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Abstract

We examine the relationship between development of global value chains and changes in the exchange rate pass-through to producer prices. In contrast to the existing research we assume that the decline in ERPT resulting from the enhanced participation in GVC may be non-linear with respect to the country's position in the global value chain, reflecting divergent firms' market power at various stages of vertical specialization process. We investigate a panel of 43 advanced and emerging economies using a panel smooth transition regression (PSTR) model and WIOD data and find that growing backward GVC participation of the suppliers of imported intermediate input results in the reduction of the ERPT to producer prices. We also provide evidence that this effect is non-linear. The exchange rate pass-through for countries, whose suppliers are strongly involved in the production along the global value chains is significantly (four times) smaller than for economies with suppliers not participating in GVC. We document that the decline in the aggregate ERPT in recent years has been mainly due to changes in the exchange rate pass-through for the EU members states due to increased backward GVC participation of their major trading partners. For other countries, the ERPT remained roughly the same throughout the analyzed period.

JEL: C23, E31, F14, F62

Keywords: Global value chains, exchange rate pass-through, inflation, PSTR model

1 Introduction

There is a broad consensus in the literature that exchange rate pass-through (ERPT) to import prices was declining over the last decades (Marazzi et al., 2005, Ihrig et al., 2006, Özyurt, 2016, Jasova et al., 2016). The authors disagree however on the causes of this phenomenon. Some of them attribute a decline in ERPT to more stable macroeconomic environment in particular to lower and less volatile inflation (Taylor, 2000, Devereux and Yetman, 2010, Jasova et al., 2016) as well as more credible monetary policy (Bailliu and Fujii, 2004, Gagnon and Ihrig, 2004). The authors who explain the drop in ERPT by low inflation usually refer to menu cost theory of price setting and emphasize that when inflation is higher, exchange rate fluctuations are transmitted more quickly and to a larger extent to domestic prices because firms have to adjust prices frequently anyway (see eg. Devereux and Yetman, 2010 and Jasova et al., 2016 for discussion). Accordingly Taylor (2000) points out to a positive correlation between the level and the persistence of inflation and argues that in the low-inflation environment there is less matching of the price and cost increases, which results in a drop in ERPT to import and consumer prices. Gagnon and Ihrig (2004) who see a prevailing role in decreasing ERPT in more credible monetary policy oriented to stabilization of inflation emphasize that firms pass through the fluctuations in their input prices to output prices to lesser extent, because they believe that the central bank takes the proper measures to counterbalance the increase in aggregated demand or cost pressure and will be successful in stabilizing inflation in the future.

Another stream of research focusing on more moderate reaction of import prices to exchange rate fluctuations put more emphasis on the composition of the foreign trade. In particular Campa and Goldberg (2002) explain a drop in ERPT to import prices in OECD countries from 1975 to 1999 by a shift in the import structure toward manufactures, and away from energy and raw materials, which are characterized usually by higher ERPT. They conclude that while the industry composition of trade is a structural phenomenon a decline in exchange rate pass-through can be perceived as a permanent change in the monetary policy transmission mechanism.

Some authors explain the drop in ERPT by micro rather than macroeconomic factors. Gust et al. (2010) argue that a higher trade integration followed by a decrease in trade costs resulted in strategic complementarity of importers' price setting. The importing companies may pose higher and therefore more volatile markups and accommodate the shocks to the exchange rate to keep their market share constant. In this strand of research Amiti et al. (2014) and Auer and Schoenle (2016) emphasize the role of increased competition, complementarity in price setting and higher variations in mark-ups in explaining the differences in ERPT to import prices on the micro level.

In our paper we follow another strand of literature, which relates the drop in ERPT to import prices to development of global values chains (GVC). As pointed out by some authors (Amiti et al., 2014, Georgiadis et al., 2019, De Soyres et al., 2018) vertical specialization within global value chains accompanied by higher import intensity of exports may result in weaker response of import prices to exchange rate fluctuations. This mechanism can be described as follows. If a firm in a given country imports intermediate goods for production of its export then the changes in this country exchange rate, which affect the price of its export influence simultaneously its cost of imported intermediate goods. Appreciation (depreciation) of exchange rate negatively (positively) affects the profitability of export while at the same time decreases (increases) the costs of intermediate inputs. With high import intensity of exports the firm may adjust export prices in its local (home) currency to keep prices in destination (foreign) currency unchanged ensuring the markups relatively stable. Accordingly the larger is the pass-through to local currency export prices the lower pass-through to destination currency import prices. The strength of exchange rate pass-through depends on the degree of GVC participation (import intensity of exports) of suppliers (so called backward GVC participation).

The process of reorganization of world's production and development of global value chains has been particularly visible in the 1990s and 2000s until the global financial crisis of 2009. Fragmentation of production was possible on the one hand due to technological advances in both communication technology reducing transaction costs as well as shipping and production technology reducing transportation costs. On the other hand thanks to the Uruguay Round of GATT/WTO and regional trading agreements, trade in manufactures became increasingly free (see eg. Baldwin, 2016 for a detailed account of the process and Amador and Cabral, 2014 for a survey of measures and data sources related to GVC). Last but not least, some developing countries such as those in Eastern Europe became more open to trade, inflow of FDI and off-shoring activities. This process led to a massive increase in trade - the ratio of global imports to global GDP increased between 1995 and 2008 by around 53% (see eg. Cabrillac et al., 2016), to a large extent due to reallocation of production, as the global average import content of exports increased by roughly the same factor over the same period. While the fragmentation process have rather abruptly halted due to the global economic crisis in 2009, after slight recovery in the following years it has stalled afterwards (see Figure 1), which may be due to little marginal benefit from further fragmentation as well as failure of significant further trade liberalization (WTO Doha round, TTIP) and the rise of protectionism. We therefore expect the drop in ERPT to occur mainly in the period of the development of GVCs which we largely cover in our estimation sample.

The existing research on the role of GVCs in explaining a downward trend in exchange rate pass-through is however still scarce and focused on the ERPT to import and export prices only. In this strand of literature Georgiadis et al. (2019) propose a structural two-country model with trade in intermediate goods and local/producer-currency pricing to study a variation in the share of imported intermediate goods in the overall production costs. They evidence a decrease in ERPT to import prices and increase in ERPT to export prices in local (home) currency due to the growing GVC participation for 33 advanced and emerging economies in 2000-2014. De Soyres et al. (2018) report a decline in exchange rate pass-through to export prices in destination (foreign) currency as a result of more intensive GVC participation for 40 developed and emerging economies in years 1995-2009. Moreover they find that export volumes are also less sensitive to exchange rate fluctuations for countries involved in global value chains. Amiti et al. (2014) use Belgian firm-product-level data and find that import intensity of export and market share are the main determinants of ERPT in the cross-section of firms. They also document that these two effects are correlated with each other since the largest exporters have simultaneously high market share and feature high import intensity of their export. They conclude that this micro evidence has important implications for aggregate pass-through since the firms with the low pass-through account for a disproportionately large share of exports.

In general in this stream of literature two different modeling approaches are used. The first method is a two-step approach. In the first step the exchange rate pass-through coefficient is calculated for a rolling sample and next the estimates of ERPT from the first step are regressed on various GVC participation measures (Georgiadis et al., 2019). The second approach is a one-step method and uses linear models with explanatory interaction variables constructed as a product of nominal exchange rate and different measures of GVC participation (De Soyres et al., 2018). Both methods assume the linear relationship between the degree of GVC participation and the value of exchange rate pass-through.

In contrast to the existing research we postulate non-linearity in the relationship between ERPT and the stage of country's involvement in global value chains. This concept is related to the distribution of gains from participating in GVC along the value chain. The literature documents the relationship between the share of value added in output and the position in the GVC to be non-linear, ie. exhibiting u-shaped patterns, or the so called smiling curve. A thorough description of the process of the off-shoring and the mechanisms resulting in the u-shaped pattern is to be found, inter alia, in Baldwin and Evenett (2015), who also provide several case studies. While there are many reasons why the u-shaped pattern exists in global value chains, the important source of this non-linearity is a different market power of firms at subsequent stages of production. In particular, off-shored tasks tend to be easily replaceable and requiring little innovation, making the respective firms price takers rather than price setters. In particular, manufacturing stages of production are generating less value added than post-production services and pre-production R&D activity. Dollar et al. (2017) show such relationship for sectoral data, Rungi and Prete (2018) confirm the smile curve hypothesis using large scale firm-level data while Gradzewicz and Mućk (2019) exploring also firm level data relate it directly to firms' market power. In the latter paper, the authors argue that companies with high share of foreign value added in export are rather price takers than price setters. Moreover these firms compete usually with price and are more exposed to growing competition from other suppliers.

