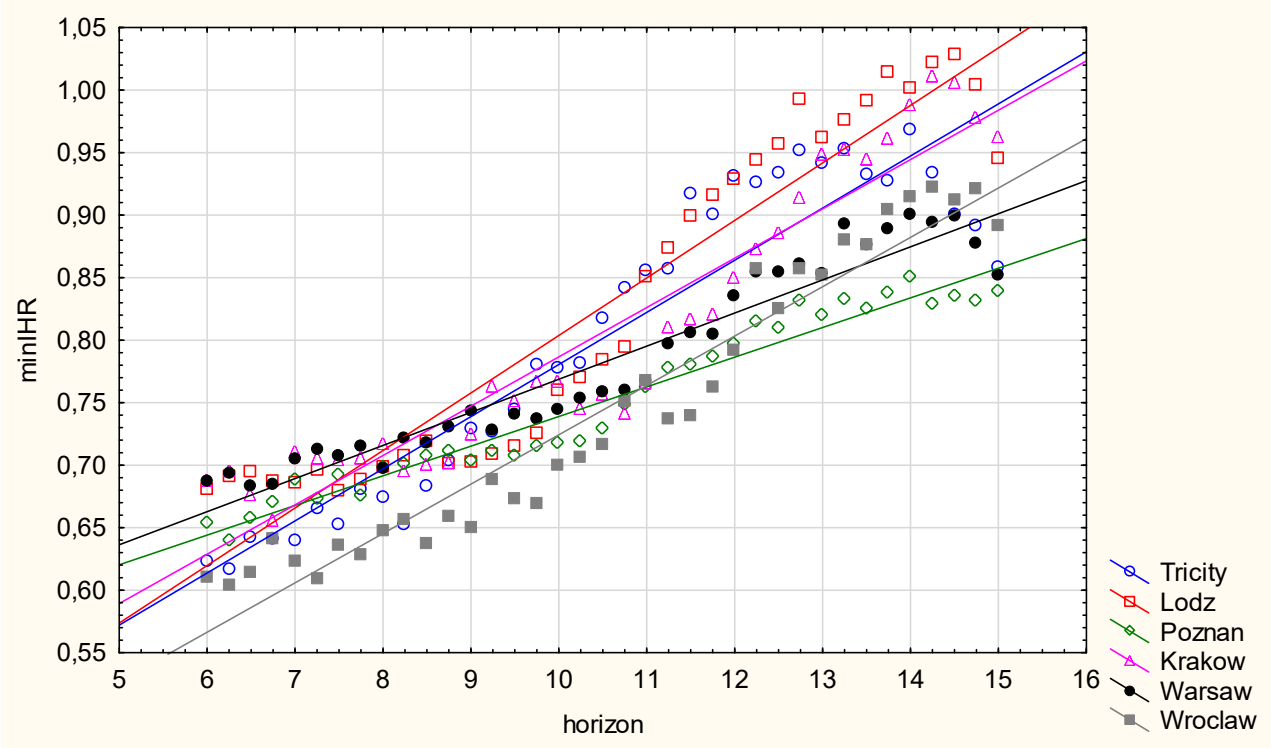


Fig. 1. MinIHR values calculated for investment A, for 6 cities. *Source*: own elaboration.

