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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. 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 stabilizing their prices in the destination markets.

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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). In such circumstances, exchange rate movements generate expenditure-switching effects between home and foreign goods and, consequently, have implications for the real economy: depreciations boost international competitiveness and, thus, tend to increase net exports, while appreciations tend to hamper it. Therefore, under producer

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currency pricing (PCP) the exchange rate facilitates macroeconomic adjustment, thereby making an active exchange rate policy aimed at preventing currency misalignment advisable. If, however, prices are set in importers' currency, destination prices are insulated from exchange rate movements. Under the 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 stabilization.

The overwhelming empirical evidence indicates, however, that the exchange rate pass-through is incomplete, i.e. neither null, nor full (i.a. Campa & Goldberg, 2005; Goldberg & Knetter, 1997; Gopinath & Itskhoki, 2010; Gopinath & Rigobon, 2008; Gopinath, Itskhoki, & Rigobon, 2010; Nakamura & Steinsson, 2008). The elasticity of destination prices with respect to the exchange rate proves usually to be significantly different from both zero and one, and is on average close to one half,¹ showing however substantial heterogeneity across countries, industries and time (see e.g. Bussière, Delle Chiaie, & Peltonen, 2014; Ca'Zorzi, Hahn, & Sánchez, 2007; Campa & Goldberg, 2005; Choudhri & Hakura, 2006; Knetter, 1993 for extensive comparisons). Several theories explaining the incompleteness of ERPT have been put forward in the literature. In the short run it can be ascribed to exporters' price setting behaviour, being a mixture of PCP and LCP, matched with price rigidities (e.g. menu costs or staggered price contracts), rendering price changes costly and, thus, infrequent (Bacchetta & van Wincoop, 2003; Betts & Devereux, 2000; Devereux & Engel, 2001; Giovannini, 1988). Persistence of the incompleteness into the long run suggests, however, other factors behind it than just price inertia. These can be local cost components of traded goods (such as distribution and marketing costs, e.g. Burstein, Eichenbaum, & Rebelo, 2005; Corsetti & Dedola, 2005), driving a wedge between actual prices of imported goods and those charged by exporters, as well as imported inputs, affecting production costs and, thus, offsetting the impact of ER movements on firms' profits. Partial pass-through may, however, arise also from strategic pricing behaviour of exporters (a phenomenon dubbed pricing-to-market, Dornbusch, 1987; Klein, 1990; Krugman, 1987), endogenously adjusting their markups in response to exchange rate movements. By absorbing non-favourable currency fluctuations, firms stabilize prices in the destination market and, thus, protect their market share. Numerous empirical studies (i.a. Atkeson & Burstein, 2008; Goldberg & Hellerstein, 2013; Gopinath, Gourinchas, Hsieh, & Li, 2011; Hellerstein, 2008; Nakamura, 2008; Nakamura & Zerom, 2010) suggest that, indeed, time-varying markups contribute most to the pass-through determination, followed by the existence of non-traded costs. The role of nominal rigidities is negligible as they explain only the sluggishness of the pass-through, and not its long-run persistence.

The majority of studies indicating the incompleteness of ERPT rely on the 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 the literature suggests possible regime-dependence in the data generating process (DGP), with the transition variables of either micro- or macroeconomic nature. The initial literature in this field (e.g. Dornbusch, 1987; Feenstra, Gagnon, & Knetter, 1996; Knetter, 1989; 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 (Choudhri & Hakura, 2006; Gagnon & Ihrig, 2004; Taylor, 2000), volatility of the exchange rate (Campa & Goldberg, 2002; Devereux & Yetman, 2010; Ozkan & Erden, 2015) or position in the business cycle (Ben Cheikh & Rault, 2016; Ben Cheikh, Ben Zaided, Bouzgarrou, & Nguyen, 2018; Chew, Ouliaris, & Tan, 2011; Nogueira Jr & Leon-Ledesma, 2011). Another form of state-dependence is suggested in Forbes (2016), Forbes, Hjortsoe, & Nenova (2017), Comunale & Kunovac (2017) and Forbes, Hjortsoe, & Nenova (2018). These contributions indicate that the ERPT fluctuates over time more quickly than can be explained by slow-moving structural changes (such as market structure or inflation environment) and suggest that the reason for this is different reaction of prices to exchange rate depending on what kind of shock caused its movement, i.e. that the pass-through is shock-dependent.

