“Ukrainian hryvnia under the floating exchange rate regime: diagnostics of the USD/UAH exchange rate dynamics”

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UKRAINIAN HRYVNIA UNDER THE FLOATING EXCHANGE RATE REGIME: DIAGNOSTICS OF THE USD/UAH EXCHANGE RATE DYNAMICS

Abstract

The study identifies the features of the USD/UAH exchange rate dynamics for the period from January 2014 to May 2020. The main purpose of the empirical analysis is to determine the current trend of the USD/UAH exchange rate (is it random or permanent), indicate the presence of seasonality in foreign exchange rate dynamics and evaluate its sensitivity to external shocks. Three hypotheses are tested using several methods of time series analysis (autocorrelation analysis, ADF, Phillips-Perron and Granger tests), including a trend-season model using a time series of one variable (ARMA), a multifactor VAR-model, impulse functions. The results show that, the movement of the hryvnia exchange rate against the US dollar is a stochastic process. Its trend has a random component and tends to change sharply over time. Moreover, exchange rate fluctuations are seasonal. It depreciates in the first and second quarters, and strengthens in the third and fourth. Some macroeconomic indicators cause a positive or negative reaction of the USD/UAH exchange rate. This indicates that today the Ukrainian foreign exchange market is relatively efficient, but stable, since its reaction to external shocks is short-term, insignificant and tends to fade out. Although the findings are controversial, they support the generally accepted view that the exchange rate formation is a multifactorial process that depends on several macroeconomic factors. However, high volatility and random walk specification indicate that it is almost impossible to predict its future value at this time.

Keywords external shocks, foreign exchange rate, foreign exchange regime, market efficiency, seasonality, random walk

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INTRODUCTION

Despite macroeconomic and financial imbalances and socio-political tensions in Ukraine, the country's currency tends to periodically strengthen or depreciate. Such changes are often perceived as "anomalies" because they contradict the efficient market hypothesis (EMH). In December 2019, hryvnia has hit a new low against US dollar for the previous three years achieving USD/UAH exchange rate of 23.46. Given the fact that the Ukrainian economy is dollarized, it can be assumed that any exchange rate fluctuations occur not only for country-specific reasons, but also for global reasons. As a result, the volume of foreign trade, capital movements, consumption, production, living standards and other indicators of economic and social development depends significantly on the situation in the foreign exchange market. Besides, in 2014, Ukraine began to live in a new "exchange rate reality" due to the transition from a stabilized arrangement to floating exchange rate formation and inflation targeting policy. From that moment, businesses and other economic entities operate in a new condition – unpredictable and with macroeconomic instability. Thus, the study of the features of USD/UAH

exchange rate dynamics, the origin of its trend, seasonal patterns and response to external shocks under the floating exchange rate regime is relevant for preventing imbalances in the foreign exchange market and mitigating intense volatility on the part of the central bank of Ukraine (NBU).

1. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The classical theory of finance suggests that market anomalies occur after events that contradict the principles of an efficient market. Fama (1970), in the efficient market hypothesis (EMH), defines an efficient market as a market with a large number of rational profits, which motivates economic entities to actively compete with each other. They try to predict future market fluctuations using relevant and freely available information.

Foreign exchange market is highly liquid; it allows carrying out large-scale transactions with low transaction costs with freely available information to participants. Despite this fact, most scientists tend to assume that it is inefficient or relatively efficient. Meese and Rogoff (1983) suggest that exchange rates are hardly predictable. Although the unpredictability factor proves that the market is efficient, it does not work with exchange rates. Such a dilemma is a challenge for the financial system. Boothe and Longworth (1986), Levich (1989), Oh, Kim, and Eom (2007) have a similar point of view.

According to the EMH, the exchange rate changes must fully reflect the behavior of foreign exchange market participants. Also, any related information is available to them. This rule should prevent speculators from making abnormal returns. However, today, speculative and arbitrage transactions are actively conducted in the foreign exchange market, which contradicts the EMH.

Based on the random walk model, Kallianiotis (2018) has confirmed that foreign exchange market participants do not need all the information about the market condition, but only that related to currency expectations. Since exchange rate volatility is a random process.

Currency anomalies and different financial systems of countries have become the basis for the formation of various trading strategies using which foreign exchange market participants can make abnormal returns: carry trade, output gap, momentum investment (Dahlquist & Hasseltoft, 2015), value investment (Asness, Moskowitz, & Pedersen, 2013), based on information in the volatility risk premium (Corte, Ramadorai, & Sarno, 2014), optimal dynamic currency strategies (Maurer, To, & Tran, 2019), etc.

For example, Burnside, Eichenbaum, and Rebelo (2011) have identified that most investors tend to borrow in low-yield currency and invest in high-yield currency (carry trade strategy), because the exchange rates of different countries vary from each other. Moreover, each country sets its interest rates. Colacito, Riddiough, and Sarno (2019) have concluded that a business cycle factor is essential in forecasting future revenues and choosing an output gap strategy. Following this strategy, the currency of countries with strong cyclical position should be more expensive compared to the currencies with the weak cyclical position.

Modern research in currency fluctuations is often based on the theory of behavioral finance. For example, Bartram, Djuranovik, and Garratt (2018) made a broad empirical analysis of 76 currencies for the period from January 1971 to June 2018 (the Ukrainian hryvnia was included in the basket of currencies). They determined that the world foreign exchange market is "relatively" efficient, and rapid currency ups and downs occur as a result of expectations biased of analysts and actions of market participants who follow their advice but in their own way. This behavior is named "publication effects or publication bias". McLean and Pontiff (2012) appoint this behavior as "statistical biases".

Many factors that possibly affect the behavior of the exchange rate are described and analyzed in various studies. In particular, the most commonly used are key macroeconomic indicators such as inflation, discount rates, GDP and special indices (index of economic freedom, Sharpe-ratio, etc.).

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The behavioral factor is also taken into account in many cases. Accordingly, currency anomalies are the result of the irrational behavior of market participants and their future expectations. The role of the state monetary policy is also considered.

It should be noted that the studies of the exchange rate behavior of the Ukrainian hryvnia against the US dollar are still limited, especially for the period after the transition to a floating exchange rate regime. There are not pretty much works with mathematical modeling of Ukrainian currency behavior, confirming or refuting the presence of the seasonality factor, as well as the impact of external shocks on its volatility.

However, Zhuravka et al. (2019) investigated the influence of politically generated shocks on the monetary sphere in Argentina, Turkey, and Ukraine, but in the context of comparative analysis. It was found that foreign exchange markets are the most volatile. In addition, shocks arising after the use of international sanctions against certain countries cause the increase in national exchange markets volatility.

For this reason, the purpose of the study is to identify the core features of the USD/UAH exchange rate dynamics, the origin of its trend, seasonal patterns and response to external shocks under the floating exchange rate regime. To achieve these aims, the following hypotheses are tested:

H1: USD/UAH exchange rate fluctuations are a random walk process.

H2: USD/UAH exchange rate does not change seasonally.

H3: USD/UAH exchange rate dynamics respond to external shocks.

2. METHODOLOGY

This study used monthly statistics regarding the official exchange rate of hryvnia against the US dollar and all other indicators. The period is from January 2014 to May 2020. All data is taken from the websites of the National Bank of Ukraine and the State Statistics Committee of Ukraine. OPEC "basket" oil prices are taken from the database of the Organization of the Petroleum Exporting Countries.

The research includes the following stages:

1) Providing descriptive statistics and an initial description of the behavior of the USD/UAH exchange rate.

2) Checking the exchange rate behavior: identification of the presence of randomness, patterns and periodicity in the time series (autocorrelation analysis).

3) Structural analysis for time series stationarity (ADF and Phillips-Perron tests).

