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Poland–USA sectoral trade balances: regime shifts and the nonlinear impact of currency fluctuations

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Abstract

Purpose – The Polish economy has undergone major challenges and changes over the past few decades. The country's trade flows, in particular, have become more firmly tied to the country's Western neighbors as they have grown in volume. This study examines Poland's trade balances in ten Standard International Trade Classification (SITC) sectors versus the United States of America, first testing for and isolating structural breaks in each time series. These breaks are then included in a set of the cointegration models to examine their macroeconomic determinants.

Design/methodology/approach – Linear and nonlinear and nonlinear autoregressive distributed lag models, both with and without dummies corresponding to structural breaks, are estimated.

Findings – One key finding is that incorporating these breaks reduces the significance of the real exchange rate in the model, supporting the hypothesis that this variable already incorporates important information. It also results in weaker evidence for cointegration of all variables in certain sectors.

Research limitations/implications – This study looks only at one pair of countries, without any third-country effects.

Originality/value – An important country pair's trade relations is examined; in addition, the real exchange rate is shown to incorporate economic information that results in structural changes in the economy. The paper extends the existing literature by conducting an analysis of Poland's trade balances with the USA, which have not been studied in such a context so far. A strong point is a broad methodology that lets compare the results the authors obtained with different kinds of models, both linear and nonlinear ones, with and without structural breaks.

Keywords Trade balances, USA, Poland, Cointegration, Structural breaks

Paper type Research paper

1. Introduction

Through the decades of economic restructuring and reintegration with the rest of Europe, Polish trade flows have grown substantially. Understanding the determinants of the flows is of particular importance for businesspeople and policymakers, as they navigate a rapidly changing economic environment. More importantly, with a floating exchange rate, Poland is

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especially sensitive to both changes and volatility in the zloty. While it might be closely linked to the Eurozone through interest-rate policy, Narodowy Bank Polski (NBP) (Central Bank of Poland) must still keep effects on trade with all major trade partners in mind when setting monetary policy. With the world's largest economy by many measures, the sheer size of the United States of America makes it an attractive source and destination of exports to and imports from Poland.

The described study examined Poland's trade balances in 10 sectors by scrutinizing structural breaks in the time series before entering these balances into a macroeconomic model that includes Polish and USA income, the zloty-dollar real exchange rate and the volatility of this rate. Both linear and nonlinear cointegration models – with and without structural breaks included – produced illuminating results. In particular, the F-test rejected the null hypothesis of no cointegration in fewer cases when the basic, linear autoregressive distributed lag (ARDL) model was modified to incorporate these innovations. However, there appeared very few instances of asymmetries in the effect of exchange rate changes; fewer than half the trade balances showed at least one significant coefficient for positive or negative sums.

In addition to this analysis, we postulated that because the real exchange rate serves as a relative price, it should incorporate all relevant information regarding international markets. As a result, if a specific event was captured as a structural break, the price variable would become redundant. The corresponding coefficient could therefore be insignificant in a model that also included structural breaks. As our results show, we find this indeed to be the case.

This article extends the literature with an analysis of Poland's trade balances with the USA, which have received no such scrutiny in this context so far. To show differences between various industry sectors in their sensitivities to USD/PLN currency fluctuations is a novelty in the scholarship. The added value is also a broad methodology that allows results comparison with different kinds of models: both linear and nonlinear ones; with and without structural breaks. Although Muege and Vural (2016), Rajković, Bjelić, Jaćimović, and Verbič (2020), Bahmani-Oskooee, Huynh, and Nasir (2021) and Bahmani-Oskooee and Karamelikli (2021) find no evidence for the relationship between the real exchange rate and the trade balance in the countries they analyzed, we show that it exists for some sectors between the USA and Poland. Similar to Kang and Dagli (2018) and Rajković *et al.* (2020) – but for different countries – we notice that the inclusion of structural breaks diminishes this relationship.

This article proceeds as follows. Section 2 will provide a very detailed overview of specific sectors in Polish trade. Section 3 will outline the literature. Section 4 will describe the methodology, and Section 5 will provide the results. Section 6 will conclude.

