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Trade balance dynamics and exchange rates: In search of the J-curve using a structural gravity approach

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Abstract
This paper uses a structural gravity approach, specifying currency movements as trade cost component to derive an empirical trade balance model, which incorporates multilateral resistance terms and accounts for the cross-country variation in the exchange rate pass-through into import and export prices. The model is estimated using quarterly bilateral trade flows between 47 countries over the period 2010Q1 to 2017Q2, disaggregated into 97 commodity groups. Our results support the existence of an "aggregate" J-curve, pooled over commodity groups; at the same time they point to considerable heterogeneity in the trade balance dynamics across industries below the surface of aggregate data.

JEL CLASSIFICATION
F12; F31; F32

1 | INTRODUCTION

The prevalence of large and persistent global imbalances is seen as a major threat to the stability of the world economic system. Hence, identifying and quantifying the effects of the main determinants of the current (and financial) account is an issue that is repeatedly raised to the fore in both academic and public debates. The exchange rate, as the most important single price of an economy and crucial determinant of relative prices between domestic and foreign goods, is one key factor influencing global imbalances. In policy discussions of bilateral imbalances, the allegation of exchange rate manipulation and demands for realignments can be observed quite frequently.

From a theoretical perspective, the standard Marshall–Lerner condition specifies when a depreciation leads to an improvement of the trade balance, assuming perfect competition, rigid prices, complete exchange rate pass-through and infinite export supply elasticities. It reveals that a depreciation has three effects: a price effect, since imports become more expensive, and quantity responses of exports and imports owing to changes in their relative prices. This basic insight also holds true under more general assumptions.

The price effect typically materializes more quickly than the quantity effects. As a consequence, a depreciation may lead to an incipient deterioration of the trade balance, which subsequently turns into a positive effect after the quantity effects have worked themselves out. This gives rise to a J-curve effect of a depreciation on the trade balance (or an inverted J-curve effect of an appreciation on the trade balance).

The J-curve phenomenon and the "sluggishness of quantity" was first considered in detail by Magee (1973). Up to the late 1980s, the J-curve hypothesis has then been repeatedly tested using aggregate trade data, investigating the link between a country's real effective exchange rate and its trade balance vis-à-vis its most important trading partners using time-series techniques (e.g., Bahmani-Oskooee, 1985; Himarios, 1985). These types of studies, which show mixed results on the presence of J-curves, were criticized for being potentially subject to an aggregation bias that conceals effects taking place at the bilateral level (Bahmani-Oskooee & Brooks, 1999).

Rose and Yellen (1989) were the first to use bilateral trade data and test the J-curve hypothesis for country pairs, utilizing cointegration techniques proposed by Engle and Granger (1987), but they find no support for the presence of a J-curve. More recent studies make use of an error-correction version of an autoregressive distributed lag (ARDL) model, suggested by Pesaran, Shin, and Smith (2001). Overall, as suggested by the comprehensive survey by Bahmani-Oskooee and Ratha (2004), the empirical evidence on the existence of a J-curve is rather mixed.

The most widely used models for the analysis of trade balance dynamics strongly resemble early empirical gravity equations by relating the export–import ratio to relative economic size (proxied by GDP) and the (real) exchange rate. Additional (ad-hoc) variables included in previous studies are GDP growth, government consumption or the level of high-powered money (see Bahmani-Oskooee & Ratha, 2004).

A shortcoming even of recent studies on trade balance dynamics is that they do not reflect the considerable progress that has been made in the gravity literature, which emphasizes the importance of multilateral resistance terms (Anderson & Van Wincoop, 2003) and incorporates the exchange rate (and its pass-through) as trade cost component (Anderson, Vesselovsky, & Yotov, 2016). This widespread lack of a rigorous theoretical foundation may be an explanation for the mixed or negative results about the presence of a J-curve in the vast majority of previous studies.

The present paper addresses these shortcomings by setting up a trade balance model that builds on a structural gravity model, shifting the focus from a bilateral to a multilateral analysis, accounting for third-country effects and incorporating cross-country differences in the exchange rate pass-through. The empirical model is tested for a comprehensive and recent dataset over the period 2010 to 2017, including quarterly observations on bilateral trade flows between 47 (mainly OECD) countries, disaggregated into 97 commodity groups, with a total of up to 64,860 observations per commodity group.[1]

We find that, when pooling across commodity groups, the trade balance deteriorates over the first two quarters following a depreciation. This effect persists for four quarters and is then followed by a trade balance improvement in the long run, thus providing evidence for an "aggregate"

J-curve. The results of the estimates for the 97 commodity groups are less clear cut and show considerable heterogeneity, though their average closely resembles the results from the pooled estimation.

The remainder of the paper is structured as follows: Section 2 reviews a theoretically founded gravity model with exchange rate effects. Section 3 sets up a closely related, gravity based short- and long-run trade balance model. Section 4 presents the results from testing the J-curve hypothesis based on the corresponding empirical model, both pooled across and disaggregated for 97 commodity groups. Section 5 concludes.

2 | GRAVITY AND EXCHANGE RATES AS DETERMINANTS OF TRADE COSTS

In this section we consider a structural gravity model including the exchange rate, which builds the backbone of our empirical analysis.

2.1 | The basic gravity model

Specifically, our analysis builds on Anderson and Van Wincoop (2003). They use a multi-country monopolistic competition model to derive a gravity equation, which implies that the export shipment from country i to country j for commodity k at time t ($\bar{X}^k_{ijt}$) is given by

$$\bar{X}^k_{ijt} = Y^k_t s^k_{it} b^k_{jt} \left(\frac{t^k_{ijt}}{\Pi^k_{it} P^k_{jt}} \right)^{1-\sigma_k}, \tag{1}$$

where the bar over the dependent variable is meant to indicate that Equation 1 describes an equilibrium outcome for period t; Y^k_t is the world shipment from all origins to all destinations of commodity (group) k (total sales and expenditures), s^k_{it} is the share of world shipments of commodity k coming from origin i, b^k_{jt} is the share of world shipments of commodity k going from all origins to destination j, and $Y^k_t s^k_{it} b^k_{jt}$ is the predicted frictionless trade flow of commodity k from country i to country j.

The second ratio is thus to be interpreted as the ratio of predicted trade (given trade costs) to predicted frictionless trade (Anderson, 2011), where the variable t^k_{ijt} depicts iceberg-type bilateral trade costs (equal to one under frictionless trade), and σ_k is the elasticity of substitution parameter. Finally, Π^k_{it} and P^k_{jt} are the exporter (outward) and importer (inward) multilateral trade resistance terms (henceforth MRT), respectively, defined as

$$(\Pi^k_{it})^{1-\sigma_k} = \sum_j \left(\frac{t^k_{ijt}}{P^k_{jt}} \right)^{1-\sigma_k} b^k_{jt} \quad \text{and} \quad (P^k_{jt})^{1-\sigma_k} = \sum_i \left(\frac{t^k_{ijt}}{\Pi^k_{it}} \right)^{1-\sigma_k} s^k_{it}, \tag{2}$$

that is, they can be regarded as income-share weighted average of the exporter's and importer's bilateral resistances (trade costs) with all trading partners. In a frictionless world with zero trade costs, Equation 1 simplifies to its first expression, that is, $X^k_{ijt} = Y^k_t s^k_{it} b^k_{jt}$, and trade flows solely depend on world output (sales/expenditures) and the exporter's sales and importer's expenditure shares therein.

2.2 | Exchange rate effects in the gravity model

Following Anderson et al. (2016), the exchange rate is modeled as a time-variant per unit trade cost, where a depreciation could be equivalently interpreted as a tax on imports or subsidy on exports. Accordingly, bilateral trade costs in period t are defined as

$$t_{ijt}^{k} = \frac{\tau_{ij}^{k}}{E_{ijt}^{\rho_j^k}}, \tag{3}$$

where τ_{ij}^{k} is the (bilateral) commodity-specific, time-invariant trade cost component, related to distance and contiguity and de facto time-invariant variables such as, for example, language, cultural or institutional differences or transport technology.

In Equation 3, the variable E_{ijt} reflects the bilateral exchange rate between countries i and j; it is time-specific and hence introduces time variation into (total) bilateral trade costs t_{ijt}^{k}. It is defined such that an increase in the exchange rate is associated with a depreciation of country i's currency vis-à-vis country j's currency (price notation).

Of course, whether the decomposition of trade costs into a time-invariant component and the exchange rate as the only time-variant component is appropriate, depends on the time period considered. For our empirical analysis with a time span of 7 years, we argue that this approach can be reasonably justified.

Exchange rate changes matter for country i's exports only, if they translate into consumer prices of country j (i.e., country j's imports in domestic currency). Hence, another crucial determinant of trade costs is the variable ρ_j^k, reflecting the exchange rate pass-through (ERPT) to country j's import prices.[2] According to Equation 3, a 1% depreciation of the exporter's currency relative to the importer decreases trade costs by $(100 \times \rho_j^k)$% in industry k, that is, if ERPT is complete, then $\rho_j^k = 1$. On the other extreme, if exporters fully (have to) "absorb" the depreciation, import prices do not respond at all, $\rho_j^k = 0$, and trade is invariant to exchange rate changes.

Substituting Equation 3 into Equation 1 yields the following augmented gravity equation:

$$\bar{X}_{ijt}^{k} = Y_t^k \frac{s_{it}^k}{(\Pi_{it}^k)^{1-\sigma_k}} \frac{b_{jt}^k}{(P_{jt}^k)^{1-\sigma_k}} \left(\frac{\tau_{ij}^k}{E_{ijt}^{\rho_{jt}^k}} \right)^{1-\sigma_k}. \tag{4}$$

According to Equation 4, a country with a higher ERPT of the importer country will experience larger export effects of exchange rate changes.

