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Empirical estimation of REER trend for Ukraine

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Abstract

In this study, we apply BEER and FEER approaches to estimate the REER trend on Ukrainian data. By applying BEER we were able to identify the long-run factors which explain the dynamics of the REER trend. FEER approach gives us information on the determinants and measurements of the current account norm for Ukraine. Although the two approaches are different in their nature, both of them identify the periods of REER undervaluation in the first half of the 2000s, after the crises of 2008-2009 and 2014-2015. Significant overvaluation was detected in the period 2011-2013. For more recent years estimates indicate moderate overvaluation of the REER which decreased in the second half of 2020.

Keywords: BEER, FEER, REER trend, misalignment, current account norm, underlying current account.

JEL Classification: F31, F32.

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1. Introduction

The real effective exchange rate (REER from now on) is one of the main macroeconomic indicators since it provides information about both the tightening of monetary conditions and the price competitiveness of domestic producers in world markets. The appreciation of the REER can occur either due to the appreciation of the nominal exchange rate of the national currency or due to higher relative inflation in the economy. In any case, a real appreciation means an increase in prices for goods of domestic producers relative to prices for similar goods of trading partners.

As for other economic indicators, the dynamics of the REER can be dictated by the influence of fundamental factors that drive the trend of the indicator, as well as by transitive effects, under the impact of which arises the gap (misalignment) of the REER[2]. Following the conventional macroeconomic theory, monetary policy, should minimize gaps, including REER's gaps, to keep the economy on an equilibrium trajectory of development. This necessitates a need for central banks to estimate the REER gap, i.e. real exchange rate misalignment, and to understand the factors behind it.

Since 2015, Ukraine has a regime of inflation targeting and, accordingly, a floating exchange rate regime, which increases the degree of impact of monetary policy on the economy. Under such a regime of monetary policy, the decisions of the National Bank of Ukraine (NBU) for the policy rate affect the dynamics of the REER and this channel of monetary transmission mechanism becomes extremely powerful. Therefore, the need for an estimate of the deviation of the REER from an "equilibrium" becomes especially important.

It is suggested that prolonged periods of overvalued REER, meaning an exchange rate which is above "equilibrium", pose a threat to economic growth as it implies that domestic prices are too high and domestic producers are not competitive[3]. Instead, a significant and stable undervaluation of REER leads to an excessive vulnerability of the economy to external shocks and the formation of bubbles in the domestic financial market. It happens since the artificially created conditions of high price competitiveness increase openness of the economy to the flows of goods and capital. Accordingly, "sudden stops" that occur regularly in the world economy, prick the financial market bubbles and lead to a hard adjustment to the exchange rate. These effects are especially appreciable in emerging markets. Another disadvantage of

[2] Note that trend and equilibrium of REER as well as REER gap and REER misalignments are used interchangeably in this paper.

[3] For instance, Bussière et al. (2014) provide an empirical assessment of the impact of appreciations, productivity booms, and capital flow surges on the output growth based on a broad sample of emerging and advanced economies. They show that appreciations associated with higher productivity have a larger impact on growth than appreciations associated with capital inflows. Furthermore, the appreciation per se tends to have a negative impact on growth. Studying the sample of EU countries, Comunale (2017) argues that the real effective exchange rate misalignments associated with the foreign capital inflows have been a further cause for the decline in GDP, in a long-run perspective, while they do not play a role in the short run.

maintaining a negative REER gap for a long time is the lack of incentives for domestic firms to increase their efficiency, as price competitiveness is already high.

In the present study, we estimate equilibrium exchange rate according to the Behavioral Equilibrium Exchange Rate and Fundamental Equilibrium Exchange rate (BEER and FEER, respectively) approaches, which are the most common, but quite different in nature. The focus of the study is the estimation of equilibrium REER and identification of economic fundamentals that drive, in principle, the REER in the long-run. This research question is strongly relevant to monetary policy decisions as deviations from the equilibrium (REER gap) tell a lot about the tightness of monetary conditions. The REER gap also provides valuable information on the prospects of inflation developments, GDP growth, and nominal exchange rate movements. Empirical estimation of REER trend with the application of alternative methodologies gives valuable information for international comparisons, and analysis of differences in results produced by BEER/FEER approaches. Implementation of the standard trend-gap decomposition techniques for REER will also add significantly to the analytical capacities of the NBU. As far as we know, this is the first study focused on the estimation of the REER trend for Ukraine.

The structure of this paper is as follows. Section 2 presents the review of the literature on equilibrium exchange rates. In Section 3 and 4, we describe the theoretical basis of the BEER and FEER approaches respectively, providing data characteristics and the main results of our estimations for Ukraine. Section 5 presents the comparison of our different estimates. Conclusions are presented in Section 6.

2. Literature review

For scientific studies and policy analysis, central banks use several standard approaches to REER trend estimation, which can be divided into three major groups: Fundamental Equilibrium Exchange Rate (FEER, see Williamson, 1994), Natural Equilibrium Exchange Rates (NATREX, see Stein, 1994), and Behavioral Equilibrium Exchange (BEER, see Clark and MacDonald, 1998, 2004). Alternatively, structural vector-autoregressive models (SVAR) estimate the REER trend based on impulse response functions of variables to various structural shocks (Clarida and Gali, 1994), as well as structural macroeconomic models (Detken, 2002).

The FEER approach includes the MB (Macroeconomic Balance) and ES (External Sustainability) methods. This approach generally consists of two stages. At the first stage, the "normal" value of the current account is estimated (CA norm) which is different for the MB and the ES methods. MB models a CA norm using regressions for estimation of the equilibrium relationship between the current account and fundamentals that determine the equilibrium in the long-run. In the case of ES, CA norm is estimated from a system of macroeconomic identities and is defined as the current account that stabilizes or leads to a certain target the level of net foreign assets (NFA). In both cases, on the second stage, the elasticity of the current account to

REER[4] is used to estimate by how much the REER needs to depreciate/appreciate to close the gap between "normal" and "underlying" current account. "Underlying" current account, in turn, is estimated by adjusting the actual current account for the cycles of the domestic and the world economy as well as the last changes in the REER.

A fairly basic fit of panel regression to estimate the CA norm is presented in Lee et al. (2008)[5]. They suggest that the fundamentals determining the position of the current account in the long run are the fiscal policy (the ratio of the general government balance to GDP), the age structure and growth rates of the population, the level of income in the economy, the initial level of net foreign assets, and energy dependence. This rather parsimonious form of the model, or similar specifications, is often used to estimate the CA norms of individual countries (Ajevskis et al., 2012; Comunale, 2015). Note also that there are a number of propositions to improve the model to estimate CA norms by adding new, more relevant variables or applying new methods for estimating long-term relationships between fundamentals and the current account (Phillips et al., 2013; Mano et al., 2019). However, as it is usually the case with panel data, a disadvantage of this approach to the estimation of CA norm is its generality. This is reflected in the estimation of the model parameters based on the panel for a number of countries. The parameters obtained in this way are the means for the whole sample. For individual economies, these parameters may actually differ significantly. This difference can be especially large between advanced economies and emerging markets. Nonetheless, for our study we rely on these estimates for several reasons. First, since long-run elasticities should converge to one level (Bussiere et al., 2010). Second, estimation of long-term relationships between fundamentals and the current account on the country level may be problematic as in this case cointegration between variables is assumed. However, the current account is usually I(0) process, while the fundamentals are I(1) (Lee et al., 2008). The proposed econometric solution is to use panel data since in this case cross-country heterogeneity makes the current account a non-stationary variable. Third, the "generality" problem can be attenuated if on relies on panels of countries that are closest in their characteristics to the economy under study. This allows getting regression coefficients that are closer to the true parameters of a particular economy. For example, in Comunale (2015), the MB approach is used to estimate the equilibrium REER on the panel data of Central and Eastern Europe countries. The author estimates several alternative regression specifications to determine the CA norm, including those proposed by the author herself.

In general, the FEER approach assumes that the economy is in a state of external and internal equilibrium. Internal equilibrium is defined as the level that keeps output at the

[4] It is assumed that exports and imports of goods and services respond to changes in the REER, so the current account gap is closed through the trade balance adjustments.

[5] The estimation sample includes 54 economies, including Eastern Europe emerging markets, and the euro area, for the period from 1973 to 2004, and four-year averages are used in the estimation.

potential level. External equilibrium, in turn, is in accordance with current and future values of the current account to stable long-term capital flows.

In the case of the NATREX approach, the conditions of the FEER approach are incremented by the requirement that, in the long run, the REER meets the equilibrium value of capital accumulation and the external debt of the economy. The NATREX approach is based on a structural macroeconomic model that includes behavioral equations for consumption, investment and trade balance, and equations that describe the dynamics of capital accumulation and external debt. The solution of this model for REER allows to obtain the equilibrium value of the real exchange rate at which the current account is equal to the savings minus investments, and the level of capital and external debt are set at their long-term equilibrium values (Detken et al., 2002).

The most popular and easiest to apply is the BEER approach, which involves the construction of a regression that directly estimates the long-term relationships between REER and fundamentals. The availability of data and generally uncomplicated econometrics make the BEER approach popular in studies of emerging markets (see Table A1 in Annex A). Having estimates of the elasticities of REER to fundamentals, as well as trends of fundamentals, one can obtain an estimate of the trend of REER, i.e. the equilibrium exchange rate. Misalignments are then calculated as the difference between observed and equilibrium values. Besides the simplicity of application, this method also provides information on contributions of fundamentals in the dynamics of REER trend. This is a significant analytical advantage over other approaches.

BEER estimates can be implemented both on country-specific and panel data. In Fidora et al. (2017) the BEER model was estimated at a quarterly frequency for 1999 -2016 on a sample of 57 countries, which included euro area countries. The authors assessed if both the size and the persistence of REER misalignments from the levels implied by economic fundamentals are affected by the participation in the monetary union. The main finding of the study is that the misalignments are smaller but more persistent in the euro area than in its main trading partners. At the same time, the reactivity of real exchange rates to past misalignments increased after the global financial crisis.

To ensure the robustness of the results, in many studies, several approaches to the estimate the equilibrium REER are presented. For instance, Ajevskis et al. (2012) present an equilibrium REER for Latvia estimated with the application of a set of standard methods[6]. By averaging the results, researchers and policymakers try to reduce the uncertainty of estimates and the risks of making the wrong decisions. Uncertainty is an inherent feature of existing methods for estimating equilibrium REER, as they assume estimating the non-observable variable using non-observable variables as determinants (current account and fundamentals of the REER must also be

[6] ES, MB, NATREX, SVAR

on their equilibrium trajectories). All this is compounded by the uncertainty that comes with econometric estimates of regression parameters.

The problem of uncertainty is well described in the study of Bussière et al. (2010) which provides a number of solutions to deal with the large uncertainties surrounding equilibrium exchange rate estimates. They study model uncertainty in estimations of current account norms, introducing Bayesian Averaging of Classical Estimates (BACE) as a solution. The second kind of uncertainty appears when estimating export and import exchange rate elasticities. As a solution Bussière et al. (2010) proposed special identification scheme with sign restrictions on coefficients. The third issue is the uncertainty associated with the estimation of a reduced form relationship for the real exchange rate within the BEER approach. According to the results, uncertainty can be reduced by panel estimation of the equilibrium exchange. The final issue identified in Bussière et al. (2010) is the presence of strong and weak cross-section dependence in panel estimation. Concerning this, the authors suggest which panel estimators could be used in this case.

Another important reason for using several methods at once is to study their forecasting abilities with respect to the REER and to identify the impact of certain economic processes on the exchange rate, which can be detected in the difference of estimates for various approaches. For instance, Salto and Turrini (2010) applied alternative methodologies for estimating real exchange rate misalignment for EU countries. They show that current account-based approaches and relative-price based approaches give consistent results even though sometimes differences among the approaches are non-negligible. Analyzing the predictive power of different misalignment measures the authors conclude that only current-account based misalignment is a significant predictor of forthcoming current account developments. On the contrary, misalignments estimated by BEER are significantly related to medium-term developments in real exchange rates.

Lòpez-Villavicencio et al. (2012) use annual data from 1982 to 2007 of five industrialized and twelve emerging economies to compare REER misalignments estimated by FEER and BEER approaches. The estimations demonstrate that both methods give closely related results. However, for some county-period subsamples misalignments can be very different. The reasons for such local divergences in results may be the specific formation of international prices and its effects on the current account or/and the valuation effect and its impact on net foreign assets.