2. Discussion of the Poland–USA trade relations by specific sectors

The USA economy is one of the most competitive and innovative one in the world. The World Economic Forum's (WEF) 2019 competitiveness ranking lists the USA economy in the second position (In Schwab, 2019), whereas it's the WEF's 2020 innovativeness ranking ranks it in the third position (Dutta, Lanvin, & Wunsch-Vincent, 2020). Poland was listed in both rankings in positions 37 and 38, respectively. Highly processed and technologically advanced goods dominate the trade between these two countries.

According to the UN Comtrade Database (2020), imports from the USA are worth 3.1% of total Polish imports, and the USA ranks eighth among Polish importers. The structure of product categories did not change significantly; the three main sections were the same in 1995 and in 2020. From the beginning of the period up to the end, the highest volume sector of USA imports from Poland remains machinery and transport equipment. The USA imports increased sharply from 1995 to 2020: from \$0.21 billion to \$4.55 billion, which is an increase of more than 20 times its original size. In 1995, machinery and transport equipment was a sector with the highest share in total USA imports from Poland, and it not only retained its position in 2020 but even strengthened it. This happened mostly thanks to the specialization of Polish enterprises in the automotive industry and aviation, which is possible thanks to Poland's high-quality system of higher education for engineers. In 2020, machinery had the highest share of USA imports, with more than one-third of USA imports from Poland ($2.6 billion).

The structure of USA imports from Poland changed only slightly over the years under scrutiny. This is probably due to the large increase in the miscellaneous manufactured articles section compared to manufactured goods, classified chiefly by material, albeit the three most important sections remain the same as in 1995. This picture shows a stable, growing trade relations between these two countries. The slight structural changes can be explained by fluctuations in competitiveness and needs. Polish products are treated in the USA as high-quality and relatively inexpensive. From the Polish perspective, the American market is large and with strong purchasing power. Moreover, we should bear in mind the demand for Polish products that comes from people with Polish ancestors who live in the USA. According to the United States Census Bureau (2018), they number about 9.15 million. Furthermore, import tariffs imposed on China by the USA in recent years provided further advantages to imports from EU countries such as Poland. Thus, USA imports from Poland are probably influenced by psychological, besides purely economic reasons. The downside to having the USA as a trade partner is the long distance between it and Poland, which increases the cost of transport.

Polish imports from the USA in 1995 were worth $1.14 billion, whereas in 2020 they reached $7.90 billion, which is a fivefold increase. From 1995 to 2020 they increased on average by more than 9% annually (Chart 2), which is nevertheless a weaker increase than that of USA imports from Poland. The highest increase in total imports from the USA was more than 44% in 1996 (from $1.14 in 1995 to $1.64 billion in 1996) and almost 33% in 2008 (from $3.46 in 2007 to $4.59 billion in 2008). In 1995, the highest share of Poland's imports from the USA belonged to the following industries: manufactured goods industry, classified chiefly by material ($0.48 billion; almost 42% of total imports); animal and vegetable oils, fats and waxes ($0.17 billion; over 15% of total imports); machinery and transport equipment ($0.13 billion; almost 12% of total imports). In 2020, Poland's imports from the USA were mainly in the following industries: machinery and transport equipment ($3.57 billion; over 45% of total imports); chemicals and related products ($1.94 billion; almost 25% of total imports); miscellaneous manufactured articles ($0.87 billion; 11% of total imports).

The data show that the structure of imports changed from 1995 to 2020. Manufactured goods classified chiefly by material were the most important import sector in 1995, and in 2020, they were ranked in the fourth position with $0.59 billion. The value increased slightly in this period, however, together with a sharp growth of total imports and other categories, its share dramatically decreased. Poland had a negative trade balance with the USA in 1995–2014. Beginning in 2015, the balance was positive. The largest negative trade balance appeared in 2008 (-$1.87 billion), whereas the highest positive balance happened in 2020 ($0.97 billion).