That is why we may expect that the drop in ERPT resulting from the enhanced participation in GVC may be more than proportional for suppliers of intermediate goods with higher share of foreign value added in export and therefore weaker firms' market power and less than proportional for countries with low contribution of foreign value added in export once the firms are rather price setters. We verify this hypothesis using a novel one-step econometric approach, which allows for potential non-linearities in the impact of intensity of GVC participation on ERPT.

We also contribute to the existing literature by investigating the impact of GVCs development on the exchange rate pass-through to broader price measures than import prices only. In particular we focus on the relationship between the intensity of GVC participation of country's trading partners supplying intermediate goods and the ERPT to producer prices. Therefore we may examine how the globalization reflected by development of GVCs affects the transmission of shocks to exchange rate into the prices in the whole economy.

Our econometric approach is the panel smooth transition regression (PSTR) model proposed by González et al. (2005), which allows for capturing the non-linearity in the relationship between the degree of GVC participation and the strength of exchange rate pass-through. The PSTR model assumes the existence of two or more different regimes for which the ERPT may be different and allows for a smooth transition between these regimes. In our case we may interpret these regimes as regimes of low and high GVC participation (of suppliers importing to given country). Therefore the ERPT coefficient in our model may vary with respect to the intensity of GVC participation of supplying countries reflecting the pricing power and position in vertical specialization of the firms operating in those countries.

We analyze a panel of 43 advanced and emerging economies and confirm that the strength of the exchange rate pass-through to producer prices corresponds with the degree of countries involvement in a trade within global value chains. The higher the intensity of GVC participation of suppliers the lower sensitivity of producer prices to exchange rate fluctuations. We also document that this relationship is non-linear. The decline in ERPT is more than proportional for countries with high foreign value added in export and therefore weaker firms' market power and less than proportional for countries with low foreign value added in export given the market power of firms operating in such countries is higher. Accordingly we evidence that the exchange rate pass-through for countries importing from suppliers strongly involved in global value chains is significantly weaker (four times) than for countries with suppliers not participating intensively in GVC.

The rest of the paper is structured as follows. Section 2 introduces the theoretical model. Section 3 presents the data and the econometric approach. Section 4 discusses the main results. Section 5 contains a number of robustness checks and Section 6 concludes.

2 Theoretical framework

The empirical specification of our model is motivated by a simple theoretical framework based loosely on Ahn et al. (2016). In an imperfectly competitive industry of a given country a firm i charges a markup over marginal costs, ie:

$$P_{it} = \mu_{it} MC_{it} \tag{1}$$

and in logs:

$$lnP_{it} = ln\mu_{it} + lnMC_{it}. \tag{2}$$

Provided that the production function is of a Cobb-Douglas type and encompasses domestically produced and imported inputs as well as labor, in an open economy the marginal cost can be decomposed into the following components:

$$lnMC_{it} = \alpha_{1i} lnULC_{it} + \alpha_{2i} lnIIPPI_{it} + \alpha_{3i} lnDIPPI_{it} + \epsilon_{it}, \tag{3}$$

where ULC_{it} denotes unit labour costs, $IIPPI_{it}$ stands for unit price of imported intermediate goods, $DIPPI_{it}$ stands for unit price of domestic intermediate goods and ϵ_{it} is random optimization error. The parameters $\alpha_{1,i}$, $\alpha_{2,i}$ and $\alpha_{3,i}$ are the shares of labor costs, imported input and domestic input in the production costs. Note that both price indices are expressed in domestic prices, ie. the $IIPPI$ is equal to the foreign price index times the exchange rate. Combining both above equations, we derive the following pricing rule:

$$lnP_{it} = ln\mu_{it} + \alpha_{1i} lnULC_{it} + \alpha_{2i} lnIIPPI_{it} + \alpha_{3i} lnDIPPI_{it} + \epsilon_{it}. \tag{4}$$

Then we assume that all firms in respective economy are identical and that a country level aggregates are weighted averages of firm level components. For simplicity of notation from this point we denote a country by subscript i. Under the assumption that the degree of markup adjustment in response to certain cost shocks depends on the source of shocks, we can express an average markup in country i as a function of the respective shocks:

$$ln\mu_{it} = ln\mu_i + \sigma_{1i}\alpha_{1i} lnULC_{it} + \sigma_{2i}\alpha_{2i} lnIIPPI_{it} + \sigma_{3i}\alpha_{3i} lnDIPPI_{it}. \tag{5}$$

The aggregated price setting equation in country i can be then written as:

$$\begin{aligned} lnP_{it} &= ln\mu_i + (1+\sigma_{1i})\,\alpha_{1i} lnULC_{it} \\ &+ (1+\sigma_{2i})\,\alpha_{2i} lnIIPPI_{it} + (1+\sigma_{3i})\,\alpha_{3i} lnDIPPI_{it} + \epsilon_{it}, \end{aligned} \tag{6}$$

where $(1+\sigma_{k,i})$ for $k = 1,2,3$ is a measure of markup adjustment to specific shock.

Finally we decompose the import price index in domestic currency to nominal exchange rate and import price index in foreign currency:

$$
\begin{aligned}
lnP_{it} &= ln\mu_i + (1+\sigma_{1i})\,\alpha_{1i} lnULC_{it} + (1+\sigma_{21i})\,\alpha_{2i} lnNEER_{it} \\
&+ (1+\sigma_{22i})\,\alpha_{2i} lnIIPP^{*}_{it} + (1+\sigma_{3i})\,\alpha_{3i} lnDIPPI_{it} + \epsilon_{it},
\end{aligned} \tag{7}
$$

where $IIPPI^{*}_{it}$ is an import price index in foreign (supplier) currency. By differentiating between σ_{21i} and σ_{22i} we allow for different markup adjustment to shocks to nominal exchange rate and to import prices in foreign currency respectively. Equation (7) serves as the basis for the empirical model where $(1+\sigma_{21i})\,\alpha_{2i}$ is the degree of nominal exchange rate pass-through to domestic (producer) prices.

In our estimation strategy described in Section 3.3 we account for varying shares of labor costs and imported input in the production costs over time and across countries. In the empirical model we adjust first the variables reflecting the unit labor costs, nominal exchange rate and price indices of intermediate goods by their respective shares in the production costs $(\alpha_{k,i})$. Therefore we estimate directly the measures of markup adjustments $(1+\sigma_{k,i})$ in equation (7) and derive the ERPT to producer prices indirectly as a product of $(1+\hat{\sigma}_{21i})$ and α_{2i}. Moreover in the empirical analysis we substitute the price index of domestic intermediate goods by country's GDP growth to avoid the endogeneity problem[1].

[1] The substitution of price index of domestic intermediate goods by GDP variable allows us to control additionally for cyclical fluctuations in domestic demand pressure.

3 Data and econometric approach

3.1 Data

We use annual panel data for 43 advanced and emerging economies included in the World Input Output Database (see Section 3.2 for details). The time span extends from 2001 to 2014 providing 14 annual observations for every country.

The dependent variable in our model is the producer price index – PPI (the prices of gross output) drawn for respective countries from the Socio Economic Accounts (SEA) accompanying the WIOD tables.

Our main explanatory variable is the nominal effective exchange rate calculated using bilateral nominal exchange rates and the weights corresponding to the shares of respective countries and sectors in imported intermediate input in given country.

