

HOUSING RENTAL AVAILABILITY INDEX: A TOOL FOR ADDRESSING SUPPLY-DEMAND CHALLENGES IN RENTAL MARKETS

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Abstract. We develop a Housing Rental Availability Index (*HRAI*) to measure rental housing availability across Poland by incorporating household income, rental prices, and supply-side factors. The *HRAI* is constructed using the structured parametric approach, offering a comprehensive and adaptable framework for analysing rental housing dynamics in Poland. Based on the Polish rental market data from 2021 to 2024, the *HRAI* reveals that supply constraints and rent fluctuations have a greater impact on rental availability than household income. This result challenges traditional affordability metrics. Sensitivity analysis confirms that rental availability emerges from the interaction of supply and demand rather than from either factor alone. This integrated approach positions *HRAI* as an “anti-separatist” indicator and presents an original approach to examining rental housing availability. The index can help local and national policymakers design targeted rent subsidies, address supply-demand imbalances, and promote spatial equity. Our findings highlight the value of combining economic measures into a single availability index and provide a framework for applying the *HRAI* in both academic research and housing policy decisions.

Keywords: rental housing, Housing Rental Availability Index (*HRAI*), supply-side factors, housing affordability, housing market dynamics, rental housing policies.

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1. Introduction

Over the past several decades, there has been a growing financial strain on housing budgets due to rising housing prices (Egan et al., 2024). Rental housing has increasingly emerged as an essential alternative to property ownership, with an estimated 1.2 billion individuals worldwide choosing this form of accommodation (Gilbert, 2016). According to Eurostat data in 2021, approximately 30% of the European Union (EU) population rent their accommodations. The demand for rental housing has been steadily increasing, consequently impacting the supply side of housing.

The availability of rental housing in Poland has been the subject of recent research and requires further exploration. Martyniak (2025) observes a growing trend in housing availability in Poland, noting that it remains insufficient to meet the needs of average households. Suszynska (2017) emphasizes the prevalence of owner-occupied housing in Poland, with over 75% of the housing stock being owner-occupied. This suggests a limited supply of rental housing. Several studies indicate a decline in the availability of public rental housing in Poland, signaling an underdeveloped private rental housing sector and suggesting the necessity for a more comprehensive understanding of the rental housing market (Rubaszek, 2019; Rubaszek & Rubio, 2019).

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The topic of rental housing availability in Poland has garnered interest from diverse academic circles, market research institutions, and government organizations due to the challenges in addressing housing needs in the Polish economy. Although there is a strong desire for home ownership, certain constraints force some individuals to opt for renting (Rubaszek & Rubaszek, 2021). In Poland, the primary factor driving rentals is economic constraints, particularly the inability to acquire real estate (Derkacz & Gajda, 2023). This makes the rental housing segment a crucial socio-economic and political concern. Thus, the question of the availability of apartments capable of meeting the demand for rental accommodation emerges. While considerable research and analysis have been conducted on the availability of apartments for sale, there is a noticeable lack of attention given to the rental segment. Therefore, to address the gap in understanding the rental housing segment, this research seeks to develop a synthetic indicator to assess and analyze the level of rental housing availability in Poland.

Existing literature often equates housing availability with vacancy rates (Gabriel & Nothaft, 1988), which

provide limited insights into whether those vacant units are accessible for potential tenants. While other measures, such as the OECD housing need index and the UN-Habitat urban housing indicators, are useful in assessing national housing adequacy or monitoring slum conditions, they are less effective in capturing availability of rental housing (OECD, 2021; Citaristi, 2022). Yet, neither captures the complex interaction between tenants' financial ability and the availability of housing units. In this study, we refer to availability in the context of the ability of households to access rental units that are both present in the market and affordable relative to their income levels.

Through investigating and analyzing the rental housing segment, we conclude that estimating housing availability solely based on average incomes and median transaction prices is insufficient. Although household budget constraints are a significant determinant in the decision to rent, they are not the sole factor. Equally important, if not more so, is the issue of housing availability on the supply side of the market. Tenant preferences also play a significant role in constraining the housing supply, effectively limiting it from the perspective of a specific tenant. Therefore, a one-sided approach to housing access—whether based on affordability alone or supply-side metrics alone—is theoretically inadequate. We hypothesize that although income factors primarily influence the availability of rental housing in Poland, supply-side factors also significantly impact it. One should not claim, for example, that housing is affordable for households if they are not able to choose housing according to their preferences. On the other hand, a variety of rental offers on the market cannot be considered sufficient if households cannot afford to rent or buy a dwelling. Such observations have led us to the above hypothesis. Our analysis treats these two components as coequal dimensions of housing availability.

The primary contribution of this research is the proposed method for estimating a synthetic index of rental housing availability that has been validated using data from the real economy. In the econometric analysis, we utilize rental listing data from Otodom.pl, one of the Polish real estate market's largest and most popular online platforms. This platform features thousands of active rental listings across Poland each month. Our results accurately reflect the real estate market's dynamics, as we observe changes in rental housing availability that align with expert opinions in the real estate market. In addition, the proposed index estimation method allows for a relatively precise interpretation of results over the analyzed periods. Despite its seemingly uncomplicated construction, the presented index is a potentially universal tool for researching rental housing availability in Poland. Our results could also serve as an impetus for further research, particularly regarding the impact of rental housing availability on rental prices. All these factors contribute to the potential of this index to effectively fill the cognitive gap in this area.

The remainder of the paper is structured as follows. First, we critically review the literature on affordability, structural supply constraints, and conceptual limitations in

measuring rental availability. Next, we provide a detailed background of the proposed Housing Rental Availability Index (*HRAI*) method and methodological framework. We then interpret the research results in the results section. In the last section, we conclude our findings with a discussion and implications for housing policy and future research.

2. Related literature review

In recent years, the concept of rental housing availability has received growing attention in global policy and academic debates. While rental housing affordability, typically expressed as rent-to-income ratio in a way that does not impose a financial burden (Favilukis et al., 2023; Abelson, 2009; Stone, 1994; Arnerić et al., 2024), has long been the focus of housing research, this approach often overlooks supply-side factors and real-time market responsiveness. In reality, households may face a paradox: despite meeting affordability thresholds, they are unable to access suitable rental housing due to limited supply, misaligned quality, or location constraints (Derkacz & Gajda, 2022). This conceptual distinction is central to the development of the *HRAI*.