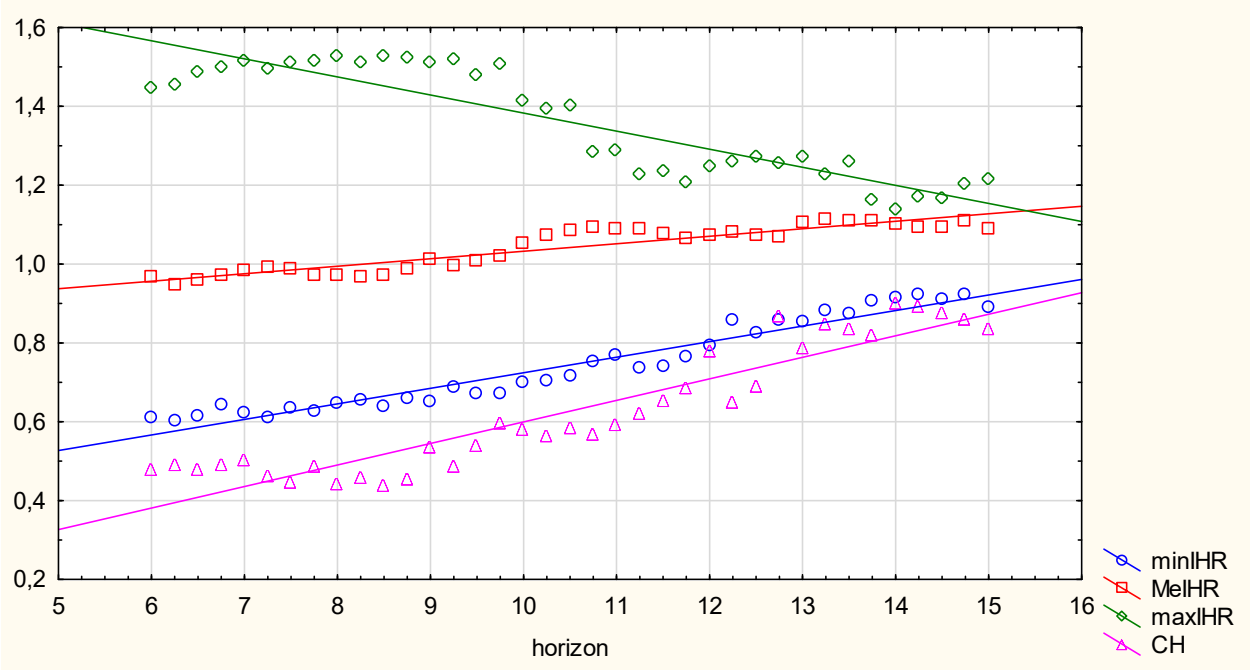


Fig. 2. IHR and CH values calculated for investment A, for Wroclaw. *Source*: own elaboration.

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Table 5

The slopes of regression functions with significance and coefficient of determination (R^2)

city	IHR	Investment A		Investment B	
		the slope of the regression function	R^2	the slope of the regression function	R^2
Warsaw	minIHR	**0.026**	0.93	**0.032**	0.6
	MeIHR	-0.001	0.01	0.003	0.04
	maxIHR	-0.004	0.02	0.005	0.03
	CH	**-0.012**	0.17	**0.023**	0.62
Krakow	minIHR	**0.039**	0.9	**0.051**	0.88
	MeIHR	**0.015**	0.41	0.008	0.08
	maxIHR	**-0.031**	0.77	0.007	0.02
	CH	**0.050**	0.83	**0.025**	0.92
Tri-City	minIHR	**0.042**	0.88	**0.047**	0.61
	MeIHR	-0.005	0.1	0.002	0.01
	maxIHR	-0.011	0.08	-0.003	0.01
	CH	**0.017**	0.21	0.022	0.38
Wroclaw	minIHR	**0.039**	0.94	**0.061**	0.87
	MeIHR	**0.019**	0.85	**0.021**	0.59
	maxIHR	**-0.046**	0.81	**-0.027**	0.51
	CH	**0.055**	0.87	**0.024**	0.68
Poznan	minIHR	**0.024**	0.95	**0.036**	0.76
	MeIHR	**-0.010**	0.41	-0.002	0.02
	maxIHR	**0.010**	0.21	**0.026**	0.6
	CH	**-0.016**	0.33	**0.024**	0.86
Lodz	minIHR	**0.046**	0.9	**0.064**	0.83
	MeIHR	**0.011**	0.56	**0.025**	0.71
	maxIHR	**0.069**	0.71	**0.091**	0.8
	CH	**0.060**	0.91	**0.018**	0.61

Bold slopes are statistically significant. The results consistent with the null hypothesis and statistically significant are marked with a gray background. Source: own calculation.

The results varied depending on the city and the IHR. However, for each city, we failed to reject the null hypothesis for minIHR (the null hypothesis has been positively verified). Secondly, we failed to reject the null hypothesis for all IHR (the null hypothesis has been positively verified for all IHR) only in the case of Lodz. For the remaining cities, depending on the IHR adopted and the type of investment (A or B), we either failed to reject the null hypothesis, or rejected the null hypothesis.

4. Discussion

Previous researchers have typically adopted a hedging definition that assumes a positive relationship between housing prices and inflation. The research presented in this paper is not a correlation or cointegration study but was conducted using an innovative method based on a time series of the real HPY and original IHR measures. These reflect a different definition of inflation hedging (see Introduction) than previous studies. According to some researchers, regression or cointegration analyses may give a negative result concerning inflation hedging abilities, while the real return is positive (Hin Li & Lin Ge, 2008; Tang et al., 2019). Therefore, differences in definitions of inflation hedging ability should be considered when comparing the obtained results.

Given the calculated IHR values, the results of the conducted study can be considered similar to those of studies that identified housing as a perfect hedge or partial hedge investments and different from those of studies identifying housing investments as "zero hedges" or an "against hedge". The found high importance of capital gain in protecting capital from inflation confirms the results obtained by Ojo et al. (2021) and Essafi Zouari and Nasreddine (2023).

When analyzing the variation in local markets, it is worth noting the multidimensionality of the study. The shallow values of the coefficient of variation indicate very low variation among cities in terms of the level of inflation hedging, which can be considered similar to the results obtained by Tang et al. (2019). The result can also be considered to coincide with the results of Bełej and Kulesza (2014), who detected that each of these six local markets responded to the changes in the market environment in a very similar way and underwent similar changes in terms of time and value. On the other hand, the identified differences between

the best and worst cities and the differences in the impact of the investment horizon on the level of inflation hedging for each city allow us to indicate some correspondence with the results of Stevenson (1999), Wu and Tidwell (2015), Essafi Zouari and Nasreddine (2023).