Note that with homogeneous ERPT, that is, $\rho_j^k = \rho_i^k = \rho^k$, the effects of exchange rate shocks on trade costs are fully symmetric, since $E_{jit} = E_{ijt}^{-1}$:

$$\left| \frac{\Delta t_{ijt}^k}{\Delta E_{ijt}} \right| = \left| \frac{\Delta t_{jit}^k}{\Delta E_{jit}} \right| = \rho^k \frac{\tau_{ij}^k}{E_{ijt}^{\rho^k - 1}}, \tag{5}$$

that is, the effects of exchange rate changes on the exporter's and importer's trade costs are mirror images.

Note that in Equation 4, ρ can only be interpreted as "pure" ERPT, if the (absolute) elasticity of country j's import demand with respect to prices is equal to $(1-\sigma_k)$ and hence invariant over destination countries j. We relax this assumption by replacing ρ_j^k by $\eta_j^k \Phi_j^k$, where η_j^k is the "pure" ERPT, which represents the amount of the change in exchange rates between currencies of i and j that is reflected in importing prices for country j, and where Φ_j^k (together with σ_k) reflects the (destination-country variant) elasticity of country j's import demand with respect to any changes in importing prices (which is assumed to be invariant across countries of origin i). As argued above, in case that $\Phi = 1$, $\rho = \eta$. As a result, trade costs are redefined as

$$t_{ijt}^k = \frac{\tau_{ij}^k}{E_{ijt}^{\eta_j^k \Phi_j^k}}, \tag{6}$$

and the augmented gravity model is given by

$$\bar{X}_{ijt}^k = Y_t^k \frac{s_{it}^k}{(\Pi_{it}^k)^{1-\sigma_k}} \frac{b_{jt}^k}{(P_{jt}^k)^{1-\sigma_k}} \left(\frac{\tau_{ij}^k}{E_{ijt}^{\eta_j^k \Phi_j^k}} \right)^{1-\sigma_k}. \tag{7}$$

Equation 7 shows that bilateral export flows depend positively on the exchange rate (increase with a depreciation) and that this relationship is stronger, when the ERPT (η_j^k) is large and when the price elasticity (related to exchange rate changes) w.r.t. foreign products is large, that is, when Φ_j^k and σ_k are large in magnitude.

3 | TRADE BALANCE GRAVITY, EXCHANGE RATES, AND THE J-CURVE

In the following, we translate the export gravity Equation 7 into a trade balance gravity equation, which will be used to test the J-curve hypothesis, according to which a depreciation is instantly followed by a deterioration of the trade balance (price effect) and a consecutive improvement (quantity effect) that is large enough make up for the incipient negative short-run effect.

In order to test the J-curve hypothesis, two modifications of the structural gravity equation defined in Equation 7 are required: First, the dependent variable of interest is the trade balance (*TB*) rather than exports. Second, Equation 7 does not distinguish between short-run and long-run effects of the exchange rate on the trade balance and therefore does not allow for opposite signs of short- and long-run effects, which is at the heart of the J-curve hypothesis.

3.1 | Trade balance gravity

Addressing the first issue, we define the bilateral trade balance TB_{ij}^k as the ratio of (commodity k) exports of country i to country j relative to the exports of country j to country i, that is, $\overline{TB}_{ijt}^k = \bar{X}_{ijt}^k / \bar{X}_{jit}^k$. Making use of Equation 7, this yields the following trade balance version of the gravity model

$$\overline{TB}_{ijt}^k = \frac{\bar{X}_{ijt}^k}{\bar{X}_{jit}^k} = \frac{Y_t^k}{Y_t^k} \frac{s_{it}^k b_{jt}^k}{s_{jt}^k b_{it}^k} \left(\frac{\tau_{ij}^k}{E_{ijt}^{\eta_j^k \Phi_j^k} \Pi_{it}^k P_{jt}^k} \right)^{1-\sigma_k} \left(\frac{\tau_{ji}^k}{E_{jit}^{\eta_i^k \Phi_i^k} \Pi_{jt}^k P_{it}^k} \right)^{\sigma_k - 1}, \tag{8}$$

which specifies net exports as a function of relative income shares and relative (time-invariant and time-varying) trade costs, adjusted by the ratio of countries' MRTs. Since parameters s and b pertain to frictionless trade, $Y_t^k s_{it}^k b_{jt}^k = Y_t^k b_{it}^k s_{jt}^k$ by symmetry, such that the first and second term in Equation 8 cancel out. We obtain

$$\overline{TB}_{ijt}^{k} = E_{ijt}^{(\eta_j^k \Phi_j^k + \eta_i^k \Phi_i^k)(\sigma_k - 1)} \left(\frac{\tau_{ji}^k}{\tau_{ij}^k} \right)^{\sigma_k - 1} \left(\frac{\Pi_{it}^k}{P_{it}^k} \right)^{\sigma_k - 1} \left(\frac{P_{jt}^k}{\Pi_{jt}^k} \right)^{\sigma_k - 1}, \tag{9}$$

where we have made use of the fact that $E_{jit} = E_{ijt}^{-1}$. Hence, in the trade balance gravity equation Equation 9 referring to trade with frictions, imbalances occur as a result of asymmetries in trade costs t_{ijt}^k.

Equation 9 shows that an increase in the exchange rate E (depreciation) leads to an improvement of the trade balance, and the effect is larger, the greater the increase in exports and the decrease in imports. The effect on exports in turn is larger, the larger (in magnitude) the price elasticity of country j w.r.t. to foreign goods, that is, $\Phi_j^k(\sigma_k - 1)$, and the more exchange rate changes pass through to country j's consumer prices of country i's exports (η_j^k).

The effect on imports is larger, the larger (in magnitude) the price elasticity of country i w.r.t. to foreign goods, that is, $\Phi_{it}^k(\sigma_k - 1)$ and the more exchange rate changes pass through to consumer prices of country i's imports from country j (η_i^k). Taking logs we obtain the following empirical model:

$$\begin{aligned} \ln \overline{TB}_{ijt}^{k} = {} & \ln \kappa_{ijt}^k + \Phi_j^k(\sigma_k - 1)(\eta_j^k \times \ln E_{ijt}) + \Phi_i^k(\sigma_k - 1)(\eta_i^k \times \ln E_{ijt}) \\ & + (\sigma_k - 1) \ln \left(\frac{\tau_{ji}^k}{\tau_{ij}^k} \right) + (\sigma_k - 1) \ln \left(\frac{\Pi_{it}^k}{P_{it}^k} \right) + (\sigma_k - 1) \ln \left(\frac{P_{jt}^k}{\Pi_{jt}^k} \right) + \varepsilon_{ijt}^k, \end{aligned} \tag{10}$$

which relates the trade balance (TB) to the exchange rate (E), interacted with importer ERPT (η_j) and exporter ERPT (η_i), relative trade costs ($\frac{\tau_{ji}^k}{\tau_{ij}^k}$) and the ratios of countries' MRTs; finally, ε_{ijt}^k is an idiosyncratic error term.

Our trade balance gravity model expressed in Equation 9 can be interpreted as a generalization of the widely used J-curve model by Rose and Yellen (1989) and Bahmani-Oskooee and Brooks (1999), which establish a simple relationship between bilateral trade balances, exporter and importer GDP and (real) exchange rates. The latter can be retrieved from our model by imposing the following restrictions: First, assuming that both pass through to exporter's and importer's prices (η_i and η_j) are complete, and interpreting effects of changes in real exchange rate on the trade balance "as indicating approximate response of the trade balance to a nominal devaluation" (Himarios, 1985, p. 561). The variable of interest therefore becomes *real* instead of *nominal* exchange rate. Second, assuming bilateral trade costs to be symmetric, such that the second term within parentheses on the right-hand side of Equation 9 drops out. Third and most importantly, by omitting third country effects, and analyzing each bilateral trade balance separately, such that both MRT ratios in Equation 9 simplify to a ratio of demand over supply (i.e., b_{jt}/s_{jt} and s_{it}/b_{it}), proxied in the literature by exporter and importer GDP.

3.2 | Direct short-run and long-run effects

We next turn to a dynamic version of Equation 10 that is able to distinguish between direct short- and long-run effects on the trade balance with potentially different signs; by *direct* effects on the trade balance, we refer to short- and long-run effects as a result of exchange rate changes (translating into a change in the value of imports) and price changes related to the change in the exchange rate (and the implied import- and export-quantity effects, depending on the exchange rate pass-through and the demand responses), a point to which we will return after introducing the empirical model below.

A preliminary inspection of the time-series properties of our key variables—the trade balance and the exchange rate—indicates that around 88% of the 1,908 series contain a unit root for *TB* and 95% for *E*, when four lags are considered (the same applies when controlling for a time trend). This share drops with a shorter lag-length (particularly for *TB*), such that we conclude that most of our series are integrated of order one, with a small subset of stationary series.

Against this background, we opt for the dynamic fixed-effect estimator for non-stationary heterogeneous panels by Pesaran and Smith (1995).[3]

$$\begin{aligned}\Delta \ln TB^k_{ijt} = {} & \delta^k_1 \ln TB^k_{ijt-1} + \delta^k_2(\eta_j \times \ln E_{ijt-1}) + \delta^k_3(\eta_i \times \ln E_{jit-1}) \\ & + \sum_{q=1}^{Q} \psi^k_q \Delta \ln TB_{ijt-q} + \sum_{p=0}^{P} \nu^k_p \Delta(\eta_j \times \ln E_{ijt-p}) \\ & + \sum_{p=0}^{P} \omega^k_p \Delta(\eta_i \times \ln E_{ijt-p}) + \alpha^k_{it} + \gamma^k_{jt} + \mu^k_{ij} + \varepsilon^k_{ijt}.\end{aligned} \quad (11)$$

Equation 11 will be estimated separately for each specific commodity group *k* (i.e., with cross-section dimension *ij*) as well as a panel that is pooled over commodity groups *k*, the latter case corresponding to Equation 11 with superscript *k* dropped (apart from α^k_{it}, γ^k_{jt}, and μ^k_{ij}) and with cross-section dimension *ijk* rather than *ij*.

