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PREFACE BY THE CHAIRMAN OF THE EDITORIAL BOARD

Dear readers,

The current issue of the *Visnyk of the National Bank of Ukraine* deals with the practical problems faced by central banks when conducting monetary and macroprudential policies. The findings our contributors set out in their papers have considerable policy implications, and will be of value to policymakers.

The first article in this issue, *A Neutral Real Interest Rate in the Case of a Small Open Economy: Application to Ukraine*, by Anton Grui, Volodymyr Lepushynskyi and Sergiy Nikolaychuk, measures the neutral interest rate in Ukraine, which can be used by policy-makers to decide whether to take a contractionary or expansionary monetary policy stance. The authors emphasize that the current policy rate of the National Bank of Ukraine is well above the estimated neutral rate. This spread is expected to remain positive for some time to come, and will ensure both that there is stable disinflation, and that inflation targets are achieved.

The next article, by Oleksandr Faryna, Oleksandr Talavera, Tetiana Yukhymenko – *What Drives the Difference between Online and Official Price Indexes?* – introduces a unique dataset of online prices of consumer goods collected by the National Bank of Ukraine, and demonstrates its ability to approximate official CPI inflation. One very important conclusion drawn in the paper is that online prices may represent new information not captured by official statistics. Thus, in these large data sets, Ukraine's central bank has gained an additional tool to investigate price behavior, and can use that knowledge to ensure price stability.

The third article, entitled *Macroeconomic Effects of Introducing a Capital Conservation Buffer in the Ukrainian Banking Sector,* by Pervin Dadashova, Magnus Jonsson, and Hanna Onyshchenko, explores, using a dynamic stochastic general equilibrium model, the macroeconomic consequences of the introduction of a capital conservation buffer in Ukraine. Although the new regulation will yield long-term benefits by strengthening the resilience of the banking system, the researchers look for a way to reduce initial short-term output costs. This study argues that the output loss can be substantially decreased by preannouncing and gradually implementing the buffer.

We are certain these articles will stimulate discussion about the above topics and promote follow-up studies. The *Visnyk of the National Bank of Ukraine* is a peer-reviewed journal indexed by IDEAS/RePEc, Index Copernicus International, and Ulrich. It stands for the best publishing practices, presenting high-quality research, and provides room for debate on topical issues in economics and finance. The Editorial Board encourages research contributors to submit their manuscripts for publication in *the Visnyk of the National Bank of Ukraine.*

Best regards,
Dmytro Sologub

A NEUTRAL REAL INTEREST RATE IN THE CASE OF A SMALL OPEN ECONOMY: APPLICATION TO UKRAINE

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Abstract This paper measures a neutral interest rate in Ukraine by means of applying a Kalman filter to a semi-structural model with unobserved components. We rely on a medium-term concept of a neutral interest rate, where it is defined as a real interest rate consistent with output at its potential level and inflation at its target level after the effects of all cyclical shocks have disappeared. Under this concept, and accounting for the small open nature of Ukrainian economy, the neutral interest rate is determined by the global economy's cost of capital and domestic long-term factors that influence risk-premium and changes in the real exchange rate. Conditional on long-term forecasts for output, demographic trends, real exchange rate changes and risk premium, the neutral rate is projected to decrease gradually from its 2.5% level as of the beginning of 2018 to 2% in real terms, or to 7% in nominal terms under a 5% inflation target. However, in the following years the gap between the National Bank of Ukraine's policy rate and the neutral rate should remain positive – reflecting the tight monetary stance needed to ensure stable disinflation.

JEL Codes C32, E43, E52

Keywords neutral interest rate, Kalman filter, monetary policy stance

1. INTRODUCTION

In 1898, Knut Wicksell introduced an idea of a natural rate of interest, at which "the demand for loan capital and the supply of savings exactly agree, and which more or less corresponds to the expected yield on newly created [physical] capital" (p. 193, Wicksell, 1898). Wicksell believed that the natural rate is fully determined by the real sector of economy, and is neutral in respect to commodity prices – tending neither to raise nor to lower them. Loan rates have a tendency to adjust to the natural rate, but could diverge from it because of credit expansion by banks. In that case, upward price adjustment continues while there is a gap between loan rates and the natural rate.

Keynes criticized the idea of the Wicksellian natural rate, saying this concept "has anything very useful or significant to contribute". Keynes pointed out that the definition of a natural rate does not imply full employment, and assumes only a stable price level. He replaced the concept of a natural rate with a "neutral" or "optimum" rate of interest, "which prevails in equilibrium where output and employment are such that the elasticity of employment as a whole is zero" (Keynes, 1936). In modern terms, it means that GDP is at its potential level, and the economy is characterized by full employment (thus, employment does not react to additional surges in demand for products, meaning there is zero elasticity).

Current monetary policymaking is based on models that just do not reflect this old debate between the Austrian (which developed Wicksell's ideas) and Keynesian schools of economic thought. Today, for the purposes of monetary policymaking, both the natural and the neutral rates express the same: a medium-term concept of an equilibrium interest rate, which is defined as a short-term, risk free real interest rate consistent with output at its potential level, and inflation at its target level after the effects of all cyclical shocks have disappeared.

In this article we prefer to use term "neutral interest rate" as such an equilibrium rate implies a monetary policy stance providing neither inflationary, nor deflationary pressure.

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Thus, a monetary policy is considered contractionary (expansionary) when the short-term policy interest rate in real terms exceeds (is lower than) the neutral rate. The original Taylor (1993) interest rate policy rule explicitly employs this concept, claiming that the real rate should be above the 2% "equilibrium" real rate when inflation exceeds its target, and vice versa, all else equal. While in Taylor's original paper lagged inflation serves as a proxy for expected inflation, in practice many central banks exploit inflation forecasts, effectively relying on inflation-forecast targeting (Svensson, 1997). Thus, the neutral interest rate is the level where interest rates converge in a steady state.

In practice, estimating the neutral interest rate is not a trivial task for policy makers. First, it is unobservable variable, and has to be inferred from the data, often with a high degree of uncertainty. Second, while the neutral interest rate should by definition reflect slow-moving, long-term structural factors, these exhibit quite a lot of volatility – especially in emerging market economies undergoing rapid structural changes and recurring financial tensions.

The topic of measuring the neutral interest rate has attracted a great deal of attention in the literature recently. Much of the focus is on advanced economies, where ultra-low interest rates were not able to provide the required stimulus, as the real neutral interest rate fell significantly as well – in the United States it fell from the pre-crisis consensus of 2% to almost 0% (Holston et al. (2017), Ball et al. (2016), Carvalho et al. (2016) among others). The main factors behind this decline in real neutral interest rates in advanced economies are considered to be shifting demographics towards an aging and savings-oriented population, slower productivity growth, a general savings glut and persistent weak demand for capital.

In this paper, we focus our analysis on the case of a small open economy and apply it to Ukrainian data. Our empirical approach employs a semi-structural model with unobserved variables by using the Kalman filter algorithm. We exploit data on real GDP, inflation, the exchange rate, and short-term interest rate to extract the long-term trend or equilibrium components of the output, exchange rate and interest rate.

Our approach differs from other research by its strong focus on the features of a small open economy – such as the importance of real exchange rate changes and the risk premium in determining the neutral interest rate. Specifically, we rely on the concept that Ukraine, as a small open economy accepting a price of capital that is determined on the global capital markets and adjusted through risk premium. Besides, this "external" price of capital in foreign currency is decomposed into a neutral interest rate in national currency, and trend real exchange rate changes.

Our analysis yields the following results. First, since 2005, the neutral interest rate in Ukraine has been very volatile – mainly reflecting large swings in the risk premium. Second, most of the time between 2005 and 2015 the National Bank of Ukraine (NBU) allowed a loose monetary stance when the real interest rate was significantly below the neutral level. Such a strongly accommodative monetary policy was the main cause of relatively high and volatile inflation in Ukraine. However, since the beginning of 2016 the NBU has maintained its key policy rate in real terms well above the neutral interest rate, thus ensuring disinflation in accordance with the announced inflation targeting framework. Third, projections of the neutral interest rate, based on forecasts for productivity, demographic trends, real exchange rate changes, and the risk premium, suggest that the neutral rate is likely to gradually decrease from 2.5% at the beginning of 2018 to 2% in real terms, or to 7% in nominal terms under the 5% medium-term inflation target. However, the current gap between the NBU's policy rate and the neutral rate in the following years should remain positive, reflecting the tight monetary stance needed to ensure stable disinflation.

The rest of the paper proceeds as follows. The second section provides a brief review of the literature, while the third section presents the analytical framework employed for the empirical assessment of the neutral rate in Ukraine. The results and their interpretation are described in the fourth section. The final section presents our conclusions.

2. LITERATURE REVIEW

Despite the central role of neutral interest rate in the Taylor rule, the literature on the topic of measuring real neutral interest rates has flourished recently. The seminal paper of Laubach and Williams (2003) introduced Kalman filter estimates of the US neutral rate, leading to widespread applications of semi-structural models augmented by statistical filters and state space representations among central banks (e.g. Baksa et al. (2013) and Kreptsev et al. (2016) for emerging markets). Other popular methods include:

(1) applying simple statistical filters such as the Hodrick-Prescott, Ravn-Uhlig, and Christiano-Fitzgerald time-varying filters (e.g. Perelli and Roache (2014) applied these filters for ex-post real interest rates in Ukraine and other countries, and found that in Ukraine the real neutral rate fluctuated from 3.2% in 2002-2004 and -4.4% in 2005-2008 to 3.1% in 2010-2013, exhibiting one of the highest variations in the sample of countries);

(2) using Dynamic Stochastic General Equilibrium (DSGE) models (often New-Keynesian models), which impose relationships between the variables based on economic theory, with a view to building an "ideal" economy of full employment or of flexible prices and wages (e.g. Barsky et al. (2014), Del Negro et al. (2015), and Curdia et al. (2015));

(3) assessing an implicit natural rate from the co-movement of the yields of financial instruments, or by estimating the slope of the yield curve (e.g. Giammarioli and Valla, 2004, Basdevant et al., 2004).

Simple statistical filters are poorly suited to the Ukrainian case, where the real interest rate has been characterized by pronounced volatility in the past, due to both highly volatile inflation and nominal interest under a hard exchange rate peg. Instead, semi-structural models, imposing mild theoretical restrictions, account for additional information from other macroeconomic indicators, such as inflation and output, during the estimation. Another important advantage of a more structural approach is that by imposing some fundamental constraints, it is easier to disentangle to what extent volatility in certain periods reflects movements in the neutral rate, or movements in the policy stance. This cannot be done with simple filters.

On the contrary, DSGE models impose too strong theoretical restrictions that are more prone to misspecification, especially in the presence of near-nonstationarity in observed real rates (Pescatori and Turunen, 2015). Besides, neutral interest rates derived through DSGE models can vary

Figure 1 presents all of the above-mentioned rates and concepts schematically.

Figure 1. Decomposition of short-term nominal rates

<table>
<tr><td colspan="4">Observed nominal interest rate</td></tr>
<tr><td colspan="3">Ex ante real interest rate</td><td rowspan="3">+ Expected inflation</td></tr>
<tr><td colspan="2">Neutral real interest rate</td><td rowspan="2">+ Monetary policy reaction (cyclical factors)</td></tr>
<tr><td>Long run equilibrium (or steady state) real interest rate</td><td>+ Medium-term economic factors (demographics, productivity, capital flows, risk premium etc.)</td></tr>
</table>

substantially, depending on the specific assumptions in the model. Equations of semi-structural models are inspired by the structural equations of New-Keynesian models, but take a more flexible form. Compared with the DSGE approach, the use of semi-structural models imposes fewer economic constraints on the data and, as a result, is more robust in the case of possible errors in model specification.

Relying on financial market information is a promising topic, but one for future research in the Ukrainian case, due to the market being underdeveloped, and presence of only a short sample of active monetary policy (the transition to inflation targeting occurred only in 2015).

The prevailing theoretical concept used in semi-structural and DSGE models defines a neutral interest rate as one that equilibrates savings and investment, and does not create either inflationary or deflationary pressures. This means that a neutral interest rate is the rate of interest that should prevail in the medium term after the effects of business cycle shocks disappear, and output stabilizes at its potential (or full employment) level. Thus, the deviation of the observed policy rate from the neutral one determines the stance of monetary policy.

At a global level (or in a closed economy) the main role in determining the neutral interest rate is played by the Euler equation, which makes a consumer indifferent between extra consumption and savings, and links the neutral interest rate with potential output growth.[1] It provides the framework for analyzing the determinants of the neutral interest rate through their influence on saving and investment. Among these determinants are long-term fundamentals such as households' propensity to save, demographic trends, and technological advances – as well as medium-term factors like productivity shocks, imbalances in private or public sector savings, and financial market or economic policy disturbances that in various ways affect saving or investment decisions.

Considering a sufficiently long period to enable all markets to clear and all economic variables to settle at constant growth rates, and in the absence of new shocks, we come up with the long-term equilibrium or steady state of the economy, and so the equilibrium interest rates under long-term concept.

However, even accepting the concept of a neutral interest rate consistent with a zero output gap in the medium term, relying exclusively on domestic factors that determine savings and investments is not a good approach for a small open economy, where the gap between savings and investment can be covered by capital inflows. Mendes (2014) indicates that domestic demand for investment in an open economy is conditioned by not only the domestic availability of savings, but the net supply of foreign savings as well. Moreover, if a country is a pure price-taker, then domestic forces do not matter at all, and the neutral interest rate is determined by external ones exclusively. Perrelli and Roache (2014) also show that in emerging market economies, the real rates depend heavily on global factors that determine both trends and cyclical movements. The IMF (2014) proves that common global factors play an increasingly important role for interest rates as international financial integration expands.

However, according to Perrelli and Roache (2014), the neutral interest rate can be partially influenced by internal factors in the case of less-than-perfect financial integration. Moreover, a country may be subject to a sovereign risk premium, which also depends on domestic factors. Mendes (2014) proposes domestic net foreign assets as a source for such a premium. The size of the premium decreases if foreign assets are accumulated domestically. Among other internal factors are credit spreads and potential output growth. The former reduces investments and increases savings, thus lowering the neutral interest rate. The latter reflects productivity growth and presumably shapes demand for investment. However, the author remains uncertain about the relative importance of domestic and foreign factors for the Canadian economy.

Kreptsev et al. (2016) state that the neutral interest rate must remove arbitrage between investments in physical and financial assets as well as domestic and foreign ones (through uncovered interest parity). The literature often considers these conditions separately, but they may be coherently combined in a general equilibrium model. The authors examine different approaches for calculating the neutral interest rate, and obtain a wide variety of assessments for the Russian economy.

Among the recent work on estimating neutral interest rates in emerging economies it is worth mentioning Stefański (2017), who adds some innovations to the method developed by Laubach and Williams (2003), applying it to economies

[1] See Parker (2007) for background reading.

in Central and Eastern Europe (CEE). He concludes that neutral rates declined from pre-crisis levels (before 2008) in CEE countries as a result of spillovers from developed economies. The main channel of such spillover is the decline in potential output growth rates because of global factors. Population aging in the euro area also contributed to the fall in neutral rates, but only marginally.

3. ANALYTICAL FRAMEWORK

In a closed economy or at the global level, all investments must be financed by savings, thus these two are equal. Equilibrium is found at the intersection of the propensity to save and the propensity to invest (Figure 2, left). The former increases with returns, while the latter decreases with costs.

In a small open economy, in contrast, savings do not need to be equal to investments. In fact, Ukraine invests more than it saves. The difference is covered by foreign capital flows, for which Ukraine is a price-taker. However, the available amounts of capital inflows are virtually unlimited, which means that the capital supply curve is flat (Figure 2, right).

Thus, for the purposes of our research, we use the argument that global factors are the prevailing determinants of the cost of capital for Ukraine. Meanwhile, the risk premium also depends on domestic, country-specific factors, such as fiscal and external sustainability, political turbulence, banking sector performance, demographic changes, and so on.

We use the uncovered interest rate parity (UIP) as the central point to calculate the neutral real interest rate in the medium-term perspective:

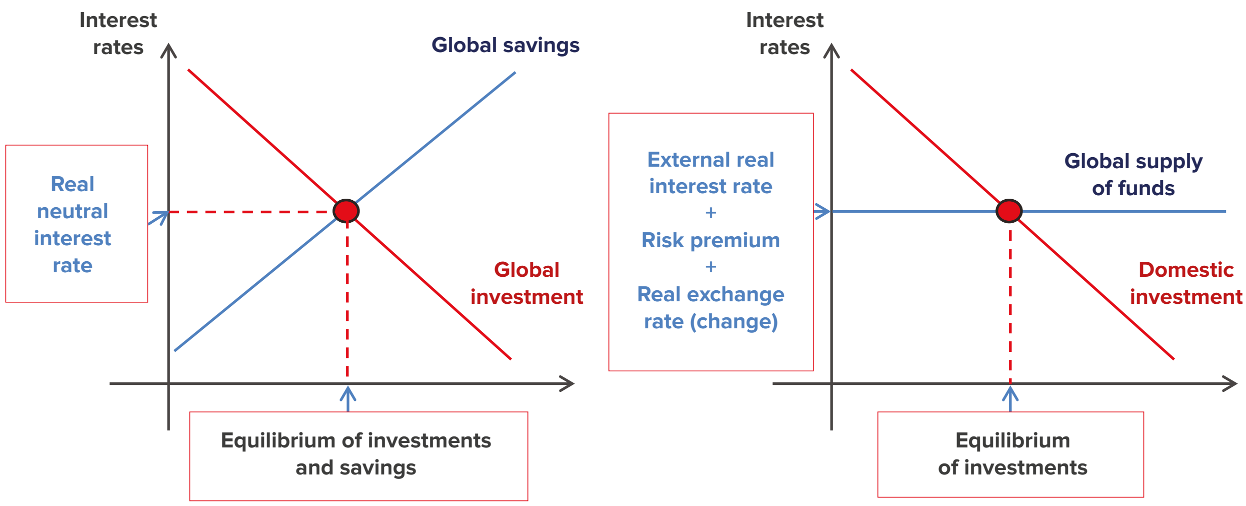
$$r = r^* - \Delta z + rp,$$

where

r^* is the world real interest rate (or global cost of capital);

Δz is the expected change in the real exchange rate, where an increase means the appreciation of the local currency. Real exchange rate appreciation means that domestic assets become more valuable. Thus, an investor receives income not only in the form of interest payments in local currency, but additionally from the appreciation of the

Figure 2. Difference in determining real neutral interest rate in closed economy and in a small open economy



local asset's value. Consequently, higher income from a real appreciation (due to nominal exchange rate appreciation and/or higher growth in domestic prices) means that an investor would agree to a lower interest rate in local currency.

