Household Expenditures in Cities During the War: Modelling the Estimation Through the Correlation of Housing Rent Costs and Consumer Goods Prices

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Abstract

This article determines the effect of crisis changes on the structure of household expenditures in the following different regions of Ukraine: Kyiv, Lviv, Kharkiv, Odesa, and Vinnytsia. The study covers the period before the full-scale Russian invasion (2017–2022) and after its onset (2022–2024). We analysed the data through correlation analysis and the Cobb–Douglas consumption function model to determine the structure of expenditures depending on two factors: the cost of housing rental and consumer goods prices. Before the full-scale invasion, we observed a stable positive correlation in most cities between the cost of housing and prices of goods, with changes in one indicator being reflected in the other. After the invasion began in the affected regions (Kharkiv and Odesa), the correlation between prices of goods and the cost of housing rental changed from positive to negative. In the regions that were less affected (Lviv, Vinnytsia, and Kyiv), the correlation remained or grew stronger due to increased demand. This article therefore contributes to understanding consumer behaviour in times of crisis.

Keywords

urban policy, household expenditures, housing rent costs, consumer goods prices, Cobb–Douglas consumer function, military operations.

Introduction

The rapid development of the social and economic situation in Ukraine caused by hostilities, and its negative aspects – depopulation of territories, the emergence of internally displaced persons (IDPs), and the need for new housing and employment opportunities – have caused changes in the structure of household expenditures, as well as an increase in the expenditures themselves. Hypothetically, a larger share of household expenditure should be spent on rent (and it should increase) in cities that have received a significant number of refugees. Similarly, prices for goods vary from city to city, and it is evident that this depends not only on the factor of displacement and the increase in the city's population, but also on pricing and the market's general economic situation. However, an empirical analysis of statistical data has shown that rental costs have not changed (increased or decreased) in some cities that have received IDPs. This article examines the factors that influence rental costs in different cities in Ukraine.

The aim of this study is to create a mathematical dynamic model that will allow users to identify the spatial impact of the war on the structure of household consumption expenditure in Ukraine. To do this, we must accomplish the following: define costs for housing rent and consumer good prices in five Ukrainian cities from different regions; analyse the correlation between housing rent costs and consumer goods prices using the Cobb–Douglas model; and propose recommendations for regulating expenditure further and ensuring the availability of basic resources for households.

Taken together, the factors ‘rent’ and ‘consumer goods’ are decisive for the choices of residence and employment, and lead to a change in the structure of household expenditure. In turn, this has a significant impact on the transformation of human capital. Including such factors in our analysis will allow us to identify changes in the structure of household expenditure in different cities depending on the dynamics of the social situation. Taking these factors into account, as they are the most dynamic and indicative for the analysis of the structure of household expenditures, and comparing these expenditures in cities of different regions on the basis of the results obtained, will allow us to supplement and improve the methodology for spatial modelling of the changes in citizens’ basic needs.

Literature review

Many authors have studied household expenditures, both in aggregate form and by individual components. In particular, we note the work by Madudova and Corejova (2024), which analyses the effect of household expenditures on economic growth. Measuring household consumption expenditure is crucial for analysing economic growth, inflation and overall economic performance. For budgeting and financial planning, it is necessary to know and understand the household size in terms of the number of members, the number of children and their consumption needs. To determine the correlation between consumption expenditure and household size for households with different numbers of children, Madudova and Corejova conducted a linear regression and goodness of fit analysis. The results of the correlation analysis and hypothesis test show a significant difference in the types of consumption expenditure depending on household size (number of children). The results confirm that there are significant differences in consumption expenditure between the different household sizes and thus confirm the significance of the results. We will use Madudova and Corejova’s approaches in our study.

Many researchers have studied the application of the Cobb–Douglas function to the study of urban economies. Notable examples include Sisman *et al*. (2021), Wang (2020), Xu *et al*. (2022) and Yalpır *et al*. (2022). With regard to the objectives of our article, we note the particular relevance of the following studies. First, Davis and Ortalo-Magné (2011) consider a Cobb–Douglas model with rent and housing-related consumption parameters. Their model demonstrates that the relative housing prices in two metropolitan statistical areas (MSAs) disproportionately reflect the income disparity between them and do not depend on the housing supply within each MSA. According to the model’s predictions, rental price dispersion between low- and high-income MSAs should be greater than is observed; high-income MSAs such as San Francisco are surprisingly inexpensive compared to low-income MSAs such as Pittsburgh. Second, Sancho (2024) investigated the properties of an extended linear cost system that uses the Stone–Geary utility function with constant elasticity of substitution (CES). Based on Spanish data, Sancho considered and illustrated the characteristics of the demand system generalizing the standard linear Stone–Geary demand structure.

To find the parameters of the Cobb–Douglas function, we used the least squares method (Wolberg, 2005). To check the adequacy of the model, we applied the F-test, which is used to test the null hypothesis that two independent samples have identical mean (expected) values (Zimmerman, 1998).

While significantly influencing the structure of household expenditure, housing costs and consumer prices have an equally powerful effect on the spatial balance of human capital allocation. Buchholz (2022) and Liu *et al*. (2022) discuss problems of spatial balance, while Glaeser and Gottlieb (2009) review the concept, demonstrating how it can be employed to comprehend urban growth in Sunbelt cities. Stanton and Tiwari (2021) investigated differences in housing choices between households with remote and on-site workers.

Mikulić *et al*. (2021) examined the correlation between tourism activity and housing affordability using a sample of different municipalities. Their article explores how tourist accommodation, population concentration and seasonality affect housing affordability. Their findings suggest that tourism seasonality has a particularly strong impact, indicating general negative externalities such as employment fluctuations, difficulties in maintaining economic status and income instability in areas subject to seasonal tourism fluctuations.