The other explanatory variables are unit labor costs, intermediate import price index and real GDP growth. The unit labor costs for respective countries are calculated as the compensation per employee multiplied by the number of employees and divided by the gross output (in constant prices). Due to data limitation we approximate the intermediate import prices in foreign (supplier) currency by a composite index formed through aggregation of producer price indices for supplying countries with the weights computed as the shares of the respective countries and sectors in imported intermediate input in given country (the same weights as for nominal effective exchange rate). The bilateral nominal exchange rates, compensation per employee, the number of employees and the gross output come from Socio Economic Accounts, while the weights are derived from WIOD tables. The real GDP growth is taken from the IMF World Economic Outlook (WEO).

When doing the robustness check we use also some other control variables: the energy price index and the productivity growth of trading partners. The former variable is taken from IMF WEO while the latter is calculated using the number of employees and the gross output from Socio Economic Accounts with the same weights as for calculation of effective exchange rate and intermediate import price index.

3.2 Measures of GVC participation

Following Johnson and Noguera (2012) among others we employ two measures of GVC participation in our analysis. We compute them using the World Input Output Database (Timmer et al., 2015) in its 2016 edition covering 43 countries and 65 sectors for the period of 2001-2014. They are: $GVC_{Backward}$ (denoted further for notation simplicity as $FVAX$) and $GVC_{Forward}$ - backward and forward participation of countries in global value chains. Both of these measures are based on exports of value added. The former is the foreign value added (imported value added - FVA) content of a country i exports divided by country i's gross exports and the latter is the country i's domestic value added (DVA) embedded in all other countries' exports, again relative to country i gross exports. Computation of value added is performed as follows.

Let A be an international matrix of input output coefficients ($GN \times GN$, where G is the number of sectors and N is the number of countries), V is a diagonal matrix of value added coefficients (also $GN \times GN$) and E is the diagonal matrix of gross exports. Let $L = (I - A)^{-1}$. Consider a matrix:

$$T = VLE.$$

In that case, the foreign value added FVA for country i will be a sum of all the columns of matrix T corresponding to country i excluding the $G \times G$ block submatrix corresponding to country i. The DVA for country i will be a sum of all the rows corresponding to country i excluding the $G \times G$ block submatrix corresponding to country i. The corresponding $GVC_{Backward}$ and $GVC_{Forward}$ can be calculated by normalizing the obtained measures by the value of exports of country i. In our basic model we use a measure of backward GVC participation (of suppliers), which corresponds to the mechanism explained in Section 1. However as a robustness check we examine also in the model the forward GVC participation measure (see Section 5).

3.3 Econometric model

We investigate the relationship between intensity of GVC participation and exchange rate pass-through using a non-linear panel smooth transition regression (PSTR) model. The PSTR model was proposed initially by Granger and Teräsvirta (1993) and Teräsvirta (1994) for time series and cross sectional data and extended by González et al. (2005) for panel data. The model allows for switching between the regimes of high and low ERPT, which depend on the degree of GVC participation of suppliers importing to country i. We expect that the regime of high ERPT is associated with low GVC participation and regime of low ERPT corresponds to the strong involvement of country's suppliers in vertical specialization within global value chains. We formulate then a fixed effects PSTR model, which can be written as follows:

$$PPI_{it} = \mu_i + \delta_1 NEER_{it} + G\left(s_{it}; \gamma, c\right) \delta_2 NEER_{it} + \delta_3 IIPPI^*_{it} + \delta_4 ULC_{it} + \beta' x_{it} + u_{it}, \qquad (8)$$

where $G(s_{it}; \gamma, c)$ is a transition function allowing for the non-linear relationship between the producer prices PPI_{it} and nominal effective exchange rate ($NEER_{it}$). The variable $IIPPI^*_{it}$ stands for effective weighted (by country and sector) price index of imported intermediate input expressed in foreign (suppliers) currency, while ULC_{it} measures domestic unit labor costs. Moreover x_{it} is a vector of other variables affecting the producer prices (GDP growth, other control variables), μ_i expresses the country fixed effects and u_{it} is the error term.

The variable s_{it} in (8) is the transition variable, c is a threshold parameter, and γ is a transition parameter, which measures the speed of transition from one regime to the other.

There are two alternative transition functions usually proposed in the literature, the logistic function:

$$G(s_{it}; \gamma, c) = (1 + \exp\{-\gamma(s_{it} - c)\})^{-1}; \quad \gamma > 0 \qquad (9)$$

and the exponential function:

$$G(s_{it};\gamma,c) = 1 - \exp\{-\gamma(s_{it} - c)^2\}; \quad \gamma > 0, \tag{10}$$

where the restriction $\gamma > 0$ is an identifying restriction.

The transition functions defined by (9) and (10) are bounded between 0 and 1. It means that the parameter measuring the exchange rate pass-through to producer prices may vary between δ_1 and $\delta_1 + \delta_2$ along with the transition variable s_{it}. The logistic function (9) approaches zero for very small values of the transition variable and approaches unity for very large values. The exponential function (10) approaches unity for both very small and very large values of the transition variable s_{it} and is close to zero when s_{it} is equal to the value of the threshold parameter c.

We examine in our paper whether the exchange rate pass-through to producer prices varies with the involvement of country's i suppliers in global value chains. Therefore the transition variable s_{it} in equation (8) reflects the degree of GVC participation of suppliers of intermediate input (backward GVC participation - $FVAX$). The PSTR model (8) can be then written as:

$$y_{it} = \mu_i + \delta_1 NEER_{it} + G\left(FVAX_{it};\gamma,c\right)\delta_2 NEER_{it} + \delta_3 IIPPI^*_{it} + \delta_4 ULC_{it} + \beta' x_{it} + u_{it}. \tag{11}$$

We believe that the exchange rate pass-through to producer prices is declining monotonically with the increasing participation of country's suppliers in vertical specialization within GVC that is why we expect the transition function to be the logistic one. Nevertheless we verify this assumption empirically. If the PSTR model with the logistic transition function (9) is validated, it implies that the changes in exchange rate affect producer prices to a different extent when the GVC participation of suppliers is low and when it is high.

The shape of the desired logistic transition function (9) determined by the value of transition parameter γ reflects the potential divergence in pricing power of the firms involved in the subsequent stages of vertical specialization within global value chains. The hypothesis corresponding to logistic form of the transition function is that the firms with low share of foreign value added in export (low degree of backward GVC participation) have usually stronger pricing power than the firms with high foreign value added in export (high degree of backward GVC participation). Therefore if the logistic function is steep and the transition from one regime to another is sharp the changes in pass-through are less than proportional to degree of involvement in GVC (import intensity of export) for firms with low degree of GVC participation and more then proportional for firms with high degree of GVC participation. On the other hand if the logistic function is rather flat and close to the linear function the pricing power is equal for the firms with low and high degree of backward GVC participation. The higher the value of the transition parameter and more rapid transition from one regime to another the more pronounced divergence in pricing power of the firms at different stages of global value chain.

Adopting the method proposed by Granger and Teräsvirta (1993) and Teräsvirta (1994) we test first for the presence of general PSTR non-linearity in the form implied by model (11) against the linear panel model. Model (11) is linear if $\gamma = 0$ or $\delta_2 = 0$. However under both hypotheses the PSTR model contains unidentified parameters and the respective tests are non-standard (see Hansen, 1996 and Luukkonen et al., 1988 for discussion). Therefore we approximate the non-linear PSTR model (11) by its Taylor series expansion around $\gamma = 0$, which is the auxiliary regression for the proposed test:

$$
\begin{aligned}
y_{it} = {} & \mu_i + \lambda_0 NEER_{it} + \delta_3 IIPPI^*_{it} + \delta_4 ULC_{it} + \beta' x_{it} + \lambda_1 NEER_{it} \cdot FVAX_{it} \\
& + \lambda_2 NEER_{it} \cdot FVAX^2_{it} + \lambda_3 NEER_{it} \cdot FVAX^3_{it} + u_{it}.
\end{aligned} \tag{12}
$$

The null hypothesis of linearity is:

$$H^*_0 : \lambda_1 = \lambda_2 = \lambda_3 = 0$$

and may be tested using Wald or LM type statistics.