2.1. Structural supply constraints and demand pressures in rental housing

Empirical literature suggests that housing supply refers to the quantity of rentals, or the existing housing stock (Kholodilin, 2024). The availability of housing stock, or housing supply, is categorized not only by the size (like the housing stock, new construction of new or demolition of old homes or apartment buildings), but also by its composition, which can be expressed by ownership structure and vacancy rates. Structural determinants—such as the cost of land, construction rates, regulations, housing policies, and restrictions (refer to supply-side constraints)—significantly impact the capacity and responsiveness of the housing supply (Hilbers et al., 2008; Kim & Seo, 2021). Thus, a reduction in supply can occur through reduction of construction, demolition, conversion to non-residential uses, or the transformation of rental units to owner-occupied homes, regulatory restrictions on new developments or land-use, increased construction costs, all of which can deepen the housing shortage and further impact the rental market. A high rate of homeownership can reduce the share of housing available for rent, potentially marginalizing the private rentals sector (Suszynska, 2017).

International research provides compelling evidence that demand-side dynamics also shape the availability of rental housing. These include robust macroeconomic trends, growing immigration, rising interest rates, and an increased number of renter households due to the lack of affordability in the housing market, and increasing rents (Chapman, 2021; Kleshcheva, 2021; Tajani et al., 2022), adding extra stress on the rental market. Tax incentives can also influence demand (Wood & Ong, 2013). Additionally, platforms like Airbnb and rising tourism have expanded short-term rental demand, thereby reducing availability of

long-term rental units (Ključnikov et al., 2020; Kettunen & Ruonavaara, 2022; Seiler et al., 2023) and leading to rising apartment prices (Trojanek et al., 2023). In Italy, for example, real estate values have risen significantly since the early 1980s, without delivering more accessible housing options (Rondinelli & Veronese, 2011). These supply-side constraints and demand-side pressures further exacerbate structural imbalances, particularly in contexts of growing income inequality and shifting renter demographics.

Additionally, exogenous shocks, such as the COVID-19 pandemic (Shen & Wilkoff, 2022) and recent high rent inflation due to geopolitical conflicts (e.g., the war in Ukraine), have affected housing availability by disrupting supply and pushing rents upwards. These factors interact with constraints to influence rental prices, vacancy rates, and market equilibrium.

2.2. Income inequality and barriers to rental housing access

The relationship between income inequality and access to rental housing is well-documented. Rising income disparity often leads to increased rents in prime urban areas, crowding out lower-income households (Dong, 2017; Kang et al., 2023). Glaeser et al. (2009) highlight that in areas with high income inequality, the demand for higher-quality rental units from wealthier households leads to increased rents, reducing access for other households. Although it might appear that higher incomes should improve housing affordability, this is not always reflected in increased availability, as the relationship between income and housing availability is not as strong as expected (Udensi et al., 2024). This dynamic helps explain why the correlation between income and rental availability is weaker than expected in this study, as income inequality and limited housing supply combined create additional barriers, making the situation even worse for low-income households, who cannot afford housing. This is partly due to the widening gap between people on high and low incomes and obstacles such as the limited housing supply. As wealthier people demand more expensive and better housing, lower-income residents have fewer options, making it more difficult to find a home. This finding is consistent with the observation that the relationship between income and access to rental housing may be weaker, mainly due to income inequality and supply constraints.

2.3. Conceptual gaps in measuring rental housing availability

A review of scientific literature in this area reveals that rental housing availability is often analyzed primarily from an income perspective of affordability. The foundation of the concept of housing affordability lies in the relationship between household incomes and relative prices, and in the rental segment, household incomes and rent (Stone, 1994). This perspective emphasizes purchasing power as a determinant of both homeownership and ac-

cess to rental housing. Affordability is typically analyzed through budgetary constraints, with two main approaches: the proportion of household income allocated to housing cost (purchase or rental, including utilities), and the amount of residual disposable income for other expenses (Stone, 2006; Arnerić et al., 2024). Numerous definitions of housing affordability have been proposed (Williams, 1990; Hancock, 1993; Freeman et al., 1997; Burke & Ralston, 2004; Robinson et al., 2006; Gan & Hill, 2009), yet they all fundamentally center on the income side. Existing approaches tend to reduce availability to affordability metrics, such as the rent-to-income ratio (Stone, 2006). Although the concept of availability can, in principle, be considered from the perspectives of buyers, tenants, and property owners, in the context of the rental segment, it is typically framed in terms of tenants' income relative to rental costs (Zakrzewska-Półtorak & Pluta, 2023). For instance, some studies use affordability measures to refer to availability, such as calculating the number of square meters accessible at prevailing market rents for an average wage (Szelągowska, 2021). However, these approaches combine financial ability with actual market supply, ignoring whether such housing is physically available in sufficient quantity. While affordability focuses on a household's ability to pay, availability refers to the actual existence of accessible and suitable housing units. As Yoshida and Kato (2022) argue, availability must also be analyzed in relation to supply-side constraints, such as construction rates, regulatory barriers, and the spatial distribution of units. Studies exploring affordability in terms of investment costs, financing, and macroeconomic conditions (Abelson, 2009; Kleshcheva, 2021; Liu & Ong, 2021) fall short of capturing how these factors translate into rental access.

Beyond affordability metrics, several additional indicators have been proposed to measure housing availability. A widely referenced measure is the vacancy rate, which reflects the percentage of unoccupied rental units (Gabriel & Nothaft, 1988). While it indicates underused housing stock, it does not account for whether vacant units are affordable, well-located, or of desirable quality (Gabriel & Rosenthal, 2005). Moreover, in a tight market, vacancy rates may often remain low, despite existing unmet demand.

At the international level, several indicators aim to capture housing conditions and needs more broadly. The OECD's Housing Need Indicator, as a part of the OECD Affordable Housing Database, serves as a comparative tool to assess access to adequate and affordable housing across countries using household surveys. It incorporates metrics such as housing quality, affordability, and public policy evaluation (OECD, 2021). However, while useful for cross-country comparisons of housing needs, its focus is primarily based on household well-being and policy outcomes, rather than on the market dynamics of rental availability. Similarly, the UN-Habitat Urban Housing Indicators focus on global urban housing challenges, particularly in slums and informal settlements (Citaristi, 2022). While valuable for tracking broad housing quality and infrastructure

gaps, these indicators are less suited for assessing rental housing availability.

Furthermore, research on housing supply elasticity (Molloy, 2020) predominantly focuses on the housing sales market. Studies that do examine rental housing (Molloy et al., 2022) tend to analyze affordability by adjusting rent levels for housing quality or using indirect indicators like property size, land area, and household location choices. Yet, even these efforts fail to address the broader structural conditions that determine whether suitable housing is available in the first place.

The filtering model of housing markets provides an important theoretical framework for understanding rental housing availability across different income levels. The model highlights that in conditions of limited supply or rising costs, housing units initially priced at higher levels may gradually become available to lower-income households over time (Somerville & Holmes, 2001). This model helps contextualize the *HRAI* within a broader understanding of housing market dynamics and account for both affordability and actual housing stock availability.