Wilhelmsson (2023) analyses waiting times and estimates the demand for rent-regulated apartments, as well as the income elasticity of the market. Using empirical data from lease contracts, he investigates the correlation between waiting times and acceptable rental prices, as well as household characteristics such as income, age, and family composition. His empirical analysis reveals a high willingness to pay for apartments with regulated rents, particularly in large buildings in better locations with lower regulated rents.

Meanwhile, Haffner *et al*. (2021), Galster and Lee (2021), and Lee *et al*. (2022) provide an overview of research on housing affordability. Calabrese (2024) analyses the ratio between housing rental prices and food prices. The author applies the Tieboo model to study the impact of government restrictions on local government taxing powers on household income. They examine the effect of such restrictions on housing markets, community citizens and the types of expenditure made by local governments.

Hirota, Suzuki-Löffelholz, and Udagawa (2020) conducted laboratory experiments in which the real estate market opened earlier than the rental market and investigated whether the purchase price influences the behaviour of owners with regard to rent. They found that the higher the purchase price, the higher the rent offered. They also confirmed that higher contractual rents lead to higher prices in subsequent real estate markets. This points to a positive interaction between property prices and rents in the real economy, which could explain the acceleration in price growth frequently observed on the real estate market.

Dustmann *et al*. (2022) studied the correlation between housing costs and income inequality. Using German households as an example, they demonstrated that the proportion of income spent on housing has increased disproportionately for the lowest income quintile and decreased for the highest income quintile, as measured by the Gini coefficient. Factors contributing to these trends include a decline in the relative cost of owning versus renting; changes in household spending patterns; falling real incomes among low-income households; and migration to large cities. Younger age groups tend to spend more on housing and save less than older age groups, which will affect their future wealth accumulation, particularly at the lower end of income distribution.

It is beneficial to take advantage of research approaches obtained in other works, as this would enable us to address issues related to our topic more broadly (including those related to security, internally displaced persons and the effects of the pandemic). Benton *et al*. (2022) and Glauben *et al*. (2022), for example, discuss the threats to global food and energy security posed by the war in Ukraine. Voznyak *et al*. (2023), Mykhnenko *et al*. (2022) and Jurić (2022) have addressed issues relating to internally displaced persons.

This study's findings are likely to prove important for informing the government's economic policies during times of crisis. Voigtländer and Whitehead (2023) note that interest in rent control has increased over the last two decades as housing affordability has deteriorated and the private rented sector has become increasingly important. This has led to increased political pressure supporting tighter rent regulation and a growing body of research into different ways of developing a better functioning private rental sector, including how best to support poorer tenants.

Fafard, St-Germain and Tarasuk (2020) examined the role of housing debt, housing costs and housing assets in Canadian households. They showed that there are significant differences in food security between households with different housing tenures (i.e., renting or owning). While housing policies that support homeownership and provide affordable mortgages can improve food security, policy actions are also required to address renters' vulnerability to food insecurity.

On the basis of these and other studies, we analyse the correlation between costs for housing rent and consumer goods prices, and their impact on household expenditure patterns. In doing so, we take into account the uneven situation in the cities we analyse and the rapid and unpredictable dynamics of changes in the prices and costs of goods and services.

Materials and methods

Since the start of the Russian Federation's full-scale invasion of Ukraine in February 2022, the country has faced not only a humanitarian and security crisis, but also major structural changes in the economic environment, particularly in the area of consumer spending. The hostilities have led

to a sharp increase in internal migration, destruction of infrastructure, changes in logistics chains, and significant fluctuations in the prices for basic goods and services. In such circumstances, it is particularly important to study the spatial specificity of changes in the structure of household expenditure, particularly consumer prices and costs for housing rents as key components of household expenditure.

We undertake our analysis in respect of five cities, regional centres that differ in their locations and the level of damage caused by the hostilities (i.e., the degree of their involvement in the war zone): Kyiv (Ukraine's capital and centre of government), Lviv (a city in the western region far from the fighting), Vinnytsia (a city in the rear of the centre with a high level of internal migration), Kharkiv (a city on the border with Russia, constantly under fire), and Odesa (a port city on the frontline, important for logistics and trade, also constantly under fire). This selection allows us to carry out a spatial analysis of the spread of economic phenomena using contrasting regions that have experienced different degrees of destabilisation.

We use the Cobb–Douglas function to model the dependence of household expenditure on two main factors: housing rent costs and consumer goods prices. Using the Cobb–Douglas consumer function, we identify changes in the correlation between rental costs and consumer prices in different regions before and after the outbreak of hostilities. This function allows us to analyse the elasticity of expenditure for each factor and to examine how consumption priorities changed in the context of the war. Our methodology involves a comparative analysis of data for the period up to February 2022 and after the start of the active phase of the invasion (after February 2022), which allows us to identify structural shifts in consumer behaviour patterns in a regional context. This makes it possible to understand how the crisis (war) has affected household spending and to formulate practical recommendations for city and governmental economic policies in order to stabilise spending on basic needs.

The steps we take in this study are as follows. First, we identify changes in the structure of household expenditures. Second, we study the impact of housing costs and consumer prices on changes in the structure of household expenditures in several Ukrainian cities from different regions both before February 2022 (the beginning of the full-scale invasion) and after that date. Third, we predict the further development of the situation regarding the role of these two factors in household expenditures in the spatial dimension. Finally, we develop practical recommendations on the impact on the population location and the consumer goods market, which is especially important in the context of intensified warfare.

To achieve these aims, we construct the following Cobb–Douglas function to model Ukrainian households' wartime expenditures as a function of housing rent and consumer goods prices:

$$F(C, H) = AC^{\alpha} H^{\beta} \tag{1}$$

where F is total monthly household expenditure (approximated by the average nominal wage) in Hryvnia (UAH), C is the average monthly consumer goods price level in UAH, H is the average monthly rent for a one-bedroom apartment in UAH, and A, α and β are the estimated parameters of the Cobb–Douglas function.