In case of an emerging market economy, this reflects the Balassa-Samuelson effect or the process of "catching up" with advanced economies. The faster productivity growth in a developing economy leads to an appreciation of the real exchange rate. Other factors also have a hand in determining real exchange rate dynamics. In fact, in estimating long-term real exchange rate, following the logic of the External Balance Assessment methodology developed by Phillips et al. (2013), we take into consideration a set of domestic factors. However, we also compare these domestic factors with the relevant factors in the global economy. Such an approach is consistent with the concept of a small open economy – which is the central point of our research.

Ukraine is a typical small open economy. Its share in global GDP is minor (0.1% in 2016 according to World Bank data) and the share of external trade turnover to GDP exceeds 100%. Meanwhile, the Ukrainian financial market is shallow and tiny.

Thus, it is a reasonable assumption that domestic economic developments in Ukraine do not influence global interest rates. This is also one of the assumptions made by Mundell (1963) during his study of the Canadian case. Of course, we cannot use Mundell's other assumption of the indefinite persistence of the existing exchange rates. Instead, we have to take into consideration the movements of exchange rates needed to satisfy interest rate parity.

We also need to adjust another of Mundell's assumptions on perfect capital mobility – meaning that international capital flows fully equalize world and domestic interest rates. However, in the case of Ukraine, the county-specific risk premium has to be taken into account.

rp is country-specific risk premium. Investors require compensation for entering the domestic market. It reflects all other factors apart from interest and exchange rates. For instance, Archibald and Hunter (2001) indicate the following factors that increase the risk-premium:

- large and persistent debt positions;
- poor-quality economic policy and inadequate transparency;
- concerns over unexpected currency moves;
- small or illiquid markets making it more difficult or costly to pull out of an investment.

We consider the method of determining the neutral interest rate based on UIP as the most relevant in the case of Ukraine, especially for policy-making purposes. The logic behind methods based on exclusively domestic determinants of a neutral policy rate could misguide monetary policy in the case of a small open economy. For example, in the case of the Euler equation, higher potential GDP growth leads to a higher neutral rate. This logic works well for large closed economies in the long run, but in the medium term in a small open developing economy higher potential GDP growth leads to faster convergence of the economy with the developed world, and correspondingly to stronger real appreciation and a lower risk premium. That drives the neutral interest rate down.

Over an historical period, the estimation of the neutral interest rate is made with the help of the Quarterly Projection Model (QPM) of the NBU. The model is based on New-Keynesian theory (Nikolaychuk and Sholomytskyi, 2015). In this way, the neutral interest rates obtained from UIP are consistent with other trend variables, such as real exchange rate trend and potential output.

One can argue that Ukraine has widely used capital controls and is currently cut off from the international financial market. In such circumstances, domestic conditions may have some degree of autonomy from international markets. That could be relevant in the short term. However, we are considering the neutral interest rate in the medium term. In this case, capital controls lose relevance.

There is vast amount of literature supporting such an assumption. Many researchers find no or little evidence that capital controls have an effect on monetary policy autonomy, e.g. the formation of domestic interest rates. De Gregorio et al. (2000) conclude that capital controls have no significant effect on interest rate differentials and the real exchange rate. Miniane and Rogers (2007) discover no evidence that capital controls effectively insulate countries from U.S. monetary shocks. Forbes and Warnock (2012) find little association between capital controls and the probability of having surges or halts in foreign capital flows. Gunnarsdóttir and Rehnholm (2011), in their case study of Iceland, argue that capital controls do not enhance monetary policy autonomy, but have positive effects on smoothing exchange rate volatility. Pasricha et al. (2015) find limited evidence of the effectiveness of capital control measures on monetary autonomy or exchange rates.

Ukraine has always had some forms of capital controls. However, these did not insulate the economy from monetary conditions in the leading advanced economies, due to large international capital surges. Inflows of cheap capital in 2005-2008 heavily contributed to the overheating of Ukrainian economy. In the autumn of 2008, after the bankruptcy of Lehman Brothers, capital flows reversed, plunging the economy into a deep recession. The severe capital restrictions introduced at that time did little to fix the situation (Saborowski et al., 2014).

3.1. Description of the model

The NBU deploys an open-economy forward-looking New-Keynesian Quarterly Projection Model with a view to explaining the core macroeconomics dynamics in Ukraine. The QPM is a "gaps" model, as it captures the general equilibrium (trends) of the system and explains the dynamics of variables' deviations from trends (gaps). In particular, it tracks how gaps evolve and dissipate with time. The trends and gaps are unobservable (state) variables estimated with the Kalman filter.

The QPM is a small semi-structural model with rational expectations. As long as its equations are derived from microeconomic principles and comprise of forward-looking variables, the model is not subject to the Lucas critique (Lucas, 1976).

The origins of the model came from a QPM of the Bank of Canada (Coletti et al., 1996) and the Czech National Bank (Coats et al., 2003). The basic properties of the Ukrainian version are described in Grui and Lepushynskyi (2016). Currently, similar models are used by the central banks of Armenia, Romania, Serbia, the Slovak Republic and many others.

The QPM is constructed to describe the monetary policy transmission mechanism. On the one hand, it shows a macroeconomic environment that actively responds to monetary policy shocks in the short term. On the other hand, a neutral monetary policy is consistent with medium-term inflation target and potential GDP.

The model comprises about 50 equations, which are not simple definitions or identities. The parameters are calibrated rather than estimated, with a view to reflecting theoretical principles, and provide worthy modeling properties. Below we discuss the main equations that are essential for the study.

Aggregate demand curve

Output gap ($\hat{y}$) behavior is modeled in the following equation:

$$\hat{y}_t = \alpha_1 \hat{y}_{t-1} + \beta_1 \hat{y}_{t+1} - \gamma_1 \hat{z}_{t-1} - \delta_1 \widehat{lr}_{t-1} + \\ + \theta_1 \hat{w}_t + \vartheta_1 \hat{y}^*_t + \mu_1 \widehat{tot}_t + \rho_1 f_t + \varepsilon_{1,t} \,. \tag{1}$$

Equation (1) is the first to represent the "gaps" nature of the model. The output gap is estimated in terms of the percentage deviation of GDP from its potential level, which is represented by the difference in logarithms. It is designed to express the pressures of demand in an economy.

The current output gap, calculated on a quarterly basis, depends on both its own lagged values and model-consistent expectations. These smooth the estimates, as they account for overlapping contracts and consumer sentiments. Next, the gaps in the GDPs of main trading partners ($\hat{y}^*$), terms of trade $(\widehat{tot})$ and real ER ($\hat{z}$) allow external demand dynamics to be taken into account – these dynamics correspond to a large share of aggregate demand in a small open economy. The real wages gap ($\hat{w}$) captures spillovers from the labor market. Finally, other important factors in the aggregate demand dynamics are the real long-term interest rate (combining real short-term policy rate and credit premium) gap $(\widehat{lr})$ and the fiscal impulse (f). These represent the effects of monetary and fiscal policies respectively.

Aggregate supply curve

Overall inflation in the model is broken down into Core, Raw foods, Fuel and Administratively regulated components. Equation (2) depicts the general idea behind inflation, as it models Core inflation (π^{core}) in the form of a forward-looking Phillips curve:

$$\begin{gathered}\pi_t^{core} = \alpha_2\pi_{t-1}^{core} + \beta_2\pi_{t+1} + \\ +(1-\alpha_2-\beta_2)(\pi_{t-1}^{*} - \Delta s_{t-1} + \Delta\bar{z}_{t-1}) + \\ +\gamma_2\hat{y}_t - \delta_2\hat{z}_{t-1} + \theta_2\hat{w}_t + \vartheta_2(\pi_t^{food} - \pi_t^{T}) + \varepsilon_{2,t}\,. \end{gathered} \quad (2)$$

Firstly, Core inflation (annualized quarterly changes) is to a great extent determined by its own past values and by projected overall inflation (π). It depicts the weights of adaptive and rational inflation expectations, and links Core inflation to other inflation components. Secondly, the equation incorporates imported inflation, consisting of changes in the prices of the country's main trading partners (π^*), changes in nominal effective ER (Δs) as well as changes in the trend of real ER ($\Delta\bar{z}$). The latter positively contributes to inflation if it appreciates, which is a way to model the Balassa-Samuelson effect. It accounts for accelerated prices of non-tradable goods in an emerging economy. Further, gaps in GDP, real ER and real wages allow for real marginal costs to be accounted for. The last term represents spillovers from Raw foods inflation (π^{food}) relative to inflation target (π^T). Some of the factors influence Core inflation with a one-quarter delay.

Monetary policy rule

The short-term policy rate (i_t) is taken as a monetary policy instrument, and equation (3) represents the monetary policy reaction function:

$$\begin{gathered} i_t = \alpha_3 i_{t-1} + \\ +(1-\alpha_3)\left(\bar{r}_t + \pi_{t+1}^{T} + \beta_3\left(\pi4_{t+3}^{exp} - \pi_{t+3}^{T}\right) + \gamma_3\hat{y}_t\right) + \\ +\varepsilon_{3,t}\,. \end{gathered} \quad (3)$$

It follows a modified Taylor rule. Markets are assumed to incorporate changes in the policy rate in long-term credit rates.

The nominal policy rate is a function of its own lagged value. This introduces a smoothing effect, as the NBU, in line with other central banks, typically demonstrates persistence in its policy decisions. The policy rate reacts to changes in the nominal neutral rate, which is the sum of the real neutral rate ($\bar{r}$) and next quarter's inflation target. Furthermore, the policy rate responds to the deviation of projected annual inflation ($\pi4^{exp}$) from the target and the present output gap. Monetary policy impacts inflation only after a certain delay. Therefore, it needs to react preemptively to deviations from targets, and contemporaneously to the output gap, as this affects future inflation.

Long-term uncovered interest rate parity condition in real terms

Equation (4) shows how the real neutral interest rate ($\bar{r}$) is calculated:

$$\bar{r}_t = \bar{r}_t^* - \Delta\bar{z}_{t+1} + \overline{rp}_t\,. \quad (4)$$

It models the long-term financial relationship with the rest of the world.

The arbitrage condition states that, at equilibrium, the real return on capital available domestically and abroad should be equal. Thus, the domestic neutral real interest rate has to cover foreign real returns on capital ($\bar{r}^*$) and account for expected changes in the real ER. If investors expect the domestic currency to appreciate in real terms, they will accept lower yields. However, investors might require a risk premium for investing in a more vulnerable country.

Trend in real exchange rate

Equation (5) models trend in the real ER in the economy as following relative growth in potential output (reflecting the Balassa-Samuelson framework):

$$\begin{gathered}\Delta\bar{z}_t = a_5\Delta\bar{z}_{t-1} + (1-a_5)b_5(\Delta\bar{y}_t - \Delta\bar{y}_t^*) + \\ +\gamma_5\Delta\overline{tot}_t + \varepsilon_{5,t}\,. \end{gathered} \quad (5)$$

Changes in the trend in real ER are smoothed, as they depend on lagged values. The real ER is modeled to appreciate in a steady state, which is due to projected differences in productivity growth compared with trade partners. This is attributable to the Balassa-Samuelson effect, which originates from the assumption about the real convergence of the Ukrainian economy. The envisaged deviations from the Balassa-Samuelson framework come in combination with trend shifts in terms of trade. The large share of tradable goods in the economy forces real ER to appreciate with favorable terms of trade, and vice versa.

4. RESULTS

4.1. Empirical implementation

We apply the Kalman filter in order to consistently estimate unobservable variables such as the neutral real interest rate and its determinants, namely trends in the real exchange rate and risk premium. These are supplemented with the real neutral rate for the US, estimated using the Laubach and Williams (2003) methodology. This method allows the combining of actual data with assumptions about developments in unobserved variables (as presented in the previous section on model structure).

The data and specifics of model variables are described in Table 1.

Table 1. Model variables description

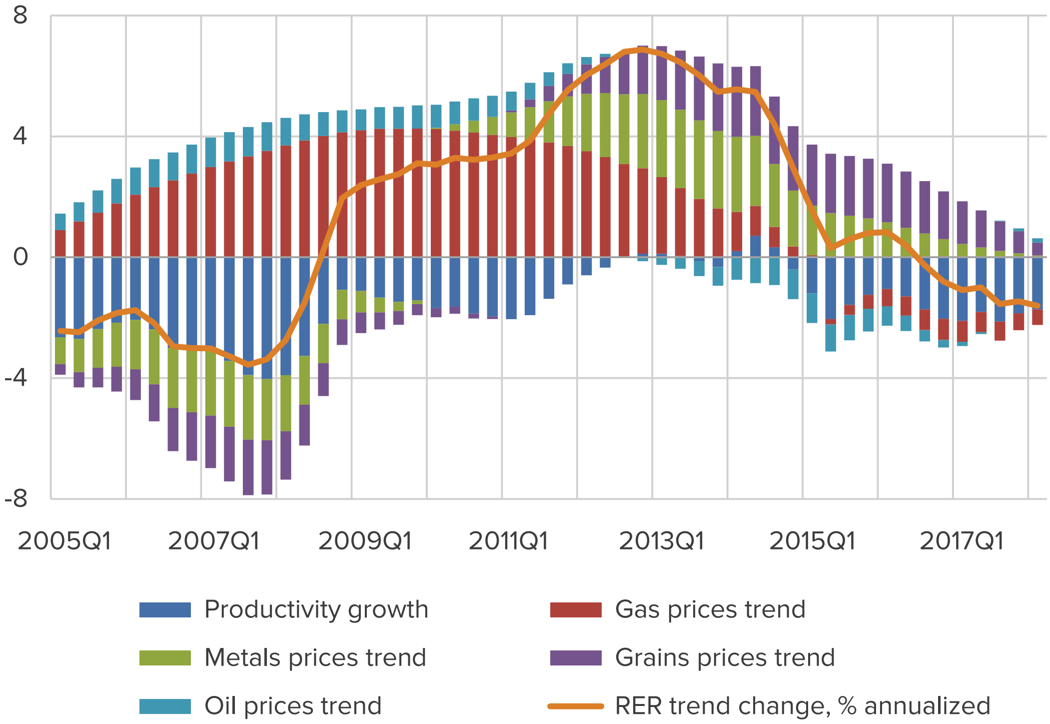
Variable	Definition	Source
Nominal short-term interest rate	Nominal average interbank overnight rate	NBU
Real short-term interest rate	Nominal short-term interest rate minus model-consistent inflation expectations	NBU; own estimates
Nominal long-term interest rate	Average interest rate on loans to non-financial corporations in UAH	NBU
Nominal short-term interest rate in US dollars	3 months LIBOR in US dollars	Thomson Reuters
Real neutral interest rate in US dollars	Natural interest rate in the US estimated using Laubach and Williams (2003) methodology	Federal Reserve Bank San Francisco
Nominal exchange rate to the US dollars	Official nominal exchange rate, UAH per US dollars	NBU
Real exchange rate to the US dollars	Nominal UAH/USD exchange rate adjusted for CPI inflation in Ukraine and in the United States	NBU; State Statistics Service; Thomson Reuters; own estimates
Nominal effective exchange rate	Weighted average of nominal exchange rates for main trading currencies (euro, US dollar, Russian ruble)	NBU, Thomson Reuters, own estimates
Real effective exchange rate	Nominal effective exchange rate adjusted by inflation rates in Ukraine and in the issuers of the main trading currencies (the Euro Area, the United States, the Russian Federation)	NBU, Thomson Reuters, own estimates
Risk premium	Difference between yields on sovereign state euro-bonds denominated in US dollars and 10Y US Treasuries	Cbonds; own estimates
GDP	Seasonally adjusted quarterly gross domestic product in real terms	State Statistics Service, own estimates
GDP of main trade partners	Weighted average of real gross domestic products in main trade partners or proxies (Euro Area, Turkey, Russian Federation)	National Statistics Agencies, own estimates
Nominal wages	Average before tax monthly wages of employees	State Statistics Service
Real wages	Nominal wages deflated by consumer price index	State Statistics Service, own estimates
Terms of trade	Ratio of weighted average of prices for main exported (grains, metals) and main imported (oil, gas) commodities	World bank, own estimates

Thereafter, we report the estimation results, focusing first on the determinants of the neutral real interest rate, and then on the rate itself.

Trend in the real exchange rate

Ukraine is an emerging market economy. Thus, considering the Balassa-Samuelson effect, it is supposed to enjoy faster productivity growth than in advanced economies, and stable real ER appreciation in a steady state. This is a reasonable assumption for the long-term perspective; but it is not historically the case (Figure 3). Over the last ten years, Ukraine has experienced two major devaluations – in 2008 and then in 2014-2015, determining the real ER depreciation trend.

