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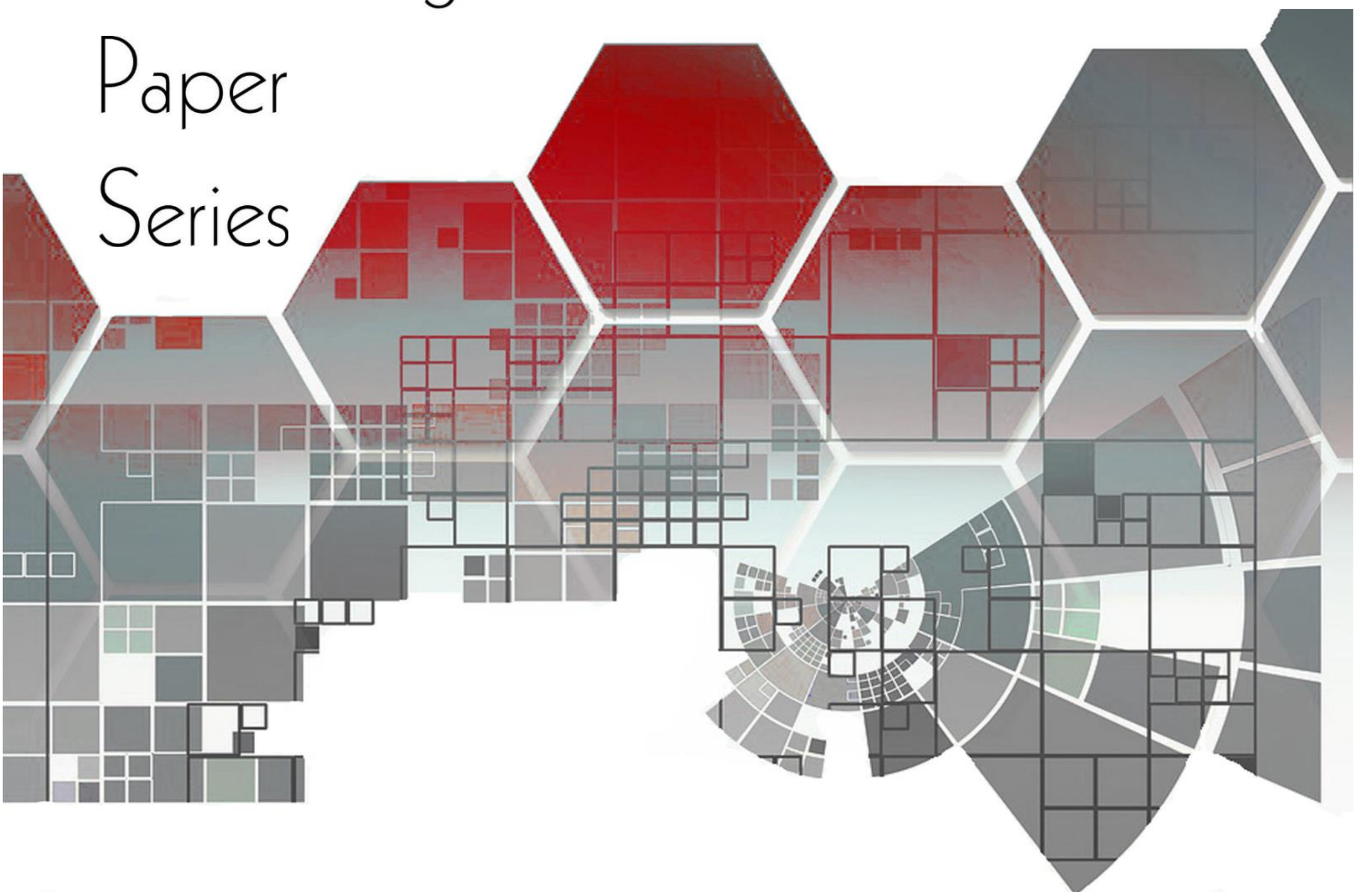

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Can inaction account for the incomplete exchange rate pass-through? Evidence from threshold ARDL model

Can inaction account for the incomplete exchange rate pass-through? Evidence from threshold ARDL model

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Abstract

Numerous empirical studies suggest that the responses of prices to exchange rate movements are muted, i.e. the exchange rate pass-through is incomplete. In this study we investigate whether this result can be explained by inaction to small changes in the exchange rate, in which case the incompleteness would constitute merely an artefact introduced by the linear specification of the pass-through equation. To this end we extend the non-linear ARDL framework of Shin et al. (2014) by allowing for threshold reactions, specifically in the form of a 'band of inaction'. The results obtained for Polish industry show significant sign- and size-dependence in the sensitivity of export prices to exchange rate movements, but only in a few cases they fully account for the incompleteness of the pass-through. The tendency for inaction is to a large extent determined by industry's characteristics, with sectors more technologically advanced and more involved in international activities, more willing or able to absorb exchange rate movements in their markups, thereby stabilising their prices in the destination markets.

Keywords: exchange rate pass-through, non-linear cointegration, non-linear ARDL, band of inaction

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1. Introduction

The exchange rate pass-through (ERPT), i.e. the sensitivity of prices to exchange rate (ER) movements, is one of the classical topics in international macroeconomics. Due to its implications for the conduct of monetary and exchange rate policy, as well as for its relevance in evaluating the impact of ER fluctuations on the real economy, the degree of ERPT has been extensively studied for three decades now, beginning with seminal contributions by Dornbusch (1987) and Krugman (1987).

The degree of ERPT depends on the way exporters set their prices. Theoretically, if prices are set in their own currency, the pass-through to destination prices (i.e. prices expressed in importers' currency) is full (destination prices move one-to-one with the ER). Under such circumstances, exchange rate movements generate expenditure-switching effects between home and foreign goods and, thus, have implications for the real economy: depreciations boost international competitiveness and, thus, tend to increase net exports, while appreciations tend to hamper it. Thus, under producer currency pricing (PCP) it makes sense for central banks to pursue active exchange rate policy aimed at preventing currency misalignment. If, however, prices are set in importers' currency, destination prices are insulated from exchange rate movements. Under extreme case of local currency pricing (LCP), when the pass-through is null, ER fluctuations spur no real effects, rendering exchange rate interventions ineffective as a tool of economic stabilisation.