We use the average nominal wage in the assessed regions (the cities of Kyiv, Lviv, Odesa, Kharkiv, and Vinnytsia) as the dependent variable. This variable is an aggregate indicator of households' financial capacity and allows us to assess their ability to adjust their consumption behaviour to changes in the prices of basic goods (consumer goods and housing rent).

We do not interpret the average nominal wage in this study as actual household consumption. Instead, we apply it as a proxy for the budget constraint that determines the maximum feasible level of monthly household expenditures. Due to the absence of city-level microdata on real consumption, we use the wage variable to approximate the financial capacity of households rather than their realized spending structure.

In the context of the Cobb–Douglas model, we interpret the dependence of wages on consumer prices as an adaptation of the household's expenditure structure in the face of changes in the economic environment. This function is a mathematical model that determines how consumption depends on consumer goods prices and housing costs.

Data overview

This study reveals changes in household spending patterns in five Ukrainian cities after the outbreak of large-scale war. It also investigates how factors such as housing costs and consumer prices have changed these patterns. We present all monetary indicators in UAH.

To build a model of household expenditure, we used monthly official statistics on average consumer prices for goods and services in the cities of Kyiv, Lviv, Odesa, Kharkiv, and Vinnytsia for the period from 1 January 2017 to 1 October 2024. We obtained these data from the open-access website of the State Statistics Service of Ukraine, which publishes monthly average prices of typical goods and services included in the consumer basket.

We collected primary data from a representative sample of outlets (markets and service establishments) in each of the selected cities. These prices are calculated on the basis of regular monitoring of the prices for typical consumer goods and services in the retail and service sectors, followed by the calculation of the average unit price. The consumer basket used for the purpose of the survey includes food (including bread, milk, meat, vegetables, and fruit) and non-food products (clothing, footwear, household appliances, and hygiene products) as well as basic services (housing and community, transport, education, medical, etc.).

Rental costs represent the average monthly market rent for a one-bedroom apartment, aggregated from regional housing market surveys conducted by statistical offices and verified through administrative sources.

In total, we use data from 7 years and 10 months of observation (i.e., 94 months). For each month in each of the five cities, we measured monthly average consumer goods prices for 34 main goods and services, based on continuous retail price monitoring. The total number of observation units comprises approximately 15,980 records (94 months × 5 cities × 34 categories of goods/services).

Despite wartime disruptions, we compiled all indicators using consistent methodology across cities and months, permitting valid comparison over time. We calculate the average consumer prices of goods and services used in this study with methodologies approved by the State Statistics Service of Ukraine.

The large amount of data allows us to calculate the correlation coefficients and parameters of the Cobb–Douglas function with sufficient statistical reliability to assess the effects of changes in costs and prices on the structure of household expenditures. To ensure the stability of the results of the Cobb–Douglas model, we used logarithmic transformations and checked the multicollinearity of the factors. This approach allows us to obtain reliable estimates of the level of consumer expenditure and to carry out a comparative analysis of differences between cities in the dynamics of the changes in costs and prices over the period studied.

We used Jupyter Notebook for visualisation and calculations.

Results

Modelling household consumer spending in wartime.

In this paper, we construct a function of the dependence of household expenditures, measured by the level of average monthly wages, on the factors of housing rental costs and consumer goods prices. We conducted the research in five Ukrainian cities comprising five different regional centres (the capital city of Kyiv; the city of Lviv, the city furthest from the combat zone; the rear city of Vinnytsia; the city of Kharkiv, which borders the Russian Federation; and the port city of Odesa, which – like Kharkiv – is often under fire).

In this study, we use average monthly wages as a proxy for household expenditure capacity rather than as a direct measure of actual spending. This approach is widely applied in regional economic analysis when detailed household consumption microdata are unavailable at the city level, while wage statistics are consistently reported across regions. Using wages does not imply equal employment ratios across cities. Instead, average wages represent a standardised indicator of households' potential financial resources and reflect the maximum feasible level of consumption

under the given price and rent conditions. Therefore, in the model, wages capture households' income-based consumption capacity in each city.

The graph below reveals the dynamics of changes in average wages in cities before, after and during the full-scale invasion (Figure 1).

