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Inflation expectations proprieties during the war: The case of Ukraine

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Abstract

This study compares consumer and professional inflation expectations in Ukraine before and during the Russian invasion of Ukraine. We apply entropy-based measures to tackle co-movements of expectations and macro variables (inflation, food inflation, exchange rate and production) and dynamic time warping to assess their forward and backward orientation. The pre-war sample spans from May 2019 to February 2022, and the war sample from March 2022 to December 2024. We expected to find differences between pre-war and wartime samples, as war constitutes a political shock with severe economic consequences. The study confirms the change of expectations: more substantial mutual information with past inflation in most cases, better alignment between professionals and consumers, and a change in the distances between expectations and past or future inflation. This is the first empirical study discussing Ukrainian

Keywords

- inflation expectations
- mutual information
- dynamic time warping
- war

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economic agents' expectations during the full-scale invasion. Its novel aspect also concerns the method applied—standard procedures cannot be used for this sample length.

JEL codes: C65, D84, E50

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Introduction

We seek to investigate inflation expectations in Ukraine because they are a key variable from the point of view of monetary policy (Woodford, 2003). However, they have not yet been analysed in the context of war, and in Ukraine, a country currently under attack, these expectations were not widely studied even in the pre-war context. In this study, we fill this gap in the literature by providing the first empirical evidence on consumer and professional expectations during the invasion, which are assessed with an alternative methodology differing from standard studies. The wartime subsample is distinctive not only because of its length (34 observations) but also due to the structural breaks and new patterns of expectation formation that can be expected in a turbulent environment. These patterns affect the distributions and properties of the time series. Thus, we have chosen to employ alternative methods rather than standard regression-based approaches for this study.

The National Bank of Ukraine (NBU) has implemented inflation targeting since 2017. This strategy is based on stabilising expectations through policy actions and has proved to be a successful policy framework in many economies. However, Ukraine is a developing economy with a shorter history of inflation targeting and interrupted disinflation process even before the surge in global inflation. During Ukraine's early years of inflation targeting, the level of inflation deviated from the upper or lower band of fluctuations, consistently raising questions about the NBU policy's impact on price stability (Gertchev, 2021).

Russia's invasion changed the structure of Ukraine's economy. The National Bank of Ukraine's priorities shifted from price stability to macro-stabilisation and to financing war expenditures (Danylyshyn & Bohdan, 2022). The inflation targeting framework was modified by pegging the hryvnia rate to the US dollar, introducing restrictions in the FX market, closer cooperation with the state administration, and the NBU financing war expenses. This change

in the economy and in monetary policy affected the expectations of economic agents. Moreover, even though the invasion occurred during an inflation surge, it triggered inflation globally, as presented by Maurya et al. (2023). The invasion affected infrastructural and production facilities, the labour market, supply channels, availability, and prices of basic consumption goods. It also triggered a psychological shock for Ukrainian citizens. Thus, there are numerous reasons why one might expect a change in the expectations formed by Ukraine's economic agents.

This study's results can provide information on the proprieties of expectations during the invasion compared to the pre-invasion period. Recognising a new pattern has practical implications for the National Bank of Ukraine. It also allows the NBU to assess the efficiency of its policy and communication.

In this paper, we use monthly aggregated data on consumer expectations derived from the NBU dataset and Consensus Forecast data for professionals. We apply entropy measures (mutual information and mutual conditional information) and dynamic time warping (DTW) to identify the co-dependencies between professional and consumer expectations and inflation, food inflation, exchange rates and production, and the degree of expectations' forward orientation during the Russian invasion of Ukraine. The study covers Ukraine from May 2019 to December 2024, and the research period is divided into a 'pre-war' and 'during the war' subsample.

Compared to standard methodology (based on regressions), the approach here has the advantage of not requiring assumptions about distributions, lags and estimators, as presented by Rutkowska and Szyszko (2022). They could also be applied to shorter samples, such as ours. DTW is often used to overcome distortions by aligning and classifying time series (El Amouri et al., 2023). It was applied to discuss business cycles by Raihan (2017), and Franses and Wiemann (2020). Entropy measures were used to identify information flow in a financial context by Lahmiri and Bekiros (2020), and Będowska-Sójka et al. (2021). Entropy-based measures are used also to analyse uncertainty and information flow. For example, Shoja and Soofi (2017) and Gülşen and Kara (2019) explore uncertainty and disagreement among economic forecasters using entropy measures, and Grimme et al. (2014) to study inflation uncertainty. Camacho et al. (2021) apply transfer entropy to develop a non-parametric Granger causality test for longitudinal data, and Behrendt and Schmidt (2021) utilise transfer entropy and mutual information to investigate the nonlinear relationships between stock prices and trading volume. Applying entropy measures to tackle expectation proprieties was presented by Rutkowska et al. (2024).

The remainder of this paper is organised as follows: Section 1 briefly reviews existing literature in the field, and Section 2 presents the sample and data used; Section 3 describes the study's methods and Section 4 presents and discusses our results and analysis. The paper concludes with our findings.

1. Literature review

The existing literature does not directly discuss the evolution of expectations in Ukraine during the war. However, some studies suggest that war affects global and local inflation. Dräger et al. (2022) consider the war to be a political shock which, like natural disasters, has significant and long-term effects on private forecasts for inflation. Liadze et al. (2023) estimate that the war increased global inflation by 2 p.p. in 2022 and 1 p.p. in 2023. The idea of war being an extra trigger for global inflation is also discussed by Maurya et al. (2023). Moreover, times of heightened general uncertainty are mirrored by increased uncertainty about future inflation (Londono et al., 2023). Although this paper does not tackle the uncertainty directly, we can assume that war-related uncertainty affects expectation formation patterns.