In Equation 11, multilateral resistance terms ratios (Π_{it}/P_{it} and P_{jt}/Π_{jt} respectively) are controlled for by time-varying exporter–commodity (α_{it}) and importer–commodity fixed effects (γ_{jt}). The time-invariant trade cost component is accounted for by the use of cross-section (exporter–importer–commodity) fixed effects (μ_{ij}).

This leaves the exchange rate (E_{ijt}), interacted with importer ERPT (η_j) and exporter ERPT (η_i), as key explanatory variable in our model. Ideally, ERPT would be measured at the commodity group level; unfortunately, for our sample, ERPT measures are only available at the country-level. Hence, the ERPT variables η_j and η_i are time invariant and country specific, both in the pooled estimation and in the estimation by commodity group. Provided there is cointegration (and the coefficients are significant), the long-run effect of a change in the exchange rate on the trade balance implied by Equation 11 is given by $-(\delta_2 + \delta_3)/\delta_1$.

Short-run impacts are traced out by cumulatively summing up over time the estimates of the parameters associated with the lagged first differences of the exchange rate ($\nu_p + \omega_p$). An advantage of the ECM approach is that it gives us a direct estimate of long-run effects, allowing us to choose a parsimonious specification of Equation 11 for the short-run. If prices were completely flexible, the (negative) price effect would materialize immediately to its full extent; if for part of the exports, the exchange rate is contractually fixed for a certain period of time, the short-run effect will materialize with a delay. We opt for a maximum lag-length of eight quarters for the first differences of both the trade balance and the exchange rate, after which we assume the short-run price effect to have fully materialized. The total short-run effect is then obtained by summing over all short-run parameters ($\sum_{p=0}^{8} (\nu_p + \omega_p)$).

As argued above, the effects traced out by the parameters δ, ψ, and ω have to be interpreted as *direct* short-run and *direct* long-run effects on the trade balance, that is, effects of exchange rate changes and price changes in direct response to exchange rate changes, whereas subsequent price adjustments are not captured by these parameters but controlled for by the time-variant (commodity–)country-fixed effects α^k_{it} and γ^k_{jt}.

Controlling for "indirect" price (and their trade balance) effects by fixed effects is perfectly consistent with our aim to test the J-curve hypothesis, which rests on an immediate effect of the exchange rate change on the value of imports and the quantity responses owing to price changes triggered by the change in the exchange rate. In the long(er)-run, allowing for indirect price effects (on the trade balance), the existence of a J-curve is much less certain; according to purchasing power parity theory, for example, these price adjustments would exactly offset the initial change in the exchange rate, such that the real exchange rate would return to 1 and the trade balance to its initial state.

Having clarified the notion of direct short-run and long-run effects, we define our estimation results to be indicative of the existence of a J-curve, if the cumulative direct short-run effect of a depreciation is significant and negative for any of the lag-lengths considered and the (cointegrating) direct long-run effect given by $-(\delta_2 + \delta_3)/\delta_1$ is significant and positive.

4 | ESTIMATION RESULTS

In order to trace out the trade balance dynamics in response to exchange rate changes and to test for J-curve effects, we use quarterly data over the period 2010 to 2017. The use of high frequency data is important, since with yearly data, offsetting effects might occur within the same time period, potentially giving a distorted picture of the shape of the reaction function.[4]

Bilateral trade flows are extracted from the UN Comtrade database, quarterly exchange rates are taken from the European Central Bank data warehouse and defined as quarterly average of units of foreign currency in domestic currency. Country-specific data for the exchange rate pass-through (ERPT) is taken from Bussiere, Gaulier, and Steingress (2016), who provide estimates of the exchange rate pass-through to import prices for 51 economies. Unfortunately their ERPT-estimates are time invariant and not disaggregated into commodity groups.

We end up with an unbalanced panel of 47 advanced and emerging economies and a total of 97 commodity groups, following the two-digit Harmonized System (HS) classification (2012 revision).[5] This yields an average of 24,944 observations (of potentially 64,860) per commodity group and 2,419,613 observations in total.

To test for a long-run (cointegrating) relationship between *TB* and *E* (interacted with importer and exporter ERPT), we carry out Pedroni (1999) panel cointegration tests for each of the 97 commodity groups. The testing procedure consists of seven statistics, four based on a pooled panel (the "within dimension"), three based on a group-mean approach, allowing parameter heterogeneity over cross-sectional units (the "between dimension").[6]

Detailed results are reported in Table A1 in the Appendix. All of the 679 tests (seven tests, 97 commodity groups) reject the null hypothesis of no cointegration. This is strong evidence for the existence of a long-run cointegrating relationship between the trade balance and the exchange rate for all 97 commodity groups (and thereby indirectly also for an overall long-run relationship in the "average" panel that is pooled across commodity groups). Of course, sign and significance of the link between *TB* and *E* remain to be determined in the estimation of the error-correction model (11).

4.1 | Results for pooled panel

To illustrate our empirical approach, Equation 1 is first estimated as a panel, which is pooled for all 97 commodity groups and can hence be considered as analysis of the aggregate trade balance.

Cross-section (exporter–importer–commodity) fixed effects and exporter–commodity–time and importer-commodity-time are included in the estimation. The cross-sectional dimension comprises

92,816 exporter–importer–commodity combinations and the time dimension ranges from 2010Q1 to 2017Q2 (30 quarters). As outlined above, the maximum number of lags of the first differences of *TB* and *E*, that is, the short-run terms, is set equal to eight quarters in line with earlier studies typically using up to six or eight quarterly lags (see, for instance, Bahmani-Oskooee & Kanitpong, 2017).

The lag-length is then determined by minimizing the joint *F*-test on the short-run coefficients of *E* and minimizing the mean-squared prediction error (MSE). In case of conflicting outcomes of these two approaches, we select the smaller number of lags for the sake of parsimony.[7] For the pooled estimation of Equation 11, the number of lags obtained is one for ΔTB and four for ΔE (interacted with both ERPT), yielding an ECM (1, 4).

Table 1 shows the estimation results for Equation 11. The first panel reports the long-run coefficients, related to the lagged level of the *TB* (δ_1) and *E*, interacted with importer ERPT (δ_2) and exporter ERPT (δ_3). The second panel reports the (short-run) coefficients of the lagged first difference of *TB* and of four lags of the first difference of *E* (along with the contemporaneous difference), interacted with importer ERPT (η_p) and exporter ERPT (ω_p). Additionally, the third and fourth panels report

TABLE 1 Estimates of pooled trade balance model, Equation 11

Quarterly lags	t	t−1	t−2	t−3	t−4
Long run (LR)					
TB		−0.706*** (0.002)			
$(\eta_j \times E)$		0.376*** (0.125)			
$(\eta_i \times E)$		0.341*** (0.129)			
Joint *F*-Test on *E*	8.14***				
Short run (SR)					
ΔTB		−0.101*** (0.001)			
$\Delta(\eta_j \times E)$	−0.097 (0.179)	−0.404** (0.196)	−0.337* (0.190)	−0.160 (0.195)	−0.122 (0.188)
$\Delta(\eta_i \times E)$	−0.250 (0.184)	−0.427** (0.199)	−0.181 (0.191)	0.038 (0.195)	−0.064 (0.187)
Aggregate SR effect					
$\Delta E \times (\eta_j + \eta_i)$	−0.348 (0.241)	−0.764*** (0.281)	−0.518** (0.256)	−0.198 (0.261)	−0.187 (0.247)
Cumulative SR effect					
$\sum \Delta E \times (\eta_j + \eta_i)$	−0.348 (0.241)	−1.112*** (0.369)	−1.631*** (0.522)	−1.829*** (0.647)	−2.017*** (0.754)
Observations	1,592,930				
Exporter–importer–commodity	92,816				
Adj. R^2	0.420				
Within R^2	0.397				

Notes. Cross-section clustered standard errors in parentheses. The model includes exporter–commodity–time (85,065), importer–commodity–time (85,272) and exporter–importer–commodity fixed effects. ***, **, * Denote significance at 1%, 5%, and 10%, respectively.

the short-run quarterly aggregate effects of E, defined as $(\eta_p + \omega_p)$, and the cumulative effect of E, obtained by summing up the aggregate effects of E over time.

Considering specification tests of our model, note that a panel Breusch–Pagan test rejects the null hypothesis of homoskedasticity. Heteroskedasticity has been a main issue in the OLS estimation of gravity equations and our application does not make an exception.[8]

In the pooled regression, the Wooldridge (2010) test for serial autocorrelation turns out significant at the 1% level. With a view to our (preferred) estimates by commodity group, we repeated the test for subsets of our sample, namely importer–exporter by commodity, importer–commodity by exporter, and exporter–commodity by importer. The corresponding results indicate that the null hypothesis of uncorrelated disturbances cannot be rejected for 79.2%, 76.6%, and 78.4% of the estimates, respectively. These results, pointing to a lack of serial correlation for the large majority of our residual series, will be enforced by our serial correlation tests of the estimates by commodity group.

To address both the presence of heteroskedasticity and serial correlation (in a subset of our series), we follow the approach suggested by Baltagi (2001) and Wooldridge (2010) and use cross-section clustered standard errors for inference.

Turning to the results, the estimate of the speed of adjustment parameter (δ_1), that is, the coefficient related to level TB, is equal to -0.706 and significantly different from zero, thus indicating a relatively quick return to equilibrium following a shock on the trade balance. The long-run effect of a depreciation passed through to export prices amounts to $-(0.376/-0.706) = 0.532$, since demand for exports goes up as a result of a decrease in prices (which in turn depends on the importer ERPT (η_j)). The long-run effect materializing through increased import prices of the exporting country $(\eta_i \times E)$ is given by $-(0.341/-0.706) = 0.483$. Interestingly, we find that the responses to the price effects passed through to exports and imports are equal in size, that is, the hypothesis that $\delta_2/\delta_1 = \delta_3/\delta_1$ cannot be rejected.

