

Article

Exploratory Data-Driven Modeling of Macroeconomic Indicators Associated with Sustainable Housing Affordability: A Comparative Analysis of Construction Economics in Poland

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Abstract

This article employs exploratory data-driven modeling to examine the relationships between selected macroeconomic indicators, residential property prices, and housing affordability pressures in Poland between 2020 and 2024. This turbulent period was selected for analysis because of the unprecedented volatility triggered by the COVID-19 pandemic and the geopolitical shocks associated with the war in Ukraine, both of which severely disrupted macroeconomic stability and construction supply chains. The study examines how key economic variables—including inflation, gross domestic product (GDP), unemployment, and average and minimum wage dynamics—are associated with residential property price dynamics within the framework of construction economics. Using statistical modeling techniques, including linear regression and Pearson correlation analysis, the study quantifies the strength, direction, and dynamics of these relationships across primary and secondary housing sectors. Our findings reveal a distinct comparative pattern of associations: average wage growth and inflation emerge as the macroeconomic indicators most strongly associated with property valuations, while macroeconomic growth and unemployment dynamics exhibit asymmetric associations across market segments. Notably, the findings suggest that the primary sector may be more sensitive to credit-related demand shocks and policy interventions, whereas the secondary sector appears to respond more directly to broader consumer trends and household purchasing capacity. By integrating macroeconomic data into a sectoral analysis, this study provides an exploratory empirical basis for discussing sustainable housing strategies. The results underscore the necessity of aligning investment and production cycles in the construction sector with macroeconomic stability to maintain long-term residential purchasing capacity and support resilient urban development.

Keywords: exploratory data-driven modeling; construction economics; economic sustainability of the construction sector; housing affordability; macroeconomic indicators; regression analysis; Poland



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1. Introduction

Real estate valuations play a pivotal role in shaping both construction sector dynamics and broader macroeconomic and financial stability. Property values serve as a critical barometer of national economic health, drawing intense interest from developers, investors, financial institutions, and public authorities. Property value—conceptually defined as the transaction price that a willing buyer is prepared to pay under specific market

conditions—represents a dynamic and multidimensional phenomenon shaped by a complex interplay of legal, locational, technical, and macroeconomic factors. The construction sector is fundamentally intertwined with the overall macroeconomic environment. Rising property valuations often signal economic recovery, improved household purchasing capacity, and financial sector stability. Conversely, market downturns typically reflect broader economic contractions, diminished consumer confidence, or restrictive credit conditions. Because residential assets constitute the collateral backbone of the banking system, major fluctuations in property prices can trigger systemic shifts in financial stability. Consequently, understanding the factors associated with these valuations is vital for building a resilient and sustainable built environment.

In the era of digital transformation, construction economics and management increasingly rely on data-driven decision support systems. Integrating quantitative modeling of macroeconomic signals is essential for predicting cost trajectories, optimizing life-cycle costing (LCC), and supporting strategic investment cycles. By establishing a robust analytical framework to decode market volatility, researchers and developers can better align building processes with macroeconomic indicators, preventing structural imbalances and fostering long-term housing affordability.

In recent years, the Polish construction sector and residential markets have experienced unprecedented volatility. Between 2020 and 2024, the market was subjected to severe external shocks, including the COVID-19 pandemic, geopolitical disruptions stemming from the war in Ukraine, rapid inflation, supply chain bottlenecks, and shifting macroeconomic conditions [1–3]. This turbulent timeframe represents a highly critical research window to analyze how state-level macroeconomic fluctuations affect construction economics, building sector stability, and sustainable housing accessibility [4].

Furthermore, evaluating residential purchasing capacity through the lens of construction economics requires a deep integration of environmental and regulatory frameworks. Under the European Union's decarbonization agenda, particularly the recast of the Energy Performance of Buildings Directive (EPBD), Polish developers have been legally required since 2021 to ensure all newly constructed residential buildings meet nearly zero-energy building (NZEB) standards. While these regulations are essential for long-term ecological sustainability, reducing operational carbon footprints, and energy conservation, they impose strict technological requirements. The integration of advanced thermal insulation, heat pumps, photovoltaic systems, and certified low-emission materials has substantially increased baseline construction costs. In a highly volatile macroeconomic environment, developers pass this ecological premium onto buyers. This creates a critical socio-economic tension between environmental standards (green building requirements) and purchasing affordability, especially for young first-time homebuyers.

The primary objective of this article is to conduct an exploratory data-driven analysis of how selected macroeconomic indicators were associated with residential property price dynamics in Poland's primary and secondary housing sectors during the volatile 2020–2024 period. Specifically, the study aims to identify key macroeconomic indicators—such as inflation, gross domestic product (GDP), unemployment, and average and minimum wage dynamics—and assess the strength of their statistical associations with housing price dynamics. Methodologically, the research utilizes linear regression models and Pearson correlation analysis to quantify the strength of associations between these selected indicators and housing prices.

The findings of this study are highly consistent with a growing body of international literature highlighting the sensitivity of housing markets to macroeconomic fundamentals. Numerous studies conducted in both developed and emerging economies confirm that income-related variables and inflation play a dominant role in shaping residential property

prices, particularly during periods of heightened economic uncertainty. Research by [5,6] suggests that monetary conditions, credit expansion, and macroeconomic shocks may exert asymmetric effects on housing markets, reinforcing the interpretation of real estate as a potential hedge against economic uncertainty. This aligns closely with classical housing market models emphasizing the role of income and credit constraints [7].

Previous research also indicates that residential property prices are influenced not only by immediate macroeconomic conditions but also by broader sustainability dimensions, including economic, social, and environmental factors [8]. Studies conducted in various housing markets confirm that macroeconomic variables such as income growth, inflation, and housing supply conditions significantly affect housing price dynamics [9]. At the same time, the issue of affordability of the residential segment has become a central component of sustainable urban development and housing policy in many countries [10,11].

Despite the growing body of research on factors associated with housing prices, relatively few empirical studies focus on the Polish housing market in the context of recent global economic disruptions. In particular, the differentiated responses of the primary and secondary residential sectors to macroeconomic fluctuations have not been sufficiently explored in the literature. This research directly addresses this gap.

Sustainable housing affordability is fundamentally conceptualized as a multi-dimensional socio-economic metric that guarantees households access to adequate shelter without compromising their capacity to satisfy basic life-sustaining needs [12]. In the realm of construction economics, achieving this stability requires a continuous balance between production input costs and the long-term purchasing power of consumers. However, during periods of structural macroeconomic turbulence, this balance is frequently disrupted by exogenous price shocks and asymmetric inflation transmission channels [12]. The prior literature emphasizes that failing to anchor housing policy within broader macroeconomic realities accelerates social exclusion and destabilizes urban ecosystems, thereby undermining the core targets of United Nations Sustainable Development Goal 11 (SDG 11) [12,13].

Compared with existing international studies, the present research contributes three major insights: First, it explicitly differentiates between the primary and secondary housing sectors in a Central and Eastern European (CEE) transitional context. While previous studies often analyze aggregate housing price indices [14], our segmentation reveals that newly built housing (primary sector) is generally more sensitive to macroeconomic expansion and credit-related demand stimulation (such as government-subsidized programs), whereas the secondary sector responds more directly to household income dynamics and inflation expectations. Second, by focusing on Poland during the 2020–2024 period, this study extends international evidence to a construction market undergoing rapid structural transformation, high inflation volatility, and significant policy interventions, thereby contributing to comparative cross-country analyses of macroeconomic transmission mechanisms. Third, from a sustainability perspective, understanding the interaction between macroeconomic conditions and housing price dynamics is shown to be essential for maintaining the economic sustainability of the construction sector and fostering balanced, resilient urban development strategies.

Extensive empirical research underscores that exploratory data-driven modeling of real estate markets requires a granular understanding of how macro-financial indicators shift consumer boundaries [15]. In the European Union, structural housing imbalances are frequently flagged as core vulnerabilities that threaten long-term macroeconomic stability [16]. This is particularly evident in transition economies, where housing price dynamics often exhibit sharper volatility and less predictable cyclical behaviors than in Western markets [17]. As a result, tracking the velocity of these changes is vital for evaluating urban resilience

and social sustainability [18]. Furthermore, it must be explicitly noted that the empirical scope of this study intentionally focuses on the high-turbulence window of 2020–2024. While this five-year quarterly series ($N = 20$) is structurally short for establishing long-term macroeconomic equilibria, it serves as a critical period for exploratory data-driven assessment. This timeframe encapsulates dense, overlapping economic anomalies—ranging from pandemic-induced structural shifts to unprecedented inflation waves and immediate state-subsidized credit interventions. Consequently, the analytical models deployed herein are aimed at exploratory mapping of short-term shock transmissions across primary and secondary housing markets rather than generalizing long-term causal mechanisms.

While the cited literature (e.g., [5,6,9,14]) extensively explores real estate valuation and price acceleration through aggregate national indices or broader macro-financial variables, it frequently masks the distinct structural boundaries separating the primary development and secondary transactional sectors. In Central and Eastern European (CEE) transition economies, such as Poland, this aggregate approach overlooks critical, parallel transmission channels. The primary sector operates predominantly under supply-side energy premiums, institutional production costs, and direct regulatory requirements (such as NZEB standards). Conversely, the secondary sector functions as an organic reflection of household disposable income, purchasing power, and consumer sentiment. Isolating these parallel channels within a unified, high-turbulence window provides novel insights into localized market resilience. By demonstrating that macroeconomic shocks propagate with fundamentally distinct velocities and sensitivities across these two segments, this study advances the structural understanding of construction economics beyond what is known from traditional aggregate market analyses.