Despite growing international attention to rental challenges, research on rental housing availability in Poland remains limited, particularly compared to studies on owner-occupied housing (Tomal, 2020). It indicates a need for a more comprehensive analysis of the rental housing segment and motivates our approach. Building on these limitations, we argue that the concept of housing availability must adopt a broader perspective, integrating supply-side constraints. In the Polish rental housing segment, we observe a recurring paradox: although rental housing seems affordable for households in terms of income and price,

it often remains unavailable due to insufficient supply or supply structure (Derkacz & Gajda, 2022). These mismatches arise not only from quantitative shortages but also from tenant expectations regarding quality, location and types of housing. This paradox motivated the development of a new indicator that captures housing availability from both affordability and supply perspectives, offering a more comprehensive view on the rental market.

Existing housing indicators and affordability metrics have contributed to understanding specific aspects of housing access; however, none comprehensively integrates supply-side constraints and market conditions in rental housing. Table 1 summarizes key indicators used in housing research, highlighting their strengths and limitations in capturing affordability, availability, and rental-specific dynamics. This comparison provides the conceptual rationale for the development of the Housing Rental Availability Index.

3. Methodology

The proposed Housing Rental Availability Index (*HRAI*) method initially emphasizes the income aspect. This means that the level of rental housing availability will be determined by household income capabilities, addressing the demand side. Naturally, the primary factor at this stage will be the level of household income (*HI*). The primary goal of this study is to develop an index that reflects the actual potential for households to rent an apartment – not just the number of units available on the market, nor whether rental prices are affordable relative to income, but how these two measures interact. Examining affordability or availability in isolation provides only a partial perspective.

Table 1. Comparative overview of key housing indicators in the rental market (source: compiled by authors)

Indicator	Main focus	Level of measurement	Captures			Rental-specific	Key limitations
			Affordability	Supply constraints	Physical availability		
Rent-to-income ratio	Affordability (financial burden)	Household	yes	no	no	yes	Ignores market availability and supply-side constraints
Vacancy rate	Stock utilization	Market/neighborhood	no	no	yes	yes	Does not consider affordability, quality, or location
Sq. m. per avg. wage	Income-based housing access	Household	yes	no	partial	yes	Assumes linear relationship; does not reflect quality or supply limits
OECD housing need indicator	Quality, affordability, policy assessment	Country/comparative	yes	partial	no	no	Not rental-focused; emphasizes policy and outcome evaluation
UN-Habitat urban housing indicators	Urban housing condition, infrastructure	Country/city	partial	no	yes	no	Broad focus on slums/informality; not adapted for rental markets
HRAI (proposed)	Rental housing availability	Household/market	yes	yes	yes	yes	Integrates affordability and supply-side constraints; suited to national rental gaps

In reality, households face both the financial constraints and the limitations of existing supply at the same time. Thus, our approach integrates both demand-side (income and rent) and supply-side (rental stock) components. While these variable are often analyzed separately in housing studies, we argue that combining them into a single index offers a more comprehensive and realistic reflection of rental market dynamics.

In this analysis stage, the level of rental housing availability is determined by the ratio of income to rent (RP). This can be expressed as follows:

$$HRAI'_t = \frac{HI_t}{RP_t}, \quad (1)$$

where: HI_t represents household income and RP_t denotes the average monthly rent payment. The subscript t denotes time. This formula reveals the income capability for renting housing at real rental prices. Thus, the value of $\alpha_t = 1 - \frac{RP_t}{HI_t}$ can be considered an indicator of average disposable incomes after rental expenses. Notably, the rent payment at this stage will be treated as an offered rent rather than a transactional one.

The availability of rental housing in the economy is also determined by supply-side factors. Therefore, the proposed method introduces the quantity of rental housing supply (RS) as an additional factor. It is defined as the number of rental listings in a given period. The $HRAI$ incorporates an index of rental supply dynamics, calculated on a month-to-month basis using the base variable formula ($rs_t = \frac{RS_t}{RS_{t-1}} \times 100$). This approach ensures that factors influencing availability and/or its changes are the dynamics of supply changes rather than their nominal values. The filtering model of housing markets informs this methodology, as it explains how changes in housing supply led to the transition of rental units between affordability tiers. As supply-side constraints increase, higher priced rental units gradually become accessible to lower income households. This dynamics is incorporated into the $HRAI$, which accounts for both supply-side factors and income disparities in assessing rental housing availability.

In this research, we assume that the rental housing supply is influenced to some extent by the level of rental prices (RP). Similarly, an index of rental price dynamics is utilized, expressed as $rp_t = \frac{RP_t}{RP_{t-1}} \times 100$. This implies that changes in rental prices may affect changes in supply. Landlords may adjust their rental offerings based on anticipated revenues, leading to potential changes in supply. Increased housing supply may result in lower rental prices due to increased supply-side competition. Conversely, higher rental prices may incentivize property owners to rent out their properties, thereby increasing the housing supply. Based on this, the supply–rent dynamic index ($SRPI$) is defined as follows:

$$SRPI_t = \frac{rs_t}{rp_t}. \quad (2)$$

It indicates the relationship between the dynamics of rental housing supply changes and the dynamics of changes in average rental prices. The levels of the $SRPI$ can be interpreted as follows:

- if $SRPI = 1$, there is a balanced price dynamics of housing supply;
- if $0 \leq SRPI < 1$, there is a delayed supply dynamics relative to rp_t ;
- if $SRPI < 0$, there is a very delayed supply dynamics relative to rp_t ; and
- if $SRPI > 1$, there is a leading supply dynamics relative to rp_t .

Delayed supply dynamics indicate that the rate of change in housing supply in the economy is slower than the changes occurring in rental prices. This also means that prices are increasing faster than changes in rental housing supply. Leading supply dynamics indicate the opposite situation. Meanwhile, balanced price dynamics of housing supply occur when $rp_t = rs_t$. This makes the $SRPI$ a specific rent elasticity of housing supply in the rental segment.