Summing up, our results for the long run suggest a positive (cointegrating) relationship between the trade balance and the exchange rate (indicating that the Marshall–Lerner condition is fulfilled for aggregate trade on average), and that the import and export channels are quantitatively of equal importance, conditional on the exchange rate pass-through.

Regarding the short-run, the coefficients of the lagged differences $\Delta(\eta_j \times \ln E)$ and $\Delta(\eta_i \times \ln E)$ are negative and significant at lag zero for the former and at the first quarter lag for the latter. The significant negative effect of $\Delta(\eta_i \times \ln E)$ is consistent with an immediate price effect on country i's imports from country j, which increase in value and hence deteriorate the trade balance. The significant negative effect of $\Delta(\eta_j \times \ln E)$ is consistent with the immediate price effect on the exporter's side, which is due to the decrease of exports' trade value that deteriorates the trade balance; this suggests that part of exports is contracted in foreign currency and that part of the depreciation is borne by the exporter.[9] By symmetry, from the importing country j's perspective, the change in the exchange rate would be associated with an appreciation and a positive price effect through a larger value of exports to country i and a smaller value of imports from country i.

Furthermore, it is worth noting that ignoring the importer and exporter ERPT by setting $\eta_i = \eta_j = 1$ yields a positive long-run coefficient of E equal to 0.733 (not reported in the table), which is close to the sum of both estimates from the first panel of Table 1 but turns out insignificant. Moreover, in this specification, none of short-run coefficients of the lagged differences of the (interacted) exchange rate are significant, such that the existence of a negative short-run (price) effect would be concealed. We conclude that accounting for the ERPT is important in the analysis of trade balance dynamics and that its omission from the analysis (as in most previous studies) may yield misleading estimates.

Remaining short-run coefficients are also negative until the last lag considered though they turn out statistically insignificant. However, if we restrict the parameters of $\Delta(\eta_i \times E)$ and $\Delta(\eta_j \times E)$ to equality and consider the combined effect of a change in the exchange rate (which can be justified by F-tests statistically), the effects reported in the third panel, that is, the overall short-run effect of change in exchange rate through both the export and import channel, show a longer lasting (negative) short-run effect up to the fourth quarter lag. The persistence of this short-run *TB* deterioration, measured by the cumulative sum of short-run coefficients in the fourth panel, lasts up to four quarters following the depreciation with a total sum equal to −2.017. There is therefore no evidence of a strong short-run recovery (or quantity effect) already in the first year after the shock. However, in light of the large standard error (0.754) and the fact that several coefficients turned out insignificant when considered separately, the magnitude of the negative cumulative short-run effect should not be overstressed.

Overall, with aggregate trade data, the J-curve hypothesis receives support by negative short-run (price) effects (reflected in negative single, aggregated and cumulative sums of short-run coefficients), which are followed by long-run quantity adjustments leading to an overall improvement of the trade balance (reflected in the positive cointegration relationship between the exchange rate and the trade balance).

It is worth emphasizing that estimation results strongly differ, when Equation 11 is misspecified by omitting proxies for the MRT ratios (time-varying exporter–commodity (α_{it}) and importer–commodity fixed effects (γ_{jt})), proxies for time-invariant asymmetric trade costs ratio (cross-section (exporter–importer–commodity) fixed effects (μ_{ij})), or both. Misspecification leads to contradictory results as well as to a severe lack of significance of the *TB* responses to changes in E. Omitting MRT ratios' proxies leads to a mix of positive and negative short-run depreciation effects on the *TB*. Omitting country-pair fixed effects as proxies of asymmetric trade costs ratio yields a inverted J-curve, that is, small but negatively significant long-run responses of the *TB* to a depreciation with positive effects in the short-run. Finally, omitting both proxies also leads to an inverted J-curve with significant negative long-run effects following a depreciation and most of the (positive) short-run effects working through the exporter's ERPT.

4.2 | Results by commodity group

Having obtain results from a bird eye's perspective on the aggregate trade balance dynamics, we next estimate Equation 11 using disaggregated data for 97 two-digit HS commodity groups, using the same time period and following the same approach as for the pooled estimation described above.[10] At this level of aggregation, the number of observations varies considerably across commodity groups, with a maximum of 33,256 observations for "Iron and steel", and a minimum of 3,456 observations for "Vegetable plaiting materials".

Optimal lag structures for the 97 estimations are again determined by minimized joint F-test on short-run exchange rate coefficients and MSE criterion as defined above. There is substantial variation in the short-run dynamics across commodity groups: 14 groups include only the contemporaneous change in exchange rate (period t) while 14 others include the maximum number of lags (from period t to $t-8$). The average number of first-differenced lags of E is four, which corresponds to the number of quarterly lags used in the pooled regression, and two for the first-differenced lags of *TB*.

Table 2 summarizes the parameter estimates of the long-run and of the short-run effect of an exchange rate depreciation, with each line representing the results for a specific commodity group. To improve readability, Table 2 shows only the short-run coefficients significant at least at the 10% level.

Overall, the fit of the models is satisfactory with an average adjusted R-squared of 0.533.

Residual diagnosis indicate that heteroskedasticity remains an issue in 58 commodity groups and serial correlation in 35 commodity groups. As in the pooled estimation, we use cross-section clustered standard errors to take these issues into account.

Before turning to detailed results, we take a look at the mean effects of the exchange rate on the trade balance, obtained by averaging the coefficients across the 97 commodity groups. The overall

TABLE 2 Estimates of Trade Balance Model for 97 Commodity Groups, Equation 11

		Long-run coefficients		Short-run Δ*E* coefficients											
Industry		*TB*	*E*	*t*	*t*−1	*t*−2	*t*−3	*t*−4	*t*−5	*t*−6	*t*−7	*t*−8	Obs.	CPFE	Adj.R^2
Live animals	ECM(6,5)	−0.81 (−17.07)	5.05 (1.08)		−15.87								6,000	420	0.65
Meat and edible meat offal	ECM(3,8)	−0.52 (−12.1)	6.88 (2.17)			−9.08	−8.60					−5.29	7,497	508	0.56
Fish and crustaceans, mollusks and other aquatic invertebrates	ECM(1,2)	−0.69 (−28.34)	−6.48 (−3.89)	−4.94									16,128	1056	0.50
Dairy produce	ECM(2,6)	−0.62 (−20.03)	−4.67 (−2)	−5.72			9.37	14.30	7.17				11,167	721	0.54
Animal originated products	ECM(1,8)	−0.67 (−23.70)	3.96 (1.67)										9,402	760	0.53
Trees and other plants, live	ECM(1,6)	−1.04 (−22.49)	−0.01 (0.00)	13.86	12.74								7,875	620	0.65
Vegetables and certain roots and tubers	ECM(8,0)	−0.98 (−25.75)	3.28 (1.52)										10,104	660	0.69
Fruit and nuts, edible	ECM(1,7)	−0.97 (−37.33)	5.6 (2.66)		−8.23								12,329	957	0.59
Coffee, tea, mate and spices	ECM(4,0)	−0.54 (−15.44)	−1.97 (−1.97)	−6.18									14,376	852	0.52
Cereals	ECM(2,1)	−0.82 (−23.41)	7.93 (2.73)		14.37								9,000	564	0.61
Products of the milling industry	ECM(2,8)	−0.68 (−22.64)	−1.84 (−0.54)			7.97						13.78	8,888	697	0.52
Oil seeds and oleaginous fruits	ECM(1,4)	−0.99 (−40.01)	1.45 (1.06)				6.37						17,792	1142	0.57
Lac	ECM(3,0)	−0.71 (−24.91)	−1.47 (−0.66)										11,182	726	0.57
Vegetable plaiting materials	ECM(4,0)	−0.64 (−11.47)	1.94 (0.13)	−38.99									3,426	250	0.61
Animal or vegetable fats and oils and their cleavage products	ECM(3,0)	−0.63 (−33.43)	−1.62 (−1.15)										16,778	1000	0.49
Meat, fish or crustaceans, mollusks or other aquatic invertebrates	ECM(1,8)	−0.84 (−33.65)	−0.23 (−0.08)			−21.36							10,301	770	0.57
Sugars and sugar confectionery	ECM(3,2)	−0.63 (−27.91)	1.70 (1.41)			−9.7							17,402	984	0.50

(Continues)

TABLE 2 (Continued)