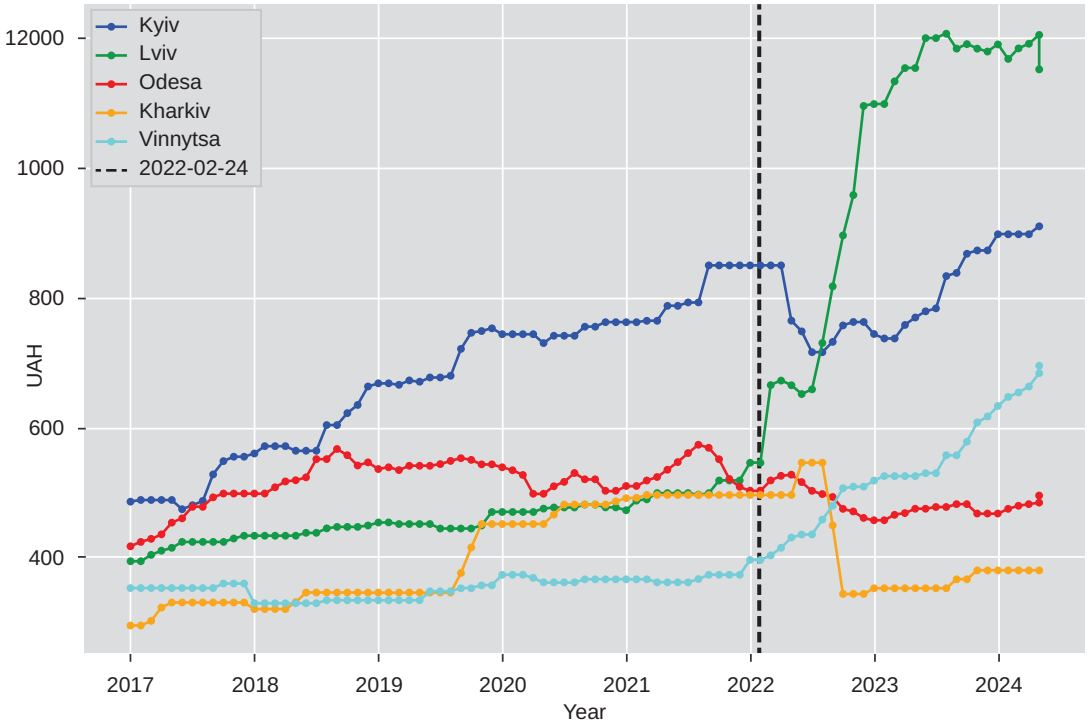

Figure 1. Wages in cities

Source: Authors' elaboration of the data provided by the State Statistics Service of Ukraine.

Fig. 1 shows the dynamics of average salaries in different Ukrainian cities (Kyiv, Lviv, Odesa, Kharkiv, and Vinnytsia) from 2017 to 2024. The vertical dotted line marks the date of the beginning of Russia's full-scale invasion of Ukraine: 24 February 2022. Thereafter, there is a significant stratification of average salaries across the regions. Growth in Lviv, as well as stability in Kyiv and Odesa, contrasts with a drop in Kharkiv and low-level stability in Vinnytsia. After February 2022, the average wages in Lviv increase rapidly and exceed the level in the other cities. This may be due to the relocation of companies and workers to the west of Ukraine, which has led to increased demand for labour and higher wages. Kyiv has seen a steady increase in wages since 2017, which continued after the start of the war, although not as rapidly as in Lviv. In Kharkiv, average wages have fallen significantly since the start of the war and remain relatively low. This is due to the city's proximity to the war zone, which affects economic activity and labour demand. Odesa demonstrates relatively stable dynamics without significant fluctuations, although average salaries remain lower than in Kyiv and Lviv. This may indicate the stability of the city's economy, but without significant growth. The average wages in Vinnytsia are the lowest of all the cities on the map, although these have also increased slightly since 2022.

Table 1 shows the change in the share of the cost of renting a one-bedroom apartment relative to the average wages in different cities of Ukraine in 2017–2024. It reflects the effect of economic, social and military factors on the rental market in Ukraine. The war has changed regional supply and demand significantly, resulting in substantial differences in the share of the rental cost relative to the average wage.

Most cities (notably Vinnytsia and Kyiv) saw a gradual decline in the share of rent costs by 2021. This may have been due to rising average wages or a relative stabilisation of rental prices. With the invasion (2022), there is a sharp increase in the share in Lviv (to 54%) and a stabilisation or even decrease in other cities. This may be due to a shift in demand as people were displaced to the west

of Ukraine. In 2023 the difference becomes even more pronounced: Lviv reaches the highest value (70%), while Kharkiv and Odesa show a significant decline, especially Kharkiv (to 24%). This is probably due to the impact hostilities had on the economy and the housing market in these regions. The 2024 data show that rental costs increased in Kyiv (to 47%), which may indicate a recovery in demand or a change in the economic situation. In Lviv, the share significantly decreased (to 55%), which may be due to a gradual balancing of demand, and Kharkiv and Odesa show minimal costs, which can be explained by the instability of these regions during the war.

Table 1. Rent for a 1-bedroom apartment as a percentage of the average wage in each city.

Year	Kyiv	Lviv	Kharkiv	Odesa	Vinnytsia
2017	46%	66%	52%	71%	59%
2018	44%	55%	44%	67%	43%
2019	44%	49%	41%	59%	37%
2020	44%	46%	47%	50%	36%
2021	36%	40%	44%	44%	30%
2022	36%	54%	34%	35%	36%
2023	34%	70%	24%	29%	38%
2024 (until May)	47%	55%	20%	24%	37%

Source: Authors' elaboration of the data provided by the State Statistics Service of Ukraine.

Table 2 shows households' consumer monetary expenditures in the surveyed Ukrainian cities.

Table 2. Households' consumer monetary expenditures (UAH per household per month)

Year	Kyiv	Lviv	Kharkiv	Odesa	Vinnytsia
2017	8330	7435	5880	6190	7273
2018	9975	9214	6811	7083	8101
2019	12611	11499	7348	8332	9783
2020	11079	10495	8058	8440	9326
2021	12894	13643	8871	9463	11153
2022	15473	16372	11089	11356	13940
2023	16247	17026	11532	11810	14498
2024 (until May)	16572	17367	11763	12046	14788

Source: Authors' elaboration of the data provided by the State Statistics Service of Ukraine.

All these cities have seen a steady increase in consumer spending, indicating rising prices on the one hand and rising household incomes on the other. The largest increase in spending from 2017 to 2023 occurred in Kyiv (+7917 UAH), indicating its significant economic development. The increase in expenditure in 2022 is likely to be due to the crisis caused by the war, changes in the economy and higher prices for basic goods. The largest percentage increase in expenditure from 2021 to 2022 occurred in Vinnytsia (+25%), which may indicate an additional burden on households due to higher prices. Table 2 shows an increase in expenditure in all cities.