Figure 3. Real exchange rate trend growth and its determining factors, %



Such depreciation trend can be explained by two main factors – worsening terms of trade and low productivity growth. First, about 70% of Ukraine's trade is in raw commodities, with grains and base metals being the main exported goods, and oil products and natural gas – the main imported ones. The global commodities markets have been unfavorable for Ukraine over the last ten years, reflecting the global commodities super cycle. The real ER lost almost 30% over the same period.

Until 2014, the continuous increase in natural gas import prices was the main reason for the deterioration in the terms of trade. However, before 2008 its negative effect was compensated for by a surge in prices for exported commodities. The terms of trade trend was stable, and the real ER was appreciating. After the global financial crisis, the prices for grains and base metals were able to recover quickly, but their trends were set to decline. There was nothing to compensate for the upward trending oil and natural gas prices. This was enough to create adverse trend in terms of trade and RER. In 2014, the prices of imported commodities dropped, which allowed the RER to stabilize.

A large chunk of the remaining RER depreciation trend was due to lower than expected productivity growth. Potential GDP never recovered after the financial crisis, and was stalled until 2014. There was a setback in reforms, and Ukraine dropped in the international rankings. The business climate worsened, in contrast to the situation seen up until 2009, when productivity was fast improving in line with the real convergence process.

The situation with productivity has been improving since 2015, while the contribution of the terms of trade trend has been fading. As a result, at the beginning of 2018 the trend in the real appreciation of the domestic currency was close to 1.5%.

Sovereign risk premium

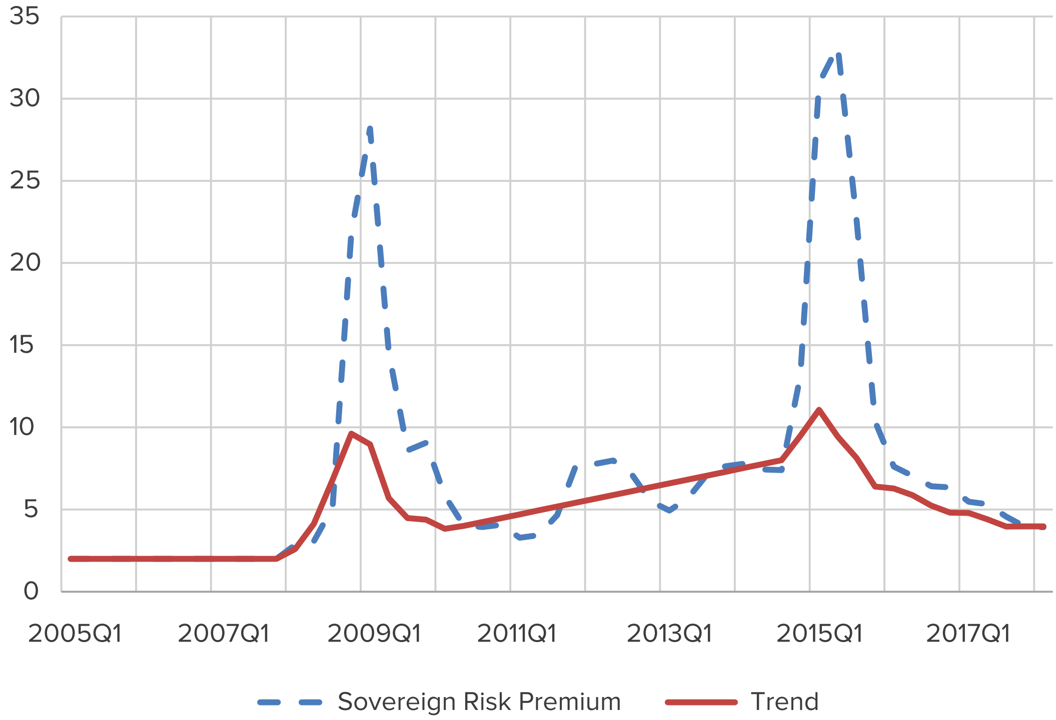
We use the difference between the yield on Ukraine's sovereign Eurobonds in USD and US treasury bills to express the risk premium. Such a variable is an appropriate proxy for the risk premium, as it represents solely the risk of default by the state, and excludes other risks, such as:

- exchange rate risk – as both Ukraine's sovereign Eurobonds and US treasury bills are nominated in USD;
- legal risks – as Ukraine's sovereign Eurobonds are issued under international law;
- transaction costs – as both securities are traded internationally and there is no need for investors to enter local markets and be subject to domestic FX regulations.

In addition, the benefit of using such a proxy is that data is available with the appropriate frequency.

The premium has been above 3% ever since 2008 (Figure 4). Moreover, it surged abnormally twice during the crises episodes. The risk premium first hiked in 2009, when the financial crisis increased global risk averseness. Capital flows relocated from Ukraine as the risks grew. Subsequently, the premium lowered in line with initial success of the Stand-by program of the IMF, the exchange rate adjustment, and mitigated risks. From 2011 to 2013, the risk premium continuously increased, as investors' sentiments were undermined. This was due to Ukraine's inconsistent macroeconomic policy and worsening business climate. From 2014 to 2015, the sovereign risk premium spiked again, reflecting the escalation of the military conflict in eastern Ukraine. Since then it has gradually decreased until the present time.

Figure 4. Sovereign risk premium and its trend, %

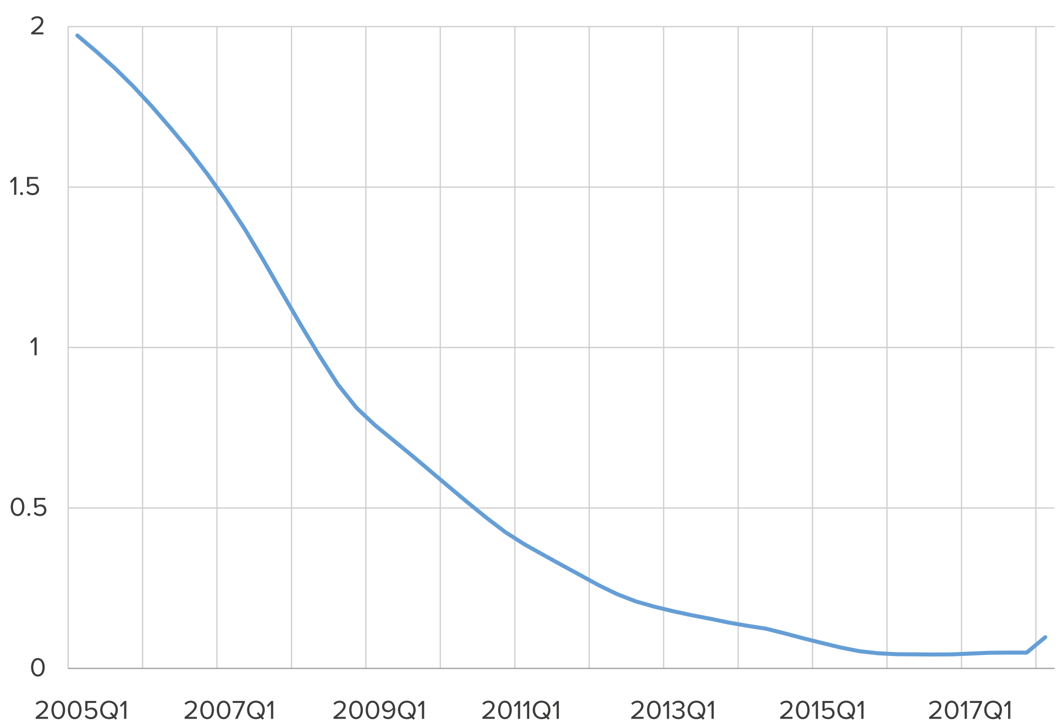


For the sake of calculating the neutral interest rate, we employ the risk premium trend. It reflects the overall dynamics of the indicator, but mitigates, in particular, for excessive volatility and abnormal surges. At the beginning of 2018, it was close to 4%.

Real neutral interest rate in the US

To determine the global cost of capital, we use smoothed estimates of the natural rate of interest in U.S. obtained using Laubach-Williams (2003) methodology, which are published by the Federal Reserve Bank of San Francisco (Figure 5). These estimates have declined significantly over the last 13 years, which is due to shifts in world supply and demand for funds. In 2017 and at the beginning of 2018, the natural rate of interest in USD was close to zero. Holston et al. (2017) explain this as being due to the ageing population, the global savings glut, and slowing potential growth. The authors also show that these factors are common for several other advanced economies.

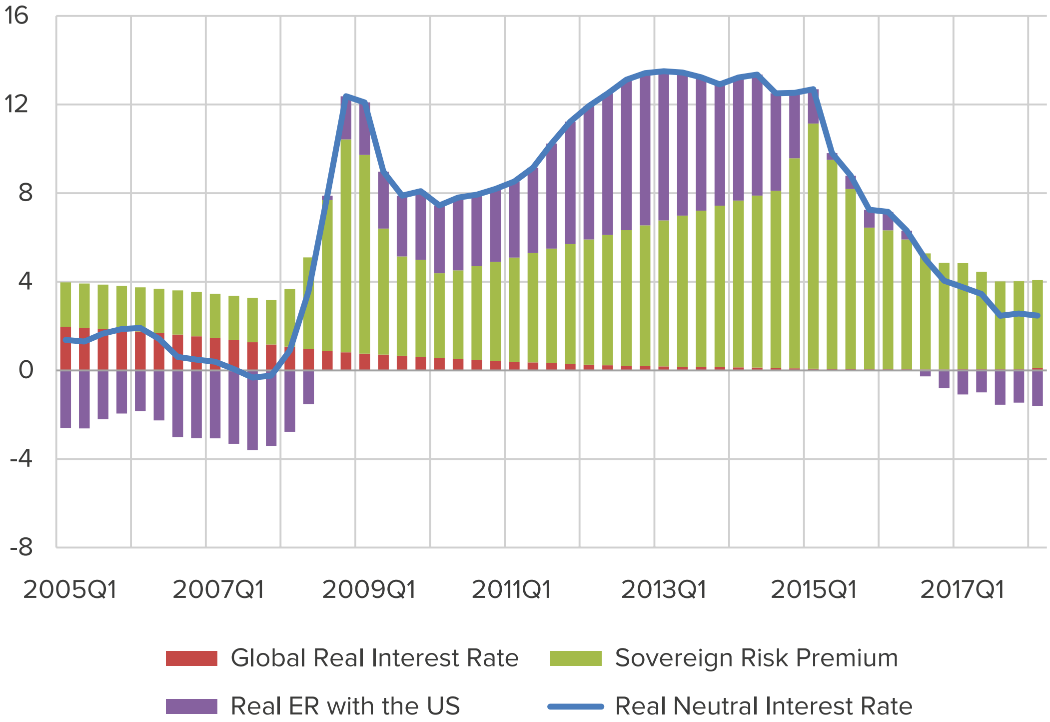
Figure 5. Neutral real interest rate in the US, %



Real neutral interest rate in Ukraine

The combination of the above-mentioned factors shapes the dynamics of the neutral real interest rate in Ukraine (Figure 6). From 2005 to 2007, the neutral rate fluctuated between 0% and 2% on the background of a low risk premium and appreciating real ER. In general, the rate in Ukraine was decreasing in line with its US counterpart, and even used to be below it.

Figure 6. Real neutral interest rate decomposition, %



However, the hike in the sovereign risk premium and simultaneous break in the real ER trend caused a surge in the real neutral rate to 12% in 2008-2009. The mitigated risk premium in 2010 brought some relief, with the rate rolling back to about 7%. However, until 2015 the neutral rate in Ukraine was increasing, in contrast with the decreasing rate in the US. It reached 13% in 2014, as both the growing risk premium and the real ER depreciation trend had unfavorable effects. In 2015, the neutral rate was above 15%, mostly due to a surge in the risk premium.

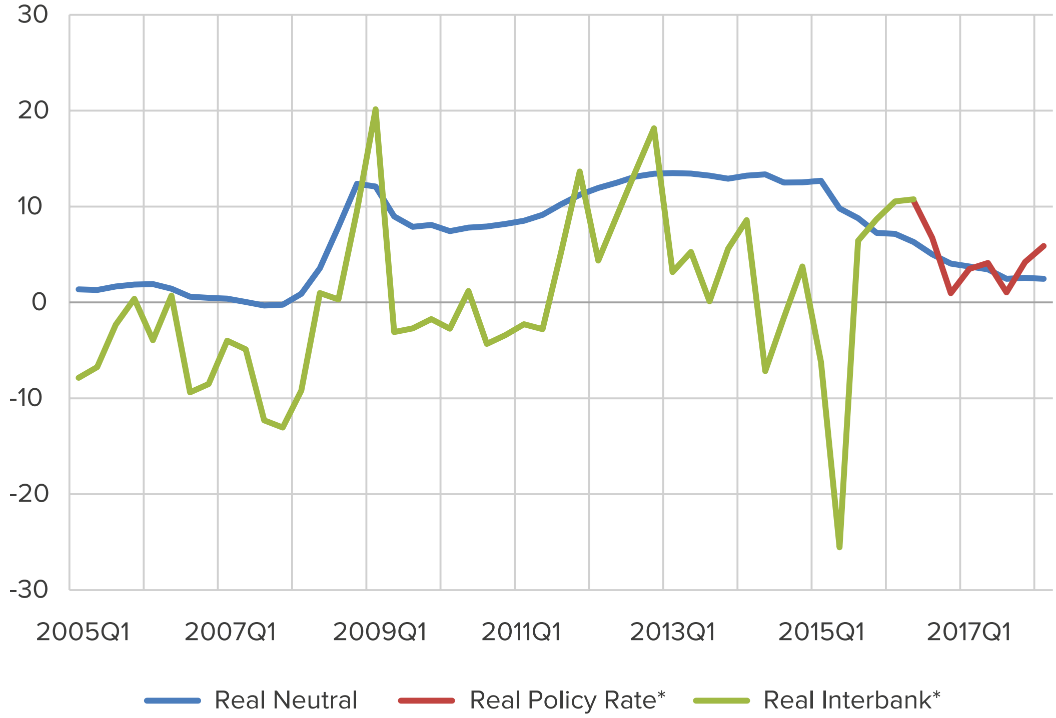
As of the beginning of 2018, the rate is close to 2.5% and continues to decrease with the return to a real ER appreciation trend and a lowering risk premium, as well as a low rate in the United States.

Assessing monetary stance

We now focus on the behavior of the real interest rate, defined as the nominal short-term interest rate adjusted for expected inflation. A key policy rate was de-facto absent in Ukraine until 2014, since the former monetary policy framework relied on an exchange rate peg against the US dollar. To reflect the monetary policy stance at that time, we used the overnight interbank interest rate. Under the current inflation targeting framework, this interest rate plays the role of an operational policy target. Such an approach allows us to conduct a continuous analysis in a situation in which there is a switch in monetary policy regimes.

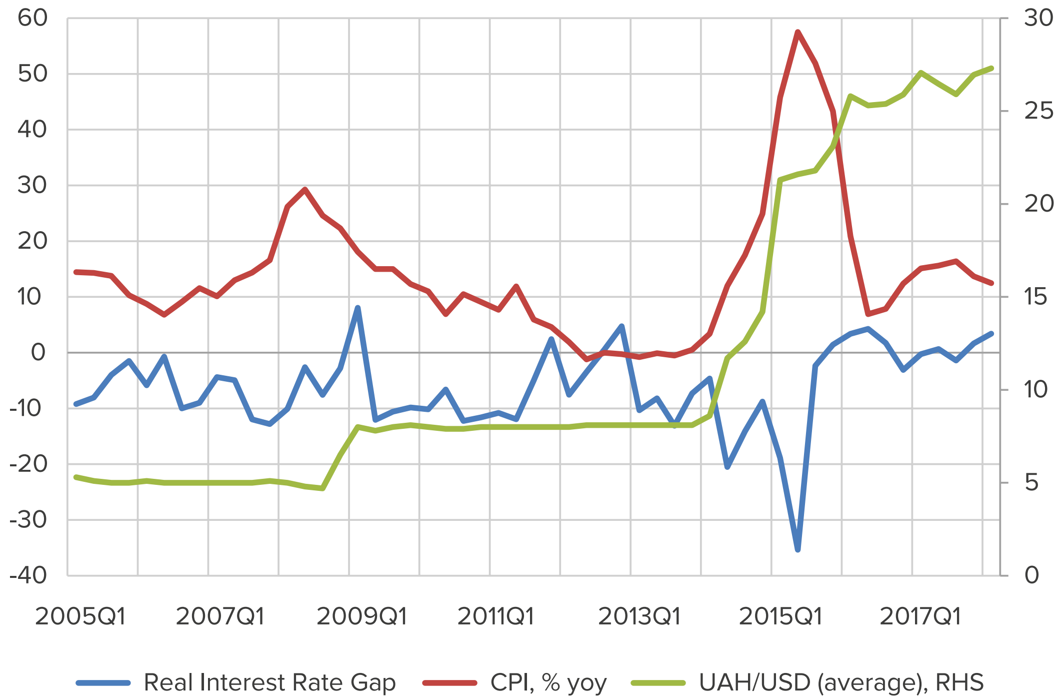
The concept of the neutral interest rate provides a useful tool for an ex-post monetary policy analysis. Figure 7 plots the estimated real neutral rate. The persistent negative gap between the overnight interbank rate and the neutral rate evidences in favor of there being a highly accommodative policy stance for most of the historic horizon.

Figure 7. Monetary policy stance, %



Since 2005, there were only eleven quarters during which the real interbank rate was on average above its neutral level (Figure 8). Seven of them were in the period since 2015, which testifies to there being a strict monetary policy with a view to achieving a disinflationary trend. The other five were due to devaluation pressures and reflected efforts to protect the fixed exchange rate – they were mainly in late 2011 and 2013. The tight monetary stance contributed to the recession and close to zero inflation in 2012 and 2013. However, the exchange rate peg to the US dollar at an overvalued level contributed to low inflation even more, and finally resulted in currency crisis in 2014.