		Long-run coefficients		Short-run ΔE coefficients											
Industry		TB	E	t	$t-1$	$t-2$	$t-3$	$t-4$	$t-5$	$t-6$	$t-7$	$t-8$	Obs.	CPFE	Adj.R^2
Cocoa and cocoa preparations	ECM(6,8)	−0.70 (−18.22)	5.35 (1.52)										9,592	638	0.56
Preparations of cereals, flour, starch or milk	ECM(1,3)	−0.64 (−27.21)	−0.11 (−0.10)										20,016	1173	0.47
Preparations of vegetables, fruit, nuts or other parts of plants	ECM(2,5)	−0.6 (−26.40)	−2.14 (−1.95)						3.33				18,736	1142	0.47
Miscellaneous edible preparations	ECM(1,8)	−0.74 (−34.14)	−1.85 (−1.21)	−3.74					4.87				18,690	1313	0.51
Beverages, spirits and vinegar	ECM(1,4)	−0.68 (−33.92)	3.47 (2.78)		−5.44	−4.32	−5.56						23,781	1421	0.50
Food industries, residues and wastes thereof	ECM(8,6)	−0.62 (−13.48)	−0.84 (−0.35)				12.29						9,396	650	0.54
Tobacco and manufactured tobacco substitutes	ECM(7,5)	−0.57 (−11.23)	2.68 (0.44)						14.09				5,706	422	0.59
Salt	ECM(1,7)	−0.73 (−25.36)	3.61 (1.64)	6.99									16,945	1208	0.49
Ores, slag and ash	ECM(1,7)	−0.73 (−25.10)	1.51 (0.17)				24.85						6,241	554	0.58
Mineral fuels, mineral oils and products of their distillation	ECM(1,1)	−0.65 (−32.12)	−0.91 (−0.37)	−7.84									20,730	1188	0.46
Inorganic chemicals	ECM(1,0)	−0.59 (−36.48)	2.06 (1.88)										25,474	1424	0.46
Organic chemicals	ECM(1,2)	−0.65 (−31.33)	4.41 (3.68)	−2.83									24,925	1450	0.46
Pharmaceutical products	ECM(1,6)	−0.72 (−29.62)	−0.42 (−0.31)	−3.86									23,131	1445	0.47
Fertilizers	ECM(2,1)	−0.93 (−31.79)	−1.09 (−0.37)										9,114	592	0.64
Tanning or dyeing extracts	ECM(2,6)	−0.63 (−23.69)	0.58 (0.41)				3.54						20,838	1360	0.48
Essential oils and resinoids	ECM(1,7)	−0.71 (−31.63)	2.42 (2.09)							4.04			21,739	1431	0.48
Soap, organic surface-active agents	ECM(3,6)	−0.62 (−27.06)	−2.04 (−1.33)							3.95			18,781	1167	0.50

(Continues)

TABLE 2 (Continued)

Industry		Long-run coefficients		Short-run Δ*E* coefficients											
		TB	*E*	*t*	*t*−1	*t*−2	*t*−3	*t*−4	*t*−5	*t*−6	*t*−7	*t*−8	Obs.	CPFE	Adj.R^2
Albuminoidal substances	ECM(2,7)	−0.63 (−22.16)	−1.02 (−0.78)										15,668	1098	0.50
Explosives	ECM(3,6)	−0.75 (−14.34)	−0.27 (−0.04)		−13.84								5,886	399	0.61
Photographic or cinemato-graphic goods	ECM(3,3)	−0.55 (−19.52)	4.11 (1.63)	9.13									9,712	600	0.56
Chemical products n.e.s.	ECM(1,7)	−0.73 (−34.45)	1.91 (1.33)	2.94									22,268	1495	0.48
Plastics and articles thereof	ECM(2,4)	−0.57 (−30.68)	1.78 (1.80)			−4.76							31,815	1702	0.43
Rubber and articles thereof	ECM(3,3)	−0.58 (−29.78)	1.15 (1.15)	3.74									27,664	1516	0.46
Raw hides and skins (other than furskins) and leather	ECM(1,2)	−0.64 (−34.97)	−0.05 (−0.03)										15,427	1018	0.49
Articles of leather	ECM(2,7)	−0.64 (−23.55)	3.97 (1.68)		−11.25	5.87			−6.89				20,310	1355	0.50
Furskins and artificial fur	ECM(2,3)	−0.87 (−24.02)	1.73 (0.40)										9,250	615	0.62
Wood and articles of wood	ECM(1,3)	−0.72 (−37.19)	1.44 (1.11)		3.20								25,806	1518	0.46
Cork and articles of cork	ECM(4,8)	−0.70 (−12.25)	17.22 (1.29)								−34.01	−44.32	3,911	304	0.67
Manufactures of straw, esparto or other plaiting materials	ECM(1,8)	−0.93 (−27.90)	−14.48 (−1.44)								−29.81		4,642	409	0.67
Pulp of wood or other fibrous cellulosic material	ECM(1,0)	−0.47 (−14.77)	−5.98 (−1.48)										8,476	574	0.51
Paper and paperboard	ECM(1,3)	−0.64 (−35.35)	1.32 (1.13)		−2.95								29,130	1619	0.42
Printed books, newspapers, pictures and other products of the printing industry	ECM(6,6)	−0.72 (−28.00)	2.44 (1.93)	−5.23		−6.11	−7.91	−7.36	−6.65	−5.79			22,189	1308	0.50
Silk	ECM(2,5)	−0.81 (−17.94)	−8.12 (−1.42)										4,550	345	0.63
Wool, fine or coarse animal hair	ECM(5,5)	−0.68 (−16.51)	−0.25 (−0.08)		10.37				7.19				8,640	562	0.60
Cotton	ECM(2,8)	−0.81 (−26.11)	−5.24 (−2.18)		6.48	5.83			11.86	9.00			12,402	892	0.55

(Continues)

TABLE 2 (Continued)

Industry		Long-run coefficients *TB*	*E*	Short-run Δ*E* coefficients *t*	*t*−1	*t*−2	*t*−3	*t*−4	*t*−5	*t*−6	*t*−7	*t*−8	Obs.	CPFE	Adj.R^2
Vegetable textile fibers	ECM(8,8)	−0.72 (−9.97)	4.25 (0.76)			13.68	−19.09		−13.79		15.38	−20.05	5,528	392	0.63
Man−made filaments	ECM(2,3)	−0.62 (−26.97)	−0.79 (−0.54)			6.49							16,685	1037	0.50
Man−made staple fibers	ECM(5,3)	−0.59 (−21.16)	−4.42 (−1.95)	−4.82		7.11							12,840	824	0.50
Wadding, felt and nonwovens, special yarns	ECM(2,0)	−0.54 (−24.81)	3.14 (2.12)										19,798	1148	0.48
Carpets and other textile floor coverings	ECM(3,5)	−0.69 (−22.39)	0.95 (0.45)										11,740	744	0.56
Fabrics	ECM(3,0)	−0.60 (−20.98)	3.47 (1.79)										16,098	978	0.51
Textile fabrics	ECM(1,8)	−0.73 (−27.95)	0.61 (0.29)				−7.06	−8.73				−5.29	14,881	1061	0.51
Fabrics	ECM(6,3)	−0.60 (−18.37)	−1.54 (−0.49)				12.49						9,717	644	0.59
Tin	ECM(7,8)	−0.60 (−16.12)	2.29 (1.30)	−6.42	−5.72			−4.67	−7.31				18,017	1164	0.53
Metals	ECM(2,7)	−0.70 (−30.23)	−1.66 (−1.01)	−3.99		6.43		−4.4		3.88			20,989	1386	0.51
Apparel and clothing accessories	ECM(1,3)	−0.71 (−36.38)	2.94 (2.46)	−3.37	−3.52	−3.32							25,878	1499	0.48
Apparel and clothing accessories	ECM(1,6)	−0.68 (−32.32)	−1.33 (−0.65)		−12.69	−6.96							17,596	1246	0.53
Tools, implements, cutlery, spoons and forks, of base metal	ECM(3,3)	−0.73 (−22.91)	−5.54 (−3.26)	−4.98			7.17						16,590	976	0.58
Metal	ECM(6,0)	−0.82 (−17.46)	8.6 (1.84)										6,422	392	0.66
Textiles, made up articles	ECM(6,5)	−0.63 (−16.45)	−7.81 (−1.87)	−11.92		30.67							5,372	360	0.66
Footwear	ECM(3,7)	−0.64 (−21.92)	0.78 (0.47)		−3.74					5.87			18,810	1236	0.51
Nuclear reactors, boilers, machinery and mechanical appliances	ECM(3,4)	−0.66 (−27.43)	3.15 (2.28)			−3.73	−3.78						19,232	1140	0.52
Headgear and parts thereof	ECM(1,1)	−0.65 (−35.98)	−0.51 (−0.45)										27,572	1524	0.46

(Continues)

TABLE 2 (Continued)

		Long-run coefficients		Short-run Δ*E* coefficients											
Industry		*TB*	*E*	*t*	*t*−1	*t*−2	*t*−3	*t*−4	*t*−5	*t*−6	*t*−7	*t*−8	Obs.	CPFE	Adj.R^2
Umbrellas, sun umbrellas, walking−sticks, seat sticks, whips, riding crops	ECM(6,6)	−0.64 (−24.76)	3.00 (1.68)			−6.87				−4.81			18,988	1146	0.48
Feathers and down, prepared	ECM(7,4)	−0.66 (−19.03)	−3.57 (−2.06)					−4.71					16,194	1030	0.48
Electrical machinery and equipment and parts thereof	ECM(3,5)	−0.64 (−30.80)	−0.42 (−0.42)					3.87					28,101	1597	0.47
Railway, tramway locomotives, rolling−stock and parts thereof	ECM(1,6)	−0.67 (−32.9)	5.25 (2.20)				5.78	−7.15	−7.30				19,566	1283	0.46
Stone, plaster, cement, asbestos, mica or similar materials	ECM(7,6)	−0.80 (−14.74)	2.08 (0.38)			13.08							6,494	458	0.54
Ceramic products	ECM(1,0)	−0.57 (−30.84)	2.30 (2.00)										28,128	1516	0.41
Vehicles	ECM(1,4)	−0.56 (−20.31)	−15.41 (−2.08)		30.52	16.64	42.65						5,537	415	0.58
Aircraft, spacecraft and parts thereof	ECM(1,7)	−0.58 (−19.27)	6.39 (0.73)						−14.49				8,570	640	0.52
Ships, boats and floating structures	ECM(1,7)	−0.62 (−17.38)	1.26 (0.12)							−20.74			4,903	385	0.60
Glass and glassware	ECM(6,7)	−0.77 (−22.46)	8.87 (2.15)				−10.77				12.51		8,147	562	0.55
Natural, cultured pearls	ECM(1,4)	−0.75 (−35.18)	3.81 (4.08)		−4.95	−5.87	−3.01	−4.01					26,618	1532	0.48
Optical, photographic, cinematographic, measuring, checking, medical or surgical instruments and apparatus	ECM(1,8)	−0.72 (−30.09)	−1.44 (−0.89)					−4.09					20,022	1342	0.48
Iron and steel	ECM(1,4)	−0.79 (−50.20)	−0.41 (−0.68)										33,256	1806	0.49
Clocks and watches and parts thereof	ECM(3,6)	−0.68 (−34.60)	0.39 (0.54)					2.65		−3.63			28,650	1696	0.45
Iron or steel articles	ECM(3,1)	−0.60 (−22.22)	5.22 (2.26)	17.08									9,872	604	0.52