The remainder of this paper is structured as follows: Section 2 reviews the theoretical framework of key macroeconomic indicators in construction economics. Section 3 details the data sources and statistical methodology. Section 4 presents the consolidated empirical correlation and regression analyses for inflation, GDP, wages (average and minimum), and unemployment, including structural multicollinearity diagnostics. Section 5 provides a comprehensive discussion of the results, policy implications, and study limitations, while Section 6 concludes the paper and outlines future research directions.

2. Key Macroeconomic Indicators in Construction Economics

The structural intersection between macroeconomic volatility and housing asset pricing is extensively documented in contemporary housing economics. According to [12], residential real estate does not operate in a vacuum; rather, its price velocity is a direct function of macro-financial transmission mechanisms that channel aggregate demand and supply shocks into urban property markets. In Central and Eastern European (CEE) contexts, these dynamics are further compounded by institutional transitions and shifting credit accessibility parameters, making local housing cycles highly sensitive to sudden macroeconomic inflections [13]. Understanding these transmission channels is crucial for establishing benchmarks for sustainable housing affordability, as price-to-income relationships frequently decouple during periods of high monetary volatility [12].

Assessing a nation's macroeconomic performance and its corresponding financial condition relies heavily on the analysis of selected indicators that exert direct or indirect feedback loops on the construction sector. Within the domain of construction economics, the most important macroeconomic indicators associated with residential property valuations include Gross Domestic Product (GDP), inflation, and labor market dynamics (including wages and unemployment). Understanding these transmission mechanisms provides deeper theoretical and empirical insights into the forces shaping property valuations in Poland. The international literature robustly supports the premise that these

macroeconomic fundamentals—primarily representing income capabilities and credit conditions—possess strong explanatory power regarding housing price trajectories and aggregate construction demand [14]. Recent empirical updates by Augustyniak et al. [17] underscore that the Polish residential sector is structurally characterized by cyclical supply-side lag effects and highly reactive demand impulses. When external macroeconomic pressures—such as high inflation or rapid nominal wage appreciation—converge with aggressive state-sponsored demand-side interventions (e.g., subsidized credit regimes), the traditional equilibrium metrics of construction economics are heavily distorted [13]. This creates a strong rationale for conducting data-driven analyses that isolate how primary and secondary market segments differentially process these intense, short-term economic shocks.

2.1. Gross Domestic Product (GDP)

Gross Domestic Product (GDP) serves as the primary metric of aggregate economic productivity and macroeconomic health [19,20]. An expansion in real GDP denotes heightened economic performance, which systematically elevates household disposable incomes and stimulates private and institutional investment in construction projects. Within a growing economy, enhanced corporate profitability and rising consumer confidence typically translate into accelerated demand across both residential and commercial property developments. Consequently, GDP growth acts as a leading indicator of investment intensity and capital allocation within the broader construction sector.

The linkage between GDP growth and residential real estate assets is historically mediated through household wealth effects and institutional credit availability. As argued by [12], sustained macroeconomic expansion drives both primary and secondary housing demand by improving long-term employment expectations. However, in emerging markets like Poland, this transmission mechanism can become heavily asymmetric during short-term economic shocks, where property price growth may temporarily decouple from fundamental GDP trajectories due to speculative capital inflows or structural supply bottlenecks [21,22].

2.2. Inflation and Material Costs

Inflation acts as a dual-channel transmission mechanism influencing residential property valuations [3,23]. On the supply side, inflationary pressures directly escalate construction costs by driving up the prices of building materials, labor, energy, and land, which developers subsequently pass on to consumers in the primary sector. On the demand side, high inflation erodes real household purchasing power and significantly diminishes borrowing capacity. However, during periods of prolonged macroeconomic uncertainty and monetary depreciation, real estate is frequently utilized by domestic and international investors as a tangible capital hedge. This asset-hedging behavior often maintains high transaction volumes and upward pressure on prices, even in high-inflation environments. High inflationary environments introduce complex distortions into construction economics and consumer behavior. According to [24], rising consumer price indices (CPI) not only inflate material production costs on the supply side but also accelerate the erosion of cash reserves, prompting households to shift liquid capital into residential assets as an inflation hedge. Under such high-inflation regimes, traditional housing affordability indices are subject to severe stress, transforming affordable housing from a standard urban metric into a critical socio-economic challenge [25].

2.3. The Theoretical Transmission of Unemployment in Housing Valuation

The unemployment rate serves as a foundational macroeconomic proxy for both household income security and consumer sentiment. In housing economics, a contraction in

unemployment expands the pool of eligible mortgage applicants and reduces default risks, thereby accelerating aggregate demand on the residential market [12]. Conversely, during macroeconomic shocks, the unemployment rate acts as a psychological anchor; even minor upward fluctuations tend to compress speculative demand and decelerate housing price velocity, as potential buyers prioritize liquidity over long-term capital commitments [12]. Within the Central and Eastern European context, low structural unemployment operates as an underlying stabilizer, maintaining high entry-level competition for properties even under severe inflationary pressures [12,13].

2.4. Labor Market, Wages, and Household Affordability

Labor market conditions and wage dynamics represent the foundational pillars of housing demand and social sustainability [26]. The health of the labor market directly governs consumer confidence and the financial capacity of households to commit to long-term mortgage debt.

2.4.1. Average Wages

Average wage growth is one of the key indicators associated with household creditworthiness. Wage growth directly expands the borrowing capacity of potential buyers, enabling access to higher-quality housing and driving growth in the primary development sector. From an investment and development perspective, stable wage growth ensures predictable cash flows, reduces credit default risks, and underpins the economic sustainability of residential investments.

2.4.2. Minimum Wage Policy

While minimum wage adjustments primarily affect lower-income households who rarely participate directly in the high-end primary housing market, they carry substantial indirect weight in construction economics. Increases in the statutory minimum wage elevate the saving and rental capacities of low-income cohorts, thereby expanding demand in subsidized, social, or affordable housing segments and the private rental market. Over time, statutory wage floors contribute to broader price dynamics by establishing a support level for lower-tier property valuations, particularly within highly urbanized regions where affordable housing remains a critical urban development challenge.

Evaluating housing accessibility requires robust, automated data-driven frameworks that continually benchmark asset pricing against real income adjustments [27]. When nominal wage growth fails to keep pace with localized property price acceleration, the secondary market often processes the resulting demand displacement differently than the primary sector [28]. This segmentation highlights the necessity of distinguishing between newly constructed buildings and existing housing stocks when measuring the broader sustainability of urban housing ecosystems [25,28].

3. Methodology

The research framework applied in this study utilizes a quantitative, data-driven analytical approach to evaluate the relationship between selected macroeconomic indicators and residential property valuations. The empirical dataset covers the highly volatile period from 2020 to 2024 and incorporates both quarterly and annual observations.

3.1. Data Sources and Data Preprocessing

To ensure the highest academic reliability and reproducibility, raw empirical data were obtained exclusively from recognized state and international statistical repositories.

Property price indicators—specifically, the average transaction prices per square meter—were gathered from the databases of the National Bank of Poland (NBP), utilizing

official transaction registries (the BaRN database), and Statistics Poland (GUS). The study segments these valuations into two separate sectors of construction economics:

The primary development sector (representing newly constructed residential buildings).

The secondary transactional sector (representing existing properties).

The independent macroeconomic variables were acquired from official institutional repositories, including:

- Inflation dynamics (Consumer Price Index—CPI) and Gross Domestic Product (GDP) growth rates from Statistics Poland (GUS).
- Labor market data (unemployment rates, average monthly wages, and statutory minimum wages) from Statistics Poland (GUS) and Eurostat.

The quarterly dataset was aligned chronologically to eliminate seasonal variations and standardized to ensure mathematical comparability across all variables.

The primary dependent variables analyzed in this empirical framework are the nominal transaction prices per square meter (1 m²) of residential property, segmented across the primary and secondary housing sectors. While transaction pricing fundamentally tracks market valuation, it is deployed in this study as a foundational baseline component for computing housing affordability. In the contemporary sustainability literature, housing affordability cannot be measured using isolated consumer prices; rather, it manifests through the dynamic interface between purchasing power (wages) and real estate asset velocity. Thus, these dependent pricing variables are utilized to map the shifting socio-economic entry barriers for households across the investigated timeline. Accordingly, housing affordability is interpreted in this study as a relative socio-economic condition emerging from the relationship between housing prices and household income, rather than from housing prices alone.

3.2. Statistical Modeling and Mathematical Framework

Statistical preprocessing, correlation analysis, and regression diagnostics were conducted using STATISTICA (version 13.3 software from StatSoft Polska Sp. with a license from the Silesian University of Technology). This software was used for all statistical computations and data analyses reported in the study. The statistical modeling consisted of two main analytical phases: Pearson correlation analysis and bivariate linear regression.

To determine the strength and direction of the linear relationship between each selected macroeconomic indicator and property prices, the Pearson correlation coefficient (r) was calculated using the following mathematical formula:

$$r = \frac{n\sum(XY) - (\sum X) \cdot (\sum Y)}{\sqrt{(n\sum X^2 - (\sum X)^2) \cdot (n\sum Y^2 - (\sum Y)^2)}} \quad (1)$$

where:

- n represents the number of quarterly observations.
- X represents the independent macroeconomic variable (e.g., inflation, wages, GDP).
- Y represents the dependent variable (average price per square meter in either the primary or secondary sector).