The overwhelming empirical evidence indicates, however, that the exchange rate pass-through is incomplete, i.e. neither null, nor full (i.a. Goldberg and Knetter 1997, Campa and Goldberg 2005, Gopinath and Rigobon 2008, Nakamura and Steinsson 2008, Gopinath and Itskhoki 2010, Gopinath et al. 2010). The elasticity of destination prices with respect to exchange rate proves usually to be significantly different from both zero and one, and is on average close to one half[2], showing however substantial heterogeneity across countries, industries and time (see e.g. Knetter 1993, Campa and Goldberg 2005, Choudhri and Hakura 2006, Ca'Zorzi et al. 2007, Bussière et al. 2014 for extensive comparisons). Several theories explaining the partiality of ERPT have been put forward in the literature. It has been ascribed to price rigidities (e.g. menu costs or staggered price contracts) that render price changes costly and, thus, infrequent (Giovannini 1988, Devereux and Engel 2001, Bacchetta and van Wincoop 2003) and to local cost components of traded goods (such as distribution and marketing costs, e.g. Burstein et al. 2005, Corsetti and Dedola 2005), driving a wedge between actual prices of imported goods and those charged by exporters. The incompleteness of ERPT may also stem from strategic pricing behaviour of exporters (pricing-to-market, Krugman 1987, Dornbush 1987, Klein 1990): by absorbing non-favourable exchange rate movements, they stabilise prices of their goods in destination market currency and, thus, protect their market share. Numerous empirical studies (i.a. Atkeson and Burstein 2008, Hellerstein 2008, Nakamura 2008, Nakamura and Zerom 2010, Gopinath et al. 2011, Goldberg and Hellerstein 2013) suggest that time-varying markups together with non-traded costs contribute most to the pass-through determination. The role of nominal rigidities is negligible: their existence explains only the sluggishness (i.e. short-run incompleteness) of the pass-through, but not its long-run partiality observed in the data.

The majority of studies indicating the incompleteness of ERPT rely, however, on linear specification of the pass-through equation, i.e. assume that the sensitivity of prices is independent of the magnitude or sign of the ER changes, as well as of any economic fundamentals. There are, however, several rationales for why the linearity assumption may not hold. One strand of literature suggests possible regime-dependence in the data generating process (DGP), with the transition variables of either micro- or macroeconomic nature. The initial literature

[2] E.g. based on the sample of 23 OECD countries over the period of 1975-2003 the average degree of ERPT to manufacturing import prices is approximately 0.43 after one quarter and 0.62 in the long run (Campa and Goldberg 2005).

in this field (e.g. Dornbusch 1987, Knetter 1989, Feenstra et al. 1996, Yang 1997) emphasized the role of microeconomic phenomena, such as competitive structure of foreign markets, degree of market segmentation, product substitutability, exporter's market power or convexity of the demand curve. More recent contributions shifted the focus towards macroeconomic determinants of pass-through variability, mainly inflation environment in the destination market (Taylor 2000, Choudhri and Hakura 2006, Gagnon and Ihrig 2004) or volatility of the exchange rate (Campa and Goldberg 2002, Devereaux and Yetman 2010, Ozkan and Erden 2015). Another form of state-dependence is suggested in Forbes (2016), Forbs et al. (2017) and Forbs et al. (2018). These contributions indicate that ERPT fluctuates over time more quickly than can be explained by slow-moving structural changes and suggest that the reason for this is different reaction of prices to exchange rate depending on what shock caused its movement, i.e. that the pass-through is shock-dependent.

Another strand of literature concentrates on the role of the sign and size of the ER changes in the pass-through determination. First of all, exporters may be more motivated to absorb ER appreciations, since their failing in doing so translates into losses in their competitiveness and, consequently, market share. Depreciations, on the other hand, can be used to expand market share, as well as – especially if firms face capacity constraints – to compensate for previous or to build a buffer for future markup squeezes caused by currency strengthening. This points to possible asymmetry in the relation between the ER and destination prices that has been studied and confirmed in several studies thus far (e.g. Knetter 1994, Pollard and Coughlin 2004, Przystupa and Wróbel 2011, Delatte and López-Villavicencio 2012, Brun-Aguerre et al. 2016). Secondly, exporters' ability to absorb ER movements by adjusting their markups is limited, as beyond a certain point it would imply negative profit margins, suggesting size-dependence in the data generating process (e.g. Larue et al. 2010, Frankel et al. 2012, Bussière 2013).

Against this background, the present study aims to contribute to the literature by combining asymmetry and size-dependence in the pass-through equation and, thereby, testing for the existence of a ‘band of inaction’ (see Belke et al. 2013 for theoretical underpinnings of the inaction concept), within which the ERPT is relatively weak and beyond which stronger reactions – at least in the case of ER apperceptions – are triggered. For this purpose we develop a threshold ARDL model as an extension to non-linear modelling framework proposed by Shin et al. (2014). Polish industry serves as an application example. We also test whether inaction can explain the partiality of ERPT that is observed under linear specification of the pass-through equation. Namely, if the ‘band-of-inaction’ hypothesis is true, the degree of pass-through obtained assuming linearity of the DGP constitutes a weighted average of lower (‘within-the-band’) and higher (‘beyond-the-band’) degrees, possibly rendering the incompleteness an artefact introduced by the linearity conjecture. In such case, the ERPT parameter obtained within a linear model would underestimate (overestimate) the degree of pass-through of ‘large’ (‘small’) ER changes, giving misleading implications for the conduct of exchange rate policy. Introducing threshold-type non-linearities can, therefore, provide a new insight into ERPT variability over time as well as serve as a useful guidance to policy-makers.

The paper is organized as follows. Section 2 discusses econometric methodology employed in the study as well as specifies empirical framework and data upon which the estimates are based. Section 3 brings and discusses the empirical results. The last section concludes.

2. Empirical strategy

2.1. Methodology

In the presence of nominal rigidities it takes many periods for exchange rate changes to be transmitted to prices, rendering the ERPT a dynamic phenomenon. Therefore, for the purpose of its modelling we use cointegration analysis. Specifically, we utilize and extend cointegration analysis within the non-linear

ARDL model proposed by Shin et al. (2014), building upon a linear framework developed by Pesaran and Shin (1999) and Pesaran et al. (2001).

In Shin et al. (2014) non-linearity in the cointegration equation takes the form of asymmetry:

$$x_t = \delta_0 + \delta_1^+ y_t^+ + \delta_1^- y_t^- + \varepsilon_t \tag{1}$$

where $y_t^+ = \sum_{i=1}^{T} \Delta y_i^+ = \sum_{i=1}^{T} \max(\Delta y_i, 0)$ and $y_t^- = \sum_{i=1}^{T} \Delta y_i^- = \sum_{i=1}^{T} \min(\Delta y_i, 0)$ constitute partial sums of positive and negative changes in y_t so that $y_t = y_0 + y_t^+ + y_t^-$. Since y_t is decomposed into y_t^+ and y_t^- around the threshold zero, parameter δ_1^+ captures the long-run response of x_t to the increase in y_t, whereas δ_1^- the response to a decrease. The framework can be generalized by imposing a different threshold or by determining its value endogenously (e.g. *via* a grid search).

