COLLEGIUM OF ECONOMIC ANALYSIS
WORKING PAPER SERIES

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Kamila Kuziemska-Pawlak and Jakub Mućk

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Kamila Kuziemska-Pawlak † Jakub Mućk ‡

March 25, 2024

Abstract

This paper proposes an extension of the fundamental equilibrium exchange rate (FEER) model that accounts for the trade linkages within the Global Value Chains (GVCs). In the modified FEER framework, both backward and forward linkages are taken into consideration. To demonstrate the empirical relevance of the complex nature of existing trade linkages, the proposed FEER model is applied to analyze exchange rate fluctuations of the selected Central and Eastern European countries against the euro. It is documented that in Czechia, Hungary, and Poland the standard FEER framework predicts rapid appreciation of the equilibrium exchange rate after 2010, which implies deepening undervaluation of the actual real exchange rate towards the end of the analysed period. Instead, when the GVCs' linkages are taken into account in the framework, actual real exchange rates are broadly in line with the fundamental equilibrium exchange rates, and hence the missing real appreciation of the Czech krone, the Hungarian forint and the Polish zloty is to a large extent an equilibrium phenomenon.

Keywords: exchange rate, current account, foreign trade, Global Value Chains
JEL Classification Numbers: C32, C33, F12, F31, F32

*The views expressed herein belong to the authors and have not been endorsed by Narodowy Bank Polski. We would like to thank participants of 27th International Conference on Macroeconomic Analysis and International Finance in Rethymno as well as seminar participants at Narodowy Bank Polski for helpful comments and discussions.

†Narodowy Bank Polski, University of Lodz, Poland. E-mail addresses: kamila.kuziemska-pawlak@nbp.pl, kamila.kuziemska@uni.lodz.pl (K. Kuziemska-Pawlak). ORCID: 0000-0002-7409-8317.

‡Corresponding author. Narodowy Bank Polski, SGH Warsaw School of Economics, Poland. E-mail addresses: jakub.muck@nbp.pl, jakub.muck@sgh.waw.pl (J. Mućk). ORCID: 0000-0002-6345-3133.

Introduction

International macroeconomics and finance are replete with intriguing, empirical puzzles. One of them is the weak relationship (except, perhaps, in the long run) between the exchange rate and other macroeconomic variables (see: the purchasing power parity puzzle (Rogoff, 1996), the forecasting puzzle (Meese and Rogoff, 1983), the neutrality of exchange rate regime puzzle (Baxter and Stockman, 1989)). This points to difficulties in explaining the exchange rate behavior and computing the equilibrium exchange rate level. Nevertheless, the issue is of interest to both academics and policy institutions.[1] The real exchange rate is a key relative price. When it becomes significantly overvalued, it may hurt growth, endanger financial stability, and lead to currency crisis (see Chile in 1982, Mexico in 1982 and 1994, Finland in 1992; Dornbusch et al. (1995)).

This paper is linked to two strands of literature. The first is the literature on equilibrium exchange rates. There are several empirical approaches to estimating the equilibrium exchange rate (see Driver and Westaway, 2005). In this paper, we consider the fundamental equilibrium exchange rate model (hereafter, FEER). The term Fundamental Equilibrium Exchange Rate (FEER) was introduced by Williamson (1985), and was intended to connote the obverse of *fundamental disequilibrium* that provided the criterion for a parity change in the Bretton Woods system. Conceptually, the FEER is defined as the exchange rate that is consistent with macroeconomic balance, meaning the simultaneous achievement of both internal and external balance (Williamson, 1994, p. 179).

Another strand of literature is associated with the development of Global Value Chains (GVCs), which has been reorganizing global trade since 1970s. Due to trade and capital flow liberalization and the ICT revolution, production of goods has become fragmented and economies have become vertically specialized in stages of production, rather than particular products and services, within the GVC framework (see Baldwin, 2014; Amador and Cabral, 2016, for a detailed discussion). The development of GVCs and related changes in organization of global trade have changed the sensitivity of trade flows to fluctuations in exchange rates. If the backward participation in the GVC is high, which means a substantial dependence of export-oriented production on imported intermediates, then the responsiveness of net exports to movements in exchange rates is limited, since a depreciation of the exchange rate improves competitiveness but simultaneously increases the cost of imported intermediates (see Ahmed et al., 2017; de Soyres et al., 2021, for supportive evidence). Apart from backward, the cross-border linkages could be forward, which consist in exported intermediates being used (by the importing country) in export-oriented production. In this vein, de Soyres et al. (2021) provide empirical evidence that a more intensive forward participation could increase sensitivity of exports to movement in the exchange rate. Given this, the role of participation in GVCs in shaping net export elasticity probably depends on the particular stage of production process.

Our contribution is twofold. First, we incorporate the GVCs' linkages in an assessment of exchange rate equilibrium level. To do so, we modify the trade block within the FEER approach. In our framework, we allow for both backward and forward linkages that could be essential in an assessment of the role of demand factors in shaping trade flows as well as in an identification of real exchange rate elasticities. Second, we show the

[1] The assessment of exchange rates, apart from external positions, is a key mandate of the International Monetary Fund (IMF).

empirical relevance of the proposed framework. In particular, we study the exchange rates fluctuations in the selected Central European Economies (hereafter, CEE), i.e. Czechia, Hungary and Poland. Over the last 25 years these transition economies have benefited a lot from a tight economic integration within the GVC. Hagemejer and Mućk (2019) document that the growth in exported value added played a crucial role in the convergence of CEE countries towards advanced economies and was supported mostly by rising backward GVC participation and capital deepening in CEE economies.[2] We document that a standard FEER approach, which is broadly similar to the one found in previous studies for the CEE currencies (see Coudert and Couharde (2003), Bulir and Smidkova (2005), and Rubaszek (2009)), predicts fast appreciation of the equilibrium exchange rates in 2010s that is not coherent with the path of actual exchange rates. However, when the GVCs' linkages are incorporated in the framework, the missing real appreciation of the Czech krone, the Hungarian forint and the Polish zloty exchange rates is to a large extent an equilibrium phenomenon.

Our key empirical findings pass a number of robustness checks. First, we account for heterogeneity in trade flows by their decomposition into goods and services. Second, our estimates are robust to the definition of the target current account. Apart from the standard intertemporal solvency criterion, the TCA is additionally calculated in line with the saving and investment identity approach. Third, our key findings are valid even if we employ panel data estimation instead of a time series approach. It turns out that limiting potential structural heterogeneity between economies does not change the implication about exchange rate misalignment.

The rest of this paper is structured as follows. Section 1 presents the FEER model. Data and methodology are described in section 2. Section 3 provides baseline estimates of the standard and extended FEER for the CEE economies. The robustness of the results is discussed in section 4. The last section concludes.

1 The FEER model

In this section we provide a brief summary of the FEER model. Fundamental equilibrium exchange rate is the hypothetical level of the real exchange rate that is consistent with the simultaneous attainment of internal and external equilibrium. This can be synthesized as follows:

$$Y_{it} = YPOT_{it}, \tag{1}$$

$$YF_{it} = YFPOT_{it}, \tag{2}$$

$$UCA_{it}\left(FEER_{it}, \ldots\right) = TCA_{it}, \tag{3}$$

where i and t stand for the country and time index, respectively. Since the Y_{it} (YF_{it}) denotes aggregate demand at home (foreign) economy and $YPOT_{it}$ ($YFPOT_{it}$) is the domestic (foreign) potential output the conditions (1)-(2) mean that output gaps in the home and foreign economy are closed. Meanwhile, the (3) corresponds to the situation that UCA_{it} equals the so-called target current account (TCA_{it}).

[2] More generally, Constantinescu et al. (2019) provide empirical evidence that more intensive backward participation in GVC (higher share of imported intermediates) improves labor productivity.

In general, the UCA_{it} is the sum of the balance on trade ($X_{it}PX_{it} - M_{it}PM_{it}$), the primary income balance (CA_{it}^{PIB}) and the combined capital account balance and secondary income balance ($CA_{it}^{KA\_SIB}$):

$$UCA_{it} = X_{it}PX_{it} - M_{it}PM_{it} + CA_{it}^{PIB} + CA_{it}^{KA\_SIB}, \tag{4}$$

where PX_{it} and PM_{it} denote respectively price levels of exports and imports, X_{it} and M_{it} denote respectively volume of exports and imports.

At the center of the FEER model, there are foreign trade equations. In the associated literature, the flows of imports and exports are predominantly linked to three macroeconomic variables: relative prices, aggregate demand and economic potential (supply-side factors). In Armington (1969), export (import) volume depends on foreign (domestic) demand and the ratio of import price level to domestic price level, i.e. the real exchange rate.[3] A depreciation of the real exchange rate boosts demand for domestic goods, and increases the trade balance. In turn, high growth of domestic GDP leads to an increase in imports, and decreases the trade balance. In Gagnon (2007) real bilateral imports is a function of importer real expenditures, the ratio of price of imports and the price level of competing goods in the importing country and exporter and world real potential output. It is found that there is a strong correlation between the average growth of manufactured imports and the average growth rate of GDP in the exporting country.[4] In turn, following Rubaszek (2009), the logged aggregate volume of exports (denoted as x_{it}) can be described as follows:

$$x_{it} - yf_{it} = \beta_i^{x-yf,0} + \beta_i^{x-yf,ypot} ypot_{it} + \beta_i^{x-yf,rer} rer_{it} + \varepsilon_{it}^{x-yf}, \tag{5}$$

where yf_{it} is the (logged) demand abroad, $ypot_{it}$ is the (logged) potential output at home, ε_{it}^{x-yf} is the error term. The rer_{it} is the standard (logged) real exchange rate:

$$rer_{it} = py_{it} - pyf_{it} - e_{it}, \tag{6}$$

where the e_{it} denotes the (logged) nominal exchange rate, defined as the number of units of domestic currency per one unit of foreign currency, while py_{it} and pyf_{it} are the (logged) price indices at home and abroad, respectively.

To account for a potential heterogeneity between economies, we allow parameters to vary between countries. In (5) this translates into country-specific relative price ($\beta_i^{x-yf,rer}$) and potential output ($\beta_i^{x-yf,ypot}$) elasticities of real exports.

Likewise, the standard FEER equation for the real imports (m_{it}) can be defined as:

$$m_{it} - y_{it} = \beta_i^{m-y,0} + \beta_i^{m-y,ypoft} ypotf_{it} + \beta_i^{m-y,rer} rer_{it} + \varepsilon_{it}^{m-y}, \tag{7}$$

where y_{it} is the aggregate demand at home, $ypotf_{it}$ refers to the potential output abroad and ε_{it}^{m-y} captures the error term.

Both (5) and (7) are constructed under the assumption about a unitary demand elasticity of trade flow as in Bulir and Smidkova (2005) and Rubaszek (2009). Thus, both equations describe the ratio of particular flows to general aggregate demand.

[3] This approach to international trade modelling has been termed the *elasticities approach*.

[4] Long-term changes in potential output are assumed to be equal to long-term changes in actual output.

To account for complex trade linkages within the GVC, we redefine the equation (5) and (7). In the above form, demand for both exported and imported goods abstracts from forward and backward linkages. Therefore, in the GVC-extended FEER model, we consider the following modification for the real exports:

$$x_{it} = \beta_i^{x,0} + \beta_i^{x,ddf} ddf_{it} + \beta_i^{x,xf} xf_{it} + \beta_i^{x,fdi} fdi_{it} + \beta_i^{x,prod} prod_{it} + \beta_i^{x,rer} rer_{it} + \varepsilon_{it}^{x}, \quad (8)$$

where ddf_{it} is the (logged) domestic demand (absorption) abroad, xf_{it} is the (logged) real exports of foreign economy, fdi_{it} is the inward foreign direct investment (as a ratio to GDP), $prod_{it}$ is relative productivity, while ε_{it}^{x} denotes the error term. It should be noted that the parameter $\beta_i^{x,xf}$ would capture possible forward linkages. Assuming an important role of these linkages, one might expect that a rise in foreign exports requires exports of intermediates from the home economy to support export-oriented production in the foreign economy. Thus, a positive sign of $\beta_i^{x,xf}$ could be some suggestive evidence in favor of forward linkages.

In comparison to (5), there are two additional modifications in (8). First, we relax the standard assumption about unitary demand elasticity of gross real exports. Second, other supply-side exports' drivers are included in order to avoid the omitted variable problem, which can bias estimates of $\beta_i^{x,xf}$. To do so, we add relative general labor productivity and the FDI as control variables in (8). The latter should also measure potential import of technology that has enhanced productivity in the CEE economies since the 1990s.[5]

The backward linkages will be embodied in the equation describing real imports:

$$m_{it} = \beta_i^{m,0} + \beta_i^{m,dd} dd_{it} + \beta_i^{m,x} x_{it} + \beta_i^{m,rer} rer_{it} + \varepsilon_{it}^{m}, \quad (9)$$

where dd_{it} is domestic demand (absorption) at the home economy and ε_{it}^{m} is the error term. We incorporate exports as a driver of imports, in line with Comunale and Hessel (2014). This should capture imports of intermediates that are directly linked to the production for exports, and hence allow to measure the effect of backward GVCs' participation.

To sum up, the set of equations given by (1)-(3) allows to calculate both the standard and the GVC-extended FEER. In particular, any differences between these estimates will result from discrepancies in UCA_{it} that are related to corresponding trade blocks while CA_{it}^{PIB} and $CA_{it}^{KA\_SIB}$ will be adjusted to abstract from short-run variation and, more importantly, will be the same for both variants of the FEER model. In the standard approach the UCA_{it} will be calculated using estimates of (5) and (7) while the GVC-extended FEER will be based on estimation of (8)-(9).