4) Making a forecast using of time series of one variable based on autoregression with a moving average (ARMA) plus a trend model (additive and multiplicative).

5) Analysis of the effect of external shocks on the exchange rate dynamics of the hryvnia against the US dollar (VAR model, Granger test, impulse functions).

6) Checking the quality of models (R-squared, RMSPE, MAPE, Taylor coefficient).

3. RESULTS

3.1. Initial description of the USD/UAH exchange rate behavior

The study covers the period from January 2014 to May 2020. Such a tight time frame can be explained as follows. Firstly, from 2014 to 2016, the third systemic banking crisis took place in Ukraine. After that, the principles of work of the banking, financial and other sectors changed significantly. The National Bank of Ukraine has actively pursued a policy of macroprudential regulation, and currency liberalization has begun.

Secondly, in February 2014, a floating exchange rate regime was officially established as part of the anti-crisis policy plan for 2014–2015. Since then, the volatility of the USD/UAH exchange rate has become higher than in previous years.

Source: National Bank of Ukraine.

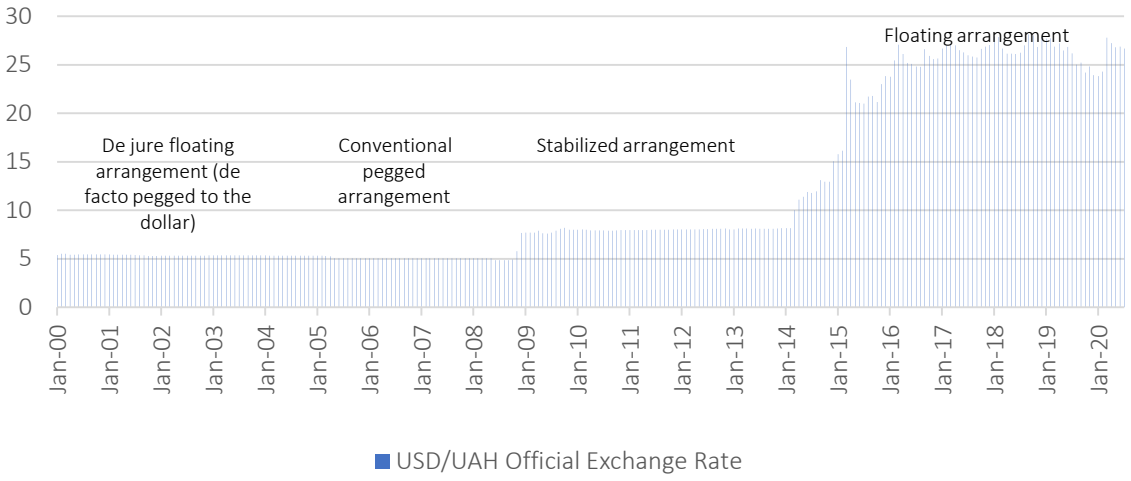

Figure 1. Dynamics of the USD/UAH official exchange rate, 2000 – May 2020

This is because when the hryvnia appeared in money circulation (September 2, 1996), the NBU followed the policy of pegged exchange rate arrangements: pegged exchange rate within horizontal bands (1996–1999), de-jure floating arrangement (de-facto pegged to the dollar, 2000–2004), conventional pegged arrangement (2005–2008) and stabilized arrangement (2009–2013).

As a result, the hryvnia revalued and devalued when the state regulator nominally changed the exchange rate of the national currency (Figure 1). Therefore, the information for previous years is not relevant in the context of this analysis. Since during the previous arrangements, the exchange rate moved without significant fluctuations as it was kept within regulated limits.

Also, the current situation in the foreign exchange market is atypical compared to past trends. As 2019 shows, the Ukrainian hryvnia, which classically tends to fall (especially from 2014 to 2017), strengthened in September and December. The USD/UAH exchange rate reached a minimum of 23.87 and 22.95 in these months for the first time.

The National Bank of Ukraine, in the Report on the Implementation of the Basic Principles of Monetary Policy (NBU, 2019, February 25), suggests that this anomaly is caused by the following market factors:

- Growth in non-residents' demand for UAH-denominated government bonds (before buying bonds, non-residents exchange foreign currency for hryvnia on the Ukrainian interbank market through authorized banks. As a result, the supply of foreign currency exceeds the demand and the hryvnia exchange rate strengthens).
- Record crop capacity of cereals in Ukraine, the rapid growth of sunflower oil prices and stable price level of grain (the more expensive these goods are on international markets, the more foreign currency proceeds Ukraine receives).
- Increase in workers' remittances from abroad (large remittances of migrants cause the revaluation of the national currency).
- Significant optimism of investors and society (unprecedentedly high level of trust in the government, the positive reaction of the international community to the results of the presidential election in April 2019 and snap elections to the Verkhovna Rada in July of the same year).

Therefore, special attention in the study will be paid to mathematical confirmation of the existence of the influence of these factors on the exchange rate of the hryvnia against the US dollar.

Thirdly, it is inflation. In Ukraine, the inflation rate is the main indicator on which the monetary

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Source: National Bank of Ukraine, State Statistics Committee of Ukraine.

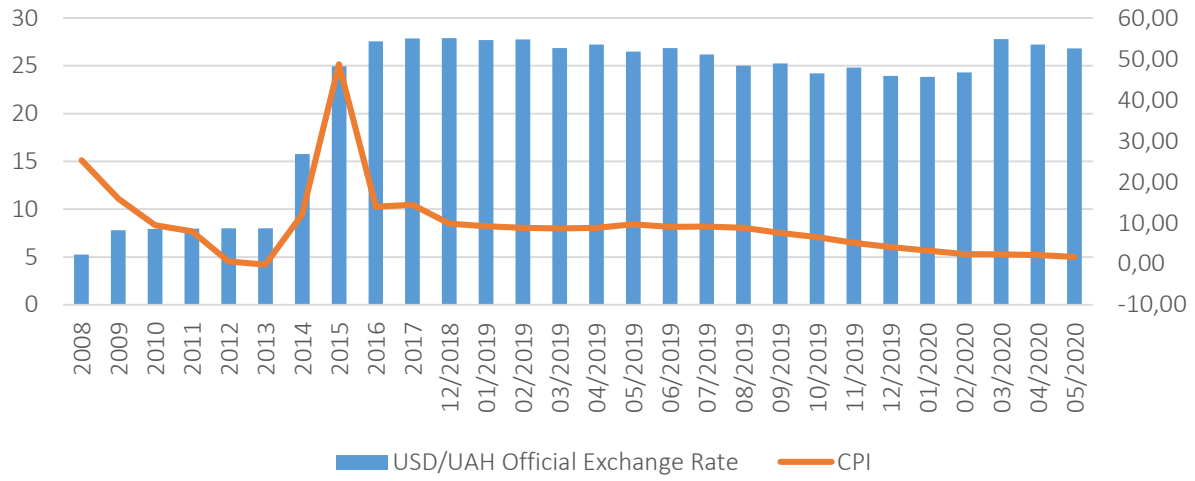

Figure 2. Dynamics of the USD/UAH official exchange rate and CPI, 2008 – May 2020

policy direction depends. Since 2014, the NBU has ensured price stability using the inflation targeting regime.

The implementation of the regime generated a rapid jump from the lowest value in the history of 0.57% in 2012 to 12.07% in 2014, and lately to 48.70% in 2015. It happened due to the hryvnia devaluation and a sharp rise in prices and tariffs (Figure 2).

As for the current trend, the CPI has been gradually slowing down since December 2018. In May 2020, the index was 1.7%. It is below than the target range (5% ± 1 pp). The disinflation process occurs due to lower energy prices and the effect of the hryvnia strengthening in 2019, which also manifested itself in prices. The inflation rate did not even increase with the growth in consumer demand due to the agiotage in March, provoked by quarantine (NBU, 2020, April).