In order to test for the existence of a 'band of inaction' in the exchange rate pass-through DGP, we propose to extend this framework by incorporating threshold-type non-linearities into the cointegration equation:

$$x_t = \delta_0 + \delta_1^+ y_t^+ + \delta_1^0 y_t^0 + \delta_1^- y_t^- + \varepsilon_t \tag{2}$$

where $y_t^- = \sum_{i=1}^{T} \Delta y_i^- = \sum_{i=1}^{T} \min(\Delta y_i, \tau_1)$, $y_t^+ = \sum_{i=1}^{T} \Delta y_i^+ = \sum_{i=1}^{T} \max(\Delta y_i, \tau_2)$, and $y_t^0 = \sum_{i=1}^{T} \Delta y_i^0$, where $\tau_1 \leq \Delta y_i^0 \leq \tau_2$. In line with the 'band-of-inaction' hypothesis we additionally restrict the threshold values so that $\tau_1 < 0$ and $\tau_2 > 0$.

Following Pesaran and Shin (1999), the estimation of short- and long-run elasticises as well as testing for the existence of a cointegration relationship is performed within the ARDL(p,q) model. Its threshold version takes the following form:

$$x_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i x_{t-i} + \sum_{i=0}^{q} (\beta_i^+ y_{t-i}^+ + \beta_i^0 y_{t-i}^0 + \beta_i^- y_{t-i}^-) + \vartheta_t \tag{3}$$

After reparametrisation the model is estimated in the unrestricted error correction form:

$$\Delta x_t = \alpha_0 + \gamma x_{t-1} + \beta^+ y_{t-1}^+ + \beta^0 y_{t-1}^0 + \beta^- y_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i \, \Delta x_{t-i} + \sum_{i=0}^{q-1} (\beta_i^+ \Delta y_{t-i}^+ + \beta_i^0 \Delta y_{t-i}^0 + \ \beta_i^- \Delta y_{t-i}^-) + \vartheta_t \qquad (4)$$

where $\gamma = -(1 - \sum_{i=1}^{p} \alpha_i)$, $\beta^+ = \sum_{i=0}^{q} \beta_i^+$, $\beta^0 = \sum_{i=0}^{q} \beta_i^0$ and $\beta^- = \sum_{i=0}^{q} \beta_i^-$.

In order to recover the long-run parameters from the estimated ECM, its restricted version can be derived:

$$\Delta \hat{x}_t = \hat{\alpha}_0 + \hat{\gamma} \left(x_{t-1} + \frac{\hat{\beta}^+}{\hat{\gamma}} y_{t-1}^+ + \frac{\hat{\beta}^0}{\hat{\gamma}} y_{t-1}^0 + \frac{\hat{\beta}^-}{\hat{\gamma}} y_{t-1}^- \right) + \sum_{i=1}^{p-1} \hat{\alpha}_i \, \Delta x_{t-i} + \sum_{i=0}^{q-1} (\hat{\beta}_i^+ \Delta y_{t-i}^+ + +\hat{\beta}_i^0 \Delta y_{t-i}^0 + \hat{\beta}_i^- \Delta y_{t-i}^-) \qquad (5)$$

where $-\frac{\hat{\beta}^+}{\hat{\gamma}}$, $-\frac{\hat{\beta}^0}{\hat{\gamma}}$ and $-\frac{\hat{\beta}^-}{\hat{\gamma}}$ are the estimated long-run elasticities, $\hat{\delta}_1^+$, $\hat{\delta}_1^0$ and $\hat{\delta}_1^-$ respectively, and $\hat{\gamma}$ is the error correction coefficient.

The existence of a long-run relationship is established using bounds-testing approach proposed by Pesaran and Shin (1999). It consists in testing the null hypothesis of $\gamma = \beta_1^+ = \beta_1^0 = \beta_1^- = 0$. The framework is applicable for both I(1) and I(0) regressors. Therefore, there are two asymptotic critical values: one under the assumption that all regressors are I(1) and the other assuming their stationarity. If the test statistics falls outside the critical value bounds, the null of no level relationship can be rejected. If it falls within the bounds, the inference is inconclusive. The relevant critical values are tabulated in Pesaran et al. (2001).

Thresholds τ_1 and τ_2 are estimated by means of a grid search so as to minimise the sum of squared residuals Q:

$$[\hat{\tau}_1, \hat{\tau}_2] = \underset{\tau_1, \tau_2 \in D}{\operatorname{argmin}} \, \mathrm{Q}(\tau_1, \tau_2) \qquad (6)$$

in the error correction model (equation 4). The domain D is set by trimming extreme observations (at the 15th and 85th percentile, Hansen 1999). Due to the fact that thresholds τ_1 and τ_2 are unknown and, consequently, have to be estimated, the Wald statistics used for the purpose of testing long-run linearity ($\delta_1^+ = \delta_1^0 = \delta_1^-$) follows a nonstandard asymptotic distribution (the Davies problem, 1977). For this reason the approximate critical values are obtained by means of a bootstrap procedure proposed in Hansen (1996, 2000).

The lag structure of ARDL models is established using the 'general-to-specific' approach (based on the Schwarz information criterion) and controlling for serial correlation of residuals.

2.2. The model and data

The degree of ERPT is estimated within a variant of a standard pass-through equation that has been employed throughout the literature following Knetter (1989):

$$p_t^{exp*} = \delta_0 + \delta_1 e_t + \varphi y_t^* + \phi c_t + \varepsilon_t \tag{7}$$

where the transmission of exchange rate (e_t) changes to destination prices (p_t^{exp*}) is estimated controlling for the marginal costs borne by exporting firms (c_t) as well as the demand in the destination market (y_t^*).

The equation incorporating threshold-type relationship between the exchange rate and destination prices, allowing to test for the 'band-of-inaction' hypothesis, takes the following form:

$$p_t^{exp*} = \delta_0 + \delta_1^+ e_t^+ + \delta_1^0 e_t^0 + \delta_1^- e_t^- + \varphi y_t^* + \phi c_t + \varepsilon_t \tag{8}$$

where:

- $e_t^- = \sum_{i=1}^{T} \Delta e_i^- = \sum_{i=1}^{T} \min(\Delta e_i, \tau_1)$ and $\tau_1 < 0$,
- $e_t^+ = \sum_{i=1}^{T} \Delta e_i^+ = \sum_{i=1}^{T} \max(\Delta e_i, \tau_2)$ and $\tau_2 > 0$,

- $e_t^0 = \sum_{i=1}^{T} \Delta e_i^0$, where $\tau_1 \leq \Delta e_i^0 \leq \tau_2$.