Table 3 shows how the war has affected the correlation between consumer prices and housing costs in different Ukrainian cities. In some cities, the correlation between consumer prices and housing costs has weakened or even reversed in the face of the war, reflecting the volatile economic situation. In cities where the demand for housing has fallen as a result of the hostilities (e.g., Kharkiv and Odesa), the correlation has become negative. In relatively safe regions (e.g., Lviv and Vinnytsia and, to a lesser extent, Kyiv), the correlation remained positive or even increased due to increased demand, most probably due to the displacement of people from the affected regions, which has led to higher rental costs and higher prices for goods.

Table 3. Correlation between consumer goods prices and housing rents

	Before the war (from 01-2017 to 02-2022)	During wartime (from 03-2022 onwards)
Kyiv	0.929	0.529
Lviv	0.964	0.871
Kharkiv	0.833	-0.729
Odesa	0.601	-0.782
Vinnytsia	0.546	0.780

Note: Consumer goods prices (C) represent the monthly average price level of 34 essential goods and services (in UAH). Housing rents (*H*) are presented as the average monthly rent for a one-bedroom apartment (in UAH per month). The correlation shown in the table is the Pearson correlation coefficient, calculated using the standard formula for two continuous variables.
Source: Authors' elaboration of the data presented by the State Statistics Service of Ukraine.

Our results correlate with those of Wilhelmsson (2023). People display a willingness to pay for apartments with regulated rents, especially for large houses in better locations with lower regulated rents (e.g., Lviv, Vinnytsia, and Kyiv).

Changes in the correlation between consumer goods prices and housing rental costs in Kharkiv city before and during the war.

Without limiting our general approach, we note the values for Kharkiv city particularly (Table 3). Studying the data for Kharkiv city is particularly important given the city's proximity to the front line and the periodic shelling it experiences. Identifying the ratio between the structure of household expenditure and the housing rental costs and consumer prices in a frontline city will help to identify the mood of the city's residents, their preferences, the market dynamics in play, changes in the structure of human capital, and prospects for recovery. This will be useful in developing municipal policies to regulate the situation on the labour, property and consumer markets in frontline areas.

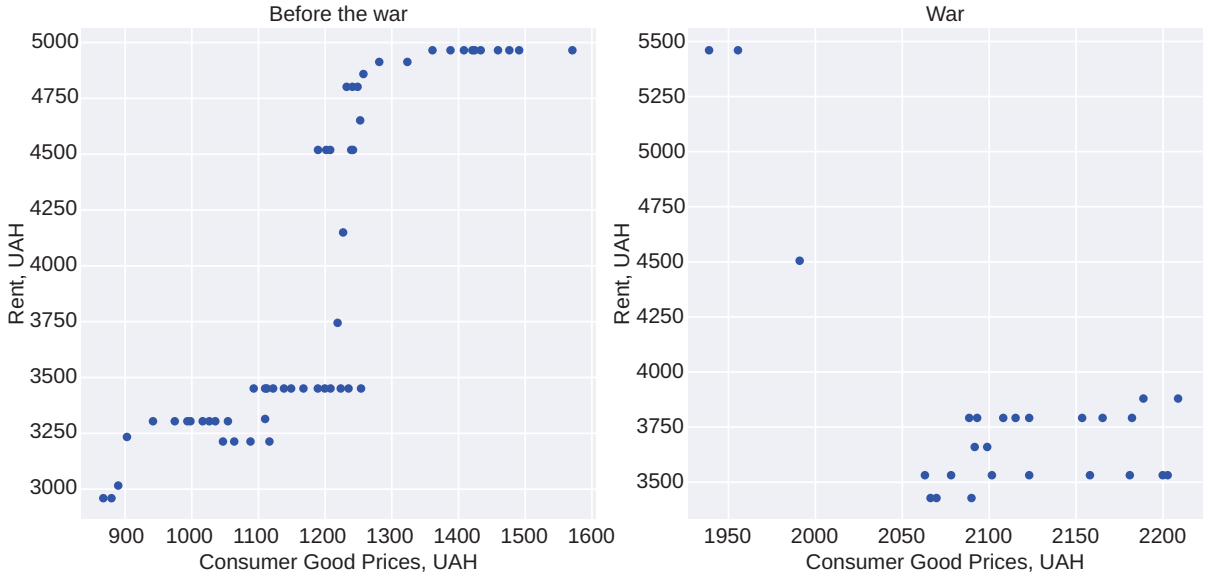

Figure 2. Dot plot showing the variables *consumer goods prices* and *costs for housing rent* for Kharkiv city. Figure 2 (a) covers the period before the war; Figure 2 (b) covers the wartime period.

Source: Authors' elaboration of the data provided by the State Statistics Service of Ukraine.

Until February 2022, the correlation (0.833) shows that there is a strong direct link between consumer goods prices and housing rental costs. This means that increases in consumer goods prices have generally been accompanied by increases in housing costs, and vice versa. Such a highly positive correlation may indicate a stable economic situation in which both markets (commodities and rents) have developed in parallel.

From March 2022, the correlation (-0.729) indicates a strong inverse relationship between goods prices and housing costs. This fact points to economic instability and crisis. It also indicates the priority of basic needs (food and essential goods), with housing costs assuming reduced importance. This is due to the regular shelling of Kharkiv as a result of military aggression: the demand for housing decreased significantly and approached zero.

Figures 2 (a) and (b) show the correlation between the variables of consumer goods prices and costs for housing rents before and during the war, which confirms the above conclusions.

Changes in consumer spending in Kharkiv and other cities: an analysis applying the Cobb–Douglas model to data from before and during the war

Table 4 shows the values of the parameters of the Cobb–Douglas function and the p-value. Since the p-value > 0.0, there is no reason to reject the null hypothesis that the means of the two samples are equal.