Finally, there are new factors that have affected the country's economic activity and the stability of the foreign exchange market. This is a military conflict in eastern Ukraine, which began in 2014 and, at the same time, the signing of the EU-Ukraine Association Agreement on June 27, 2014, which suggests the fulfilment of obligations in trade, economic and financial cooperation, as well as the adaptation of national currency legislation to EU norms and standards.

In general, today the country has begun to operate in a new exchange rate regime, different from previous periods. Therefore, it is necessary to focus on the latest trends in exchange rate dynamics.

3.2. Checking the USD/UAH exchange rate behavior

Any economic process often implies the presence of a correlation between its observations, which can be detected using autocorrelation coefficients. The left side of Figure 3 shows a typical time-series correlogram of dynamics with a linear-additive trend in which the decrease occurs by approximately the same amount for each moment.

The correlogram shows that there is the dependence between the autocorrelation coefficients on each lag. That is, as the lag increases, the values of the autocorrelation coefficients decrease, and the maximum value corresponding to the first lag (0.9300). The coefficient *Prob* > *Q* is 0.0000 on each lag. This indicates a correlation between all lags.

The autocorrelation coefficient of the first order is the highest, which indicates a trend in the time series. Also, from the first to the sixth lag, the correlation function significantly differs from zero, which highlights the non-stationarity of the time series.

The results of the correlogram of the first differences show a completely different tendency. As Figure 3 (right side) shows, the strict linear dependence

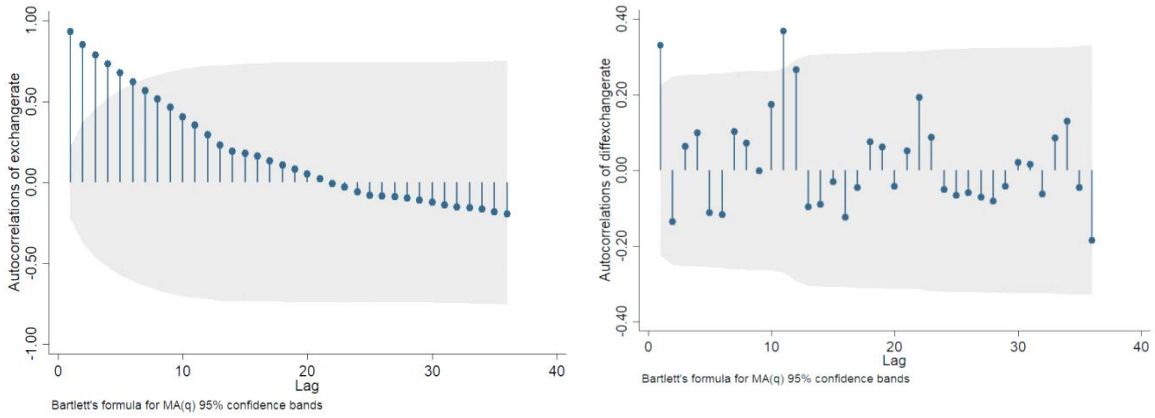

Figure 3. Autocorrelation diagrams, USD/UAH exchange rate, 2014 – May 2020 (left side – in absolute values, right side – in first differences)

has disappeared and there is a set of chaotically scattered dots that constantly change their sign and value (from –0.1858 to 0.3677).

The highest coefficients are of the 1st, 11th and 12th order (0.3307, 0.3677, and 0.2654). Thus, the time series contains periodic fluctuations and it is non-stationary. The *Prob. > Q* coefficients showed that only 8-10 lags are not autocorrelated. Table A1 (Appendix A) gives the detailed information regarding autocorrelation coefficients.

It can be assumed that the exchange rate movement is a stochastic process. Its trend contains a random walk component and tends to change rapidly over time, which confirms the presence of dots at which autocorrelation abruptly falls or rises.

3.3. Structural analysis for time series stationarity

Testing of the hryvnia exchange rate against the US dollar time series for stationarity is carried out in several variations – absolute values, the first differences and with a decrease in the time series by the required number of lags.

For this purpose, ADF and Phillips-Perron tests for the presence of a unit root are used. They allow taking into account different lags, determining whether the time series has a trend or it is a random walk process. Also, the ADF test is one of the stages of data preparation for building the VAR model used in the study (Table 1).

Table 1. Dickey-Fuller test for unit root (USD/UAH official exchange rate)

No.	Specification	Test statistics	Critical value			Stationarity		Trend/Drift	
			1%	5%	10%	p-value	Summary	p-value	Summary
1	Suppress constant	1.519	–2.610	–1.950	–1.610	0.133	–	...	...
1.1	1st difference	–5.792	–2.610	–1.950	–1.610	0.000	–	...	...
1.2	Lag (1)	0.830	–2.610	–1.950	–1.610	0.002	+	...	...
2	Include trend term	–2.234	–4.093	–3.474	–3.164	0.4707	–	0.904	–
2.1	1st difference	–6.428	–4.095	–3.475	–3.165	0.000	–	0.060	–
2.2	Lag (1)	–2.380	–4.095	–3.475	–3.165	0.018	+	0.697	–
3	Include drift term	–3.576	–2.378	–1.666	–1.293	0.0003	–	0.001	+
3.1	1st difference	–6.028	–2.379	–1.666	–1.293	0.000	–	0.000	+
3.2	Lag (1)	–3.085	–2.379	–1.666	–1.293	0.018	–	0.003	+
3.3	Lag (2)	–3.354	–2.381	–1.667	–1.294	0.004	–	0.001	+
3.4	Lag (3)	–2.571	–2.382	–1.668	–1.294	0.113	–	0.012	+

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Table 2. Phillips-Perron test for unit root (USD/UAH official exchange rate)

No.	Specification	Test statistics	Critical value			Stationarity		Trend/Drift	
			1%	5%	10%	p-value	Summary	p-value	Summary
1	Suppress constant	1.188	–2.610	–1.950	–1.610	0.000	+	...	...
1.1	1st difference	–5.644	–2.610	–1.950	–1.610	0.001	–	...	...
1.2	Lag (1)	1.255	–2.610	–1.950	–1.610	0.001	+	...	...
2	Include trend term	–2.228	–4.093	–3.474	–3.164	0.4744	–	0.904	–
2.1	1st difference	–6.258	–4.095	–3.475	–3.165	0.0000	–	0.060	–
2.2	Lag (1)	–2.229	–4.093	–3.474	–3.164	0.4736	–	0.904	–
2.3	Lag (2)	–2.227	–4.093	–3.474	–3.164	0.4745	–	0.904	–
2.4	Lag (3)	–2.228	–4.093	–3.474	–3.164	0.4745	–	0.904	–

Initially, a test with suppress constant specification shows that the time series is not stationary. Although the test statistic (1.519) exceeds critical values, and *p*-value (0.133) proves that the result is not statistically significant. Thus, the hypothesis of the non-stationarity of time series and the presence of a unit root is confirmed.

The time series with the first differences is also non-stationary, but in this case, the result is statistically significant (p = 0.000). To get a stationary time series, it was shifted by one lag. Test statistic (0.830) is more than critical values, and *p*-value is 0.002. Thus, the hypothesis of the presence of a unit root is refuted and a time series is stationary.

Next, given the trend term specification, it was identified that the time series is also non-stationary. In addition, the presence of a trend was excluded due to statistically insignificant results both in absolute values and in the first differences (0.904, 0.060). As in the first case, the inclusion of the 1st lag turned the time series into a stationary one (p = 0.018).

Moreover, considering the drift term specification, it was confirmed that the dynamics of the hryvnia exchange rate against the US dollar is a non-stationary and random walk process in all three cases, and even when the time series is shifted by three lags.