2 Data and Methodology

In this section, we discuss our empirical strategy.

To measure macroeconomic processes, we compile several data sources and perform the necessary transformations. For the sake of brevity, we delegate a detailed description of variables and data sources to the Appendix A. In general, the home country is defined as Czechia, Hungary, and Poland, respectively, while the foreign country is defined as the

[5] In the associated literature, Bulir and Smidkova (2005) extend the exports equation by the FDI stock.

euro area. The national account data on seasonally adjusted nominal and real exports, imports, GDP, and domestic demand are taken from Eurostat (see A.1-A.3). Similarly, the data concerning the external sector, i.e. the current and capital accounts, primary and secondary income balances, net international investment position and foreign direct investment position, as well as the average nominal exchange rate against the euro, are taken from Eurostat. Finally, the data on labour productivity are taken from Eurostat, while the data on the annual output gap is taken from the OECD. When needed, time series' interpolation and extrapolation methods are applied (see A.1-A.3). Standard business cycles were isolated from the data by using a HP filter, with smoothing factor $\lambda = 1600$, for quarterly series.

The foreign trade models are estimated using data for the period 1996Q1-2021Q3, which translates into 103 quarterly observations in time series analysis (see A). The standard trade model, consisting of (5) and (7), is estimated with a typical SUR method (seemingly unrelated regression) to account for potential correlation of residuals between equations. For the GVC-extended trade model this approach would not be appropriate. Since we account for backward linkages (9), one might expect simultaneity, which could lead to an endogeneity problem. Therefore, the parameters of the system consisting of (8) and (9) are estimated using the three-stage least squares (3SLS) method, which combines typical two-stage least squares (2SLS) estimation with the SUR estimation.

In our baseline estimates of the FEER we incorporate the definition of the target current account based on intertemporal solvency. An economy is solvent if the present discounted value of future current account balances equals current external indebtedness. Lane and Milesi-Ferretti (1996) treat the current account deficit (surplus) as the positive (negative) increment to the stock of external liabilities and claim that the long-run net resource transfer that an indebted country must undertake in order to keep the debt to output ratio from increasing depends on the average future value of world interest rates, domestic growth, and the long-run trend in the real exchange rate.

In particular, we compute the level of the target current account, following Rubaszek (2009), who uses an extended version of the Lane and Milesi-Ferretti (2007) framework. In the medium term, the target current account might differ from null for the following reasons: i) in order to allow the adjustment of the net international investment position IIP_{it} to a steady-state level $\overline{IIP}$, ii) positive growth of nominal GDP ($Y_{it}PY_{it}$), iii) the presence of valuation effects (ve_{it}; Rubaszek, 2009):

$$tca_{it} = \rho\left(\overline{iip} - iip_{it-1}\right) + iip_{i,t-1}\left(\Delta py_{it} + \Delta y_{it}\right) - ve_{it}, \tag{10}$$

where the lower-case letters define the ratios with respect to GDP. The calibration of (10) is as follows. Following Rubaszek (2009), first we set the convergence pace, captured by ρ, to 0.025, and thus assume that within a quarter there is a decrease of 2.5% in the distance between the 1 period lag, actual and the steady-state level of the net international investment position. Second we take the growth rate of HP filtered values of the GDP deflator, as the growth rate of prices, Δpy_{it}, and potential output growth, as the growth rate of output, Δy_{it}. Third, we assume that valuation effects are equal to 1.0% of the lagged net international investment position to GDP ratio, iip_{it-1}. Finally, we assume the steady-state level of the net international investment position, $\overline{iip}$, to be -35% of annual GDP, which is the threshold for this indicator in the European Commission's

Macroeconomic Imbalance Procedure scoreboard.

The results of the calculated target current account are presented in figure B.1 in the Appendix. They show that the changes of the target current account balance, as a share of GDP, were mainly due to changes in the net international investment position to GDP ratio. With net foreign liabilities increasing between 2000 and the beginning of the 2010s, ensuring the country's solvency required an improvement of the target current account balance. Thereafter, a decrease in net foreign liabilities, as a ratio of GDP, allowed for a decrease of the target current account balance. Moreover, between 2000 and 2021, in general, the target current account was negatively affected by potential GDP growth, and positively affected by valuation effects.

3 Baseline results

In this section, we provide baseline results for the standard and the GVC-extended FEER models for the CEE currencies. We start with a discussion of estimates for the trade blocks.

Table C.1 contains an estimation results for the trade blocks. The first two columns present the results for the standard trade system. In both cases, it is assumed that foreign (domestic) real GDP elasticity of real exports (imports) is unitary while foreign and domestic potential output elasticities are the same. In the second column we additionally restrict the price elasticity of exports and imports to be opposite, because in initial estimates (1) for Czechia and Hungary the real exchange elasticity of exports is positive. Estimates in (2) highlight the role of supply-side factors, since the estimated potential output elasticity to exports is above unity and ranges from 1.7 to 3.3.

In the next step, we estimate the GVC-extended trade system (8)-(9). Our initial estimates (column (3) in table C.1) highlight the importance of both backward and forward trade linkages. In particular, the parameters capturing demand for imported intermediates, i.e. $\beta_i^{m,x}$ are quite high. To rationalize this number, we take long-run averages of the import content of gross exports (the share of foreign value added, hereafter FVA, in exports) which are calculated based on the World Input-Output Database (WIOD, Timmer et al., 2015).[6] The estimation results with these restrictions are in the column (4). In comparison to the standard trade system, the counterintuitive estimates of the real exchange elasticity of exports are now reported only for Hungary. For comparability, we also assume that price elasticities of trade flows are opposite. With these restrictions (column (5)) the estimates of the trade system still point at the important role of both forward and backward linkages. In addition, estimates of other supply side factors are statistically significant and in line with economic intuition.

Most of the series are not stationary. To avoid a risk of spurious regression, we run the stationarity test for the residuals. In general, the results for Czechia and Poland suggest stationarity of residuals. Importantly, in the case of the exports equation for Czechia, the

[6] In particular, we employ the method proposed by Wang et al. (2013), which allows us to estimate the share of FVA at the industry level for each economy. In this part, the country-specific weighted (by gross exports of industries) average is taken as a proxy. But in section 4.1 the weighted average will be calculated only for manufacturing, since the key structural difference between trade in goods and services, consisting in fragmentation of production referring mainly to trade in products, will be accounted into the estimation.

probabilities values are below the typical 5% level in the GVC-extended version, while in the standard approach it is hard to reject the null hypothesis of a unit root. This could confirm the role of complex trade linkages. For Hungary the results are more mixed.

Next, for illustrative purposes, we present the underlying current account estimates. In this regard, the UCA_{it} is the current account balance that would prevail if domestic and foreign output gaps were closed, trade volumes and prices were at their medium-term levels, and primary, secondary income balances and the capital account balance were adjusted for temporary factors. In addition, in our operational definition, we take the HP trend of primary income balance, combined capital account and secondary income balance as their proxy for the medium-term path.

The implied UCA_{it}, together with the actual and target current account, are portrayed on Figure B.2. Here, estimates of the GVC-extended trade system ((5) in table C.1) are utilized, while the real exchange rates correspond to their observations. It is straightforward to observe that the difference between the underlying current account and the target current account in Poland was the most evident in 2008Q3 (-6.7 pp, on the negative side) and in 2019Q4 (4.2 pp, on the positive side), in Hungary in 2004Q4 (-23.5 pp) and in 2017Q2 (10.7 pp). In turn, in the case of Czechia the underlying current account stood most evidently below the target current account in 2008Q3 (-11.2 pp), and above it in 2020Q4 (10.4 pp). The above differences between the underlying current account and the target current account will be crucial in identifying misalignment of exchange rates. Within the FEER concept, if the level of the underlying current account balance is above the level of the target current account balance, $UCA_{it}\left(RER_{it}, \ldots\right) > TCA_{it}$, the real exchange rate is undervalued. In contrast, if the level of the underlying current account balance is below the level of the target current account balance, $UCA_{it}\left(RER_{it}, \ldots\right) < TCA_{it}$, the real exchange rate is overvalued.

Finally, we estimate the FEER and the scale of exchange rate misalignment. The results are model-dependent due to differences in UCA_{it}. According to the estimates of the standard FEER model (column (2) in table C.1), while between 1996Q2 and 2011Q4 the FEER was broadly relatively stable, since 2012Q1 it has been appreciating persistently (Figure 1), resulting in a real exchange rate undervaluation of the CEE currencies towards the end of the analysed period (Figure B.4). Given the surprisingly long period of missing actual real exchange rate adjustment (appreciation) in the CEE economies, implied by the standard FEER model, the question was asked, whether the equilibrium is measured correctly and the GVC-extended FEER model was proposed. This long-lasting undervaluation is not observed for the GVC-extended FEER estimates. If complex trade linkages are taken into account, the scale of real equilibrium exchange rate appreciation, observed since 2012Q1, is smaller. On average, in this period according to the GVC-extended FEER estimates (column (5) in table C.1), the equilibrium exchange rate appreciated by 1.6% y/y in Czechia (5.1% according to model presented in column (2), table C.1), 3.4% in Poland (4.3%), and depreciated by 1.0% (appreciated by 6.0%) in Hungary (see Table 1), implying a reduction in the real exchange rate misalignment (compared to the standard FEER estimates).

To understand the above differences, we decompose the FEER changes based on both the standard (Figure 2, left panel) and the GVC-extended (Figure 2, right panel) model. In the case of the standard FEER approach, the changes in the equilibrium exchange rate depend to a large extent on three factors: changes in potential GDP in the respective

country and in the foreign country (the euro zone), changes in the target current account balance, and changes in the medium-term balance on the primary income, secondary income and capital account. The results of such decomposition show that one of the central arguments of the FEER changes in the CEE countries was the catching-up process. Faster growth of potential GDP in the CEE economies than in the euro area led to the appreciation of the FEER. Another source of the FEER changes, which is also related to the real convergence process, was the evolution of the net international investment position. An initial increase in net foreign liabilities and an associated rise in the target current account balance contributed to the depreciation of the FEER, while a subsequent decrease in net foreign liabilities and an associated decline in the target current account balance contributed to the appreciation of the FEER.

Table 1: Medium-run trends in the RER and FEER estimates (average annual growth rate, in %)

	1996Q2-2021Q3			2012Q1-2021Q3		
	CZE	HUN	POL	CZE	HUN	POL
Real exchange rate	2.2	1.7	1.0	0.3	−0.1	−0.3
Standard FEER	2.7	2.6	1.6	5.1	6.0	4.3
GVC-extended FEER	2.8	1.5	1.4	1.6	−1.0	3.4

Note: the standard FEER is based on the trade estimates in column (2) in table (C.1), while the GVC-extended FEER is calculated using the estimates in column (5) in table (C.1). A positive value stands for appreciation of the home currency.

Turning to the GVC-extended FEER estimates, the changes in the equilibrium exchange rate can be broadly attributed to two groups of factors: supply and demand but, in comparison to the standard FEER approach, in the GVC-extended framework, it is possible to identify particular supply-side channels. Most of them are related to the tight integration within the GVC. The FEER was supported by the CEE economies' forward linkages within GVCs, measured by exports of the euro zone. Integration within the EU, and reduction of barriers to trade led to the growth of intra-industry trade, which was manifested in the case of CEE countries in exports of intermediates that were used in the euro zone's final goods export production. Intra-company trade between Western and CEE economies was facilitated by considerable inflows of foreign direct investment. The contribution of both forward GVC participation and the inward FDI to GDP ratio to the changes in the FEER has been declining recently, which has been related to the ongoing slowdown of the globalization process since the beginning of the 2010s (see Cabrillac et al. (2016), Constantinescu et al. (2020) for empirical evidence).[7] Other supply-side factors enhancing export-oriented production are captured by the non-negligible role of relative labor productivity. In this context, the CEE economies have experienced a spectacular boost in labor productivity in the analysed period.[8] The rise in total factor productivity and capital deepening seemed to be key forces behind export-oriented production. Finally, the FEER was supported by the improvement of the terms of trade, probably due to a

[7]The situation is a bit peculiar in the case of Hungary, where between 2017Q1 and 2021Q3 inward FDI contributed positively to FEER changes.