(Continues)

Industry		Long-run coefficients		Short-run Δ*E* coefficients											
		TB	*E*	*t*	*t*−1	*t*−2	*t*−3	*t*−4	*t*−5	*t*−6	*t*−7	*t*−8	Obs.	CPFE	Adj.R^2
Musical instruments	ECM(3,0)	−0.49 (−28.11)	1.38 (2.09)										27,898	1480	0.50
Arms and ammunition	ECM(3,2)	−0.72 (−34.73)	−2.24 (−1.00)										16,166	912	0.52
Copper and articles thereof	ECM(1,8)	−1.05 (−39.25)	−12.76 (−1.71)		32.78	20.56	30.93				33.65		7,012	611	0.62
Nickel and articles thereof	ECM(3,2)	−0.60 (−29.31)	0.42 (0.81)										32,200	1652	0.46
Furniture	ECM(1,2)	−0.65 (−35.09)	5.30 (3.25)			4.85							17,865	1009	0.49
Aluminum and articles thereof	ECM(3,0)	−0.70 (−23.02)	−1.16 (−0.87)										11,668	700	0.58
Toys, games and sports requisites	ECM(6,1)	−0.72 (−17.77)	6.78 (3.77)										7,154	426	0.59
Lead and articles thereof	ECM(1,3)	−0.74 (−39.89)	0.13 (0.11)		−2.98								29,331	1630	0.50
Zinc and articles thereof	ECM(3,0)	−0.73 (−30.53)	−3.42 (−3.31)										23,955	1334	0.52
Miscellaneous manufactured articles	ECM(3,5)	−0.59 (−32.19)	2.31 (1.83)		−5.77		−3.46		−4.92				21,340	1335	0.48
Works of art	ECM(2,7)	−1.09 (−38.31)	−6.03 (−1.51)					−13.06	9.66				10,152	769	0.61
Commodities not specified according to kind	ECM(2,3)	−0.58 (−22.87)	−0.85 (−0.83)										15,232	843	0.57

Notes. *t*-values in parentheses. ECM(*q*,*p*) indicates the number of lag *q* for Δ*TB* and *p* for Δ*E*. Only significant short-run Δ*E* coefficients are reported. The parameter estimates are obtained by OLS and standard errors are country-pair clustered. All the 97 models include exporter-year, importer-year and bilateral country-pair fixed effects. CPFE: Number of bilateral country-pairs.

mean long-run depreciation effect of the exchange rate on the trade balance amounts to 0.852 (and 1.457 when taking only coefficients significant at 10% into account). Hence, the magnitude of the estimated average long-run effect is well in line with the results from the pooled estimation (1.015).

The estimated mean short-run effects of the exchange rate and their cumulative sum reveal interesting aspects of the short-run trade balance dynamics. The cumulative sum of the mean values of the short-run coefficients is illustrated in Figure 1. The contemporaneous and first lags are characterized by a deterioration of the trade balance and are then followed by consecutive quarters of short-run *TB* improvements before this effect vanishes in the last quarter ($t-8$). Combined with a mean long-run effect of E amounting to 0.852, this pattern is indicative of the presence of an average J-curve. Moreover, the implied inter-temporal shape of the *TB* dynamics is in line with the pooled estimation, though the latter suggests that the improvement of the trade balance starts after lag four (rather than after lag two).

We next take a closer look at the commodity-specific estimates. Summarizing the key long-run results, a depreciation is linked to an improvement of the trade balance in 26 commodity groups, as reflected in significant and positive sum of long-run coefficients for the exchange rate interacted with importer and exporter ERPT ($\delta_2 + \delta_3$). In twelve groups, a depreciation is associated with a long-run deterioration of the trade balance, for the remaining 59 commodity groups, the long-run effect of the exchange rate on the trade balance is insignificant.

Significant short-run effects, as measured by the sum of the short-run coefficients for the difference of the interacted exchange rate ($\eta + \omega$) show up primarily within the first four quarters (including the contemporaneous quarter), following the change in the exchange rate. The peak in the number of significant short-run coefficients appears in the second-quarter lag with a total of 20 commodity groups. The number then falls throughout the remaining four quarters with a maximum of eleven coefficients at the fifth-quarter lag and a minimum of three coefficients at the eighth-quarter lag. This suggests that short-run trade balance deviations from the equilibrium caused by a change in the exchange rate occur mainly within a year. In total, 42 significant negative short-run coefficients and 33 significant positive short-run coefficients are obtained for our sample in the first year following the depreciation. The highest frequency of negative short-run effects, 13, occurs contemporaneously (t), while the highest frequency of positive short-run effects (twelve) is observed for the third quarter ($t-2$).

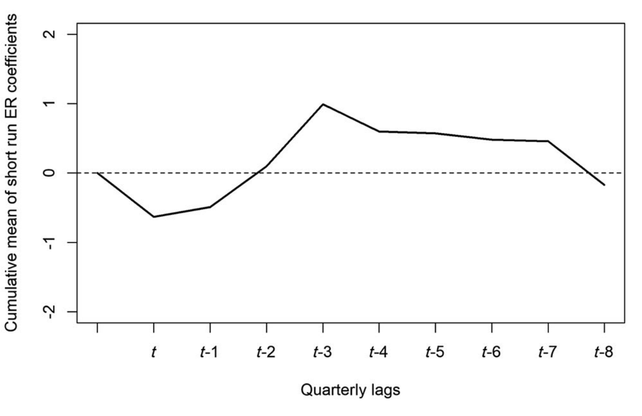

FIGURE 1 Mean of cumulative short-run reaction of *TB* to *E*. *Notes*. Mean (over all 97 commodity groups) of cumulative values of the sum of the coefficients of ($\eta_i \times \Delta \ln E$) and ($\eta_j \times \Delta \ln E$) for all eight quarterly lags. All insignificant coefficients have been set equal to zero

Turning to significant cumulative short-run effects (not reported in the table), 77 of them are negative and 49 positive. Alike the significant single short-run coefficients, they are mainly observed within the first year following the depreciation. Also worth noting, with the exception of two commodity groups, no significant cumulative effects are found within the last three quarters of the second year. It is an indication that, in our sample, short-run trade balance dynamics triggered by exchange rate changes fade out after five quarters.

Overall, out of the subset of 26 commodity groups with positive long-run effects of the exchange rate, eleven J-curves are found with solely negative short-run coefficients.[11] Furthermore, for eight commodity groups[12] the long-run effects are positive with no short-run trade balance deterioration after the change in the exchange rate.[13]

A total of six commodity groups are characterized by both a significant short-run and long-run deterioration of the trade balance, where quantity adjustments seem absent.[14]

A total of 59 commodity groups with no long-run depreciation effect are identified, where 17 solely exhibit negative short-run effects (thus no sign of quantity adjustment in the short-run) and 18 positive effects (thus no sign of a price effect in the short-run). Out of this subset of 59 commodity groups without long-run depreciation effect, 20 are characterized by "short-run J-curve" dynamics, where negative short-run coefficients are followed by positive ones. For these commodities the depreciation effect seems to be only temporary and vanishes after 2 years.

5 | CONCLUDING REMARKS

The literature on the J-curve hypothesis has offered a variety of approaches on how to estimate intertemporal responses of the trade balance to exchange rate shocks. While most studies focus on the investigation of bilateral relationships, the present study provides a multilateral and sectoral perspective in a gravity framework for a sample of 47 countries and 97 commodity groups over the period 2010Q1 to 2017Q2.

We build on Anderson et al. (2016) and derive a structural trade balance gravity equation that includes the exchange rate and its pass through to prices as a component of trade costs. The inter-temporal aspects of the empirical relationship between the trade balance and the exchange rate are investigated with an error-correction model, modeling the long-run cointegrating relationship between the trade balance and the exchange rate as well as short-run effects.

A test of the J-curve hypothesis for the 47 countries (2162 country-pairs, pooled across all 97 commodity groups) reveals that on average, there is a negative short-run (price) effect materializing "immediately" within the first two quarters and significantly deteriorating the trade balance. The negative effect persists throughout the entire short-run period of eight quarters considered. A long-run improvement of the trade balance is indicated by the existence of a long-run cointegrating relationship, suggesting that a 1% depreciation is associated with a 1.04% improvement of the trade balance. Hence, for our country and commodity sample and period of investigation, the trade balance dynamics seems to follow a J-curve pattern on average.

The analysis at the commodity level yields a much more diverse picture. A positive long-run effect is obtained only for a subset of 26 of the 97 commodity groups (of which eleven show a J-curve pattern), for 59 groups there is no significant long-run effect (20 of which show a short-run J-curve pattern).

Overall, in light of the anything but clear-cut long-run relationship between the exchange rate and the trade balance at the sectoral level and the anything but uniform short- and long-run patterns of trade balance responses, exchange rate policy does not appear to be a suitable instrument to influence and steer a country's trade balance dynamics.

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ENDNOTES

[1] The country list is provided in Appendix Table A1.

[2] In line with Anderson et al. (2016), the ERPT is assumed to be time invariant.

[3] The use of alternative cointegration techniques for panel data, such as the mean group and pooled mean estimators proposed by Pesaran, Shin, and Smith (1999), is infeasible owing to the presence of gaps in the data.

[4] Our initial approach to use monthly data was given up because of the huge number of missing observations at the commodity level used, which would have forced us to drop a significant amount of observations from the analysis.