Once the linearity is rejected the next step is to select between the PSTR model with the logistic or exponential transition functions. Therefore we test following hypotheses:

$$H^*_{03} : \lambda_3 = 0$$

$$H^*_{02} : \lambda_2 = 0 \mid \lambda_3 = 0$$

and

$$H^*_{01} : \lambda_1 = 0 \mid \lambda_2 = \lambda_3 = 0.$$

Teräsvirta (1994) points out that the even powers of the Taylor series expansion of the PSTR model with the logistic transition function are zero while these terms are non-zero when the transition function is of the exponential type. On the other hand the odd powers of the Taylor series expansion of the PSTR model with the exponential function are zero while they are different from zero for the logistic transition function. By that reasoning Teräsvirta (1994) proposes to choose the PSTR model with logistic transition function if the minimum p-value is obtained for H^*_{03} or H^*_{01}, conditionally on rejecting linearity. If the minimum p-value is found for H^*_{02} the PSTR model with exponential transition function is the proper one.

After the transition function has been selected we estimate the parameters of the non-linear model (11) following the approach proposed by González et al. (2005). They estimate the smooth transition regression model with fixed effects using the combination of within estimator and non-linear least squares (NLS). In this approach we remove first the fixed effects from the model (11) by subtracting the individual specific means from the data as for the linear within estimator and then we apply the non-linear least squares estimator to the transformed variables.

The algorithm which allows to compute the within estimator for the panel smooth transition regression model differs slightly from the linear case. Since the model is non-linear the values of some explanatory variables in (11) depend on the parameters of the transition function c and γ.

Therefore when applying the non-linear least squares the values of these variables and their individual specific means vary with the iterative estimation of the parameters of the transition function. For that reasons they have to be recomputed at each iteration (see González et al., 2005 for details).

4 Results

Before we analyze the regression results in detail, we look into the evolution of GVC participation, which affects the exchange rate pass-through to producer prices in our model in two ways. First the growing participation in the world's vertical specialization results in the varying (presumably increasing) share of the imported intermediate input in the overall production costs, which is captured in the theoretical model (7) by α_{2i} parameter. As discussed in Section 2 we account for the varying α_{2i} in the empirical model (11) by pre-multiplying the import price indices and nominal effective exchange rate by time and country specific α_{2i}.

Second, the GVC participation of given country' trading partners affects the response of its import prices in local currency to nominal exchange rate fluctuations (parameters δ_1 and $\delta_1 + \delta_2$) in the non-linear model (11) while the measure of GVC participation is a transition variable which determines the switch between regimes of high and low ERPT.

The evolution of GVC participation is presented in Figure 1 for aggregate values as well as in Figure 2 for main groups of countries. Both figures reflect very rapid development of global value chains between 2000 and the global financial crisis of 2009. Both backward and forward participation have stagnated since. These figures also show a division of tasks across the world, ie. while the backward participation has historically been the highest and experienced the highest increase in the New Member States (NMS) of the EU as well as in the EU-15[2], the remaining countries in the world have been mostly forward-participating in GVC through exports of relatively unprocessed intermediates and natural resources. This analysis is confirmed by Figure 3 that can serve as an illustration of the organization of worlds production with the upstream countries having relatively low backward participation and high forward participation (resource countries as well as countries with considerable intellectual property inputs, regarded as primary factor) and the downstream countries (with vertical specialization in the later stages of manufacturing as well as accompanying services) with low forward participation and high backward participation. The distance from the point of origin could be treated as a measure of overall GVC participation. Moreover, Figure 4 shows the evolution of the share of imported intermediate input in the overall production costs (α_{2i} in equation (7)), which by definition is a different measure than backward participation, but in fact captures the similar phenomenon, ie. dependence on foreign intermediates.

Let us discuss next the regression results. We examine first the linear model of exchange rate pass-through to producer prices with country fixed effects disregarding at this stage the impact of GVCs development on ERPT coefficient (we impose the restriction $\delta_2 = 0$ on model (11)). The model is estimated with and without time dummies using fixed effects within estimator. For all variables we take the logs first and then transform them into first differences to ensure the stationarity. The results are presented in Table 1 (columns 1 and 2 respectively).

The relationship between changes in nominal effective exchange rate and dynamics of producer prices proves to be statistically significant. This result is robust to the presence of time dummies. It has to be remind that once we adjust the nominal effective exchange rate by the share of imported

[2]EU-15 refers to the 15 member states of the European Union prior to the accession of ten candidate countries on 1 May 2004, while NMS (New Member States) are the countries, which jointed EU after 1 May 2004.

intermediate input the estimated coefficient of this variable does not have a direct economic interpretation. Therefore we have to derive the exchange rate pass-through to producer prices indirectly by multiplying this coefficient by the share of imported intermediate input in production costs (parameter α_{2i} in equation (7)). We calculate the average ERPT across countries and over time to producer prices as a product of the respective estimate and the share of imported intermediate output in the production costs averaged by year and country. The average ERPT to producer prices amounts to 0.26-0.28 depending on the presence of time dummies, which means that the change in the exchange rate dynamics by 1 p.p. raises the producer price inflation by 0.26-0.28 p.p. within the same year. These numbers are in line with estimates reported by previous literature.

Then we move from linear to non-linear model defined by (11) and allow for variability in exchange rate pass-through in respect to the intensity of country's involvement in global value chains. First we investigate whether the relationship between ERPT to producer prices and the stage of GVC participation of country's trading partners is non-linear. We test the non-linearity using the algorithm proposed by Teräsvirta (1994) and described in Section 3.3. Therefore we investigate the Taylor series expansion of the PSTR model, which is the auxiliary regression in this test. We test the joint significance of the variables being the products of subsequent powers of GVC participation measure and the nominal effective exchange rate. The results of the Teräsvirta test are collected in Table 2. The outcomes strongly reject the linearity in favor of general STR type of non-linearity. The rejection of linearity is robust to the presence of time dummies. Once the linearity has been rejected we select between logistic and exponential transition functions.

The findings stemming from this step of the testing procedure are however not fully unambiguous. For the model with time dummies (Table 2, column 2) the test statistics clearly justify the choice of the logistic function. The p-value is the lowest when rejecting the hypothesis under which the third power of the transition variable in the auxiliary regression (12) is zero. On the contrary for the model without times dummies (Table 2, column 1) the lowest p-value is obtained when verifying the hypothesis on the significance of the second power of the transition variable in the auxiliary regression. It is worth to note however that the difference between p-values for the second and the third powers are relatively small as compared with the outcomes for model with time dummies.

We complement the results of Teräsvirta test by Escribano and Jordá (2001) non-linearity test to make the selection of the transition function more robust. In this test the auxiliary regression is the second order Taylor series expansion of the PSTR model with exponential transition function, which implies that the auxiliary regression includes the products of exchange rate and the subsequent powers of GVC participation measure up to the fourth power. The testing procedure is also a two-step approach. In the first step the general PSTR non-linearity is tested as in Teräsvirta test[3]. In the second step the form of the transition function is determined. In order to distinguish between logistic and exponential transition function two parallel hypotheses are tested. The first one assumes that the odd powers of the transition variable (multiplied by exchange rate) are zero, which implies the exponential type of the transition function. Under the second hypothesis the even

[3]In Escribano and Jordá approach the joint statistical significance of the subsequent powers of the transition variable up to fourth power is tested as compared with testing up to third power in Teräsvirta test.

powers are zero, which corresponds to the logistic function. The choice of the transition function is based on the comparison of the p-values related to both hypotheses. We choose the logistic function if the p-value for the first hypothesis (assuming odd powers of the transition variable equal to zero) is smaller and the exponential function in the opposite case conditionally on rejecting linearity in the first step. We present the outcomes of Escribano and Jordá test in Table 3. The test statistics reject the linearity for the models with and without time dummies at any conventional significance level (first row in Table 3). The selection between the logistic and the exponential function is now unambiguous. For both models the minimum p-value is obtained when rejecting the hypothesis, which assumes that the odd powers of the transition variable are equal to zero (second row in Table 3) implying clearly the choice of the logistic function.

Summing up the results of both tests we may conclude that the relationship between exchange rate pass-through to producer prices and the intensity of GVC participation of given country's trading partners is strongly non-linear and that the logistic function in the proposed PSTR model is appropriate. These findings confirm our main hypothesis that the decline in ERPT due to countries growing involvement in GVCs may be less or more than proportional in regard to their position in the production process within global value chains.