Our findings are important to the Poland–USA trade relations, as they show differences between various industry sectors in their sensitivities to currency fluctuations. Thus, they may be useful both to show manufacturers whether they should apply currency risk hedging methods and to remind policymakers they should remember about these differences when managing the economy.

3. Literature review

The literature pays a great deal of attention to the analysis of relations between the exchange rate volatility and trade balance with the most important trading partners, not only for the world's largest economies but also for smaller ones. Many study results showed to ambiguous results, depending on the methodology used (most recently: whether linear or nonlinear models are used), the research period and its length, the countries considered and whether total flows are disaggregated to the industry level. Early research modeled "symmetric" effects, in which increases and decreases had proportional results. Today, more and more often authors also seek "asymmetric" relations, reflected in nonlinear models that treat positive and negative changes in a variable separately. Moreover, they check whether the relations change with the appearance of structural breaks. Although there emerged so much research in recent years, the relation between exchange rate and trade remains ambiguous, as McKenzie (1999) or Broil and Eckwert (1999) noticed already years ago. Our article fills one such gap in this research.

The literature devoted to studies on the influence of exchange rate volatility on the trade value can be divided into five groups. The first strand consists of articles that reject the nexus between the abovementioned variables. Such results are rarely found. The second group comprises articles that prove the presence of a relationship either for exports or imports only, but not for both. We also include here articles that separately analyze the effects of currency appreciation and depreciation. Papers in the third group conclude that this effect exists and is stronger when nonlinear analysis is applied. In the fourth group, we gather the studies that surmise this relation decreases over time. These are done with the analysis of structural breaks. The fifth group emphasizes that although there exist many different methods to hedge against the exchange rate risk with financial derivatives, these instruments are used by large companies that operate in countries with highly developed financial markets. Thus, they do not solve the global problem as far as the influence of the exchange rate on the trade balance is concerned.

Many articles in the first group find no relationship between real exchange rate and trade balance. These include Muege and Vural (2016) for Turkey and Germany, Rajković *et al.* (2020) for the Western Balkan and Central and Eastern European countries, along with Bahmani-Oskooee and Karamelikli (2021, 2022) and Bahmani-Oskooee and Karamelikli (2021). There are ambiguous effects for exchange rate volatility. Sy-Hoa, Trung-Thanh, and To-The (2021) concludes that total trade between the USA and Vietnam is symmetrically influenced by volatility, but the effects are mixed for specific industries. Bahmani-Oskooee and Saha (2020) prove that this relationship may depend on the country and that for some of them it does not exist.

The second group includes Doğanlar (2002), who finds that increased volatility diminishes exports in five Asian countries; Fathima Thahara *et al.* (2021), who finds similar results for Sri Lanka; Erdal, Erdal, and Esengün (2012), who examine agriculture in Turkey; and Nguyen, Tran, and Nguyen (2021), who finds nonlinear effects for the Vietnam–Japan trade balance.

In the third group of articles, Bahmani-Oskooee, Usman, and Ullah (2020) studied the Pakistan–China trade relations to surmise that results are stronger for the nonlinear model than for the linear model. Similar nonlinearities in which the impact of positive and negative shocks differ are confirmed by Bahmani-Oskooee and Karamelikli (2021) in a study of trade flows between Germany and Great Britain; Baum *et al.* (2004), who point out that the relation is nonlinear and that it depends on the country; Al-Rashidi and Lahiri (2013), who studied bilateral trade in 165 countries from 1990 to 2009; and Bahmani-Oskooee and Karamelikli (2022), who found more evidence for the nonlinear model in an analysis of UK–China trade relations.