As in most empirical studies in this field, we employ a single-equation model of the pass-through. The estimates obtained on its basis are, however, subject to simultaneity bias should the variables be endogenously determined, which is especially likely in the case of exchange rates and prices. In such a case system approach should be followed, e.g. by estimating a VAR model (e.g. McCarthy 2007, Hahn 2003, Choudhri et al. 2005, Faruqee 2006, Ca'Zorzi et al. 2007, Ito and Sato 2008). In our case, however, the sectoral structure of the data allows to unambiguously determine the direction of causality (sectoral prices – unlike the overall price level – do not cause exchange rate movements), which justifies the utilisation of a univariate analysis.

All the data used in the analysis come from Eurostat and are expressed in natural logarithms. The sectoral coverage includes 22 divisions of NACE rev. 2 section C (*manufacturing*). For basic characteristics of the sectors see Table 1. Data are of monthly frequency and cover years 2006 through 2018 (till September).

Destination prices are export prices denominated in importers' currency. Two measures of prices can be used in this respect: unit values and production prices. Unit value index can be derived from international trade statistics as a FOB value of traded goods over their harmonized quantity. Its advantage over available price indices is that, using customs data, it can be calculated separately for every trading partner. The index has been, however, criticized in the literature for its biasedness in the face of compositional changes in quantities and in quality of what is exported or imported (Silver 2010). Price indices, on the other hand, measure the evolution of prices of representative goods and, thus, are superior in the face of product differentiation (United Nations 1979 and 1981). Additionally, price indices are aggregated according to economic activity (NACE) rather than (or along to) product (e.g. SITC) classification, which ensures compatibility of prices and costs (which are available only by activity) in the pass-through equation. For these reasons we use non-domestic production price index as a proxy for export prices. The series are derived from short-term business statistics (STS) database and show the average price developments (expressed in the national currency) of all goods and services sold outside of the domestic market. Destination prices are computed as a product of non-domestic production price index and the exchange rate.

The employment of price indices for geographically aggregated exports necessitates the use of effective exchange rate in the pass-through equation that was approximated by nominal effective exchange rate (NEER) vis-à-vis the currencies of 42 main trading partners. It should be, however, borne in mind that the series were computed using weights for the overall exports, which could be a source of bias if the sectoral weights substantially differ from the overall pattern. The rate is defined as the number of foreign currency units for one unit of domestic currency (direct quotation), implying that its increase indicates appreciation of home currency.

Costs incurred by the exporters are approximated in the literature either by wages (or unit labour costs), or by prices of domestic production. Due to possible variation (e.g. over the business cycle) in the cost pass-through, we decided, along e.g. Vigfussen et al. (2009), on the latter proxy. For lack of a better alternative, demand in the destination market is surrogated by sectoral volumes of production (by NACE sectors) in the main Polish trading partner, i.e. the EU. Nonetheless, a high share (ca. 81% as of 2016) of the EU in Polish manufacturing exports ensures measurement consistency with other variables in the pass-through equation.

Table 1: Sectoral characteristics

Manufacture of:	NACE code	Technologic intensity	Sales in non-domestic markets as percent of total industry	Sales in non-domestic markets as percent of total sales	Import intensity of production
food	C10	L	10.0%	24.4%	15.9%
beverages	C11	L	0.4%	8.4%	
textiles	C13	L	1.4%	50.0%	36.6%
wearing apparel	C14	L	0.7%	34.6%	
leather and related products	C15	L	0.5%	48.1%	
wood, cork, straw and wicker products	C16	L	2.3%	29.6%	15.5%
paper and paper products	C17	L	2.8%	34.8%	26.5%
printing and reproduction	C18	L	0.6%	20.1%	26.5%
coke and refined petroleum products	C19	L	3.2%	23.3%	58.1%
chemicals and chemical products	C20	H	5.2%	39.6%	36.6%
pharmaceutical products	C21	H	1.4%	46.0%	36.6%
rubber and plastic products	C22	M	7.5%	44.1%	37.1%
other non-metallic mineral products	C23	M	2.8%	26.5%	20.2%
basic metals	C24	M	4.6%	46.3%	28.3%
metal products	C25	L	7.4%	36.5%	34.6%
computer, electronic and optical products	C26	H	5.4%	69.1%	49.0%
electrical equipment	C27	H	7.8%	67.4%	46.1%
machinery and equipment n.e.c.	C28	H	4.0%	42.0%	41.7%
motor vehicles, trailers and semi-trailers	C29	H	22.4%	79.9%	38.3%
other transport equipment	C30	H	3.0%	68.1%	51.8%
furniture	C31	L	5.2%	59.1%	28.7%
other products	C32	M	1.2%	47.1%	

Notes: Data come from Polish Statistical Office and OECD and are for the year 2015. Technologic intensity is assigned according to UNIDO classification, where L stands for low technology, M for medium technology and H for medium-high or high technology. Import intensity of production is defined as a share of imported inputs in intermediate consumption.

3. Empirical findings

Cointegration analysis within the ARDL model as proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) can be used for a mixture of I(0) and I(1) series but not for variables of higher degree of integration. For this reason the I(2)-ness of the series has to be excluded. The results of unit root tests indicate integration of order 1 with some weak signs of stationarity (the non-stationarity null rejected at the 10% significance level) in a few cases (see Table 2), allowing for the application of the ARDL methodology.

First, a linear specification of the pass-through equation (equation 7) was estimated (see Table 3). In most industries the null hypothesis of the cointegration test is rejected, pointing to the existence of a long-run relationship between variables. However, in several sectors the relation is degenerate, with the long-run pass-through parameter non-significantly different from zero. Therefore, there seems to be no linear relationship between the exchange rate and destination prices in almost a third of industries, most of which are high or medium-high technology sectors according to the UNIDO classification[3]. The average estimated degree of pass-through[4] is approximately 40%[5] (38% and 43% in trade-weighted and non-weighted case, respectively), indicating that a 10% appreciation (depreciation) of PLN translates on average into 4% rise (fall) in destination prices. However, the estimates vary substantially across sectors. Corroborating the results of previous studies (e.g. Campa and Goldberg 2002, Gaulier et al. 2008), the highest pass-through estimates were obtained for industries manufacturing low-technology goods (beverages, coke and refined petroleum products, wood, rubber and plastic,

[3] United Nations Industrial Development Organization classification of manufacturing sectors by technological intensity (http://stat.unido.org/content/focus/classification-of-manufacturing-sectors-by-technological-intensity-%2528isic-revision-4%2529;jsessionid=4DB1A3A5812144CACC956F4B8137C1CF).