Despite the importance of recognising expectations patterns after the day of the invasion, Ukrainian consumers and professionals have not yet been empirically tested for changes in their expectations. However, some studies for European economies confirm the immediate change in expectations due to the invasion: one for Germany (Afunts et al., 2023) and one for Italy (Ropele & Tagliabracci, 2024). They analyse the expectations survey results among individuals and companies. They also replicate natural experiment settings, as both started before the day of the invasion and continued afterwards. The results report an immediate response to expectations due to the war eruption.

Additionally, Dräger et al. (2022) surveyed German economic experts just after the day of the invasion and confirmed the immediate response to their forecasts of inflation: they increased by 0.75 p.p. for 2022. The descriptive question regarding the possible reasons for this increase proves that German experts attribute it directly to war-related factors. Interestingly, when the results were compared to the study of a representative sample of households, the authors found consumers' reactions were both lagged and much lower.

Past studies on Ukraine's expectations are rare and not linked directly to political shock. Studies discussing expectation forward- and backward-lookingness hardly exist. As indicated by Lukianenko et al. (2022), when forecasting prices, professionals tend to base on past forecasts, especially if the economic situation in the country is mostly unstable and there is significant uncertainty about inflation in subsequent periods. However, no econometric analysis supports this assertion. Zholud et al. (2019) conclude that private forecasts are non-rational, identifying some forward-looking components in expectations, which are higher for professionals. Gertchev (2021) notes that consumer and professional inflation expectations before the pandemic diverged from actual inflation and the NBU forecasts, concluding that households deliberately ignored or disagreed with the central bank's announcements. Again, this conclusion is based on data observations not supported by a statistical study.

Ukrainians operate in a higher-inflation environment, which transforms into more attention being paid to inflation than by private entities in advanced economies with a longer history of successful inflation targeting (Coibion et al., 2020). The Ukrainian economy operated in a more turbulent environment even before the war. Past studies on expectations conducted for Ukraine and published in English are observational studies that do not cover the most recent evolution of expectations. Therefore, the novel aspect of this work lies in its empirical analysis of recent dependencies between expectations of two groups of economic agents and macro variables.

Assuming that the rational expectation hypothesis does not describe the actual behaviour of expectations when searching for theoretical premises regarding the change of expectations due to the invasion, we can refer to the fact that economic agents face the costs of collecting, absorbing and processing information. As presented by Mankiw and Reis (2002) and Reis (2006), they remain inattentive and do not update expectations daily. The outbreak of war is an event worth noting and, contrary to how standard economic news is disseminated, news about military aggression spreads quickly and easily among society. Thus, we assume inflation expectations during the invasion behaved differently to the pre-invasion period. The differences appear in orientation towards the future, coordination of information content, and alignment.

In addition to the theoretical premises that allow us to assume that Ukrainian consumers and professionals changed their expectations, there are several other channels through which the war can affect expectation formation. These are linked to the economic shock initiated by the invasion, psychological and behavioural factors, and policy measures applied. These channels interlink. Determining which matters most is challenging because individual respondents can simultaneously associate the war with multiple aspects directly affecting the economy and inflation (Afunts et al., 2023). Moreover, professionals might react to different factors than consumers.

Psychological factors relate to the intense psychological pressure stemming from the invasion. This pressure affected the perception of the current and future economic situation. The panic was well grounded in the current political and economic situation, also affecting expectation formation. The most immediate consequences of Russia's invasion were deaths, the physical destruction of infrastructure and production facilities, and the occupation of some territories (NBU, 2022a). The war disrupted supply chains, reduced the supply of some goods, raised companies' operating costs and increased business risk. Seiler (2022) attributes the increase in inflation expectations in Ukraine directly to supply-side distribution and the surge in energy costs. Economic agents, especially households, become more pessimistic in such circumstances and less able to process incoming information. As presented by Guirola and Kataryniuk (2022), consumers whose medium-term inflation forecasts went up during the Russian invasion of Ukraine were, on average,

those who became most pessimistic about the economic outlook. The rise in pessimism as a mechanism that transforms into higher expectations was also confirmed for German consumers (Afunts et al., 2023). A similar situation could arise in Ukraine: a pessimistic economic outlook and elevated expectations.

Due to the direct consequences of the invasion, economic agents operated under a psychological shock, which the National Bank of Ukraine also noted and incorporated in its decisions: the NBU abandoned the standard policy instrument, interest rates, as their transmission was deemed ineffective (NBU, 2022a). Pegging the exchange rate and introducing FX restrictions were policies to support macro stabilization and anchor economic agents' expectations. Still, the monetary policy framework change is one of the most important channels affecting expectation formation after the outbreak of the war. The nominal anchor was shifted from the inflation target to the exchange rate.

The next aspect that could lead to a change of expectations formation during the war was the economic agents' lifetime inflation experience. Past inflation experience matters when consumers make decisions on the direction of future price changes, but is less relevant when considering the level (Conrad et al., 2022). Ukraine's economic agents experienced many economic crises and inflation episodes, which could fuel the increase in inflation expectations. It is also linked to the rise in global inflation just after the breakout of war: one of the possible channels through which the invasion could impact expectations negatively in Ukraine is the elevated global and domestic inflation at the time of the invasion. As inflation remained high and rose, the war was an extra boost for economic agents to raise their expectations in unfavourable conditions. Ukrainians also reacted to higher energy prices, food prices (the most important components of their consumption basket), and the unavailability of some goods and services. As suggested by Galati et al. (2022), inflation outcomes speak louder than central bank words (declaration) when it comes to households' inflation expectations. The higher risk of unanchored expectations under more extended periods of elevated inflation is more profound for consumers and companies but also occurs for specialists (Coibion et al., 2020; Galati et al., 2022). This effect is observed even in advanced economies (Moessner & Takáts, 2020). More focus on current inflation is also expected for Ukraine's economic agents (Coibion & Gorodnichenko, 2015; Coibion et al., 2020).