Another strand of the literature concentrates on the role of the direction of ER changes in the pass-through determination. On the one hand, exporters should be more motivated to absorb ER appreciations than depreciations, since their failing in doing so translates into losses in their competitiveness and, ultimately, their market share, while passing through exchange rate depreciations can help to expand their position in the destination market. On the other hand, however, if quantities of exported goods are rigid upwards (due to export quotas or capacity constraints) and prices are rigid downwards (due to nominal rigidities), exporters may be unable to realize their gain in price competitiveness. In such a case they would rather increase their markups, thereby compensating for previous or building a buffer for future markup squeezes caused by currency strengthening. Both lines of reasoning point to possible asymmetry (albeit opposite in direction) in the relation between the ER and destination prices that has been studied and confirmed in several empirical studies thus far (e.g. Brun-Aguerre et al. 2012; Brun-Aguerre, Fuertes, & Greenwood-Nimmo, 2017; Delatte & López-Villavicencio, 2012; Knetter, 1994; Pollard & Coughlin, 2004; Przystupa & Wróbel, 2011).

The literature provides also theoretical arguments for possible size-dependence in the sensitivity of export prices to exchange rate movements. Firstly, it may arise from the limited ability of exporters to absorb ER movements in their markups, as beyond a certain point it would imply negative profit margins. This is additionally amplified by changes in the market structure caused by currency fluctuations. Due to the existence of irreversible entry and exit costs (Baldwin, 1988; Dixit, 1989) exporting activity is marked by a certain degree of hysteresis, i.e. only after a sufficiently large ER appreciation (depreciation), market exits (entries) are triggered, thereby changing competitive pressure in the destination market. Therefore, when a 'pain threshold' of exchange rate appreciation is exceeded and the ensuing losses exceed exit costs, forcing firms to leave the foreign market, a higher pass-through is expected. However, the empirical evidence on size-dependence in the ERPT is scarce and shows little consistency across countries (Busière, 2013; Larue, Gervais, & Rancourt, 2010) and sectors (Pollard & Coughlin, 2004).

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',² 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, Yu, & Greenwood-Nimmo (2014).

Polish industry serves as an application example. We also test whether inaction can explain the partiality of ERPT that is observed under the 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 the econometric methodology employed in the study as well as specifies the 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, Shin, & Smith (2001).

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

$$x_t = \delta_0 + \delta_1^+ y_t^+ + \delta_1^- y_t^- + \varepsilon_t \quad (1)$$

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, we propose to extend this framework by incorporating threshold-type non-linearities into the cointegration equation:

$$x_t = \delta_0 + \delta_1^+ y_t^+ + \delta_1^0 y_t^0 + \delta_1^- y_t^- + \varepsilon_t \quad (2)$$

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 elasticities 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:

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

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

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

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:

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

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 & 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 minimize the sum of squared residuals Q:

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

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).

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):

$$p_t^{\text{exp}*} = \delta_0 + \delta_1 e_t + \varphi y_t^* + \phi c_t + \varepsilon_t \quad (7)$$

where the transmission of the exchange rate (e_t) changes to destination prices ($p_t^{\text{exp}*}$) 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 the threshold-type relationship between the exchange rate and destination prices, allowing to test for the 'band-of-inaction' hypothesis, takes the following form:

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

where:

- $e_t^- = \sum_{i=1}^T e_i^- = \sum_{i=1}^T \min(\Delta e_i, \tau_1)$ 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. Ca'Zorzi et al., 2007; Choudhri, Faruquee, & Hakura, 2005; Comunale & Kunovac, 2017; Faruquee, 2006; Hahn, 2003; Ito & Sato, 2008; McCarthy, 2007). 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 utilization of a univariate framework.

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 (Marczewski, 2014; United Nations, 1979, 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

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.

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 the 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. Vigfusson, Sheets, and Gagnon (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.