At this point, it is possible to present the final form of the $HRAI$:

$$HRAI_t = \frac{HI_t}{RP_t} \times rs_t \times \frac{1}{rp_t}. \quad (3)$$

This formulation reveals the combined determinism of three aspects of rental housing availability: (1) the income aspect from the perspective of households, (2) the supply aspect, and (3) the aspect of rental prices. Consequently, an increase in income levels and higher supply dynamics relative to rent dynamics increase the value of the $HRAI$. Conversely, an increase in the dynamics of rental prices reduces the availability of rental housing for households. Equation (3) can be transformed into another form using the formulas of the dynamics index rp_t :

$$HRAI_t = HI_t \times rs_t \times \frac{RP_{t-1}}{RP_t^2} \times 100. \quad (3.1)$$

This form of the index emphasizes the rent aspect. The level of rents in period t significantly influences the value of the $HRAI_t$ more strongly than in period $t - 1$. The value of RP_t is raised to the power of 2. In addition, the value of the $HRAI_t$ is directly proportional to the level of rents in period $t - 1$ and inversely proportional to those in period t . This means an increase in rents in period t compared to period $t - 1$ will exponentially decrease rental housing availability. This relationship can be defined as the rental housing availability rent index $\rho_t = \frac{RP_{t-1}}{RP_t^2} \times 100$. Therefore, we have the following:

$$HRAI_t = HI_t \times rs_t \times \rho_t. \quad (3.2)$$

An increase in the $HRAI$ may indicate an improvement in market conditions (supply-side perspective) regarding the dynamics of changes in rent levels. This directly contributes to an improvement in rental housing availability.

Therefore, it can be said that the p index affects the sentiments of potential tenants regarding market rent levels.

When $HRAI_t = 1$, it indicates that with the balanced price dynamics of housing supply ($SRPI = 1$), the rent has become equal to household income. In practice, this may indicate that the income of such a household does not allow for renting a property due to basic consumption needs. For theoretical interpretation purposes, we assume that the rental price level accepted by the household due to the level of essential consumption cannot exceed $HI \times 0.5$. This would mean that only when $HRAI_t = 2$ will renting be available for such a household under certain market conditions. Furthermore, the value of the $HRAI$, the higher the rental housing availability under specific market conditions.

During the research, an additional argument suggests that availability should be based not on incomes and rental prices in a given month, but on their changes. Therefore, certain adjustments are made to the original assumptions.

Equation (1) now includes the values $hi_t = \frac{HI_t}{HI_{t-1}} \times 100$ and rp_t , which was defined earlier. Therefore, the final form of the $HRAI$ is written as follows:

$$HRAI_t^D = \frac{hi_t}{rp_t} \times rs_t \times \frac{1}{rp_t} = hi_t \times rs_t \times \frac{1}{rp_t^2}. \quad (4)$$

We will refer to this index version as the dynamic index, to distinguish it from the form in Equation (3). This change does not significantly affect the interpretation of the index. Only the income aspect gains dynamic significance. This form of the $HRAI$ has additional research value. Since many available datasets provide only indices of changes in the variables used here, utilizing the dynamic version of the $HRAI$ allows for a new interpretation. Notably, the results $HRAI_t^D$ will constantly oscillate around the value of 1. In this context, the following interpretational rules can be introduced. Depending on the obtained results, we have the following:

- if $HRAI_t^D = 1$, there is balanced availability;
- if $HRAI_t^D > 1$, there is increased availability; and
- if $HRAI_t^D < 1$, there is decreased availability.

Balanced rental availability indicates a certain equilibrium between the dynamics of household income changes and the housing supply in relation to the dynamics of rental price changes. An increase in rental availability indicates that the values from the numerator have increased faster than rents. Conversely, a decrease in housing availability indicates that the rental housing market is unfavorable for households seeking rental accommodation.

To examine how the $HRAI$ responds to shifts in market conditions, we carry out a sensitivity analysis by adjusting the key variables – HI , RP , and RS . This approach illustrates the index's behavior under different economic scenarios and allows for an initial assessment of its stability.

We verify the proposed method for estimating rental housing availability in Poland based on offer data from two primary sources. The first is the online platform Otodom.pl, owned by the OLX Group. Alongside Olx.pl and

Nieruchomości-online, Otodom.pl is one of the largest platforms where Poles post offers for, among other things, rental housing. Rental agencies also utilize such platforms, making data from these sources optimal for analyzing housing supply in the rental housing segment. Based on this data, we establish the following:

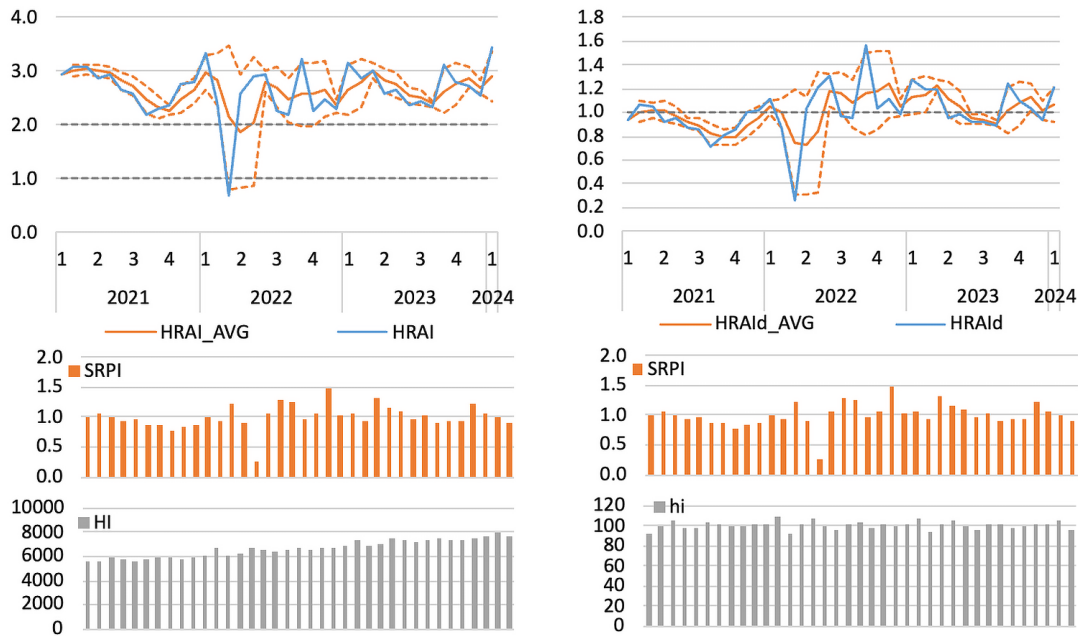
- RP_t is the average monthly rent for rental apartments in Poland, and
- RS_t is the number of monthly rental offers (number of offers at the end of the period).

The second source of statistical data is Statistics Poland. From these databases, we utilize information on the average gross monthly wage in the enterprise sector, which we assign to the variable HI_t .

4. Results

We simultaneously estimate the rental availability index using Equations (3) and (4) with a monthly frequency. This allows for a comparison of the results and their interpretation methods. Figure 1 presents the estimated $HRAI$ and $HRAI^D$ their average values over 3 months (AVG). We find that from January 2021 to January 2024, the average value of the $HRAI$ was 2.18, with a median of 2.22. This result indicates that the average rental availability in Poland is sufficient. The rental availability index meets the condition $HRAI > 2$. However, it should be emphasized that the coefficient of variation during this period was 16.3%. This indicates relatively low variability, although it is statistically significant. Analyzing the monthly results of the $HRAI$ throughout the entire period reveals periods when its value falls below 2.0. This means that during these periods, rental housing availability is insufficient.