The results of the Phillips-Perron test are similar to the ADF test results. The only thing is that it takes into account only trend term specification. Stationarity was confirmed after shifting the time series by one lag. Test statistic (1.255) is more than critical values, and *p*-value is 0.001 (Table 2).

Consequently, as in Kallianiotis (2018), the results of testing the time series for stationarity confirmed hypothesis *H1*. The fluctuation of the exchange rate of the hryvnia against the US dollar is a random walk and unpredictable process.

3.4. Forecast of the USD/UAH exchange rate (ARMA plus additive and multiplicative trend models)

Preliminary analysis of stationarity shows that to model the forecast of the USD/UAH exchange rate, first of all, it is necessary to identify and remove the seasonal component from the time series. To do this, the seasonal average and the adjusted seasonal average should be calculated according to the principles of additive and multiplicative models. Tables B1 and B2 in the Appendix provide more detailed information on the forecast values calculation.

Multiplicative and additive models make it possible to predict the indicator for the next two periods using the trend equation. In this study, it is the 3rd and 4th quarters of 2020. As a result, six equations with different degrees of quality and adequacy of forecasts are obtained (Table 3).

The results are controversial. For example, forecasts based on a linear trend are the most pessimistic. They indicate that the USD/UAH exchange rate will be 30.47 and 31.02 (additive), 30.35 and 30.65 (multiplicative). However, they are not statistically significant (R^2 is 0.59).

On the contrary, the trend model based on the polynomial function of the 2nd degree shows the most optimistic forecast. The approximate USD/

UAH exchange rate will be 21.95 and 20.60 (additive), 22.02 and 20.56 (multiplicative). The quality of the forecast is high, and the results are statistically significant.

The forecast based on the logarithmic function indicates that by the end of the year the Ukrainian currency will depreciate to 28.61 and 28.80 hryvnias per US dollar (additive), 28.51 and 28.48 (multiplicative). It is also statistically significant and with high forecast accuracy.

It can be added that the trend-season model with a forecast based on the logarithmic function is closer to the real situation that is currently happening in the Ukrainian foreign exchange market. At the beginning of the third quarter of 2020, the hryvnia began to depreciate. In early July it was 26.67 hryvnias per US dollar, but to the end of the same month – 27.75.

Figures B1 and B2 in Appendix B graphically present the results. As can be seen in both cases, there is the amplitude of fluctuations. This indicates the correspondence of the time series to the additive and multiplicative models.

In general, calculations based on the additive model show that the Ukrainian currency tends to depreciate in the first and second quarters (the adjusted seasonal average is 0.39 and 0.67, accordingly), while strengthening is observed in the third and fourth quarters (–0.51 and –0.55).

The results of the multiplicative model are similar. The strengthening is in the third and fourth quarter (0.98 and 0.97), and depreciation is in the first and second (1.01 and 1.04) (Table B1 in Appendix B). The indicators characterizing the quality of the models are almost the same, so the results are equally statistically significant.

As a result, the seasonality test shows that the exchange rate of the hryvnia against the US dollar changes seasonally. This fact rejects hypothesis *H2*.

The reason for the seasonal strengthening of the USD/UAH exchange rate, which begins in the summer, is that, firstly, at this time export of agricultural products from Ukraine is growing. Hence, Ukraine's economy receives more foreign currency than in other periods.

The export of cereals, fats and oil is especially important for the economy and financing of the state budget. In 2019, total exports amounted to USD 19.5 billion, of which USD 6.6 billion (33.8% of the total) takes this group of goods.

The second reason is labor migration, which in Ukraine also has a predominantly short-term seasonal origin. For example, according to the NBU, during January-June 2019, on average, USD 930 million were transferred monthly, and since July, approximately USD 1.07 billion. A total of USD 12.017 billion of remittances from people working abroad was transferred in 2019.

3.5. Analysis of the effect of external shocks on the USD/UAH exchange rate dynamics

Today, according to the principles of a floating regime, the exchange rate must respond to current market trends. Therefore, it is important to identify which of them really affect it. To do this, the VAR-model is used, which includes the following indicators:

1. Consumer price index (%).
2. Exports of cereals, fats and oils (billion US dollars).
3. UAH-denominated government bonds owned by non-residents (UAH billion).
4. Remittances of workers from abroad (billion USD).
5. Discount rate (%).
6. OPEC Basket price (dollars per barrel).

To build a model, one first needs to check each time series for stationarity.

As Table C1 (Appendix C) shows, each time series is non-stationary except for UAH-denominated government bonds owned by non-residents. Therefore, additional calculations were made with a shifting them by one lag. This helped to turn all data set into a non-stationary one.

Next, the VAR lag order selection criteria are applied to determine the optimal lags structure of

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Table 3. Trend equations of multiplicative and additive models (forecast for the 3rd and 4th quarter of 2020)

No.	Model	R2	RMSE	MAPE	Taylor coefficient	Forecast	Adequate
	Additive model						
1	$y = 0.5905x + 15.035$ (linear)	0.5929	2.6466	18.1080	0.0777	30.47 31.02	–
2	$y = 6.495\ln(x) + 7.7027$ (logarithmic)	0.8608	1.1303	8.8014	0.0463	28.61 28.80	+
3	$y = -0.0687x^2 + 2.4221x + 6.488$ (polynomial of the 2nd degree)	0.9434	0.6878	5.1576	0.0288	21.95 20.60	+
	Multiplicative model						
4	$y = 0.5879x + 15.079$ (linear)	0.5921	2.6257	18.1762	0.0778	30.35 30.65	–
5	$y = 6.454\ln(x) + 7.8094$ (logarithmic)	0.8562	1.0976	9.0400	0.0459	28.51 28.48	+
6	$y = -0.0676x^2 + 2.4143x + 6.5565$ (polynomial of the 2nd degree)	0.9432	0.6856	5.2257	0.0293	22.02 20.56	+

Note: Forecast accuracy: up to 10% – high; 10-20% – good; 20-40% – satisfactory; 40-50% bad; more than 50% – unsatisfactory.

Table 4. Results for the lag structure test of the VAR-model

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	–1758.82	...	...	...	1.3e+12	47.7248	47.8117	47.9427
1	–1186.83	1144	49	0.000	918699	33.5899	34.2855	35.3335*
2	–1106.01	161.62	49	0.000	402253*	32.7301*	34.0343*	35.9994
3	–1057.11	97.801*	49	0.004	441194	32.7328	34.6456	37.5278

Note: * The criterion value indicates the optimal lag.

the model by five information criteria. They are the likelihood ratio test (LR), the final prediction error (FPE), the Akaike's information criterion (AIC), the Hannan and Quinn information criterion (HQIC), and Schwarz's Bayesian information criterion (SBIC). The maximum number of lags is three.

As Table 4 shows, the optimal lags for inclusion in the model are 2 (p = 0.001), according to three indicators (FPE, AIC, HQIC).

It is assumed that each time series of the VAR-model affects each other. As a result, seven equation systems were obtained. The R-squared coefficients are high for six of the seven equations (0.93-0.99) and significant enough for one (0.66). This indicates that the model is adequate (Table C2 of Appendix C).

The further step is to test for causality between the factors of model using the Granger test (Table 5). The results obtained are somewhat unexpected. It would be logical to assume that in most cases the exchange rate variable should be endogenous. However, the Granger test confirmed that it is an exogenous factor too. A significant relationship is observed between the indicators:

- discount rate – consumer price index;
- consumer price index – discount rate;
- exchange rate – remittances of workers from abroad and OPEC Basket price;
- remittances of workers from abroad – the exchange rate and OPEC Basket price;
- OPEC Basket price – exchange rate and discount rate.
- UAH-denominated government bonds owned by non-residents – exports of cereals, fats and oils, remittances of workers from abroad and OPEC Basket price.