3. Empirical findings

Cointegration analysis within the ARDL model as proposed by Pesaran & 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

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 : $\delta_1 = 1$	$\hat{\beta}_0$	B-G test for autocorrelation	p	q
food	19.42***	0.40	46.60***	101.49***	0.49***	5.70	1	0
beverages	7.14**	0.63	2.72*	0.61	0.35***	1.54	1	0
textiles	16.36***	0.84	31.51***	1.20	0.53***	1.98	1	0
wearing apparel	11.93***	0.67	13.04***	3.07*	0.47***	4.54	1	0
leather and related products	29.23***	0.59	15.84***	7.52**	0.47***	1.60	1	0
wood, cork, straw and wicker products	34.50***	0.76	123.80***	12.26***	0.51***	2.01	1	0
paper and paper products	10.16***	0.52	10.64***	9.29***	0.31***	8.16*	1	0
printing and reproduction	27.97***	0.59	17.00***	8.33***	1.06***	8.32*	1	0
coke and refined petroleum products	18.57***	1.06	32.37***	0.11	0.82***	3.72	1	0
chemicals and chemical products	2.68	–	–	–	0.45***	2.60	1	2
pharmaceutical products	3.06*	–0.23	0.10	–	0.70***	8.76*	1	0
rubber and plastic products	12.47***	0.74	25.67***	3.30*	0.41***	0.32	1	0
other non-metallic mineral products	10.22***	0.21	1.79	–	0.35***	9.28*	1	0
basic metals	11.01***	0.69	13.89***	3.82*	0.47***	7.72	1	0
metal products	21.12***	0.61	32.41***	13.58***	0.42***	3.01	1	0
computer, electronic and optical products	1.81	–	–	–	0.58***	2.51	1	0
electrical equipment	0.00	–	–	–	0.44***	4.49	1	0
machinery and equipment n.e.c.	4.11**	0.21	0.99	–	0.49***	5.17	1	0
motor vehicles, trailers and semi-trailers	20.54***	0.31	27.78***	136.13***	0.41***	6.40	1	1
other transport equipment	15.08***	0.50	18.41***	19.06***	0.39***	4.94	1	0
furniture	4.45**	0.56	16.29***	10.20***	0.68***	1.44	1	0
other products	6.10**	0.62	5.68**	2.11	0.73***	3.56	1	0

Notes: Cointegration test verifies H₀: $\gamma = \beta_1 = 0$. One, two and three asterisks indicate statistical significance at the level of 10%, 5% and 1%, respectively. B-G stands for the Breusch-Godfrey test. *P* stands for the number of lags of ρ_t^{exp} , *q* - for the number of lags of e_t . The lag structure is established based on the Schwarz information criterion and controlling for serial correlation of residuals.

estimated degree of the long-run pass-through ($\hat{\delta}_1$) is approximately 40%⁴ (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 & Goldberg, 2002; Gaulier, Lahrèche-Révil, & Mejean, 2008), the highest pass-through estimates were obtained for industries manufacturing low-technology goods (beverages, coke and refined petroleum products, wood, rubber and plastic, 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 long-run pass-through parameters for low-, medium- and high-technology sectors equal to 0.66, 0.51 and 0.12, respectively. Interestingly, this difference is much less pronounced in the case of short-run parameters ($\hat{\beta}_0$) averaging at 0.55, 0.49 and 0.50, respectively. In low- and medium-technology sectors,

the degree of pass-through in the long-run is mostly similar (or higher) than in the short-run. However, in the technologically advanced sectors the on-impact elasticities by far surpass the long-run ones, implying that the initial changes in destination prices caused by exchange rate movements tend to be subsequently absorbed in the exporters' markups.

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 (Equation 8). For all sectors the estimated threshold values are below one standard deviation of the exchange rate distribution (1.7%), 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.⁵ 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 most industries the long-run 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. However, in most cases the short-run responses show no sign of threshold behaviour (see Table 5), i.e. the on-impact reactions of destination prices are equal, irrespective of the sign or size of the exchange rate changes triggering them. It seems, therefore, that the estimated short-run elasticities roughly reflect the extent of producer currency pricing in a given sector, i.e. the percentage of goods with prices fixed in producers' currency for which the instantaneous pass-through is – by construction – full. Only in a couple of industries (manufacturing of beverages, clothes, paper, metal products and electrical equipment) some patterns indicating on-impact adjustment emerge, albeit they are less pronounced than in the long run.

The long-run elasticities estimated within the threshold equation (see Table 6) 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 (δ_1^0) is significantly lower than the 'beyond-the-band' ones (δ_1^- and δ_1^+) – in some cases even significantly negative – suggesting that the 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 the industries the partiality of traditionally-estimated ERPT seems to result from the linear, and apparently inadequate, specification of the pass-

Table 4. Threshold specification estimates (1).