In the fourth group of articles, emphasizing the decline of influence over time and the existence of structural breaks, Kang and Dagli (2018) and Rajković *et al.* (2020) notice the reduction of the influence of exchange rate on trade balance after the global financial crisis. Ibarra and Blecker (2016) examined structural changes in Mexico's exports and imports in response to changes in the chosen parameters to find that the effect of real exchange rate fluctuations on the trade balance decreased in the period from 1960 to 2012. Fitrianti (2017) examines Indonesian exports and considers the structural break caused by the global financial crisis. Ollivaud, Rusticelli, and Schwellnus (2015) recognize that global value chains used by firms contribute to the reduction of the linkage between the exchange rate and trade. The same conclusion is made by Swarnali, Appendino, and Ruta (2017), who analyzed 46 countries in 1996–2012 to reveal decreasing export elasticities compared to changes in real effective exchange rates over time. Kang and Dagli (2018) studied 64 exporters and 72 importers to find differences in the relationship between exchange rates and trade during the time before and after the global financial crisis of 2008. Dincer and Kandil (2011) consider relations between exchange rate and trade change over time due to structural breaks caused by several reforms launched after the Turkish crisis; as they analyzed two periods (1996–2002 and 2003–2008) to conclude that exchange rate changes positively influenced exports in the first period, but affected them negatively in the second one.

Last but not least, in the fifth group, Allayannis and Ofek (2001) examined nonfinancial firms from the S&P index to surmise that they apply derivatives in hedging, which may make exchange rate fluctuations less significant. However, this could suggest that only in countries with highly developed financial markets like the USA or UK the exchange rate risk is not a significant factor influencing the real economy. Paligorova and Staskow (2014) analyze nonfinancial publicly listed Canadian firms to conclude that one-third of them apply derivatives to risk management; they stress that these instruments can diminish financial risk, albeit are more popular among large companies. The latter can be explained by the high cost of employing people with deep knowledge of financial instruments and the existence of lower financial awareness in small companies. In turn, Sang-Ik, Tae-Hyun, Hoon, and Tae-Joong (2020) studied Korean companies to show that they apply derivatives to manage accounting risk rather than market risk. Besides, risk may be hedged with derivatives in certain periods of time (short- or mid-term) and hedging strategies do not last forever. Furthermore, Muller and Verschoor (2005) show that firms hedge only a part of their risk.

Summarizing, the contradictory conclusions described above confirm that there is no single attitude to the relationship between exchange rate volatility and trade balance and that conclusions can often be contradictory. Thus, this problem requires further scientific research and discussion. It is especially important to apply not only linear but also nonlinear models, as the former do not capture all relationships. Besides, structural breaks deserve to be included in every analysis. Our article links all the abovementioned aspects, describing a study of trade between Poland and the USA. Thus, the article fills in the gap existing in the scholarship.

Our findings are made based on both linear and nonlinear models – as in Nguyen *et al.* (2021) – and include structural breaks, as in Ibarra and Blecker (2016) and Fitrianti (2017). Although the findings refer to countries whose bilateral trade has not been analyzed so far (Poland and the USA), they agree with Bahmani-Oskooee and Karamelikli (2021, 2022), Bahmani-Oskooee and Karamelikli (2021) and Sy-Hoa *et al.* (2021), who show that there are no significant effects in the majority of industries both for positive and negative exchange rate changes. Moreover, our findings show a sensitivity of results to different model assumptions similar to that found by Al-Rashidi and Lahiri (2013).

4. Methodology

This study made use of annual trade data covering the period from 1995 to 2020. The time span was based on data availability, determined by the evolution of Polish currency policy and the operative exchange rate regime. Before March 1989, the national currency monopoly remained in effect in Poland (DzU 6.33/1989). Since January 1990, the Polish zloty has been convertible. Its culmination was a major liberalization of foreign exchange law that took effect on January 1, 1995, preceding the introduction of limited external convertibility pursuant to Article 7 of the International Monetary Fund (Ancyparowicz, 2013, pp. 226–227), which became effective on June 1995. At the same time, the Polish exchange rate regime was liable to significant changes. Initially, since 1990, a fixed exchange rate to the US dollar has been introduced. This exchange rate was known as an "anchored" exchange rate, and it was a part of an anti-inflation policy. Since May 20, 1991, there has been a switch of the peg to the collective unit, whose value was determined by the basket of five currencies: 45% – USD, 35% – DM, 10% – GBP, 5% – FRF and 5% – CHF. In October 1991 the authorities introduced a crawling peg with preannounced crawling devaluation, and since 1992, currency banks could settle inter accounts according to their own exchange rates, independent of the official ones (Zarządzenie Prezesa NBP z dnia 18 grudnia, 1991). Since May 16, 1995, the zloty exchange rate has been partially floated, and a pegged exchange rate within horizontal bands (crawling bands) has been introduced. The central parity rate stopped serving as the official exchange rate and became just the basis for determining the range of deviations of the zloty exchange rate in the interbank market. Before April 12, 2000, when the zloty exchange rate was fully floated, the fluctuation band was widened every time the interbank exchange rate dangerously approached the set fluctuation range (Jurek & Marszałek, 2008, p. 32). Therefore, the Polish zloty exchange rate has in fact been shaped by the market since 1995, and its realization was merely a formality.