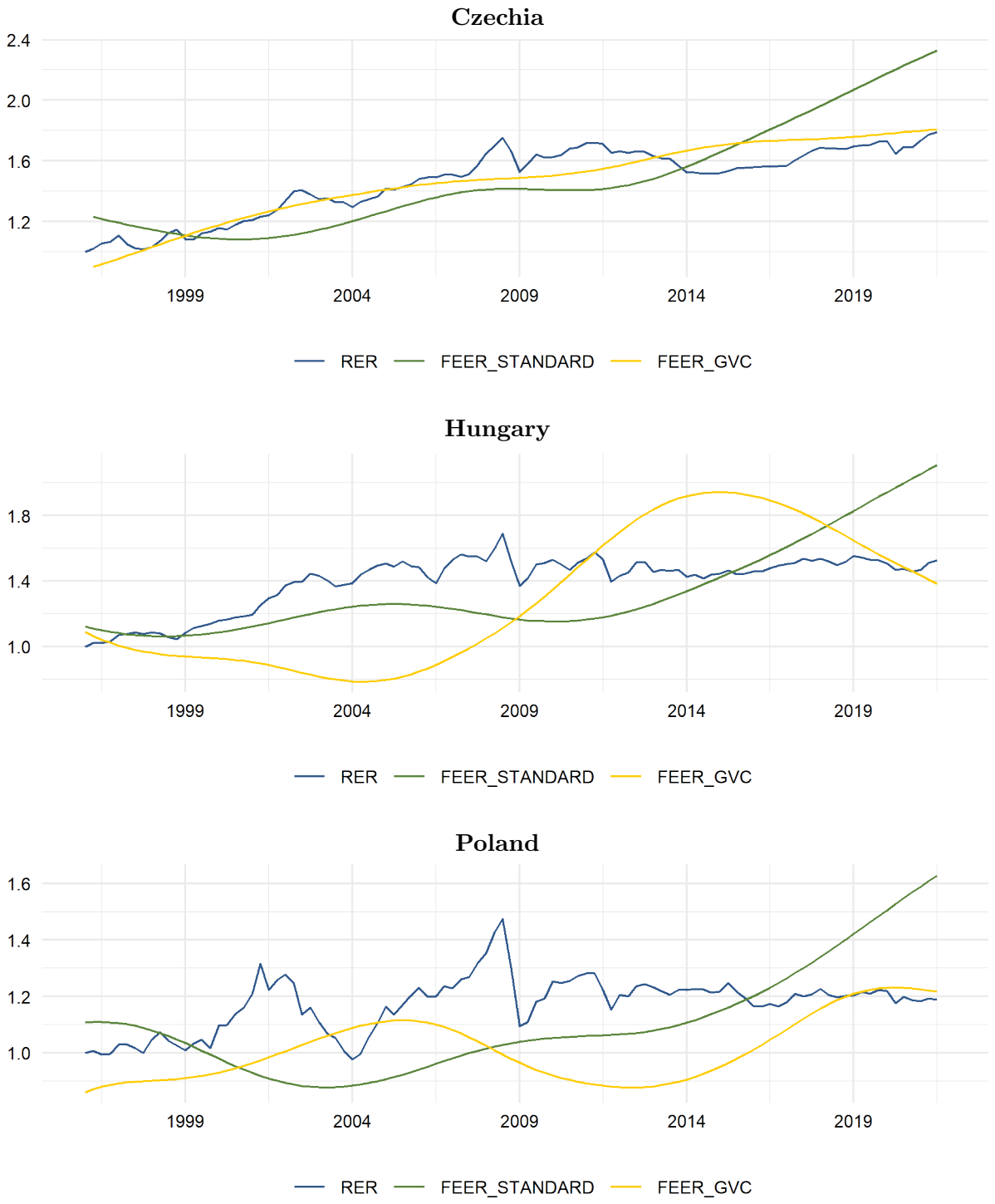
[8]Between 1995Q1 and 2021Q3 the real labor productivity (per hour worked) increased by 81% in Czechia, by 82% in Hungary, and by 154% in Poland while this gain in the euro zone was around 29%.

substantial upgrade of the CEE exports.[9]

At the same time, the above supply-side effects were limited by demand side effects in the CEE economies. Higher disposable income growth in the CEE countries, compared to the euro zone, which was associated with the CEE's real convergence process, required imports of both consumption and investment goods and hence resulted in the depreciation of the FEER. It needs to be stressed that the role of this factor is not identified in the standard FEER model due to the assumption (restriction) of unitary demand elasticity of trade flows. Finally, the role of the international investment position is consistent with the estimates of the standard FEER model because the target current account balance is conceptually the same in the standard FEER and GVC-extended FEER framework.

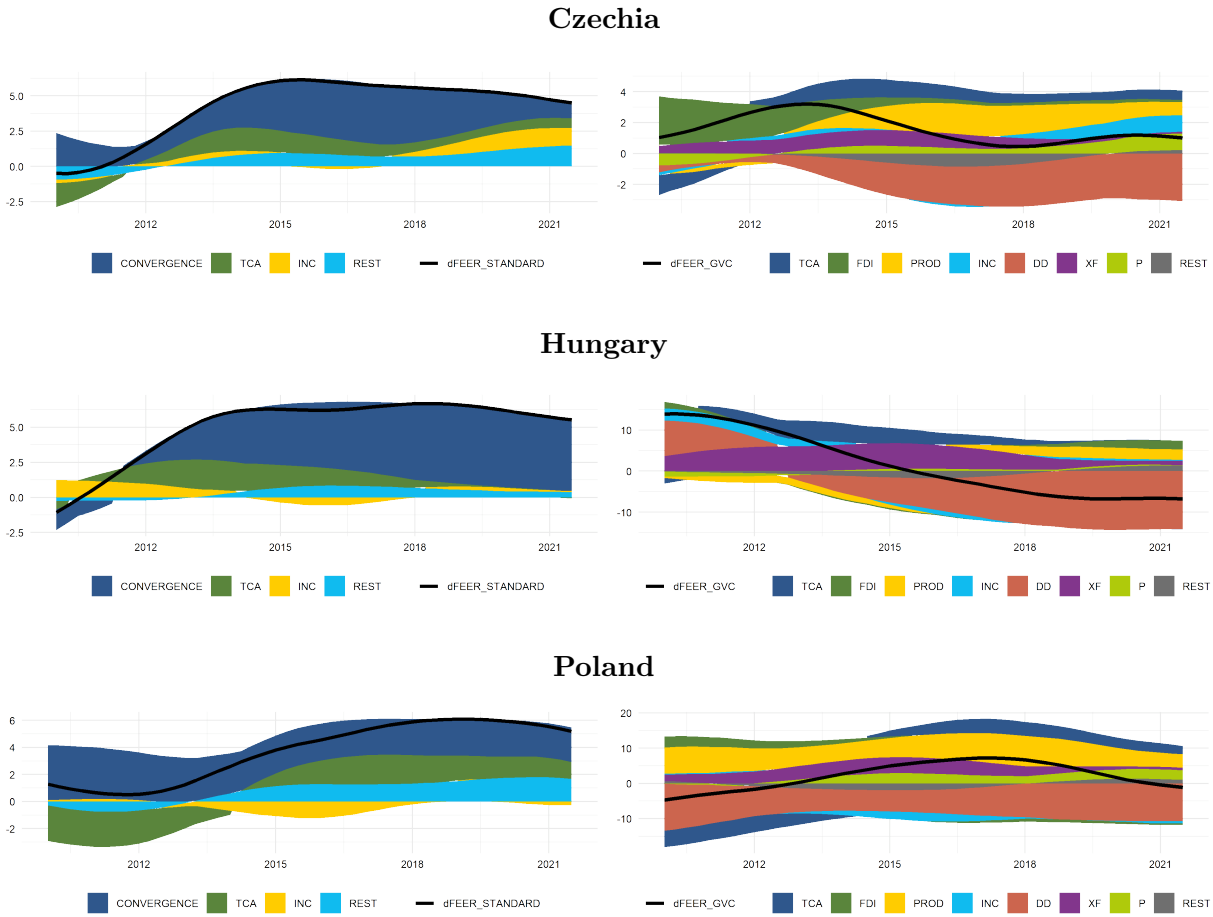
[9] Benkovskis and Rimgailaite (2011) found that all New EU Member States were able to increase the average quality of their exports to the EU during the period 1999-2009.

Figure 1: Baseline FEER estimates (RER level as of 1996Q1=1)



Note: the standard FEER is based on the trade estimates in column (2) in table (C.1), while the GVC-extended FEER is calculated using the estimates in column (5) in table (C.1). An increase in the real exchange rate stands for appreciation of the home currency.

Figure 2: Decomposition of the FEER changes (y/y, in % and pp.)



Note:
The standard FEER (left panels): dFEER_STANDARD – annual change in the standard FEER (specification 2 in table C.1), CONVERGENCE – difference between change in potential GDP in the respective country and the foreign country (euro area), TCA – level of target current account balance, INC – level of primary income balance, secondary income balance, and capital account balance, REST - the unexplained. The starting point of the decomposition is 2009Q1.
The GVC-extended FEER (right panels): dFEER_GVC – annual change in the GVC-extended FEER (specification 5 in table C.1), TCA – level of target current account balance, FDI – foreign direct investment position as a share of GDP (HP), PROD – HP-filtered difference in log productivity in respective country and the log productivity in the foreign country, INC – level of balance on primary income, secondary income, and capital account, DD – change of HP-filtered logarithm of real demand in respective country at the level of the change of HP-filtered logarithm of real demand in the foreign country, XF – products and services exports of the foreign country (log, HP), P – change in HP-filtered exports (same for imports) prices at the level of the change in HP-filtered domestic prices, REST - the unexplained. The starting point of the decomposition is 2009Q1.

4 Robustness check

In this section we provide the robustness check. The FEER is computed as the level of the real exchange rate that equates the underlying current account with its target or equilibrium level. Hence, the FEER is as viable as the underlying and target current accounts. Thus, we address the sensitivity of the FEER results to (i) the specification of the foreign trade model, (ii) the method of calculating the equilibrium or target current

account balance, (iii) using panel estimation instead of the standard time series approach.

4.1 Disaggregated trade model

Our first robustness check is related to more disaggregated specification of the trade model. In our baseline setup it is assumed that traded goods are homogenous and, therefore, demand for them is determined by the same set of factors. To relax this assumption, the demand equations are subsequently divided into two broad categories: products and services. One of the key advantages of such classification is the fact that, at the industry level, on-going international fragmentation of production has been affecting manufacturing rather than services. If so, then at least structural parameters capturing the import content of gross exports are, by construction, different and assuming their homogeneity could lead to substantial bias in price elasticities as well as other underlying parameters.

To account for potential discrepancies between products and services, we consider the four-equation system. The demand for exported products can be described as in our baseline specification (see eq. (8)):

$$xg_{it} = \beta_i^{xg,0} + \beta_i^{xg,xgf} xgf_{it} + \beta_i^{xg,ddf} ddf_{it} + \beta_i^{xg,prod} prod_{it} + \beta_i^{xg,fdi} fdi_{it} + \beta_i^{xg,rer} rer_{it} + \varepsilon_{it}^{xg}, \quad (11)$$

where xg_{it} is the real exports of products and the ε_{it}^{xg} is the error term. In addition, to capture the forward linkages, in eq. (11) we replace xf_{it} by real exports of products xgf_{it}. The reason for that is the fact that forward linkages highlight the role of exporting intermediates that are further used in export-oriented production. Therefore, the exports of only products from the euro area is a better proxy of forward linkages than exports of products and services.

The same applies to demand for imported products, which is assumed to be similar as in the baseline (see eq. (9)):

$$mg_{it} = \beta_i^{mg,0} + \beta_i^{mg,dd} dd_{it} + \beta_i^{mg,xg} xg_{it} + \beta_i^{mg,rer} rer_{it} + \varepsilon_{it}^{mg}, \quad (12)$$

where mg_{it} is the real imports of products and the ϵ_{it}^{mg} is the error term.

As the international fragmentation affected products more than services, as regards services we will consider the more standard approach that links external demand for services only to income and prices. Accordingly, the real imports of services (denoted as ms_{it}) depends on the real exchange rate and domestic demand:

$$ms_{it} = \beta_i^{ms,0} + \beta_i^{ms,dd} dd_{it} + \beta_i^{ms,rer} rer_{it} + \varepsilon_{it}^{ms}, \quad (13)$$

where ϵ_{it}^{ms} is the error term.

In analogous fashion, demand for exported services could take the following form:

$$xs_{it} = \beta_i^{xs,0} + \beta_i^{xs,dd} dd_{it} + \beta_i^{xs,prod} prod_{it} + \beta_i^{xs,rer} rer_{it} + \varepsilon_{it}^{xs}, \quad (14)$$

where xs_{it} is the real exports of services and ϵ_{it}^{xs} denotes the error term. In comparison to (13), we extend the standard demand equation with relative labor productivity. This choice stems from the fact that the CEE economies have benefited a lot from a substantial rise in labor productivity. At the industry level, this improvement in the general efficiency

took place also in services. At the same time, the production in the services is based to a larger extent on labor while capital plays only a limited role. Thus, the general labor productivity seems to be a good proxy for supply-side factors supporting export-oriented production.

The estimation results for the system described by (11)-(14) are reported in the tables C.2-C.4. As previously, the parameters for each country are separately estimated with the 3SLS estimator. For each economy we consider the same set of specifications. In the first specification, we only impose the restriction that the elasticity of the imported goods to changes in domestic demand is the same as the export's elasticity to changes in foreign demand, i.e. $\beta_i^{mg,dd} = \beta_i^{xg,ddf}$ and $\beta_i^{ms,dd} = \beta_i^{xs,ddf}$. Although most of the estimates are in line with economic intuition, for Hungary the price elasticity of goods exports is positive, while for Czechia it is not statistically significant. To rationalize these estimates, we restrict parameters capturing the import content of gross exports to be consistent with the estimates from WIOD. These estimates are tabulated in columns (2)-(4) of tables C.2-C.4. However, it still does not ensure that all price elasticities have the expected signs. Therefore, we subsequently impose the previous restrictions: the price elasticity of imports and exports are opposite for trade in products (column 3, $\beta_i^{mg,rer} = -\beta_i^{xg,rer}$) and, finally, we also add the same restriction for services (column 4, $\beta_i^{ms,rer} = -\beta_i^{xs,rer}$).