[4] We only present and discuss the long-run estimates, since the short-run elasticities are affected by transitory phenomena such as nominal rigidities.

[5] We imputed zeros for long-run elasticities in sectors whose export prices are not cointegrated with the exchange rate.

textiles, basic metals), in some of which the null hypothesis of complete pass-through cannot be rejected. The pattern is, however, far from being clear, since relatively small sensitivity of prices to ER movements was estimated in the case of food industry (40%) which constitute a large portion of low-technology exports. Nevertheless, the sensitivity of destination prices to exchange rate movements seems to be decreasing with technology-intensity, with the unweighted average pass-through parameters for low-, medium- and high-technology sectors equal to 0.66, 0.51 and 0.12, respectively.

Next, in order to investigate possible sign- and size-dependence in the sensitivity of export prices to exchange rate movements, we turned to a threshold specification of the pass-through equation (8). In all cases the no-cointegration null is strongly rejected and in most of them (except for manufacturing of electrical equipment) the relation is non-degenerate (at least one of the long-run elasticities is significantly different from zero), implying the existence of a meaningful long-run relationship between the exchange rate and prices (see Table 4). Moreover, the long-run linearity hypothesis (i.e. $\delta_1^+ = \delta_1^0 = \delta_1^-$) is also rejected in virtually all sectors, pointing to the existence of a threshold-type relationship in the DGP. In most industries the response of destination prices differs significantly depending not only on the size of exchange rate fluctuations, but also on their sign, since the symmetry null (i.e. $\delta_1^+ = \delta_1^-$) is rejected. In most cases also the band given by the threshold values seems to be asymmetrical with respect to zero. For all sectors the estimated threshold values are below (albeit mostly close to) one standard deviation of the exchange rate distribution, which – together with relative symmetry of this distribution – ensures that in all three regimes ('large' depreciations, 'small' ER changes, 'large' appreciations) there are enough observations to efficiently estimate the parameters (on average circa 20%, 60% and 20% of the sample, respectively).

The long-run elasticities estimated within the threshold equation (see Table 5) give a puzzling insight into the nature of exchange rate pass-through in Polish industry. In most sectors the 'band-of-inaction' hypothesis seems to be supported by the data, i.e. the ‘within-the-band’ elasticity is significantly lower than the ‘beyond-the-band’ ones (in some cases even significantly negative), suggesting that exporters tend to neglect minor changes in the exchange rates until some pain threshold is passed. However, a few sectors (manufacturing of food, beverages, wood, coke and rubber) exhibit the opposite pattern with prices reacting to a greater extent to ‘smaller’ exchange rate fluctuations than to ‘larger’ ones. In all of those cases the degree of pass-through within the band is full, or even significantly surpasses 100%, whereas beyond the band it is smaller, especially in the case of ‘large’ appreciations. There is also no clear-cut pattern regarding the asymmetry of the exchange rate pass-through. In most sectors ‘beyond-the-band’ reactions of destination prices seem fairly symmetrical or are slightly stronger in the case of appreciations, whereas in some cases (mostly less technologically-advanced industries) prices are significantly more responsive to ‘large’ depreciations.

In approximately half of industries the partiality of traditionally-estimated ERPT seems to result from the linear, and apparently inadequate, specification of the pass-through equation. The strictly defined ‘band-of-inaction’ hypothesis, i.e. the pass-through that is complete ‘beyond-the-band’ and significantly lower (preferably insignificant) ‘within-the-band’, seems to be true in three cases: manufacturing of chemicals, metals and computers. In three additional cases (manufacturing of leather, paper and metal products) the hypothesis is partially true, since beyond a threshold point appreciations are fully transmitted to destination prices, while in the case of ‘large’ depreciations the response is still muted. In the case of manufacturing of food, beverages, wood, coke and rubber the opposite pattern (‘band-of-action’) seems to prevail, since ‘small’ changes in the ER are fully passed to prices (even with some overshooting), while larger changes (especially appreciations) tend to be absorbed.

Table 2: Unit root tests

Manufacture of:	prices		costs		demand	
	H_0: I(1)	H_0: I(2)	H_0: I(1)	H_0: I(2)	H_0: I(1)	H_0: I(2)
food	-2.76*	-10.05***	-1.68	-6.77***	-2.68	-15.01***
beverages	-1.89	-11.79***	-2.34	-12.84***	-3.51**	-12.71***
textiles	-2.46	-9.93***	-1.49	-11.71***	-2.06	-4.38***
wearing apparel	-1.84	-10.90***	-0.79	-11.77***	-1.73	-12.59***
leather and related products	-1.74	-11.38***	0.12	-10.94***	-2.31	-12.40***
wood, cork, straw and wicker products	-2.04	-8.97***	-1.38	-4.73***	-0.77	-12.85***
paper and paper products	-2.12	-12.59***	-0.66	-10.05***	-1.81	-5.29***
printing and reproduction	-1.45	-7.25***	-0.81	-14.47***	-1.67	-16.47***
coke and refined petroleum products	-2.31	-7.78***	-1.97	-8.23***	-2.41	-15.65***
chemicals and chemical products	-2.61	-5.93***	-2.14	-8.38***	-2.46	-11.18***
pharmaceutical products	-1.94	-14.74***	-0.14	-17.04***	-1.44	-11.63***
rubber and plastic products	-2.05	-11.65***	-0.80	-10.53***	-2.35	-5.34***
other non-metallic mineral products	-1.92	-12.12***	-2.29	-6.58***	-1.38	-14.51***
basic metals	-2.70	-7.61***	-2.33	-6.21***	-3.47*	-4.71***
metal products	-2.04*	-9.96***	-2.63*	-10.63***	-2.40	-4.04***
computer, electronic and optical products	-0.47	-10.79***	-1.91	-13.15***	-1.87	-11.53***
electrical equipment	-1.65	-9.96***	-0.75	-12.44***	-3.09	-3.88***
machinery and equipment n.e.c.	-2.73*	-12.45***	-1.81	-14.27***	-3.41*	-3.95***
motor vehicles, trailers and semi-trailers	-2.91*	-12.38***	0.18	-12.52***	-2.86	-7.29***
other transport equipment	-0.45	-12.41***	-2.85*	-14.18***	-1.69	-14.06***
furniture	-3.30*	-9.11***	-2.05	-13.62***	-0.78	-16.58***
other products	-2.16	-9.91***	-2.39	-14.65***	-1.27	-12.27***

Notes: The table presents the ADF statistics. One, two and three asterisks indicate statistical significance at the level of 10%, 5% and 1%, respectively.