Table 4. Parameters of the Cobb–Douglas function and p-value means

$F(C,H) = A \cdot C^{\alpha} \cdot H^{\beta}$								
	Before the war (from Jan 2017 to Feb 2022)				Wartime (from Mar 2022)			
	A	α	β	p-value	A	α	β	p-value
Kyiv	3.77	0.20	0.74	0.685	0.81	0.47	0.68	0.644
Lviv	0.10	0.19	1.24	0.156	0.65	0.62	0.59	0.251
Kharkiv	4.32	0.32	0.63	0.147	0.01	1.19	0.55	0.254
Odesa	6.48	0.52	0.41	0.796	0.01	0.82	0.88	0.284
Vinnytsia	0.16	0.44	0.91	0.678	6.98	0.17	0.70	0.369

Source: Authors' elaboration of the data provided by the State Statistics Service of Ukraine.

Table 5 (below) offers a more detailed breakdown of the change in consumer preferences in Kharkiv.

Table 5. Calculation of changes in consumer confidence using Kharkiv as an example.

	Kharkiv	
	Before the war (Pre-Feb 2022)	During the war (Post-Feb 2022)
	$F_1(C,H) = 4.32 \cdot C^{0.32} \cdot H^{0.63}$	$F_2(C,H) = 0.01 \cdot C^{1.2} \cdot H^{0.55}$
Consumer goods prices	The price elasticity of consumer goods is 0.32, which means that consumption is not very sensitive to price changes.	The elasticity rose significantly to 1.2, indicating a sharp increase in the sensitivity of consumption to consumer goods prices. After this date, consumption became more responsive: a 1% increase in consumer goods prices now leads to a 1.2% increase in consumption.
Changes in the impact of housing rental costs	The elasticity of rents was 0.63, meaning that costs for rents affected consumption more than consumer goods prices.	The elasticity falls to 0.55, indicating a decrease in the sensitivity of consumption to the cost of housing rent. After February 2022, changes in rental prices have a reduced impact on consumption. This could mean that people spend less on housing, or are less sensitive to changes in rental prices.
Baseline consumption level	The initial coefficient of 4.32 showed a high initial level of consumption. This indicated a stable economic situation, with consumption dependent on consumer goods prices and housing rental costs.	The baseline coefficient fell sharply to 0.01, indicating a sharp decline in total consumption. This is a consequence of the economic crisis and the war, which have significantly affected living standards.

Table 5. cont.

	Kharkiv	
	Before the war (Pre-Feb 2022)	During the war (Post-Feb 2022)
	$F_1(C,H) = 4.32 \cdot C^{0.32} \cdot H^{0.63}$	$F_2(C,H) = 0.01 \cdot C^{1.2} \cdot H^{0.55}$
General changes	Consumption in Kharkiv was stable, with a greater dependence on housing costs than on consumer goods prices. People could afford to spend more on housing, while consumer goods prices had less of an impact.	The economic situation changed dramatically. Consumption became very sensitive to changes in the prices of goods. Housing rental costs have faded into the background and consumption has fallen because of other economic factors.
Results	Until February 2022, Kharkiv had a stable economic situation, with consumption being more dependent on housing conditions (rent) and goods prices having a limited impact.	Since February 2022, social and economic changes have meant that the prices for consumer goods have become the main factor influencing consumption. This may indicate a deterioration in living conditions, where spending on basic goods has become a priority and the ability to spend more on housing has diminished.

Source: Authors' elaboration of the data provided by the State Statistics Service of Ukraine.

Fig. 3 presents three-dimensional graphs illustrating the Cobb–Douglas consumption function for Kharkiv city before the war (left) and from the full-scale invasion onwards (right).

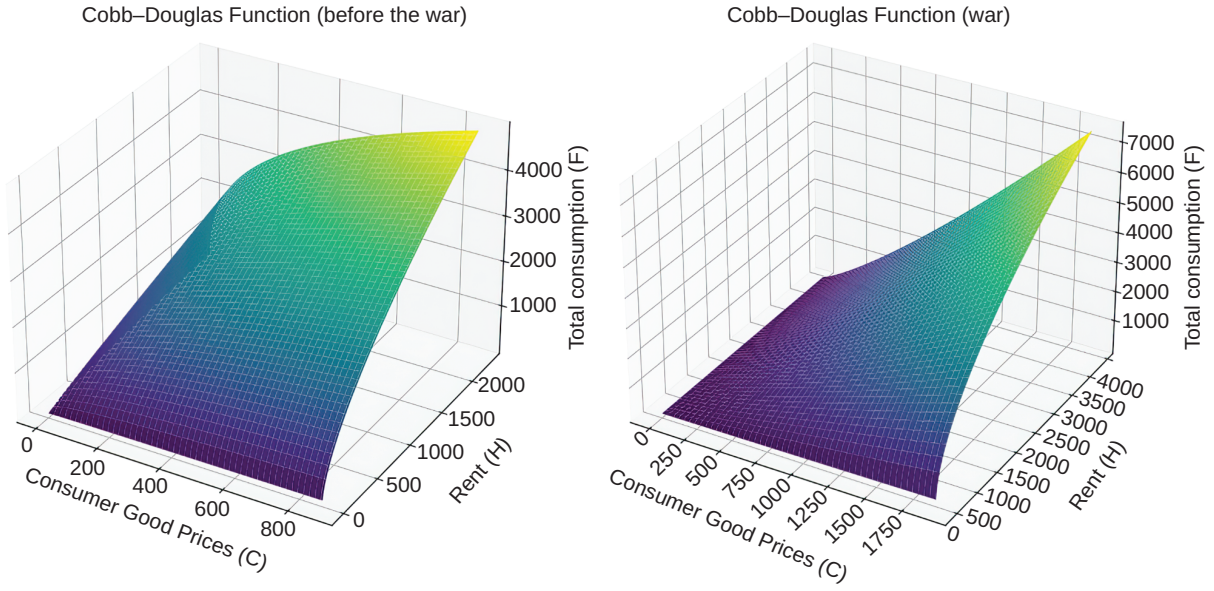

Figure 3. Cobb–Douglas function for Kharkiv.