Although the estimation results of the trade model reveal interesting features about differences between the international trade in services and products, they do not change our key findings. The implied FEER trajectories are depicted in figure B.5. It is straightforward to observe that the trajectory of equilibrium exchange rates is quite similar to the baseline estimates and, importantly, does not predict very fast appreciation in the 2010s, resulting in substantial real exchange rate undervaluation.

Moving to the key drivers of the FEER dynamics, the general picture is the same as in the baseline calculations. Viewed from the supply side perspective, the equilibrium exchange rates in CEE economies has been broadly supported by improvement in labor productivity as well as a tight integration within GVCs (see figure B.7). Relative (to foreign economy) domestic demand has mostly limited the FEER appreciation since the real convergence in incomes has been fast during this period. Finally, an improvement in the net international investment position also broadly supported the FEER appreciation.

4.2 Alternative target current account

In the second robustness check we redefine the target current account. In this regard, there are two main approaches. The first one is related to intertemporal solvency of economy, while the second one is based on the relationship between saving and investment. To check whether our key findings are sensitive to the baseline choice, we perform the FEER calculation for the second approach.

Generally, it is assumed that the current account balance is equal to the sum of the budget balance and the private saving-investment gap. The empirical application of this approach involves the panel or cross-sectional data estimation of a reduced-form equation, relating the current account to a number of variables, which have an impact on saving and investment, e.g. (relative) income *per capita*, demographic variables, budget balance, terms of trade volatility (e.g. Chinn and Prasad, 2003; Chinn and Ito, 2007; Ca' Zorzi et al., 2012; Chinn and Ito, 2022).

In the current study, we use the recent strategy employed by Kuziemska-Pawlak and Mućk (2020), who regress the current account on income *per capita*, budget balance and lagged net international investment position. Because Kuziemska-Pawlak and Mućk (2020) provide the so-called structural current account estimates on annual data, we extrapolate their estimates to quarterly frequency. All necessary transformations are described in table A.3.

As in section 3, we perform the FEER calculations for the standard and baseline GVC-extended trade models. All these implied trajectories are portrayed in figure B.3. Clearly, our key findings are still valid. Namely, by accounting for complex linkages within the GVC, the appreciation of equilibrium exchange rates is not so fast and the FEER estimates exhibit a non-monotonic pattern. At the same time, the non-GVC FEER estimates suggest a quite fast and almost monotonic appreciation, which implies a strong decoupling between the observed and equilibrium real exchange rates.

Turning to the FEER decomposition, it is straightforward to see that the key drivers of the changes in FEER are the same as in the baseline case. Equilibrium exchange rates in the considered CEE economies have been supported by mostly supply-side factors, i.e. intensive activity within the GVC and a substantial rise in labor productivity. Importantly, as globalization slowed down after the Global Financial Crisis, the role of the GVC-related factors has been diminishing since the beginning of 2010s. On the other hand, the FEER has been weakened by domestic demand, which rose more rapidly than its foreign counterpart (the euro zone). Finally, the FEER was weakened by the changes in the structural current account (B.8). This observation lies in stark contrast to the baseline estimates of the FEER. The opposite contributions are strictly related to conceptually different definitions of the *desired* current account. The structural current account is estimated according to the criterion of consistency with the economic fundamentals (CA *norm*). In turn, the target current account is calculated according to the criterion of prudence against the the risk of a balance of payments crisis (CA *prudential* threshold). This implies different patterns of the *desired* current account over time. In particular, the estimated, structural current account gradually increases, which requires a weaker exchange rate to stimulate exports and reduce imports. In contrast, the target current account goes down after reaching country-specific peaks (2012 in Czechia, 2011 in Hungary and 2014 in Poland). In these cases, an appreciation of the exchange rate would allow to achieve external equilibrium by deteriorating the trade balance. Besides, it should be noted that the role of the structural current account is almost negligible in shaping the FEER.

4.3 Panel estimation of the trade model

In our last robustness check we use the panel estimation instead of the country-specific time series approach. There is a natural trade-off between these approaches. Panel data estimation naturally boosts the efficiency of the estimation of underlying parameters. But the potential pitfall of pooling all the observations is that it ignores heterogeneity between economies.

In our study, we use the fixed effect estimation of the system consisting of equations (5), (7)-(9). This translates into a set of restrictions on all parameters between countries except the constant terms which are still allowed to vary between economies. As previously, we

use the SUR estimation for the standard FEER model while the 3SLS estimation is used in the GVC-extended FEER. The corresponding estimates for the standard non-GVC trade model are in the first column of table C.5. As previously, we impose an additional restriction on price elasticities to mitigate the effect of the counterintuitive sign of the price elasticity of exports. These estimates are in the second column in table C.5. In the case of the trade model extended with the GVC linkages, we also allow for different parameters measuring backward linkages (column (3) in table C.5). We additionally fix these parameters (column (4) in table C.5) and, for the sake of comparison between various specifications, we impose a restriction postulating the opposite sign for the prices elasticities of the trade flows, i.e. $\beta^{m,rer} = -\beta^{x,rer}$ (columns (5) in table C.5). All these estimates are in corresponding ranges derived from country-specific results. The estimates for the GVC-extended disaggregated trade model are in table C.6.

Combining the panel estimates with the country-specific calculations of the FEER for the selected CEE economies, it can be found that the panel estimation does not change our results. In fact, the trajectory for the standard non-GVC FEER exhibits substantial appreciation resulting in increasing undervaluation of the real exchange rate. When the complex linkages within the GVC are taken into consideration, the FEER trajectories become non-monotonic, which does not support the hypothesis about permanent undervaluation of the currencies of interest.

5 Concluding remarks

The aim of this paper is to extend the fundamental equilibrium exchange rate model by the trade linkages within the Global Value Chains. We document the empirical relevance by applying the model to analyze exchange rate fluctuations of the CEE economies. It turns out that the application of the standard FEER model (see e.g. Rubaszek (2009)) points at permanent appreciation of the CEE currencies between 2012Q1 and 2021Q3. But, this appreciation is not confirmed by the data - actually, the real exchange rates of Czechia, Hungary, and Poland were broadly stable in this time span. Such a long period of missing real appreciation calls into question the way the equilibrium exchange rate is measured. This motivates us to propose an extension of the standard FEER model (e.g. Coudert and Couharde (2003); Bulir and Smidkova (2005)) which takes into account the CEE economies' participation in GVCs.

In the GVC-extended framework, real equilibrium exchange rate changes can be broadly attributed to two groups of factors: supply and demand. Most of them are related to the tight integration within GVC. The FEER was supported by CEE forward GVC linkages, measured by exports of the euro zone, inward foreign direct investment, the increase in relative labor productivity, and the improvement in terms of trade. At the same time, the above supply-side effects were limited by demand-side effects in the CEE economies. Higher disposable income growth in the CEE countries, compared to the euro zone, resulted in the depreciation of the FEER.

Taking all these complex mechanisms into account, we are able to explain the exchange rate fluctuations of the CEE currencies over broadly the last two decades. We find that the missing real appreciation of the Czech krone, the Hungarian forint and the Polish zloty against the euro, observed since 2012, was to a large extent an equilibrium phenomenon.

What do our results imply? If interdependencies within GVCs are not accounted for in the real equilibrium exchange rate framework, this can lead to overestimation of the level of the real equilibrium exchange rate, and resulting inaccurate conclusions on the real exchange rate undervaluation of the CEE currencies. The question remains whether similar patterns can be drawn in other Emerging Market countries. We hope to open the door for broader research on the link between the real equilibrium exchange rate and the geography of global production within GVCs.

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A Description of variables

Table A.1: Variables used in the estimation of the foreign trade model, data description and sources

Variable	Description	Source
x_{it}	(Logged) Real exports. Domestic economy. Description: Exports of goods and services, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
xg_{it}	(Logged) Goods real exports. Domestic economy. Description: Exports of goods, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
xs_{it}	(Logged) Services real exports. Domestic economy. Description: Exports of services, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
xf_{it}	(Logged) Real exports. Foreign economy. Description: Exports of goods and services, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
xgf_{it}	(Logged) Goods real exports. Foreign economy. Description: Exports of goods, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
m_{it}	(Logged) Real imports. Domestic economy. Description: Imports of goods and services, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
mg_{it}	(Logged) Goods real imports. Domestic economy. Description: Imports of goods, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
ms_{it}	(Logged) Services real imports. Domestic economy. Description: Imports of services, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
dd_{it}	(Logged) Real demand. Domestic economy. Description: Final consumption expenditure and gross capital formation, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
ddf_{it}	(Logged) Real demand. Foreign economy. Description: Final consumption expenditure and gross capital formation, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data.	Eurostat, own calculations.
rer_{it}	(Logged) Real exchange rate. Domestic economy. Description: GDP deflator in domestic economy divided by the product of GDP deflator in foreign economy and national currency against the euro average exchange rate.	Eurostat, own calculations.
$prod_{it}$	(Logged) Relative productivity. Domestic economy. Description: The ratio of Real labour productivity per hour worked (index, 2015=100, seasonally and calendar adjusted data) in Home economy to Real labour productivity per hour worked (index, 2015=100, seasonally and calendar adjusted data) in Foreign economy.	Eurostat, own calculations.
$ypot_{it}$	(Logged) Potential GDP. Domestic economy. Description: Exp of HP filtered ($\lambda = 1600$) log Potential output {GDP (volumes, seasonally and calendar adjusted data) divided by [1 + output gaps (deviations of actual GDP from potential GDP as % of potential GDP; interpolated from annual to quarterly)]}.	Eurostat and OECD data, own calculations.
$yfpot_{it}$	(Logged) Potential GDP. Foreign economy. Description: Exp of HP filtered ($\lambda = 1600$) log Potential output {GDP (volumes, seasonally and calendar adjusted data) divided by [1 + output gap (deviation of actual GDP from potential GDP as % of potential GDP; interpolated from annual to quarterly)]}.	Eurostat and OECD data, own calculations.
fdi_{it}	Share of foreign direct investment in annual GDP. Domestic economy. Description: Financial account; Direct Investment (liabilities; positions at the end of period, million units of national currency) divided by [4 times Gross domestic product at market prices (million units of national currency, seasonally and calendar adjusted data)]; %. FDI data interpolation using Denton-Cholette method for Czechia (1996Q1-1999Q4), Poland (1996Q1-2003Q4).	Eurostat, own calculations.

Table A.2: Data used in FEER calculations, descriptions and sources

Variable	Description	Source
PX_hp_{it}	Exports deflator. Domestic economy. HP. Description: Exports of goods and services (current prices, million units of national currency, seasonally and calendar adjusted data) divided by Exports of goods and services (chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data). HP filter.	Eurostat, own calculations.
PXG_hp_{it}	Goods exports deflator. Domestic economy. HP. Description: Exports of goods (current prices, million units of national currency, seasonally and calendar adjusted data) divided by Exports of goods (chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data). HP filter.	Eurostat, own calculations.
PM_hp_{it}	Imports deflator. Domestic economy. HP. Description: Imports of goods and services (current prices, million units of national currency, seasonally and calendar adjusted data) divided by Imports of goods and services (chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data). HP filter.	Eurostat, own calculations.
PMG_hp_{it}	Goods imports deflator. Domestic economy. HP. Description: Imports of goods (current prices, million units of national currency, seasonally and calendar adjusted data) divided by Imports of goods (chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data). HP filter.	Eurostat, own calculations.
PMS_hp_{it}	Services imports deflator. Domestic economy. HP. Description: Imports of services (current prices, million units of national currency, seasonally and calendar adjusted data) divided by Imports of services (chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data). HP filter.	Eurostat, own calculations.
PIB_hp_{it}	Balance on current transfers. Domestic economy. HP. Description: Primary income balance (million units of national currency). Data backward extrapolation for Poland: 1996Q1-2003Q4. HP filter.	Eurostat.
$KA\_SIB\_hp_{it}$	Balance on income. Domestic economy. HP. Description: Sum of capital account and secondary income balance (million units of national currency). Data backward extrapolation for Poland: 1996Q1-2003Q4. HP filter.	Eurostat, NBP data, own calculations.
IIP_{it}	Net international investment position to GDP ratio. Domestic economy. Description: Net international investment position [(financial account, net positions at the end of period, million units of national currency), HP filter] divided by quarterly nominal potential GDP [(GDP deflator, HP filter) multiplied by Potential GDP], per cent. Backward extrapolation of net international investment position data for Poland: 1996Q1-2003Q4. Interpolation of net international investment position data using Denton-Cholette method for Czechia for 1996Q1-1999Q4.	Eurostat.
xf_hp_{it}	(Logged) Real exports. Foreign economy. HP. Description: Exports of goods and services, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data. HP filter.	Eurostat, own calculations.
xgf_hp_{it}	(Logged) Goods real exports. Foreign economy. HP. Description: Exports of goods, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data. HP filter.	Eurostat, own calculations.
dd_hp_{it}	(Logged) Real demand. Domestic economy. HP. Description: Final consumption expenditure and gross capital formation, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data. HP filter.	Eurostat, own calculations.
ddf_hp_{it}	(Logged) Real demand. Foreign economy. HP. Description: Final consumption expenditure and gross capital formation, chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data. HP filter.	Eurostat, own calculations.
PY_hp_{it}	GDP deflator. Domestic economy. HP. Description: Gross domestic product (current prices, million units of national currency, seasonally and calendar adjusted data) divided by gross domestic product (chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data). HP filter.	Eurostat, own calculations.
PYF_hp_{it}	GDP deflator. Foreign economy. HP. Description: Gross domestic product (current prices, million units of national currency, seasonally and calendar adjusted data) divided by gross domestic product (chain linked volumes (2010), million units of national currency, seasonally and calendar adjusted data). HP filter.	Eurostat, own calculations.
$YPOT_{it}$	Potential GDP. Domestic economy. Description: Exp of HP filtered ($\lambda = 1600$) log Potential output {GDP (volumes, seasonally and calendar adjusted data) divided by [1 + output gaps (deviations of actual GDP from potential GDP as % of potential GDP; interpolated from annual to quarterly)]}.	Eurostat, OECD, own calculations.