3. BEER approach to the estimation of REER trend for Ukraine

3.1. The essence of BEER

The BEER concept emerged as a reaction to the inconsistency of Purchasing Power Parity (PPP) as the equilibrium value of the exchange rate. From an empirical point of view, the criticism referred to the fact that deviations of the REER from the PPP were very persistent and mean-reverting speed very low (Rogoff, 1996). From a theoretical point of view, the PPP as an equilibrium value of the exchange rate does not take into account the impact of capital flows and other economic variables on the REER (MacDonald, 2000). On the contrary, the BEER approach, in a fairly transparent econometric manner, directly links the REER with economic variables that have a fundamental long-term impact on it. However, a caveat is that the non-observable variable (the equilibrium REER) is estimated by inclusion in the regression of observable economic variables. This carries several sources of uncertainty in the final estimates.

The model for estimating the BEER is derived from the uncovered interest rate parity (UIP) condition and thus takes into account the impact of capital flows. Introducing the assumption that the expected future REER is determined by economic fundamentals, the BEER approach also takes into account their impact (Hossfeld, 2010).

According to Clark and MacDonald (2004), UIP condition can be represented as:

$$E_t(\Delta s_{t+k}) = -(i_t - i_t^*), \quad (1)$$

where s_t is the nominal exchange rate in foreign currency units per domestic currency unit, i_t is nominal interest rate, Δ is a first difference operator, E_t is conditional expectations operator, *k* the maturity horizon of the bonds, * denotes foreign values for the variable. In real terms (1) can be converted by adding the expected inflation differential to both sides of the equation, giving:

$$q_t = E_t(q_{t+k}) + (r_t + r_t^*) + e_t, \quad (2)$$

where r_t is the real interest rate, q_t real exchange rate, e_t the disturbance term. Equation (2) implies that the equilibrium real exchange rate depends on the expected real exchange rate and the real interest rates differential with maturity $t+k$. Assuming that the unobserved expected real exchange rate equals the long-run equilibrium exchange rate ($\bar{q}_t$), (2) can be rewritten for the current equilibrium real exchange rate:

$$q_t' = \bar{q}_t + (r_t + r_t^*). \quad (3)$$

Thus, the current equilibrium exchange rate consists of a long-term systematic component and a real interest rate differential.

In Clark and MacDonald (2004) considered the relative prices of tradables and non-tradables (as a proxy for the Balassa-Samuelson effect) and the net foreign assets as variables determining the real exchange rate, q_t. Accordingly, these variables should be included in the regression to fit the long-run value of the equilibrium real exchange rate. Note that the literature have suggested a number of other potential determinants

of equilibrium REER such as fiscal policy parameters, terms of trade, economy openness[7].

Essentially the BEER approach is a two-stage procedure. In the first stage, cointegrated relationship, i.e. a long-run relationship, between the REER and economic fundamentals is estimated. In the second stage, the estimated regression coefficients of the first stage are applied to the equilibrium values of the economic fundamentals selected in the first stage. The result obtained from this equation is an estimate of the equilibrium REER[8].

3.2. Empirical Framework and Data description

We estimate the equilibrium exchange rate using quarterly data covering the period from 2005 to 2020 Q3. Short data characteristics are provided in Table A2 while time series of potential REER fundamentals and their HP trends are plotted in Figure A1 (Annex A).

The real exchange rate in our study is CPI-based REER, which is calculated by the National Bank of Ukraine (NBU) based on the weights of 39 major trading partners of Ukraine. The base year for the REER index is 2012. To obtain long-term elasticities and avoid seasonality problems, REER was transformed in logs and seasonally adjusted by the Census X-12 algorithm.

Regarding the fundamentals, we use the following standard set of variables for Ukraine, which are conventional for empirical literature:

The Net foreign assets (NFA) is an indicator that reflects the country's status as a net creditor/debtor relative to the rest of the world. The fall of the NFA means an increase in the country's indebtedness. It leads to an increase in future debt service payments, which should be offset by an improved trade balance. The adjustment of trade balance happens due to the depreciation of the exchange rate. Thus, the relationship between NFA and REER is expected to be positive. To estimate NFA we applied the methodology of Lane and Milesi-Ferretti (2007) to Ukrainian data on the components of international investment position published by the NBU. The data reported in the *External Wealth of Nations Mark II database*[9] (EWN) are not feasible for our goals as estimates for Ukraine are made with annual frequency and do not cover the entire sample of this study (2005-2020). At the same time, comparisons of Ukrainian NFA data published in the EWN and our estimates indicate a very high correlation.

[7] Broad review of potential determinants can be found in Edwards and Savastano (1999).
[8] It is important to mention that the equilibrium values of fundamentals can also be estimated by different methods. The most common is the application of the Hodrick-Prescott filter (HP) or the use of five-year projections of the corresponding fundamentals.
[9] Estimates of the NFA for the majority of countries in the world basing on the methodology of Lane and Milesi-Ferretti (2007).

Trade openness – the proposition is that higher openness of the economy leads to increased competition in the markets of tradables. Since, in principle, competition reduces inflation, the openness of the economy is expected to have a negative sign in the regression. The ratio of exports and imports to GDP was used as an indicator of economic openness. This variable is a relative one, i.e. it indicates the percentage difference between the openness degree of Ukraine and its main trading partners. The degree of openness of trading partners was estimated using the same weights as for REER estimation[10]. The same logic was applied to all relative variables in this study. The source of data on foreign trade and GDP was the IMF databases (IFS).

Commodities terms of trade (CTOT) – it is assumed that better terms of trade cause a positive wealth effect. Income growth leads to a revival of demand for non-tradables and, consequently, to an acceleration of inflation. Also, the positive balance of foreign currency flows leads to a situation where there are no prerequisites for the depreciation of the nominal exchange rate. Therefore, a positive sign in the regression is expected for this fundamental. Commodity terms of trade index (CTOT) was calculated based on the NBU data on the structure of exports and imports of Ukraine, as well as the dynamics of prices for the relevant items of exports and imports. The weighting structure of exports/imports items was calculated relative to GDP. The base period for the index is 2012.

Productivity differential – this variable is a proxy of the Balassa-Samuelson effect. According to the Balassa-Samuelson hypothesis, productivity in the sectors that produce tradable goods grows faster than in the sectors that produce non-tradables. Increased productivity leads to higher wages in the sectors that produce tradables, but since the labor market is competitive and flexible, wages are also rising in other sectors of the economy. Rising wages without corresponding productivity growth in non-tradable sectors lead to the accelerating of inflation. Therefore, the growth of relative productivity should lead to the appreciation of REER. Productivity differential acts as a proxy to reflect the impact of the Balassa-Samuelson effect on REER. This variable, like a number of others in this study, is relative and indicates the percentage difference between real GDP per capita in Ukraine and its main trading partners. IMF databases (IFS) were used to calculate this indicator.

Fiscal policy – loose fiscal policy (low taxes or high budget expenditures) stimulates demand and, as a result, inflation. The expected sign in regression is then positive, as the growth of expenditures or budget deficit leads to the appreciation of REER. The impact of fiscal policy is introduced into the model through the relative indicator of general government expenditures to GDP. This variable is based on IMF data (IFS) and is a proxy that reflects the relative tightness or looseness of fiscal policy towards trading partners[11].

[10] Weights are floating and are changing on yearly basis to reflect actual trading flows between the countries.
[11] In % of GDP

Regarding the methodological aspects and as shown in Table A1, when constructing BEER models for individual countries, the vector error correction models (VECM) are mainly used. For the case of Ukraine, such an approach cannot be considered entirely acceptable due to several features of the data. First, VECM regressions require a large number of observations due to the large number of parameters to estimate. In our case, the sample consists of 63 observations (quarterly data from 2005 to 2020 Q3), which is insufficient for VECM regression with 6 endogenous variables.

Second, the use of VECM requires that all endogenous variables were I(1) processes and the existence of a cointegrated relationship. However, data for emerging economies is usually available for short periods of time and structural breaks in the data are usually found. These features lead to the fact that standard unit root and cointegration tests significantly lose their power.

A more flexible approach to estimating long-term relationships is the ARDL approach. As this is a univariate model, the requirements for the number of observations are not as tight as in the case of VECM. Unlike VECM, ARDL does not require the same integration order of all variables. The regression variables can be I(0) and/or I(1), which removes the problem of pre-testing of the variables for stationarity (Pesaran et al, 2001). The algorithm of VECM estimation includes the choice of the number of endogenous and exogenous variables, the inclusion of deterministic components, and the optimal number of lags. ARDL is a more flexible model that allows using the optimal number of lags for each endogenous variable separately.

Given that we have 5 potential fundamentals that determine long-term equilibrium REER, there exists some model uncertainty. Actually, there are 31 variants of regressions with a unique combination of variables. To take into account this uncertainty, we used the following model selection algorithm[12]:

1. Run 31 ARDL regressions with a unique combination of regressors and optimal lag structure, determined using the Akaike criterion;
2. Selection of the models where a long-run relationship between variables is confirmed according to the Bounds test;
3. Selection is based on sign restrictions, where we select the models with correct signs of the coefficients.
4. Analysis of the joint distribution of coefficients in selected regressions.
5. Estimation of REER trends corresponding to the selected models.

To estimate the equilibrium REER, coefficients from BEER regression must be applied to fundamentals that are themselves in equilibrium. As is common in similar studies, to get the equilibrium dynamics of fundamentals, we smooth them by HP filter (Clark and MacDonald, 1998; Gylanik, 2012; Ajevskis et al., 2014).

[12] This selection algorithm closely corresponds to the procedure suggested in Bussière et al. (2010).

3.2. Results

Estimates of all the ARDL models with the optimal number of lags and a unique combination of variables give us a set of long-term elasticities for each variable (Figure A2). Analysis of distribution plots shows that in most cases the coefficients have the correct sign: for each potential fundamental, the frequencies of the coefficients are concentrated in those areas that correspond to the theoretical assumptions about their signs.

The second and third rounds of the model selection algorithm were based on the Bounds test and sign restrictions. Only 6 models of possible 31 have passed the Bounds test. The general picture of the distribution of the variables among the selected models and their signs is demonstrated in Figure 1. The relative openness of the economy did not pass this procedure as a potential fundamental for the equilibrium REER selection based on sign restrictions. Only one model that contained this variable passed the Bounds test, but the sign of the respective coefficient did not correspond to our assumptions. Having a set of estimated coefficients from the models that passed all stages of selection, we made assumptions about the normality of their distribution and plotted their joint distributions (Figure A3). The values of the coefficients for NFA and fiscal policy are fairly concentrated around medians. The variances of CTOT and relative productivity coefficients are somewhat higher.

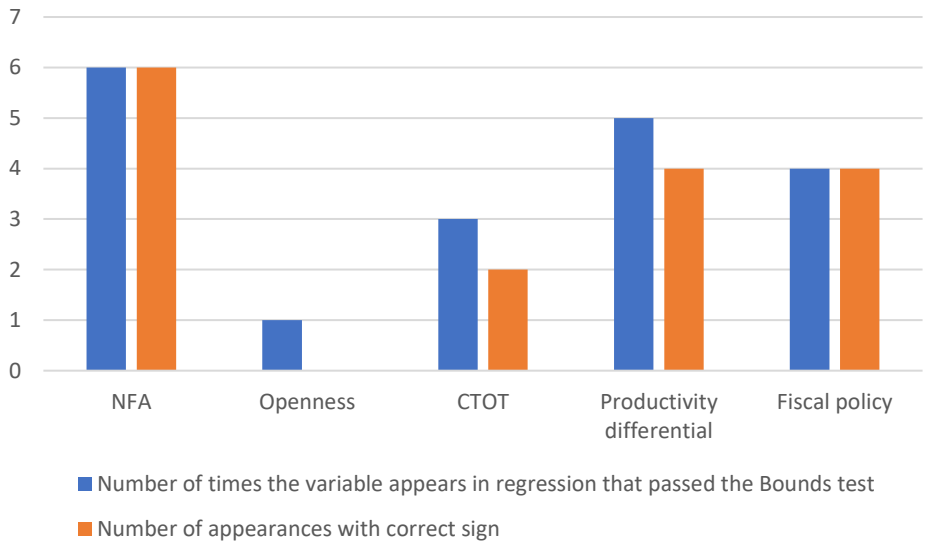

Figure 1. Frequency of appearance into selected models and sign characteristics of variables.

To estimate the equilibrium REER, we first obtained the trend component of each fundamental through the use of a Hodrick-Prescott (HP) filter (Figure A1). We then applied long-term coefficients from the selected ARDL models to the trends of fundamentals. As a result, was obtained a set of REER trends, which corresponded to the selected models. Figure 2 shows the area covered by the set of equilibrium

trajectories of REER while the average contributions of the fundamentals to the trend changes are plotted on the Figure 4.