Once the type of transition function has been selected we estimate the parameters of the non-linear PSTR model with the logistic transition function using fixed effects estimator. We grid the starting values using the algorithm proposed by González et al. (2005). The estimation results are collected in Table 4. In the first column we present the results for model without time dummies while the second column contains the numbers for the model with time dummies.

The estimation results validate the choice of the panel smooth transition regression model with the logistic transition function and backward GVC participation measure as a transition variable. We evidence that the exchange rate pass-through to producer prices differs in respect to the intensity of GVC participation of country's trading partners. The ERPT in countries importing intermediate goods from suppliers strongly involved in cooperation within global value chains is significantly (four times) lower than ERPT in countries, whose trading partners do not participate in vertical specialization within GVC. The parameter measuring the impact of nominal exchange rate fluctuations on the dynamics of producer prices in the regime of low GVC participation (of suppliers) is statistically significant and different from the corresponding parameter in the regime of high GVC participation. This result is robust to the presence of time dummies (Table 4, columns 1 and 2). The exchange rate pass-through to producer prices in the regime of low GVC participation derived indirectly from the estimates presented in Table 4 amounts to 0.32-0.34 (dependent on the presence or absence of time dummies) and is ca. 20% higher than the corresponding parameter in the linear ERPT model discussed above, which does not explicitly accounts for the role of vertical specialization within GVC. The interpretation of the estimated ERPT coefficient is as follows: higher by 1 p.p. dynamics of appreciation (depreciation) of nominal effective exchange rate reduces (raises) the producer price inflation within one year by 0.32-0.34 p.p. On the other hand the ERPT in the regime of high GVC participation is equal to 0.07-0.09 only (but still statistically different from zero)[4]. In this regime the increase in appreciation (depreciation) by 1 p.p. lowers (increase) the producer price inflation by 0.07-0.09 within the same year.

The switch from one regime to another determined in our model by the value of the transition parameter γ is relatively sharp. The logistic transition function (9) plotted using the coefficient estimates collected in Table 4 is presented in Figure 5. Moreover Figure 6 shows the fitted values of the ERPT (computed for average share of imported intermediate input in the production costs) for individual observations. From the latter figure we can observe, that our transition from low to high GVC participation regime is indeed very sharp, ie. only few data points end up between the two regimes. This is due to the fact that not only the shift of median backward GVC participation over time was rather quick (at least up to the onset of global financial crisis) but also to the fact that after 2009 the distribution of backward GVC participation has become flatter, ie. increasing the mass of distribution in its tails (Figure 7) which means the higher dispersion of GVC involvement across countries. The country and time-specific estimates of exchange rate pass-through (Figure 8) show that the decline of aggregate ERPT has been mainly caused by changes occurring in ERPT for the EU-15 and the New Members States due to enhanced backward GVC participation of their major trading partners, while the ERPT of other countries have in fact remained roughly the same throughout the analyzed period. All in all the intensity of GVC participation in our sample is strongly diverged not only over time but also across countries. The same conclusion can be drown from comparison of the transition parameter for models with and without time dummies. The value of this parameter for the model with time dummies capturing to some extent the evolution of backward GVC participation over time is significantly lower than for model without time dummies however still very large. It is worth to note that the threshold level for the measure of backward GVC participation, which differentiates between the regimes of low and high ERPT has been estimated at 0.25 for both models, which is close to its median value over the sample.

This sharp transition from the regime of high exchange rate pass-through to the regime of low exchange rate pass-through resulting from the steep transition function supports our hypothesis that the drop in ERPT is less than proportional to the intensity of GVC participation of suppliers with low share of foreign value added in export and more than proportional for countries with high contribution of foreign value added in their export. One of the explanations of this phenomenon may be related to different pricing power of companies at various stages of vertical specialization within GVC as pointed out by Gradzewicz and Mućk (2019). The steeper transition function the stronger discrepancy in pricing power at subsequent stages in global value chains.

Finally we focus on other variables, which according to our specification of the exchange rate pass-through model may potentially affect producer price inflation. We find that in the model without time dummies all explanatory variables proposed in the initial specification prove to have statistically significant impact on dynamics of producer prices. In the model with time dummies

[4]It is worth to remind that in the PSTR model (11) with two regimes we estimate directly the parameter measuring the exchange rate pass-through in the first regime and the parameter measuring the difference between ERPT in first and second regime. The ERPT in the second regime can be then calculated indirectly as the sum of these two values. We test however additionally whether the sum of both estimated parameters equals to zero, which is in fact the test whether the ERPT in the second regime differs from zero. This hypothesis is rejected for both models at any conventional significance level.

however only unit labor costs remain significant while two other variables: import prices in foreign currency and GDP growth turn out to be statistically irrelevant.

When interpreting the relationship between dynamics of unit labor costs and producer price inflation we have to adjust first the estimates reported in Table 4 by the share of labor costs in the production costs, which averaged by years and countries amounts to 0.3. The derived coefficient amounts to 0.59-0.64, which means that the increase in the dynamics of unit labor costs by 1 p.p. raises the producer price inflation by 0.59-0.64 p.p. within the same year.

5 Robustness checks

We conduct a number of robustness checks to evaluate the sensitivity of our results to changes in the model specification. First we confront our findings with alternative explanation of the decline in exchange rate pass-through proposed by Gust et al. (2010). They argue that the increase in exporters' productivity accompanied by the reduction in trade costs results in higher but more volatile markups, complementarity in price setting and lower exchange rate pass-through to import prices in destination currency. Therefore we add to our basic model (11) additional control variable measuring the productivity growth of country's trading partners (suppliers of imported intermediate goods) weighted by the contribution of respective countries and sectors in imported input. The estimation results for the extended model are collected in columns 1 and 2 in Table 5. In the model without time dummies the productivity growth of trading partners is significant with expected negative sign (the growth in productivity of suppliers of imported input reduces domestic producer price inflation). In the model with time dummies this variable proves to be insignificant (but with negative coefficient). The inclusion of the variable reflecting the productivity growth of trading partners does not alter our main results. In both models (with and without time dummies) the coefficient of nominal exchange rate in the regime of low GVC participation remains significant and statistically different from the coefficient of exchange rate in the regime of high GVC participation. Moreover the estimates of ERPT in both regimes are close to the numbers obtained for our basic PSTR model presented in Table 4.

As a second robustness check we control additionally in our model for the fluctuations of commodity prices, which in our sample affected to large extent the dynamics of producer price index in various economies. Therefore we include in our basic PSTR model an additional explanatory variable, which is the energy price index published by the IMF (see Section 3.1 for details). We report the outcomes for this specification of the model in column 3 in Table 5. The additional control variable is statistically significant with expected sign but its presence does not change our previous findings. The estimates of ERPT in regimes of both low and high GVC participation and related standard errors are almost identical as in our basic model. Also the other parameters determining the shape of the transition function are very close to the corresponding numbers in the basic specification reported in Table 4.

Finally we check whether the other characteristics of the trade within global value chains affect the exchange rate pass-through to producer prices as well. In particular we investigate the role of the forward linkages within GVC in reducing the degree of ERPT. De Soyres et al. (2018) argue that aside from the mechanism described in Section 1 referred as backward linkages also the forward GVC linkages may affect the sensitivity of export volume to exchange rate fluctuations. They find that the higher the share of export that returns to given country as an import the weaker responsiveness of export volume to bilateral country's exchange rate. They find no evidence however that the forward linkages affect the ERPT to export/import prices. Nevertheless we check empirically (using different sample and modeling strategy) whether the increase in domestic value added of a given country exported by its trading partners further to third countries, which may potentially return as part of import, reduces the country's exchange rate pass-through to producer prices. Thus we substitute in our basic model the backward GVC participation measure by the forward GVC participation measure as defined in Section 3.2. We present the results of this exercise in Table 6. We find that the coefficient of nominal effective exchange rate in the regime of low forward GVC participation is significant (and close to the corresponding number in our basic model for backward GVC participation measures) but statistically not different from the analogous coefficient in the regime of high GVC forward participation. It means that the country's involvement in forward linkages within global value chains does not affect its ERPT to producer prices.