Manufacture of:	Test for cointegration	Test for		$\hat{\gamma}$	$\hat{\tau}_1$	$\hat{\tau}_2$	B-G test for autocorrelation	p	q
		LR linearity	Test for LR symmetry						
food	31.56***	22.60***	16.01***	-0.28***	-1.2%	0.1%	7.32	1	0
beverages	20.19***	7.44**	8.36***	-0.21***	-1.0%	0.5%	5.30	1	0
textiles	57.52***	40.43***	11.75***	-0.37***	-0.8%	1.0%	2.07	1	3
wearing apparel	37.59***	24.25***	18.38***	-0.31***	-1.6%	0.7%	2.44	1	0
leather and related products	43.52***	13.19***	3.84*	-0.16***	-1.7%	1.3%	2.48	1	0
wood, cork, straw and wicker products	34.73***	5.64*	2.61	-0.16***	-1.5%	1.0%	3.90	1	2
paper and paper products	25.16***	33.12***	29.54***	-0.26***	-1.2%	1.4%	8.30*	1	0
printing and reproduction	41.76***	1.34	0.07	-0.49***	-0.7%	0.9%	5.72	1	1
coke and refined petroleum products	25.22***	15.45***	12.61***	-0.33***	-1.0%	1.4%	4.10	1	1
chemicals and chemical products	9.02***	11.64***	11.42***	-0.14***	-0.1%	1.0%	4.69	1	1
pharmaceutical products	17.12***	13.80***	5.76**	-0.23**	-1.5%	0.9%	4.51	1	0
rubber and plastic products	25.82***	17.20***	4.83**	-0.22***	-1.2%	1.3%	6.28	1	3
other non-metallic mineral products	23.74***	18.01***	9.12***	-0.29***	-1.0%	1.5%	4.79	1	1
basic metals	6.52**	12.64***	7.58***	-0.18***	-0.4%	1.1%	6.13	1	0
metal products	33.24***	21.00***	17.66***	-0.17***	-0.7%	1.5%	0.60	1	3
computer, electronic and optical products	10.27***	10.80***	2.42	-0.12***	-1.0%	1.2%	4.02	1	0
electrical equipment	3.61*	9.71***	0.25	-0.07*	-0.6%	0.7%	3.99	1	0
machinery and equipment n.e.c.	4.54**	5.54*	0.67	-0.21***	-0.9%	0.7%	4.40	1	0
motor vehicles, trailers and semi-trailers	27.33***	25.70***	15.49***	-0.24***	-1.0%	0.8%	6.12	1	1
other transport equipment	12.34***	9.92***	1.23	-0.16***	-1.4%	0.5%	6.43	1	1
furniture	13.46***	13.38***	6.04**	-0.18***	-0.9%	0.8%	1.75	1	1
other products	18.79***	5.96**	0.03	-0.13***	-1.1%	1.0%	7.21	1	0

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 the Breusch-Godfrey test. p stands for the number of lags of p_t^{exp} , q – for the number of lags of e_t . The lag structure is established based on the Schwarz information criterion and controlling for serial correlation of residuals.

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’

Table 5. Threshold specification estimates (2): the short-run estimates.

Manufacture of:	$\hat{\beta}_0^-$	$\hat{\beta}_0^0$	$\hat{\beta}_0^+$	Test for SR linearity
food	0.57***	0.43***	0.42***	1.74
beverages	0.07	1.25***	0.46**	4.50***
textiles	0.56***	0.52***	0.60***	0.13
wearing apparel	0.30***	0.47*	0.66***	2.65*
leather and related products	0.54***	0.33*	0.34***	0.62
wood, cork, straw and wicker products	0.53***	0.47***	0.50***	0.12
paper and paper products	0.21**	0.72***	0.29**	2.64*
printing and reproduction	0.98***	0.40***	0.27***	0.49
coke and refined petroleum products	0.54***	1.21***	0.80***	1.12
chemicals and chemical products	0.45***	0.62***	0.48***	0.34
pharmaceutical products	0.75***	0.58**	0.46***	0.75
rubber and plastic products	0.46***	0.52***	0.31***	0.58
other non-metallic mineral products	0.43***	0.35*	0.28***	0.46
basic metals	0.40***	0.43*	0.61***	0.96
metal products	0.32***	0.42***	0.55***	3.77**
computer, electronic and optical products	0.50***	0.52*	0.67***	0.72
electrical equipment	0.29***	0.06	0.69***	9.56***
machinery and equipment n.e.c.	0.60***	0.63**	0.36***	2.06
motor vehicles, trailers and semi-trailers	0.42***	0.30**	0.46***	0.83
other transport equipment	0.33***	0.59***	0.47***	1.86
furniture	0.65***	0.76***	0.72***	0.92
other products	0.67***	0.53*	0.82***	1.08

Notes: Linearity test verifies $H_0: \beta_0^+ = \beta_0^0 = \beta_0^-$. One, two and three asterisks indicate statistical significance at the level of 10%, 5% and 1%, respectively.

changes in the ER are fully passed to prices (even with some overshooting), while larger changes (especially appreciations) tend to be absorbed.