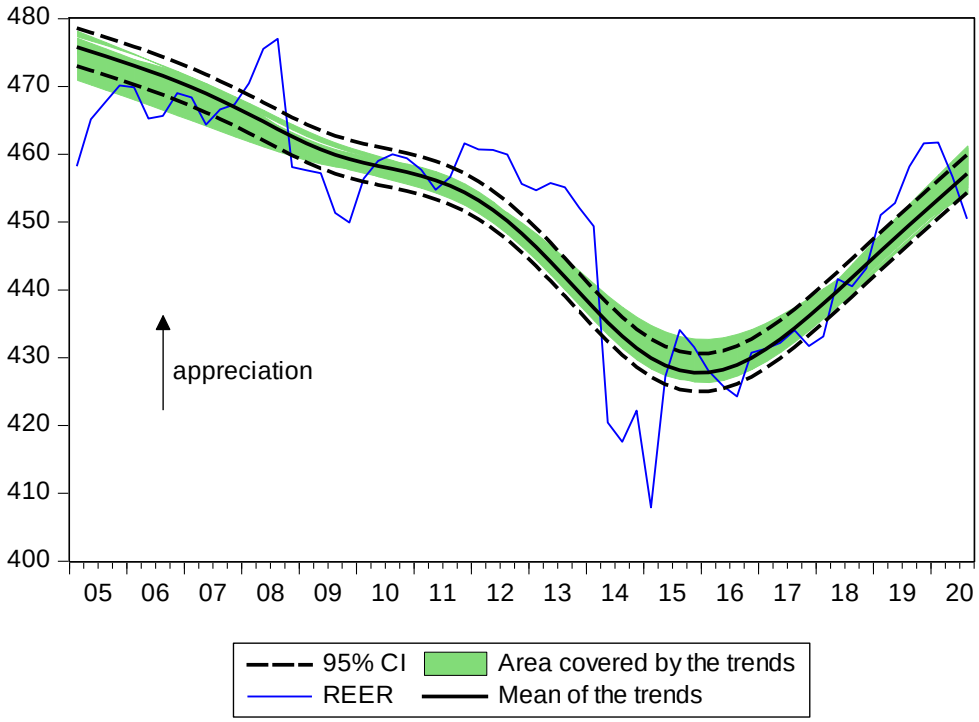

Figure 2. BEER estimates of REER trend and area covered by estimated trends

The presented estimates of the equilibrium REER indicate that even taking into account the model uncertainty during 2019, the real exchange rate was somewhat overvalued (Figure 3). However, REER gap closed in the second half of 2020. Also noteworthy is the fact that the obtained results identify two more periods of significant overvaluation of REER. The first is during 2008 (boom in commodity markets, which opened large terms of trade gap) and the second between 2011 and 2013 (the period of fixed nominal exchange rate regime). Interestingly, after the periods of overvaluation of REER, there were quite rapid exchange rate adjustments. Thus, in 2009-2010 it was connected with the Great Recession, and in 2014-2015 with the economic crisis in Ukraine caused by the annexation of Crimea by Russia and military conflict in the eastern part of the country.

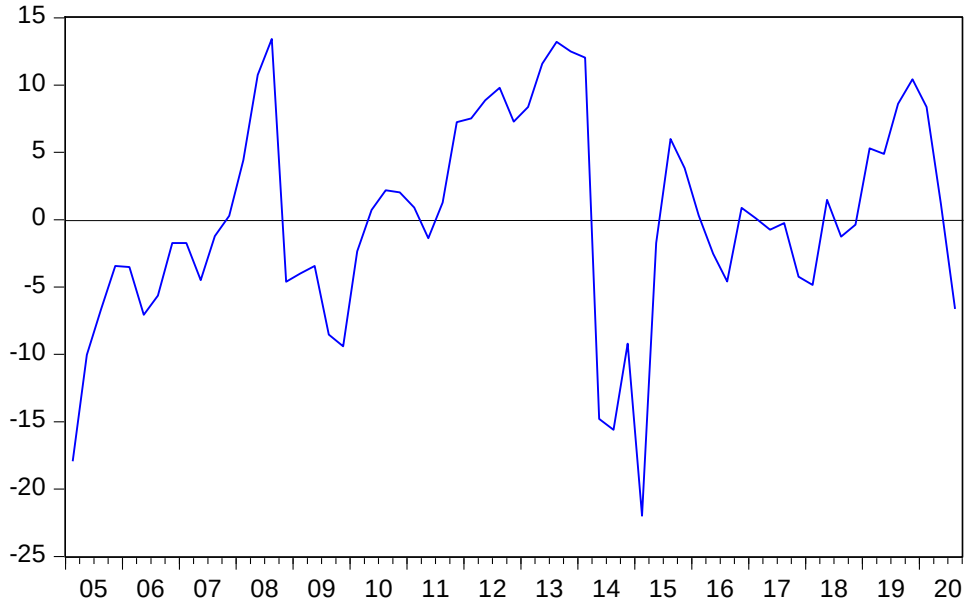

Figure 3. REER gap (% deviation from the trend)

A meaningful story is provided by the analysis of the contributions that fundamentals made to the change in the equilibrium REER (Figure 4). For the recent period, the appreciation of the equilibrium REER is mainly driven by the fast NFA growth, which mitigates the problem of future external debt financing and, consequently, allows to maintain a more negative trade balance. The picture with the impact of fiscal policy, which was very tight after 2013 due to fiscal consolidation caused by the political and economic crisis, also looks adequate. The reduction of budget expenditures restrained the acceleration of inflation and, respectively, the appreciation of the REER. The negative contribution of the relative productivity is gradually declining and reflects the fact that after the structural shock of 2014, Ukraine's economy is recovering. The stabilization of productivity relative to major trading partners in 2019 led to a decrease in depreciation pressure on the equilibrium REER. In 2020 there is a positive but very small contribution of relative productivity into the REER trend. The trend of terms of trade conditions has been declining for most of the sample, having a depreciation effect on the equilibrium REER. However, the positive price dynamics on commodity markets in recent years has led to a shift in the equilibrium REER towards appreciation, although not to a large extent.

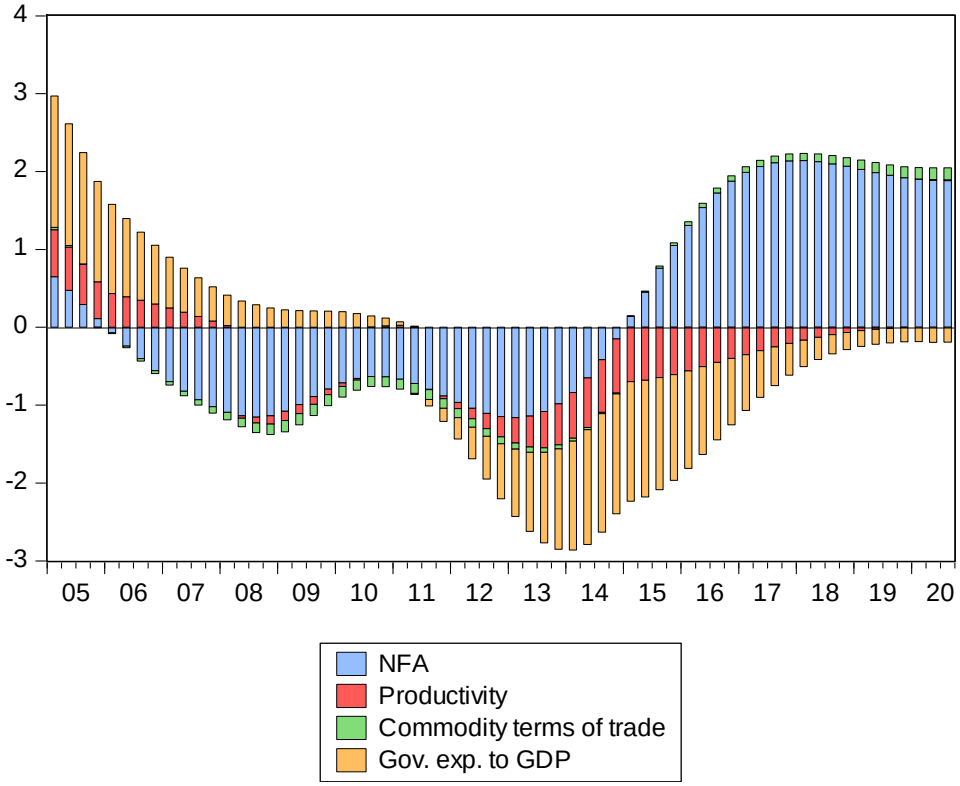

Figure 4. Average contributions of fundamentals into changes of REER trend

4. Estimates of FEER with the application of the macroeconomic balance approach

4.1. MB approach

MB approach does not estimate equilibrium REER directly, however, it aims to compute REER misalignments. The misalignment is defined as the required change in the REER to close the gap between the "underlying" current account balance, i.e., a value of the current account purged from transitory and temporary factors, and an "equilibrium" current account. "Equilibrium" current account is called the CA norm and is estimated based on long-run relationships with fundamentals. Each of these steps are described below[13]:

Step 1. Estimation of current account norm for Ukraine.

To estimate the current account norm, we used estimates of panel regression coefficients from Comunale (2015). In this study, the estimates were conducted for a set of emerging economies in Central and Eastern Europe[14]. These economies have already passed the transition from quasi-communist regimes to democracies with

[13] See Ajevskis et al. (2014) or Salto and Turrini (2010) for a good descriptions of the steps needed to apply the MB approach provided in. In this study, we follow these guidelines.

[14] Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia.

market economies, and therefore faced the problems that are inherent in Ukraine today. The status of these countries as small open economies with emerging markets justifies applying the estimates obtained from their data to Ukraine. The regression specification itself corresponds to that proposed in Medina et al. (2010). The estimates were conducted on annual panel data for the period 2004-2015.

Note that, we do not use the results of estimation CA norm panel regression obtained based on the External Balance Assessment (EBA) Methodology (Mano et al., 2019) by the IMF. Indeed, even though the set of variables that determine the current account in this technique is richer than in Medina et al. (2010), some of this data is not available for Ukraine. Also, the estimated coefficients are less relevant to Ukraine, as they are based on advanced economies data.

Step 2. Estimation of the underlying current account for Ukraine.

The difference of underlying current account and CA norm is commonly used to estimate the current account gap that should be closed due to real exchange rate adjustment. The observable current account is influenced by a number of transitory factors, such as booms in commodity markets, which must be taken into account in the estimations. In other words, when estimating the current account gap, our goal is to compare the current account in "normal" times (underlying current account) and the equilibrium value of the current account (CA norm).

Underlying current account (UCA) estimation is usually done in two ways. The first is the *projection-based method*, which assumes that medium-term current account forecasts are equivalent to the UCA, as transitional factors are eliminated over the several years horizon. The IMF's WEO projections are used as medium-term forecasts. The second approach, the *elasticities-based method*, involves adjusting the current account for the impact of business cycles of the global and national economy, as well as local changes in REER. To take into account the impact of these factors, the following standard reduced-form equation is used[15]:

$$\frac{CA}{Y} = \alpha - \left[\left(\frac{M}{Y}\right)\beta_m + \left(\frac{X}{Y}\right)\beta_x\right](\delta_0 \ln R + \delta_0 \ln R_{t-1} + \delta_n \ln R_{t-n}) + \left(\frac{M}{Y}\right)\ln R - \\ - \left(\frac{M}{Y}\right)\mu_m YGAP + \left(\frac{X}{Y}\right)\mu_x YGAPF, \quad (4)$$

where *CA* is the current account balance, *Y* the nominal GDP, *M* imports, *X* – exports, *R* is the REER, *YGAP* corresponds to the GDP gap of the domestic economy, *YGAPF* is the GDP gap of trading partners, α is the constant, β_m and β_x are the REER elasticity of import and export, μ_m and μ_x the GDP elasticity of import and export and δ_n the lagged effects of REER changes.

[15] Here we closely use notation from Ajevskis et al. (2014)

It is commonly assumed that the impact of REER is completely implemented in the current account after 3 years. That's why *n* in (4) equals 3 and the sum of δ_n equals 1 (Chapter V in Isard and Faruqee, 1998).