Inflation expectations could also be fuelled by the massive financing of budget needs introduced immediately after the invasion. In 2022, the NBU financed one-third of the state's borrowing needs. Even though the NBU announced that it would only finance critical government and social expenditures while maintaining maximum transparency of these transactions (NBU, 2022b), economic agents, especially professionals, might expect an inflationary effect from such an action.

Past studies regarding expectation evolution allow us to assume that:

H1: The characteristics of economic agents' expectations in Ukraine are different during the war as compared to pre-invasion.
H2: During the war, economic agents are more oriented toward the future when forecasting inflation.
H3: As war and war news spread widely and fast, the coordination between professionals and consumers is higher during the invasion.

2. Sample and data

2.1. Dataset

The study focuses on short-term expectations (12M), as long- term surveys are unavailable for consumers. The sample was divided into two subsamples: 'the pre-war' (May 2019–February 2022) and 'during the war' (March 2022–December 2024). We arbitrarily chose the sample to keep the same number of observations in both subsamples. The 'during the war' sample starts in March, as the invasion occurred after the surveys were conducted. As presented in Section 2, studies regarding expectation formation just after the invasion for other economies suggest a change in the formation pattern. Moreover, a preliminary study also identified structural breaks in the expectations time series for Ukraine. In this study, we use the following data sets:

– for consumers: quantified results of expectation surveys provided by the NBU,
– for professionals: Consensus Forecasts of Consensus Economics,
– inflation rate, including food inflation: the main statistical office's data collection,
– the industrial production index, exchange rates of Ukrainian hryvnia to the euro (EUR/UAH), and US dollar (USD/UAH): NBU statistical releases.

For consumers, we use the National Bank of Ukraine dataset. The NBU declares that the methodology used for conducting these surveys aligns with international standards (NBU, 2025). However, a more detailed description can only be derived from the work of Coibion and Gorodnichenko (2015). Consumers select from a set of inflation brackets running at five percent increments. They respond to the survey question: 'Inflation over the next twelve months will be':

– less than zero (prices will fall),
– between 0 and 5%,

– between 5 and 10%, etc.,
– more than 30% (extended to 50% in 2015),
– it is difficult to answer.

The last bracket from the set of responses, allowing responders to choose the highest inflation, changes over time, reflecting economic conditions. The proxy of expectation is the arithmetically weighted average value of responses. 'It's difficult to answer' answers are excluded from quantification.

Consensus Economics forecasts of professionals are fixed-event forecasts. Professionals present their expectations for the end of the current and the following year. We transform them into fixed-horizon (12M) forecasts, as suggested by Dovern et al. (2012), using weighted averages of fixed-event forecasts.

We consider standard macro variables, which are important drivers of expectations, in the analysis of codependencies run with mutual information. These are inflation, food inflation, hryvnia exchange rates vis-a-vis the euro and US dollar and industrial production index (IPI). This set of variables is a standard when expectations drivers are discussed (e.g., see Łyziak, 2014; Łyziak & Mackiewicz-Łyziak, 2014; Szyszko et al., 2020). As the NBU pegged the hryvnia exchange rate for the first 18 months of the invasion and then applied market interventions to stabilise it, making the exchange rate a nominal anchor, we perceive it as an essential inflation driver in the case of Ukrainian economic agents' expectations. The industrial production index represents Ukraine's real economic evolution. During the war, changes in economic growth or even production possibilities were easily observed, and this is why we decided to discuss them in the context of common information.

Additionally, food inflation was used as one of the coordinating factors. It is more straightforward for consumers to observe, as its weight in the consumer basket accounts for 46%.[4] This is of great significance for the perceived inflation, which constitutes the benchmark for expectation formation. Abildgren and Kuchler (2021) confirm that consumers may have another price concept in mind (food prices) rather than consumer prices in general when interviewed about the level of inflation. The reaction of food inflation to geopolitical risk was confirmed by Sohag et al. (2023).

We report the dependencies between expectations and macro variables, assuming that economic agents are informed about inflation lagged by 1M and 2M when forecasting inflation. This is the standard assumption, as inflation estimates for a previous month are published at the end of the subsequent month. The survey preceded the publication date. Moreover, due to their low level of financial and economic literacy and the slow spread of economic news, consumers need more time to process news on inflation. We

[4] The latest estimates by the State Statistics Service of Ukraine provided for 2021. The basket structure during war time was not updated.

assume that a 1M lag could be enough for professionals but not necessarily for consumers. A longer lag is a standard assumption when expectation proprieties are tested (see Gerberding, 2001; Łyziak & Mackiewicz-Łyziak, 2014). We applied a 2M lag for the industrial production index, as the publication lag is more substantial than for inflation. Finally, only 1M lag was used for the exchange rate, since this variable is easily observed on a daily basis.

To analyse forward and backward orientation, we compared the distances between expectations and inflation or food inflation because the inclusion of other variables (industrial production index and exchange rate) would not be economically meaningful in this context.

The dataset provided above was used to identify (1) the dependencies between variables with the entropy measures and (2) the forward and backward orientation of consumer and professional expectations with the DTW algorithm.