6 Conclusions

The existing research documents the role of global value chains development in reducing the responsiveness of domestic inflation to exchange rate fluctuations. Vertical specialization of the production process and growing import intensity of exports, decrease the exchange rate pass-through to import prices changing firm's price setting mechanism. The previous literature usually assumes a linear relationship between the intensity of country's GVC participation and the degree of ERPT. Some authors point out, however, that the pricing power of firms involved in vertical specialization within GVC may be different with respect to their position in the global value chains. Firms with high share of foreign value added in exports tend to be price takers rather than price setters. Therefore the decline in ERPT resulting from the enhanced participation in GVC may be more than proportional for countries with suppliers having higher share of foreign value added in exports and therefore weaker firms' market power and less than proportional for countries with suppliers, which have the low contribution of foreign value added in export once the firms are rather price setters.

Our paper proposes a novel modeling approach, which in contrast to the previous research accounts for potential non-linearities in the relationship between the intensity of GVC participation of country's trading partners and the degree of the exchange rate pass-through to its producer prices. We use the panel smooth transition regression model as proposed by González et al. (2005), which assumes the existence of two regimes associated with the intensity of country's trading partners GVC participation, for which the ERPT may be different and a smooth transition between the regimes. We interpret these regimes as the regimes of low and high GVC participation.

We analyze a panel of 43 advanced and emerging economies in years 2001-2014 using WIOD data and investigate the role of backward and forward linkages within GVC in affecting exchange rate pass-through mechanism. We find that the growing backward GVC participation of the suppliers of imported intermediate input results in reducing the ERPT to producer prices. We also evidence that this effect is non-linear. It is more than proportional for countries with suppliers having high share of foreign value added in their exports and less than proportional for countries, whose suppliers feature low degree of backward GVC participation. The transition between regimes of low and high GVC participation is indeed relatively sharp reflecting the divergence in firms' market power at various stages of vertical specialization. Accordingly the ERPT for countries, where suppliers are strongly involved in the production within global value chains is significantly (four times) smaller than for economies with suppliers not participating in GVC. In particular in the regime of low GVC participation the exchange rate pass-through to producer price inflation (PPI) amounts to 0.32-0.34. In the regime of high GVC participation the ERPT to PPI inflation drops to 0.07-0.09, however remains statistically significant.

The country and time-specific estimates of exchange rate pass-through show that the decline of aggregate ERPT has been mainly due to changes occurring in ERPT of the EU members states due to increased backward GVC participation of their major trade partners. The ERPT of other countries have in fact remained roughly the same throughout the analyzed period.

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Tables and figures

Table 1: Estimation results - linear model

	(1)	(2)
	FE	FE, TD
NEER (δ_1)	-1.428***	-1.562***
	(0.151)	(0.146)
ERPT (derived)	**-0.256**	**-0.280**
IIPPI*	1.243***	0.262
	(0.255)	(0.338)
ULC	0.647***	0.595***
	(0.064)	(0.063)
GDP	0.189***	0.079
	(0.044)	(0.054)
Const	0.018***	0.028***
	(0.002)	0.003
R2	0.619	0.668
Adj R2	0.588	0.632
Obs	602	602

Note: The numbers in columns 1 and 2 refer to model with fixed effects and model with fixed effects and time dummies respectively. HAC standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Testing for non-linearity - TR test

	(1)	(2)
	FE	FE, TD
$H_0: \lambda_1 = \lambda_2 = \lambda_3 = 0$	7.388***	8.001***
	(0.0001)	(0.0000)
$H_{0L}: \lambda_3 = 0$	8.986***	11.198***
	(0.0028)	(0.0009)
$H_{0E}: \lambda_2 = 0 \mid \lambda_3 = 0$	9.312***	10.509***
	(0.0024)	(0.0013)
$H_{0L}: \lambda_1 = 0 \mid \lambda_2 = \lambda_3 = 0$	3.624*	2.024
	(0.0575)	(0.1554)

Note: The numbers in columns 1 and 2 refer to the fixed effects and fixed effects with time dummies models respectively. We use LM F-type test statistics. Test p-values in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Testing for non-linearity - EJ test

	(1)	(2)
	FE	FE, TD
$H_0 : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$	5.739***	6.381***
	(0.0002)	(0.0001)
$H_{0L} : \lambda_1 = \lambda_3 = 0$	7.293***	9.270***
	(0.0007)	(0.0001)
$H_{0E} : \lambda_2 = \lambda_4 = 0$	5.793***	7.431***
	(0.0032)	(0.0007)

Note: The numbers in columns 1 and 2 refer to the fixed effects and fixed effects with time dummies models respectively. We use LM F-type test statistics. Test p-values in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Estimation results - non-linear model

	(1)	(2)
	FE	FE, TD
NEER (δ_1) - regime I	-1.771***	-1.889***
	(0.593)	(0.597)
ERPT - regime I (derived)	**-0.317**	**-0.338**
NEER (δ_2)	1.392**	1.369*
	(0.683)	(0.708)
NEER ($\delta_1 + \delta_2$) - regime II	-0.379	-0.519
ERPT - regime II (derived)	**-0.068**	**-0.093**
Transition parameter (γ)	11873.7	2062.1
	(38439.3)	(2656.2)
Threshold parameter (c)	0.247***	0.247***
	(0.0002)	(0.001)
IIPPI*	1.274***	0.343
	(0.390)	(0.447)
ULC	0.638**	0.593**
	(0.290)	(0.276)
GDP	0.194***	0.078
	(0.072)	(0.118)
R2	0.336	0.422
Adj R2	0.329	0.402
Obs	602	602

Note: The numbers in columns 1 and 2 refer to the fixed effects and fixed effects with time dummies models respectively. HAC standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Estimation results - robustness checks

	(1)	(2)	(3)
	FE	FE, TD	FE
NEER (δ_1) - regime I	-2.062***	-1.996***	-1.773***
	(0.652)	(0.665)	(0.602)
ERPT - regime I (derived)	**-0.369**	**-0.357**	**-0.317**
NEER (δ_2)	1.726**	1.459*	1.357*
	(0.744)	(0.767)	(0.692)
NEER ($\delta_1 + \delta_2$) - regime II	-0.335	-0.536	-0.416
ERPT - regime II (derived)	**-0.060**	**-0.096**	**-0.074**
Transition parameter (γ)	569.7	1988.8	9728.7
	(940.4)	(2313.7)	(31053.3)
Threshold parameter (c)	0.247***	0.246***	0.247***
	(0.002)	(0.001)	(0.0002)
IIPPI*	1.438***	0.344	0.669
	(0.369)	(0.428)	(0.477)
ULC	0.590**	0.602**	0.656**
	(0.274)	(0.283)	(0.298)
GDP	0.180**	0.090	0.158**
	(0.072)	(0.114)	(0.071)
PRODUCTIVITY	-0.051**	-0.029	-
	(0.021)	(0.025)	
ENERGY INDEX	-	-	0.0252***
			(0.009)
R2	0.367	0.414	0.346
Adj R2	0.360	0.394	0.339
Obs	602	602	602

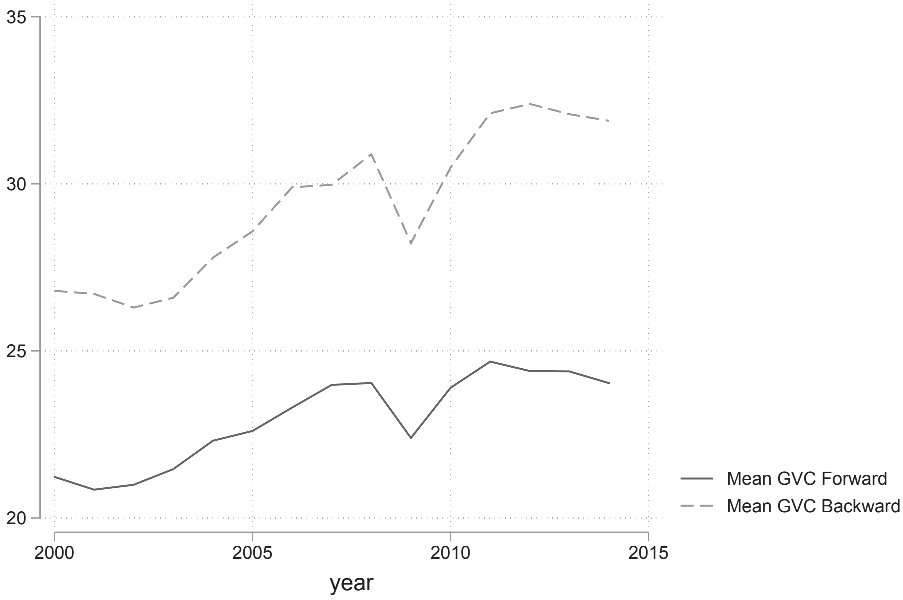
Note: The numbers in columns 1 and 2 refer to models with productivity growth of country's trading partners and fixed effects or fixed effects with time dummies respectively. The numbers in column 3 refer to fixed effects model with energy price index. HAC standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Estimation results - forward GVC linkages