[5] Approximately 6% of the country-pairs (accounting for 21% of total exports in our dataset) are characterized by a common currency ($\ln E = 0$). We also estimated our models excluding these observations and obtained virtually identical results.

[6] The "within-dimension" test statistics are obtained from pooled unit root tests on the residuals estimated from a pooled regression of $\ln TB$ on $\eta_j \times \ln E$ and $\eta_i \times \ln E$ (by commodity group), while the "between-dimension" test statistics are obtained by averaging cross-section specific statistics calculated from the residuals of a panel with heterogeneous slope parameters (again by commodity group). Both sets of testing regressions contain cross-section specific fixed effects as well as importer– and exporter–time fixed effects.

[7] Choosing the lag-length according to the Akaike or Schwartz information criterion turned out infeasible, since their values keep falling with the number of lags included, therefore inevitably reaching the maximum number of lags.

[8] The approach by Silva and Tenreyro (2006), who recommend the use of quasi-Poisson maximum likelihood estimation, is not applicable in the present context, where a dynamic gravity equation is estimated in first differences as an unrestricted ECM with negative observations on the dependent variable.

[9] This effect does not show up in the standard Marshall–Lerner condition, which assumes that all exports are contracted in the exporter's currency.

[10] The two-digit HS classification (Version 2012) comprises about 5,300 commodity descriptions arranged in 97 groups or 15 sections: 01–05, Animal & Animal Products; 06–15, Vegetable Products; 16–24, Foodstuffs; 25–27, Mineral Products; 28–38, Chemicals & Allied Industries; 39–40 Plastics/Rubbers; 41–43, Raw Hides; Skins, Leather, & Furs; 44–49, Wood & Wood Products; 50–63, Textiles; 64–67, Footwear/Headgear; 68–71, Stone/Glass; 72–83, Metals; 84–85, Machinery/Electrical; 86–89, Transportation; and finally, 90–97, Miscellaneous.

[11] Apparel and clothing accessories; Beverages, spirits and vinegar; Fruit and nuts, edible; Meat and edible meat offal; Miscellaneous manufactured articles; Natural, cultured pearls; Nuclear reactors, boilers, machinery and mechanical appliances; Organic chemicals; Plastics and articles thereof; Printed books, newspapers, pictures and other products of the printing industry; Umbrellas, sun umbrellas, walking-sticks, seat sticks, whips, riding crops.

[12] Animal originated products; Inorganic chemicals; Wadding, felt and non-wovens, special yarns; Fabrics; Metal; Ceramic products; Musical instruments; Toys, games and sports requisites."

[13]This complies with the definition of J-curve by Rose and Yellen (1989), where insignificant short-run and positive long-run effects represent a sufficient condition for the existence of a J-curve.

[14]Coffee, tea, mate and spices; Dairy produce; Feathers and down, prepared; Man-made staple fibers; Textiles, made up articles; Tools, implements, cutlery, spoons and forks, of base metal.

REFERENCES

Anderson, J. E. (2011). The gravity model. *Annual Review of Economics*, *3*, 133–160.

Anderson, J. E., & Van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *The American Economic Review*, *93*(1), 170–192.

Anderson, J. E., Vesselovsky, M., & Yotov, Y. V. (2016). Gravity with scale effects. *Journal of International Economics*, *100*, 174–193.

Bahmani-Oskooee, M. (1985). Devaluation and the J-curve: Some evidence from LDCs. *The Review of Economics and Statistics*, *67*(3), 500–504.

Bahmani-Oskooee, M., & Brooks, T. J. (1999). Bilateral J-curve between US and her trading partners. *Weltwirtschaftliches Archiv*, *135*(1), 156–165.

Bahmani-Oskooee, M., & Kanitpong, T. (2017). Do exchange rate changes have symmetric or asymmetric effects on the trade balances of Asian countries? *Applied Economics*, *49*(46), 1–11.

Bahmani-Oskooee, M., & Ratha, A. (2004). The J-curve: A literature review. *Applied Economics*, *36*(13), 1377–1398.

Baltagi, B. H. (2001). *Econometric analysis of panel data* (2nd ed.). Chichester, U.K.: Wiley.

Bussiere, M., Gaulier, G., & Steingress, W. (2016). *Global trade flows: Revisiting the exchange rate elasticities* (Technical Report). Paris, France: Banque de France.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica: Journal of the Econometric Society*, *55*(2), 251–276.

Himarios, D. (1985). The effects of devaluation on the trade balance: A critical view and re-examination of mile's new results. *Journal of International Money and Finance*, *4*(4), 553–563.

Magee, S. P. (1973). Currency contracts, pass-through, and devaluation. *Brookings Papers on Economic Activity*, *1973*(1), 303–325.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, *61*(S1), 653–670.

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association*, *94*(446), 621–634.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326.

Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics*, *68*(1), 79–113.

Rose, A. K., & Yellen, J. L. (1989). Is there a J-curve? *Journal of Monetary Economics*, *24*(1), 53–68.

Silva, J. S., & Tenreyro, S. (2006). The log of gravity. *The Review of Economics and Statistics*, *88*(4), 641–658.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. Cambridge, MA: MIT Press.

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APPENDIX

TABLE A1 List of the 47 countries and their 37 currencies

Country	Currency	Country	Currency
Argentina	Argentine peso	Rep. of Korea	South Korean won
Australia	Australian dollar	Mexico	Mexican peso
Austria	Euro	Morocco	Moroccan dirham
Belgium	Euro	Netherlands	Euro
Brazil	Brazilian real	New Zealand	New Zealand dollar
Canada	Canadian dollar	Norway	Norwegian krone
Sri Lanka	Sri Lankan rupee	Pakistan	Pakistani rupee
Chile	Chilean peso	Peru	Peruvian sol
China	Chinese yuan renminbi	Philippines	Philippine peso
Colombia	Colombian peso	Poland	Polish zloty
Czech Rep.	Czech koruna	Portugal	Euro
Denmark	Danish krone	Russian Federation	Russian ruble
Finland	Euro	Singapore	Singapore dollar
France	Euro	South Africa	South African rand
Germany	Euro	Spain	Euro
Greece	Euro	Sweden	Swedish krona
Guatemala	Guatemalan quetzal	Thailand	Thai baht
Hong Kong SAR	Hong Kong dollar	Turkey	Turkish lira
Hungary	Hungarian forint	Egypt	Egyptian pound
Indonesia	Indonesian rupiah	United Kingdom	Pound sterling
Ireland	Euro	United States of America	U.S. dollar
Israel	Israeli new shekel	Uruguay	Uruguayan peso
Italy	Euro	Switzerland	Swiss franc
Japan	Japanese yen		

TABLE A2 Results from Pedroni panel cointegration tests

Name	Obs.	Pooled				Group-mean		
		ν	η	t (PP)	t (ADF)	η	t (PP)	t (ADF)
Animals	5,648	6.44	−27.74	−39.08	−27.64	−23.56	−46.55	−25.90
Meat and edible meat offal	7,702	3.00	−21.43	−32.04	−18.66	−18.27	−39.09	−18.41
Fish and crustaceans, molluscs and other aquatic invertebrates	11,896	5.34	−29.1	−43.28	−28.52	−22.27	−49.85	−28.00
Dairy produce	11,058	7.64	−27.83	−38.72	−28.5	−21.84	−44.34	−29.11
Animal originated products	8,154	5.79	−23.43	−31.31	−21.13	−19.51	−36.85	−22.04
Trees and other plants, live	6,200	1.99	−29.78	−48.93	−20.76	−26.24	−61.87	−16.85
Vegetables and certain roots and tubers	12,172	2.35	−34.39	−59.90	−40.67	−28.46	−73.67	−37.73
Fruit and nuts, edible	10,642	3.76	−33.76	−54.26	−35.35	−27.82	−65.30	−31.64
Coffee, tea, mate and spices	12,866	8.16	−33.35	−48.46	−31.26	−28.12	−59.31	−33.31
Cereals	6,390	5.34	−27.49	−41.82	−31.19	−22.90	−49.27	−31.21
Products of the milling industry	8,240	6.70	−25.45	−34.40	−24.74	−21.37	−41.02	−24.90
Oil seeds and oleaginous fruits	14,892	5.76	−46.45	−73.98	−46.12	−39.32	−89.40	−45.83
Lac	8,354	9.07	−35.98	−48.33	−37.32	−31.12	−57.88	−38.76
Vegetable plaiting materials	2,256	4.09	−15.93	−21.34	−13.52	−13.24	−25.12	−14.51
Animal or vegetable fats and oils and their cleavage products	14,618	9.05	−34.27	−48.04	−35.51	−28.13	−55.86	−36.81
Meat, fish or crustaceans, molluscs or other aquatic invertebrates	10,494	4.30	−27.58	−40.27	−28.76	−22.50	−47.61	−30.65
Sugars and sugar confectionery	15,350	9.64	−36.03	−50.42	−36.79	−29.48	−59.31	−38.25
Cocoa and cocoa preparations	11,516	6.93	−35.20	−50.85	−33.52	−28.06	−58.31	−33.21
Preparations of cereals, flour, starch or milk	17,444	6.66	−33.96	−48.13	−31.23	−27.95	−57.14	−30.26
Preparations of vegetables, fruit, nuts or other parts of plants	18,552	8.10	−38.66	−55.57	−38.24	−31.54	−66.29	−37.73
Miscellaneous edible preparations	21,328	9.89	−40.77	−57.79	−45.08	−34.46	−68.87	−48.62
Beverages, spirits and vinegar	20,894	8.82	−44.68	−63.02	−42.76	−37.81	−76.50	−43.24
Food industries, residues and wastes thereof	11,168	7.82	−31.81	−44.59	−33.51	−25.33	−51.01	−33.16
Tobacco and manufactured tobacco substitutes	5,738	6.11	−21.97	−32.92	−23.27	−17.12	−39.40	−23.85
Salt	16,724	10.71	−46.22	−62.11	−43.15	−39.29	−72.76	−43.65