The statistical significance of the correlation coefficients was rigorously evaluated at the 95% confidence level ($\alpha = 0.05$), ensuring that the observed associations are mathematically sound and not the result of random fluctuations. To quantify the proportion of variance in property valuations that is predictable from the macroeconomic indicators, the coefficient of determination (R^2) was calculated.

Subsequently, bivariate linear regression models were constructed to quantify the sensitivity of the construction sectors to macroeconomic shocks. The regression equation is defined as:

$$Y = b_0 + b_1 \cdot X + \varepsilon \quad (2)$$

where:

- Y is the predicted property value per square meter.
- b_0 is the intercept constant.
- b_1 is the regression coefficient (representing the sensitivity parameter of the sector).
- X is the macroeconomic indicator.
- ε represents the residual error term.

By running these regression models separately for the primary and secondary sectors, we compare how different market segments respond to identical economic pressures.

To ensure the statistical validity of utilizing separate bivariate linear regression models rather than a single pooled multivariate ordinary least squares (OLS) model, preliminary diagnostics for multicollinearity were rigorously conducted. Macroeconomic predictors during highly turbulent periods typically exhibit extreme degrees of mutual interdependence. In this study, key independent variables demonstrate strong concurrent trends, which introduces a severe structural risk when deployed within a single multivariate OLS framework. To quantify this, the Variance Inflation Factor (VIF) was computed for each macroeconomic predictor. As synthesized in the research, the mean VIF values for associated factors such as the CPI (5.08), Average Wage (10.04), and Statutory Minimum Wage (9.07) significantly exceed the conservative econometric threshold of 5.

Such high VIF values (particularly for wages and CPI) statistically destabilize multivariate coefficient estimates, inflate standard errors, and cause severe sign-reversal anomalies, making it mathematically impossible to isolate the clean, individual marginal effects of each macroeconomic indicator. As a result, the application of individual bivariate regression models is methodologically justified and vital to analyze the unweighted elasticity of primary and secondary housing prices relative to each specific macroeconomic signal.

3.3. Methodological Limitations and Assumptions

While this analytical framework offers high transparency and robust explanatory power, several methodological boundaries must be acknowledged: First, the quantitative models are based on bivariate correlations and simple linear regressions. While this method allows for a highly transparent interpretation of individual indicators and direct comparisons between the primary and secondary sectors, it does not fully capture the multidimensional, simultaneous pressures acting on construction economics. Therefore, the reported relationships should be interpreted as strong statistical associations and transmission trends rather than strict, isolated causal effects. Second, the potential for multicollinearity among the explanatory variables (such as inflation, GDP growth, and wage levels) is inherent in macroeconomic systems. In a real-world economy, these variables do not operate in isolation; wage increases often coincide with inflationary pressure and GDP expansion. While separate modeling of each indicator was deliberately chosen to maintain direct comparability across the primary and secondary sectors, this study addresses this systemic limitation by incorporating post-estimation Variance Inflation Factor (VIF) diagnostics within the results synthesis to validate the boundaries of the empirical framework. Third, this study employs contemporaneous statistical correlations. In practice, macroeconomic shocks—such as shifts in consumer price inflation or labor market security—often affect construction demand and consumer behavior with a temporal lag. Households and institutional investors typically require one or more quarters to

adjust their financial planning and complete transactions. Although contemporaneous modeling was chosen to establish a clear, direct baseline comparison, the existence of lagged responses is a critical factor in interpreting these dynamics. This acknowledges that temporal adjustments represent a valuable path for future dynamic macro-modeling.

Fourth, the deliberate exclusion of central bank reference interest rates and direct quantitative credit availability indicators from the formal linear regression models stems from critical econometric and structural considerations. Throughout the examined 2020–2024 macro-cycle, credit conditions in Poland were subjected to extreme, non-linear regulatory shifts and unprecedented institutional engineering—most notably the sharp tightening of credit-scoring criteria by the Polish Financial Supervision Authority (KNF) in 2022, followed by the immediate, aggressive demand stimulus of the state-subsidized “Safe 2% Mortgage” program in 2023. These events generated highly fragmented, step-wise structural breaks in borrowing capacity that cannot be accurately captured via continuous bivariate linear estimators. Consequently, incorporating policy rates directly into contemporaneous linear equations would introduce severe statistical specification errors, artificially distorting the stable parameters of underlying macroeconomic indicators. Instead, the multi-layered impact of monetary policy shifts and credit tightening is systematically isolated and addressed through a qualitative-structural approach within the discussion framework. This methodological boundary prevents the quantitative models from generating biased elasticity estimates while recognizing credit policy as a fundamental non-linear driver of demand-side market shocks.

3.4. Time-Series Properties and Sample Constraints

When analyzing macroeconomic data from the 2020–2024 period, several specific time-series properties and dataset limitations must be addressed. First, because the study focuses strictly on the unique “double-shock” cycle triggered by the COVID-19 pandemic and the geopolitical crisis associated with the war in Ukraine, the temporal window was intentionally constrained to the 2020–2024 period. Quarterly aggregation yielded $N = 20$ observations representing consecutive quarters from Q1 2020 to Q4 2024. Although the regression framework formally consists of 20 observations, each quarterly data point represents an aggregated macroeconomic and housing-market indicator derived from substantially larger national datasets reported by Statistics Poland (GUS), the National Bank of Poland (NBP), Eurostat, and sectoral housing-market databases. Therefore, each observation reflects the averaged dynamics of numerous monthly, regional, transactional, and institutional data sources characterizing the Polish macroeconomic and residential market environment during the analyzed period. Quarterly aggregation was intentionally applied to improve data comparability, reduce short-term volatility, and better capture medium-term macroeconomic transmission mechanisms affecting housing affordability. While the adopted sample size allows exploratory bivariate estimation and comparative trend analysis, it remains insufficient for more advanced dynamic econometric modeling approaches such as Vector Error Correction Models (VECM), Vector AutoRegression (VAR), or Auto-Regressive Distributed Lag (ARDL) models, which generally require substantially longer non-crisis time horizons and larger observational datasets. Consequently, due to these structural sample size constraints, the reported confidence intervals and p -values are highly sensitive to minor data variations; thus, the empirical outputs are strictly interpreted as descriptive, exploratory markers of this localized crisis cycle rather than absolute, generalizable statistical inferences.

Second, during this hyper-inflationary period, both the independent variables (wages, CPI) and the dependent variables (housing prices) exhibited strong, simultaneous upward trends. Econometrically, such co-trending behavior can inflate the coefficient of deter-

mination (R^2), introducing a risk of partial spurious association where high statistical explanatory power reflects common nominal inflation rather than a direct, long-term equilibrium relationship. To mitigate this, readers should interpret the reported R^2 values as measures of contemporaneous co-movement during an exceptional economic shock phase, rather than permanent, structural elasticities.

As an additional robustness assessment, non-parametric Spearman rank correlations were calculated for the principal affordability-related relationships involving residential property prices, inflation, and wage indicators (Appendix A Table A1). The results remained directionally consistent with the Pearson correlation estimates reported in Table 1, supporting the robustness of the observed descriptive relationships. Nevertheless, due to the short observation window and the common upward trajectories observed among several variables, these findings should still be interpreted as exploratory evidence of short-term macroeconomic co-movement rather than proof of stable structural relationships.

Table 1. Pearson correlation matrix (r) of housing prices and macroeconomic indicators (2020–2024).

Market Segment	CPI (Inflation)	GDP Growth	Average Wage	Minimum Wage	Unemployment Rate
Primary Market	0.94 **	0.56 *	0.98 **	0.97 **	−0.45 *
Secondary Market	0.96 **	0.51 *	0.97 **	0.96 **	−0.39

Note: * $p < 0.05$; ** $p < 0.01$ (two-tailed test). $N = 20$ quarterly aggregated observations derived from national macroeconomic and housing-market datasets covering Q1 2020–Q4 2024.

Furthermore, to structurally address the inherent scale discrepancies among the independent variables—where wages are denominated in nominal currency units (PLN) and GDP growth or unemployment in percentages—the analytical architecture explicitly integrates a cumulative percentage change analysis normalized to a common baseline (Q1 2020 = 0%). This mathematical transformation standardizes the divergent dimensions into a uniform scale, ensuring that the visual and structural velocity of the affordability gap can be directly compared without scale-induced or unit-driven distortions. Accordingly, housing affordability is not measured directly through a formal affordability index, but is assessed indirectly through the relative dynamics of residential property prices and household income indicators.

Although the application of first differences or detrending techniques could formally eliminate the shared nominal trend, this study intentionally utilizes nominal values. This approach directly reflects the decision-making perspective of average consumers and developers, who operate in the market using current transaction prices rather than statistically adjusted ones.

Future research utilizing longer and more stable observation periods will allow for formal integration and cointegration testing (e.g., Augmented Dickey–Fuller and Johansen tests) as well as the application of dynamic econometric frameworks such as VAR and VECM models. These approaches would facilitate a clearer distinction between short-run fluctuations and long-run equilibrium relationships. Until such analyses become feasible, the statistical outputs reported in this study should be interpreted primarily as descriptive indicators of short-term macroeconomic co-movement rather than as robust inferential evidence of stable long-term economic relationships.

4. Empirical Results and Quantitative Macroeconomic Synthesis

To enhance systemic readability and eliminate empirical redundancies associated with fragmented bivariate reporting across multiple subsections, the quantitative results for

the examined macroeconomic indicators (CPI, GDP, average wage, statutory minimum wage, and unemployment) are integrated within a consolidated empirical synthesis. This approach enables a direct, parallel comparison of transmission velocities, predictive fit, and structural sensitivities across the primary development and secondary transactional real estate sectors throughout the turbulent 2020–2024 economic cycle.