Underlying current account assumes that the gap of domestic and world GDP is zero (YGAP, YGAPF) and changes in the REER are fully reflected in the current account balance. Accordingly, the equation for the UCA looks like:

$$\frac{UCA}{Y} = \alpha - \left[\left(\frac{M}{Y}\right)\beta_m + \left(\frac{X}{Y}\right)\beta_x\right](\delta_0 \ln R + \delta_0 \ln R_{t-1} + \delta_n \ln R_{t-n}) + \left(\frac{M}{Y}\right)\ln R. \quad (5)$$

Since the short-term effects to be removed from the current account are the difference between $\frac{CA}{Y}$ and$\frac{UCA}{Y}$, this allows us to obtain an equation for the UCA by subtracting equation (5) from equation (4):

$$\frac{UCA}{Y} = \frac{CA}{Y} + \left(\frac{M}{Y}\right)\mu_m YGAP - \left(\frac{X}{Y}\right)\mu_x YGAPF - \left[\left(\frac{M}{Y}\right)\beta_m + \left(\frac{X}{Y}\right)\beta_x\right](\delta_1(\ln R - \ln R_{t-1}) + \cdots + \delta_n(\ln R - \ln R_{t-n})). \quad (6)$$

The parameters of equation (6), estimated in Isard and Faruqee (1998) for advanced economies, are: β_m = 0.92, β_x = 0.71, μ_m = 1.5, μ_x = 1.5, δ_1 = 0.25, δ_1 = 0.15. The most important parameters for the estimation of the equilibrium REER are the elasticities of exports and imports to the real exchange rate. These parameters are used not only to estimate the UCA but also in step 3 to estimate the required REER adjustment. Estimates for advanced economies can differ significantly from elasticities in emerging economies. Thus, in Isard and Faruqee (1998) the estimates for emerging markets are β_m = 0.69, β_x = 0.53. At the same time in Bussière et al. (2010) estimates were conducted for time series of 21 countries, of which 14 advanced and 7 emerging market economies. On average, the obtained elasticities were β_m = 0.53, β_x = 0.75. The peculiarity here is that the elasticity for exports is higher than for imports.

In Annex C we provide our estimates of export/import REER elasticities for Ukraine. According to our results β_m approximately equals 0.95, which is higher than respective elasticities in Bussière et al. (2010) or Isard and Faruqee (1998). On the other hand, β_x from different regressions equals (-0.5) and (-0.77), which is pretty close to elasticities from the abovementioned sources.

To provide robust results, in this study, we use both projection-based and elasticities-based approaches to the estimation of UCA, as well as three variants of the REER elasticities of exports and imports taken from: Isard and Faruqee (1998), Bussière et al. (2010) and our estimates from the Annex C.

Step 3. An estimate of the REER adjustment required to close the gap between the CA norm and the UCA.

In the case of a REER overvaluation, the UCA is more negative than the CA norm and, therefore, the REER must be depreciated to close this gap. The inverse logic works

when REER is undervalued. The size of the required adjustment is determined as follows:

$$\frac{(R_t - R_t^*)}{R_t^*} = \frac{uca_t - ca_t^{norm}}{\varepsilon_t}, \quad (7)$$

where, R_t^* is the equilibrium REER, uca_t is the underlying current account, ca_t^{norm} is the current account norm, ε_t is the REER elasticity of current account.

The elasticity of the current account to REER is estimated by the following equation:

$$\varepsilon_t = \left(\beta_x \frac{X}{Y}\right) - ((\beta_M - 1)\frac{M}{Y}. \quad (8)$$

As one can see, estimations of export and import elasticities to REER are also used here. To be consistent we will use elasticities for emerging markets from Step 2.

4.2. Data sources and characteristics

The variables used to estimate the CA norm are shown in Table B1 (Annex B). The dataset consists of annual data for the period 2004-2019. Data on the initial NFA value were taken from the updated EWN database (Lane and Milesi-Ferretti, 2007). The source of data on foreign direct investment and oil balance is the balance of payments of Ukraine, compiled by the NBU. The IMF database (WEO) was a source of information on the GDP of Ukraine and its trading partners, government revenues and expenditures. Population growth rates and the old-age dependency ratio were taken from World Bank (WDI) statistics. The real GDP growth rate per capita was formed based on UNCTAD statistics.

The REER weights were applied to estimate the variables which characterize Ukrainian economy in relation to its trading partners (Table B1). As in the case of the BEER estimation, the fundamentals must be at their equilibrium values to estimate the equilibrium value of the current account. Usually in the literature for this purpose are used the 5 or 7-year real-time forecasts of the fundamentals. Unfortunately, for Ukraine, such long-term forecasts are absent for most years of our sample, both in the WEO and in other databases. For this reason, we smoothed fundamentals by a 7-year moving average.

Due to the economic crises of 2008-2009 and 2014-2015, GDP growth per capita was very volatile. This significantly shifted the equilibrium current account up. To eliminate the effect of these outliers from the estimations, we smoothed the growth of GDP per capita for Ukraine in 2009, 2014, and 2015, taking the average value of the three years before the crisis and three years after it.

The UCA estimation in Step 2 includes the use of GDP gap data. The gap of world GDP was estimated as the weighted average of the GDP gaps of Ukraine's main trading partners. GDP gaps of main trading partners were extracted by Hodrick-Prescott filter.

For weighting were used the REER weights. As a Ukraine's GDP gap, we used the NBU's estimates, which are regularly published in its Inflation Reports[16].

4.3. Results

The estimates of CA norms are presented in Figure 5. In recent years, this indicator is quite stable and equals about -2.7% of GDP. During the period 2004-2020, the CA norm significantly increased starting from the value -7.1% at the beginning of the sample. The CA norm increase was due to a less negative contribution of the old-age dependency ratio and fiscal policy. This means that the percentage of elderly people to the working population in Ukraine was higher than that of the main trading partners, but gradually these indicators leveled off due to the "aging" of the trading partners' population. This could happen because of a gradual shift in the focus of foreign trade on EU countries since 2015. Fiscal policy after the economic crisis in 2014 has become tighter, so reducing its negative impact on the current account looks logical. The gradual decrease of FDI in 2012-2018 led to an increase in the CA norm during this period. In 2019 and 2020, there was a significant increase in investments, which made the equilibrium current account more negative. Population growth in Ukraine is constantly lower than in trading partners, which makes a positive contribution to the equilibrium value of the CA norm. The most volatile indicator is the relative growth of GDP per capita. In 2004-2009 and 2016-2020, this indicator in Ukraine was higher than that of trading partners, so it reduced the equilibrium current account. In 2010-2015, GDP growth per capita fell significantly due to the economic crises of 2008-2009 and 2014-2015, raising CA norms.

[16] The methods used by the NBU for the estimation of GDP gap can be found in NBU (2016)

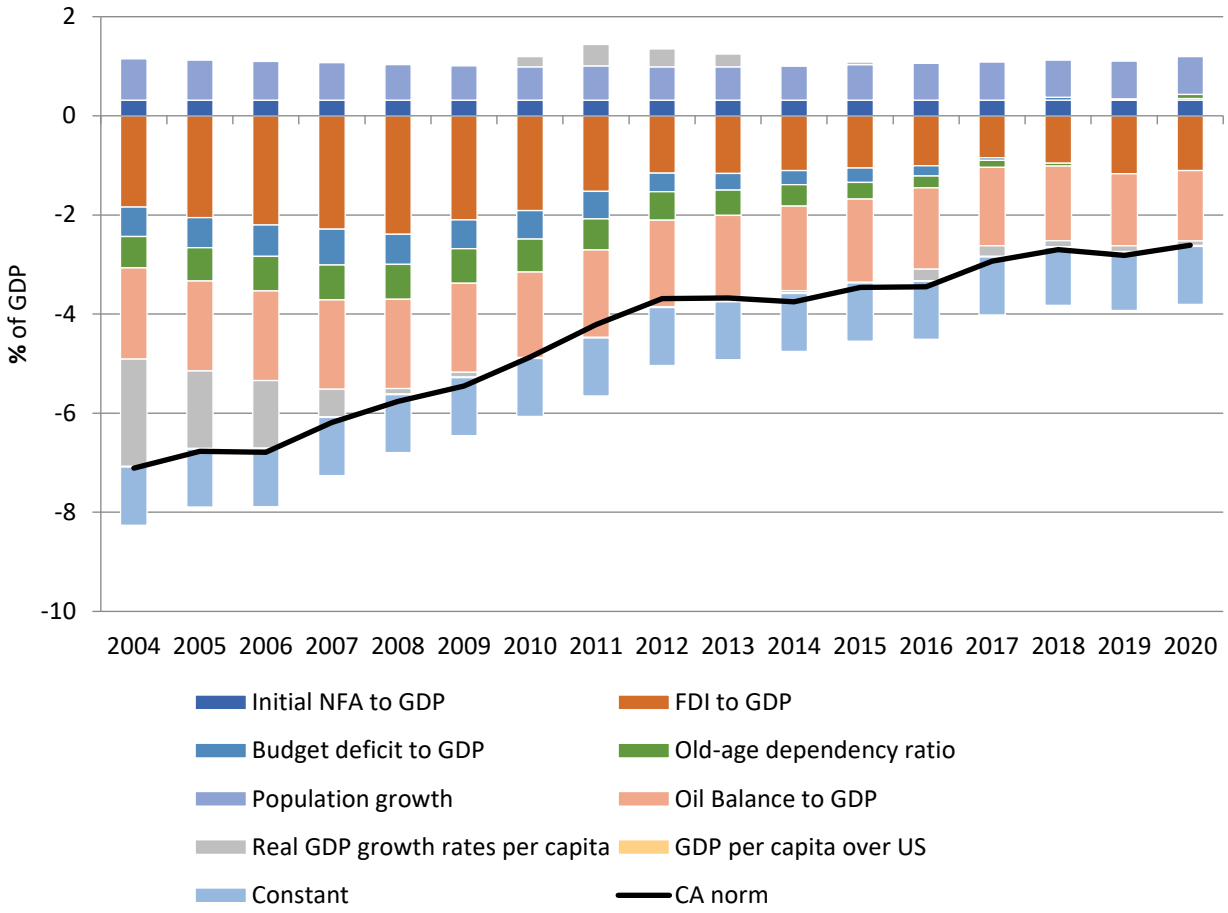

Figure 5. Estimates of CA norm and contributions of fundamentals

UCA estimates and the corresponding REER gaps are shown in Figures B1 and B2. UCA was calculated applying the elasticities-based approach using three sets of REER export and import elasticities: (-0.53) and 0.69 (Isard and Faruqee, 1998) (UCA_F), (-0.75) and 0.53 from Bussière et al. (2010) (UCA_B), (-0.77) and 0.95 (our estimates, UCA_V). We also report two variants of the UCA projections-based estimates: UCA_proj and UCA_ma_7. UCA_proj are the IMF's projections of the current account for the maximum horizon[17] made in each year of our sample. The horizons of IMF's projections for Ukraine are very unstable, reflecting uncertainty about the perspectives of emerging markets in crisis periods. The instability of projections' horizons leads to the volatility of projections themselves. To deal with this problem we estimated 7-year moving averages, which included current account projections at the maximum horizon and historical data (UCA_ma_7). Estimates of the REER gaps are based on the application of appropriate elasticities to UCA estimates.

[17] The projection horizons for Ukraine are different due to the high degree of uncertainty. In the crisis years, it was 2 years, in the years of stability - 7 years.

Table 1. BEER and FEER-MB estimates of REER misalignments

	REER_mis_elast_F	REER_mis_elast_B	REER_mis_elast_V	REER_mis_Pure_proj_F	REER_mis_Pure_proj_B	REER_mis_Pure_proj_V	REER_mis_ma_7_F	REER_mis_ma_7_B	REER_mis_ma_7_V	BEER
2005	-77.9	-64.7	-20.7	-62.5	-48.9	-19.5	-108.7	-85.0	-33.9	-9.5
2006	-42.4	-37.2	-12.4	-33.3	-26.7	-9.3	-114.8	-91.9	-32.1	-4.5
2007	-25.9	-21.2	-7.2	0.2	0.1	0.0	-109.7	-90.2	-27.5	-1.8
2008	17.1	10.7	3.9	-0.3	-0.2	-0.1	21.5	18.0	5.0	6.0
2009	0.3	9.2	0.1	-28.7	-22.8	-8.3	-37.2	-29.6	-10.8	-6.3
2010	-0.4	1.0	0.6	-17.2	-13.8	-4.8	-28.9	-23.1	-8.1	0.6
2011	18.0	14.2	3.9	-2.7	-2.2	-0.7	-1.2	-0.9	-0.3	2.0
2012	47.0	38.3	10.5	22.0	18.4	5.2	29.4	24.5	7.0	8.4
2013	59.9	54.2	12.7	51.4	43.5	11.6	51.5	43.5	11.6	11.4
2014	-0.7	14.1	-1.3	-5.6	-4.5	-1.5	-1.0	-0.8	-0.3	-6.9
2015	-41.3	-26.9	-11.9	-8.9	-7.1	-2.5	-11.8	-9.4	-3.4	-3.5
2016	6.5	5.3	-0.1	-14.3	-11.8	-3.5	-19.6	-16.1	-4.8	-1.5
2017	21.4	14.6	3.4	0.5	0.4	0.1	0.5	0.4	0.1	-1.3
2018	50.0	36.0	9.5	5.0	4.2	1.1	6.8	5.7	1.5	-1.2
2019	35.1	15.2	7.1	6.6	5.6	1.5	5.7	4.8	1.3	7.3
2020	-57.1	-47.5	-16.4	8.6	6.8	2.5	-4.0	-3.2	-1.2	1.0
Sum of absolute deviations from BEER	333.5	266.2	62.3	140.6	114.3	39.1	188.8	152.1	40.6	

The time series of the estimated REER gaps (Table 1) allows us to distinguish three periods of significant deviation from the trend. The period 2005-2006 was characterized by a huge undervaluation of REER. This is due to the abnormally high value of UCA, more than 10% of GDP[18] according to elasticity-based approach and low equilibrium current account (Figure B1). In 2011-2014, there was a high overvaluation of REER. The economic crisis of 2014-2015 led to a significant devaluation of the nominal exchange rate and a surge in inflation. Estimates from the elasticities-based approach indicate that, as a result of these events, the REER became undervalued for a short period of 2015-2016, after which it returned to an overvalued stance. The *elasticity-based* approach clearly indicates overvaluation in 2019 and undervaluation in 2020. In both cases, deviations from the trend look too large.