Particular attention should be paid to March 2022, when the $HRAI$ dropped to 0.69. This dramatic decrease in rental availability is the result of a significant influx of immigrants from war-torn Ukraine. During this time, several million Ukrainians arrived in Poland. Some of them settled in private homes and apartments of Poles, who also abandoned market rentals in favor of assisting refugees. This situation had a very intense impact on the housing market, especially in the rental segment. Based on this, we conclude that the proposed $HRAI$ correctly revealed the described changes. If we analyze the phenomenon in March 2022 from the household income (HI) perspective, rental availability, based solely on the income aspect, we should not have reacted at all. As the average monthly wage increased compared to February 2022, availability should have increased. The supply-rent dynamics index ($SRPI$) used in the proposed method behaved entirely differently. It clearly revealed the ongoing changes in the real economy regarding the decrease in supply caused by the shock of newly arrived Ukrainians, accompanied by an increase in rental prices. The situation described here, although socially tragic, turned out to be a circumstance that positively verifies the correctness of this study's rental housing availability index.



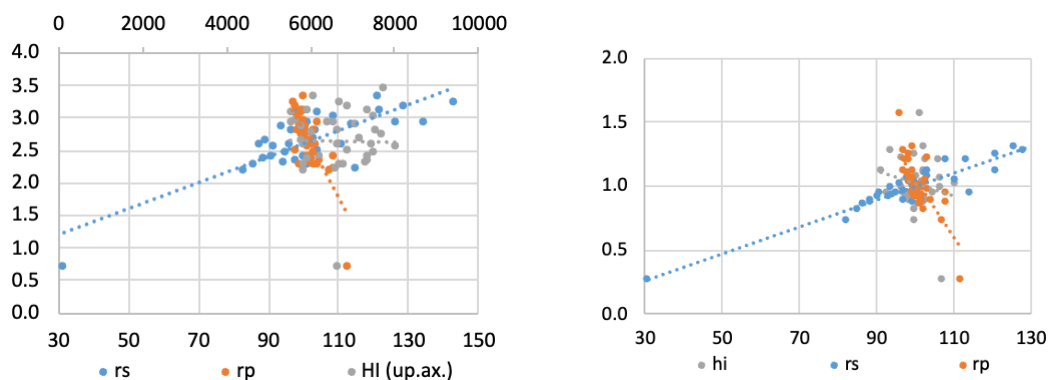
Note: Refers to the estimated Housing Rental Availability Index ($HRAI$) and dynamic $HRAI$ ($HRAI^D$) from January 2021 to January 2024, along with Supply-Rent Dynamics Index ($SRPI$) and Household Income (HI/hi) indicators. See the text for details on the methodology and impact of external shocks.

Figure 1. Comparison of the $HRAI$ (left panel) with the dynamic $HRAI^D$ (right panel) against their $SRPI$ and HI/hi indicators (source: compiled by authors, OLX Group, Statistic Poland)

Next, we address the dynamic rental housing availability index ($HRAI^D$) presented in the right panel of Figure 1. Analyzing the results obtained from January 2021 to January 2024, we observe that the median reached 1.00, the mean was 1.01, the standard deviation was 0.18, and the coefficient of variation was 17.7%. Comparing the two values, it must be noted that they exhibit strong convergence. The Pearson coefficient was 0.93, and the R -squared value was 0.87. A distinctive feature of the $HRAI^D$ is its greater dynamism. However, the directions of change are the same. This means that the significance of the two rental housing availability index versions is highly similar. However, the way relevant to this study's results, which should be noted. The theoretical methodological assump-

tions are confirmed. For the dynamic index, the critical value is $HRAI^D = 1$. This value indicates balanced rental housing availability. We find that this defined critical value for the $HRAI^D$ coincides with the critical value of $HRAI = 2$. This allows for utilizing either of the two options of the rental housing availability index in research and analysis of the rental segment. However, it is essential to remember the interpretational rules explained in the methodology section.

We next focus on the main determinants that influence the outcomes of the $HRAI$ and $HRAI^D$: (1) the income aspect from the perspective of households, (2) the supply aspect, and (3) the aspect of rental prices (see Figure 2). We observe that household income levels have a relatively



Note: rs refers to dynamics of change in rental supply; rp refers to the dynamics of changes in rent; HI – household income; hi – dynamics of changes in household income. See the text for details of correlations.

Figure 2. Correlations of the $HRAI$ (left panel) and the dynamic $HRAI^D$ (right panel) with respect to the main determinants (source: compiled by authors, OLX Group, Statistic Poland)

weak influence on the values of both versions of the rental housing availability index. The Pearson correlation coefficient was -0.02 for the *HRAI* and 0.15 for the *HRAI^D*. There is no significant correlation in either case. Completely different relationships are observed in relation to the supply change index (*rs*). In this case, the Pearson coefficient was 0.90 for the *HRAI* and 0.95 for the *HRAI^D*. This means that a dynamic increase in housing supply (number of rental offers) strongly influences the increase in rental availability. We observe another relationship of the availability index in relation to the dynamics of rental price changes (*rp*). The Pearson correlation coefficient was -0.93 for the *HRAI* and -0.89 for the *HRAI^D*. In this case, we also observe a strong correlation, albeit inversely proportional. This implies that a dynamic increase in rental prices results in a decrease in rental housing availability.

A detailed analysis of the above dependencies suggests another conclusion. The relatively stronger impact on the rental housing availability index – in each of the two versions – is exerted by the indices of changes in each of the three factors rather than their nominal values. Table 2 presents a comparison of the Pearson coefficients. The results may indicate that the level of supply or rental price in a given month is not as important as the fact that this value has increased or decreased. The dynamics of changes in the values of these variables have proven to be significantly more important.

The relationship between changes in supply or rental price levels and housing availability appears justified in the real economy. The issue of rental housing availability concerns individuals making decisions about renting accommodation. In this context, the more crucial information might be whether the number of offers for preferred housing has increased or decreased. Similarly, this applies to the rental price and income levels. Positive changes in any of these three factors will serve as stimuli for making decisions about renting accommodation rather than their current state. Therefore, it can be argued that the dynamic index of income-supply-based housing availability has an advantage over the original *HRAI*. Thus, it can be concluded that changes in supply and rental price levels primarily determine the level of rental housing availability. Therefore, changes in the socio-economic environment are more significant than the current state in which potential tenants decide to rent accommodation.