Export and import flows in US dollars are available for sectors 0–9 in the Standard International Trade Classification (SITC) as well as their aggregate ("total") trade; also referred to as "all." The data come from the UN Comtrade Database. Due to their availability, but also to provide continuity and comparability in the long term, we gathered them according to SITC rev. 1, as imports reported by Poland from the USA and imports reported by the USA from Poland. The means of the dollar values as well as their shares of total trade are presented in Table 1. We see that the largest sectors were industries 5 (chemicals and related products, n.e.s.) and 7 (machinery and transport equipment). Sector 8 (miscellaneous manufactured articles) also makes up more than 10% of total exports.

In the remainder of our analysis, we converted Polish export and import flows into Polish trade balances with the formula $TB_i = ln\left(\frac{X_i}{M_i} + 1\right)$. This transformation accounted for possible zero values. As noted by Bahmani-Oskooee and Hegerty (2011), this ratio is unit-free and requires no conversion into a specific currency or real terms. Here, balanced trade (where $\frac{X}{M} = 1$) would result in a value of ln(2) or 0.693.

The next step was to examine and test for the presence of structural breaks in each series. For each trade balance, we performed the Bai–Perron test (1998) for structural breaks in the mean, which is equivalent to performing a regression on a constant. Specific break dates were extracted, which we assessed to see whether they conformed to major dates in Polish economic history, such as the accession to the European Union or the onset of the 2007–2008 financial crisis.

We also included these structural breaks in our econometric model of the macroeconomic determinants of each Polish trade balance. Following Bahmani-Oskooee and Hegerty (2009) and Bahmani-Oskooee, Harvey, and Hegerty (2018) – along with the classic model of Goldstein and Khan (1985) – the macroeconomic fundamentals included domestic and foreign gross domestic product (GDP) to proxy income effects as well as the real exchange rate to proxy relative price effects. Here, the USA served as the "foreign" economy, both for GDP and as the partner country in the zloty per dollar real exchange rate: $q_t = E_t \frac{P_t^{US}}{P_t^{PI}}$. Moreover, we include volatility in real exchange rate. Following Bahmani-Oskooee and Hegerty (2007) and McKenzie (1999), this risk may reduce trade if merchants are risk-averse, but it has often been shown to have a positive effect on trade flows. In many cases, however, it has no effect at all.