Source: Authors' elaboration of the data provided by the State Statistics Service of Ukraine.

In both graphs, the axes represent the following indicators:

X-axis: Consumer goods prices (in UAH).

Y-axis: Housing rental cost (H), (in UAH).

Z-axis: Total consumer costs (consumer function), (in UAH).

In the graph on the left (before the war), the consumption function shows a smooth, gradual increase. As consumer goods prices and costs for housing rents rise, total consumer spending rises, but it does so gradually (as is typical of stable economies). This suggests a smooth increase in consumer spending in response to rising goods prices and rents, which we interpret as a sign of a relatively stable standard of living. During the war (right), the function shows a much steeper rise than in the pre-war period. This sharp change is due to the economic consequences of the war, in which spending on consumer goods far outweighs spending on housing rents.

The graphs show that during the war there has been a significant increase in total consumer expenditure in Kharkiv for the same set of basic needs. This is indicative of a difficult economic

environment, in which inflation and market instability force households to increase expenditure in order to maintain a minimum level of consumption. The total results obtained should be analysed in detail in future studies to determine the importance of each of the above factors in the structure of household expenditure in each city.

Suggestions for public policy with regard to housing policy and consumer price regulation

Our analysis of the situations in the cities, which suffer the effects of hostilities in different ways, and our conclusions regarding the interdependence of indicators result in a need to develop a new urban policy. Such a policy should provide measures to regulate both the housing rental market and the consumer price market. This is because the dynamics of these indicators and parameters set the tone for the movement of human capital and business, shape the real estate market, and determine the guidelines for social policy. These measures will be repeated in some respects, and in others they should differ in individual cities; these differences form the basis for differentiated urban policies and different approaches to regulating the specified variables. The urban policy measures we propose later in this section are formed, firstly, on the basis of the analysis we have conducted, which provides an understanding of citizens' behaviour as a basis for developing urban policy; and secondly, by taking into account the current urban development strategies, which define the guidelines for urban trends. Such measures will also be useful for other cities in similar situations.

Based on our research and our assessment of each city's overall socio-economic situation, we propose a number of national and urban policy measures. Such measures can adjust the situation in consumer markets, meet the current needs of consumers, and apply to the security situation. The extent to which the proposed measures are appropriate is driven by the efforts of local authorities and government to preserve cores of stability in cities and prevent the growth of negative trends. The measures are aimed at both expanding production and making full use of resources, as well as launching new activities that could become catalysts for each region's development. Such renewal should be based on the requirements indicated by the intelligent specialisation of each region, as well as of "knowledge economy" approaches. The necessity of a low-carbon transition and economic stabilisation should also be taken into account.

For each city, we propose measures in three areas: (1) saving areas of stability and the basis for economic development; (2) stimulating the development of promising industries; and (3) making structural changes in the socio-economic sphere.

These measures are as follows:

1. *Saving areas of stability and the basis for economic development, maintaining the current level of development:*
   - In Vinnytsia, this means maintaining the level of wages and incomes; public control over prices for goods and services; increasing exports of goods; and maintaining the amount of industrial and construction production.
   - In Kyiv, this means maintaining the level of wages and incomes; maintaining the amount of construction and industrial production; and increasing retail trade.
   - In Lviv, this means maintaining the amount of construction and industrial output; and expanding exports.
   - In Odesa, this means maintaining the amount of construction and industrial production; increasing retail trade; and ensuring the operation of seaports and transport routes.
   - In Kharkiv, the focus must be on eliminating the consequences of military pollution and destruction; solving unemployment problems; and protecting the city from military threats.
2. *Stimulating the development of promising industries:*
   - In Vinnytsia, this involves utilising the city and region's transit potential; improving municipal infrastructure; and making use of existing industrial parks.
   - In Kyiv, the focus must be on repairing roads; maintaining the amount of construction and industrial production; and using the city and region's transit potential.
   - In Lviv, policies should help internally displaced persons to adapt to a new life; assist in finding them effective employment and comfortable housing; and use and develop the city and region's transit and international potential.

- In Odesa, this involves engaging with the potential for alternative energy development; making increased use of recreational and rehabilitation facilities; and saving the functional suitability of seaports and developing them.
- In Kharkiv, the focus must be on eliminating the consequences of shelling; disposing of hazardous waste; maintaining the amount of construction and industrial production; and increasing retail trade and the population's income level.

3. *Making structural changes in the socio-economic sphere and re-profiling production by attracting and involving investment:*
   - In Vinnytsia, this involves development of innovation and educational potential; increased use of alternative energy resources; and active participation in cross-border cooperation.
   - In Kyiv, the focus must be on using water resources efficiently; preserving and expanding alternative energy use; and developing the food, wood-processing and machine-building industries.
   - In Lviv, efforts should be made to engage internally displaced persons in economic activity; solve the solid waste management problem; and upgrade border infrastructure.
   - In Odesa, this involves reducing dependence on external energy supplies; increasing domestic energy production; and repairing roads and related infrastructure.
   - In Kharkiv, the focus must be on expanding the potential of the food and machine-building industries; increasing the city's scientific and technical potential; and using available brownfield and greenfield sites.

Programmes and projects designed to stimulate industrial development should be incorporated into city development strategies nationally.

These measures will help to stabilise the economic sector and protect it from external shocks. They will also support a balance between stabilisation and laying the groundwork for growth and gradual transformation. Taken together, they will stabilise prices (either through market forces or limited government regulation), thus strengthening households' economic foundations and improving their well-being.