The study effectively highlights the hypothesis that supply-side factors dominate rental availability while household income has a limited influence. To strengthen this, the study could explicitly test and refine sub-hypotheses. One poten-

tial sub-hypothesis could be: “Supply-side constraints have a statistically significant negative impact on rental availability”. In this context, supply-side constraints should be defined as a decrease in the size of *RS*. This means that $rs < 100$. This would involve focusing on measurements when there is a decrease in supply, which would allow for the verification of the sub-hypothesis. At the same time, these are the measurements that reveal an increase in the supply-side constraint. Based on this, a Pearson correlation coefficient of $R = 0.925$ was obtained. The result of the Student’s *t*-test was $p = 3.85E-18$, providing strong evidence to reject the null hypothesis. This means that an increase in restrictions on the supply of rental housing is highly likely to have a downward effect on rental availability. Furthermore, this relationship is highly statistically significant.

Another potential sub-hypothesis could be: “An increase in household income has a significant and positive effect on rental availability” (H_0 : An increase in household income is consistent with an increase in rental availability). To test this hypothesis, the values of *HI* and *HRAI* were compared only during periods when $hi > 100$. This yielded a Student’s *t*-score of $p = 1.96E-23$ and an *R*-score of $R = -0.02$, which indicates that rental housing availability is relatively rigid to increases in household income. Therefore, the null hypothesis can be rejected.

Formulating these example hypotheses as formal statements further clarify the analytical focus of the study and provides a structured path for empirical validation. This approach also facilitates a clearer interpretation of the results. Additional sub-hypotheses could be defined and explored. However, we leave this aspect for further research to validate and refine the proposed method.

The obtained results can certainly be subjected to various statistical tests. However, our primary objective was to propose an indicator that captures rental housing availability from both an income and supply perspective. The key novelty lies in integrating these two dimensions. In the course of the academic discussions, a novel interpretation—referring to the *HRAI* as an “anti-separatist” indicator. This term reflects the fact that the Housing Rental Availability Index simultaneously incorporates both demand-side (income/affordability) and supply-side (housing stock/rental availability) factors.

To illustrate this, we briefly present the results of a sensitivity analysis. The results reveal how housing availability in the rental market will change as a result of changes in the main independent variables. The Equation (3”) was used to conduct the simulations. Table 3 shows the results for the example period of December 2023, during which the *HRAI* value was 2.35, the *HI* was 8033 EUR, and the *rs* variable was equal to 90.6%. This *HRAI* value serves as the baseline and is highlighted in the tables below. In the simulation, we assumed that household income changes by 2% (decreases to the left, increases to the right of the baseline) and the *rs* indicator by ± 1 pp. The following Tables 4 and 5 also for alternative variable pairings, specifically *HI-rp* and *rp-rs*.

Table 2. The Pearson correlation coefficients of the rental housing availability indices with the independent variables (source: compiled by authors)

	<i>HI</i>	<i>hi</i>	<i>RS</i>	<i>rs</i>	<i>RP</i>	<i>rp</i>
<i>HRAI</i>	-0.08	-0.38	0.33	0.90	-0.17	-0.92
<i>HRAI^D</i>	0.11	-0.24	0.08	0.95	0.11	-0.88

Table 3. Sensitivity analysis of the *HRAI* index against changes in *HI* and *rs* variables for December 2023 (left panel) and relative changes (in %) against the baseline *HRAI* index over the baseline period (right panel)

2023_12		HI - household income											
rs - rental supply dynamics	HRAI=	7230	7390	7551	7712	7872	8033	8194	8354	8515	8676	8836	
	2.35												
	85.6	1.99	2.04	2.08	2.13	2.17	2.22	2.26	2.30	2.35	2.39	2.44	
	86.6	2.02	2.06	2.11	2.15	2.20	2.24	2.29	2.33	2.38	2.42	2.47	
	87.6	2.04	2.09	2.13	2.18	2.22	2.27	2.31	2.36	2.40	2.45	2.49	
	88.6	2.06	2.11	2.16	2.20	2.25	2.29	2.34	2.39	2.43	2.48	2.52	
	89.6	2.09	2.13	2.18	2.23	2.27	2.32	2.37	2.41	2.46	2.51	2.55	
	90.6	2.11	2.16	2.20	2.25	2.30	2.35	2.39	2.44	2.49	2.53	2.58	
	91.6	2.13	2.18	2.23	2.28	2.32	2.37	2.42	2.47	2.51	2.56	2.61	
	92.6	2.16	2.21	2.25	2.30	2.35	2.40	2.45	2.49	2.54	2.59	2.64	
	93.6	2.18	2.23	2.28	2.33	2.37	2.42	2.47	2.52	2.57	2.62	2.67	
	94.6	2.20	2.25	2.30	2.35	2.40	2.45	2.50	2.55	2.60	2.65	2.69	
	95.6	2.23	2.28	2.33	2.38	2.43	2.47	2.52	2.57	2.62	2.67	2.72	

2023_12		HI - household income											
rs - rental supply dynamics	HRAI=	7230	7390	7551	7712	7872	8033	8194	8354	8515	8676	8836	
	2.35												
	85.6	-15.0	-13.1	-11.2	-9.30	-7.41	-5.52	-3.63	-1.74	0.15	2.04	3.93	
	86.6	-14.0	-12.1	-10.1	-8.24	-6.32	-4.41	-2.50	-0.59	1.32	3.23	5.15	
	87.6	-13.0	-11.0	-9.11	-7.18	-5.24	-3.31	-1.38	0.56	2.49	4.43	6.36	
	88.6	-12.0	-10.0	-8.07	-6.12	-4.16	-2.21	-0.25	1.71	3.66	5.62	7.57	
	89.6	-11.0	-9.01	-7.04	-5.06	-3.08	-1.10	0.87	2.85	4.83	6.81	8.79	
	90.6	-10.0	-8.00	-6.00	-4.00	-2.00	0.00	2.00	4.00	6.00	8.00	10.00	
	91.6	-9.01	-6.99	-4.96	-2.94	-0.92	1.10	3.13	5.15	7.17	9.19	11.21	
	92.6	-8.01	-5.97	-3.93	-1.88	0.16	2.21	4.25	6.29	8.34	10.38	12.43	
	93.6	-7.02	-4.96	-2.89	-0.82	1.24	3.31	5.38	7.44	9.51	11.57	13.64	
	94.6	-6.03	-3.94	-1.85	0.24	2.32	4.41	6.50	8.59	10.68	12.77	14.85	
	95.6	-5.04	-2.93	-0.82	1.30	3.41	5.52	7.63	9.74	11.85	13.96	16.07	

Table 4. Sensitivity analysis of the *HRAI* index against changes in *HI* and *rp* variables for December 2023 (left panel) and relative changes (in %) against the underlying *HRAI* index over the base period (right panel)