The importance of the investment horizon in relation to hedging ability has been studied in detail only by Brounen et al. (2014). The results of the research presented in this article partly confirm the results of Brounen et al. (2014), who found an increase in hedging ability with the lengthening of the investment horizon.

Comparing the obtained results with other studies of the Polish market, we can recognize their correspondence with the results of Trojanek (2004) and Melnychenko et al. (2022), indicating the inflation-hedging ability of the Polish residential market. The discrepancy with the results of Wolski (2023), who concluded that the Polish residential market does not effectively hedge against inflation, is due to using different data and applying a different research method.

This paper proposes an alternative method for examining the inflation-hedging abilities of investments in the housing market (using a time series of the real HPY instead of the traditional co-movement analysis and cointegration testing). The IHR measures used allow for a detailed assessment of the inflation-hedging potential of investments. The importance of closing the identified methodological gap should be emphasized, as according to Essafi Zouari and Nassredine (2023), "saying real estate can prevent from inflation erosion is very vague and imprecise." The weaknesses and limitations of the research are mainly due to the availability of data on local housing markets. To reduce the risk of the impact of a change in the quality of dwellings on the change in price over time, hedonic price indices provided by the NBP were used for the research. These are calculated for the secondary market only (so the study does not include an investment involving the purchase of a flat on the primary market). The indices are not entirely without flaws. Firstly, the data obtained from the NBP are averaged quarterly data. Secondly, Trojanek et al. (2022) showed a significant delay between the transaction date and data entry in the Property Price Register in Warsaw, so data from the NBP database may also be shifted in time. The research period of 2006-2022 resulted in the most extended investment horizon being limited to 15 years, while Brounen et al. (2014) adopted 30 years as the maximum horizon. The adopted research period also results from the availability of hedonic indices data and rental data in the NBP database. Furthermore, in Poland, the CPI is measured for the whole country rather than for local markets, whereas Tang et al. (2019) used CPI for local markets in China in their study.

The estimates did not include costs incurred in the property's acquisition, sale, and management (like renovations, improvements, notary's fee, land registry fee, and broker's fee). Considering these would lower the HPY and, therefore, the IHRs. A relatively optimistic assumption of no vacancy and annual rent updates was made for investment in rental housing[8]. The reinvestment of rental income and the risk of a non-paying tenant were also not considered.

A more in-depth study of the potential of investments in local housing markets as an inflation hedge is warranted. The variation of the hedging level depending on the inflation level and investments in smaller local markets should be examined.

5. Conclusions

This paper presents four original inflation hedge ratios based on the distribution of the real HPY. They are universal and can also be used in studies of other inflation hedge investments (gold, equities), including foreign markets. Because of their interpretation, IHRs provide a valuable methodological contribution. They can be used in assessing the suitability of an investment for an investor whose objective is to hedge capital against inflation. Using them, the author conducted an in-depth study on the potential of residential real estate as an inflation hedge investment in Poland (two types of investments, six local markets, and different investment horizons - from 6 to 15 years). The main conclusions formulated concerning the research questions are given below.

1. The minIHR measure showed that, in the highly pessimistic timing scenario, an investment in housing with only capital gains (investment A) secured at least 60% of the real value of the capital, while an investment with rental income (B) secured at least 71% of the real value of the capital. In a moderate timing scenario (based on MeIHR), investment A secured at least 88% of

[8] It is worth mentioning, however, that the Mzuri company (a nationwide leader in managing flats for rent) uses provisions in its rental contracts to update rents annually.

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the real value of the capital and investment B secured at least 100% (with MeIHR=120%). In the highly optimistic timing scenario (based on maxIHR), both investments secured at least 100% of the real value of the capital (investment A with maxIHR=114% and investment B with maxIHR=144%). The chance of at least maintaining the real value of capital for investment A ranged from 27% to 100%; for investment B, it ranged from 74% to 100%.

2. It was found that the variation between the six cities studied, in terms of the level of inflation hedging through housing investments, was very low. However, when analyzing the differences in the level of hedging characterizing investments in the best and worst cities, the differences could be considered significant from an investor's point of view.
3. The question of how lengthening the investment horizon affected the level of inflation hedging was not unambiguously answered. Most often, extending the investment horizon was accompanied by an increase in the value of the IHR (less often a decrease or a statistically insignificant change). Considering the minIHR (reflecting the highly pessimistic scenario) for each city, we found that extending the investment horizon increased the minimum inflation hedging level. Furthermore, only in the case of Lodz did the values of all IHRs increase with the lengthening of the investment horizon.

Summing up, we positively assess the potential of residential real estate in Poland as an inflation hedge investment. In all cities, investments yielding only capital gains (A) made it possible to achieve an attractive level of inflation hedging. Investments additionally taking into account the rental income (B) offered a high level of inflation hedging.

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