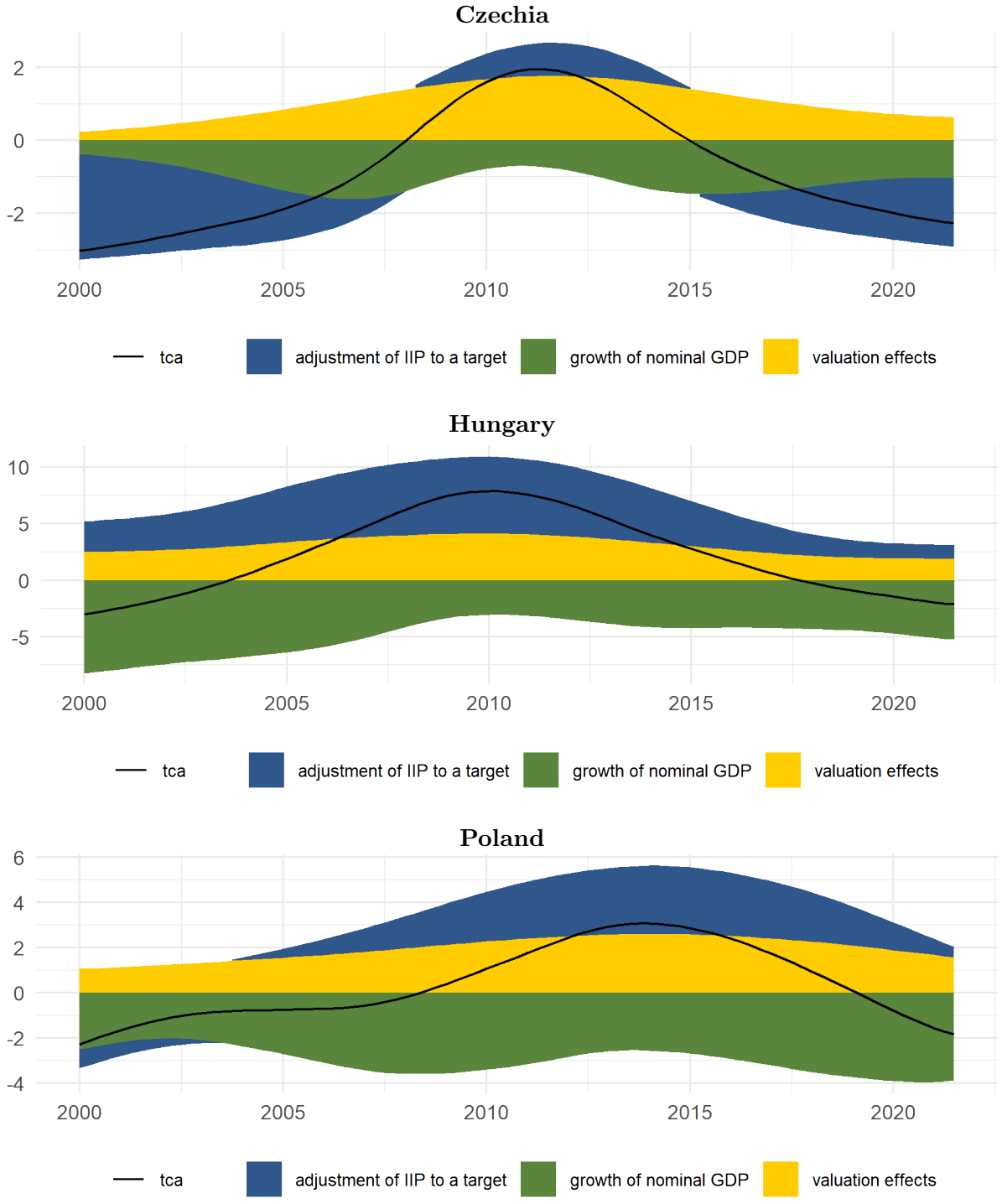
$YFPOT_{it}$	Potential GDP. Foreign economy. Description: Exp of HP filtered ($\lambda = 1600$) log Potential output {GDP (volumes, seasonally and calendar adjusted data) divided by [1 + output gaps (deviations of actual GDP from potential GDP as % of potential GDP; interpolated from annual to quarterly)]}.	Eurostat, OECD, own calculations.
fdi_hp_{it}	Share of foreign direct investment in annual GDP. Domestic economy. HP. Description: Financial account; Direct Investment (liabilities; positions at the end of period, million units of national currency) divided by [4 times Gross domestic product at market prices (million units of national currency, seasonally and calendar adjusted data)]; %. FDI data interpolation using Denton-Cholette method for Czechia (1996Q1-1999Q4), Poland (1996Q1-2003Q4). HP filter.	Eurostat, own calculations.

Table A.3: Variables used in SCA extrapolation, data description and sources

Variable	Description	Source
GGB_hp_{it}	Fiscal balance, share of GDP. Domestic economy. Description: Net lending (+) /net borrowing (-) of general government (seasonally and calendar adjusted data, % of GDP). HP filter.	Eurostat, own calculations.
$GGBF\_hp_it$	Fiscal balance, share of GDP. Foreign economy. Description: Net lending (+) /net borrowing (-) of general government (seasonally and calendar adjusted data, % of GDP). HP filter.	Eurostat, own calculations.
$YPOT_{it}$	Potential GDP. Domestic economy. Description: Exp of HP filtered ($\lambda = 1600$) log Potential output {GDP (volumes, seasonally and calendar adjusted data) divided by [1 + output gaps (deviations of actual GDP from potential GDP as % of potential GDP; interpolated from annual to quarterly)]}.	Eurostat and OECD data, own calculations.
$YFPOT_{it}$	Potential GDP. Foreign economy. Description: Exp of HP filtered ($\lambda = 1600$) log Potential output {GDP (volumes, seasonally and calendar adjusted data) divided by [1 + output gaps (deviations of actual GDP from potential GDP as % of potential GDP; interpolated from annual to quarterly)]}.	Eurostat and OECD data, own calculations.
IIP_{it}	Net international investment position to GDP ratio. Domestic economy. Description: Net international investment position [(financial account, net positions at the end of period, million units of national currency), HP filter] divided by quarterly nominal potential GDP [(GDP deflator, HP filter) multiplied by Potential GDP], per cent.	Eurostat, OECD data, own calculations.

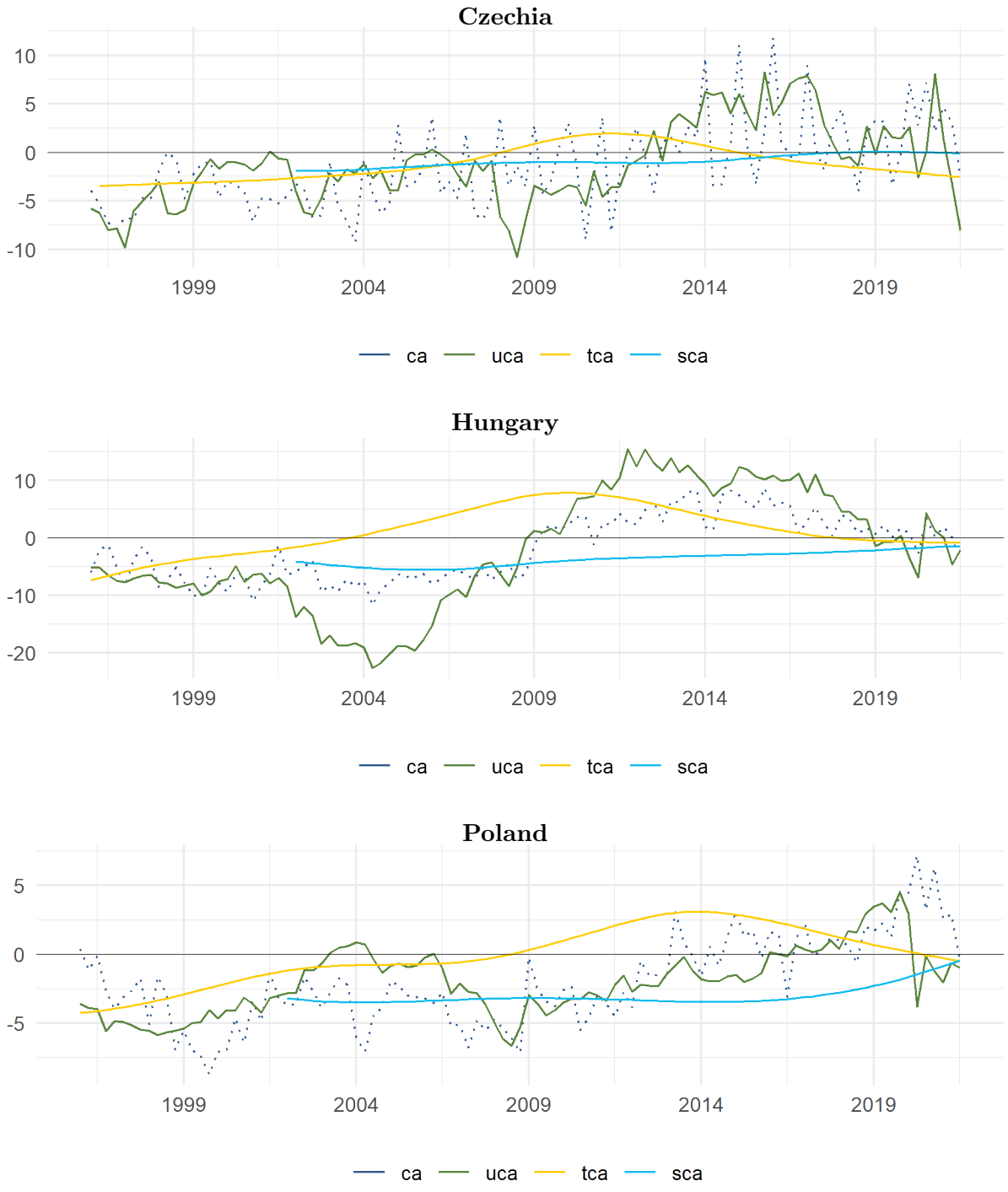
B Additional figures

Figure B.1: Target current account (in % of GDP)



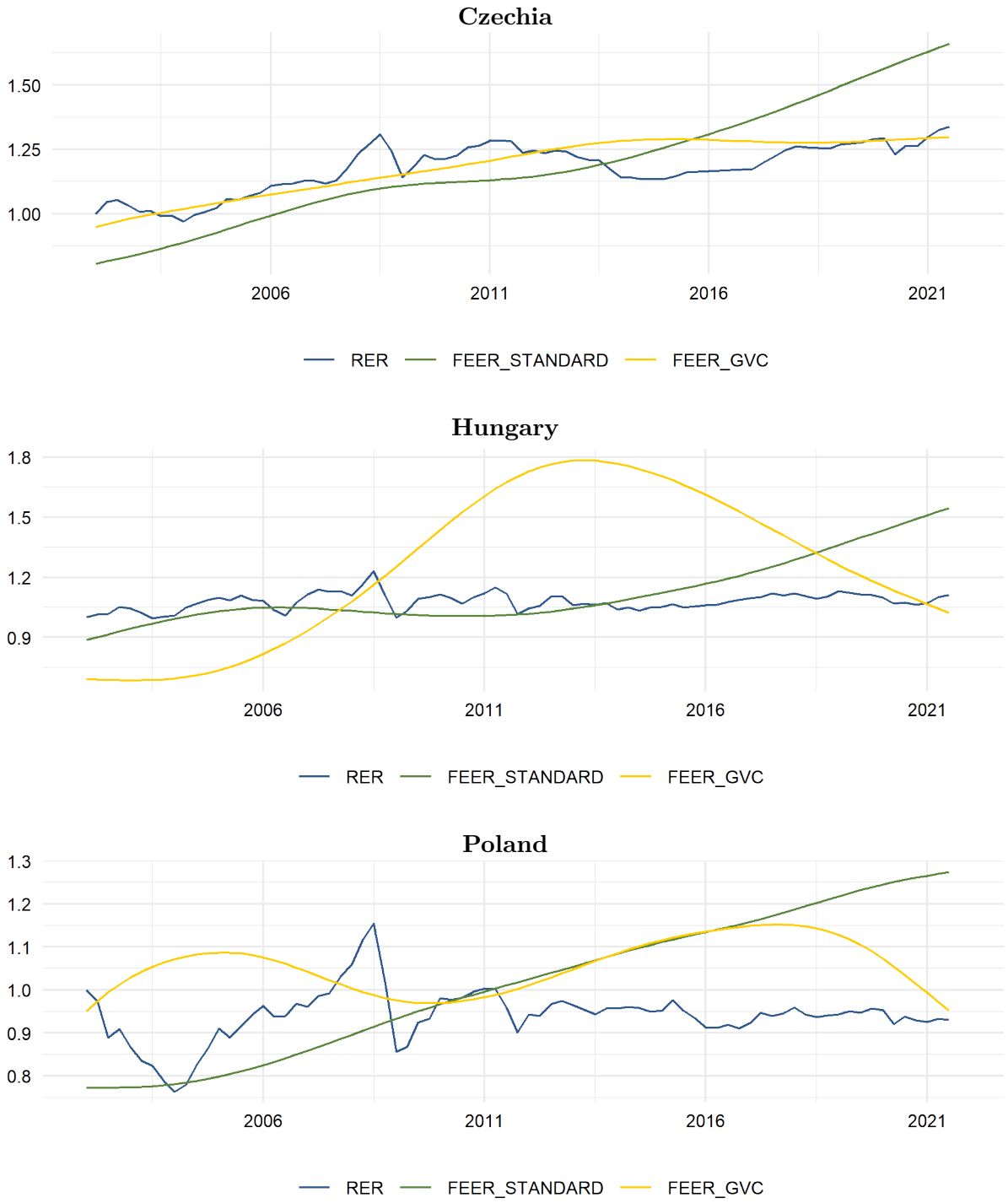
Note: target current account (as a share of GDP; (tca, eq. (10))) can be decomposed into the three following elements: i) adjustment of IIP to a target: $\rho(\overline{iip} - iip_{it-1})$, ii) growth of nominal GDP: $b_{i,t-1}(\Delta py_{it}+\Delta y_{it})$, and valuation effects: ve_{it}.