Figure 8. Real Interest Rate Gap and Consumer Inflation, %



Most of the time the real interbank rate has been markedly below its neutral level – under the exchange rate peg framework, during periods of strong capital inflow, monetary policy was accommodative, as the central bank relied on unsterilized FX interventions to maintain the peg. In 2008, these loose monetary conditions contributed to the severe BOP and currency crises. In 2014 and at the beginning of 2015, the depreciation pressure was not contained, as the interest rate had been rendered negative in real terms.

4.2. Long-term values

Trend of the real exchange rate

In our assessment of the long-run real exchange rate (LR RER) trend with the US, we rely heavily on Phillips et al. (2013), which introduces the External Balance Assessment methodology developed by the IMF's Research Department. We use coefficients from Table 5 of the paper to link LR RER appreciation with projections of changes in certain macroeconomic variables. See section IV of the paper for methodological clarifications.

Our results are summarized in Table 2 of this paper, and we estimate a 2% annual appreciation of LR RER against the US dollar. The approach requires the making of several assumptions, which are listed below:

• Ukrainian GDP is projected to grow by 4% annually in the long term. This estimate is close to current developments in peer economies, e.g. Poland, as well as Romania, Hungary, and the Czech Republic, which were recently able to increase their growth rates in the wake of the financial crisis. In fact, this growth rate is used by the NBU in its Quarterly Projection Model to represent potential GDP growth in a steady state. However, 4% is above the 3.2-3.5% projected for Emerging and Developing Europe in 2018-2022 in the IMF's World Economic Outlook (October 2017);

• Relative economic growth for Ukraine is 2%, as long as it is calculated in comparison with the projected 2% GDP growth in the US. Projections for the US are taken as being equal to recent estimates of potential GDP growth made using the methodology of Laubach and Williams (2003);

• The unfavorable demographic trend in Ukraine significantly restrains LR RER appreciation. The projected population growth in the US and the decline in Ukraine both contribute to the pace of negative 1% for the relative change in population. The negative demographic trend in turn causes population aging, which stimulates an increase in savings. Such trends increase the current account norm, which creates depreciation pressure on LR RER;

• The relative changes in population and relative projected GDP growth both shape relative GDP per capita, which is a proxy for productivity;

• Foreign exchange purchases (on average 1% of GDP annually) are projected in line with attempts to achieve an adequate level of net international reserves, matching the IMF's composite measure. Thus, in the medium to long term the NBU will be forced to steadily increase the level of reserves in order to keep up them at a level in line with the growth of the economy and the financial sector. Given that capital flows are not fully free, they will be a restraining factor on RER appreciation;

• We estimate capital account openness to be 0.5 on a scale from 0 to 1;

• We do not expect other factors to have significant effects on RER in the long run. Specifically, there is no reason to assume any changes in risk aversion, the share of domestic debt owned by residents, commodity terms of trade, trade openness, or the real interest rate differential in the medium to long term;

• According to statistical data, the real sector in Ukraine seems to be overloaded with loans. This is the legacy of related-party lending schemes (or oligarch-style banking) that have dominated the Ukrainian banking system for decades. In fact, this was not banking per se, but rather a way for big businesses to finance itself. After large-scale reforms in the banking system, more than a half of bank loans were declared to be non-performing. We conservatively project no growth in the private credit to GDP ratio over the long term;

• We assume that price liberalization processes will be finished in the next few years. Thus, there will be no changes in the share of administered prices in the medium to long term.

The share of health expenditure in GDP in Ukraine is close to the level in peer countries. We assume that healthcare system reforms will lead to changes in the structure of such expenditures, but not in its share of GDP.

The sensitivity of this and some other assumptions is tested in section 4.3 of this paper.

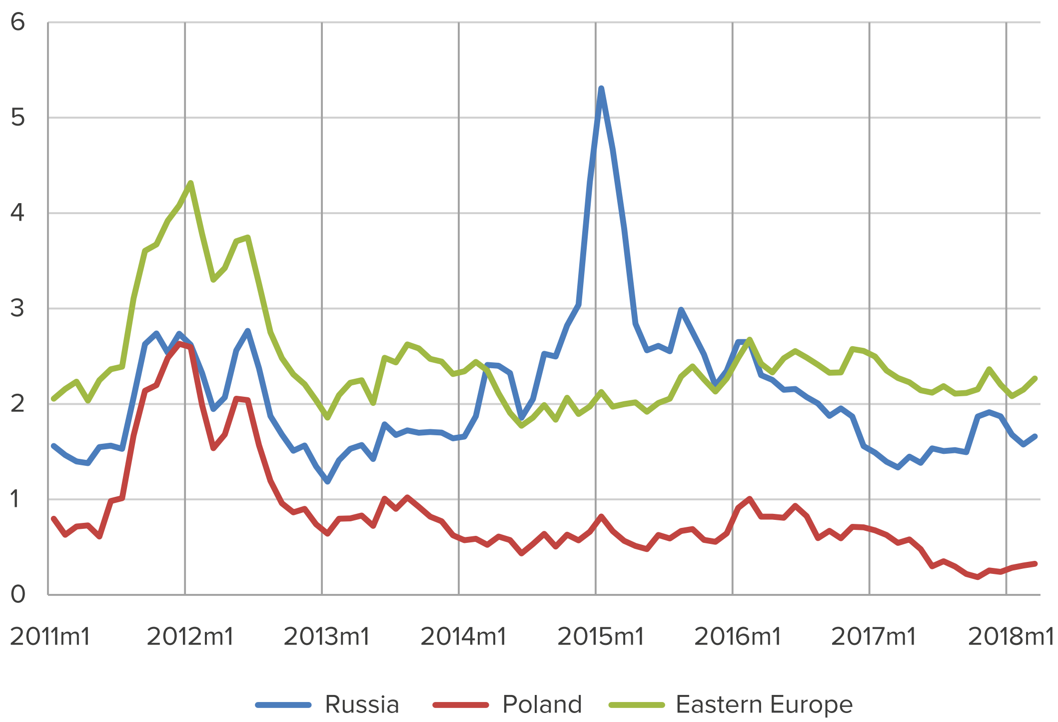
Table 2. Determinants of long-term real ER

Variable	Coefficient	Changes in Ukraine	Impact
Relative GDP per capita * K controls	0.52	**3.0**	1.6
Global risk aversion	-0.24	**0**	0
Share of domestic debt owned by residents	0.34	**0**	0
Relative population growth	3.50	**-1.0**	-3.5
Relative GDP in 5 years	2.32	**2.0**	4.6
Terms of trade	0.08	**0**	0
Avg (export, import)/GDP	-0.36	**0**	0
Share of admin. prices	-1.86	**0**	0
Health expenditures/GDP	1.78	**0**	0
FX Net Reserves/GDP * K controls	-0.72	**1.0**	-0.7
Real rate differential * K openness	0.35	**0**	0
Private credit/GDP	0.13	**0**	0
Long-term RER annual appreciation (Total)			**2.0**

Sovereign risk premium

The steady state value of the sovereign risk premium in Ukraine is assumed to be at 3 percentage points. The premium exceeded this level in the first half of 2008, and has never been lower than this since then. However, the recent enduring decline, on the background of the program with IMF and anticipated reforms, makes us optimistic about the long-term prospects. That level is above average since 2013 for Eastern European countries with investment ratings – at 2.2 percentage points[2] (Figure 9).

Figure 9. Sovereign risk premium in peer economies, %



Source: Cbonds.com, own estimates.

[2] Cbonds.com

Real neutral interest rate in the US

The long-term value of the real equilibrium interest rate in the US is projected to be equal to 1%.

Holston et al. (2016), in their study of advanced economies (the Euro Area, Canada, the United States, and the United Kingdom) link real neutral interest rates to potential GDP growth. Both indicators have been slowing for at least the last 25 years, thus, future real rates cannot be calculated as a simple historical average. The reasons for this deceleration include demographic shifts and a slowdown in productivity growth. These reasons are common to all of the advanced economies. Furthermore, their real neutral interest rates dropped sharply after the crisis in 2008.

However, in the long run, the negative effects of the financial crisis are expected to subside, so real interest rates should come back to their pre-crisis values - around 1% for the United States according to the methodology of Laubach and Williams (2003). Moreover, Yellen (2016) states that 1% is the median long-term projection of the Federal Open Market Committee.

Real neutral interest rate in Ukraine

We assess the long-term value of the real neutral interest rate in Ukraine as a sum of the long-term values of the real natural interest rate in the United States and the Ukrainian sovereign risk premium, minus the long-term value of real ER appreciation. This gives a result of 2% annually. This number is expected to determine a neutral monetary policy over the long term.

4.3. Long run sensitivity analysis

Over the long term, the real neutral rate is a subject to uncertainty due to possible variations in its components.

First, investor sentiments may alter the sovereign risk premium. Our projections assume the convergence of Ukraine with its peer economies, which will lead to a relatively low risk premium of 3 percentage points. However, a swift convergence might result in an even lower rate of 2 percentage points, which is just below average for the country's Eastern European peers. On the other hand, a halting of reforms could bolster the risks and stall the premium rate at the current 4 percentage points. These options yield a possible diapason of the sovereign risk premium of 2-4 percentage points in the long run.

Second, the real natural interest rate in the United States will be determined on the global markets. According to estimates under the Laubach and Williams (2003) methodology as of the second half of 2017, the current rate is below zero, which is a historic low. A sluggish world economy may result in the rate get stuck halfway to 1% i.e. at 0.5%. In contrast, faster world economy growth might yield a higher neutral interest rate of 1.5% – the pre-financial crisis value. Thus, the projected diapason is 0.5-1.5% in the long run.

One final source of uncertainty comes from assumptions about LR RER appreciation. The point projection for the long run is 2% yearly. However, historically over the last 10 years real exchange rate has mostly depreciated, which makes us conservative about projections for the future. The rate has had an appreciating trend as of the beginning of 2018, but we see zero as the lower bound for LR RER changes.

From the optimistic point of view, the current pace of appreciation may continue to increase to pre-financial crisis levels of around 3% annually. So the diapason of projections for LR RER appreciation spans 0-3% annually.

According to Table 2, there are several macroeconomic variables that generate uncertainty in real ER projections:

- Capital account openness interacts with coefficients in the table, and thus influences the contributions of other variables. On a scale from 0 to 1 and all other things being equal, this factor may alter annual LR RER appreciation from 1.8% to 2.2%. Higher capital openness yields lower appreciation. Jahan and Wang (2016) argue that 0.7 is the median value for emerging market economies. This value is associated with 1.9% annual appreciation;

- Ukrainian GDP is vulnerable to external conditions, while LR RER is sensitive to assumptions about its potential growth. A lowering of potential real GDP growth by 0.1 percentage points, all other things being equal, could lead to LR RER appreciation slowing by 0.3 percentage points. The last ten years of low GDP growth – even excluding the crisis periods – shifts the risk for LR RER to lower appreciation;

- LR RER appreciation is nearly as sensitive to relative population growth as to potential GDP growth. If relative population growth is as little as 0.1 percentage points higher, it could result in 0.3 percentage points higher LR RER appreciation.

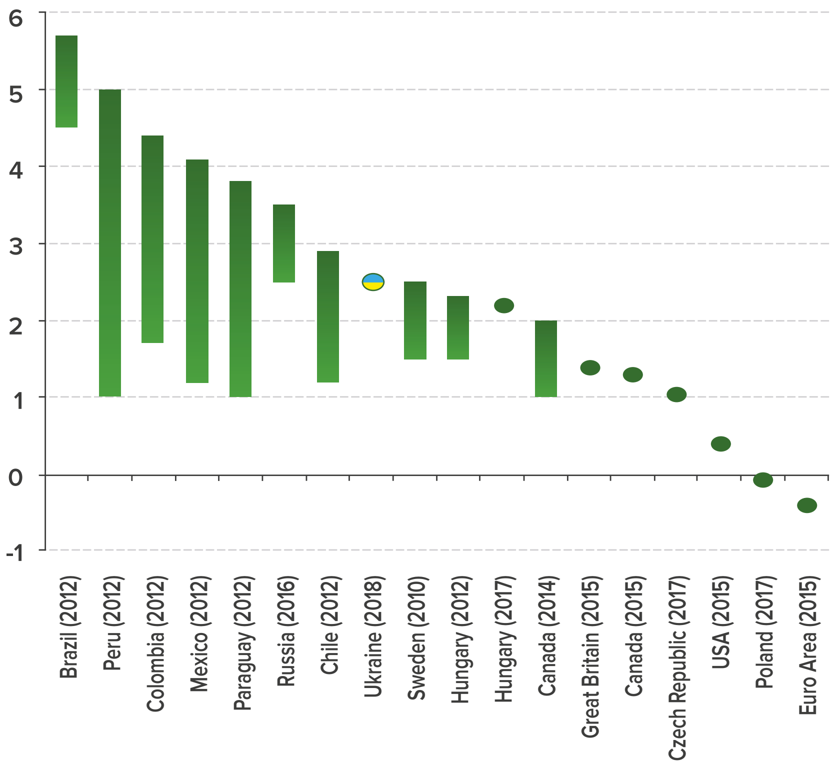
In the case of an adverse macroeconomic scenario in Ukraine, its long term sovereign risk premium might hit its upper bound, and RER appreciation – its lowest. A favorable scenario would have the opposite effect. Given that the global neutral interest rate is independent of conditions in Ukraine, we will leave it at the central projection point of 1%.

This combination of factors yields a diapason of 0-5% for the long-term projection of the neutral interest rate.

4.4. Comparison with the international estimates

This is the first study of the neutral interest rate in Ukraine, and so we are unable to compare our results with other works. However, it might be worth comparing our results for Ukraine with the results for other countries, as presented in Figure 10.

Figure 10. International estimates of neutral real interest rates, %



Source: Magud and Tsounta (2012) for Brazil, Peru, Colombia, Mexico, Paraguay, and Chile in 2012; Kreptsev et al. (2016) for Russia; Baksa et al. (2013) for Hungary in 2012; Stefanski (2017) for Czech Republic, Poland and Hungary in 2017; Sveriges Riksbank (2010) for Sweden; Mendes (2014) for Canada in 2014; Laubach and Williams (2017) for Canada, Great Britain, Euro Area, and USA in 2015.

That said, comparing the neutral rates of different countries could be misleading, as estimates can vary a lot depending on the methods used and the assumptions made. However, our estimate for Ukraine lies within the ranges seen in other studies of other countries.

The level of the neutral interest rate is close to the results obtained by Magud and Tsounta (2012) for most Latin American countries. Their average of estimates (the authors compare seven methods) is close to 2%. Brazil has about 5%, but it is rather a unique case, historically having the highest interest rates in the region.

Recent studies both of advanced and developing economies indicate rather low neutral interest rates, in the range of 0 to 2%. This reflects ample global liquidity and other factors described in the Section 2.

5. CONCLUSIONS

In this paper, we estimated the neutral interest rate for Ukraine using a small open economy framework, based on uncovered interest rate parity. This approach is the most suitable, especially for policymaking purposes, in the case of the Ukrainian economy, which may rely on external sources of capital. We explored a semi-structural gap version of a dynamic New Keynesian small open economy model, and accounted for the trends in real exchange rate and risk premium. For empirical estimates of a time-varying neutral rate, we applied a Kalman filter algorithm to historical data.

Our findings show that the estimated neutral interest rate in Ukraine demonstrated significant variation over time, mainly reflecting swings in the risk premium, while the trend changes in the real exchange rate and the foreign neutral rate also contributed. In 2016 and 2017, the neutral rate in Ukraine declined to 2.5%, driven both by a lowering sovereign risk premium and a return to a real exchange rate appreciation trend due to a recovery in productivity growth. Our projections suggest that over the long term, the neutral rate is to approach 2%, reflecting a further decrease in the risk premium and an acceleration of real exchange rate appreciation trend. Meanwhile, the long term real neutral rate is a subject to uncertainty due to possible variations in its components, and is estimated to be in the range from 0 to 5%, depending on the success of economic development in Ukraine.

Measuring the neutral rate provides a useful tool for policy analysis. For instance, it shows that in the past, short-term interest rates remained below the neutral rate for prolonged periods during the exchange rate peg era (until 2014). This resulted in high and volatile inflation. Meanwhile, in the medium-term prospect, the NBU's key policy rate needs to be maintained at a level sufficiently higher than neutral level in order to ensure disinflation and stabilize expectations close to the inflation target.

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WHAT DRIVES THE DIFFERENCE BETWEEN ONLINE AND OFFICIAL PRICE INDEXES?

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Abstract This paper examines the associations between online price indexes and official statistics. First, we generate online CPI component sub-indexes, which are later aggregated to an Online Price CPI. This approach is applied to our unique dataset which contains about 3 million observations of online retail prices for consumer goods in Ukraine's five largest cities. The data span the period 2016m1 – 2017m12 and cover about 46% of Ukraine's Consumer Price Inflation basket. We find that online inflation is generally consistent with official estimates, but the matching capability varies across sub-indexes. Although the differences can partially be explained by poor dataset coverage, we find that online prices may indeed represent new information that is not captured by official statistics.

JEL Codes C55, E31, E37

Keywords online prices, web scraping, consumer price index, micro prices, big data

1. INTRODUCTION

One of the key aims of central banks is to keep inflation rates low. Inflation targeting has thus become a mainstream policy approach among policy makers in recent decades (e.g., Hammond, 2011; Jahan, 2017; Roger, 2010). However, in order to "target" inflation, central bankers need an explicit and observable measure of inflation that can serve as the nominal anchor for society. Measuring inflation is not always a straightforward exercise and it is usually beyond the remit of central banks. In particular, central banks commonly refer to publicly available indicators officially published by state statistics agencies, such as the consumer price index (CPI).