Table 1.
Structure of bilateral imports Poland–USA

Commodity code/Commodity	1995	2000	2005	2010	2015	2020	Mean	Avg. Vol. (mln USD)
Structure of polish imports from the USA (%)								
0 – Food and live animals	6.47	1.63	2.87	5.41	4.10	3.39	3.95	151.6
1 – Beverages and tobacco	2.30	0.94	1.31	1.59	2.21	1,96	1.80	69.1
2 – Crude materials, inedible, except fuels	4.51	3.60	4.89	4.17	4.04	3.09	4.22	162.1
3 – Mineral fuels, lubricants and related materials	0.65	0.11	0.75	9.11	1.47	1.20	3.43	131.8
4 – Animal and vegetable oils, fats and waxes	15.25	0.03	0.07	0.07	0.04	0.02	0.23	8.7
5 – Chemicals and related products, n.e.s	9.69	13.69	18.82	17.32	16.89	24.54	16.95	651.5
6 – Manufactured goods classified chiefly by material	41.88	5.94	9.95	8.46	9.46	7.44	9.19	353.0
7 – Machinery and transport equipment	11.69	62.51	48.62	41.40	49.43	45.15	47.30	1817.9
8 – Miscellaneous manufactured articles	0.04	9.54	12.71	12.46	11.91	11.01	11.50	442.0
9 – Commodities and transactions not classified elsewhere in the SITC	7.52	2.01	0.01	0.01	0.45	2.21	1.03	39.7
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	3843.2
Structure of USA imports from Poland (%)								
0 – Food and live animals	8.58	7.94	7.16	6.24	6.39	6.32	6.73	232.8
1 – Beverages and tobacco	0.48	3.44	4.46	3.35	1.84	1.19	2.30	79.6
2 – Crude materials, inedible, except fuels	0.28	0.50	0.64	0.39	0.80	0.66	0.62	21.4
3 – Mineral fuels, lubricants and related materials	0.57	n/a	4.80	3.14	0.20	0.35	1.63	56.3
4 – Animal and vegetable oils, fats and waxes	n/a	0.002	0.011	0.006	0.003	0.029	0.01	0.4
5 – Chemicals and related products, n.e.s	15.38	5.01	5.86	7.21	4.26	4.48	5.12	177.2
6 – Manufactured goods classified chiefly by material	24.34	31.07	21.10	17.49	11.86	12.84	14.18	490.9
7 – Machinery and transport equipment	30.26	27.67	31.07	39.99	53.02	51.29	47.12	1630.8
8 – Miscellaneous manufactured articles	18.37	18.90	22.45	19.43	17.04	18.24	18.44	638.1
9 – Commodities and transactions not classified elsewhere in the SITC	1.73	5.48	2.45	2.75	4.58	4.59	3.86	133.7
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	3461.3

Source(s): Authors' own calculations based on the UN Comtrade database (2020)

Annual real exchange rate volatility was calculated by taking the standard deviation of all monthly values of q within each calendar year.

These four macroeconomic variables were then entered into the following model as determinants of each individual trade balance:

$$\Delta tb_t = \alpha + \sum_{j=1}^{n1} \beta_t \Delta tb_{t-j} + \sum_{j=1}^{n1} \gamma_t \Delta lnY_{t-j}^{US} + \sum_{j=1}^{n2} \delta_t \Delta lnY_{t-j}^{PL} + \sum_{j=1}^{n3} \vartheta_t \Delta lnq_{t-j} + \sum_{j=1}^{n4} \pi_t \Delta \ln(qVOL)_{t-j} + \theta_1 tb_{t-1} + \theta_2 lnY_{t-1}^{US} + \theta_3 lnY_{t-1}^{PL} + \theta_4 lnq_{t-1} \theta_5 ln(qVOL)_{t-1} + \varepsilon_t \quad (1)$$

As noted previously, $tb_t = \ln\left(\frac{X_t}{M_t} + 1\right)$ is calculated for each industry separately, as well as for total trade. We expected that increases in USA GDP would help increase Polish exports, therefore positively impacting the trade balance. Moreover, we expected the increased Polish income to boost imports, with a negative impact overall. A real depreciation – here reflected as an increase in q, which is based on zlotys per dollar – should lead to a significantly positive effect on tb. As noted above, the literature provides only ambiguous effects of exchange rate volatility.

Because some – but not all – of the variables used here were stationary (via the Phillips–Perron test presented in Table 2), we applied the ARDL methodology devised by Pesaran, Shin, and Smith (2001). This model can incorporate both I(1) and I(0) variables, and as highlighted by Bahmani-Oskooee and Hegerty (2009) and Narayan (2005), it works well with small samples such as the ones we used in our study. Our cointegration model incorporated both differenced and lagged level terms for each variable.