The *projections-based* approach shows a slightly different picture. First, it indicates the undervaluation period after the crisis of 2008-2009. Second, the undervaluation of REER after the depreciation in 2015 is more persistent and lasts until 2017. For the final period of estimations, 2019-2020, results are mixed. Estimations based on pure

[18] Actual current account in 2004 was 10,6% GDP.

projections indicate overvaluation in 2019 and 2020, while projections smoothed by a 7-year moving average produce undervaluation in 2020.

5. Comparison of MB and BEER estimates

Together with the MB estimates, Figure B2 and Table 1 contain the results of the BEER approach, where the REER deviation from equilibrium was estimated relative to the mean value of the BEER trends. As seen, MB estimates are more volatile than BEER results. The correlation of estimates obtained from the two approaches is not perfect, but there are some tendencies of misalignments in both methodologies: undervaluation of REER at the beginning of the sample, after the crises of 2008-2009 and 2014-2015; significant overvaluation in the period 2011-2013. Estimates differ significantly for more recent years. According to the BEER methodology, after the crisis of 2014-2015, the REER quickly returned to equilibrium, and only in 2019 became overvalued by 7.3%. MB estimates tell different stories depending on the estimated UCAs and applied export/import elasticities.

Among all MB estimates those that were obtained based on elasticities-based approach are the most volatile and judging on the size of misalignments are not realistic. The problem with this approach is a mechanism of adjustment headline current account for the cyclical fluctuations of the world economy. This approach assumes that a negative world GDP gap should make a negative cyclical impact on the export. However, in some years it did not happen. For instance, in 2020 world economy was in a deep recession, but it did not hit Ukrainian export significantly. Terms of trade for Ukrainian goods were on the highest level since 2012 (Figure A1), while external demand did not drop very much. This means that the cyclical component of export for Ukraine was minimal in 2020, but the elasticity-based approach artificially increases it, making UCA too high and, consequently, REER too undervalued. This drawback is somewhat mitigated by introducing our estimates of export/import REER elasticities, which reduce the volatility of misalignments and deviation from BEER result (Table 1).

Projection-based UCA's produce misalignments that are rather close to BEER estimates in terms of volatility and levels. Application of our export/import estimates of REER elasticities gives a relatively good approximation of BEER misalignments, while the elasticities from Isard and Faruqee (1998) and Bussière et al. (2010) are still feasible. Misalignments estimated on the basis of pure current account projections, in general, are closer to the BEER result.

6. Conclusions

In this study, we applied to Ukrainian data two conventional approaches to the estimation of REER trends and respective misalignments. BEER and MB methods used

for empirical estimations gave consistent results on the indication of the periods when the REER was over/undervalued. According to estimates, REER was undervalued in the first half of the 2000s, after the crisis of 2008-2009 and after the crisis 2014-2015. Overvaluation periods are 2008, 2011-2013, and 2018-2019. Recent years characterized by moderately overvalued REER. Positive misalignment started to open in 2018 and closed in the second half of 2020.

BEER approach gave us a good opportunity to identify fundamentals, which drive the REER trend in the long-run. For the recent period, the appreciation of the equilibrium REER is mainly driven by the fast NFA growth. More tight fiscal policy of recent years restrained the acceleration of inflation and, respectively, the appreciation of the REER. The negative contribution of the relative productivity is gradually declining after the structural shock of 2014. The positive dynamics in commodity terms of trade in recent years have led to a shift in the equilibrium REER towards appreciation, although not to a large extent.

Within the MB approach, we estimated the current account norm for Ukraine, which is an important indicator of external imbalances of the economy. During the period 2004-2020, the CA norm significantly increased from the value of -7.51% of GDP at the beginning of the sample to the level of -2.7% in 2020. The current account norm increase was due to a less negative contribution of the old-age dependency ratio and a more tight fiscal policy.

Comparison of BEER and MB results indicated that projection-based method of estimation underlying current account is more appropriate than elasticity-based approach. The former gives less volatile and more consistent with BEER estimates of REER misalignments.

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Annex A

BEER approach

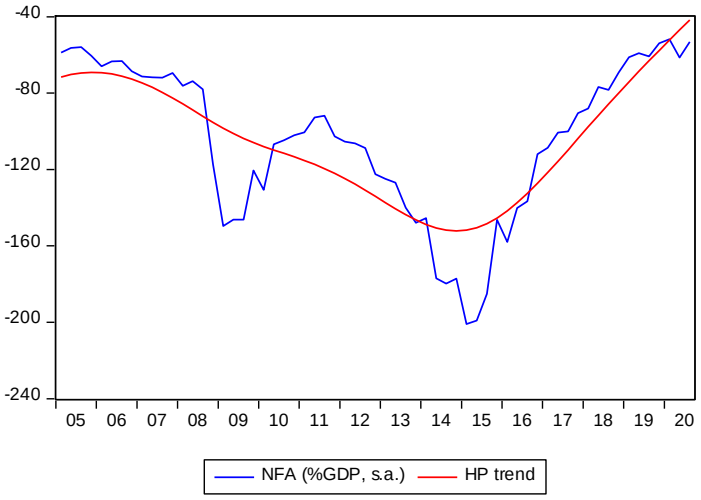
Table A1. Summary of empirical studies with application of BEER

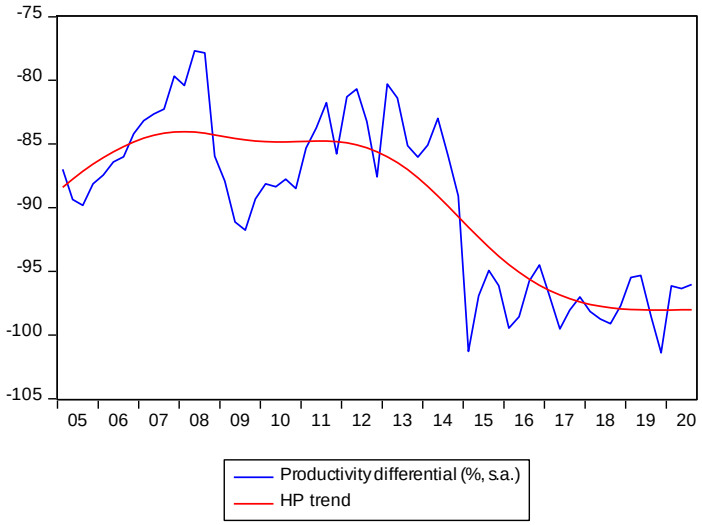
Authors	Country	Estimation	Variables	Data
Comunale (2015)	27 (EU countries)	GM-FMOLS	Foreign net capital inflows; Terms of trade; GDP per capita	1994-2012, annual
Hossfeld (2010)	17 (US and its 16 major trading partners)	Single country estimations: DOLS; FMOLS Panel estimations: Group-mean DOLS; FMOLS.	Net foreign assets to GDP; Trade balance to GDP; Terms of trade; Government consumption; Openness	1986-2006, quarterly
Couharde et al. (2017)	187 countries	Fully-Modified OLS, DOLS	Measure of sectoral productivity relative to trading partners; Net foreign asset position; Terms of trade	1973-2016, annual
Ajevskis et al. (2014)	Latvia	VECM	Net foreign assets; Fiscal balance/ Government consumption to GDP; Productivity differential; Investment ratio; Commodity terms of trade; Openness to trade;	2001 – 2010, quarterly
Gylanik (2012)	Slovakia	OLS	Labor productivity differential; Gross fixed capital formation to GDP; Net exports to GDP; Foreign debt to export ratio	1995 – 2010, quarterly
Iossifov and Loukoianova (2007)	Ghana	VECM	Real interest rate relative to trading partners; Fiscal stance; Trade openness; Net foreign assets of the banking system; Real GDP at PPP per capita relative to main trading-partner countries; Real world prices of Ghana's main export commodities	1980 – 2005, quarterly and annual
Dumitrescu and Dedu (2009)	Romania	VECM	Productivity differential; Consumption, Net foreign assets, Openness	1998 – 2006, quarterly

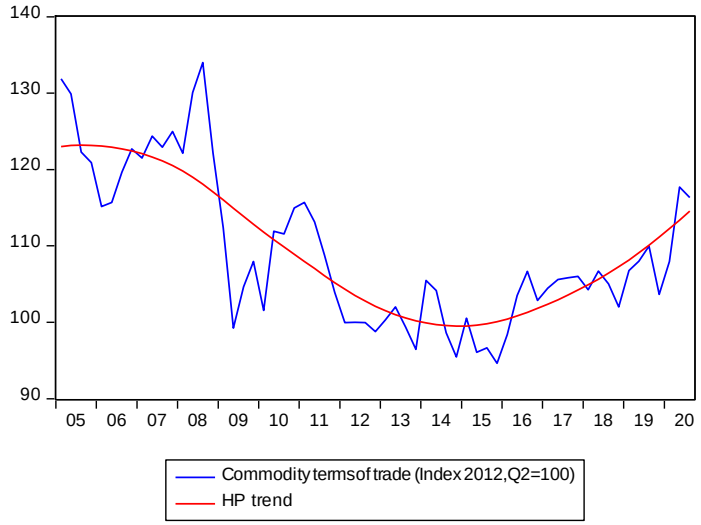
Table A2. Data characteristics

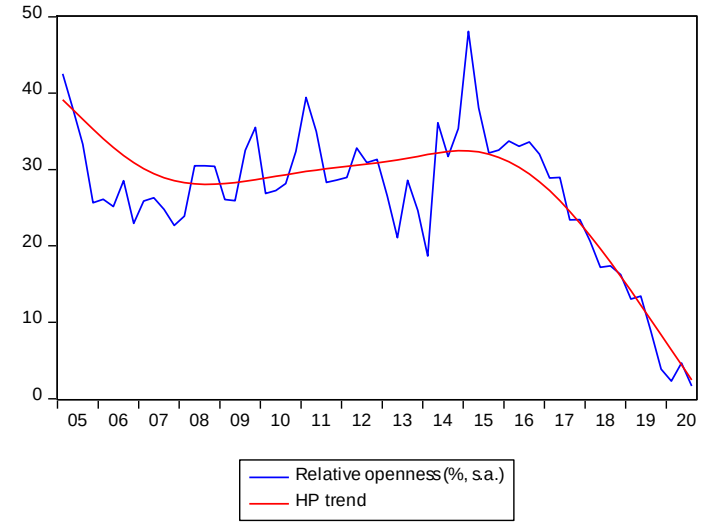
Variable	Transformations	Source	Expected sign
REER	Log of REER index, 2012 = 100, seasonally adjusted.	NBU	
NFA	International investment position relative to GDP, seasonally adjusted.	NBU	(+) - debtor's position of a country should be compensated for by improved trade balance, requiring a more depreciated real exchange rate.
Openness	(Export + Import) ratio to GDP relative to weighted average of main trading partners. Weights from REER	IMF (IFS)	(-) - tougher competition in international markets leads to smaller prices of tradables.
CTOT	Commodity terms of trade indexed based on Ukrainian trading data. 2012 = 100.	NBU	(+) - higher CTOT should lead to real exchange rate appreciation via real income effect.
Productivity differential	GDP per capita relative to weighted average of main trading partners. Weights from REER. GDP was converted in real terms (Purchasing power parity, 2011 international dollar), seasonally adjusted.	IMF (IFS)	(+) – Balassa-Samuelson effect
Fiscal policy	General government expenditures to GDP relative to weighted average of main trading partners, seasonally adjusted.	IMF (IFS)	(+) – loose fiscal policy spurs additional demand, shifting internal prices up (real appreciation)