The CPI is the indicator usually selected by central banks, as it measures the cost of living in the economy and is easily accessible to both the public and policy makers. Despite its simplicity and public acceptance, it may not be the best measure: CPI covers a limited number of goods and services in the economy and might not capture overall inflation developments as perceived by the public. This may affect the effectiveness of the central bank's decisions and question the success of monetary policy in general. Policy makers, therefore, should be armed with all possible tools and use all available sources of information to improve their ability to recognize and understand threats to price stability.

The rapid emergence of e-commerce in the retail sector has made it possible to observe the prices for various goods and services online. Web scraping (collecting data from online sources through the use of specially written software), has become a useful tool for gathering data on online prices from the web in order to complement official statistics. Many national statistics organizations and other public institutions have already launched web-scraping projects to improve their data collection process, including the U.S. Bureau of Labor Statistics (Horrigan, 2013), the U.K. Office of National Statistics (Breton et al., 2015), Statistics Netherlands (Griffioen, de Haan, Willenborg, 2014), Statistics New Zealand (Krsinich, 2015), and Statistics Norway (Nygaard, 2015). Compared to other methods of data collection, web scraping has a range of advantages: in addition to the low cost of data collection, scrapped data are available on real-time and high frequency

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basis, which can help policy makers to continually monitor inflation developments at the micro-level.

A growing literature utilizes online data for research purposes. The Billion Price Project (BPP)[1] founded in 2008 at MIT by Alberto Cavallo and Roberto Rigobon, aims to collect prices from hundreds of online retailers around the world. Cavallo and Rigobon (2016) show that online prices can be successfully used as an alternative source of information for constructing consumer price indexes. Some studies use online data to check whether official statistics is accurate and that it has not been manipulated. In particular, Cavallo (2013) uses online prices to study how online indexes match up with official statistics in five Latin American countries. The author finds that while for Brazil, Chile, Columbia, and Venezuela online price indexes approximate both the level and the main dynamics of official inflation, Argentina's web inflation was nearly three times higher than official statistics. Coupe and Petrusha (2014), in turn, find that online and official consumer inflation in Ukraine may differ considerably in the short term, but the deviation can be both positive and negative.

Comparing online and official price indexes, it is important to understand why potential differences may occur. On the one hand, online prices may indeed represent new information about long-term inflation developments that are not captured by official statistics. Meanwhile, given that online markets tend to be more flexible, online prices can adjust to new economic conditions more quickly,[2] hence producing short-term deviations, while in the long-run online inflation should be consistent with official estimates. On the flip side, differences may arise due to technical issues, fundamentally different approaches in data collection, and the methods used to construct online indexes. In contrast to official data, web-scraped data usually includes a high number of goods items, while the coverage of retailers and regions is limited. In addition, the high frequency of sampling for the online dataset often results in a high number of missing observations, due to errors in the scraping scripts or simply because goods may be out of stock. As a result, the composition of goods included in online price indexes can vary dramatically over time, which is usually inconsistent with the standard approaches used by statistics organizations. So before coming to any conclusions about whether online prices reflect new information about inflation developments that are not captured by official statistics, it is important to explore what drives such differences.

In this paper we develop an online consumer price index for Ukraine using a rich dataset of online prices and compare it to the official statistics reported by the State Statistics Service of Ukraine. We generate online CPI component sub-indexes and, thereafter, aggregate them into an Online Price CPI. Our unique dataset contains about 3 million observations of online retail prices for consumer goods in the five largest cities in Ukraine. The data span the period 2016m1 – 2017m12 and cover about 46% of Ukraine's Consumer Price Inflation basket. We find that online inflation is in general consistent with official estimates, but the matching capability varies across sub-indexes. We further explore those properties of the dataset that can account for the differences. For this purpose, we employ alternative filtering and aggregation techniques that improve or reduce the matching performance of the constructed indexes. We find that online price indexes may deviate from their official counterparts because of technical issues in data collection and poor dataset coverage. However, our analysis indicates that online prices can outpace reported estimates and convey new information that is not captured by the official CPI.

The rest of the paper proceeds as follows. The second section describes the online dataset used for our analysis. The third section introduces sub-component as well as aggregated consumer price online indexes and explores their ability to match official statistics. The fourth section gives conclusions.

2. ONLINE PRICES FOR CONSUMER GOODS IN UKRAINE

Our analysis utilizes online prices for consumer goods in Ukraine obtained from web scraping performed by the National Bank of Ukraine (NBU). In 2015, the NBU launched a web-scraping project aimed at improving data collection on consumer prices and at complementing official CPI statistics.

The Consumer Price Index provided by the State Statistics Service of Ukraine is the major indicator for tracking inflation developments used by the National Bank of Ukraine in the conduct of its monetary policy. The Ukrainian CPI basket comprises 328 sub-components, with up to 40% being food items, beverages and alcohol. Table 1 provides descriptive statistics for the Headline CPI and major CPI aggregates.

The NBU's online dataset includes several leading online retailers, which in addition to online stores have a wide network of offline supermarkets around the country in five major cities (Kyiv, Kharkiv, Dnipro, Odesa, and Lviv). These supermarkets and their online platforms offer a wide range of food items, beverages, alcohol, and tobacco products. The dataset covers up to 46% of the CPI basket and more than 130 CPI sub-components. Since the beginning of the project, the NBU's dataset has included over 75,000 goods items, with up to 3 million weekly observations[3] over two years (2016m1 – 2017m12). Most of the online prices are those of goods sold online in the Kyiv region, which could be considered the largest consumer in terms of e-commerce. Kharkiv, Dnipro, and Odesa have approximately equal shares, while Lviv is barely represented in the dataset so far. Table 2 provides descriptive statistics of the dataset.

3. CONSTRUCTING ONLINE INDEXES

The NBU's online dataset provides extended information on prices for goods at the micro level in various regions of Ukraine. In order to explore whether online price inflation is consistent with official statistics, we proceed by constructing online indexes and comparing them with their official counterparts.

[1] See for instance: http://www.thebillionpricesproject.com

[2] See, for example, Gorodnichenko & Talavera (2017).

[3] The data is collected daily, but we use weekly observations which are obtained by taking the mean price over the week. This helps us to avoid problems of an excessive number of missing observations and temporary errors in the web-scraping scripts.

3.1. Sub-Component Online Indexes

Following common practice,[4] we construct online sub-indexes as simple averages of week-on-week price changes within a narrowly defined group, namely at the CPI sub-component level:

$$\Delta p_{i,t} = \sum_{j=1}^{K} \left[\frac{(P_{ij,t} - P_{ij,t-1})}{P_{ij,t-1}} \right] \div K,$$

where Δp, $i=1,2,3...N$, states for an average week-on-week percentage change of prices at the sub-component level i; $P_{ij,t,}$ $j=1,2,3...K$, is the price for a specific good j at the sub-component level i.

Thereafter, the sub-component weekly data series are transformed into a monthly frequency data set, so as to be comparable with official statistics. Since the dataset is of the weekly frequency and the number of weeks differs across each month, we first transform the web data in order to have four observations over the month, which prevents frequency conversion problems. This is done by dividing the month into four parts and matching the web data (e.g., 1st seven days, 2nd seven days, 3rd seven days, and the rest of the days). If there is more than one observation within a particular period in a month, they are simply averaged. Thereafter, we generate month-on-month indexes and convert weekly series to monthly ones:

$$\Delta_4 p_{i,m}^{w} = \prod_{j=1}^{4} (\Delta p_{i,m+w-j} + 1),$$

where $\Delta_4\ p_{i,m}^{w}$ states for month-on-month change of online prices at week $w=[1:4]$. As a result, we get four monthly series representing month-on-month price changes.

Figure 1 plots several online sub-indexes together with their official counterparts. We present online indexes constructed at the third week of each month, since the State Statistic Service of Ukraine declares that it collects prices approximately at the same time. The matching performance of online prices varies across indexes. For example, online price indexes for eggs, apples, grapes, and kefir closely approximate both the trend dynamics and the short-term changes in the official statistics, with the errors not exceeding two standard deviations. Some indexes, e.g., for a loaf of bread, frozen fish, and sunflower oil, capture the trend dynamics of monthly inflation, but can differ considerably in the short-term. The deviation of online indexes from official data for beef tenderloin and chocolate, in turn, can be more sustained in some periods.

In addition to the visual inspection, we test the matching performance of the online indexes by calculating the Root Mean Square Error (RMSE) at the sub-component CPI level (see Table 3). For comparison purposes, we also provide RMSEs adjusted to a specific category's standard deviation of official inflation, since the volatility of sub-indexes can differ dramatically. We provide calculations for four weekly month-on-month indexes. The results suggest that even adjusted RMSEs can vary considerably across sub-indexes. The mean RMSEs exceed the official inflation standard deviation by two times. While the minimum adjusted RMSE is around 0.5%, the maximum value is over 11%. Meanwhile, in about 70% of online sub-indexes, the overshoot errors dominate those that undershoot official estimates.

In order to determine what drives the differences between the online and official price indexes, we apply various filtering techniques and explore the properties of the data which improve or reduce the performance of the online indexes. For this purpose, we construct alternative online indexes by randomly excluding goods from the dataset. In particular, we run 99 iterations in which each good has a probability of 1%, 2%, and up to 99% of remaining in the dataset. For each probability level, we repeat the procedures 100 times and, consequently, we obtain 9,900 alternative datasets with different compositions of goods. For each alternative dataset, we construct four monthly sub-component online indexes as described above. We compare the generated indexes to official statistics by calculating their RMSEs. Given that each alternative dataset comprises different numbers of goods with a different number of missing observations and a unique mean standard deviation, we can now explore which of the features of the dataset affect the matching performance of the constructed online indexes. For this purpose, we estimate a panel regression of the following form:

$$RMSE_{i,k} = \beta_o + \beta_1 Obs_{i,k} + \beta_2 Members_{i,k} + \\ + \beta_3 SD_{i,k} + u_i + \varepsilon_{ik,}$$

where $RMSE_{i,k}$ refers to an average RMSE over four weekly m-o-m sub-indexes i for iteration k; $Obs_{i,k}$, $Members_{i,k}$ and $SD_{i,k}$ state for the average number of non-missing observations, the number of sub-component group members, and the group's mean standard deviation, respectively; u_i refers to a cross-component time-invariant fixed effect, which allows the capture of component-specific performance; finally ε_{ik}, is an error term.

The coefficient estimates obtained (see Table 4) suggest that the higher the volatility of online prices at the sub-component level, the lower the matching performance of the constructed indexes. Meanwhile, the lower the number of goods in the dataset, the higher the RMSE and, hence, the less accurate is the matching performance. This suggests that the differences between online and official inflation can be caused by a poor dataset. A less intuitive result is obtained for the average number of non-missing observations, indicating a positive correlation with the forecast error. Namely, the more observations in a sample, the higher is its RMSE.

We proceed by filtering-out goods that lower the performance of the web indexes. First, we focus on excluding goods that are characterized by high standard deviations within a narrowly defined group at the sub-component level. We construct alternative web indexes by excluding the upper and lower percentiles of standard deviations (e.g. 121 iterations starting from 0 to the 50th upper and lower percentile) and calculate the share of indexes with RMSEs below average over all iterations. Figure 2 provides the results of this exercise.

[4] Our approach is similar to Cavallo (2013) but we use a simple mean of price changes instead of a geometric mean.

Indeed, as suggested by the panel regression analysis presented above, excluding up to the 20th upper percentile of goods in a narrowly-defined group with high standard deviations improves the performance of web indexes. In contrast, the exclusion of the lower percentile does not seem to lower RMSE. On the one hand, this may indicate that the online dataset includes some outliers that, for technical reasons, are collected by the web-scraping procedure. In particular, a price can change dramatically due to changes in quantities. If a retailer changes the quantity of a good but uses the same web page, the web-scraping scripts are not able to recognize this without interfering. Nevertheless, one would expect that the share of such outliers caused by technical issues should be small. In our case, however, this share can exceed 20 percent, indicating that highly volatile prices may indeed represent new information in the short-term that is not captured by official statistics.

In order to check whether the number of non-missing observations influences the forecast error, we repeat the above procedure by excluding goods with a high number of missing observations. However, the results of the panel regression are confirmed, as the mean RMSE rises with the increase of the filtering requirements. Given that the number of group members has a negative correlation with the RMSE, additional exclusion of goods worsens the performance of the web indexes. These results suggest that including goods with a high number of observations over the sample does not necessarily guarantee better performance and, therefore, the inclusion of rarely tracked goods with a high number of missing observations does not reduce the matching performance.

Finally, we test the matching performance of online indexes generated at different weeks over the month. This exercise aims to explore the capability of online indexes to match official statistics as new data appears. In addition to the weekly indexes which incorporate price dynamics over the last four weeks (e.g. m-o-m price changes), we calculate average online inflation as the time passes. For instance, at the end of the first week of the month we have information on how prices changed compared to the first week of the previous month. At the end of the second week, in addition to first week inflation, we obtain data on the second week inflation. In order to better capture price dynamics, we can also calculate the average of the first and second weeks' inflation. The same applies to the subsequent weeks. We also compare official inflation for a particular month with the last week online inflation of the previous month and the first week of the preceding month. Figure 3 presents the resulting sample's mean RMSE for different weekly month-on-month indexes.

The results suggest that the share of month-on-month online indexes with the lowest RMSEs is the highest for second-week online inflation. It is noteworthy that the State Statistics Service of Ukraine collects price data at the beginning of the second half of the month. In addition, cross-component mean RMES for online indexes which comprise the average of the last month-on-month indexes decreases as the time passes and new web data arrives. This provides additional confirmation that online inflation may outpace official estimates and, therefore, have a predictive power.

To sum up, our analysis suggests that online inflation is in general consistent with official statistics, although the matching performance differs across CPI sub-indexes. The differences can be explained both by the properties of the dataset, e.g., such as pure goods coverage, and by the fact that online prices indeed represent new information not captured by official statistics. In particular, online prices might be much more volatile and react more quickly to new economic conditions.

3.2. Aggregated Online Indexes

In the previous section we constructed online consumer price indexes at the sub-component level. Herein, we proceed by constructing the headline consumer price web index along with other CPI aggregates in order to explore how web data can approximate overall price developments in the country.

We employ several alternative approaches to constructing an aggregated online index. First, we use a simple average of all web indexes that represent a specific category. In particular, for aggregated headline inflation, we use a simple average of all online indexes, while for food online inflation we include only those indexes that belong to the food category. Alternatively, we use the officially available weights of the CPI basket structure provided by the State Statistics Service of Ukraine. Since the web dataset comprises up to 46% of the CPI basket (e.g. 134 out of 328 components) we construct relative weights using only those components that are represented in the dataset. Finally, to benchmark our results, we construct an index that comprises the average price dynamics of all goods in the dataset without constructing sub-component indexes. Table 5 reports the RMSEs of aggregated web indexes for headline CPI, constructed headline CPI (e.g., including only the components presented in the web dataset), food CPI and specific food indexes, beverages CPI, as well as alcohol and tobacco CPI. Figure 4 illustrates our results and plots official and web inflation.

For most aggregated web indexes, a weighted average of the sub-component indexes seems to improve the performance of the web data. In particular, for the constructed headline CPI, which includes only those components presented in the online dataset, the RMSE decreases from 1.06% to 0.93%. Similar applies to aggregated food indexes, as our web dataset covers most of the food sub-components.

Although, the results for the aggregated online indexes of headline CPI are mixed, the RMSE does not exceed 1%. This indicates that while the share of sub-components that are not presented in the dataset play an important role, our web dataset captures the overall price developments in the country, as the root mean square error for most indexes does not exceed one standard deviation of official statistics.

4. CONCLUSIONS

The rapid development of e-commerce over the last few decades has allowed policy-makers to enrich their toolbox for observing current developments in the economy using big data. In this paper, we construct an online consumer price index using a rich dataset of online prices obtained from webscraping performed by the National Bank of Ukraine and compare it to official statistics. We first generate sub-component online indexes and, thereafter, we aggregate them to the headline CPI index, as well as other CPI categories. Our dataset contains about 3 million observations of online retail prices for consumer goods in the five largest cities in Ukraine and spans the period 2016m1 – 2017m12. The online data cover about 46% of Ukraine's CPI basket.

We explore which properties of the dataset improve or reduce its capability to approximate official statistics. Our findings suggest that online price indexes are in general consistent with official statistics, but the matching performance of online data varies across different CPI sub-components. The differences are partially explained by technical features of the dataset. In particular, the number of goods in the dataset matters, suggesting that the capability of online indexes to match official statistics increases when the online dataset covers a wide range of goods in a narrowly defined group. In contrast, goods with high number of observations over the sample do not necessarily guarantee a better fit, suggesting that the inclusion of rarely tracked goods with a high number of missing observations does not affect the matching performance of online indexes. Finally, utilizing officially provided CPI weights in constructing aggregated indexes decreases the deviation of online price indexes from their officially provided counterparts.

On the flip side, online indexes may indeed represent new information not captured by official statistics. The online prices of some goods may be much more volatile and, consequently, excluding such goods increases the matching performance of online indexes. The ability of high frequency online data to approximate official monthly inflation increases when a broader period of online price changes is taken into account. This indicates that online prices may react to new economic conditions more quickly and, consequently, have some predictive power for official statistics.