The quantitative analysis begins by evaluating the correlation and linear regression models between cumulative inflation (CPI) and average transaction prices per square meter. The empirical findings reveal a strong, statistically significant positive relationship between inflationary pressures and property valuations across both analyzed sectors of the construction economy during the 2020–2024 period.

4.1. Correlation and Determination Analysis

For the primary development sector, the coefficient of determination ($R^2 = 0.884$ with a Pearson correlation coefficient $r = 0.94$, $p < 0.01$) indicates a very high degree of linear association. In the secondary transactional sector, the statistical metrics also confirm an exceptionally strong relationship, yielding an R^2 value of 0.916 ($r = 0.96$, $p < 0.01$). These results, graphically presented in Figure 1, demonstrate that cumulative inflation represents one of the most consistent and closely aligned macroeconomic indicators correlated with price dynamics during the analyzed timeframe.

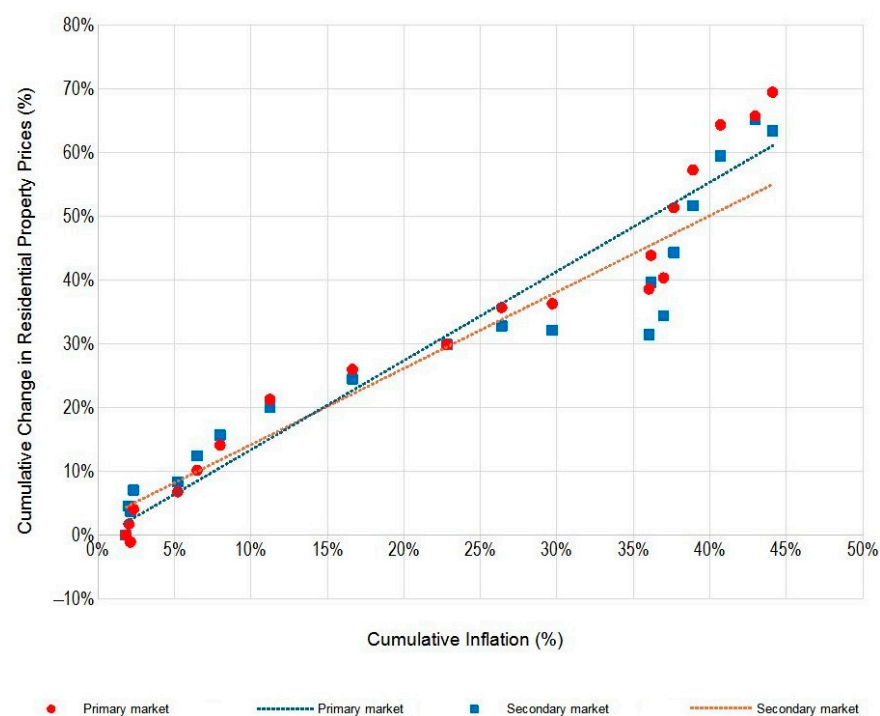


Figure 1. Relationship between cumulative inflation and residential property prices per square meter in Poland’s primary and secondary construction sectors (2020–2024). Source: Author’s elaboration based on data from [3,29,30].

4.2. Regression Modeling and Sensitivity Parameter

The bivariate linear regression analysis quantifies the sector-specific sensitivity to inflationary shocks. The regression equations demonstrate that a 1% increase in cumulative inflation is associated with an average increase of 140.23 PLN/m² (95% CI: [115.1, 165.3]) in the primary sector and an average increase of 109.84 PLN/m² (95% CI: [93.4, 126.3]) in the secondary sector. This consistent pattern indicates that the primary development sector exhibits slightly higher sensitivity to inflationary fluctuations than the secondary sector. These empirical findings are consistent with the international literature, which underscores

inflation as a key cost-push factor associated with nominal asset prices and highlights the structural role of real estate as a reliable capital hedge against monetary depreciation [5]. To ensure that this comparative sensitivity was not distorted by divergent baseline price levels between the two housing market segments, a relative elasticity assessment was additionally performed. Given that average transaction prices in the primary market remained consistently higher than those in the secondary market throughout the 2020–2024 period, the absolute sensitivity coefficients (140.23 PLN/m² versus 109.84 PLN/m²) translate into broadly comparable relative elasticities. In percentage terms, a 1% increase in cumulative inflation corresponds to an approximate 1.15% nominal appreciation in newly constructed properties and a 1.12% increase in existing housing prices. This relative alignment suggests that, even after accounting for baseline price differences, the primary housing market may exhibit slightly stronger responsiveness to inflationary conditions, potentially reflecting stronger exposure to construction cost pressures during the analyzed crisis period.

4.3. Analysis of Policy-Induced Anomalies

As illustrated in Figure 1, a distinct and systemic deviation from the linear regression trendline is observable starting in the second half of 2023. This structural anomaly was triggered by a targeted regulatory intervention—specifically, the implementation of the state-subsidized “Safe 2% Mortgage” program.

This policy created an artificial surge in consumer demand, temporarily distorting the market’s natural price-discovery mechanisms. The resulting divergence is clearly reflected in the scattered observations rising above the projected regression lines in the latter part of the time series. This deviation indicates that short-term government credit subsidies exert a powerful, measurable impact on pricing dynamics, accelerating upward price shifts even under highly restrictive central bank monetary conditions. This regulatory transmission was particularly aggressive in the primary sector, where newly qualified credit buyers concentrated their purchasing activity due to specific programmatic criteria and the immediate availability of new housing inventory.

While inflation exhibits a powerful statistical correlation with residential valuations, its underlying transmission mechanism functions primarily as an amplifying cost-push and hedging force, rather than an independent source of organic household demand.

4.4. Economic Productivity and Production Transmission (GDP Framework)

Between 2020 and 2024, a clear, robust correlation is observable between aggregate economic growth—measured by fluctuations in Gross Domestic Product (GDP)—and residential property valuations. However, the transmission intensity of this relationship varies structurally between the primary and secondary sectors of the construction economy.

The quantitative trend illustrated in Figure 2 suggests a moderate positive relationship between GDP expansion and housing valuations during the analyzed period. In the primary development sector, the coefficient of determination ($R^2 = 0.311$, with a Pearson correlation coefficient $r = 0.56$, $p < 0.05$) indicates a statistically significant but moderate linear correlation. Similarly, the secondary transactional sector exhibits a comparable level of association, yielding an R^2 value of 0.258 ($r = 0.51$, $p < 0.05$). These statistical metrics demonstrate that while broader economic productivity and national output are linked with the construction sector’s pricing mechanisms, GDP growth itself accounts for only about a quarter to a third of the contemporaneous variance in property valuations.

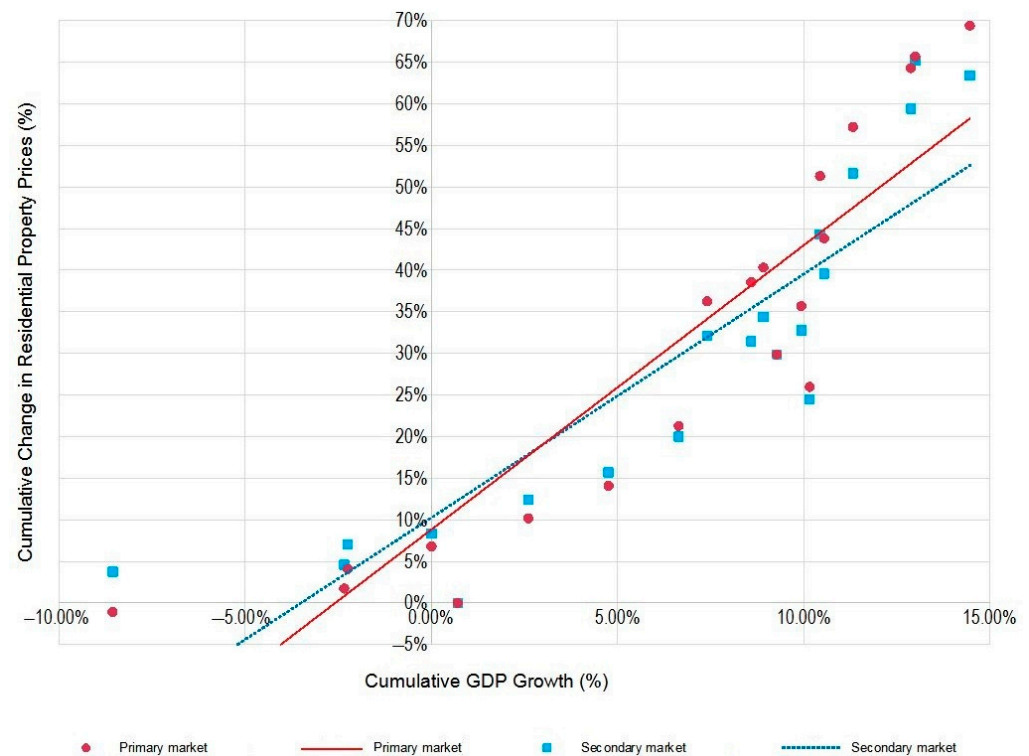


Figure 2. Relationship between GDP growth and residential property prices per square meter in Poland’s primary and secondary construction sectors (2020–2024). Source: Author’s elaboration based on data from [3,29,30].

The bivariate linear regression equations reveal that each 1% increase in GDP growth corresponds to an average transaction price increase of 175.40 PLN/m² (95% CI: [36.1, 314.7]) in the primary sector and an average increase of 123.10 PLN/m² (95% CI: [11.5, 234.7]) in the secondary sector. These results confirm that while GDP growth is moderately correlated with price trajectories in both segments, the primary development sector displays greater sensitivity to macroeconomic expansion than the secondary sector.