2.2. Data description and properties

Figure 1 presents inflation, consumer expectations and professional expectations in Ukraine. Before the full-scale war, disinflation was still in progress, with the latest inflation target set at 5%, even though it temporarily reached single-digit levels and dropped below the inflation target during the research period of this study.

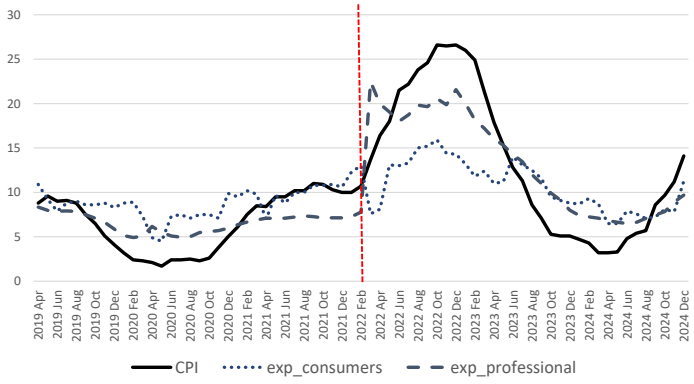

Figure 1. Inflation and expectations in Ukraine

Source: based on the datasets described in this section.

During the war, professional expectations in Ukraine were closer to actual inflation than consumers'. The reaction of Ukrainian experts to the invasion, expressed in the great increase in expectations, was immediate and simi-

lar to the response of German experts, as presented by Dräger et al. (2022). However, they overshoot inflation for only about one quarter.

Interestingly, consumers' reactions were quite the opposite. Their expectations dropped to one-digit levels in March and April 2022. The NBU assumes that they might be affected by the change of survey method from face-to-face to a telephone interview. A similar change was applied during the lockdowns, resulting in an expectation drop (NBU, 2022a). These results could also have been affected by the change in the localisation of survey participants. According to Coibion and Gorodnichenko (2015), substantial cross-regional differences in survey results occurred. Responders from East and South Ukraine expressed higher inflation expectations. As these territories were occupied, the sample could be moved to non-occupied regions, expressing lower expectations. During the invasion, particularly at the beginning, measuring and forecasting inflation was significantly hindered due to the change in the available basket of goods and services. Therefore, households that use their own basket to assess and forecast inflation might have had different forecasts than those in the standard situation. Moreover, the households might have reacted to the general stabilisation programme started by the NBU and supported by the government's actions. Fixing the exchange rate could be considered an effective stabilisation mechanism, and the information already announced regarding the government suspending rises in heat and gas prices or decreasing indirect taxes might have fostered a temporary lowering of expectations. The study by Savolchuk and Yukhymenko (2023) confirms the increase in perceived central bank credibility at the beginning of full-scale invasion as the response to applied stabilisation measures. Even though the study was conducted for companies, they are more commonly represented by individuals, not professionals. It is worth noting that the NBU did not pay great attention to the decrease in consumer expectations. It expressed fears regarding the increase in expectations driven mostly by supply-side factors and their anchoring (NBU, 2022a).

Since mid-2023, the economic situation in Ukraine has been more stable, including declining inflation, and an economic rebound. The NBU reacted accordingly, making the monetary policy more accommodative. The first interest rate cut occurred in July 2023 and was followed by several cuts, up to June 2024. The pegged exchange rate was replaced with managed floating, which provided greater scope for NBU intervention in the FX market. Since June 2023, consumers and professionals have overestimated inflation, and the time series become more aligned.

Table 1 presents descriptive statistics for our sample. As the time series are non-stationary, we do not use them to draw conclusions about differences but to provide the preliminary characteristics of the sample. The mean level of expectations for consumers and professionals after the invasion was higher. On average, specialists increased their forecasts more than consum-

Table 1. Descriptive statistics for data

	Inflation	Food inf	Exp Con	Exp Prof	EUR/UAH	EUR/UAH	IPI
	Before the war						
Mean	6.62	7.55	8.85	6.55	30.79	26.84	98.51
Median	7.50	8.50	8.80	6.98	30.97	27.07	99.80
Standard deviation	3.33	4.22	1.80	1.00	2.50	1.49	3.78
Kurtosis	–1.66	–1.34	0.68	–1.28	–1.03	–0.52	–1.49
Skewness	–0.22	0.00	–0.15	–0.33	–0.45	–0.54	–0.34
Minimum	1.70	1.30	4.50	4.92	26.10	23.85	91.90
Maximum	11.00	14.30	13.00	7.99	34.20	29.60	103.30
	During the war						
Mean	13.49	15.72	10.73	13.34	39.77	37.17	89.69
Median	12.05	13.80	11.10	12.72	39.91	36.57	97.50
Standard deviation	8.32	12.49	2.85	5.62	3.82	3.52	19.54
Kurtosis	–1.41	–1.46	–1.35	–1.68	0.21	0.99	–1.68
Skewness	0.32	0.21	0.13	0.15	–0.68	–1.03	–0.25
Minimum	3.20	–0.50	6.50	6.49	30.78	29.25	61.00
Maximum	26.60	35.70	15.90	22.47	45.79	42.04	117.20

Note: 'Exp Con' denotes consumer expectation, and 'Exp Prof' – professional expectation; 'Food inf' represents food inflation and IPI – industrial production index.

Source: own elaboration.

ers. The wartime sample shows greater standard deviation, more dispersed mean expectations across time, and more forecasts below the mean, as indicated by positive skewness.