Our analysis confirms growing evidence in the literature (e.g., Cavallo and Rigobon, 2016; Breton et. al., 2015) that online prices can be used as an additional source of information for observing current developments in the inflation environment. This might also be relevant for so-called nowcasting or short-term forecasting, since online data is available in real-time and on a high-frequency basis. Therefore, our further research will consider the development of an inflation nowcasting framework that utilizes online data together with more traditional approaches on nowcasting. In particular, online prices might potentially improve the performance of dynamic factor models, which are commonly used to nowcast macroeconomic indicators.

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APPENDIX. TABLES AND FIGURES

Table 1. Descriptive statistics of official inflation

Index	% of CPI Basket	# of Sub-Indexes	S. D.	Min	Mean	Max
CPI	100	328	1.00	-0.36	1.04	3.52
Food	39.6	113	1.26	-1.06	0.81	3.42
- Bread	7.3	21	0.69	-1.15	0.66	1.96
- Meat	10.1	23	1.61	-1.32	1.33	5.15
- Fish	2.2	9	0.59	-0.90	0.15	1.26
- Milk	6.2	14	3.83	-5.15	1.29	11.43
- Fats	4.6	6	1.13	-0.36	1.16	3.60
- Fruits	2.3	10	5.46	-5.70	1.05	13.45
- Vegetables	2.4	16	10.04	-21.50	-0.31	16.69
- Sugar	3.4	7	0.92	-1.90	0.36	2.21
Beverages	1.4	7	0.28	-0.04	0.42	1.03
Alcohol	9.2	12	1.28	-1.91	1.69	3.33

Table 2. Descriptive statistics of online dataset

Index	% of CPI Basket	Rel. Share	# of Sub-Indexes	# of Goods, 1k	# of obs., 1m	Mean S.D.
CPI	45.7	45.7	134	75.1	2.48	4.96
Food	34.1	86.2	93	34.3	1.11	5.57
- Bread	6.8	93.0	19	8.19	0.29	3.39
- Meat	7.1	70.7	16	3.51	0.11	3.42
- Fish	2.2	100	9	2.57	0.09	4.01
- Milk	5.4	86.0	11	4.96	0.15	3.80
- Fats	4.4	96.8	4	0.72	0.03	3.99
- Fruits	1.4	60.2	5	0.74	0.02	9.66
- Vegetables	2.3	99.0	15	1.90	0.06	13.18
- Sugar	3.4	100	7	6.93	0.20	3.41
Beverages	1.4	98.9	6	10.5	0.40	4.71
Alcohol	6.2	67.6	7	9.92	0.37	3.59

Figure 1. Selected online sub-indexes together with their officially provided counterparts, m-o-m %

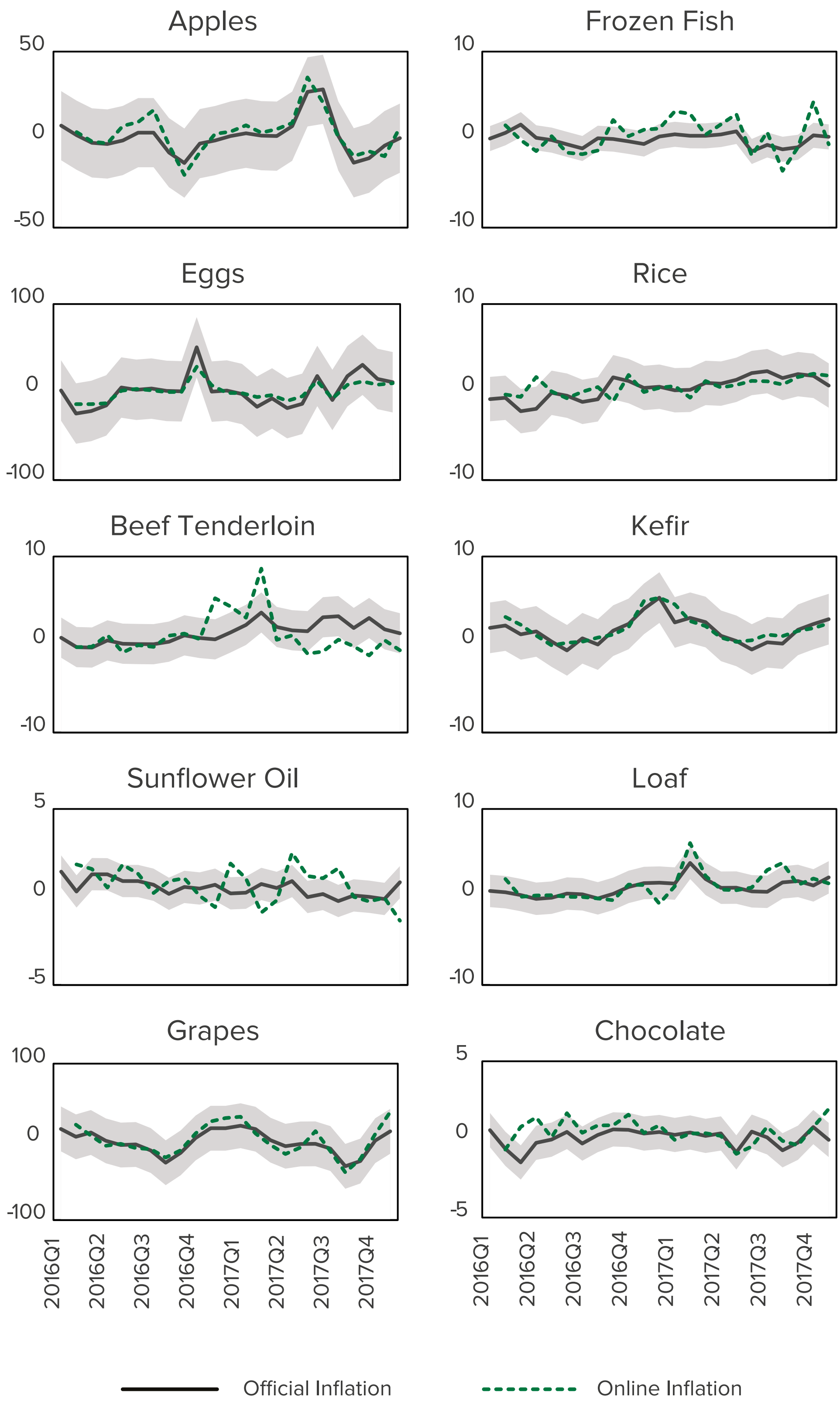


Table 3. Matching performance of online sub-indexes

		Week I	Week II	Week III	Week IV
RMSE	*mean*	4.97	4.97	5.09	5.30
	min	0.73	0.78	0.65	0.78
	max	84.75	110.30	75.82	86.17
RMSE adjusted*	*mean*	2.68	2.54	2.61	2.73
	min	0.49	0.48	0.39	0.50
	max	11.13	11.70	11.76	28.08
Mean Overshoot Error		3.99	3.81	3.95	4.11
Mean Undershoot Error		2.89	2.67	2.83	3.14
Share of predominant overshoot errors		70%	72%	72%	72%

* RMSEs here are adjusted to the specific category's standard deviation of official inflation for comparison purposes.

Table 4. Determinants of online inflation performance (panel regression)

RMSE	1)	2)	3)	4)	5)	6)	7)
Average number of observations	8.661* (0.137)			8.470* (0.137)	3.957* (0.073)		3.784* (0.073)
Number of goods		-0.001* (0.000)		-0.001* (0.000)		-0.001* (0.000)	-0.001* (0.000)
Group's mean S.D.			1.870* (0.001)		1.868* (0.001)	1.870* (0.001)	1.867* (0.001)
Fixed effect	*V*	*V*	*V*	*V*	*V*	*V*	*V*
R^2	0.844	0.838	0.955	0.844	0.955	0.955	0.956

Note: « * » indicates 1% significance level.

Figure 2. Filtering-out lower and upper percentiles of inflation SDs: Share of CPI sub-indexes with RMSE below average

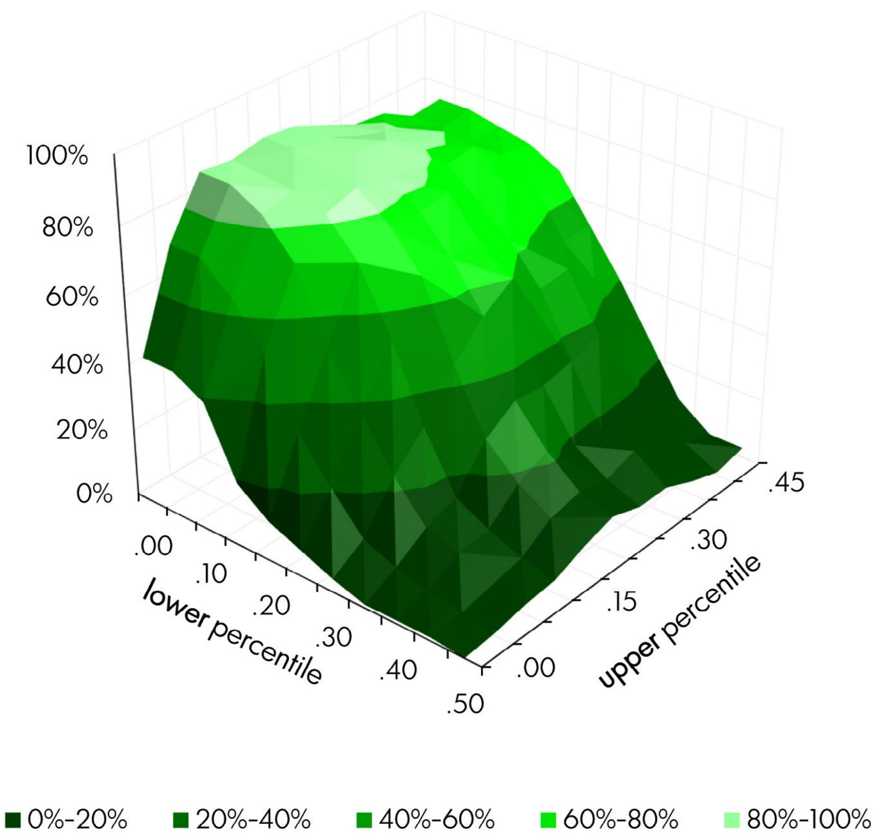
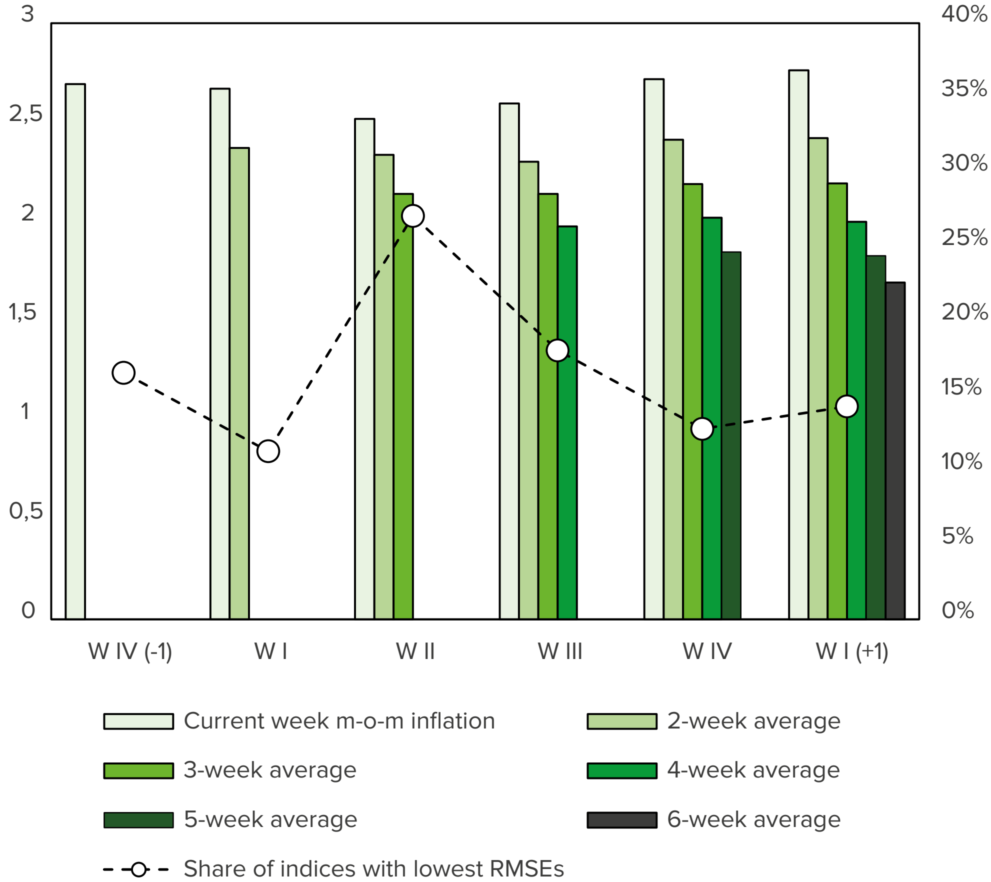


Figure 3. Weekly performance of online indexes: Mean RMSE (ls), Share of sub-indexes with lowest RMSEs (rs)



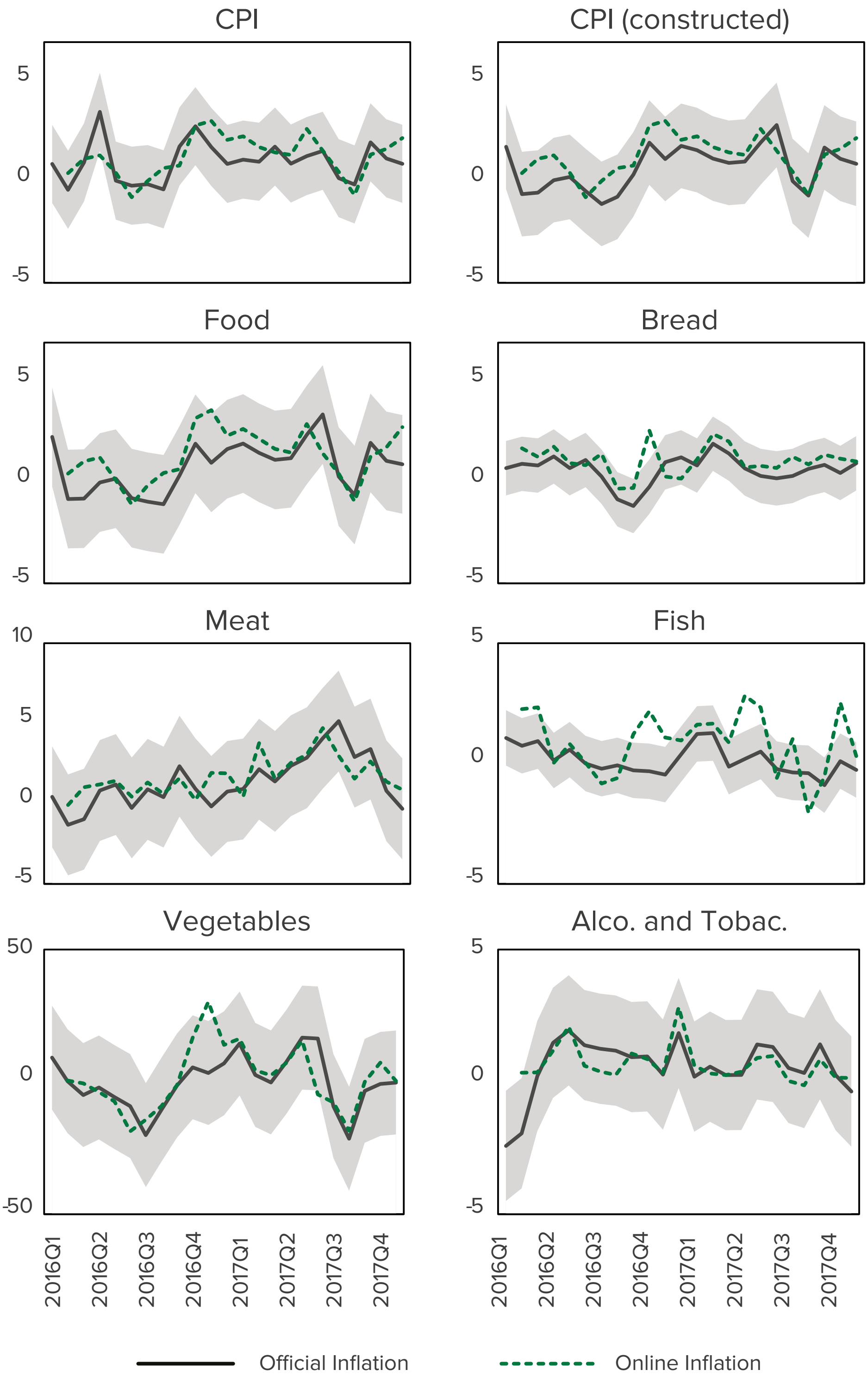
Note: RMSEs here are adjusted to the specific category's standard deviation of official inflation for comparison purposes

Table 5. RMSE of aggregated month-on-month online indexes

Index	Simple average of all goods	Simple average of online indexes	Weighted average of online indexes
CPI	**0.81 (0.82)**	1.89 (1.90)	0.90 (0.90)
CPI (constructed)	1.06 (0.99)	1.92 (1.78)	**0.93 (0.87)**
Food	1.21 (0.97)	1.98 (1.58)	**1.14 (0.91)**
- Bread	**0.79 (1.14)**	2.31 (3.33)	0.85 (1.23)
- Meat	1.37 (0.85)	2.96 (1.84)	**1.07 (0.67)**
- Fish	**1.16 (1.97)**	2.60 (4.43)	1.33 (2.26)
- Milk	2.95 (0.77)	3.37 (0.88)	**1.61 (0.42)**
- Fats	4.65 (4.11)	**1.68 (1.48)**	**2.79 (2.47)**
- Fruits	**4.06 (0.74)**	5.85 (1.07)	5.43 (1.00)
- Vegetables	**8.67 (0.86)**	9.04 (0.90)	9.45 (0.94)
- Sugar	1.11 (1.21)	2.56 (2.79)	**0.78 (0.85)**
Beverages	0.81 (2.93)	2.47 (8.90)	**0.80 (2.90)**
Alcohol	1.20 (0.94)	2.51 (1.97)	**0.82 (0.64)**

Note: numbers in brackets represent RMSEs adjusted to the specific category's standard deviation of official inflation for comparison purposes.