Table 3. Linear specification estimates

Manufacture of:	**Test for cointegration**	$\hat{\delta}_1$	**H**$_0$: $\delta_1 = 0$	**H**$_0$: $\delta_1 = 1$	**B-G test for autocorrelation**
food	19.42***	0.40	46.60***	101.49***	5.70
beverages	7.14**	0.63	2.72*	0.61	1.54
textiles	16.36***	0.84	31.51***	1.20	1.98
wearing apparel	11.93***	0.67	13.04***	3.07*	4.54
leather and related products	29.23***	0.59	15.84***	7.52**	1.60
wood, cork, straw and wicker products	34.50***	0.76	123.80***	12.26***	2.01
paper and paper products	10.16***	0.52	10.64***	9.29***	8.16*
printing and reproduction	27.97***	0.59	17.00***	8.33***	8.32*
coke and refined petroleum products	18.57***	1.06	32.37***	0.11	3.72
chemicals and chemical products	2.68	-	-	-	2.60
pharmaceutical products	3.06*	-0.23	0.10	-	8.76*
rubber and plastic products	12.47***	0.74	25.67***	3.30*	0.32
other non-metallic mineral products	10.22***	0.21	1.79	-	9.28*
basic metals	11.01***	0.69	13.89***	3.82*	7.72
metal products	21.12***	0.61	32.41***	13.58***	3.01
computer, electronic and optical products	1.81	-	-	-	2.51
electrical equipment	0.00	-	-	-	4.49
machinery and equipment n.e.c.	4.11**	0.21	0.99	-	5.17
motor vehicles, trailers and semi-trailers	20.54***	0.31	27.78***	136.13***	6.40
other transport equipment	15.08***	0.50	18.41***	19.06***	4.94
furniture	4.45**	0.56	16.29***	10.20***	1.44
other products	6.10**	0.62	5.68**	2.11	3.56

Notes: Cointegration test verifies H$_0$: $\gamma = \beta_1 = 0$. One, two and three asterisks indicate statistical significance at the level of 10%, 5% and 1%, respectively. B-G stands for Breusch-Godfrey test.

Table 4. Threshold specification estimates (1)

Manufacture of:	Test for cointegration	Test for LR linearity	Test for LR symmetry	$\hat{\tau}_1$	$\hat{\tau}_2$	B-G test for autocorrelation	No of parameters
food	31.56***	22.60***	16.01***	-1.2%	1.4%	7.32	16
beverages	20.19***	7.44**	8.36***	-1.4%	1.2%	5.30	16
textiles	57.52***	40.43***	11.75***	-0.8%	1.0%	2.07	17
wearing apparel	37.59***	24.25***	18.38***	-1.6%	0.7%	2.44	16
leather and related products	43.52***	13.19***	3.84*	-1.7%	1.3%	2.48	18
wood, cork, straw and wicker products	34.73***	5.64*	2.61	-1.5%	1.4%	3.90	18
paper and paper products	25.16***	33.12***	29.54***	-1.2%	1.4%	8.30*	16
printing and reproduction	41.76***	1.34	0.07	-0.7%	0.9%	5.72	17
coke and refined petroleum products	25.22***	15.45***	12.61***	-1.0%	1.4%	4.10	17
chemicals and chemical products	9.02***	11.64***	11.42***	-0.1%	1.0%	4.69	20
pharmaceutical products	17.12***	13.80***	5.76**	-1.5%	0.9%	4.51	16
rubber and plastic products	25.82***	17.20***	4.83**	-1.2%	1.3%	6.28	19
other non-metallic mineral products	23.74***	18.01***	9.12***	-1.0%	1.5%	4.79	19
basic metals	6.52**	12.64***	7.58***	-0.4%	1.1%	6.13	18
metal products	33.24***	21.00***	17.66***	-0.7%	1.5%	0.60	17
computer, electronic and optical products	10.27***	10.80***	2.42	-1.4%	0.9%	4.02	17
electrical equipment	3.61*	9.71***	0.25	-1.2%	0.7%	3.99	21
machinery and equipment n.e.c.	4.54**	5.54*	0.67	-0.9%	0.7%	4.40	16
motor vehicles, trailers and semi-trailers	27.33***	25.70***	15.49***	-1.0%	0.8%	6.12	17
other transport equipment	12.34***	9.92***	1.23	-1.4%	0.5%	6.43	16
furniture	13.46***	13.38***	6.04**	-0.9%	0.8%	1.75	16
other products	18.79***	5.96**	0.03	-1.1%	1.0%	7.21	16

Notes: Cointegration test verifies H_0: $\gamma = \beta_1^+ = \beta_1^0 = \beta_1^- = 0$, linearity test verifies H_0: $\beta_1^+ = \beta_1^0 = \beta_1^-$ and symmetry test verifies H_0: $\beta_1^+ = \beta_1^-$. One, two and three asterisks indicate statistical significance at the level of 10%, 5% and 1%, respectively. B-G stands for Breusch-Godfrey test.

Table 5. Threshold specification estimates (2)