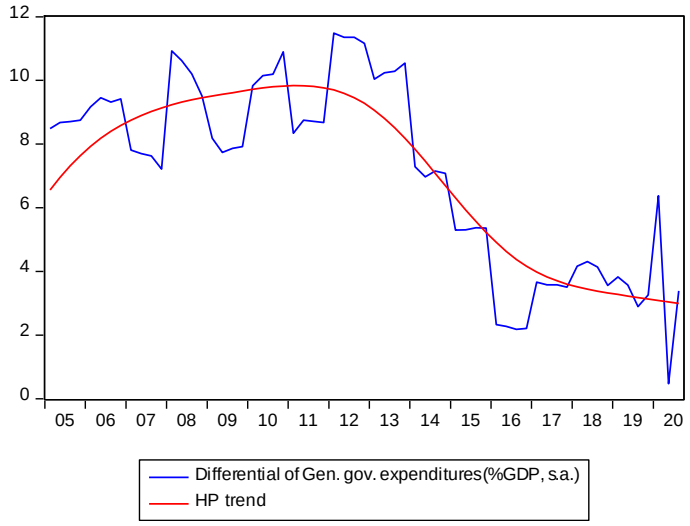
Figure A1. REER and fundamentals (HP lambda = 1600)











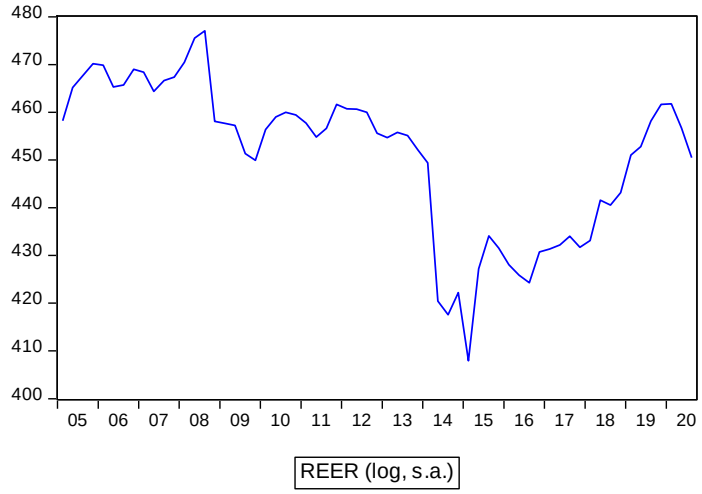
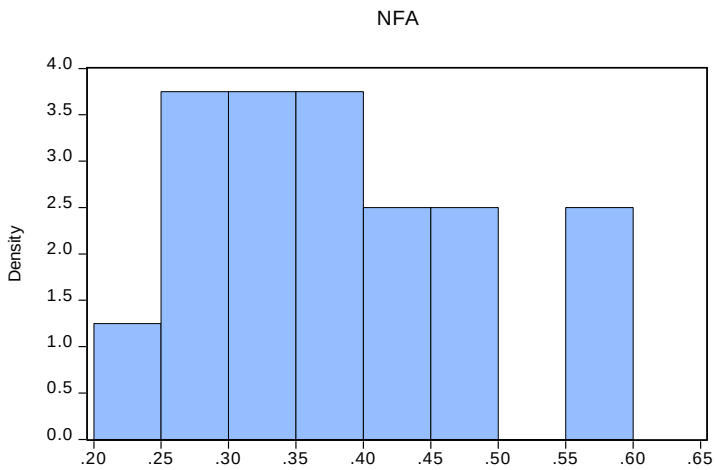
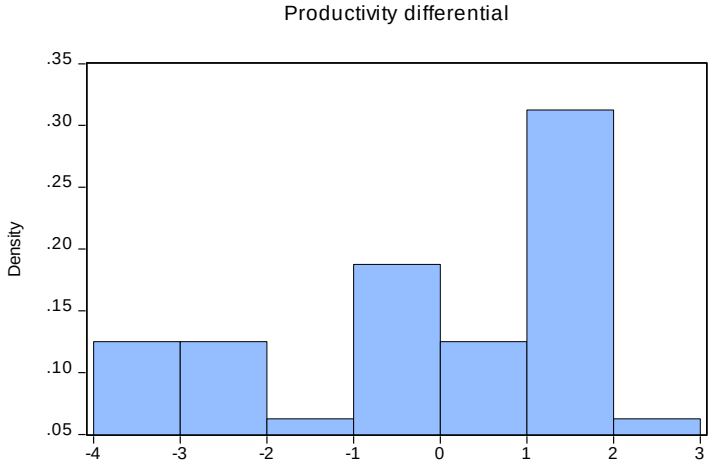
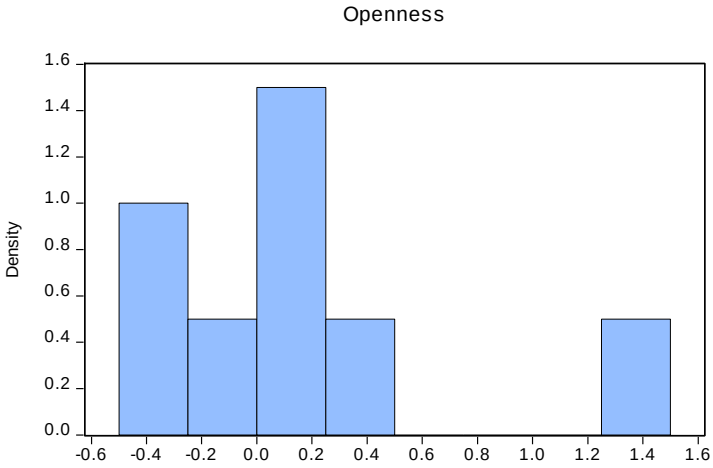
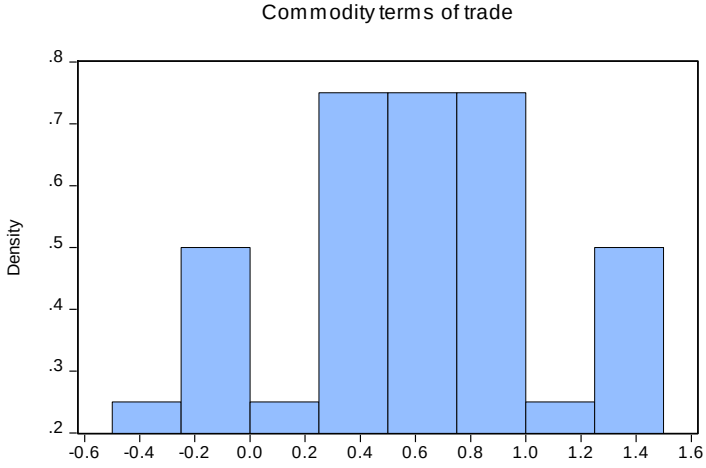


Figure A2. Densities of coefficients from all regressions









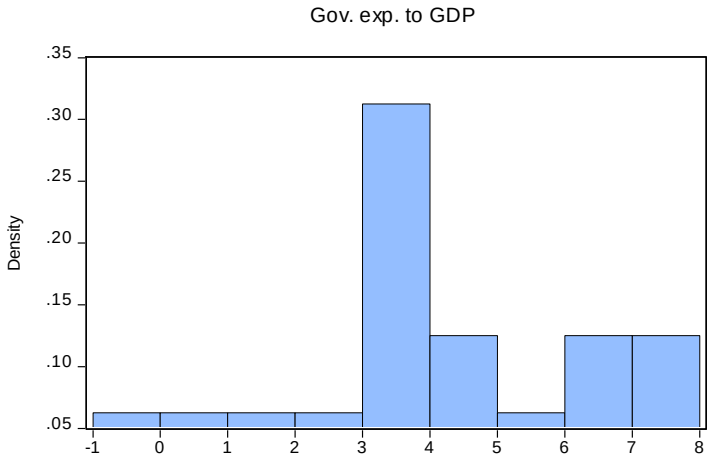
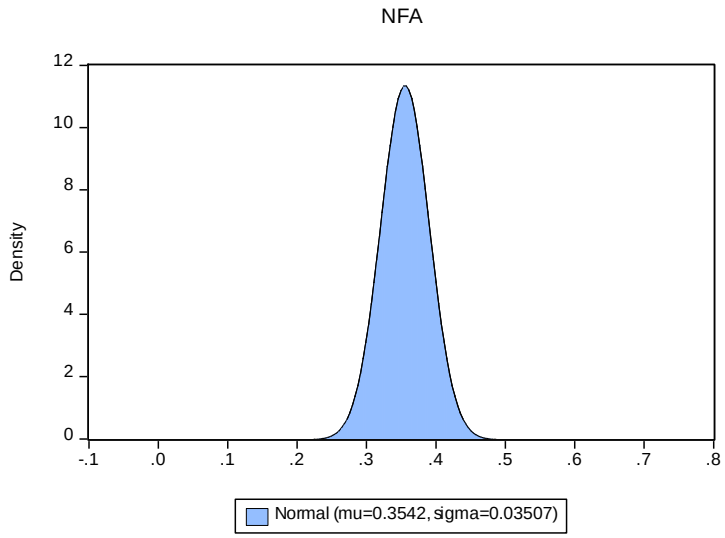
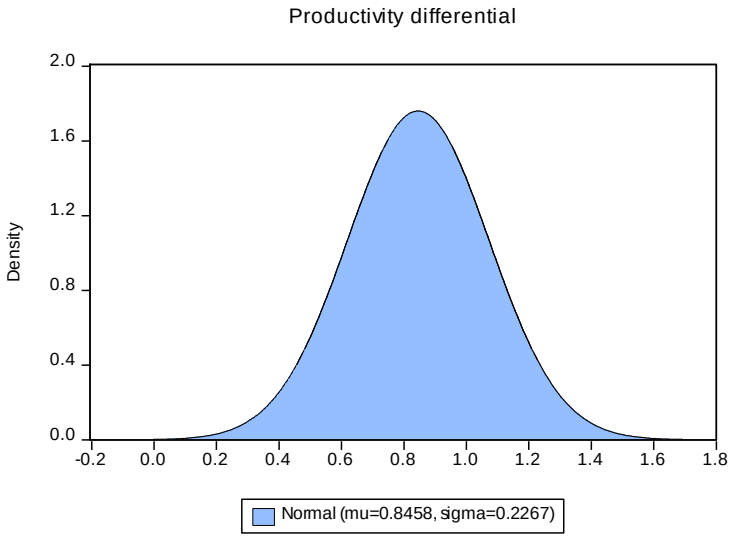
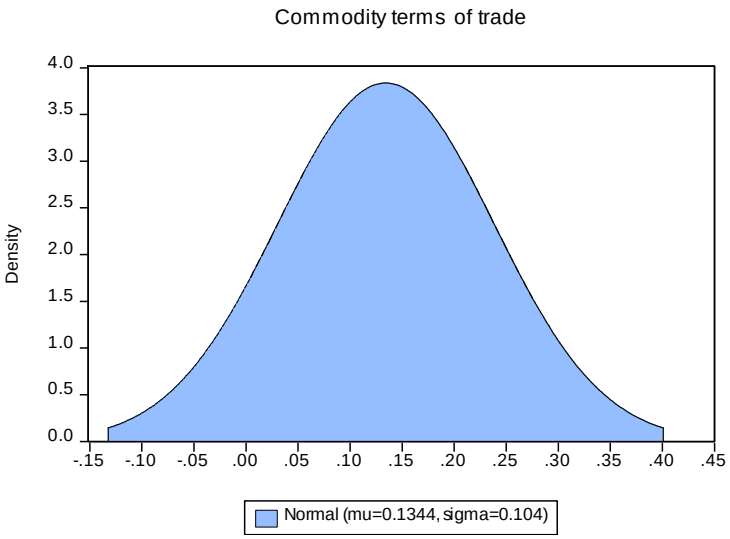
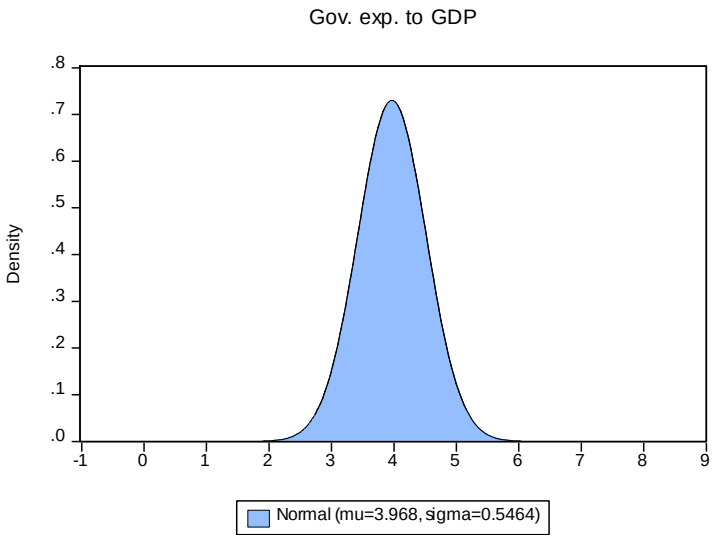