Figure B.2: Actual, underlying, target, structural current account in the CEE economies (in % of GDP)



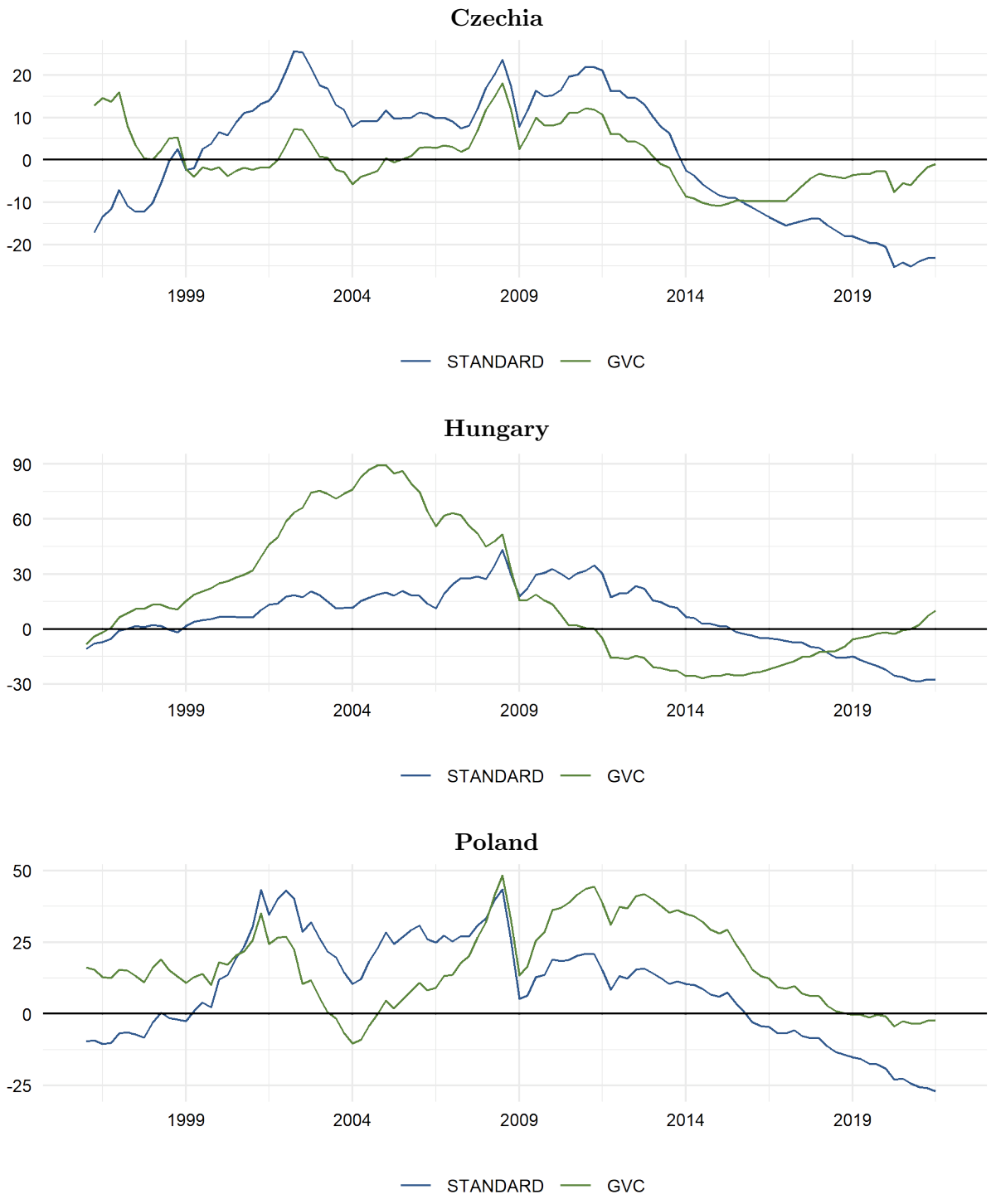
Note: underlying current account (uca) is calculated according to eq. (4) and using the estimates in column (5) in table (C.1), target current account (tca) is calculated according to eq. (10), and structural current account (sca) is calculated according to methodology presented in Kuziemska-Pawlak and Mućk (2020)).

Figure B.3: FEER estimates based on the Structural Current Account (RER level as of 1996Q1=1)



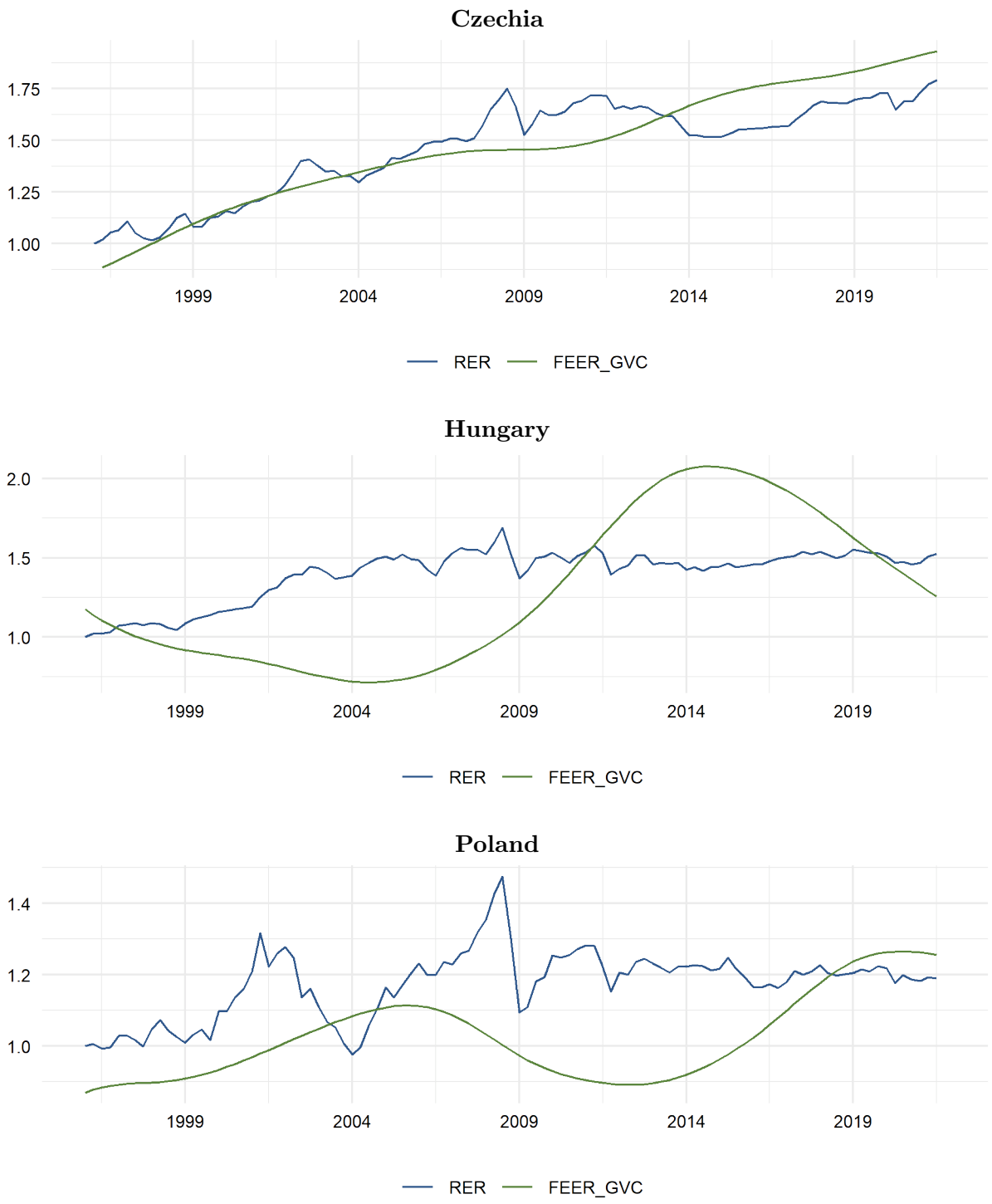
Note: the standard FEER is based on the trade estimates in column (2) in table (C.1), while the GVC-extended FEER is calculated using the estimates in column (5) in table (C.1). For both standard FEER and GVC-extended FEER, the desired current account is the structural current account, calculated according to the methodology presented in Kuziemska-Pawlak and Mućk (2020). An increase in the real exchange rate stands for appreciation of home currency.

Figure B.4: Deviation of RER from FEER, in %



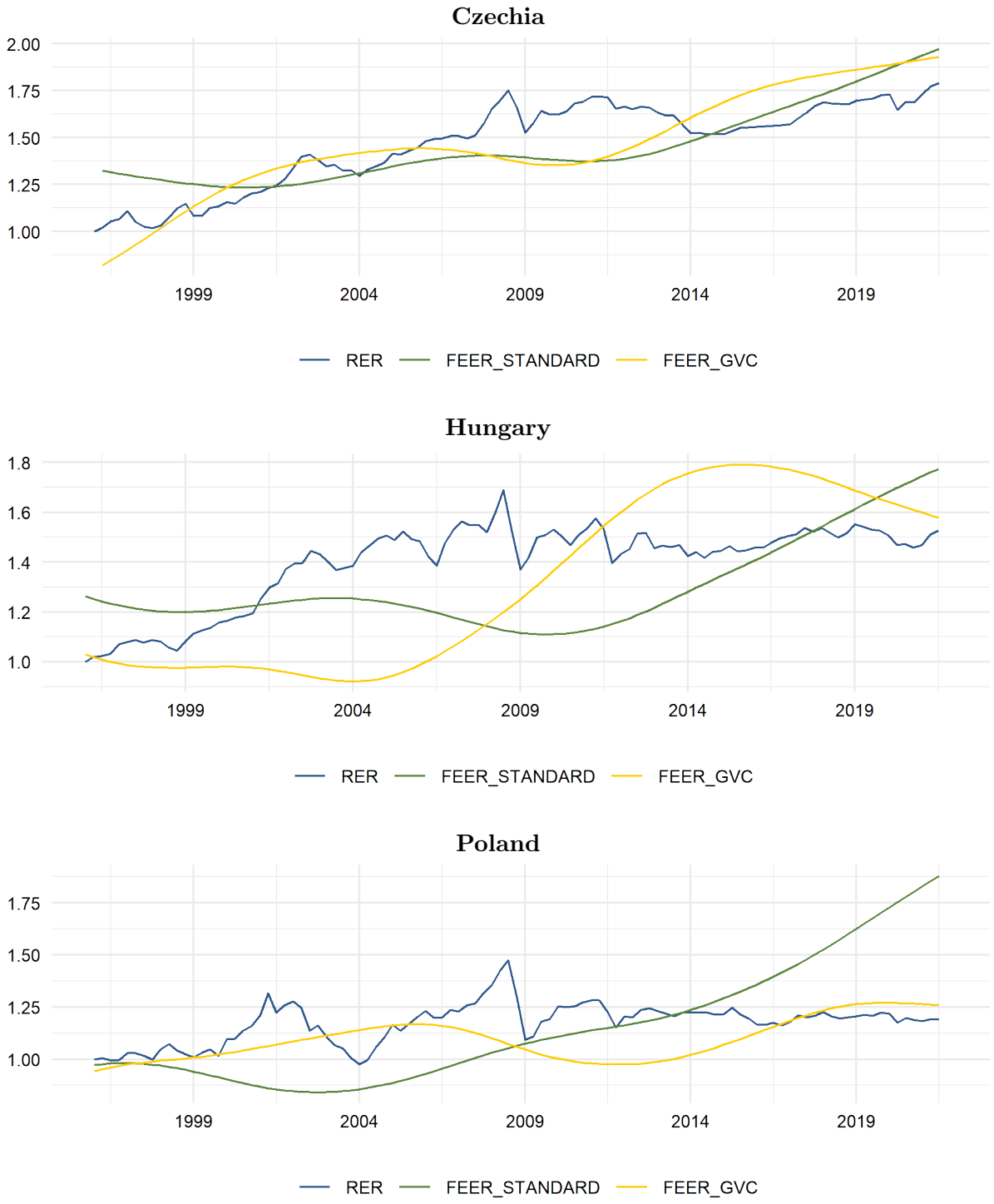
Note: Real exchange rate misalignment. Positive (negative) values stand for overvaluation (undervaluation).