Table 5. Granger causality test results for VAR (2) model factors

Regressor \ Regressant	USD/UAH	CPI	Exports of cereals, fats, oils	UAH-government bonds	Remittances of workers	Discount rate	OPEC Basket price
	Hryvnias per US dollars	%	Billion, US dollars	Billion, UAH	Billion, US dollars	%	Dollars per barrel
USD/UAH	...	0.109	0.383	0.150	0.028	0.079	0.002
CPI	0.344	...	0.943	0.321	0.998	0.029	0.163
Exports of cereals, fats, oils	0.834	0.761	...	0.216	0.052	0.697	0.886
UAH- government bonds	0.105	0.387	0.032	...	0.026	0.215	0.006
Remittances of workers	0.005	0.560	0.822	0.158	...	0.189	0.021
Discount rate	0.216	0.001	0.725	0.097	0.671	...	0.011
OPEC Basket price	0.003	0.143	0.509	0.369	0.133	0.030	...
ALL	0.22	0.000	0.080	0.379	0.000	0.012	0.027

Some interconnections can be explained as follows. Today, the National Bank of Ukraine pursues monetary policy based on inflation targeting. In this way, it tries to ensure an annual CPI increase at the declared level. To do this, first of all, the discount rate is used as the main instrument of monetary policy.

Owing to this monetary instrument, the central bank regulates the supply and demand for cash and cash equivalents. By changing the discount rate, the NBU affects short-term interest rates in the interbank money market. Over time, this influences interest rates on loans, deposits, and securities. As a result, consumption and investment are changing, and eventually inflation and the exchange rate.

The Granger test also shows that the CPI can affect the discount rate (although in reality, the discount rate is the mechanism of influence). The reason is the peculiarity of the transmission of the discount rate through inflation. Often, central banks lower the discount rate during the growing of current inflation or raise it when inflation is already declining.

This is because the central bank, which follows an inflation targeting policy, must manage inflation expectations. Thus, the central bank, given the current inflation rate, forecasts the most likely dynamics in the future.

Turning to the labor migration situation, according to the International Migration Report (UN, 2019), Ukraine is one of the ten largest donors of migrant workers in the world. Consequently, foreign exchange transfers of workers are constantly coming from other countries to Ukraine and their volume is significant. Through official channels (bank accounts and international payment systems), in 2019, the amount was USD 6.04 billion. Data from unofficial channels was almost as follows. It was USD 5.98 billion. As for the interaction, during the hryvnia devaluation and inflation growth, workers tend to transfer more foreign currency to compensate the income decline to their relatives in Ukraine.

Since some variables in the VAR model are interdependent, some parameter values provide only limited information about the response of the exchange rate to external shocks. Impulse functions make it possible to better understand its behavior (Table 6 and Figure D1 in Appendix D).

The results show that the USD/UAH exchange rate is quite sensitive to external shocks. The most noticeable is the reaction to changes in the discount rate (up to –0.41%), OPEC Basket price (up to –0.38%), and less noticeable on UAH-denominated government bonds owned by non-residents (up to –0.18%), remittances of workers from abroad (up to –0.2%) and the consumer price index (+0.18%).

The initial reaction of the exchange rate to shocks occurs in different ways, depending on the type of impulse. For example, an increase in OPEC Basket price and the volume of UAH-denominated gov-

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Table 6. Impulse reaction for VAR (2) model, %

Step (months)	CPI	Exports of cereals, fats, oils	OPEC Basket price	UAH-government bonds	Discount rate	Remittances of workers
0	0	0	0	0	0	0
1	–0.0365	0.0019	–0.0461	–0.0773	0.0337	0.1390
2	–0.0027	0.0106	–0.1979	–0.1498	–0.0738	0.2006
3	0.0503	0.0007	–0.3508	–0.1784	–0.2165	0.1698
4	0.0921	–0.0180	–0.4138	–0.1659	–0.3278	0.0965
5	0.1182	–0.0332	–0.3888	–0.1334	–0.3780	0.0281
6	0.1376	–0.0370	–0.3246	–0.0989	–0.3776	–0.0109
7	0.1568	–0.0312	–0.2666	–0.0689	–0.3513	–0.0218
8	0.1761	–0.0204	–0.2344	–0.0424	–0.3201	–0.0162

ernment bonds owned by non-residents causes the exchange rate strengthening from the first month after the shock. The hryvnia revaluates the most in the third and fourth months. However, later it returns to its starting value.

The OPEC Basket price is included in the VAR-model, since energy resources make up a significant part of Ukrainian imports. According to the State Statistics Committee of Ukraine, in 2019, USD 12.1 billion of mineral fuel, oil and its products were imported. Therefore, it is logical that any changes in the world energy market should be reflected in the exchange rate dynamics in the country.

The present market conditions are not in favor of oil-exporters. The OPEC+ agreement was terminated; the average OPEC Basket price fell to USD 17.76 per barrel in April 2020. Ukraine is not an oil exporter. The main export items among mineral products are ore (USD 3.6 billion in 2019) and metals (USD 10.3 billion). Therefore, this is a positive factor for the Ukrainian economy because energy import prices are falling. Accordingly, fuel prices are dropping. This is such an additional disinflationary factor.

If oil prices suddenly rise, it will first have a negative impact on prices in Ukraine due to the high share of the fuels and lubricants costs in the production cost. Second, it will create additional inflationary and currency pressures.

However, the impulse function shows the opposite. This can be explained by the fact that in Ukraine such risks are neutralized by rising export prices. As a result, foreign exchange earnings increase, respectively, inflationary pressure weakens and the hryvnia strengthens.

Another important channel of influence on the exchange rate is UAH-government bonds owned by non-residents. The values of the impulse function depict that their growth stimulates hryvnia strengthening (from –0.04% to –0.18%).

Unlike domestic investors, non-residents at the beginning buy the hryvnia on the Ukrainian interbank market to purchase bonds. Then, the supply of dollars in the foreign exchange market becomes greater than the demand and the hryvnia tends to strengthen.

In May 2020, the UAH-government bonds portfolio holding by non-residents amounted to UAH 102.4 billion. Demand for these securities is associated with the high NBU's discount rate (18% in February 2019, 8% in May 2020), relatively low inflation (9.2% and 1.7% accordingly), as well as the launch of a "link" with the international depository Clearstream.

The discount rate also has a positive effect on the exchange rate, but not momentary. Initially, the hryvnia depreciates (+0.03%), and from the second month, it strengthens steadily (from –0.07% to –0.4%). Transmission of the discount rate through the exchange rate in economies with free capital flows works due to the possibility of borrowing money in a country with a lower rate and put it up in another (with a higher rate). In this case, growth in the rate leads to a rise in foreign currency inflows, which one after other increases the demand for the national currency and strengthens it.

The reaction of the exchange rate to the impulse of remittances of workers from abroad contradicts the NBU's conclusions since it is negative. The growth of remittances to the country causes the weakening of the national currency (from +0.14% to +0.2%), and after five months returns to its starting value.

Pieńkowski (2020) explains this relationship as follows. Initially, recipients convert most of the received foreign currency into hryvnia, which leads to its nominal appreciation.

Secondly, Ukraine is characterized by the "Dutch disease". When the country's export is commodity-oriented, the remittances inflow increases aggregate demand, leads to higher prices for non-tradable goods and raises labor costs. This, in turn, makes all goods produced in the country more expensive.

That is, on the one hand, expand of remittances causes an increase in household incomes, their living standards and a reduction in poverty. Recipients begin to spend money mainly on their own needs and consumption, which stimulates demand. However, this may create a situation when prices rise and, therefore, the pressure on the exchange rate increases.