Comparative Context and Transmission Mechanisms

These findings align closely with patterns identified in other Central and Eastern European (CEE) economies. In these markets, GDP growth, inflation, and employment dynamics jointly shape property price trajectories. As emphasized by [18], transitional housing and construction markets exhibit heightened responsiveness to macroeconomic shocks due to their evolving financial structures, rapid urbanization, and sensitivity to external capital flows—a framework that strongly reinforces the empirical evidence observed in Poland. It is critical to note that compared to direct demand-side indicators such as wage growth and credit conditions, GDP exerts a more indirect, macro-level influence on property valuations. Rather than representing immediate household purchasing power, GDP fluctuations reflect overall economic expansion, corporate health, job security, and general investment sentiment within the national construction market.

This structural divergence aligns with classical housing models [7], which posit that asset prices adapt asymptotically to macro-level wealth shocks. However, our empirical findings reveal that under extreme economic turbulence, this adaptation is fundamentally asymmetric between sectors. Furthermore, as emphasized in recent sustainable housing frameworks [31], residential development dynamics are inextricably linked to broader spatial and infrastructure shifts; asymmetric price acceleration between newly built urban

projects and existing suburban stocks directly reshapes regional accessibility and triggers long-term structural realignments within the construction ecosystem.

4.5. Labor Market Dynamics and Organic Demand (Average Wages Framework)

Labor market dynamics, particularly household income trajectories, constitute one of the principal demand-side indicators within construction economics. Figure 3 illustrates the empirical relationship between the average monthly wage in the enterprise sector and residential property transaction prices per square meter in Poland from 2020 to 2024. The statistical output reveals an exceptionally strong, positive linear correlation across both the primary and secondary sectors of the construction market.

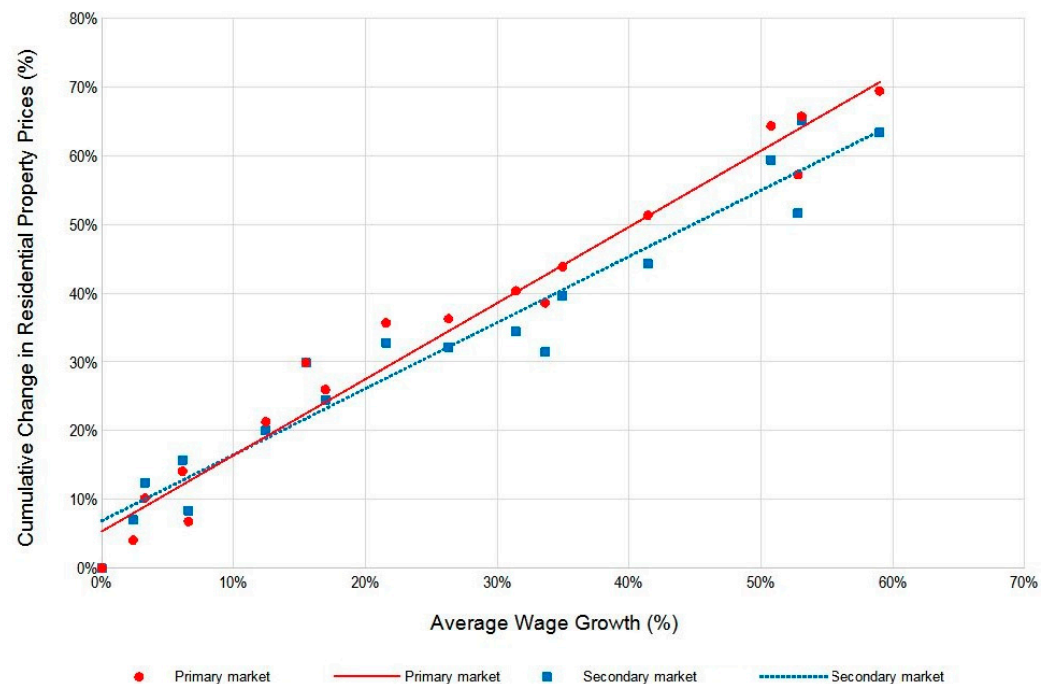


Figure 3. Relationship between average wage growth and residential property prices per square meter in Poland’s primary and secondary construction sectors (2020–2024). Source: Author’s elaboration based on data from [3,29,30].

For the primary development sector, the coefficient of determination ($R^2 = 0.966$, with a Pearson correlation coefficient $r = 0.98$, $p < 0.01$) suggests an exceptionally strong, near-perfect linear association. Similarly, the secondary transactional sector exhibits a highly robust relationship, yielding an R^2 value of 0.941 ($r = 0.97$, $p < 0.01$). These findings demonstrate that nominal wage expansion is the macroeconomic indicator most strongly associated with residential valuations during the analyzed turbulent period.

The bivariate linear regression equations reveal that every 1.00 PLN increase in the national average monthly wage corresponds to an average transaction price increase of approximately 1.11 PLN/m² (95% CI: [1.02, 1.20]) in the primary sector and 0.83 PLN/m² (95% CI: [0.74, 0.92]) in the secondary sector. These sensitivity parameters indicate that the primary sector reacts more intensively to wage improvements than the secondary sector.

The exceptionally high statistical coefficients observed for wage-related variables suggest that part of this estimated effect reflects broader macroeconomic co-movements rather than purely isolated demand-side mechanisms. In particular, wage growth, inflation, and GDP expansion evolved simultaneously during the post-pandemic recovery period, reinforcing their apparent individual influence on housing prices.

While both inflation and wage growth exhibit very strong correlations with property prices, their underlying transmission paths within construction economics differ fundamentally:

- Wage growth directly enhances effective household demand, shifting the consumer utility curve and expanding borrowing capacity.
- Inflation, conversely, amplifies price dynamics primarily through cost-push channels (rising building material and labor costs) and asset-hedging behaviors.

These observations align with the core investment principles outlined by [19], who posited that the structural foundation of long-term property appreciation lies in the stability and upward trajectory of household incomes. Sustainable income levels ensure consistent developer cash flows and support housing affordability. Ultimately, the empirical evidence for Poland suggests that household income dynamics represent not only a critical socio-economic sustainability indicator but also the primary macroeconomic indicator associated with real estate asset valuations from both a macroeconomic and investment perspective.

Among all analyzed macroeconomic indicators, average wage growth emerges as the most robust, reliable, and statistically consistent macroeconomic indicator associated with residential property prices across both the primary and secondary sectors.

4.6. Statutory Wage Regulations and Bottom-Up Price Pressures (Minimum Wage Framework)

While the average wage serves as an indicator of aggregate middle-class purchasing power, statutory wage regulations also exert a significant, indirect influence on construction economics and affordable housing dynamics. Figure 4 illustrates the empirical relationship between the statutory minimum wage and residential property transaction prices per square meter in Poland from 2020 to 2024. The data reveals a highly robust, positive linear correlation across both analyzed market segments.

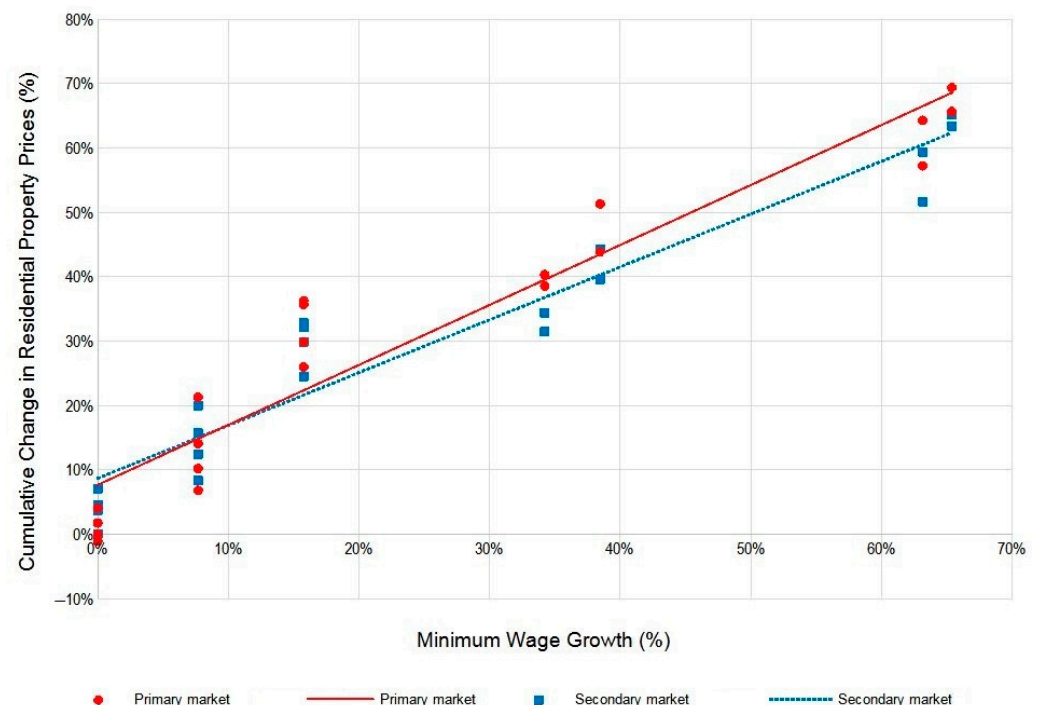


Figure 4. Relationship between minimum wage growth and residential property prices per square meter in Poland's primary and secondary construction sectors (2020–2024). Source: Author's elaboration based on data from [3,29,30].