	(1)	(2)
	FE	FE, TD
NEER (δ_1) - regime I	-2.157**	-2.114***
	(0.912)	(0.794)
ERPT - regime I (derived)	**-0.386**	**-0.378**
NEER (δ_2)	1.503	1.329
	(1.008)	(0.856)
NEER ($\delta_1 + \delta_2$) - regime II	-0.654	-0.784
ERPT - regime II (derived)	**-0.117**	**-0.140**
Transition parameter (γ)	717.3	8315.6
	(1249.6)	(145512.3)
Threshold parameter (c)	0.250***	0.254***
	(0.002)	(0.0004)
IIPPI*	1.390***	0.455
	(0.417)	(0.486)
ULC	0.640**	0.618**
	(0.287)	(0.285)
GDP	0.181**	0.078
	(0.075)	(0.123)
R2	0.344	0.414
Adj R2	0.338	0.395
Obs	602	602

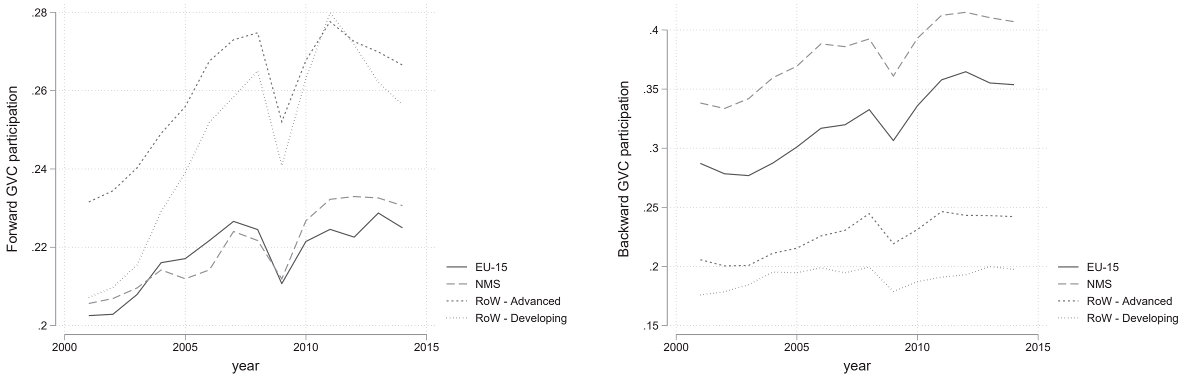
Note: The numbers in columns 1 and 2 refer to the fixed effects and fixed effects with time dummies models respectively. HAC standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure 1: GVC participation: 2000-2014



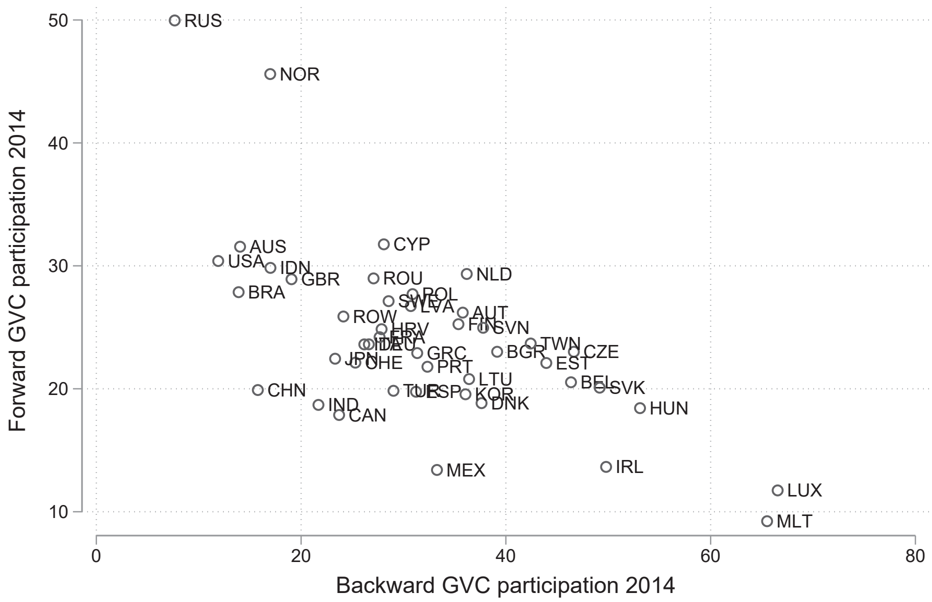
Source: WIOD.

Figure 2: Forward and backward GVC participation by groups



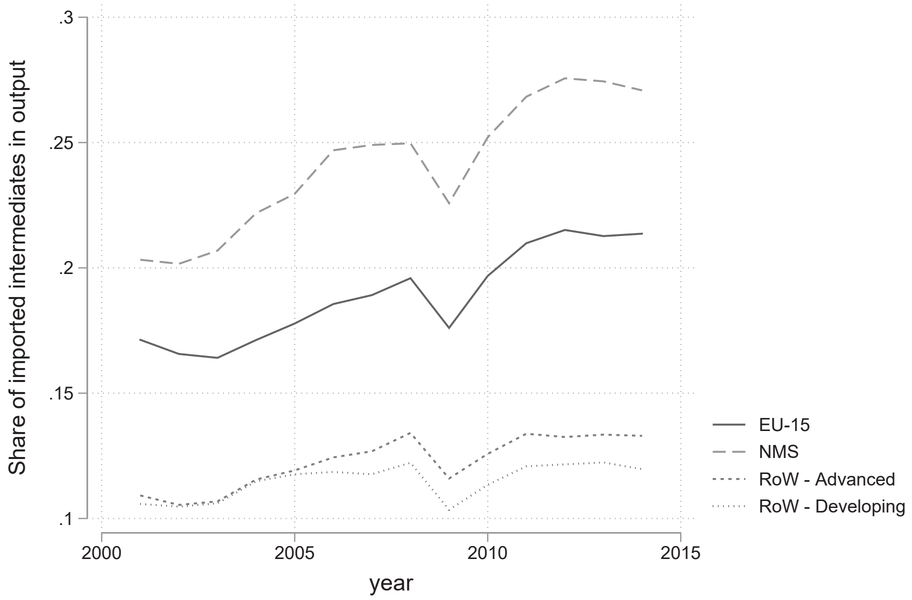
Note: EU-15 refers to the 15 member states of the European Union prior to the accession of ten candidate countries on 1 May 2004, while NMS (New Member States) are the countries, which jointed EU after 1 May 2004. RoW - Advanced stands for advanced economies in the rest of the world, RoW - Developing denotes developing economies in the rest of the world. Source: WIOD.