2023_12		HI - household income											
rp - rental price dynamics	HRAI=	7230	7390	7551	7712	7872	8033	8194	8354	8515	8676	8836	
	2.35												
	96.6	2.22	2.27	2.32	2.37	2.42	2.47	2.52	2.57	2.62	2.66	2.71	
	97.6	2.20	2.25	2.30	2.34	2.39	2.44	2.49	2.54	2.59	2.64	2.69	
	98.6	2.18	2.22	2.27	2.32	2.37	2.42	2.47	2.51	2.56	2.61	2.66	
	99.6	2.15	2.20	2.25	2.30	2.34	2.39	2.44	2.49	2.54	2.58	2.63	
	100.6	2.13	2.18	2.23	2.27	2.32	2.37	2.42	2.46	2.51	2.56	2.61	
	101.6	2.11	2.16	2.20	2.25	2.30	2.35	2.39	2.44	2.49	2.53	2.58	
	102.6	2.09	2.14	2.18	2.23	2.28	2.32	2.37	2.42	2.46	2.51	2.56	
	103.6	2.07	2.12	2.16	2.21	2.25	2.30	2.35	2.39	2.44	2.48	2.53	
	104.6	2.05	2.10	2.14	2.19	2.23	2.28	2.32	2.37	2.42	2.46	2.51	
	105.6	2.03	2.08	2.12	2.17	2.21	2.26	2.30	2.35	2.39	2.44	2.48	
	106.6	2.01	2.06	2.10	2.15	2.19	2.24	2.28	2.33	2.37	2.41	2.46	

2023_12		HI - household income											
rp - rental price dynamics	HRAI=	7230	7390	7551	7712	7872	8033	8194	8354	8515	8676	8836	
	2.35												
	96.6	-5.34	-3.24	-1.14	0.97	3.07	5.18	7.28	9.38	11.49	13.59	15.69	
	97.6	-6.31	-4.23	-2.15	-0.07	2.02	4.10	6.18	8.26	10.34	12.43	14.51	
	98.6	-7.26	-5.20	-3.14	-1.08	0.98	3.04	5.10	7.16	9.22	11.29	13.35	
	99.6	-8.19	-6.15	-4.11	-2.07	-0.03	2.01	4.05	6.09	8.13	10.17	12.21	
	100.6	-9.11	-7.09	-5.07	-3.05	-1.03	0.99	3.01	5.03	7.05	9.07	11.09	
	101.6	-10.0	-8.00	-6.00	-4.00	-2.00	0.00	2.00	4.00	6.00	8.00	10.00	
	102.6	-10.9	-8.90	-6.92	-4.94	-2.96	-0.97	1.01	2.99	4.97	6.95	8.93	
	103.6	-11.7	-9.78	-7.81	-5.85	-3.89	-1.93	0.03	1.99	3.95	5.92	7.88	
	104.6	-12.6	-10.6	-8.70	-6.75	-4.81	-2.87	-0.93	1.02	2.96	4.90	6.85	
	105.6	-13.4	-11.5	-9.56	-7.64	-5.71	-3.79	-1.86	0.06	1.99	3.91	5.83	
	106.6	-14.2	-12.3	-10.4	-8.50	-6.60	-4.69	-2.78	-0.88	1.03	2.93	4.84	

Table 5. Sensitivity analysis of the *HRAI* index to changes in the *rs* and *rp* variables for December 2023 (left panel) and relative changes (in %) to the underlying *HRAI* index over the base period (right panel)

2023_12		rs - rental supply dynamics											
rp - rental price dynamics	HRAI=	85.6	86.6	87.6	88.6	89.6	90.6	91.6	92.6	93.6	94.6	95.6	
	2.35												
	96.6	2.33	2.36	2.39	2.41	2.44	2.47	2.49	2.52	2.55	2.58	2.60	
	97.6	2.31	2.33	2.36	2.39	2.41	2.44	2.47	2.50	2.52	2.55	2.58	
	98.6	2.28	2.31	2.34	2.36	2.39	2.42	2.44	2.47	2.50	2.52	2.55	
	99.6	2.26	2.29	2.31	2.34	2.37	2.39	2.42	2.45	2.47	2.50	2.52	
	100.6	2.24	2.26	2.29	2.32	2.34	2.37	2.40	2.42	2.45	2.47	2.50	
	101.6	2.22	2.24	2.27	2.29	2.32	2.35	2.37	2.40	2.42	2.45	2.47	
	102.6	2.19	2.22	2.25	2.27	2.30	2.32	2.35	2.37	2.40	2.43	2.45	
	103.6	2.17	2.20	2.22	2.25	2.27	2.30	2.33	2.35	2.38	2.40	2.43	
	104.6	2.15	2.18	2.20	2.23	2.25	2.28	2.30	2.33	2.35	2.38	2.40	
	105.6	2.13	2.16	2.18	2.21	2.23	2.26	2.28	2.31	2.33	2.36	2.38	
	106.6	2.11	2.14	2.16	2.19	2.21	2.24	2.26	2.28	2.31	2.33	2.36	

2023_12		rs - rental supply dynamics											
rp - rental price dynamics	HRAI=	85.6	86.6	87.6	88.6	89.6	90.6	91.6	92.6	93.6	94.6	95.6	
	2.35												
	96.6	-0.63	0.53	1.69	2.85	4.02	5.18	6.34	7.50	8.66	9.82	10.98	
	97.6	-1.64	-0.50	0.65	1.80	2.95	4.10	5.25	6.39	7.54	8.69	9.84	
	98.6	-2.64	-1.50	-0.37	0.77	1.91	3.04	4.18	5.32	6.45	7.59	8.73	
	99.6	-3.62	-2.49	-1.37	-0.24	0.88	2.01	3.13	4.26	5.38	6.51	7.63	
	100.6	-4.58	-3.46	-2.35	-1.23	-0.12	0.99	2.11	3.22	4.34	5.45	6.56	
	101.6	-5.52	-4.41	-3.31	-2.21	-1.10	0.00	1.10	2.21	3.31	4.41	5.52	
	102.6	-6.44	-5.34	-4.25	-3.16	-2.07	-0.97	0.12	1.21	2.30	3.40	4.49	
	103.6	-7.34	-6.26	-5.18	-4.09	-3.01	-1.93	-0.85	0.23	1.32	2.40	3.48	
	104.6	-8.23	-7.15	-6.08	-5.01	-3.94	-2.87	-1.80	-0.72	0.35	1.42	2.49	
	105.6	-9.09	-8.03	-6.97	-5.91	-4.85	-3.79	-2.73	-1.66	-0.60	0.46	1.52	
	106.6	-9.95	-8.90	-7.84	-6.79	-5.74	-4.69	-3.64	-2.59	-1.54	-0.48	0.57	

5. Conclusions and discussion

This study introduces and validates a novel Housing Rental Availability Index, designed to capture the multidimensional characteristics of rental housing availability. *HRAI* combines factors related to households' income, rental prices, and supply-side constraints, addressing the gap in existing literature that typically focuses on affordability from an income standpoint. However, this would not be possible without access to extensive and substantive statistical data from the OLX Group, which would, at best, result in purely theoretical developments.