Figure A3. Joint distributions of coefficients from regressions which passed Bounds test









Annex B

MB approach

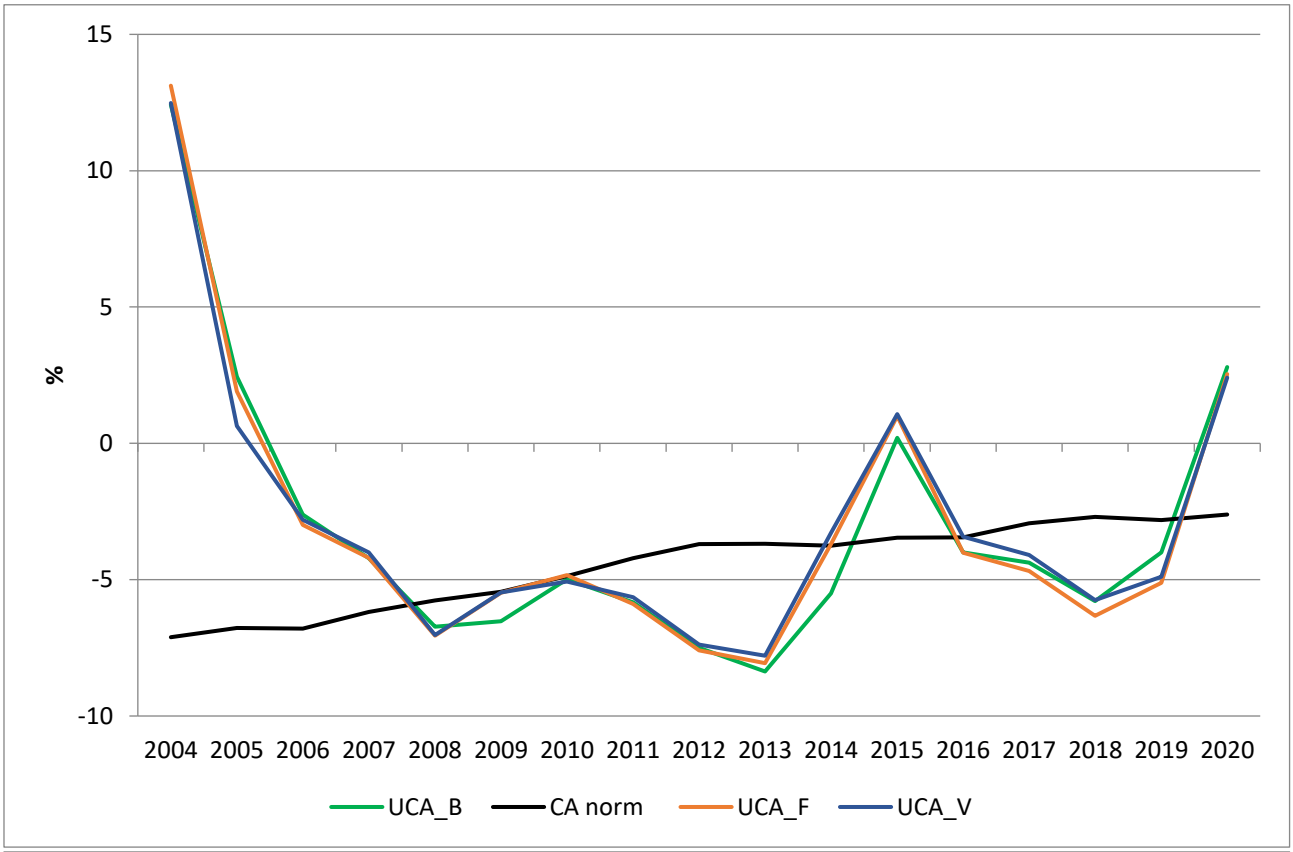
Table B1. CA fundamentals and estimates of coefficients[19]

Variable	Label	Expected sign	Coefficient
Initial NFA/GDP (2004 for this sample)	nfa	(-) - countries with negative NFA are expected to improve the CA position to preserve long-term solvency.	-0.0144 (0.0123)
Foreign direct investments to GDP	fdi	(-) - FDIs are more stable investments and less prone to sudden stops. If FDIs are directed to finance the CA deficits, this brings a decline in CA over time, because the method of financing is less uncertain and allows you to borrow and import more.	-0.435*** (0.139)
General government revenue minus expenditure over GDP (relative to partners)	fisc_bal	(+) – more tight FP increases savings in an economy, improving CA	0.258* (0.137)
Old-age dependency ratio (relative to partners)	old_age	(-) - high number of old people should bring a decrease in savings	-0.297 (0.241)
Population growth (relative to partners)	pop_gr	(-) - high number of kids should bring a decrease in savings	-0.983 (0.613)
Ratio of Oil Balance to nominal GDP in current USD	oil_bal	(+) – importers of oil products usually run lower CA	0.412** (0.171)
Real GDP growth rates per capita (relative to partners)	gdp_per_cap_gr	(-) - stronger growth is often linked with a decline in CA because of higher potential, the country can save less today	-0.635*** (0.151)
GDP per capita over US (in PPP 2017)	gdp_ov_usa	(+) - as relative income approach the income level of advanced economies, which means an increase in convergence, CA should improve	0.00927 (0.0147)

Note: Standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

[19] The fit of the panel regression comes from Medina et al. (2010). Estimates were made in Comunale (2015) on the 2004-2015 sample of annual data from Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia.

Figure B1. Estimates of UCA with different sets of elasticities



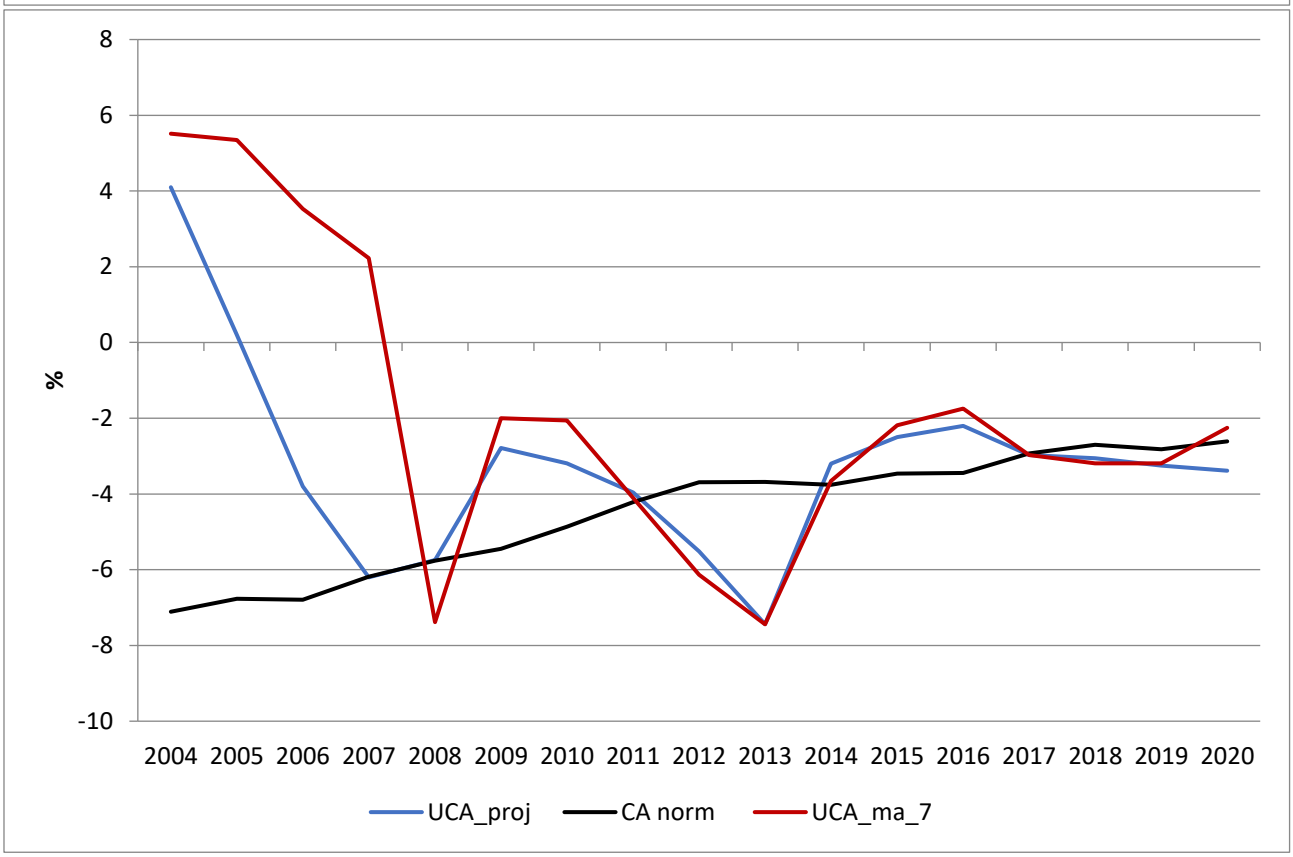
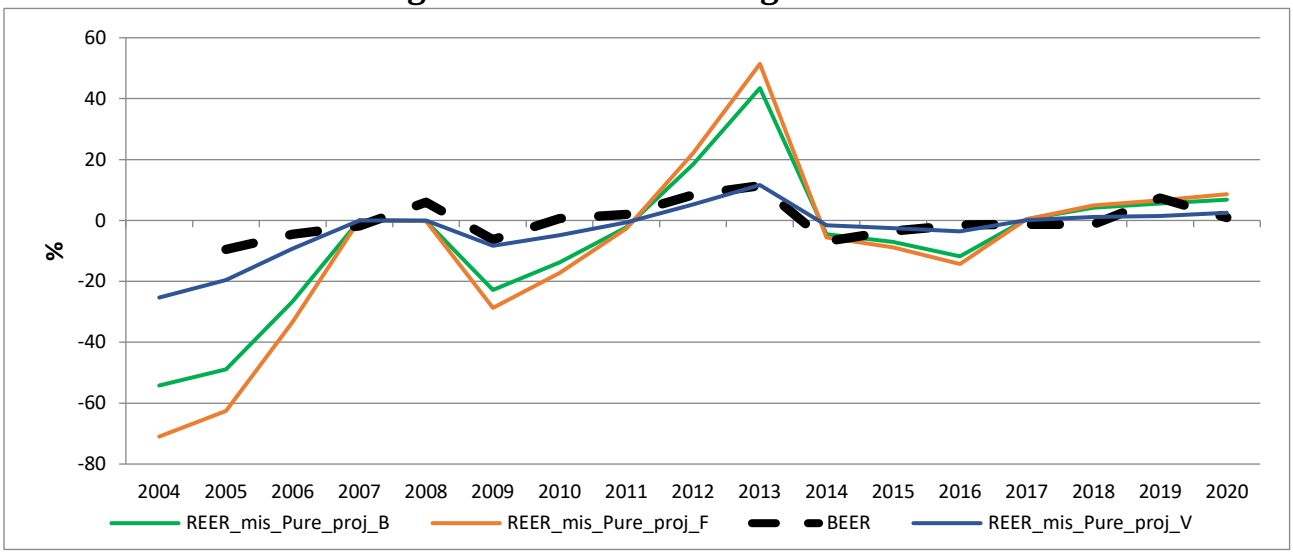
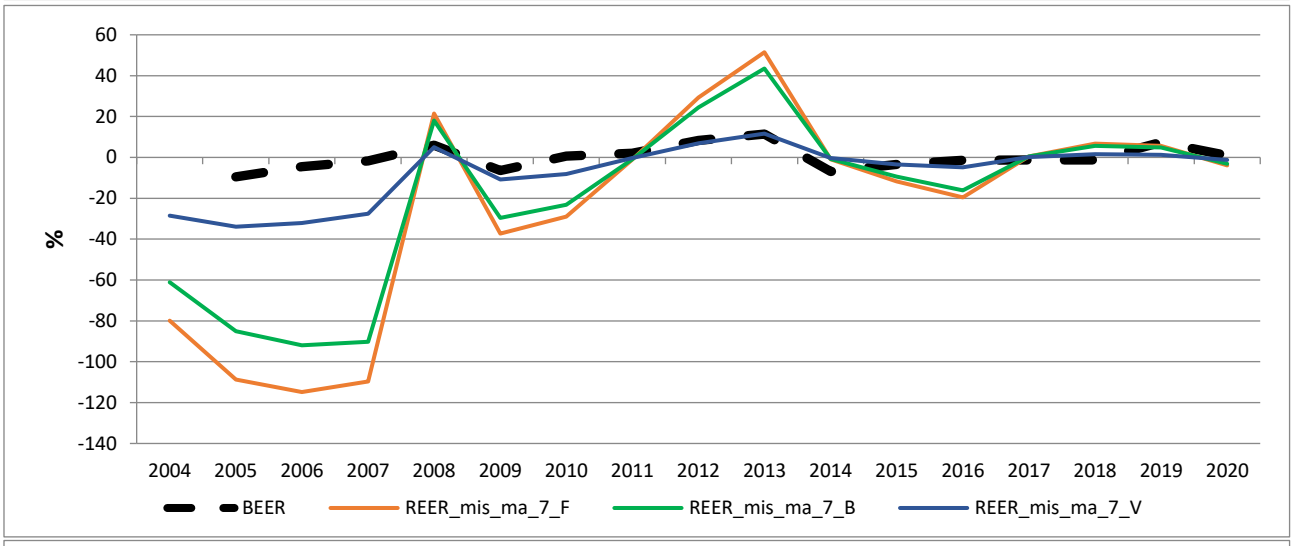
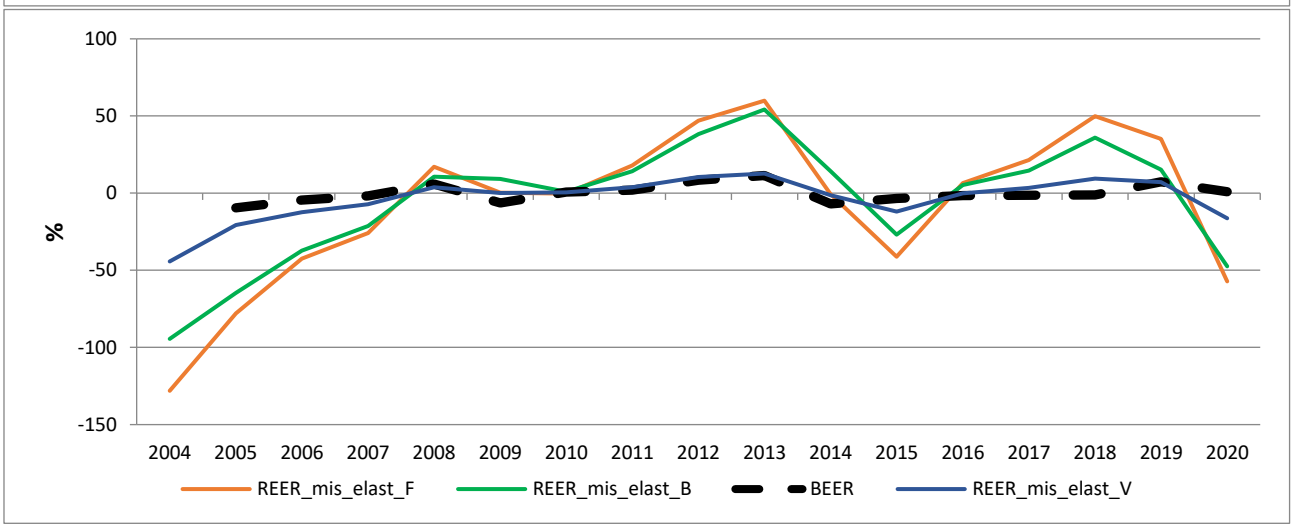