Figure B.5: FEER estimates based on the disaggregated trade model (RER level as of 1996Q1=1)



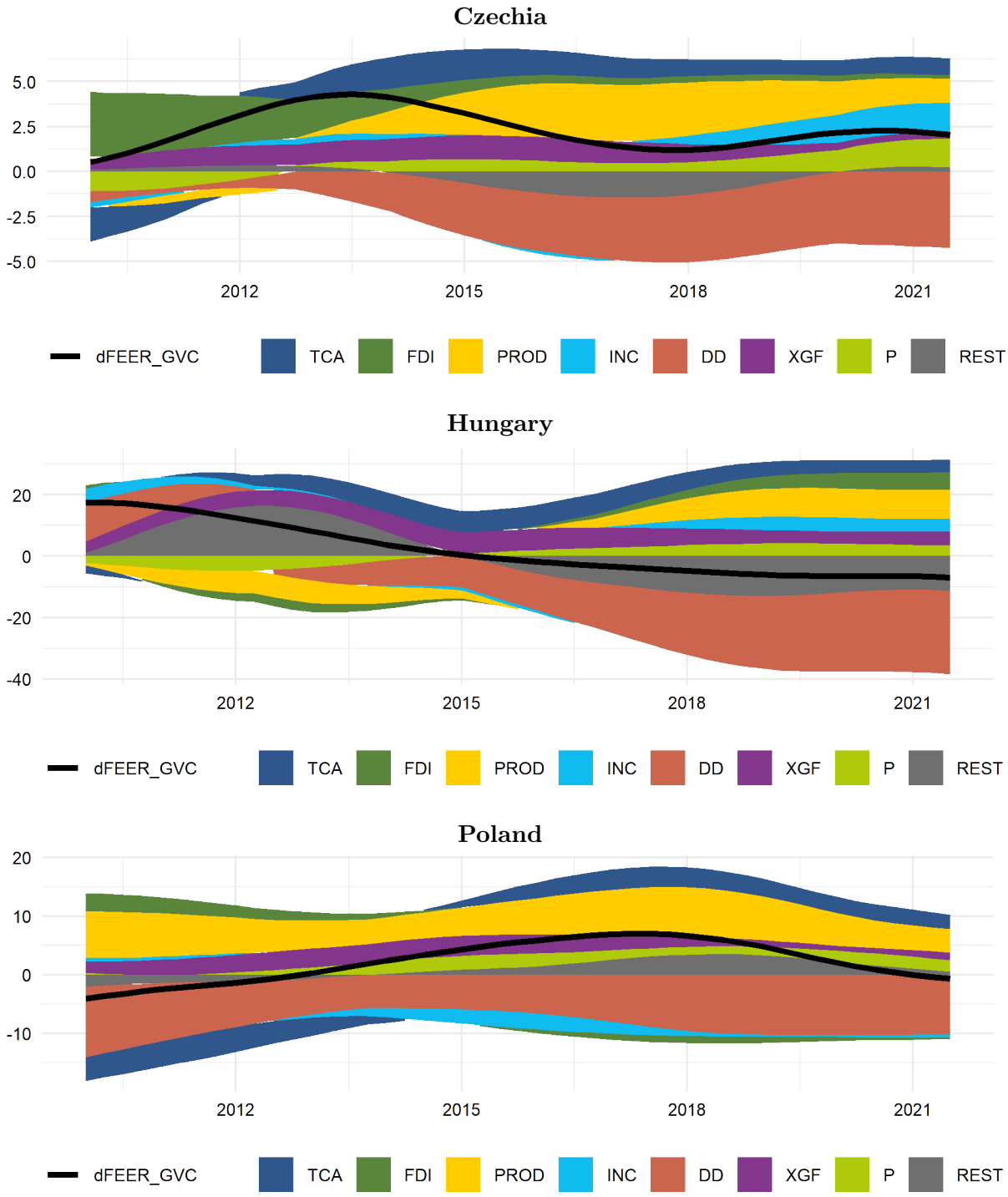
Note: The GVC-extended FEER is calculated using the estimates in column (4) in tables: (C.2), (C.3), (C.4). An increase in the real exchange rate stands for appreciation of the home currency.

Figure B.6: FEER estimates based on panel estimation of the trade model (RER level as of 1996Q1=1)



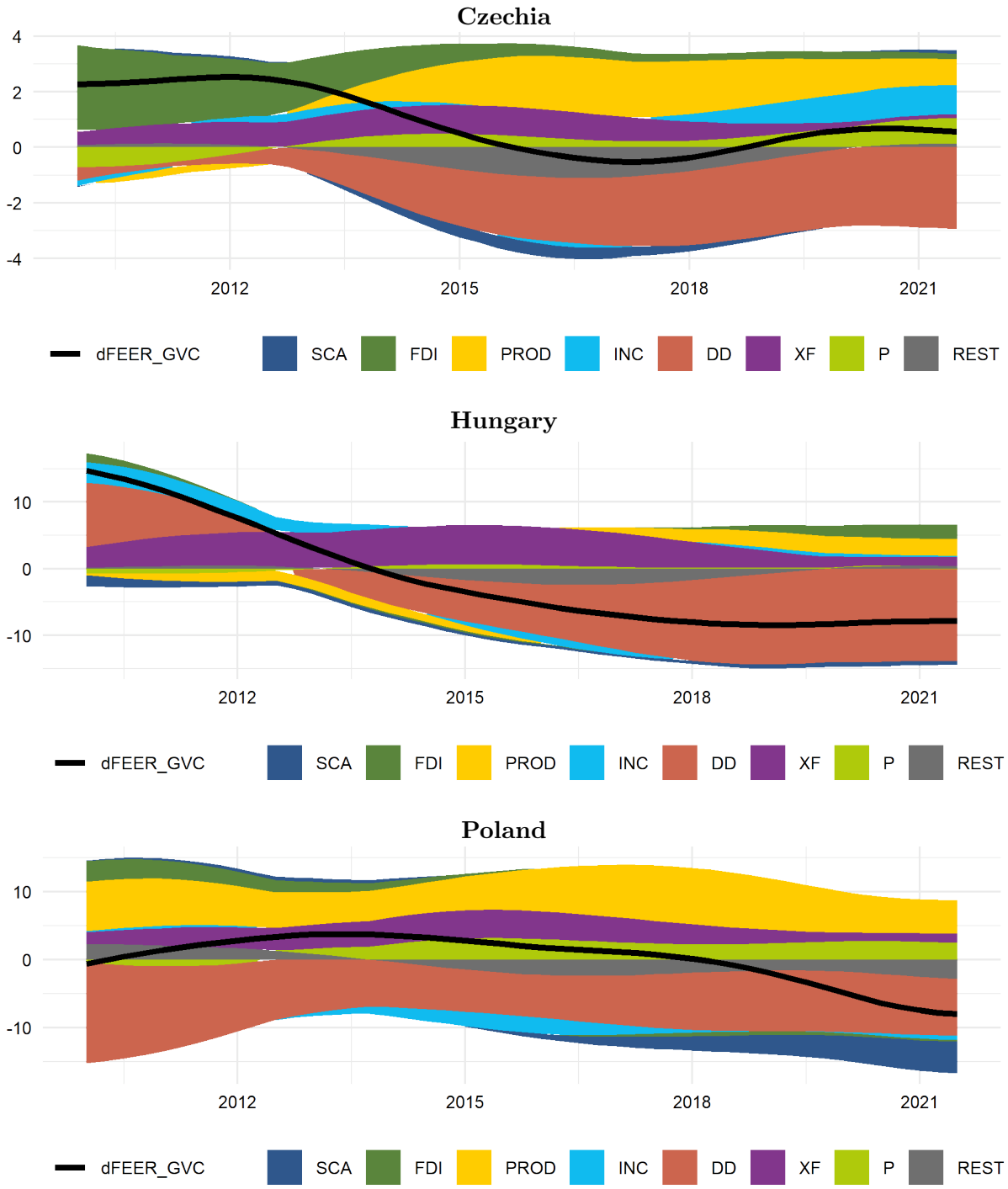
Note: the standard FEER is based on the trade estimates in column (2) in table (C.5), while the GVC-extended FEER is calculated using the estimates in column (5) in table (C.5). An increase in the real exchange rate stands for appreciation of the home currency.

Figure B.7: Decomposition of the FEER changes based on the disaggregated trade model (y/y, in % and pp.)



Note: dFEER_GVC – annual change in the GVC-extended FEER (specification 4 in tables: (C.2), (C.3), (C.4)), TCA – level of target current account balance, FDI – foreign direct investment position as a share of GDP (HP), PROD – HP-filtered difference in log productivity in the respective country and the log productivity in the foreign country, INC – level of balance on primary income, secondary income, and capital account, DD – change of HP-filtered logarithm of real demand in respective country at the level of the change of HP-filtered logarithm of real demand in the foreign country, XGF – products exports of the foreign country (log, HP), P – change in HP-filtered exports (same for imports) prices at the level of the change in HP-filtered domestic prices, REST - the unexplained. The starting point of the decomposition is 2009Q1.

Figure B.8: Decomposition of the FEER changes based on the structural current account approach (y/y, in % and pp.)



Note: dFEER_GVC – annual change in the GVC-extended FEER (specification 5 in table C.1), SCA – level of structural current account balance, FDI – foreign direct investment position as a share of GDP (HP), PROD – HP-filtered difference in log productivity in the respective country and the log productivity in the foreign country, INC – level of balance on primary income, secondary income, and capital account, DD – change of HP-filtered logarithm of real demand in respective country at the level of the change of HP-filtered logarithm of real demand in the foreign country, XF – products and services exports of the foreign country (log, HP), P – change in HP-filtered exports (same for imports) prices at the level of the change in HP-filtered domestic prices, REST - the unexplained. The starting point of the decomposition is 2009Q1.

C Additional tables

Table C.1: Baseline estimates of trade blocks in the standard and the GVC-extended FEER models

	(1)	(2)	(3)	(4)	(5)
			CZE		
m_rer	0.919***	0.336***	0.061	0.598***	0.511***
m_ypotf and x_ypot	1.798***	2.701***			
x_rer	0.76***	−0.336***	−0.354***	−0.34**	−0.511***
m_dd and x_ddf	1	1	0.336***	1.393***	1.475***
m_x			0.814***	0.35***	0.35***
x_fdi			0.008***	0.009***	0.01***
x_prod			1.891***	1.873***	1.991***
x_xf			0.703***	0.311***	0.291***
T	104	104	103	103	103
ADF (x)	[0.066]	[0.090]	[0.001]	[0.003]	[0.001]
ADF (m)	[0.012]	[0.014]	[0.009]	[0.035]	[0.030]
			HUN		
m_rer	1.093***	0.458***	0.148***	0.897***	0.262***
m_ypotf and x_ypot	2.474***	3.328***			
x_rer	0.654***	−0.458***	0.271***	0.419***	−0.262***
m_dd and x_ddf	1	1	0.626***	1.198***	1.652***
m_x			0.754***	0.43***	0.43***
x_fdi			0.001***	0.001***	0.001***
x_prod			0.712***	0.521***	1.078***
x_xf			1.233***	1.053***	1.047***
T	108	108	103	103	103
ADF (x)	[0.056]	[0.283]	[0.000]	[0.103]	[0.047]
ADF (m)	[0.025]	[0.00]	[0.002]	[0.086]	[0.164]
			POL		
m_rer	0.597***	0.317***	0.153**	0.136**	0.19***
m_ypotf and x_ypot	1.641***	1.706***			
x_rer	−0.043	−0.317***	−0.419***	−0.46***	−0.19***
m_dd and x_ddf	1	1	0.683***	1.292***	1.28***
m_x			0.546***	0.26***	0.26***
x_fdi			0.005**	0.006***	0.006***
x_prod			1.015***	1.094***	1.388***
x_xf			0.884***	0.604***	0.421***
T	108	108	103	103	103
ADF (x)	[0.016]	[0.000]	[0.012]	[0.016]	[0.032]
ADF (m)	[0.002]	[0.000]	[0.002]	[0.001]	[0.004]

Note: the superscripts $***$ and $**$ refer to the rejection of null about parameters' insignificance at 1% and 5% significance level, respectively. The expressions in squared brackets denote the bootstrapped probabilities values in the ADF test for the residuals. In case of estimates in column (1) and (2), *m_dd* and *x_ddf* is the elasticity of imports (exports) with respect to domestic (foreign) GDP. Specification (1): unitary domestic demand at home (abroad) elasticity of imports (exports), equal foreign and domestic potential output elasticity of imports and exports. (2): in addition to restrictions in (1), price elasticity of exports and imports of opposite sign. (3): equal domestic demand at home (abroad) elasticity of imports (exports). (4): in addition to restriction in (3), exports elasticity of imports at the long-run average of the share of FVA in exports. (5): in addition to restrictions in (4), price elasticity of exports and imports of opposite sign.