Our key finding indicates that rental housing availability is more affected by supply trends and fluctuations in rental prices than by the income levels of households,

challenging the prevailing belief that income alone is the primary determinant of housing availability. This finding aligns with the filtering model of housing markets (Somer-ville & Holmes, 2001), which suggests that supply-side constraints, such as limited construction or rising costs, can cause higher-priced rental units to become available to lower-income households gradually. Our results show that as supply constraints increase, higher-priced rentals filter down to lower-income households, but this process is constrained due to limited supply.

To further validate our findings, we conducted sensitivity analyses that demonstrate how housing availability in the rental market shifts with changes in income and supply. This revealed a key insight that is central to our research: availability is not driven by either income or supply

alone, but rather by their interaction. An increase in household income does not necessarily improve availability, nor does an increase in supply automatically ensure access to housing. The simulations presented reveal a form of “cumulative determinism”, which highlights that housing availability emerges from the interaction between income and supply, not from either variable in isolation.

This finding may help in explaining why political programs aimed at expanding rental housing in Poland have not always yielded the desired effect, as such initiatives often target one side of the equation (supply). For instance, the *Mieszkanie Plus* program, launched in 2016 to address the housing shortage, fell short of supply targets. While this study does not attempt to resolve this issue, we hope it encourages future research to explore this disconnect between income-side and supply-side policies more closely. We believe that the *HRAI* can support policymakers in identifying areas where rental supply is misaligned with tenant demand. For example, it could inform the design of rent subsidy programs or incentives for rental development in underserved locations. It also offers developers and social housing providers a tool to identify supply-demand gaps and adjust investment strategies accordingly.

As revealed in the study, supply volume and rental price changes are key factors influencing housing availability in the Polish rental housing segment. The dependencies of the *HRAI* primarily indicate this on its main determinants (i.e., income, supply, and rental price), as described in the research results. In other words, this means that fluctuations in rental housing supply and prices directly and significantly impact housing availability. In contrast, higher income does not necessarily lead to better access to rental housing in Poland – availability is more constrained by the physical supply of homes and the prices landlords charge. This is where the importance of the introduced supply-rent dynamic index (*SRPI*) became apparent. The *SRPI* measure, calculated as a ratio of the rate of changes in rental housing supply to the rate of changes in rental prices, indicates elasticity of the rental supply to changes in rental prices. This elasticity directly reflects the filtering process, where an increase in rental supply can make higher-priced units more accessible to lower-income households.

This is an important issue that should be stressed. It follows that an increase in housing availability in the rental market is positively correlated with an increase in the supply elasticity of rents. This conclusion is also supported by scientific literature. There is often emphasis on the need to increase the availability of rental housing to meet basic needs and foster the socio-economic development of Poland (Dziworska, 2017). Rental housing availability is equally important from the perspective of barriers to social mobility and the economic development of Poland (Zaniewska & Thiel, 2008). Based on this, we conclude that the proposed method for estimating rental housing availability may prove valuable for other scientific studies concerning the rental housing segment. The *HRAI* allows for a detailed analysis of housing availability from

the perspective of income groups and their preferences or expectations regarding optimal housing. This, in turn, makes the *HRAI* a potentially valuable policy implication tool in monitoring market conditions, allowing for policy responses to increase access to rental housing. It can also serve as a tool for planning various programs, such as rent subsidies or incentives for rental properties, supporting the fulfillment of the population's basic needs.

Despite its contributions, the *HRAI* methodology has limitations. First, it reflects the national level of rental housing availability using average values for rental prices and supply from across Poland. Nevertheless, rental availability varies significantly across locations in Poland, making it challenging to rely on a single availability index for cities or regions (e.g. Warsaw vs. Kalisz or Łódź vs. Krasnystaw), where market conditions may vary widely. Additionally, the index does not yet capture spatial disparities driven by local planning policies or income segmentation, factors that could shape housing availability. While the main objective of this research is to design, validate, and discuss the method for estimating the *HRAI* with Poland in mind, future research could focus on adapting the *HRAI* to other countries or regional contexts as well, aiming to capture local market variations more accurately. Second, rental availability is not uniformly experienced across population segments. Our analysis is based on national wage averages and does not yet incorporate varying tenant preferences or regional wage disparities. As previous studies on tenant preferences in Poland show (Derkacz & Gajda, 2023), we also presume that the availability of rental housing likely varies for households with different income levels and tenant preferences. This implies that rental availability should be analyzed from the perspective of specific characteristics of residential properties. Third, while the *HRAI* demonstrates strong internal consistency and responsiveness to real-world events, the study does not benchmark it directly against other widely used housing indicators such as vacancy rates or core housing need measures. This limits external validation and comparative utility. Future research should consider comparative analysis with established indices, such as Eurostat's housing cost overburden rate or other metrics, to further assess the robustness and added value of the *HRAI*. Fourth, our data span only the 2021–2024 period due to the limited availability of statistical data on the supply of rental housing. While this timeframe includes significant market shifts, longer-term validation is necessary to understand cyclical and structural trends. Future research should determine potential differences in rental housing availability in Poland from the perspective of different levels of differentiation of independent variables located on the right side of Equation (3). Fifth, future studies could adapt the *HRAI* for local application to address specific neighborhood or city-level rental challenges. Finally, expanding this approach to an international context could reveal commonalities or differences across diverse markets.

We acknowledge that the *HRAI* estimation method can be subjected to detailed verification. Cross-validation techniques could be used to test its robustness. Additionally, introducing nonlinear modeling techniques or interaction terms could reveal hidden relationships, such as threshold effects, where supply constraints disproportionately impact rental availability beyond certain limits. Including validation indicators or comparisons with other housing metrics (e.g., rental vacancy rates or affordability indicators) would also be valuable. Incorporating diagnostic tests, such as statistical procedures to address multicollinearity, or robustness checks for extrapolated models, would reinforce the validity of findings. Applying these methods could further enhance confidence in the reliability of the proposed *HRAI*. However, our primary goal was to present a structured parametric approach for the first time. It directly addresses the disconnect between affordability and availability, the two dimensions that are often treated separately. This approach is intended as a general framework for measuring rental housing availability and opens up new research and analytical possibilities, particularly from the perspective of statistical refinement.

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Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Ethical considerations

This study utilized anonymized statistical data provided by OLX Group. No direct interaction with human participants or collection of sensitive personal data was involved, hence ethical approval is not required.

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