For the primary development sector, the statistical model yields a coefficient of determination of $R^2 = 0.933$ (with a Pearson correlation coefficient $r = 0.97$, $p < 0.01$), indicating an extremely strong linear relationship. In the secondary transactional sector, the correlation metrics are equally compelling, with an R^2 value of 0.917 ($r = 0.96$, $p < 0.01$) confirming a highly consistent positive association. These results demonstrate that statutory wage floors are deeply aligned with the upward trajectory of property valuations during the analyzed macroeconomic cycle.

The bivariate linear regression equations reveal that every 1.00 PLN increase in the statutory minimum wage corresponds to an average price increase of approximately 2.31 PLN/m² (95% CI: [2.02, 2.60]) in the primary sector and 1.73 PLN/m² (95% CI: [1.49, 1.97]) in the secondary sector. These results suggest that statutory wage adjustments—while not directly targeting the mid- or high-tier development segments—exert a systematic, bottom-up pressure on the broader construction market.

These findings are consistent with international empirical research. In many expanding economies, minimum wage increases have been shown to correlate directly with upward shifts in local housing rents and lower-tier property valuations, particularly in highly densified urban areas [11].

However, from an analytical perspective, it is critical to distinguish between these wage metrics. While the statutory minimum wage exhibits a powerful statistical correlation with residential property prices, its overall explanatory power and direct transmission capacity remain lower than those of average wages. This indicates that statutory wage floors function primarily as a support mechanism for entry-level market segments, whereas average enterprise wages remain the primary macroeconomic indicator associated with aggregate housing demand and construction sector pricing.

4.7. Macro-Level Labor Security and Systemic Stability (Unemployment Framework)

Labor market stability, operationalized through the unemployment rate, represents a critical macro-level indicator of consumer security, creditworthiness, and systematic demand capacity. Figure 5 illustrates the empirical relationship between the national unemployment rate and residential property transaction prices per square meter in Poland from 2020 to 2024. The statistical output reveals a clear, negative linear correlation across both the primary and secondary sectors of the construction market.

For the primary development sector, the coefficient of determination ($R^2 = 0.201$, with a Pearson correlation coefficient $r = -0.45$, $p < 0.05$) indicates a moderate and statistically significant inverse relationship. However, the secondary transactional sector exhibits a weaker, non-statistically significant negative association at the standard confidence level, yielding an R^2 value of 0.151 ($r = -0.39$, $p > 0.05$). These metrics demonstrate that improvements in aggregate labor market conditions are moderately associated with primary market price growth, whereas the secondary market exhibits a less pronounced immediate response to unemployment fluctuations.

The bivariate linear regression equations reveal that a 1 percentage point decrease in the unemployment rate corresponds to an average transaction price increase of approximately 890.30 PLN/m² (95% CI: [−1740.1, −40.5]) in the primary sector. For the secondary sector, the regression coefficient is estimated at −595.40 PLN/m², but its 95% confidence interval [−1360.5, 169.7] crosses zero, confirming that this relationship is not statistically significant at the 95% level. These findings indicate that the primary development sector exhibits greater responsiveness to labor market improvements. This difference stems from the primary market's higher reliance on credit-financed transactions, which are directly sensitive to employment stability. These empirical results align with international evidence. For example, previous studies have shown that regional job creation is associated with up-

ward pressure on nearby housing valuations in European transition economies, reinforcing the spatial and structural linkage between employment security and property economics. Compared to direct income-related variables, the unemployment rate exerts a more indirect and temporally lagged influence on pricing dynamics. In construction economics, changes in employment conditions do not immediately translate into transaction volumes. Households typically adjust their investment plans gradually; a decline in unemployment strengthens purchasing power and consumer confidence with a temporal lag of several quarters before manifesting as nominal price growth. Recognizing this delayed transmission channel is essential for accurately interpreting the structural dynamics of affordable housing and sustainable urban development. To preserve methodological consistency across all examined correlates, it must be explicitly clarified that no formal exploratory time-lagged statistical estimations (e.g., lagged autoregressive or distributed lag structures) were executed within the quantitative modeling framework. The discussion of delayed transmission pathways and temporal lags relies entirely on structural–theoretical inference derived from the contemporaneous models and established macroeconomic literature. Given that employment stabilization affects household investment behaviors through a gradual restoration of creditworthiness and long-term financial confidence, these temporal dynamics are integrated into the analysis conceptually, highlighting a critical prospective boundary for future dynamic macro-modeling.

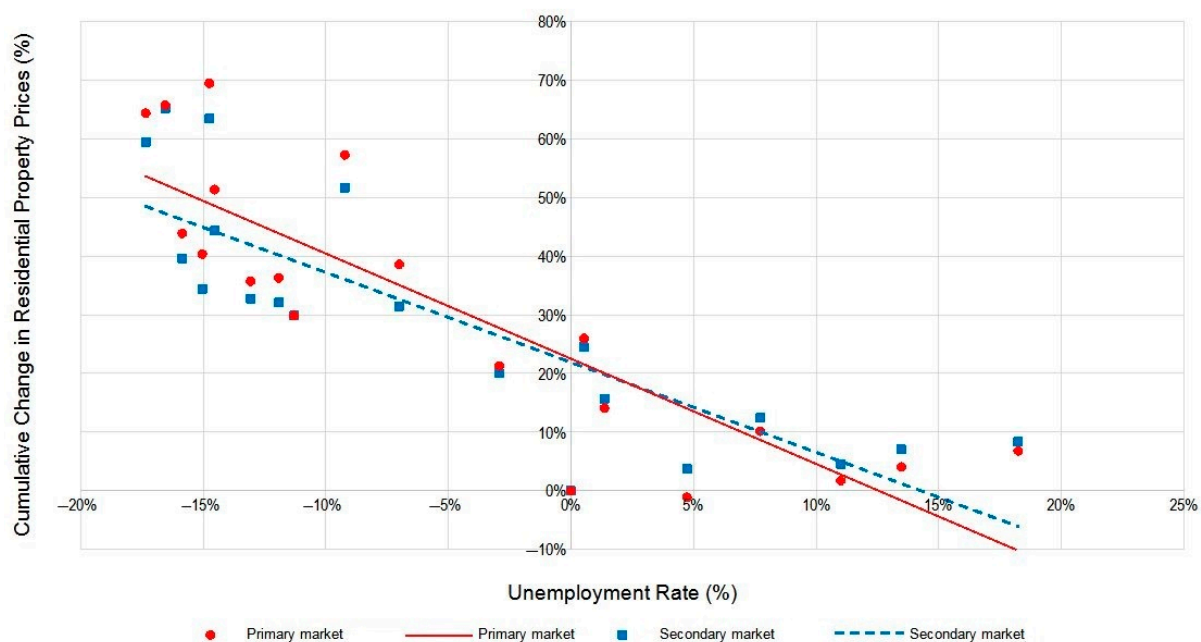


Figure 5. Relationship between the unemployment rate and residential property prices per square meter in Poland’s primary and secondary construction sectors (2020–2024). Source: Author’s elaboration based on data from [3,29,30].

4.8. Statistical Regression Synthesis and Multicollinearity Diagnostics

To provide a comprehensive comparative overview of the macroeconomic transmission mechanisms shaping construction economics in Poland, Tables 1 and 2 synthesize the statistical outputs of all analyzed modeling parameters.

Table 2. Summary of bivariate linear regression models (2020–2024).

Independent Variable	Dep. Var	Slope (b1)	95% CI for b1	R ²	Adj. R ²	RMSE	t-Stat	F-Stat	Durbin–Watson	p-Value
CPI (Inflation)	Primary Market	140.23	[115.1, 165.3]	0.884	0.878	215.4	11.71	137.1	1.89	<0.001
CPI (Inflation)	Secondary Market	109.84	[93.4, 126.3]	0.916	0.911	187.2	14.01	196.2	1.94	<0.001
GDP Growth	Primary Market	175.40	[36.1, 314.7]	0.311	0.273	524.1	2.85	8.12	2.01	0.011
GDP Growth	Secondary Market	123.10	[11.5, 234.7]	0.258	0.217	548.7	2.50	6.26	1.96	0.022
Average Wage	Primary Market	1.11	[1.02, 1.20]	0.966	0.964	102.5	22.61	511.2	2.08	<0.001
Average Wage	Secondary Market	0.83	[0.74, 0.92]	0.941	0.938	126.8	16.94	287.1	2.12	<0.001
Minimum Wage	Primary Market	2.31	[2.02, 2.60]	0.933	0.929	138.4	15.82	250.3	1.91	<0.001
Minimum Wage	Secondary Market	1.73	[1.49, 1.97]	0.917	0.912	171.9	14.12	199.4	1.95	<0.001
Unemployment	Primary Market	−890.30	[−1740.1, −40.5]	0.201	0.157	612.7	−2.13	4.53	2.17	0.047
Unemployment	Secondary Market	−595.40	[−1360.5, 169.7]	0.151	0.104	655.3	−1.79	3.21	2.11	0.089

Note: CI = Confidence Interval; R² = Coefficient of determination; Adj. R² = Adjusted coefficient of determination; RMSE = Root Mean Square Error. All models are calculated using N = 20 quarterly aggregated observations.

The quantitative models synthesized in Tables 1 and 2 provide a practical and transparent framework for scenario-based assessments of housing sector sensitivity. To ensure the statistical validity of utilizing separate bivariate linear regression models rather than a single pooled multivariate ordinary least squares (OLS) model, preliminary diagnostics for multicollinearity were rigorously conducted. Macroeconomic predictors during highly turbulent periods typically exhibit extreme degrees of mutual interdependence. In this study, key independent variables demonstrate strong concurrent trends, which introduces a severe structural risk when deployed within a single multivariate OLS framework. To quantify this, the Variance Inflation Factor (VIF) was computed for each macroeconomic predictor.