3. Methods applied

First, we analyse the dependencies between the expectations of consumers and professionals by entropy measures. We use mutual information, which quantifies the 'amount of information' obtained about one random variable by observing the other random variable (here—the degree of uncertainty dropped in expectations, assuming that inflation (or another macro variable) is known or the degree of uncertainty reduced in one group expectations as-

suming knowledge about expectations of the other group), and mutual conditional information, which expresses the mutual information of two random variables conditioned on a third (here, the degree of alignment of professional and consumer expectations excluding inflation or food inflation, industrial production index or exchange rate as a coordinating factor). The mutual information between two continuous random variables X, Y with probability destiny function $f(x)$ is given by equation (1):

$$I(X,Y)=\int_X\int_Y f(x,y)\log\frac{f(x,y)}{f(x),f(y)}dxdy \tag{1}$$

The mutual information has the following properties:

- symmetry: $I(X,Y)=I(Y,X)$,
- non negativity: $I(X,Y)\geq 0$,
- $I(X,Y)=0\Leftrightarrow X$ and Y are independent,
- $I(X,Y)$ is not bounded.

A normalised version of the mutual information was proposed by Linfoot (1957) as:

$$r(X,Y)=\sqrt{1-e^{-2I(X,Y)}} \tag{2}$$

and is called the information coefficient of correlation. In the following, all results are presented in a standardised version. Conditional mutual information between X, Y given Z with joint probability density $p_{X,Y}(x,y)$ is as follows:

$$I(X,Y\mid Z)=\int_X\int_Y\int_Z p_{X,Y,Z}(x,y,x)\log\frac{p_{X,Y,Z}(x,y,z)}{p_{X,Z}(x,z)p_{Y,Z}(y,z)}dxdydz \tag{3}$$

The conditional mutual information measures how much uncertainty is shared by X and Y, but not by Z.

In the case of continuous data, two estimation methods of the mutual information can be considered: (1) an estimation using discretisation, where the support sets of the random variables are discretised; (2) a nonparametric estimation without discretisation. In the study, we used the first method. Let X be a continuous random variable. We divide the interval of support set into k sub-intervals, called bins, with the following notation: n_k = the number of samples in bin k; N = the total number of samples; c = the total number of bins. The partition of the support set into sub-intervals provides each having the same number of data points.

After the discretisation of the variable, the entropy was estimated using an empirical estimator (Meyer, 2008):

$$H_{emp}=-\sum_{k=1}^{c}\frac{n_k}{N}\log\frac{n_k}{N} \tag{4}$$

We use the package *infotheo* (Meyer, 2014) for *R* programming to calculate entropy-based measures. The presented value is normalized mutual information, scored to scale the results between 0 (no mutual information) and 1 (perfect correlation). The mutual information denotes co-dependencies in two variables: non-linear relations between them. It indicates how much information can be obtained for a random variable by observing another random variable.

Next, we provide the distance measure using DTW algorithms, introduced in the literature by Vintsyuk (1968) and Sakoe and Chiba (1978), in both cases for speech applications. We consider two time series:

$C = \{c_1, c_2, ..., c_n\}$ and $Q = \{q_1, q_2, ..., q_n\}$ of length n and m, we construct an $n \cdot m$ distance matrix $D = (d(c_i, q_j))_{m \cdot n}$, where the entry $d(c_i, q_j)$ is the distance between points c_i and q_j. Then, we search for an optimal warping path ϕ, which minimises the accumulation of corresponding distance, subject to:

- continuity: given $\phi_k = (a, b)$ then $\phi_{k-1} = (a', b')$ where $a - a' \leq 1$ and $b - b' \leq 1$, which restricts the allowable steps in the warping path;
- monotonicity: given $\phi_k = (a, b)$ then $\phi_{k-1} = (a', b')$ where $a - a' \geq 0$ and $b - b' \geq 0$, which assure the points in to be monotonically spaced in time;
- boundary conditions: $\phi_1 = (1, 1)$ and $\phi_K = (m, n)$ and so the warping path starts and finishes in diagonally opposite corner cells of the matrix.

Dynamic time warping is invariant to time shifts, regardless of their temporal span. However, to ensure DTW remains sensitive only to local changes, constraints can be added to restrict the set of allowable paths. In this study, we apply windowing constraints suggested by Rutkowska and Szyszko (2022).

These procedures allow us to estimate not the distance between series in general but to approximate the degree of expectations orientation into the future or the past. Therefore, to measure the level of forward orientation, we search for the warping path only within the upper triangular distance matrix. Similarly, to measure the level of backward orientation, we use the lower triangular cost matrix, which is presented in Figure 2.

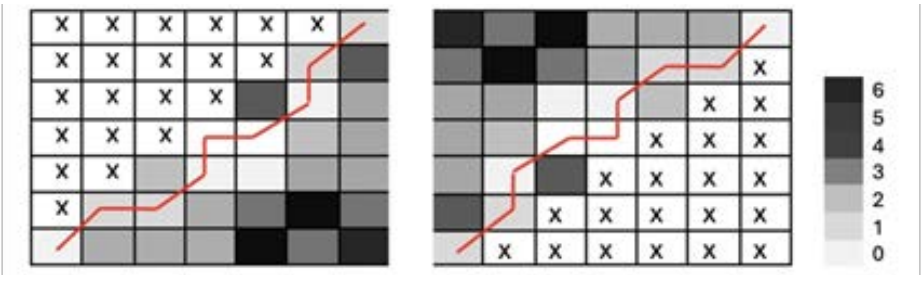

Figure 2. Distance matrix with optimal alignment and unacceptable area (marked with x) for backward (left panel) and forward (right panel) window

Source: own elaboration.