(Continues)

TABLE A2 (Continued)

Name	Obs.	Pooled				Group-mean		
		ν	η	t (PP)	t (ADF)	η	t (PP)	t (ADF)
Ores, slag and ash	4,758	6.68	−22.57	−32.25	−23.29	−18.66	−38.78	−25.10
Mineral fuels, mineral oils and products of their distillation	15,322	9.42	−38.39	−53.52	−40.86	−32.92	−63.99	−42.65
Inorganic chemicals	19,108	9.99	−42.45	−58.62	−42.06	−35.06	−68.19	−43.90
Organic chemicals	20,420	12.83	−47.59	−64.66	−49.44	−39.88	−76.11	−51.02
Pharmaceutical products	23,514	12.33	−44.84	−61.99	−46.31	−37.81	−74.13	−49.33
Fertilizers	5,920	5.794	−27.18	−40.38	−31.41	−22.51	−47.02	−32.25
Tanning or dyeing extracts	21,292	10.63	−44.66	−60.92	−43.18	−36.68	−70.68	−43.45
Essential oils and resinoids	22,652	11.14	−48.51	−67.00	−47.83	−40.26	−79.15	−48.33
Soap, organic surface−active agents	19,566	9.64	−41.98	−57.90	−38.52	−35.32	−69.65	−38.88
Albuminoidal substances	14,468	9.64	−38.73	−50.95	−35.59	−32.68	−59.28	−36.66
Explosives	5,138	6.34	−25.33	−35.40	−25.76	−21.91	−43.10	−28.36
Photographic or cinematographic goods	8,020	7.83	−21.43	−29.08	−17.66	−17.98	−34.23	−19.19
Chemical products n.e.s.	22,980	10.66	−46.30	−66.91	−50.79	−37.96	−78.58	−52.72
Plastics and articles thereof	22,026	8.00	−39.10	−56.40	−35.80	−31.90	−66.10	−35.5
Rubber and articles thereof	25,402	12.20	−46.26	−64.69	−47.92	−37.78	−76.68	−50.10
Raw hides and skins (other than furskins) and leather	10,232	7.13	−28.21	−40.22	−27.09	−23.61	−49.18	−29.11
Articles of leather	21,680	9.33	−49.89	−68.63	−46.71	−44.05	−83.44	−48.32
Furskins and artificial fur	6,492	2.88	−29.53	−45.66	−29.13	−24.74	−53.90	−29.81
Wood and articles of wood	22,126	11.27	−45.41	−63.53	−47.08	−37.88	−75.05	−47.08
Cork and articles of cork	3,106	4.72	−17.99	−23.74	−18.93	−16.21	−29.80	−20.17
Manufactures of straw, esparto or other plaiting materials	3,714	4.88	−20.73	−29.52	−21.49	−17.70	−35.37	−22.44
Pulp of wood or other fibrous cellulosic material	5,442	4.39	−15.82	−22.02	−14.58	−12.74	−25.94	−15.77
Paper and paperboard	26,432	11.23	−43.48	−61.03	−44.66	−36.81	−73.77	−48.4
Printed books, newspapers, pictures and other products of the printing industry	24,812	11.42	−53.54	−75.34	−51.46	−45.60	−90.42	−53.04

(Continues)

TABLE A2 (Continued)

		Pooled				Group-mean		
Name	**Obs.**	ν	η	*t* (PP)	*t* (ADF)	η	*t* (PP)	*t* (ADF)
Silk	3,228	5.31	−20.74	−27.03	−20.14	−17.32	−31.33	−22.16
Wool, fine or coarse animal hair	7,944	−5.15	−30.35	−42.78	−29.24	−26.50	−50.99	−30.70
Cotton	14,110	7.59	−40.91	−55.79	−38.02	−34.69	−65.29	−37.59
Vegetable textile fibres	6,142	5.59	−27.36	−36.65	−26.58	−23.53	−43.38	−26.13
Man−made filaments	14,074	9.27	−34.95	−47.13	−34.29	−28.35	−54.53	−35.21
Man−made staple fibres	12,450	6.86	−31.52	−44.10	−33.68	−27.13	−52.36	−35.03
Wadding, felt and nonwovens, special yarns	16,764	9.13	−35.75	−49.78	−35.27	−29.64	−59.15	−36.57
Carpets and other textile floor coverings	11,374	8.73	−36.95	−51.67	−38.39	−32.07	−62.83	−39.45
Fabrics	13,832	8.45	−36.79	−50.91	−36.78	−61.66	−60.85	−39.32
Textile fabrics	15,926	10.97	−39.50	−52.72	−35.23	−34.71	−64.12	−36.42
Fabrics	9,812	5.98	−30.01	−41.71	−30.59	−24.02	−48.72	−31.07
Tin	22,482	8.17	−54.34	−74.20	−44.77	−48.58	−90.33	−45.19
Metals	22,154	8.20	−52.20	−71.24	−42.40	−46.06	−86.65	−43.10
Apparel and clothing accessories	22,560	11.15	−46.20	−64.11	−43.85	−39.33	−76.47	−46.23
Apparel and clothing accessories	16,508	7.34	−49.86	−67.13	−37.25	−42.41	−79.49	−34.89
Tools, implements, cutlery, spoons and forks, of base metal	14,490	8.02	−45.66	−64.26	−48.58	−29.83	−82.13	−48.53
Metal	6,880	5.80	−30.59	−44.80	−31.93	−26.57	−55.70	−31.86
Textiles, made up articles	4,896	4.34	−25.31	−34.02	−24.74	−22.17	−42.14	−26.95
Footwear	21,092	10.22	−42.03	−59.06	−45.84	−34.81	−69.87	−48.57
Nuclear reactors, boilers, machinery and mechanical appliances	18,190	12.74	−45.33	−61.94	−45.94	−39.39	−74.51	−49.53
Headgear and parts thereof	21,872	11.35	−41.02	−56.24	−42.21	−34.41	−67.2	−45.13
Umbrellas, sun umbrellas, walking−sticks, seat sticks, whips, riding crops	20,898	9.60	−44.95	−62.01	−42.24	−37.28	−73.39	−43.43
Feathers and down, prepared	19,172	12.40	−42.54	−57.66	−44.67	−35.09	−66.88	−45.64
Electrical machinery and equipment and parts thereof	16,178	8.00	−29.20	−42.80	−29.20	−23.60	−51.10	−31.60
Railway, tramway locomotives, rolling−stock and parts thereof	19,546	10.65	−35.95	−50.05	−34.86	−30.14	−59.20	−37.45

(Continues)

TABLE A2 (Continued)

		Pooled				Group-mean		
Name	**Obs.**	ν	η	t (PP)	t (ADF)	η	t (PP)	t (ADF)
Stone, plaster, cement, asbestos, mica or similar materials	6,752	9.15	−27.49	−36.83	−24.64	−23.03	−43.06	−25.76
Ceramic products	22,656	11.50	−41.30	−56.25	−40.47	−33.81	−65.29	−42.31
Vehicles	3,458	5.93	−16.96	−21.42	−15.13	−14.64	−24.75	−16.52
Aircraft, spacecraft and parts thereof	7,496	7.48	−24.07	−32.05	−22.92	−19.40	−36.85	−23.99
Ships, boats and floating structures	3,944	5.24	−19.51	−25.51	−20.46	−16.33	−29.58	−19.72
Glass and glassware	7,976	8.88	−28.00	−37.55	−28.47	−23.43	−44.13	−29.45
Natural, cultured pearls	24,742	14.24	−50.99	−70.56	−50.79	−43.09	−83.68	−52.55
Optical, photographic, cinematographic instruments and apparatus	22,856	11.39	−41.30	−57.67	−40.43	−34.79	−68.95	−43.19
Iron and steel	29,094	9.20	−44.00	−64.40	−46.10	−37.50	−78.00	−49.20
Clocks and watches and parts thereof	6,960	10.40	−26.50	−33.90	−27.60	−22.60	−39.80	−29.90
Iron or steel articles	7,638	8.56	−22.15	−29.31	−23.04	−17.72	−33.74	−27.33
Musical instruments	26,400	12.03	−45.05	−62.72	−47.88	−36.38	−73.66	−50.21
Arms and ammunition	13,408	10.76	−42.55	−57.89	−43.71	−36.23	−68.41	−44.64
Copper and articles thereof	6,102	7.88	−34.38	−49.96	−35.21	−29.74	−61.75	−36.50
Nickel and articles thereof	27,658	8.80	−37.70	−56.20	−37.30	−35.00	−71.20	−43.10
Furniture	13,882	7.90	−31.89	−44.90	−35.08	−27.15	−53.58	−37.76
Aluminium and articles thereof	9,724	10.19	−36.65	−50.09	−38.99	−32.10	−60.87	−41.34
Toys, games and sports requisites	6,798	7.71	−29.37	−39.23	−28.70	−24.99	−46.37	−29.85
Lead and articles thereof	25,074	11.53	−49.54	−68.72	−50.97	−41.51	−81.95	−53.45
Zinc and articles thereof	21,606	9.22	−49.03	−71.35	−48.69	−41.82	−86.81	−48.88
Miscellaneous manufactured articles	21,314	7.71	−37.31	−53.00	−37.70	−31.42	−62.68	−36.88
Works of art	8,558	10.16	−41.91	−60.52	−44.97	−36.73	−73.29	−47.73
Commodities not specified according to kind	12,546	9.59	−37.21	−51.96	−37.12	−31.71	−62.71	−39.41

Note. Pedroni (1999) test for cointegration between TB, $\eta_j \times \ln E$ and $\eta_i \times \ln E$ by commodity group. ν, variance-ratio test; η and t, unit root test (PP, Philip-Perron test; ADF, augmented Dickey–Fuller test.