Table C.2: Estimates of the disaggregated trade model – Czechia

	(1)	(2)	(3)	(4)
mg_0	-2.182^{***}	-7.127^{***}	-8.685^{***}	-9.133^{***}
mg_dd	0.334^{***}	1.192^{***}	1.283^{***}	1.307^{***}
mg_rer	-0.175^{***}	0.465^{***}	0.371^{***}	0.338^{***}
mg_xg	0.773^{***}	0.41^{***}	0.41^{***}	0.41^{***}
ms_0	-8.437^{***}	-6.376^{**}	-7.979^{***}	-11.302^{***}
ms_dd	1.582^{***}	1.46^{***}	1.552^{***}	1.739^{***}
ms_rer	0.61^{***}	0.723^{***}	0.622^{***}	0.4^{***}
xg_0	-3.469^{***}	-10.333^{***}	-12.571^{***}	-12.8^{***}
xg_ddf	0.334^{***}	1.192^{***}	1.283^{***}	1.307^{***}
xg_fdi	0.007^{***}	0.009^{***}	0.01^{***}	0.01^{***}
xg_prod	2.143^{***}	2.403^{***}	2.634^{***}	2.551^{***}
xg_rer	0.05	-0.047	-0.371^{***}	-0.338^{***}
xg_xgf	0.855^{***}	0.399^{***}	0.384^{***}	0.381^{***}
xs_0	-12.515^{***}	-9.943^{***}	-11.232^{***}	-15.186^{***}
xs_ddf	1.582^{***}	1.46^{***}	1.552^{***}	1.739^{***}
xs_prod	0.563^{**}	0.285	0.192	0.514^{***}
xs_rer	-0.291	-0.051	-0.031	-0.4^{***}
goods				
T	103	103	103	103
ADF (xg)	[0.005]	[0.001]	[0.000]	[0.000]
ADF (mg)	[0.017]	[0.014]	[0.008]	[0.007]
services				
T	104	104	104	104
ADF (xs)	[0.210]	[0.187]	[0.178]	[0.246]
ADF (ms)	[0.041]	[0.043]	[0.038]	[0.035]

Note: the superscripts $***$ and $**$ refer to the rejection of null about the parameters' insignificance at 1% and 5% significance level, respectively. The expressions in squared brackets denote the p-values in the ADF test for the residuals. The probabilities values in the ADF test are obtained by bootstrapping distribution. Specification (1): equal domestic demand at home (abroad) elasticity of goods imports (exports); same for services. (2): in addition to restrictions in (1), goods exports elasticity of goods imports at the long-run average of the share of FVA in goods exports. (3): in addition to restrictions in (2), price elasticity of goods exports and imports of opposite sign. (4): in addition to restrictions in (3), price elasticity of services exports and imports of opposite sign.

Table C.3: Estimates of the disaggregated trade model – Hungary

	(1)	(2)	(3)	(4)
mg_0	-6.949^{***}	-6.521^{***}	-12.951^{***}	-14.169^{***}
mg_dd	0.609^{***}	1.051^{***}	1.322^{***}	1.366^{***}
mg_rer	-0.197^{***}	0.477^{***}	0.096	0.003
mg_xg	0.755^{***}	0.52^{***}	0.52^{***}	0.52^{***}
ms_0	-2.618	-2.563	-11.962^{***}	-16.411^{***}
ms_dd	1.624^{***}	1.627^{***}	2.004^{***}	2.155^{***}
ms_rer	1.655^{***}	1.672^{***}	1.065^{***}	0.7^{***}
xg_0	-7.537^{***}	-11.876^{***}	-21.323^{***}	-21.376^{***}
xg_ddf	0.609^{***}	1.051^{***}	1.322^{***}	1.366^{***}
xg_fdi	0.001^{***}	0.001^{***}	0.000^{***}	0.000^{***}
xg_prod	0.59^{***}	0.59^{***}	1.566^{***}	1.432^{***}
xg_rer	0.841^{***}	0.853^{***}	-0.096	-0.003
xg_xgf	1.369^{***}	1.214^{***}	1.228^{***}	1.223^{***}
xs_0	-12.359^{***}	-10.128^{**}	-15.93^{***}	-21.685^{***}
xs_ddf	1.624^{***}	1.627^{***}	2.004^{***}	2.155^{***}
xs_prod	1.722^{***}	1.264^{***}	0.927^{**}	1.269^{***}
xs_rer	-0.433	-0.03	-0.075	-0.7^{***}
goods				
T	103	103	103	103
ADF (xg)	[0.110]	[0.108]	[0.164]	[0.229]
ADF (mg)	[0.101]	[0.064]	[0.084]	[0.068]
services				
T	104	104	104	104
ADF (xs)	[0.350]	[0.400]	[0.425]	[0.365]
ADF (ms)	[0.110]	[0.108]	[0.164]	[0.229]

Note: the superscripts $***$ and $**$ refer to the rejection of null about parameters' insignificance at 1% and 5% significance level, respectively. The expressions in squared brackets denote the bootstrapped probabilities values in the ADF test for the residuals. Specification (1): equal domestic demand at home (abroad) elasticity of goods imports (exports); same for services. (2): in addition to restrictions in (1), goods exports elasticity of goods imports at the long-run average of the share of FVA in goods exports. (3): in addition to restrictions in (2), price elasticity of goods exports and imports of opposite sign. (4): in addition to restrictions in (3), price elasticity of services exports and imports of opposite sign.

Table C.4: Estimates of the disaggregated trade model – Poland

	(1)	(2)	(3)	(4)
mg_0	-4.141^{***}	-6.16^{***}	-5.893^{***}	-5.862^{***}
mg_dd	0.83^{***}	1.117^{***}	1.104^{***}	1.103^{***}
mg_rer	0.137^{**}	0.15^{***}	0.218^{***}	0.228^{***}
mg_xg	0.47^{***}	0.33^{***}	0.33^{***}	0.33^{***}
ms_0	-16.859^{***}	-16.891^{***}	-17.283^{***}	-16.601^{***}
ms_dd	2.098^{***}	2.101^{***}	2.119^{***}	2.084^{***}
ms_rer	0.018	0.014	-0.091	0.072
xg_0	-12.621^{***}	-14.366^{***}	-12.363^{***}	-12.581^{***}
xg_ddf	0.83^{***}	1.117^{***}	1.104^{***}	1.103^{***}
xg_fdi	0.006^{***}	0.007^{***}	0.007^{***}	0.007^{***}
xg_prod	0.986^{***}	1.063^{***}	1.203^{***}	1.169^{***}
xg_rer	-0.427^{***}	-0.424^{***}	-0.218^{***}	-0.228^{***}
xg_xgf	0.842^{***}	0.657^{***}	0.546^{***}	0.562^{***}
xs_0	-21.316^{***}	-21.322^{***}	-21.226^{***}	-20.214^{***}
xs_ddf	2.098^{***}	2.101^{***}	2.119^{***}	2.084^{***}
xs_prod	2.612^{***}	2.593^{***}	2.517^{***}	2.447^{***}
xs_rer	-0.701^{***}	-0.681^{***}	-0.42^{*}	-0.072
goods				
T	103	103	103	103
ADF (xg)	[0.001]	[0.002]	[0.013]	[0.010]
ADF (mg)	[0.003]	[0.001]	[0.002]	[0.002]
services				
T	104	104	104	104
ADF (xs)	[0.048]	[0.043]	[0.075]	[0.105]
ADF (ms)	[0.003]	[0.005]	[0.006]	[0.007]

Note: the superscripts $***$, $**$ and $*$ refer to the rejection of null about parameters' insignificance at 1%, 5% and 10% significance level, respectively. The expressions in squared brackets denote the p-values in the ADF test for the residuals. The probabilities values in the ADF test are obtained by bootstrapping distribution. Specification (1): equal domestic demand at home (abroad) elasticity of goods imports (exports); same for services. (2): in addition to restrictions in (1), goods exports elasticity of goods imports at the long-run average of the share of FVA in goods exports. (3): in addition to restrictions in (2), price elasticity of goods exports and imports of opposite sign. (4): in addition to restrictions in (3), price elasticity of services exports and imports of opposite sign.

Table C.5: Panel estimation (fixed effects) of the trade model

	(1)	(2)	(3)	(4)	(5)
m_rer	1.265^{***}	0.394^{***}	0.14^{***}	0.733^{***}	0.37^{***}
m_yfpot and x_ypot	1.49^{***}	2.203^{***}			
x_rer	1.193^{***}	-0.394^{***}	0.2^{***}	0.294^{***}	-0.37^{***}
m_dd and x_ddf	1	1	0.563^{***}	1.212^{***}	1.391^{***}
m_x			0.604^{***}	0.26^{***}	0.26^{***}
m_x_CZ			0.124^{***}	0.09^{***}	0.09^{***}
m_x_HU			0.166^{***}	0.17^{***}	0.17^{***}
x_fdi			0.001^{***}	0.001^{***}	0.001^{***}
x_prod			0.852^{***}	0.986^{***}	1.006^{***}
x_xf			1.153^{***}	0.884^{***}	1.047^{***}
CZE					
T	104	104	103	103	103
ADF (x)	[0.006]	[0.021]	[0.034]	[0.032]	[0.073]
ADF (m)	[0.012]	[0.043]	[0.007]	[0.027]	[0.028]
HUN					
T	108	108	103	103	103
ADF (x)	[0.027]	[0.008]	[0.052]	[0.040]	[0.013]
ADF (m)	[0.077]	[0.007]	[0.001]	[0.100]	[0.057]
POL					
T	108	108	103	103	103
ADF (x)	[0.017]	[0.055]	[0.008]	[0.008]	[0.006]
ADF (m)	[0.002]	[0.003]	[0.001]	[0.003]	[0.039]

Note: the superscript $***$ refers to the rejection of null about parameters' insignificance at 1% significance level. The expressions in squared brackets denote the p-values in the ADF test for the residuals. The probabilities values in the ADF test are obtained by bootstrapping distribution. Specification (1): unitary domestic demand at home (abroad) elasticity of imports (exports), equal foreign and domestic potential output elasticity of imports and exports. (2): in addition to restrictions in (1), price elasticity of exports and imports of opposite sign. (3): equal domestic demand at home (abroad) elasticity of imports (exports). (4): in addition to restriction in (3), exports elasticity of imports at the long-run average of the share of FVA in exports. (5): in addition to restrictions in (4), price elasticity of exports and imports of opposite sign.

Table C.6: Panel estimation (fixed effects) of the disaggregated trade model

	(1)	(2)	(3)	(4)
mg_rer	-0.071^{**}	0.501^{***}	0.165^{***}	0.135^{***}
mg_xg	0.628^{***}	0.33^{***}	0.33^{***}	0.33^{***}
mg_xg_CZ	0.082^{***}	0.08^{***}	0.08^{***}	0.08^{***}
mg_xg_HU	0.134^{***}	0.19^{***}	0.19^{***}	0.19^{***}
ms_dd	1.972^{***}	1.896^{***}	1.934^{***}	1.712^{***}
ms_rer	0.532^{***}	0.677^{***}	0.599^{***}	1.015^{***}
xg_ddf and mg_dd	0.513^{***}	1.059^{***}	1.223^{***}	1.242^{***}
xg_fdi	0.001^{***}	0.001^{***}	0.001^{***}	0.001^{***}
xg_prod	0.607^{***}	0.98^{***}	1.001^{***}	0.989^{***}
xg_rer	0.772^{***}	0.883^{***}	-0.165^{***}	-0.135^{***}
xg_xgf	1.31^{***}	0.902^{***}	1.204^{***}	1.211^{***}
xs_ddf	1.972^{***}	1.896^{***}	1.934^{***}	1.712^{***}
xs_prod	2.571^{***}	2.386^{***}	2.258^{***}	2.211^{***}
xs_rer	-1.606^{***}	-1.328^{***}	-1.169^{***}	-1.015^{***}
goods				
T	103	103	103	103
services				
T	104	104	104	104
CZE				
ADF (xg)	[0.066]	[0.051]	[0.123]	[0.127]
ADF (mg)	[0.002]	[0.010]	[0.013]	[0.006]
ADF (xs)	[0.087]	[0.110]	[0.140]	[0.155]
ADF (ms)	[0.076]	[0.078]	[0.074]	[0.070]
HUN				
ADF (xg)	[0.008]	[0.001]	[0.049]	[0.061]
ADF (mg)	[0.046]	[0.058]	[0.072]	[0.067]
ADF (xs)	[0.161]	[1.193]	[0.218]	[0.241]
ADF (ms)	[0.276]	[0.299]	[0.306]	[0.256]
POL				
ADF (xg)	[0.001]	[0.000]	[0.002]	[0.004]
ADF (mg)	[0.004]	[0.005]	[0.012]	[0.019]
ADF (xs)	[0.028]	[0.030]	[0.044]	[0.062]
ADF (ms)	[0.002]	[0.001]	[0.004]	[0.003]

Note: the superscripts $***$ and and $**$ refer to the rejection of null about parameters' insignificance at 1% and 5% significance level, respectively. The expressions in squared brackets denote the p-values in the ADF test for the residuals. The probabilities values in the ADF test are obtained by bootstrapping distribution. Specification (1): equal domestic demand at home (abroad) elasticity of goods imports (exports); same for services. (2), in addition to restrictions in (1), goods exports elasticity of goods imports at the long-run average of the share of FVA in goods exports. (3): in addition to restrictions in (2), price elasticity of goods exports and imports of opposite sign. (4): in addition to restrictions in (3), price elasticity of services exports and imports of opposite sign.