Figure B2. REER misalignments[20]







Note:

- REER_mis_elast_F corresponds to the application of elasticities (-0.53; 0.69) to UCA_F, REER_elast_mis_B - (-0.75; 0.53) to UCA_B, REER_elast_mis_V - (-0.77; 0.95) to UCA_V.
- REER_mis_Pure_proj_F corresponds to the application of elasticities (-0.53; 0.69) to UCA_proj, REER_mis_Pure _proj_B - (-0.75; 0.53) to UCA_proj, REER_mis_Pure _proj_V - (-0.77; 0.95) to UCA_proj.
- REER_mis_ma_7_F corresponds to the application of elasticities (-0.53; 0.69) to UCA_ma_7, REER_mis_ma_7_B - (-0.75; 0.53) to UCA_ma_7, REER_mis_ma_7_V - (-0.77; 0.95) to UCA_ma_7.

[20] + is overappreciation

Annex C

Estimation of export/import REER elasticities with sign-restricted BVAR

Empirical estimation of the elasticities of export/import with respect to price changes (REER in our case) is challenging. Standard VAR treats export/import and REER as endogenous variables and does not distinguish between underlying structural shocks that caused unexpected changes in international trade and prices. Drops or hikes in REER can be caused, for instance, by productivity shocks, monetary and fiscal policy shocks what will have different outcomes for trade balance. Putting it differently, REER elasticities of export and import are shock-dependent. A popular approach, which helps to impose some structure on the shocks and to make impulse response function more consistent with economic theory is the SVAR model with zero and sign restrictions developed in Arias et al. (2018)

A sign-restrictions scheme was used in Bussière et al. (2010) to estimate on a country-by-country level the long-run REER elasticities of export and import for a sample of 21 countries (including 7 emerging markets economies). They used quarterly data from 1979 to 2007 for 5 key time series: exports, imports, GDP, REER, and oil prices all in real terms and in logs. REER shock was identified by the positive feedback of imports and negative reaction of exports.

In Chmielewski et al. (2020) BVARs were used for the estimates of exports/imports elasticities with respect to different measures of relative prices (including REERs based on CPI, PPI, and unit labor cost). BVAR for exports included Polish export volume, Poland's participation in global value chains, external demand weighted by the structure of Polish exports, world prices weighted by the structure of Polish exports, Polish short-run interbank interest rate, some measure of the exchange rate. To identify the system of equations the authors imposed sign and zero restrictions, which denoted the shocks of global demand, global supply, global prices, global value chains, the domestic monetary policy, and the exogenous exchange rate shock resulting in appreciation of the zloty. A similar approach was applied to the estimation of imports elasticity.

The sources of current account fluctuation in Ukraine were investigated in Nikolaychuk and Shapovalenko (2013). The authors applied sign restricted VAR to obtain an empirical estimate of current account reactions to the different types of shocks. VAR contained terms of trade index, relative output, trade balance, and REER as endogenous variables and covered quarterly data from 2001 to 2012. VAR was tightly identified as the system of 4 endogenous contained 4 identified shocks: terms of trade shock, demand shock, supply shock, and REER shock.

In our study, we need a separate estimate for REER elasticities of export and import. To obtain the elasticities we run BVAR with a sign and zero restrictions using quarterly data for the period 2003-2020. BVAR contains 4 endogenous variables: log of real

export, log of real import, log of real GDP, REER. Export and import were converted into real terms by deflating them with export and import deflator indices. To control for external environment developments we also included the growth of terms of trade index and weighted average GDP growth of trading partners as exogenous variables. Sign restrictions imposed to identify the shocks are shown in Table C1. We identify only two shocks to keep the acceptance rate at a reasonable level. On the top of that there is no clear understanding how other types of shocks (supply shock for instance) should affect real exports/imports.

Table C1. Sign restrictions on BVAR IRFs

Shock	Demand shock	REER Shock
Export	+	-
Import	+	+
GDP	+	-
REER	+	+

We estimate BVAR with 4 lags and use two types of priors: Minnesota (full VAR) and dummy observation. Minnesota priors are used to grid search for the most appropriate hyperparameters based on the maximization of the marginal likelihood for the model. This procedure can't be repeat for dummy observations priors because it is not possible to derive the marginal likelihood for these models. That's why we applied optimized hyperparameters for Minnesota priors to the BVAR with dummy priors (Table C2). As it follows from presented hyperparameters, we assume cointegration between variables setting sum-of-coefficients and dummy initial observation priors. To get posterior distributions of BVAR parameters we made 20 000 draws with 10 000 burn-in iterations.

Table C2. Optimized hyperparameters

Hyperparameter	**Meaning**
Auto-regressive coefficient	0.6
Overall tightness (λ_1)	0.5
Cross-variable weighting (λ_2)	0.4
Lag decay (λ_3)	1
Exogenous variable tightness (λ_4)	300
Block exogeneity shrinkage (λ_5)	0.001
Sum-of-coefficients tightness (λ_6)	2.5
Dummy initial observation tightness (λ_7)	0.01

Figure C1 demonstrates impulse response functions of BVARs with respective priors. The acceptance rate for the models with both Minnesota and dummy priors is about 1.5 %, saying that unrestricted VAR results are not in tight correspondence with our

sign restrictions. Potentially, this fact is reflected in wide confidence intervals of obtained IRFs.

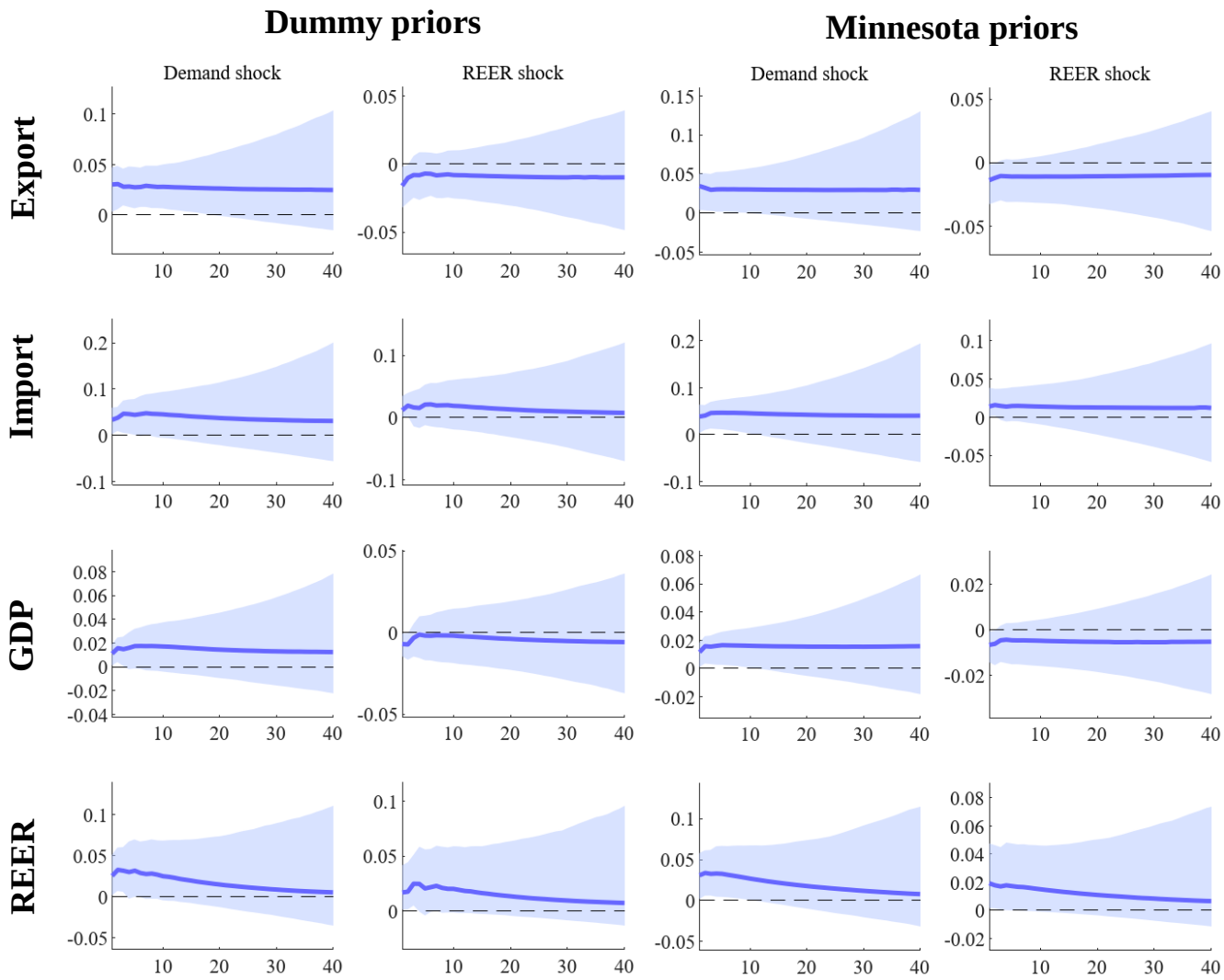


Figure C1. IRFs of sign-restricted BVARs

The ratio of export/import and REER responses to the REER shock is the REER elasticity of export/import at a given horizon. On a 5-year horizon, export and import elasticities are -0.77 and 0.95 respectively for BVAR with Minnesota priors and -0.5 0.93 for BVAR with dummy priors. Estimated REER elasticities of export are rather close to those that were obtained in Bussière et al. (2010) (-0.75) and Isard and Faruqee, (1998) (-0.53). REER elasticities of import in our results are significantly higher: approximately 0.95 against 0.53 in Bussière et al. (2010) and 0.69 in Isard and Faruqee, (1998). However, the statistical significance of our result can be questioned due to the wide confidence intervals of IRFs.