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). On the other hand, in transmitting larger depreciations and appreciations 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, Itskhoki, & Konings, 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

Table 6. Threshold specification estimates (3): the long-run estimates

Manufacture of:	$\hat{\delta}_1^-$	$H_0: \hat{\delta}_1^- = 0$	$H_0: \hat{\delta}_1^- = 1$	$\hat{\delta}_1^0$	$H_0: \hat{\delta}_1^0 = 0$	$H_0: \hat{\delta}_1^0 = 1$	$\hat{\delta}_1^+$	$H_0: \hat{\delta}_1^+ = 0$	$H_0: \hat{\delta}_1^+ = 1$
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.

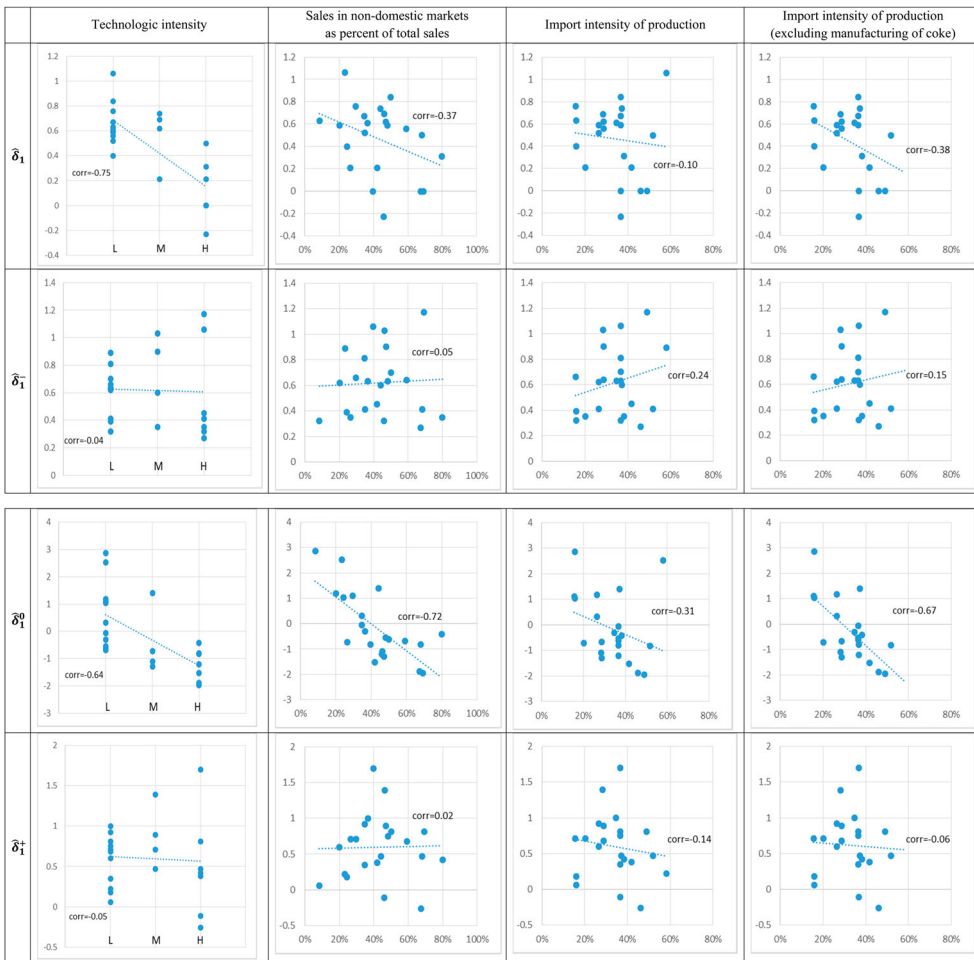


Figure 1. Pass-through estimates against sectoral characteristics.

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.