The only thing is that foreign currency flows into the country contributes to the growth of the surplus of primary and secondary income accounts in the balance of payments. As a result, the current account balance may compensate the increase in the country's trade deficit. But it will not strengthen the exchange rate.

In Ukraine, export revenues are associated with a potential strengthening of the hryvnia, as it is an inflow of foreign currency in the form of export proceeds. However, the results indicate an almost neutral effect, because during the whole period the exchange rate fluctuations go to zero (from –0.004% to +0.03%).

The exchange rate reacts greater or lesser to the momentum of the consumer price index (up to +0.2%). Thus, the shock causes a slight initial strengthening (from 0.003%) with a subsequent increase and without attenuation.

Thus, Ukraine's foreign exchange market can be considered stable, as its response to external shocks in the short term tends to fade and asymptotically approach zero. That is, the market eventually reaches a certain steady condition and the exchange rate returns to pre-shock value.

The last stage of this research is forecasting the fu-

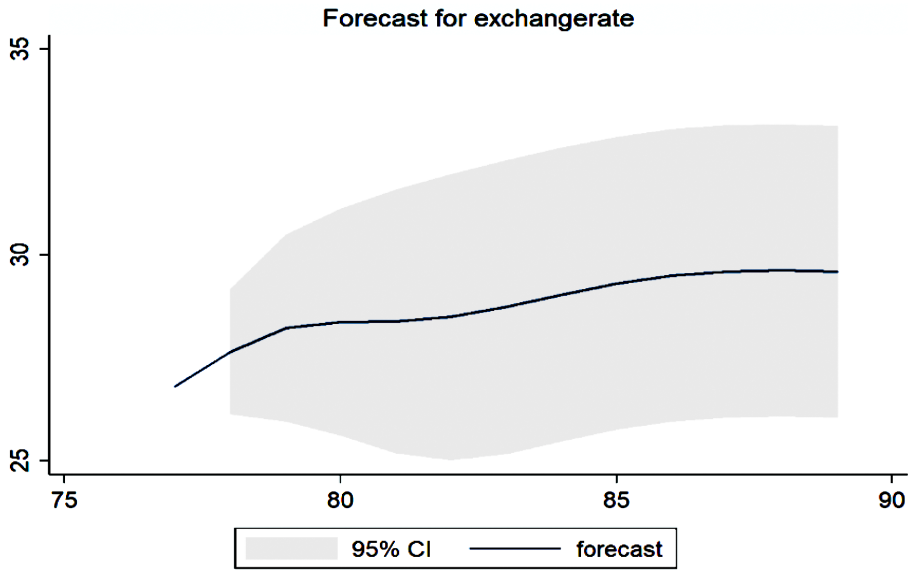

Figure 4. Current and forecast values of the USD/UAH exchange rate, calculated based on VAR (2) model

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ture exchange rate trajectory. A short term (1 year) was chosen. As Figure 4 shows, almost all forecast values are within the 95% confidence bands. Therefore, they are statistically significant. As for the level of the exchange rate, it is clear that it will tend to depreciate over the next year. The value will be approximately 28.65-33.35 hryvnias per US dollar.

In general, the study of the impact of external shocks on the exchange rate of hryvnia against the US dollar shows that the macro-variables selected for analysis have a small but positive impact on it, except for exports of cereals, fats and oils. This does not reject or fully confirm the efficient market hypothesis, and it can be concluded that the foreign exchange market of Ukraine is relatively efficient. Thus, hypothesis *H3* is accepted that the dynamics of the exchange rate depends on the external shocks.

CONCLUSION

The comprehensive study of the specificity of the exchange rate dynamics of the Ukrainian hryvnia against the US dollar shows that it is a stochastic process. Its trend is a random walk process and tends to change quickly over time. This was confirmed by autocorrelation analysis and testing of time series for stationarity (hypothesis *H1*).

It is also proved that the USD/UAH exchange rate volatility is seasonal (hypothesis *H2* rejected). Calculations show that the hryvnia tends to depreciate in the first and second quarters and strengthen in the third and fourth.

The analysis of the impact of external shocks on the exchange rate has revealed that several macro-variables have a significant impact on its course (the exception is exports of cereals, fats and oils). This does not refute or fully confirm the hypothesis of an efficient market, and it can be concluded that the Ukrainian foreign exchange market is relatively efficient (hypothesis *H3*) but stable, since the reaction to external impulses tends to fade out. That is, the exchange rate returns to pre-shock value.

However, it is worth considering the fact that the dynamics of the exchange rate in Ukraine significantly depends on the NBU's intervention policy. Therefore, the current movement of the exchange rate is largely determined by the level of the Central Bank's activity in the foreign exchange market.

In addition, it can be concluded that the results of the whole study are controversial. Even the forecast models have arguable findings. Thus, two out of six forecasts, according to ARMA models, show that by the end of 2020 the USD/UAH exchange rate will tend to strengthen, and according to the VAR model, it will depreciate.

Summarizing, the dynamics of the USD/UAH exchange rate in most cases is identified as a random process and does not necessarily react sensitively to all external factors. This situation complicates and calls into question the realness and credibility of any prediction of its future value.

AUTHOR CONTRIBUTIONS

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APPENDIX A. AUTOCORRELATION

Table A1. Autocorrelation coefficients, USD/UAH exchange rate, 2014 – May 2020 (in absolute values and in first differences)

LAG	AC	PAC	Prob.	AC	PAC	Prob.
	In absolute values			In first differences		
1	0.93	0.9357	0.0000	0.3307	0.3331	0.0033
2	0.8526	−0.2592	0.0000	−0.1358	−0.2816	0.0063
3	0.787	0.3231	0.0000	0.0625	0.2569	0.0152
4	0.7328	−0.185	0.0000	0.0992	−0.086	0.0239
5	0.6751	0.147	0.0000	−0.1126	−0.0993	0.0308
6	0.621	0.1878	0.0000	−0.1169	−0.0139	0.0362
7	0.5671	0.1414	0.0000	0.1025	0.125	0.045
8	0.5163	0.0014	0.0000	0.0714	−0.0476	0.0629
9	0.4625	0.1894	0.0000	−0.001	0.1137	0.0962
10	0.4059	0.0677	0.0000	0.1741	0.1824	0.0633
11	0.3541	−0.0248	0.0000	0.3677	0.3151	0.0017
12	0.2956	−0.1868	0.0000	0.2654	0.1762	0.0003
13	0.2297	−0.1145	0.0000	−0.097	−0.1265	0.0004
14	0.1901	0.1297	0.0000	−0.0897	0.124	0.0005
15	0.1776	−0.1109	0.0000	−0.0306	−0.1267	0.0009
16	0.1608	0.1356	0.0000	−0.1243	−0.0361	0.0009
17	0.1328	0.0675	0.0000	−0.0463	0.1343	0.0013
18	0.1073	−0.089	0.0000	0.0754	0.1054	0.0018
19	0.0819	−0.08	0.0000	0.0621	0.0247	0.0025
20	0.0522	−0.0065	0.0000	−0.0417	−0.0763	0.0037
21	0.0235	0.102	0.0000	0.0511	0.0526	0.0051
22	−0.0064	−0.0108	0.0000	0.193	0.1433	0.0023
23	−0.0308	−0.1305	0.0000	0.0871	0.0204	0.0028
24	−0.0576	−0.082	0.0000	−0.0512	−0.0417	0.0038
25	−0.078	−0.0619	0.0000	−0.0652	0.0922	0.0048
26	−0.0826	−0.1801	0.0000	−0.0588	−0.0524	0.0062
27	−0.0869	−0.0564	0.0000	−0.0704	0.0998	0.0075
28	−0.0964	−0.2219	0.0000	−0.0805	−0.0861	0.0086
29	−0.1097	−0.0285	0.0000	−0.0416	−0.0856	0.0113
30	−0.1231	−0.0261	0.0000	0.0205	−0.0356	0.0152
31	−0.1378	−0.051	0.0000	0.0153	−0.062	0.0203
32	−0.1522	−0.0172	0.0000	−0.0622	−0.2168	0.0239
33	−0.1566	0.1818	0.0000	0.0849	0.3131	0.0252
34	−0.167	−0.3765	0.0000	0.1302	−0.1079	0.0196
35	−0.1829	−0.0031	0.0000	−0.0456	0.139	0.0241
36	−0.1953	−0.4751	0.0000	−0.1858	−0.8554	0.0103