The notions of forward and backward orientations do not fully replicate the understanding of forward- and backward-lookingness as presented by standard methods (see Łyziak, 2014; Szyszko et al., 2020), based on the rationality tests, which are not applicable for the number of observations we have. The algorithm does not obey the standard lag structure when searching for the shortest distance between expectations and past or future inflation.

4. Results and discussion

The discussion of results starts with a mutual information analysis. Mutual information analysis presents the common information embedded within the expectations of professionals or consumers and inflation in Ukraine (see Figure 3 and Appendix Table A1) and the common information embedded within economic agents' expectations and industrial production index and exchange rate (see Figure 4 and Appendix Table A2).

When inflation is considered as a coordinating factor for professional expectation, we can conclude it matters less during the invasion, irrespective of the lags we discuss (see Figure 3). This result suggests that after the outbreak of war, professional forecasters in Ukraine reacted to information other than that on inflation to a greater extent than before the war. Increased macroeconomic uncertainty can encourage economic agents to put more effort into collecting data and forecasting, which is confirmed by micro-level analyses (Hope & Tony, 2005). This also aligns with the theoretical premises of bounded-rationality theories of expectation formation—economic agents become more attentive during turbulent times. They are ready for higher costs of acquiring and processing information (Mankiw & Reis, 2002). Bracha and

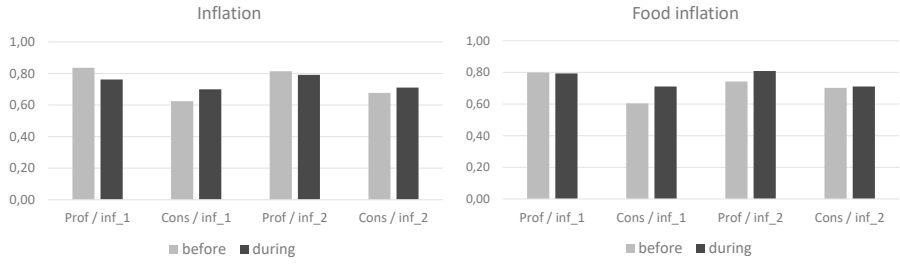

Figure 3. Mutual information between expectations and inflation

Note: 'Prof' denotes professional expectations, 'Con' – consumer expectations, 'inf_1' – 1M lagged inflation or food inflation, 'inf_2' – 2M lagged inflation or food inflation.

Source: own elaboration.

Tang (2022) confirmed this theory empirically for the U.S. However, it must be noted that this analysis does not allow us to conclude the causality between variables. It only describes co-movements whose desynchronization, as presented in Figure 1, could be due to many factors.

The jump in professional expectations just after the outbreak of war can be explained by understanding the extraordinary conditions and the effect of political shock on the economy's supply side and accounting for them in the inflation forecast. Food inflation was more important than inflation as a coordinating factor for professional expectations during the war when a 2M lag is considered. It is possible that professionals coordinated their expectations more with food inflation. Ukrainian consumers, who reported slightly higher alignment with inflation and food inflation after the invasion, could not process any extra information during increased uncertainty. However, the change in alignment for this group of economic agents is negligible, especially when a 2M lag is considered.

Mutual information between expectations and industrial production index decreased during the invasion for both groups of economic agents (see Figure 4 and Appendix Table A2). Still, the decrease was low. The assumption that during the war-related, severe economic downturn economic agents observed more closely production was not confirmed. It is worth noting that production data are published with the longest lag, and interpreting them in terms of the standard transmission mechanism is not so straightforward, especially for consumers with low economic literacy. When production collapses, the lower output gap transforms into lower inflation, as suggested by standard neo-Keynesian frameworks (Woodford, 2003). However, households do not recognise this relationship. Quite often, economic agents who

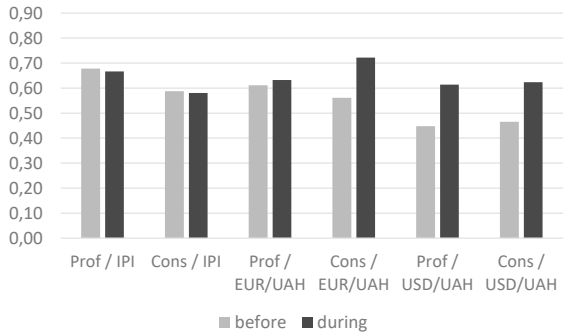

Figure 4. Mutual information between expectations and other economic variables

Note: 'Prof' denotes professional expectations, 'Con' – consumer expectations, IPI is 2M lagged, and exchange rates – are 1M lagged.

Source: own elaboration.

are more pessimistic about the economic outlook also exhibit greater pessimism about inflation and increase their forecasts for inflation. The effect of pessimism could be the case here, and transform into lower coordination between production and expectations after the war eruption.

An interesting observation can be made when mutual information between expectations and exchange rates is considered (see Figure 4 and Appendix Table A2). Knowing the exchange rate reduced the uncertainty in expectations during the war more than before it. This suggests that the NBU exchange rate policy was incorporated into expectation formation. Mutual information between professional expectations and USD/UAH rates increased more than for EUR/UAH rates when the US dollar became a nominal anchor for monetary policy. For consumers, the magnitude of change was comparable for both currencies.

When common information between expectations and inflation or other macro variables is compared, knowing inflation and food inflation has much more power to reduce expectations uncertainty than knowing production or exchange rates. Even if the exchange rate is considered an important coordinating variable for expectations in the Ukrainian economy, the focus on current inflation evolution prevails, as discussed in Section 2.

The next important question regarding expectation formation is the association between the expectations of different economic agents. Figure 5 and Appendix Table A3 present the results of the co-movement analysis between professional and consumer expectations. Common information increased after the outbreak of war.