As synthesized in Table 3, the mean VIF values for key associated factors such as the CPI (5.08), Average Wage (10.04), and Statutory Minimum Wage (9.07) significantly exceed the conservative econometric threshold of 5. Such elevated VIF values confirm substantial multicollinearity among the macroeconomic predictors. In multivariate modeling, these properties destabilize coefficient estimates, inflate standard errors, and trigger potential sign-reversal anomalies, making it structurally impossible to isolate the clean, individual marginal effects of each macroeconomic indicator.

Table 3. Multicollinearity diagnostics for macroeconomic predictors.

Variable	Mean VIF
CPI	5.08
GDP Growth	3.02
Average Wage	10.04
Minimum Wage	9.07
Unemployment	2.04

Consequently, the application of separate bivariate regression models is methodologically justified and vital to analyze the unweighted, clean elasticity of primary and secondary housing prices relative to each specific macroeconomic signal. To further strengthen statistical reliability, additional regression diagnostics were incorporated into the analytical framework. Adjusted R^2 values indicated that the explanatory performance of the models remained stable after accounting for the relatively limited quarterly sample size ($N = 20$). Root Mean Square Error (RMSE) indicators demonstrated acceptable predictive dispersion across the estimated models, while Durbin–Watson statistics remained close to the benchmark value of 2.0, suggesting no evidence of severe first-order autocorrelation within the residual structures. Although the study is based on a short-term crisis-oriented time horizon, the applied diagnostics support the internal consistency and statistical adequacy of the adopted bivariate modeling framework for exploratory macroeconomic assessment.

5. Discussion

The empirical findings of this study suggest that macroeconomic conditions are strongly associated with residential property price dynamics and broader affordability pressures in Poland. These findings remain consistent with recent sustainable housing frameworks that emphasize the necessity of aligning policy with economic reality [32]. Among the analyzed variables, average wage expansion and cumulative inflation (CPI) exhibit the most robust, direct associations with pricing trajectories across both primary and secondary transactional sectors.

This dominant statistical association of income-related variables aligns with the established housing literature. Rising nominal wages are commonly associated with higher household disposable incomes and greater mortgage borrowing capacity, which may contribute to stronger demand-side pressures in housing markets. As wage-earning thresholds rise, access to financial credit improves, enabling prospective buyers to enter the market and contributing to a strong co-movement with increasing per-square-meter property valuations.

Concurrently, the exceptionally strong positive correlation between cumulative inflation and property values reflects the unique macroeconomic shocks observed in Poland during the 2020–2024 period. During cycles of rapid monetary depreciation, real estate assets are heavily utilized as reliable wealth-preservation vehicles. This capital-hedging behavior is frequently associated with elevated transactional activity among both individual and institutional investors and may coincide with stronger nominal price growth. These strategies are supported by the established real estate investment literature [33].

Similar inflation-transmission patterns have been observed across other European transitional markets, validating the asset-hedging role of residential real estate during periods of systemic uncertainty [34,35].

However, a key contribution of this research lies in demonstrating how these macroeconomic signals correlate asymmetrically across different sectors of the construction market:

- The primary development sector exhibits significantly higher sensitivity to regulatory shifts, material cost pressures, and direct government programs. Because newly built housing is heavily reliant on developer financing structures and programmatic support, credit-subsidy programs are strongly associated with developer transaction volumes and price dynamics.
- The secondary transactional sector, by contrast, suggests a more direct alignment with broader, underlying consumer expectations and household wealth dynamics, reflecting a more gradual adjustment process to macroeconomic fluctuations. The complexity of these relationships under high inflationary pressure and their impact on affordability indices have been extensively documented in recent studies on price dynamics.

These sectoral differences were dramatically amplified by policy-driven interventions. The introduction of the “Safe 2% Mortgage” program in July 2023 serves as a prime example of how short-term demand-side regulatory credit subsidies can temporarily disrupt natural price-discovery mechanisms. By subsidizing mortgage interest rates for first-time homebuyers, this fiscal policy artificially restored household borrowing capacity in an environment otherwise constrained by high inflation. However, because housing supply is structurally inelastic in the short run due to planning and construction lags, this sudden, policy-driven demand shock led to a rapid escalation of transaction prices. This intervention appears to have disrupted the historical relationship between wage growth and property valuations, particularly in the primary metropolitan sectors, suggesting that targeted credit-subsidy programs may contribute to increased affordability pressures under conditions of constrained housing supply.

This structural reliance on credit-driven demand, especially during periods of highly volatile regulatory shifts, is thoroughly documented in national financial supervision analyses [29]. This dependency and the transmission mechanisms of demand shocks into the real estate market are further confirmed by analyses concerning macro-financial stability in the context of monetary policy [36].

The findings should also be interpreted within the broader regulatory framework governing the Polish construction sector. Since the introduction of nearly zero-energy building (NZEB) requirements under the recast Energy Performance of Buildings Directive (EPBD), developers have faced increasing obligations related to energy efficiency and environmental performance. While these measures contribute substantially to long-term sustainability objectives, they are also associated with higher construction costs resulting from the implementation of advanced building technologies and low-emission materials. In the context of the analyzed period, characterized by elevated inflation and rapidly increasing housing prices, these regulatory requirements may have further intensified affordability pressures, particularly among first-time homebuyers. This highlights the continuing challenge of balancing environmental sustainability goals with housing accessibility.

From a social sustainability perspective, housing is not merely a financial asset but a fundamental human need, requiring a continuous equilibrium between production input costs and the long-term purchasing power of consumers [12]. When property valuations grow disproportionately to household income, it exacerbates the risk of housing exclusion, disrupts the baseline level of sustainable housing affordability, and deteriorates social cohesion [12,13]. In Poland, this macroeconomic disparity has driven a major urban planning phenomenon: urban sprawl. As city centers become financially inaccessible to average earners due to asymmetric inflation transmission channels, demand shifts toward metropolitan peripheries and suburban areas where land prices are lower. This migration pattern generates significant ecological and infrastructure challenges, including increased automobile dependency, higher transport emissions, and the fragmentation of natural landscapes. Therefore, failing to anchor housing policy within broader macroeconomic realities accelerates social exclusion and destabilizes urban ecosystems, thereby undermining the core targets of United Nations Sustainable Development Goal 11 (SDG 11) [12,13]. The positive capitalization of infrastructure access into property values is a well-documented phenomenon, though in the context of suburban sprawl, it often exacerbates the spatial mismatch between residential location and employment hubs [31].

Therefore, modeling the relationship between macroeconomic indicators and housing prices is vital not only for financial forecasting but also for designing balanced housing policies that secure both economic stability and sustainable urban development.

Finally, labor market dynamics suggest that structural employment conditions underpin the economic sustainability of the construction sector. While the unemployment rate

exhibits lower contemporaneous statistical explanation compared to direct wage growth, its influence operates as a powerful underlying stabilizer. Lower unemployment levels translate into enhanced household income predictability and systemic financial security. This encourages households to undertake long-term mortgage commitments, reinforcing steady investment and production cycles within the national construction sector.

From a broader perspective of economic and social sustainability, these empirical findings yield critical policy implications. The high sensitivity of the primary construction sector to short-term demand-side credit subsidies suggests that such interventions tend to accelerate price-push dynamics rather than resolve underlying housing shortages. Accordingly, rapid price appreciation disproportionately affects younger cohorts, driving residential exclusion and accelerating suburban sprawl with its associated environmental costs (such as transport emissions and landscape fragmentation). To foster resilient urban development, public policies should pivot from short-term demand engineering toward long-term supply-side support, including the promotion of energy-efficient public housing and sustainable, long-term rental frameworks.

To accurately compare the dynamics of heterogeneous economic indicators and eliminate scale-effects, a cumulative percentage change analysis was conducted using Q1 2020 as the baseline (0%). As illustrated in Figure 6, throughout the 2020–2022 period, the growth of both the minimum and average wages closely tracked or outpaced cumulative inflation and property price growth, suggesting a relatively balanced relationship between wage growth and residential price dynamics. However, a structural divergence occurs in 2023. Driven by policy-induced demand shocks (the ‘Safe 2% Mortgage’ program), residential prices on both primary and secondary markets began to outpace wage growth, with property price cumulative growth accelerating up to 80%, potentially widening affordability pressures within the residential housing sector.