APPENDIX B. ARMA, ADDITIVE AND MULTIPLICATIVE TREND MODELS

Table B1. Estimation of the seasonal component of the additive and multiplicative models of the USA/UAH exchange rate time series, 2014 – May 2020

Year	Additive model				Multiplicative model			
	Quarter				Quarter			
	1	2	3	4	1	2	3	4
2014	–	–	–0.3060	–1.4723	–	–	0.9746	0.8979
2015	–1.2443	3.2907	0.1713	–1.1657	0.9271	1.1695	1.0079	0.9493
2016	0.5053	1.0032	–0.6604	–0.2347	1.0213	1.0407	0.9741	0.9910
2017	0.8612	0.3111	–0.8491	–0.2358	1.0328	1.0117	0.9683	0.9912
2018	1.5778	–0.9427	–0.8085	0.9052	1.0587	0.9652	0.9703	1.0333
2019	0.6557	0.0840	–0.0912	–0.6160	1.0241	1.0031	0.9965	0.9758
All	2.3557	3.7463	–2.5439	–2.8193	5.0639	5.1903	5.8917	5.8385
Seasonal average	0.4711	0.7493	–0.4240	–0.4699	1.0128	1.0381	0.9820	0.9731
Adjusted seasonal average	0.39	0.67	–0.51	–0.55	1.01	1.04	0.98	0.97
Corresponding correction factor	0.081633439				0.998534359			

Table B2. Calculations of forecast values for additive and multiplicative models

Data	USD/UAH official exchange rate	S_t	T_t	T*	ε_t	S_t	T_t	T*	ε_t
		Additive model				Multiplicative model			
1 Q 2014	7.9930	0.39	7.70	8.09	–0.10	1.01	7.81	7.90	1.02
2 Q 2014	11.6342	0.67	12.21	12.87	–1.24	1.04	12.28	12.73	0.84
3 Q 2014	11.7543	–0.51	14.84	14.33	–2.58	0.98	14.90	14.61	0.65
4 Q 2014	12.9498	–0.55	16.71	16.16	–3.21	0.97	16.76	16.28	0.63
1 Q 2015	15.8127	0.39	18.16	18.55	–2.73	1.01	18.20	18.40	0.74
2 Q 2015	22.7095	0.67	19.34	20.01	2.70	1.04	19.37	20.08	1.28
3 Q 2015	21.7574	–0.51	20.34	19.84	1.92	0.98	20.37	19.97	1.19
4 Q 2015	21.8413	–0.55	21.21	20.66	1.18	0.97	21.23	20.63	1.12
1 Q 2016	24.2597	0.39	21.97	22.36	1.90	1.01	21.99	22.24	1.19
2 Q 2016	25.6295	0.67	22.66	23.33	2.30	1.04	22.67	23.50	1.19
3 Q 2016	24.8168	–0.51	23.28	22.77	2.04	0.98	23.29	22.83	1.18
4 Q 2016	25.7573	–0.55	23.84	23.29	2.47	0.97	23.85	23.17	1.24
1 Q 2017	27.1506	0.39	24.36	24.75	2.40	1.01	24.36	24.64	1.21
2 Q 2017	26.8568	0.67	24.84	25.51	1.34	1.04	24.84	25.75	1.09
3 Q 2017	25.9693	–0.51	25.29	24.79	1.18	0.98	25.29	24.79	1.10
4 Q 2017	26.6550	–0.55	25.71	25.16	1.49	0.97	25.70	24.98	1.14
1 Q 2018	28.4343	0.39	26.11	26.50	1.94	1.01	26.09	26.39	1.16
2 Q 2018	26.1517	0.67	26.48	27.15	–0.99	1.04	26.46	27.43	0.91
3 Q 2018	26.4007	–0.51	26.83	26.32	0.08	0.98	26.81	26.29	1.01
4 Q 2018	28.1274	–0.55	27.16	26.61	1.52	0.97	27.14	26.37	1.14
1 Q 2019	27.8792	0.39	27.48	27.87	0.01	1.01	27.46	27.77	1.01
2 Q 2019	26.8115	0.67	27.78	28.45	–1.64	1.04	27.76	28.77	0.87
3 Q 2019	25.7514	–0.51	28.07	27.56	–1.81	0.98	28.05	27.50	0.88
4 Q 2019	24.8082	–0.55	28.35	27.79	–2.99	0.97	28.32	27.52	0.81
1 Q 2020	24.1194	0.39	28.61	29.00	–4.88	1.01	28.58	28.91	0.70
2 Q 2020	27.2247	0.67	28.87	29.53	–2.31	1.04	28.84	29.89	0.83
3 Q 2020	…	–0.51	29.11	28.61	…	0.98	29.08	28.51	…
4 Q 2020	…	0.39	29.35	28.80	…	0.97	29.32	28.48	…

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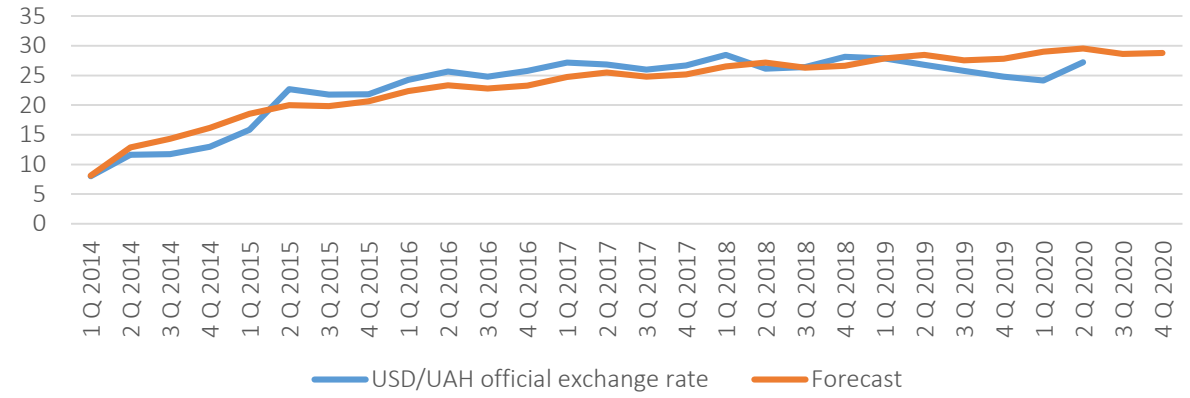

Figure B1. USD/UAH official exchange rate forecast, 3rd and 4th quarters of 2020 (additive model)