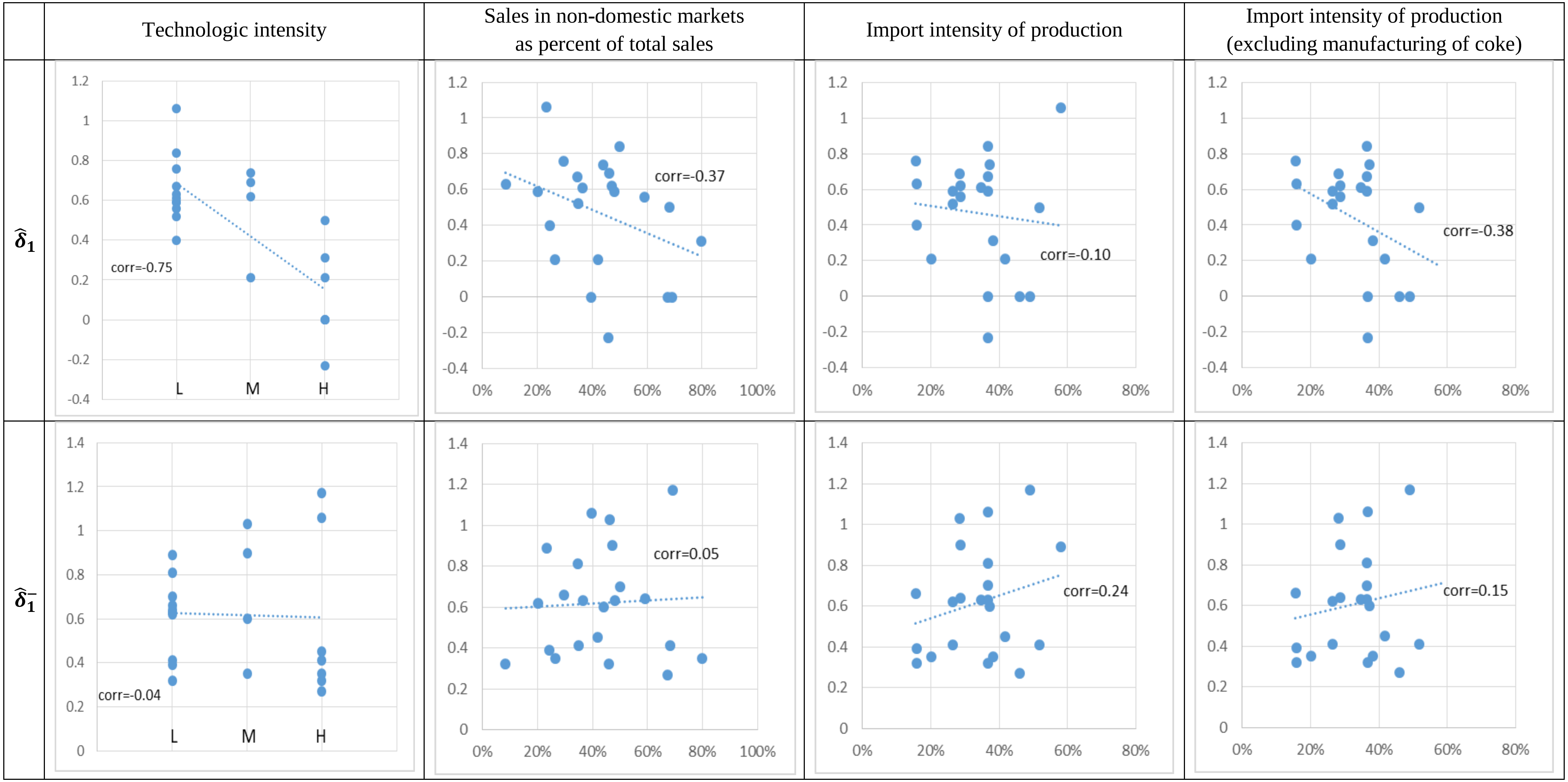
Manufacture of:	$\widehat{\delta}_1^-$	H$_0$: $\delta_1^- = 0$	H$_0$: $\delta_1^- = 1$	$\widehat{\delta}_1^0$	H$_0$: $\delta_1^0 = 0$	H$_0$: $\delta_1^0 = 1$	$\widehat{\delta}_1^+$	H$_0$: $\delta_1^+ = 0$	H$_0$: $\delta_1^+ = 1$
food	0.39	68.69***	164.51***	1.04	48.69***	0.07	0.18	5.79**	119.79***
beverages	0.32	2.78*	12.38***	2.87	22.83***	9.69***	0.06	0.06	-
textiles	0.70	126.79***	23.00***	-0.62	14.42***	97.52***	0.81	202.56***	11.10***
wearing apparel	0.81	81.56***	4.64**	-0.06	0.09	-	0.35	13.17***	43.89***
leather and related products	0.63	45.18***	15.86***	-0.54	2.51	-	0.75	16.35***	1.82
wood, cork, straw and wicker products	0.66	53.34***	14.08***	1.10	35.85***	0.30	0.71	64.64***	10.31***
paper and paper products	0.41	13.40***	28.24***	0.32	1.63	-	0.92	50.91***	0.40
printing and reproduction	0.62	23.03***	8.95***	1.18	3.66*	0.08	0.60	14.13***	6.03**
coke and refined petroleum products	0.89	31.34***	0.45	2.53	19.81***	7.24**	0.22	0.85	-
chemicals and chemical products	1.06	22.46***	0.08	-0.81	2.03	-	1.70	17.31***	2.92*
pharmaceutical products	0.32	5.32**	23.19***	-1.20	5.86**	19.67***	-0.11	0.27	-
rubber and plastic products	0.60	29.80***	13.54***	1.40	42.69***	3.43*	0.47	22.24***	27.49***
other non-metallic mineral products	0.35	22.51***	77.24***	-0.72	10.63***	60.92***	0.71	41.08***	6.63***
basic metals	1.03	23.72***	0.02	-1.10	5.26**	19.12***	1.39	19.10***	1.51
metal products	0.63	64.73***	23.01***	-0.31	1.97	-	1.00	52.61***	0.00
computer, electronic and optical products	1.17	14.36***	0.32	-1.96	7.82***	17.87***	0.81	3.13*	0.17
electrical equipment	0.27	0.53	-	-1.89	1.51	-	-0.26	0.23	-
machinery and equipment n.e.c.	0.45	24.06***	35.33***	-1.53	7.59***	20.80***	0.38	17.45***	46.93***
motor vehicles, trailers and semi-trailers	0.35	45.85***	162.51***	-0.42	2.34	-	0.42	56.19***	104.35***
other transport equipment	0.41	10.85***	21.91***	-0.82	4.27**	21.12***	0.47	8.39***	10.85***
furniture	0.64	101.12***	33.19***	-0.68	3.32*	20.25***	0.68	124.57***	27.81***
other products	0.90	25.25***	0.29	-1.29	3.08*	9.74***	0.89	16.13***	0.25