Figure 3: Countries' position in the GVC (forward vs backward)



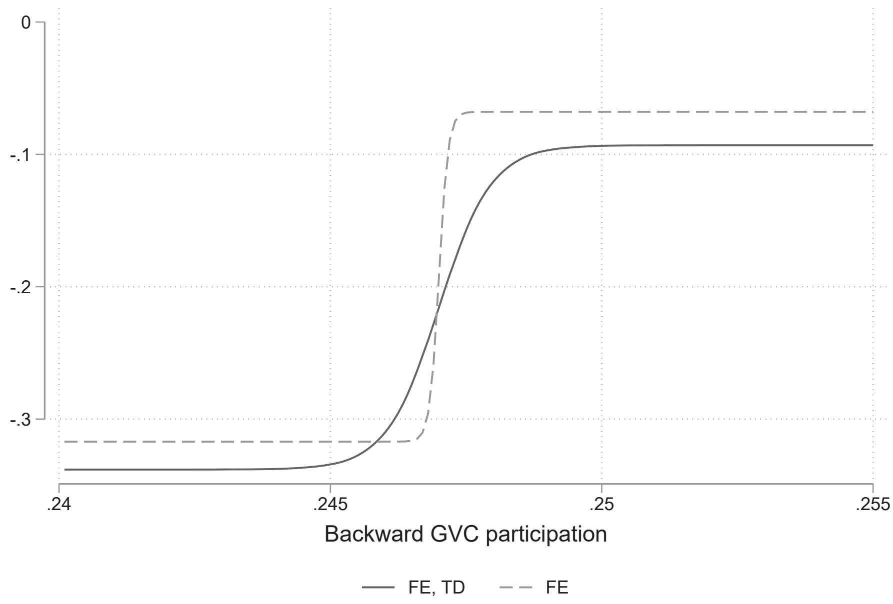
Source: WIOD.

Figure 4: Share of imported intermediates in output



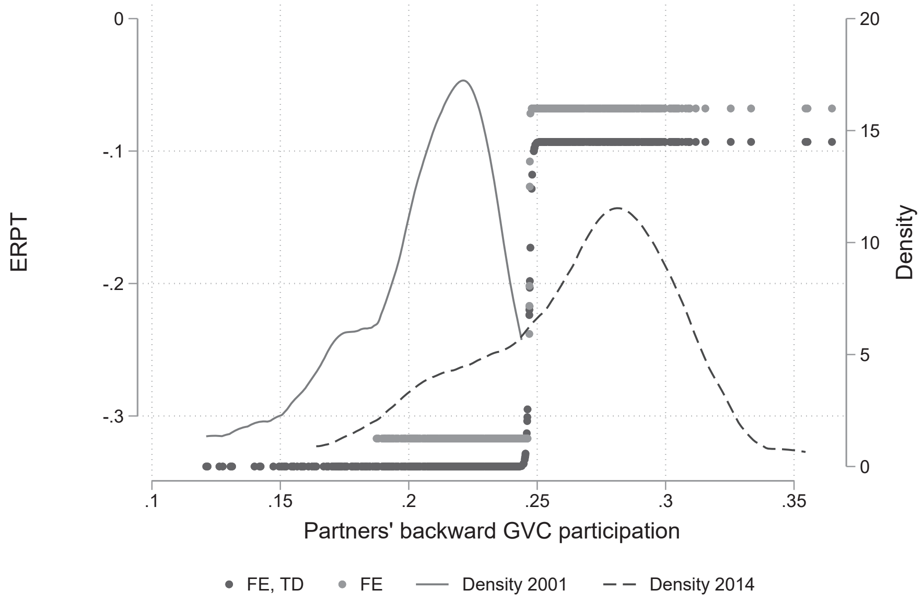
EU-15 refers to the 15 member states of the European Union prior to the accession of ten candidate countries on 1 May 2004, while NMS (New Member States) are the countries, which jointed EU after 1 May 2004. RoW - Advanced stands for advanced economies in the rest of the world, RoW - Developing denotes developing economies in the rest of the world.
Source: WIOD.

Figure 5: Fitted logistic transition function



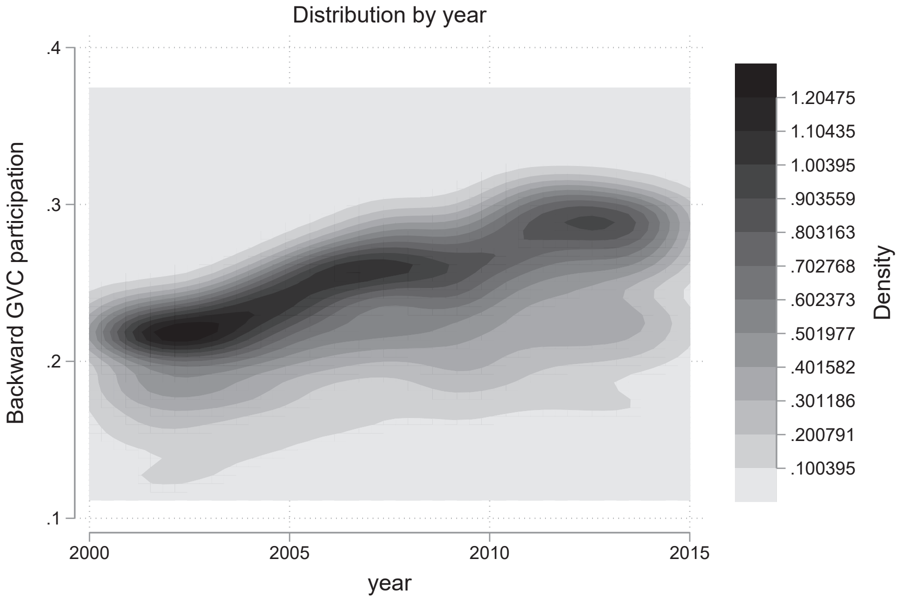
Note: The chart plots fitted logistic transition function using parameter estimates for basic non-linear model (11) collected in Table 4. FE and FE, TD refer to the fixed effects and fixed effects with time dummies models respectively.

Figure 6: ERPT estimates vs density of GVC participation



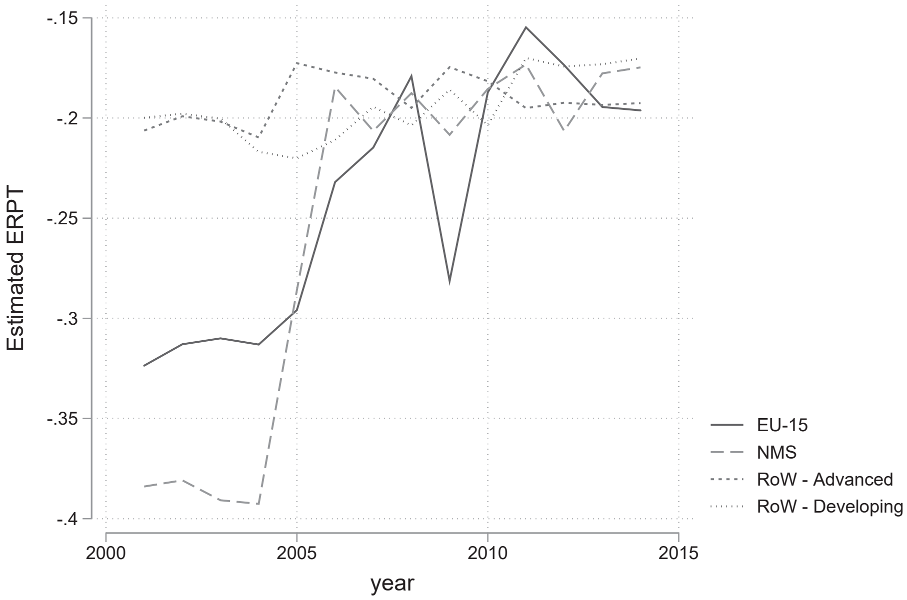
Note: The chart plots the estimates of ERPT for individual countries for basic non-linear model (11) and the density of backward GVC participation of trading partners in years 2001 and 2014. FE and FE, TD refer to the fixed effects and fixed effects with time dummies models respectively.

Figure 7: Distribution of backward GVC participation



Note: The chart plots the evolution of density function of backward GVC participation of trading partners in years 2001-2014.

Figure 8: ERPT estimates by country groups



Note: The chart plots the estimates of ERPT for basic non-linear model (11) for groups of countries. EU-15 refers to the 15 member states of the European Union prior to the accession of ten candidate countries on 1 May 2004, while NMS (New Member States) are the countries, which jointed EU after 1 May 2004. RoW - Advanced stands for advanced economies in the rest of the world, RoW - Developing denotes developing economies in the rest of the world.

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