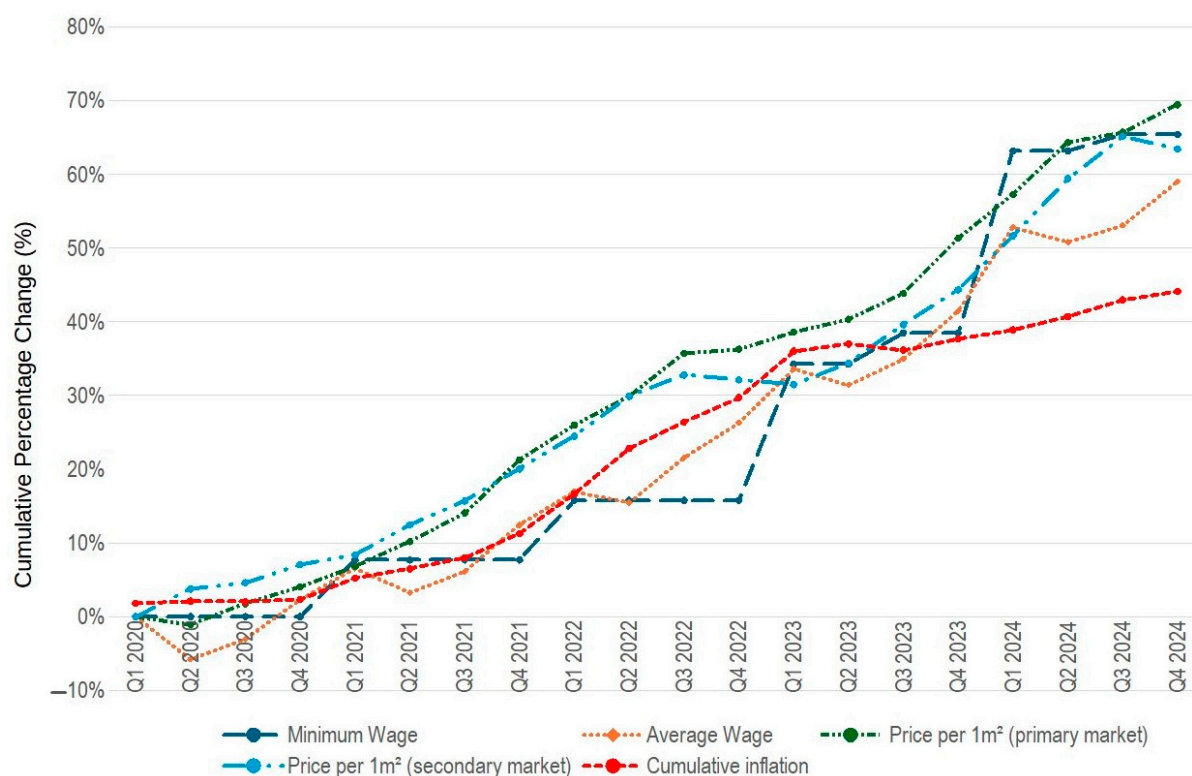


Figure 6. Comparative divergence between residential property prices and wage dynamics in Poland (2020–2024): an exploratory affordability-oriented perspective based on cumulative percentage changes (Q1 2020 = 0%). Source: Authors’ elaboration based on data from [3,29,30].

Although the analysis does not construct a formal housing affordability index, affordability pressures are explored through the relative evolution of residential property prices and household income indicators. Consequently, the affordability dimension discussed in this study should be interpreted as an exploratory assessment of the divergence between housing price growth and income growth rather than as a direct measurement of housing affordability.

By expressing all variables as cumulative percentage changes (%), the analysis normalizes differences in the original scales of macroeconomic indicators and housing price levels. This approach allows direct comparative visualization of the relative divergence between residential price growth and household income indicators during the analyzed period.

Despite the internal consistency of these findings, several methodological limitations must be explicitly detailed to guide proper interpretation. First, the persistent nominal upward trajectory of wages, consumer prices, and housing valuations during the high-inflation environment of 2020–2024 introduces an inherent risk of spurious correlation within contemporaneous linear structures. Under such macroeconomic conditions, concurrent directional movements can artificially inflate linear association parameters. Therefore, the reported regression coefficients and correlation parameters should be interpreted as descriptive indicators of short-term macroeconomic co-movement within the specific 2020–2024 crisis environment rather than as evidence of stable long-term relationships or universally transferable economic mechanisms.

Second, direct supply-side physical indicators—such as the volume of construction permits issued, housing starts, and active developer inventories—were not incorporated into the continuous quantitative framework. During the volatile 2020–2024 period, the transmission from planning permissions to completed supply was heavily distorted by material supply-chain disruptions and speculative financing pauses, making traditional linear supply-to-price elasticity parameters highly unstable. These supply-side and institutional constraints were therefore integrated qualitatively into the structural discussion. Accordingly, the reported associations should be interpreted as partial representations of housing market dynamics, since part of the observed variation in residential property prices may also reflect unobserved supply-side constraints, including construction activity, housing inventories, planning restrictions, and material cost pressures.

Third, while macroeconomic effects often propagate into the real estate market with distinct temporal lags, the quantitative modeling herein focuses strictly on contemporaneous associations due to the highly compressed, crisis-driven nature of the 2020–2024 cycle. Attempting to formally estimate distributed lag structures or cross-correlations within this restricted observational window ($N = 20$) would critically reduce the available degrees of freedom, compromise the numerical stability of the linear estimators, and substantially increase the risk of overparameterization. Accordingly, the present study should be interpreted as an exploratory macroeconomic assessment of short-term housing affordability pressures during an exceptional crisis-driven economic cycle.

6. Conclusions

The empirical investigation presented in this study, contextualized within the broader framework of construction economics and macroeconomic policy, suggests a consistent statistical pattern of association between selected macroeconomic indicators and residential property valuations in Poland between 2020 and 2024. The quantitative data-driven models reveal a clear comparative pattern of statistical association among the analyzed indicators, characterized by systematic structural asymmetries between the primary and secondary real estate segments. Income- and price-related variables exert the strongest direct statistical

influence on property valuations, while broader systemic indicators play a more complex, indirect role. Specifically:

- Average wage growth exhibited the strongest contemporaneous statistical association with residential property prices, highlighting the important role of household purchasing capacity within the analyzed housing market dynamics. Notably, the primary housing market appears to exhibit slightly stronger responsiveness to nominal wage growth compared to the secondary market segment.
- Cumulative inflation (CPI) exhibited the second-strongest statistical association with residential property prices during the analyzed period. During periods of heightened macroeconomic volatility and monetary depreciation, residential assets frequently function as capital-preservation vehicles. This cost-push transmission manifests more aggressively in newly constructed properties due to immediate building material and energy cost premiums.
- Gross Domestic Product (GDP) growth occupies an intermediate position, reflecting general economic productivity and developer investment sentiment, accounting for roughly a quarter to a third of the contemporaneous price variance across both sectors.
- The unemployment rate displayed the weakest contemporaneous statistical association, operating as an underlying economic stabilizer that transmits through delayed consumer confidence and gradual labor-market adjustments, with statistically significant impacts isolated predominantly within the credit-dependent primary sector.

This structural comparative pattern is highly consistent with empirical patterns reported for other Central and Eastern European (CEE) transition economies. Furthermore, this research highlights that targeted regulatory interventions can dramatically reshape short-term market behaviors. The implementation of the state-subsidized “Safe 2% Mortgage” program serves as a clear demonstration of policy-induced demand engineering that fundamentally disrupted the market’s organic income-to-price dynamics. While this fiscal mechanism temporarily expanded credit access, its concentration within a highly rigid supply-side environment accelerated upward price pressures, demonstrating that credit subsidies divorced from parallel supply-side housing development strategies risk undermining the core targets of United Nations Sustainable Development Goal 11 (SDG 11) by reducing long-term housing affordability.

From a practical and sustainable engineering perspective, the findings offer vital insights for public policy, urban planning, and developer investment strategies:

- For policymakers: Based on the established statistical co-movements, stabilizing housing affordability cannot be achieved in isolation. Macroeconomic stabilization, statutory minimum wage adjustments, and environmental building regulations (such as EPBD standards) must be holistically integrated into long-term housing strategies to prevent social housing exclusion, regional wealth inequalities, and urban sprawl.
- For developers and construction managers: The heightened sensitivity of the primary development sector to macroeconomic fluctuations underscores the necessity of integrating advanced, data-driven forecasting models into early-stage investment planning. Aligning production and investment cycles with wage growth and inflation trajectories is essential for optimizing life-cycle costing (LCC) and mitigating financial risks.
- From an investment standpoint: The results suggest that Polish residential valuations remain strongly aligned with nominal macroeconomic trends during the observed period and household income dynamics, reinforcing the characterization of residential real estate as a resilient, long-term asset class rather than a speculative instrument driven solely by short-term volatility.

Finally, the methodological limitations of this study point toward valuable future research directions. While the application of separate bivariate regression models was rigorously justified and validated by post-estimation Variance Inflation Factor (VIF) diagnostics to isolate the unweighted elasticities of each macroeconomic indicator, this framework does not fully capture the multidimensional, simultaneous feedback loops inherent in construction economics. Additionally, the analysis is limited by its aggregate national scope, omitting spatial regional heterogeneities and qualitative indicators such as consumer sentiment. Future research could significantly build upon these findings by employing multivariate autoregressive frameworks, incorporating formal temporal lag structures, and integrating spatial econometrics to capture localized and delayed adjustment mechanisms.

Ultimately, within the boundaries of this exploratory framework, the empirical findings indicate that sustainable housing accessibility and the economic sustainability of the construction sector in Poland are fundamentally dependent on macroeconomic stability. In the context of modern urban development, aligning housing supply timing with structural macroeconomic cycles is imperative for maintaining resilient, long-term, and balanced urban growth.

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Conflicts of Interest: Author Kamil Roter was employed by the company Beck & Pollitzer Polska Sp. z o.o. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A

Table A1. Spearman rank correlations (ρ) between residential property prices and selected macroeconomic indicators (robustness assessment).

Market Segment	CPI (Inflation)	Average Wage	Minimum Wage
Primary Market	0.993 **	0.988 **	0.985 **
Secondary Market	0.985 **	0.974 **	0.975 **

Note: Spearman rank correlation coefficients (ρ) were calculated as a supplementary robustness assessment. The results remained directionally consistent with the Pearson correlation estimates reported in Table 1, supporting the robustness of the observed descriptive relationships. ** $p < 0.01$ (two-tailed test). N = 20 quarterly observations covering Q1 2020–Q4 2024.

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