Figure 4. Aggregated online and official infalation, m-o-m, %.



Note: Aggregated web indexes here are constructed as a weighted average of sub-indexes which, in turn, are averages of four month-on-month web indexes

MACROECONOMIC EFFECTS OF INTRODUCING A CAPITAL CONSERVATION BUFFER IN THE UKRAINIAN BANKING SECTOR

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Abstract The National Bank of Ukraine (NBU) is planning to introduce a capital conservation buffer in the Ukrainian banking sector over a four-year period starting in 2020. This new regulation will yield long-term benefits by strengthening the resilience of the banks, which will reduce the likelihood and costs of financial crises. However, higher capital requirements in the form of a capital conservation buffer can also result in short-term costs by temporarily lowering output. In this study, we use a dynamic general equilibrium model calibrated to fit some long-term features of the Ukrainian economy to evaluate how different implementation strategies affect the short-term output loss. We show that the output loss can be reduced by preannouncing and gradually implementing the buffer, along the lines that have already been advanced by the NBU.

JEL Codes E17, E58, G21

Keywords capital buffers, DSGE models, banks, macroeconomic costs, macroprudential policy, Ukraine

1. INTRODUCTION

The financial crisis that hit Ukraine in 2014-2015 had destructive effects on the economy and the Ukrainian banking sector. This crisis – which was only the latest in a series of crises that have hit Ukraine since independence – made it clear that a large-scale transformation of the financial sector was necessary. Hence, in 2015 the National Bank of Ukraine (NBU) announced its intention to gradually introduce new capital requirements for banks, following Basel III standards. In addition to new capital adequacy ratios, the new requirements include a capital conservation buffer, a countercyclical capital buffer, and a systemic capital buffer for systemically important banks.

Bank capital is key in promoting financial stability and resilience of the financial system. The greater the banks’ capital, the less likely are financial crises, and the less damaging are those that do occur. However, higher capital requirements can also be associated with short-term costs. A rapid increase in capital requirements can lead to a reduction in lending, which in turn can have negative short-term effects on output and economic performance. In principle, these short-term costs can be reduced by giving banks time to adjust to the new requirements. Stricter requirements can, for example, be announced some time in advance and/or they can be introduced gradually. This gives banks time to adjust, using either retained earnings or external capital issuance.

In this study, we evaluate how different implementation strategies for introducing stricter capital requirements affect economic performance. As a case in point, we consider the introduction of the conservation buffer in the Ukrainian banking sector. The buffer is accumulated in periods of economic growth, and is used to offset potential losses incurred during economic recessions. The NBU plans to increase the buffer’s size over a four-year period starting in 2020, by 0.625 percentage points each year. In 2023, when the buffer is fully implemented, it will reach 2.5 percent.

The analysis uses a dynamic general equilibrium model calibrated to fit the main features of the Ukrainian economy. We evaluate four different implementation strategies in terms of how well they minimize the fall in short-term output.

* The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the National Bank of Ukraine or Sveriges Riksbank.

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The first strategy introduces the buffer immediately, without prior announcement. The second strategy sees the buffer being announced some time in advance, i.e., the implementation is "preannounced". The third strategy considers a gradual implementation of the buffer that is immediately implemented. The fourth and final strategy approximates the actual strategy advanced by the NBU, of first preannouncing the buffer's introduction and then gradually implementing it. We find that the short-term output loss is minimized by preannouncing and gradually implementing the buffer along the lines that have been advanced by the NBU.

The rest of the paper is organized as follows: the next section discusses the regulators' response to the global financial crisis in 2008, and the benefits and costs of higher capital requirements. In the following section we give a brief review of the Ukrainian banking sector since independence, leading up to the current situation. Then we describe the modelling framework, how the model is calibrated to some long-term features of the Ukrainian economy, and give the results of the simulations. Finally, we provide some concluding comments.

1.1. The 2008 global financial crisis, and the responses by regulators

Financial crises are often associated with high economic costs, as the recent global financial crisis in 2008 demonstrated. One major lesson from this crisis was that more has to be done than simply supervising individual financial institutions; instruments are also required to prevent certain risks that threaten the financial system as a whole, so-called macroprudential policies. Furthermore, the capital requirements in place in 2008 proved insufficient to cover bank losses, and in several countries taxpayers had to supply new funds to fill the gap.

In the wake of the crisis, the Basel Committee on Banking Supervision drew up a new framework for banking regulations, the so-called Basel III (or the Third Basel Accord). One of the objectives of this new framework is to strengthen capital requirements compared to the earlier Basel II standard. In addition, Basel III introduces new liquidity requirements, i.e., a liquidity coverage ratio, and a net stable funding ratio.

The minimum bank capital requirements in Basel III are raised from 8 percent, up to 15.5 percent of risk-weighted assets (RWA) compared to Basel II.[1] Moreover, Basel III introduces a leverage ratio requirement of 3 percent. The difference between capital requirements in terms of a risk-weighted capital-to-asset ratio and a leverage ratio can be understood by considering a simplified balance sheet of a bank.

1.2. Defining Capital and Leverage Ratios

Assume a bank with two types of assets – loans to households L^H and loans to entrepreneurs (or firms) L^E. The liabilities consist of deposits from the public D and capital (or equity) K. In this case, the balance sheet of the bank will be as follows,

$$L^H + L^E = D + K.$$

The risk-weighted capital-to-asset ratio κ^{RWA} is then defined as follows,

$$\kappa^{RWA} = \frac{K}{\omega_H L^H + \omega_E L^E},$$

where $\omega_H L^H + \omega_E L^E$ is the bank's risk-weighted loans and the parameters ω_H and ω_E denote the risk weights on household loans and firm loans, respectively. The risk weights are supposed to reflect the riskiness of the loans. If a specific category of loans are associated with higher risk, this category will have a higher risk weight. For example, firm loans are often considered more risky than household loans, which implies that in our example ω_E is higher than ω_H.

As long as the risk weight reflects the actual riskiness of the loans, regulations based on risk-weighted requirements can make capital allocation in the economy more efficient. However, risk weights are calculated by the banks' own internal methods; or as is the case in Ukraine by the NBU. If for some reason the riskiness of the loans is underestimated, then the risk weights will be too low and, as a consequence, the capital requirements will be too low. This is one reason why the capital requirements in Basel III are complemented with a leverage ratio κ^{Leverage}, which is a requirement on capital in relation to total lending, i.e.,

$$\kappa^{\text{Leverage}} = \frac{K}{L^H + L^E}.$$

The leverage ratio may thus complement the risk-weighted capital-to-asset ratio in order to ensure the resilience of the banking sector.

1.3. The benefits and costs of capital requirements

The starting point when discussing the benefits and costs of capital regulations is often the so-called Modigliani-Miller theorem, according to which capital requirements are both costless and redundant.[2] However, a number of conditions must be true for this to be the case. There should, for example, be no tax deductibility of interest rate costs, no bankruptcy costs, and no asymmetric information between borrowers and lenders. One can argue about the relative importance of each of these frictions, but it is unlikely that the Modigliani-Miller theorem would hold exactly. Requiring a certain capital-to-asset ratio can therefore play an important role in giving banks incentives to behave in a socially optimal fashion.

Bank capital requirements promote financial stability by reducing the probability of banking crises, and the costs of financial crises. If banks are well-capitalized, ex ante incentives to take on excessive risk are reduced. Bank capital requirements also act as an ex post buffer against bank losses. In other words, higher capital requirements reduce both the likelihood and the costs of financial crises by strengthening the resilience of the banking sector. However, capital requirements can also be associated with costs – both short-

[1] This is the case when all different requirements in Basel III are activated, i.e., minimum total capital, the conservation buffer, the countercyclical buffer, and the global systemically important banks charge.
[2] See Modigliani and Miller (1958) and Dagher et al. (2016) for a detailed discussion of the costs and benefits of capital requirements.

term and long-term.[3] Raising new capital can, for example, be subject to non-negligible underwriting fees and signaling costs.[4] A rapid increase in capital requirements can, as a consequence, lead to reductions in lending, which in turn may have negative effects on output and economic performance.

The short-term output loss of higher capital requirements can in principle be mitigated by giving banks time to adjust. For example, stricter requirements can be announced some time in advance, or they can be introduced gradually, or these two strategies can be combined. This gives banks time to adjust their capital buffers, using either retained earnings or external capital issuance. This may not always be possible, however. There can be circumstances in which, for example, market pressure force banks to adjust rapidly.

1.4. Capital requirements in Ukraine

In light of two severe financial crises, in 2008 and 2014, the NBU took an important step towards strengthening the banking sector by introducing amendments to the law On the *National Bank of Ukraine*. These amendments gave the NBU, among other things, the responsibility to develop and implement macroprudential policies. One of the key instruments in the NBU's macroprudential toolkit is capital requirements.

The current capital requirement of 10 percent in Ukraine will be supplemented with different capital buffer requirements, i.e., a capital conservation buffer, a systemic capital buffer, and a countercyclical capital buffer. The main purpose of the capital conservation buffer is to ensure that the banks can maintain the desired level of capital when times are bad. The conservation buffer is composed of high quality capital items (common equity tier 1 capital) to absorb potential losses during recessions. The buffer will be set at 0.625 percent in 2020, and over the next three years it will be increased by a further 0.625 percentage points each year, until it reaches 2.5 percent in 2023.

The systemic capital buffer requirement is similar to the conservation buffer, but it is applied to systemically important banks. This requirement can vary between 1 and 2 percent, depending on the importance of the bank. The NBU will decide, sometime after 2020, when this buffer will be activated, based on the economic and financial conditions in Ukraine.

Finally, risks in the financial system can be divided into cyclical and structural risks. Macroprudential instruments can also be divided along these lines, i.e., cyclical and structural instruments. Cyclical instruments are intended to change over time in response to changes in, for example, financial imbalances. Structural instruments, on the other hand, are intended to be implemented "once and for all" to create a safe and stable long-term financial environment. The countercyclical capital buffer is an example of a cyclical instrument. In times when borrowing by households and firms is rising rapidly, the buffer requirement is increased. Conversely, when banks exercise more restraint in their lending, the buffer can be reduced. Like the conservation and systematic buffers, the countercyclical buffer consists of common equity tier 1 capital. The introduction of this buffer will – just as for the systematic buffer − depend on the economic and financial conditions after 2020.

2. A DYNAMIC GENERAL EQUILIBRIUM MODEL FOR STUDYING CAPITAL REQUIREMENTS

To study the effects of higher capital requirements in the form of a conservation buffer, we use a *dynamic general equilibrium* model. In contrast to so-called *partial equilibrium* models − which restrict their attention to a particular market, taking the price of other goods as given – *general equilibrium* models are characterized by the interaction between different markets, which among other things recognizes that prices in different markets can be determined jointly. That the model is *dynamic* means that the time dimension of economic decisions is accounted for. Typically, economic decisions involve a time or "intertemporal" dimension – examples include consumption and saving decisions, investment decisions, deficit-finance decisions, etc.

The model economy is formally described and explained in Iacoviello (2015). In this section, we only provide a brief description of the maximization problems of the economic agents, i.e., households, entrepreneurs, and banks.

2.1. Households

Households, denoted by subscript H, choose consumption, housing services, one-period deposits, and leisure subject to a budget constraint in order to maximize expected utility. Formally, they are maximizing the following utility function:

$$\max E_0 \sum_{t=0}^{\infty} \beta_H^t \left(\ln C_{H,t} + \omega \ln H_{H,t} + \tau \ln\left(1 - N_{H,t}\right)\right),$$

where β denotes the subjective discount factor, C_H consumption, H_H housing services, and N_H time spent working (note that time is normalized to one, which means that leisure equals one minus time spent working). The parameters ω and τ determine the weight households put on housing services and leisure, respectively, in the utility function. The maximization is subject to the following budget constraint:

$$C_{H,t} + D_{H,t} + q_t\left(H_{H,t} - H_{H,t-1}\right) = R_{D,t-1} D_{H,t-1} + W_t N_{H,t},$$

where D_H denotes one-period deposits, R_D gross return on deposits, q the price of real estate, and W the real wage rate. Households save part of their income by providing loans – intermediated by the banks – to the entrepreneurs. Households are thus financing part of the production in the economy. Income consists of wages and interest on savings. The income is spent on consumption, housing services and savings in bank deposits.

[3] In this study, we focus on the short-term costs. In the model, there is no long-term effect on GDP growth of permanent higher capital requirements, although there is a negative level effect.
[4] See Myers and Majluf (1984).

2.2. Entrepreneurs

Entrepreneurs (can be interpreted as small self-employed firms) produce the economy's output. They are denoted by subscript *E* and they choose consumption, commercial real estate, loans from the banks, and labor input, to maximize expected utility:

$$\max E_0 \sum_{t=0}^{\infty} \beta_E^t \ln C_{E,t},$$

subject to a budget constraint:

$$C_{E,t} + q_t\left(H_{E,t} - H_{E,t-1}\right) + R_{L,t}L_{E,t-1} + \\ + W_t N_{E,t} + \gamma \frac{\left(L_{E,t} - L_{E,t-1}\right)^2}{\overline{L_E}} = Y_t + L_{E,t},$$

where R_L denotes the one-period (gross) loan rate, Y output, H_E commercial real estate, L_E loans and $\left(L_{E,t} - L_{E,t-1}\right)^2/\overline{L_E}$ the loan portfolio adjustment cost function, where $\overline{L_E}$ is the steady state level of loans extended to the entrepreneurs. The parameter γ determines how costly it is to change the loan portfolio. The budget constraint says that the entrepreneurs' resources, i.e., income from production and loans from banks, are spent on consumption, real estate, interest rates on loans, wages, and the adjustment costs of changing the loan portfolio.

Input in production is mainly labor from households, but a relatively small share (about 5 percent) consists of commercial real estate. We assume a standard Cobb-Douglas production function:

$$Y_t = H_{E,t-1}^{\alpha} N_{E,t}^{1-\alpha},$$

where the parameter α is the share of real estate in production. Entrepreneurs cannot borrow more than a fraction θ of the expected value of the real estate stock, and, following Iacoviello (2015), we also assume that the wage bill must be paid in advance:

$$L_{E,t} \leq \theta E_t \frac{q_{t+1}}{R_{L,t+1}} H_{E,t} - W_t N_{E,t} \, .$$

2.3. Banks

Banks, denoted by subscript *B*, intermediate loans between households and entrepreneurs. They maximize expected utility, which can be interpreted as if they are maximizing a convex function of dividends. Formally, they choose consumption, deposits, and loans to entrepreneurs, to solve the following maximization problem:

$$\max E_0 \sum_{t=0}^{\infty} \beta_B^t \ln C_{B,t},$$

subject to a budget constraint:

$$C_{B,t} + R_{D,t-1}D_{B,t-1} + L_{B,t} + \gamma \frac{\left(L_{B,t} - L_{B,t-1}\right)^2}{\overline{L_B}} = D_{B,t} + R_{L,t}L_{B,t-1}.$$

Banks use deposits and interest rates on loans to pay for consumption (which as noted can be interpreted as dividends), interest rates on deposits, and new loans to entrepreneurs. The conversion of deposits into loans is also subject to a portfolio adjustment cost, $\left(L_{B,t} - L_{B,t-1}\right)^2/\overline{L_B}$, where $\overline{L_B}$ is the steady state level of loans extended by the bank.

In addition, banks are limited in extending loans by a capital requirement κ:

$$\kappa \leq \frac{K_{B,t}}{L_{B,t}},$$

where K_B denotes bank capital. Note that $K_{B,t} = L_{B,t} - D_{B,t}$. Bank capital is therefore determined residually.

Finally, the following market clearing conditions must hold in equilibrium,

$$H_{H,t} + H_{E,t} = 1,$$

$$N_{H,t} = N_{E,t},$$

$$D_{H,t} = D_{B,t},$$

$$L_{E,t} = L_{B,t},$$

$$C_{H,t} + C_{E,t} + C_{B,t} + \gamma \frac{\left(L_{B,t} - L_{B,t-1}\right)^2}{\overline{L_B}} + \gamma \frac{\left(L_{E,t} - L_{E,t-1}\right)^2}{\overline{L_E}} = Y_t.$$

2.4. Calibration to Ukrainian data

In order to run a simulation with the model, its the parameters must be assigned values. We calibrate the parameter values to ensure that some long-term features of the model are in line with Ukrainian data. In practice there are two types of parameters. The first type affects mainly the long-term characteristics of the model, i.e., the steady state values. These are the parameter values that we calibrate. The second type of parameters mainly reflects short-term dynamics. For these parameters it is typically not possible to find an observable equivalent in the data. In the model there are two parameters of this type – the parameter that determines the cost for banks of adjusting lending, and the parameter that determines the cost for entrepreneurs of adjusting their borrowing. For these two parameters, we use the estimated values in Iacoviello (2015).

We calibrate the discount factors (for households, banks, and entrepreneurs) and the loan-to-value ratio of the entrepreneurs to match real deposit and lending rates in the Ukrainian banking sector, and the debt-to-GDP ratio in the corporate sector. We only consider data collected after the introduction of the inflation target in 2016, since this structural change is likely to make earlier data inaccurate in describing the Ukrainian economy going forward. The real household deposit rate is 5.3 percent in the data, while the corporate real lending rate is 7.3 percent.[5] To calculate these real rates, we used inflation expectations from the NBU survey. We set the debt-to-GDP ratio at 29 percent, which is in line with the debt-to-GDP ratio observed in the Ukrainian corporate sector in 2017.