More significant alignment is also reported for the conditional common information, regardless of which variable is excluded as the coordinating factor. In the conditional context, the results suggest that the alignment increases due to factors other than the common knowledge of the evolution of any of these specific variables. This means that co-movements could be driven by the general sentiments of professionals and consumers about the economic outlook. It is worth noting that when past inflation or food inflation is excluded, the change in coordination of expectations for pre-war and during-war subsamples is highest.

Even though the common information analysis suggested stronger links between past inflation or food inflation and expectations during the war for most of the cases, conditional mutual information suggests that during the war, other than past inflation, news transformed into a higher alignment of expectations between professionals and consumers. Still, if mutual and conditional mutual information are compared, the former is greater for all cases. This suggests that the common information embedded in professional and consumer expectations is primarily based on past inflation.

One of the most important questions regarding expectation formation is their alignment with past or expected inflation. In this study, we search for

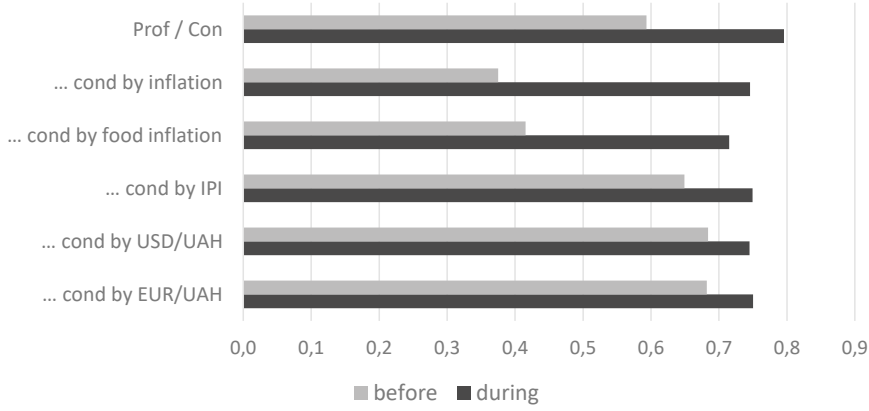

Figure 5. Mutual information and conditional mutual information between professional and consumer expectations

Note: 'Prof' denotes professional expectations, 'Con' – consumer expectations, 'cond' – conditioned by.

Source: own elaboration.

forward and backward orientation referring to actual inflation and food inflation. Figure 6 and Appendix Table A4 present the results of distance analysis returned by the DTW algorithm with the constraints on the windows (only forward or backward distance is considered). The values presented are distances divided by the number of observations of both series. The dynamic time warping provides a very good time series comparison. However, its distance is time series-dependent, and the values itself cannot be interpreted as big or low. Moreover, it shows the distance, which demonstrates the dissimilarity. If the forward distance is lower than the backward distance, expectations are more aligned with the future evolution of inflation.

As mentioned in Section 3, this understanding of forward and backward orientation differs from the standard approach, which compares expectations from period t only with past inflation from period t_{-1} or future inflation from period t_{+12}. DTW algorithm does not impose the constant lag structure. As a result, it returns the orientation for the past or future but is not understood in the same way as standard methods. It assumes that economic agents do not necessarily refer to a given period when forming expectations. DTW aligns sequences by finding the path that minimises the cumulative distance between the two sequences. This alignment allows for the non-uniform stretching and compressing of time in either sequence. The flexibility helps to match similar patterns that may occur at different speeds or be slightly shifted. Therefore, there is no fixed or constant lag across the entire sequence. Thus, if economic agents expect an inflation increase of several points, which occurs in the

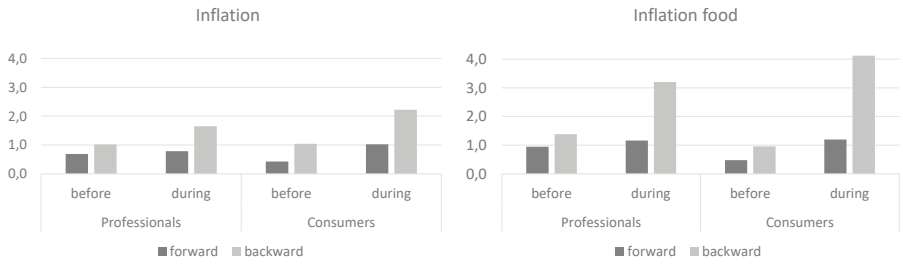

Figure 6. Distances between expectations and inflation or food inflation

Source: own elaboration.

next few months (and not necessarily equally in 12 months), their expectations are forward-oriented. If, on the other hand, they are least distant from past inflation, then they are backward-oriented.

A caveat is required here. For forward-looking analysis, the algorithm was constrained in measuring the forward distance. Expectations from March 2024 could be juxtaposed only with nine forthcoming instances of inflation or food inflation (from April to December 2024) due to the sample length.

A more forward- than backward-oriented approach is reported for Ukrainian economic agents before and after the war eruption, no matter whether we search for the distance between expectations and inflation or food inflation. This result is surprising. Ukrainian economic agents likely were more backward- than forward-looking before the invasion, as suggested by Zholud et al. (2019) and Lukianenko et al. (2022). However, the distance analysis provided in Table A4 reports shorter forward than backward distances for consumers and professionals before and during the invasion. It is worth noting that these distances increased during the war. The explanation could be linked to the importance of the exchange rate as an expectations driver. Before the invasion, Ukrainian consumers relied heavily on changes in the USD/UAH exchange rate when forecasting inflation (Coibion and Gorodnichenko, 2015). The NBU introduced restrictions on FX transactions and capital movements and fixed the USD/UAH exchange rate (NBU, 2022c), which could have affected the information consumers collect. This is in line with the observation provided by the conditional information analysis: inflation or food inflation became a much less coordinating factor for the expectations of consumers and professionals than other macro variables. Mutual information between expectations and exchange rates increased. It is worth noting that if food inflation is considered, the backward distance during the war increased more than for inflation. The change in forward distance was comparable regardless of whether food inflation was discussed.