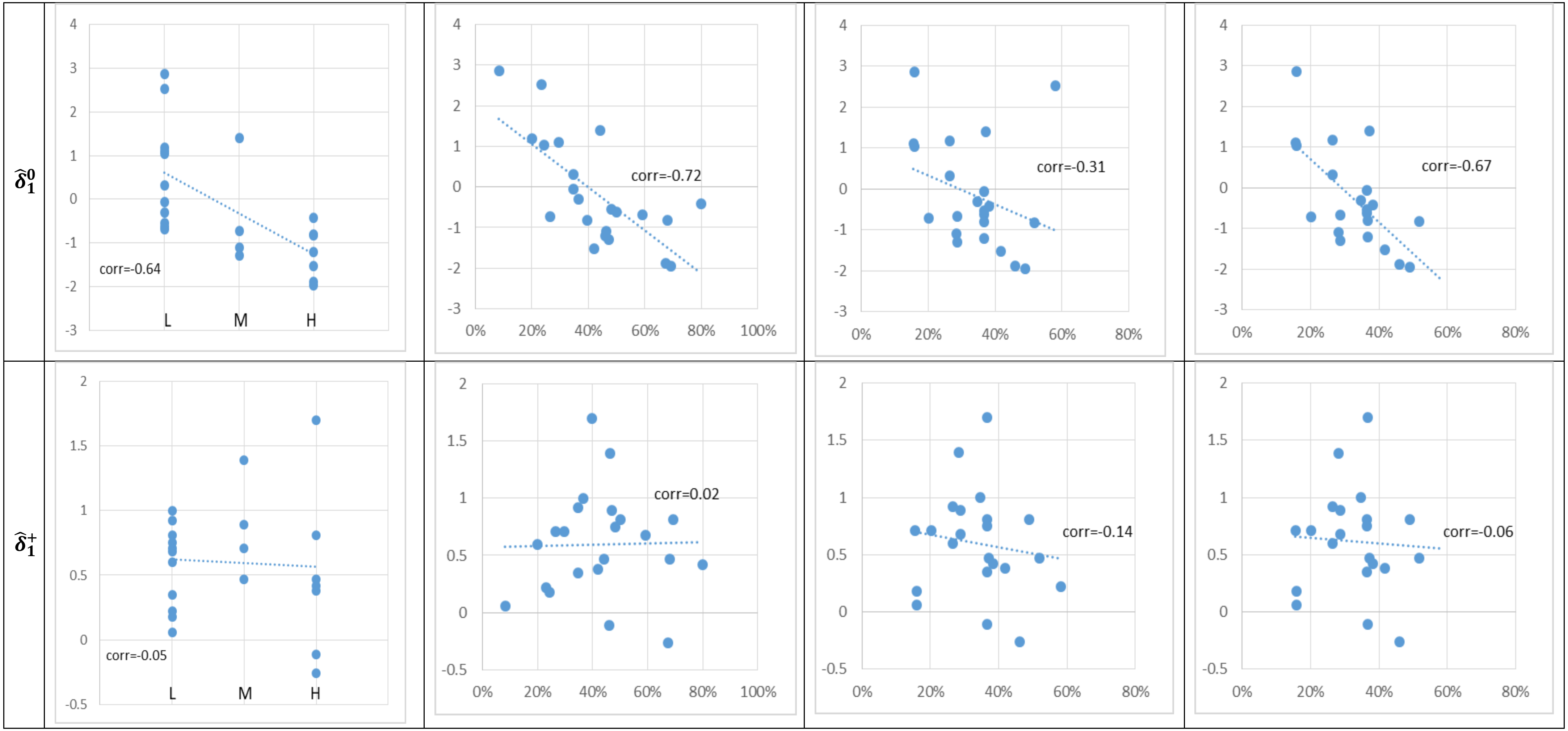
Notes: One, two and three asterisks indicate statistical significance at the level of 10%, 5% and 1%, respectively.

In order to shed some light on the factors behind the observed heterogeneity in ER transmission patterns, we tabulated each industry's estimated pass-through parameters against its characteristics: technologic intensity, export penetration and import intensity of production (see Figure 1). As mentioned before, the degree of pass-through estimated within a linear model seems to be higher for low-technology sectors than for more advanced ones. However, this seems to pertain only to the reactions to 'small' ER changes, as in the case of relatively large depreciations and appreciations the behaviour of destination prices does not depend on industry's technologic intensity. A similar pattern can be observed in the case of export penetration (a ratio of non-domestic sales to total sales). There seems to be some negative relation (Pearson's correlation coefficient equal to -0.37 and significant at 0.1 level) between the share of non-domestic sales and the estimated linear pass-through parameter, suggesting that the more reliant the industry on foreign markets, the bigger its incentive to price-to-market. However, again this result hinges upon the reactions of destination prices to 'small' exchange rate movements that are more muted (mostly insignificant, or even negative) for industries with higher export penetration (correlation coefficient equal to -0.72 and highly significant). In the transmission of larger depreciations and appreciations, on the other hand, exports-reliance plays no role whatsoever.

Import intensity of production is often found in the literature to be one of the most important factors explaining ERPT variability, with import-intensive firms or sectors having lower pass-through to their export prices (e.g. Amiti et al. 2014). Our results seem to contradict previous findings, since none of the estimated elasticities is significantly correlated with the share of imported inputs in intermediate consumption, and in the case of 'large' depreciations the relation appears to be even slightly positive. However, the obtained results are highly influenced by just one sector: manufacturing of coke and refined petroleum products. Despite almost 60% share of imports in its intermediate consumption, the sector is characterized by the highest degree of pass-through. Its exclusion from the sample renders the elasticity from the linear model negatively correlated with import intensity of production (significant of 0.1 level). However, this correlation stems again from the behaviour of destination prices in response to ‘small’ exchange rate changes that – with correlation coefficient equal to -0.67 – seem to be strongly influenced by the offsetting effects of imported inputs on industry’s costs and, consequently, profit margins. Again, even after the exclusion of the outlying sector, the pass-through of ‘large’ appreciations and depreciations is independent of industry’s import-reliance. It seems, therefore, that sectoral characteristics (technologic intensity, export- and import-reliance) explain not so much the degree of pass-through as the industry’s tendency for inaction (up to some point) to exchange rate movements, with exporters from sectors that are more technologically advanced and more involved in international activities, more willing or able to stabilise their prices in destination markets.

Figure 1. Pass-through estimates against sectoral characteristics





Notes: Technologic intensity is assigned according to UNIDO classification, where L stands for low technology, M for medium technology and H for medium-high or high technology. *Corr* stands for Pearson's correlation coefficient.

4. Conclusions

This study investigates size- and sign-dependence in the exchange rate pass-through. To this end a threshold cointegration framework is developed, allowing to test for inaction in the transmission of exchange rate movements into manufacturing export prices. The methodology is applied to Polish industrial sectors.

Firstly, the empirical results point to substantial heterogeneity in the pass-through patterns across industries. The estimates obtained assuming linearity of the DGP range from null to full ERPT, with the average parameter equal approximately to 0.4. However, in virtually all sectors the linearity assumption is strongly rejected, indicating the need to incorporate both asymmetry and size-dependence in the pass-through equation. In two thirds of industries this threshold-type relationship takes the form of a 'band of inaction' with the transmission of 'small' exchange rate movements to destination prices much weaker (often null) than in the case of 'large' appreciations or depreciations. In the remaining one third of sectors – mostly low-technology ones – the opposite pattern prevails, with price responses to 'large' ER changes more muted than in the case of 'small' ones. The incompleteness of the ERPT obtained within a linear specification of the pass-through equation proves to be – in light of threshold-equation estimates – an artefact in half of industries.

To some extent, the observed heterogeneity in ERPT patterns can be explained by sectoral characteristics (technologic intensity, export- and import-dependence). Specifically, they seem to determine exporters' willingness or ability for inaction to 'small' exchange rate movements, but do not explain their reactions to 'large' appreciations or depreciations. It seems that the more technologically advanced and the more involved in international trade the sector is, the lower its degree of pass-through until, however, some pain threshold is passed.

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