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

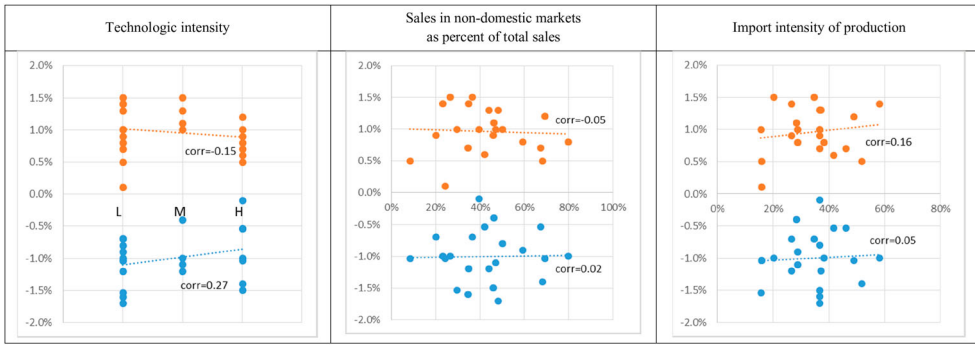


Figure 2. Estimated thresholds against sectoral characteristics.

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. Blue dots represent the lower threshold ($\hat{\tau}_l$), while the orange ones – the upper threshold ($\hat{\tau}_u$).

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 stabilize their prices in destination markets.

As for the width and symmetry of the band given by the threshold values, no clear-cut patterns emerge when tabulated against sectoral characteristics (see Figure 2). The upper threshold seems to be slightly higher in the case of industries with higher import intensity of production (suggesting that the offsetting impact of imports on costs gives the industry more scope for inaction) and the band is slightly narrower in the case of more technically-advanced industries, but the correlation coefficients are too low to ensure significance at conventional levels, given the number of observations in the sample. On the other hand, the estimated speed of adjustment to the long-run equilibrium is significantly correlated with both import-intensity and technological advancement (see Figure 3). It seems that the sectors less reliant on imports for their production and producing goods of lower technology adjust their export prices quicker.

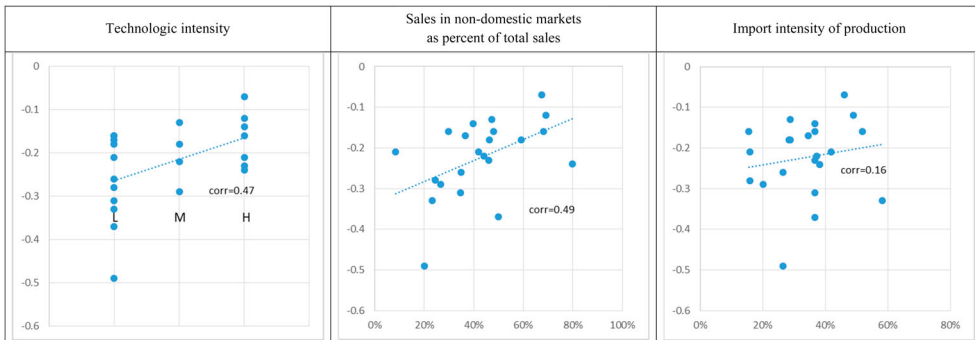


Figure 3. Estimated speed of adjustment to the long-run equilibrium against sectoral characteristics.

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 in 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 in the long-run (albeit not in the short-run), 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 the threshold-equation estimates – an artefact in half of industries.

To some extent, the observed heterogeneity in ERPT patterns can be explained by sectoral characteristics (technological 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.

Notes

1. 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 & Goldberg, 2005).
2. 'Band of inaction' is a term introduced by Belke, Göcke, and Günther (2013) to describe hysteretic behaviour of export quantities in response to exchange rate movements, resulting from the existence of market entry/exit costs.
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-%2528sic-revision-4%2529;jsessionid=4DB1A3A5812144CACC956F4B8137C1CF>).
4. We imputed zeros for long-run elasticities in sectors whose export prices are not cointegrated with the exchange rate.
5. The width of the band given by the threshold values amounts on average to 2 percentage points and ranges from 1.1 p.p. to 3 p.p. In the case of the industry with the widest band (manufacturing of leather and related products) the regimes cover 17%, 56% and 27% of the sample, respectively. For the industry with the narrowest band (manufacturing of chemicals and chemical products) these shares amount to 41%, 26% and 33%, respectively.

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