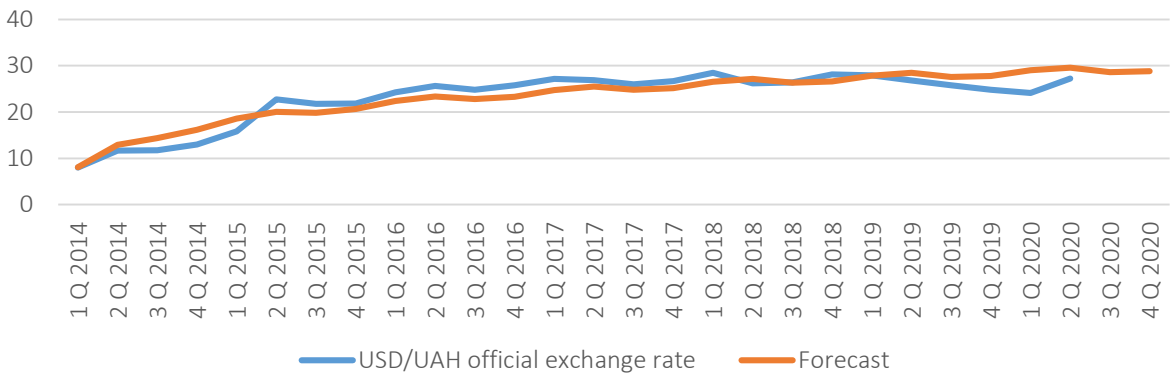

Figure B2. USD/UAH official exchange rate forecast, 3rd and 4th quarters of 2020 (multiplicative model)

APPENDIX C. VAR (2) MODEL

Table C1. Dickey-Fuller test results for all indicators of the VAR-model (suppress constant specification)

No.	Indicator	Test statistics	Critical value			Stationarity	
			1%	5%	10%	p-value	Summary
1	Consumer price index	–0.655	–2.610	–1.950	–1.610	0.514	–
1.1	Lag (1)	–1.390	–2.610	–1.950	–1.610	0.000	+
2	Exports of cereals, fats and oils	–0.270	–2.610	–1.950	–1.610	–2.610	–
2.1	Lag (1)	0.106	–2.610	–1.950	–1.610	0.003	+
3	UAH-denominated government bonds owned by non-residents	2.941	–2.610	–1.950	–1.610	0.004	+
3.1	Lag (1)	–0.699	–2.610	–1.950	–1.610	0.000	+
4	Remittances of workers	0.153	–2.610	–1.950	–1.610	0.879	–
4.1	Lag (1)	0.439	–2.610	–1.950	–1.610	0.011	+
5	Discount rate	–0.401	–2.610	–1.950	–1.610	0.689	–
5.1	Lag (1)	–0.627	–2.610	–1.950	–1.610	0.001	+
6	OPEC Basket price	–1.887	–2.610	–1.950	–1.610	0.063	–
6.1	Lag (1)	–1.678	–2.610	–1.950	–1.610	0.003	+

Table C2. VAR (2) model results (standard OLS regression summary statistics)

Equation number	1	2	3	4	5	6	7
	USD/UAH	CPI	Exports of cereals, fats, oils	UAH-government bonds	Remittances of workers	Discount rate	OPEC Basket price
USD/UAH	−0.2135	−0.3043	−0.1434	−0.1791	0.0994	−0.4456	1.5151
P > |z|	0.109	0.455	0.559	0.973	0.375	0.083	0.115
CPI	0.0382	−0.4586	0.0135	−0.6635	0.0013	−0.0924	−0.0304
P > |z|	0.187	0.000	0.799	0.564	0.958	0.098	0.884
Exports of cereals, fats, oils	0.0193	0.1460	0.0121	2.5498	0.0363	0.0837	0.2210
P > |z|	0.780	0.488	0.924	0.351	0.531	0.528	0.657
UAH-government bonds	0.0026	−0.0032	−0.0045	−0.6769	0.0052	−0.0019	0.0098
P > |z|	0.894	0.679	0.336	0.000	0.014	0.701	0.589
Remittances of workers	0.0855	0.1919	0.1120	3.4509	0.2731	0.0797	1.6628
P > |z|	0.540	0.653	0.663	0.534	0.020	0.767	0.099
Discount rate	−0.0933	−0.7461	0.0633	−0.0912	−0.0526	−0.2099	−1.2649
P > |z|	0.199	0.001	0.636	0.975	0.389	0.134	0.016
OPEC Basket price	−0.0294	0.0097	0.0277	−0.3907	0.0045	−0.0831	−0.4709
P > |z|	0.076	0.848	0.364	0.553	0.747	0.009	0.000
_cons	6.1575	9.6371	1.7310	6.8170	−1.0119	5.6967	34.2525
P > |z|	0.000	0.213	0.516	0.905	0.405	0.041	0.001
RMSE	0.7864	2.4008	1.4485	31.234	0.6605	1.5164	5.6755
R-squared	0.9791	0.9801	0.657	0.994	0.9535	0.9316	0.9299

APPENDIX D. IMPULSE FUNCTIONS

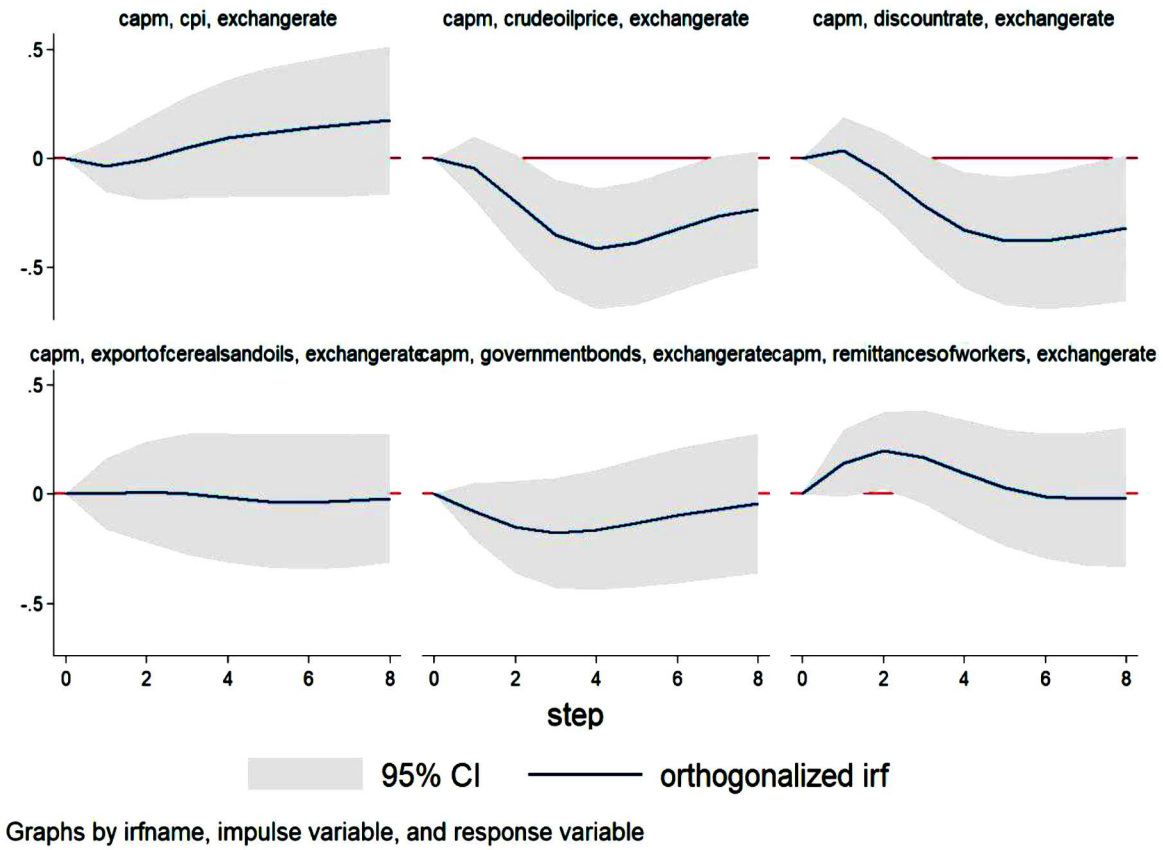

Figure D1. Impulse response functions for the VAR (2) model

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