DTW distances highlight another piece of information that the mutual information analysis offers. They refer to distances between the levels of time

series, whereas mutual information is a measure of the extent to which knowledge of one variable reduces uncertainty about the other. Thus, expectations may be more aligned with past inflation after the invasion and report higher backward distances as the difference in levels increases. This is the case in this study.

Conclusions

The paper provides the first empirical analysis of expectation changes in Ukraine, comparing their proprieties before and during the invasion. The study applies entropy measures and the dynamic time warping algorithm to provide a preliminary analysis of the change in expectations characteristics. Applying standard measures is not possible as the war sample is relatively short. Still, recognising expectation formation patterns is a crucial topic from a central bank perspective.

The results reported here confirm the change in expectations during the war (H1: The characteristics of economic agents' expectations in Ukraine are different during the war as compared to pre-invasion). Assuming the past inflation is known, the uncertainty reduction in expectations decreased in the case of Ukrainian professionals and increased for Ukrainian consumers. If inflation was replaced by food inflation, the uncertainty was reduced for consumers and professionals (for 2M lag). Mutual information, including conditional mutual information (assuming that inflation, food inflation, industrial production index or exchange rate is not a coordinating factor), increased during the invasion. The forward orientation towards inflation or food inflation of economic agents prevailed before and during the invasion, even though all the distances (forward and backward) were higher during the invasion. Thus, the second hypothesis (H2: During the war, economic agents are more oriented toward the future when forecasting inflation) was partially confirmed: professionals and consumers were more forward- than backward-oriented after the invasion, but during the war, the forward-looking distances were longer, which signals less accurate forecasts. Eventually, the coordination between professionals and consumers increased during the invasion (H3), even in a conditional context (excluding another macro variable as a coordinating factor).

From the central bank perspective, economic agents should be forward-looking or even rational to avoid their expectations being driven by past inflation during periods of surging inflation. The homogeneity of expectations among different economic agents also facilitates monetary policy, as its instruments are not selective. Forward orientation and co-movements of inflation expectations between consumers and professionals are good news

for central banks. As expectations did not rocket just after the invasion began (they were relatively stable and below the actual inflation rate), the NBU's fears regarding their evolution were not realised. Moreover, the central banks observe how expectations evolve regularly, paying much greater attention to them when a crisis occurs. This paper contributes to such monitoring under special circumstances by describing the changes or similarities in expectations behaviour after the invasion as compared to the pre-invasion period.

Several caveats should be made regarding the results of this study. Firstly, as usual, there is a tradeoff between the advantages of different methods. In this case, alternative methods were applied, which made it possible to conclude for a relatively short sample without any assumptions regarding the sample proprieties and length. By choosing this method, we need to abandon the greater comparability of the results with the existing studies and the possibility of a more straightforward interpretation. Secondly, during the research period of this study, global and domestic economies underwent rapid inflation surges, which then decreased. The inflation trends and not only war-related factors could affect how expectations are formed. However, while past studies justified choosing the date of the invasion as the breakpoint in inflation, the causal analysis requires a longer sample.

Appendix

Table A1. Mutual information between expectations and inflation

Subsample	Prof / inf_1	Cons / inf_1	Prof / inf_2	Cons / inf_2
Inflation				
Before war	0.8356	0.6242	0.8143	0.6763
During war	0.7621	0.6991	0.7912	0.7107
Food inflation				
Before war	0.7986	0.6041	0.7428	0.7018
During war	0.7939	0.7107	0.8090	0.7107

Note: 'Prof/inf' refers to mutual information between professional expectations and inflation; 'Con/inf' between consumer expectation and inflation; 'inf_1' denotes inflation or food inflation lagged by 1M; 'inf_2' denotes inflation or food inflation lagged by 2M.

Source: own elaboration.

Table A2. Mutual information between expectations and other variables

Subsample	Industrial production index	EUR/UAH	USD/UAH
	Professionals		
Before war	0.6781	0.6116	0.4479
During war	0.6671	0.6323	0.6135
	Consumers		
Before war	0.5877	0.5610	0.4653
During war	0.5805	0.7222	0.6240

Source: own elaboration.

Table A3. Mutual and conditional mutual information between professional and consumer expectations

		Before war	During war
Prof / Con		0.5932	0.7959
Prof / Con conditioned on:	Inflation	0.3753	0.7458
	Food inflation	0.4153	0.7150
	Industrial production index	0.6492	0.7494
	USD/UAH	0.6839	0.7452
	EUR/UAH	0.6823	0.7502

Source: own elaboration.

Table A4. Distances between expectations and inflation

		Forward	Backward	Backward--forward
Inflation	Consumers			
	before	0.4294	1.0397	0.6103
	during	1.0215	2.2227	1.2012
	Professionals			
	before	0.6904	1.0208	0.3304
	during	0.7874	1.6476	0.8602
Food inflation	Consumers			
	before	0.4809	0.9603	0.4794
	during	1.1993	4.1213	2.9220
	Professionals			
	before	0.9468	1.3865	0.4397
	during	1.1625	3.2020	2.0395

Note: 'Backward' measures the distance between expectations and past inflation; 'Forward' represents the distance between expectations and future inflation.

Source: own elaboration.

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