Discussion

Our objective with this study was to devise a dynamic mathematical model that would facilitate the determination of the spatial impact of war on the structure of household consumption expenditure in Ukraine. In this study, we do this by analysing the relationship between housing rental expenditure and consumer goods prices. The impact of changes in housing rents and consumer prices on the structure of household expenditure in Ukraine in the context of a full-scale war is an important criterion by which to assess the welfare of the population of different cities across the country. As an exogenous shock, the war has significantly changed the economic environment, leading to high inflation, shifts in demand, increased uncertainty and lower incomes for a large part of the population. Under these conditions, the adaptive behaviour of consumers, driven by the need to meet basic needs, appears in changes in the share of expenditure on housing, food, transport, and other essential goods and services. We pay particular attention to assessing how households reallocate their budgets in response to changes in the prices of key goods, and propose an analytical assessment of such changes based on the construction of a cost model using the Cobb–Douglas consumer function.

It is obvious that various types of income and social assistance are important factors influencing households' actual purchasing capacity. Income other than the basic wages helps households to survive difficult conditions. Social assistance is aimed at equalising the living conditions of citizens. Given the lack of a unified system for accounting for such income and frequent changes in the list of entities receiving it, accurate calculation of such data is not possible and has objective statistical limitations. This comprises the main limitation of this study.

At the same time, the structure of the pool of all household incomes offers a basis for further narrow scientific and practical research.

The relevance of our topic is a result not only of the profound socio-economic consequences of the war for the population of Ukraine, but also of the need to update consumer behavioural models

to take into account new challenges and constraints. In particular, a number of studies (Dustmann *et al*., 2022; Galster & Lee, 2020) indicate an increase in the share of housing costs in the consumer expenditure structure of internally displaced persons, as well as a change in consumer priorities in favour of essential goods.

We chose the Cobb–Douglas model as the analytical framework for the study because of its mathematical convenience, theoretical soundness and ability to provide a first formalised view of the changing expenditure structure under changing prices. In future studies, we plan to carry out a comparative analysis using models with a variable elasticity of substitution or more flexible functional forms that take adaptive consumer behaviour into account.

The study by Hirota *et al*. (2020) investigates the relationship between real estate purchase prices and the rents offered by property owners. Their findings highlight the positive interaction between property prices and rental levels, which can provide insights for understanding rental market dynamics, although it does not directly analyse household wages or expenditure patterns.

The war had a significant impact on household consumption expenditure in Ukraine, changing the balance between spending on housing and on consumer goods. Using the Cobb–Douglas function, we found that cities in different regions responded to the crisis in different ways, depending on the local level of security, economic activity and consumer expectations.

Analysing empirical data on housing rent costs, consumer goods prices and their mutual influence on household expenditure in five Ukrainian cities enables us to understand the spatial dimension of changes in the allocation of human capital. In future, we will be able to predict spatial changes in housing markets and consumer goods market, as well as their impact on household expenditure, depending on the situation in the country.

Our study highlights the importance of taking an individual approach to economic policy in cities at the regional level and of supporting the population in times of instability. Particular attention should be paid to the setting/regulation of prices for basic goods and changes in the rental housing market – for instance, through the provision of sufficient temporary social housing for internally displaced persons.

In regions severely affected by hostilities, government and local authorities should focus on stabilising the prices of basic consumer goods and ensuring the availability of housing for internally displaced persons. In relatively safe areas where there is a high demand for housing, it is advisable to regulate the rental market to prevent speculative price increases. In particular, this could be done by reviewing the tax base and rates of property tax and land charges, which are the responsibility of local authorities.

To better understand the structure of household expenditure during the crisis, we plan to undertake further research that will take into account factors such as income levels, subsidies for people and social support. Finally, it is also worth considering the impact of changes in international trade chains on consumer prices and inflation in the country.

Conclusion

Our analysis revealed significant fluctuations in the correlation between housing costs and consumer prices in various Ukrainian cities. Before the full-scale invasion, there was a stable positive correlation between costs for housing rent and consumer goods prices in most cities, indicating that changes in one were reflected in the others due to relatively stable economic conditions. However, after the outbreak of full-scale war, the correlation became negative in cities directly affected by the fighting, such as Kharkiv and Odesa. This can be attributed to a decline in housing demand due to population migration, coupled with a substantial rise in food prices resulting from logistical challenges and other sources of instability.

In relatively safe regions such as Lviv, Vinnytsia, and Kyiv, the correlation remained positive and, in some cases, increased. This suggests an increase in demand for rental housing and consumer goods due to the influx of internally displaced persons. These regions are characterised by an increased proportion of household expenditure on both types of goods (housing rent and consumer goods), which can be explained by rising prices and structural changes in demand for basic necessities and housing.

Using the Cobb–Douglas function, we found that the elasticity of household expenditure on housing and goods changed significantly during the war. In regions heavily affected by the war, spending on consumer goods increases as a proportion of the total household budget, while spending on housing declines. This suggests that households are trying to optimise their spending on basic necessities by prioritising essential goods and, if possible, reducing their housing expenditure.

While absolute rent levels did not increase significantly in cities receiving refugees, the budget share allocated to rent grew notably in safer regions, reflecting both higher rental prices and stronger demand pressures.

The approach we developed enables us to identify the spatial dimension of shifts in the market situations in cities in different regions of Ukraine, while taking into account unpredictable event dynamics. The uncertainty and difficulty of predicting the situation when indicators are constantly changing in each of the cities under study, and the possibility of incorporating this into a spatial development model, allow us to improve the spatial research methodology.

In practice, our study's results offer the basis for recommendations for adapting socio-economic policy to martial law. These recommendations could support vulnerable populations, regulate the rental housing market and ensure the availability of basic consumer goods in cities across different regions of Ukraine.

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