[5] The deposit rate is determined by households' discount factor, 5.3=100*((1/β_H)^4)-1), while the expression for the lending rate is more complicated and involves endogenous variables.

The weight on leisure in the utility function determines labor supply and hours worked. We set this parameter to ensure that households work on average about eight hours a day. We lack data on the housing value to GDP and the income share of real estate in production. Hence, we use the estimates from Iacoviello (2015) for the weight on housing in the utility function and the income share of real estate. We set the capital-to-asset ratio equal to the current requirement of 10 percent. The calibrated parameter values are summarized in Table 1.

advance, which is enough to illustrate the principal effects of preannouncing. The third strategy considers a gradual implementation that is immediately introduced. We allow the buffer to be gradually implemented over a four-year period. This approximately replicates the gradual part of the strategy advanced by the NBU. The final and fourth strategy approximately replicates the strategy advanced by the NBU. The buffer is preannounced, two years in advance, and is then gradually implemented over a four-year period.

Table 1. Parameter values

	Parameter in model	Value
Discount factor – households	β_H	0.9872
Discount factor – banks	β_B	0.942
Discount factor – entrepreneurs	β_E	0.94
Weight on leisure in utility function	τ	2.00
Weight on housing services in utility function	ω	0.075
Share of real estate in production	α	0.05
Portfolio adjustment cost parameter	γ	0.125
Loan-to-value ratio	θ	0.925
Capital-to-asset ratio	κ	0.10

3. MACROECONOMIC EFFECTS OF INTRODUCING A CAPITAL CONSERVATION BUFFER

The NBU plans to introduce a capital conservation buffer starting in 2020. The buffer will be implemented over a period of four years, increasing by 0.625 percentage points each year. In 2023, when the buffer requirement is fully implemented, the buffer will be 2.5 percent. The NBU is thus following a strategy of preannouncing and then gradually implementing the buffer.

The short-term costs in terms of lower output associated with higher capital requirements depend, among other things, on how the requirements are implemented.[6] We therefore evaluate the implementation strategy of the NBU against three other strategies. In the first, the buffer is immediately implemented, i.e., the implementation is not announced in advance to the public. The financial markets are taken by surprise, and the banks cannot gradually adjust their capital holdings. This is the benchmark case; not because it is a realistic strategy in practice, but because it gives an upper bound of the short-term costs.

In the second strategy, the NBU announces the introduction in advance. The NBU first announced the introduction of the capital conservation buffer in 2015. However, in our simulation we consider an announcement of two years in

The different strategies are evaluated in terms of how well they minimize the short-term output loss. Hence, the evaluation does not account for the longer-term benefits that stricter requirements also imply – reductions in the likelihood of financial crises, and a lessening of their costs.

3.1. Short-term output loss with immediate implementation

Consider first the benchmark case of immediate implementation. The NBU introduces a new buffer of 2.5 percent at the end of the first period, without informing the banks in advance, see Figure 1 in Appendix.[7] In the next period, the banks therefore increase the capital-to-asset ratio from 10 to 12.5 percent. To fulfil the new buffer requirement, the banks can adjust capital or lending, or both. As we can see from the figure, the banks choose to adjust both capital and lending.

In the long-term the increase in capital is almost 14 percent, and lending is decreased by about 9 percent. Changes in lending are associated with adjustment costs, which means that lending is only gradually adjusted towards the new long-term value. This means that banks must immediately raise new capital above the long-term level in order to fulfil the buffer requirement. Capital increases by about 24 percent initially. After this initial increase, capital slowly decreases towards the long-run level.

[6] This study focuses on short-term effects, but also long-term effects can be of interest, see for example the study by Finocchiaro et al. (2016) who evaluates the long-term effects of different macroprudential policies.
[7] Each period is a quarter.

Entrepreneurs' production costs are partially financed by bank loans. The fall in lending reduces the entrepreneurs' options for financing production. Hence, they hire less labor and hours worked fall, which inhibits production and, as a consequence, output falls. The fall in output implies that the debt-to-GDP ratio initially increases, even though lending is falling. This is, however, only an initial increase, and the debt-to-GDP ratio subsequently falls. In the long-term, the debt-to-GDP ratio falls from 29 to 26 percent.

The initial fall in output also implies that fewer resources can be used for consumption. After an initial fall in consumption (not shown in the figures), consumption increases towards the long-term level. Marginal utility is thus decreasing – and consequently the "intertemporal marginal rate of substitution", i.e., the willingness to substitute (give up) consumption today for consumption tomorrow, also increases throughout the transition. Since the marginal rate of substitution is positively associated with interest rates, there is upward pressure on deposit and lending rates. Moreover, upward pressure on the lending rate also comes from the entrepreneurs' borrowing constraint, which becomes more binding.

3.2. Preannouncement can reduce the output loss

One way to reduce the initial output loss is to announce the new buffer requirement in advance. The red line in Figure 2 shows the effects of preannouncing the buffer two years (eight periods in the figure) in advance. At the end of the first period, the NBU announces that the capital buffer will be raised by 2.5 percentage points in two years' time. This strategy is compared to the benchmark strategy of immediate implementation, i.e., the blue line.

By announcing the buffer in advance, the initial output loss is reduced. There is an initial fall in output when the announcement becomes public, by about 1 percent, and a slightly larger fall when the regulation is de facto implemented. However, the cumulative output loss is lower compared to immediate implementation.

3.3. Gradual implementation can also reduce the output loss

Another way to reduce the output loss is to implement the buffer gradually. The red line in Figure 3 shows the effect of implementing the buffer over a four-year period. This strategy is also compared to immediate implementation, i.e., the blue line. There is an initial decrease of output of about 1.5 percent. Output then gradually returns to its long-term value. The figure suggests that the cumulative output loss with gradual introduction is somewhat lower compared to immediate introduction.

3.4. Gradual implementation and preannouncement minimize the output loss

We have seen that both preannouncing and gradually implementing the buffer reduce the initial output loss. This suggests that a combination of preannouncing and gradual implementation is the most effective strategy in terms of minimizing the output loss. Figure 4 illustrates that this is indeed the case. In accordance with this strategy, the NBU announces at the end of period 1 that the buffer will be gradually implemented over a four-year period, starting two years from now. The red line shows this strategy, while the blue line shows immediate implementation.

The output loss is reduced compared to the benchmark strategy. Moreover, the effects on deposit and lending rates are also reduced (not shown in the figure). It is notable that the banks do not, to any great extent, adjust capital and lending until the buffer is formally introduced (not shown in the figure).

In Table 2 we show the cumulative output loss after four years, in terms of the percentage deviation of output from the long-term value, under the four different implementation strategies. If the buffer is immediately implemented, the cumulative output loss is about 3.4 percent. With preannouncing, the loss falls to about 2.3 percent, while by gradually implementing the buffer, the loss falls to about 3.2 percent. By both preannouncing and gradually implementing the buffer, the output loss is about 2.1 percent. This suggests that the NBU's strategy of both preannouncing and gradually implementing the capital buffer is the most effective strategy of the ones we have considered.

Table 2. Cumulative output loss of different implementation strategies, in percent

Implementation strategy	Four years' cumulative output loss
Immediate	3.4
Preannounced	2.3
Gradual	3.2
Preannounced and gradual	2.1

4. DISCUSSION

The NBU has a dual mandate of promoting stable prices and financial stability. To promote financial stability the NBU supervises and regulates the banking sector. The NBU's aim is to follow the recommendations of the Basel Committee on Banking Supervision, the European Systemic Risk Board, EU Capital requirements regulations, and the corresponding EU directive (CRR/CRD IV). After the financial crisis in 2014 and 2015, the NBU decided to introduce a capital conservation buffer (as well as systemic and countercyclical capital buffers) in order to increase the resilience of the Ukrainian banking sector. The introduction of the conservation buffer will start in January 2020.

In this article we studied how the introduction of a capital conservation buffer might affect the Ukrainian economy. In particular, we studied how different implementation strategies affect short-term costs in terms of lower output. The analysis was carried out through the lens of a dynamic general equilibrium model calibrated to fit some long-run features of the Ukrainian economy. We have shown that the output loss associated with the introduction of a capital conservation buffer can be reduced by preannouncing and gradually implementing the buffer, along the lines that have already been advanced by the NBU.

There are a few caveats, however: economic models are based on a number of simplifying assumptions regarding the decision-making of the economic agents and the features of the economic environment. Even though the model is calibrated to fit some specific features of the Ukrainian economy, the results should be considered as calculated examples that illustrate and quantify some of the mechanisms at work, on the assumption that nothing else changes in the economy. In other words, the results should not be viewed as a conventional forecast of what will happen when the buffer is introduced.

Moreover, we have not carried out a formal analysis of which implementation strategy is optimal from a social welfare perspective. Output can, and often is, used as an approximation for social welfare. However, in our model, the utility function provides the formal measure of welfare, i.e., the sum of consumption, housing services and leisure (with various weights). The conclusions could thus potentially be different if we instead evaluated the different implementation strategies in terms of the utility functions of the agents. At the same time, there are arguments against this approach as well. For example, in actual economies, fluctuations in labor are primarily due to changes in the extensive margin (the number of individuals in employment) and to a lesser extent to changes in the intensive margin (the average number of working hours). In the model, all changes in labor are in the intensive margin, and we thus ignore the extensive margin. It could be argued that a formal welfare analysis that ignores the extensive margin (and the negative welfare effects of unemployment) may not give a more appropriate evaluation of welfare than a simple analysis that looks at output.

Finally, financial stability issues have not been accounted for in the analysis. To carry out an appropriate welfare analysis, the long-term benefits of higher capital requirements – in terms of a more resilient financial system – should ideally be evaluated against the short-term costs of lower output.

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APPENDIX. FIGURES

Figure 1. Macroeconomic effects of an immediate implementation of a conservation buffer of 2.5 percentage points

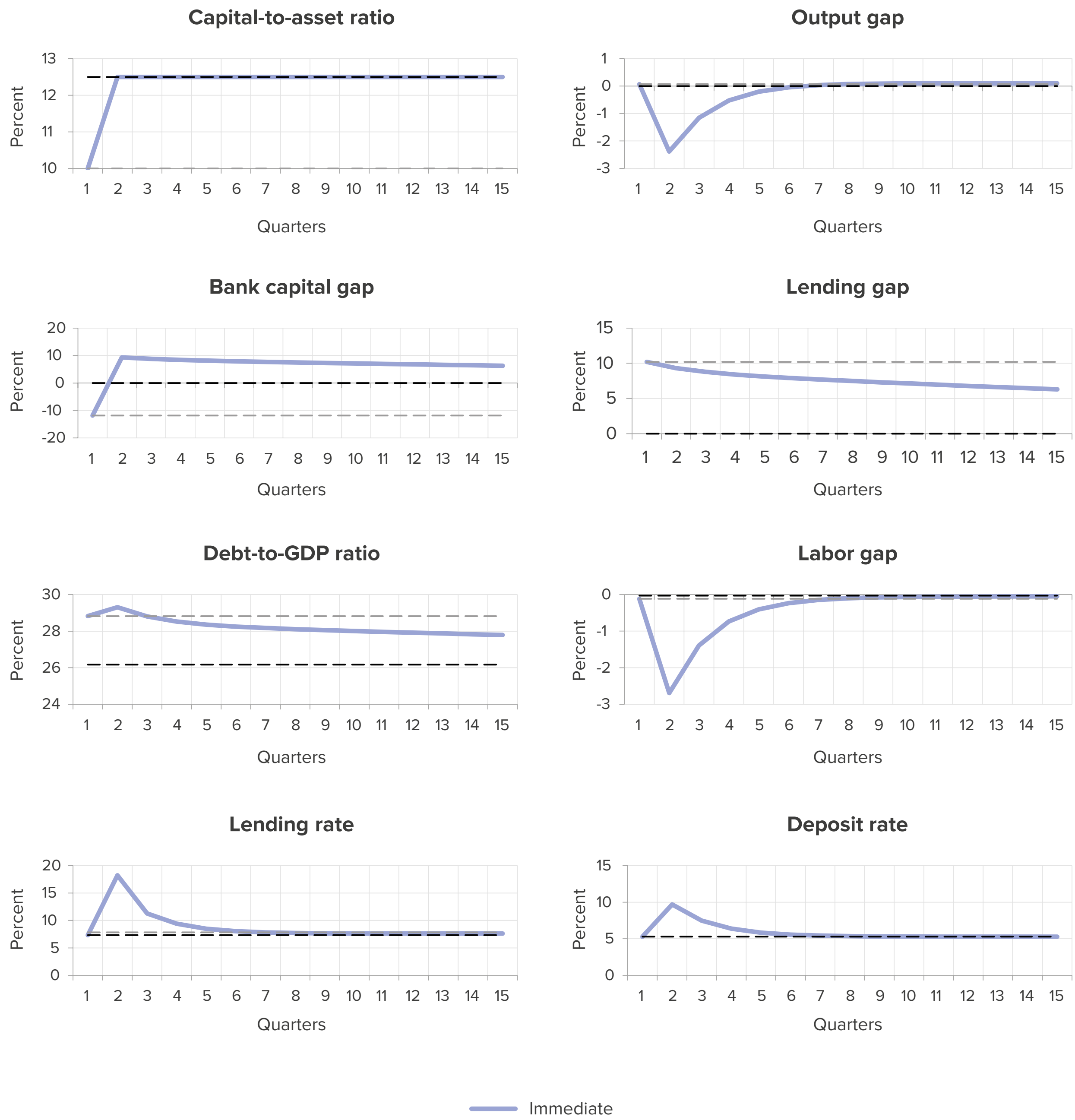

Figure 2. Macroeconomic effects of a preannounced implementation, two years in advance, of a conservation buffer of 2.5 percentage points compared to immediate implementation

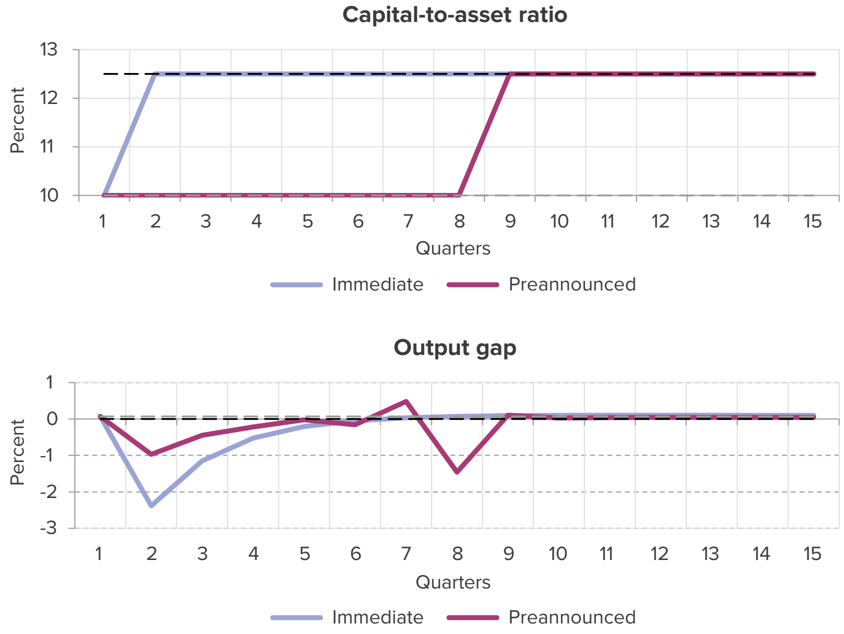

Figure 3. Macroeconomic effects of a gradual implementation of a conservation buffer of 2.5 percentage points over a four-year period, compared to immediate implementation

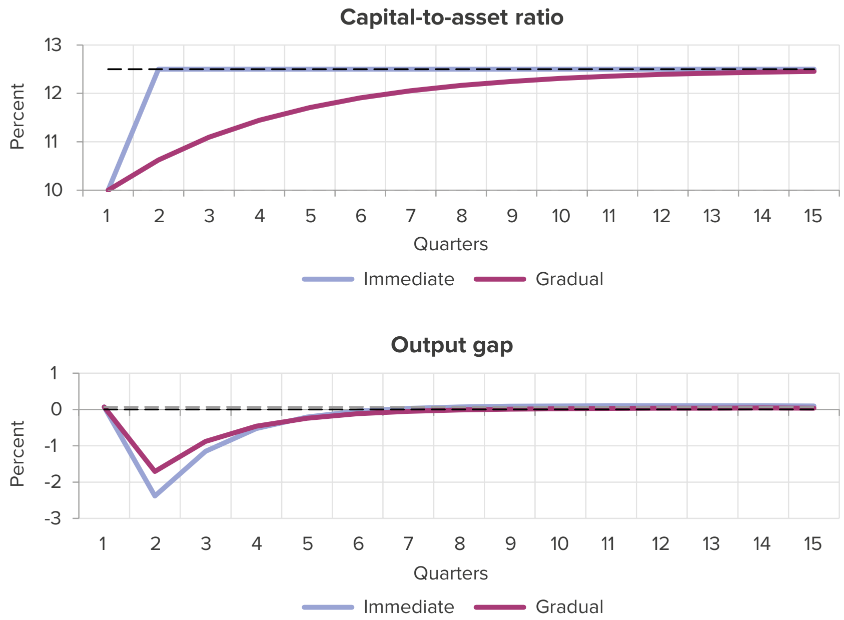

Figure 4. Macroeconomic effects of a combined preannounced, two years in advance, and a gradual, over a four-year period, implementation of a conservation buffer of 2.5 percentage points compared to immediate implementation