Because of the relatively short time series, we selected lag lengths from a maximum of 2 based on the Akaike information criterion. The key focus here was to determine whether the relevant variables were cointegrated. If the lagged level variables were jointly significant, then there was evidence of a long-run relationship between them. The critical values were provided first by Pesaran *et al.* (2001), with an adjustment for small samples by Narayan (2005). For cointegrated trade models, we especially focused on long-run coefficients, which

SECTOR	Breaks 1	2	3	4	5
0	1998	2007	2013		
1	1999	2002	2005	2012	
2	2011				
3	2000	2003	2006		
4	2014	2017			
5	2001				
6	1998	2006	2009		
7	2010				
8	1997	2000	2004	2009	2015
9	1997	2003	2010		
Total	2002	2006	2010	2014	

Source(s): Authors' own elaboration

Table 2. Bai–Perron structural break dates

we could use to see the effects of income, prices, exchange rates and volatility on sectoral trade between Poland and the USA.

We estimated each trade balance using this "linear" ARDL model twice, with and without dummy variables for the structural break dates that we extracted. It could happen that – if markets are efficient –the real exchange rate would already incorporate political and economic events. Including the same events twice was to reduce the overall fit of the model. We compared each alternative using its adjusted R-squared.

Because the effects of macroeconomic variables were often nonlinear, we also applied the approach of Shin, Yu, and Greenwood-Nimmo (2014) to separate exchange rate appreciations from depreciations. We did this by defining two new variables as the positive and negative partial sums of the real exchange rate:

$$qPOS_t = \sum_{j=1}^{t} \max\ (\Delta \ln(q_t), 0) \tag{2a}$$

$$qNEG_t = \sum_{j=1}^{t} \min\ (\Delta \ln(q_t), 0) \tag{2b}$$

The above were then entered into the model presented in Equation (1), both with and without the dummy variables. Thus, not only could we assess the validity of these structural breaks, but we could also compare the linear and nonlinear ARDL models. It was possible that the Non-Linear Autoregressive Distributed Lag NARDL model would show a significant impact on a given sector only by a currency appreciation or depreciation. Therefore, these asymmetric effects could prove interesting to policymakers. We present the results of the four alternative models below.

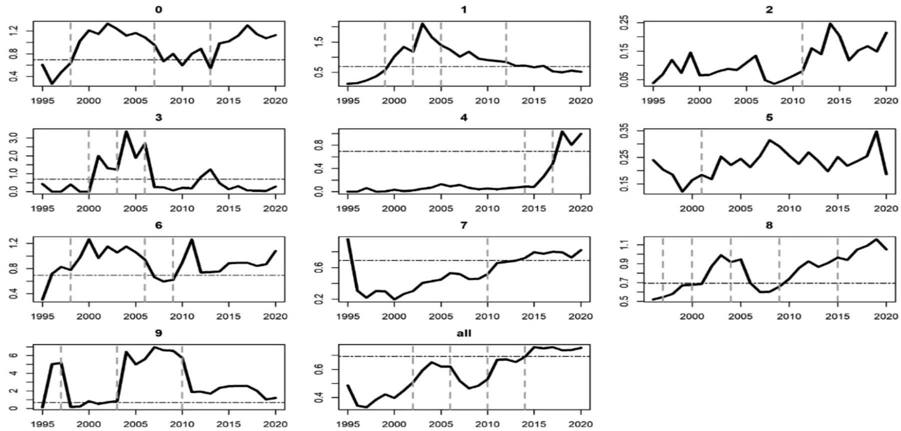
5. Results

Table 2 presents the structural breaks extracted using the Bai and Perron (1998) method for each trade balance. We may see that important events in Poland and the world indeed do correspond to such breaks in many – but not all – cases. The 1997 Asian financial crisis is tied to a break in four of nine individual trade flows. Poland's accession to the European Union resulted in one break in 2004 and one in 2005. The 2007–2008 corresponds to structural breaks in two trade balances.

Figure 1 shows the time series for each trade balance as well as these structural breaks. Many of these series show overall increases over time, with a temporary dip around 2008. Sector 7, which makes up a large share of total trade, follows such a pattern, as do total trade and the (smaller) sectors 2 and 8. The latter trade balance (miscellaneous manufactured articles) also registers a sharp decline following Poland's accession to the EU.

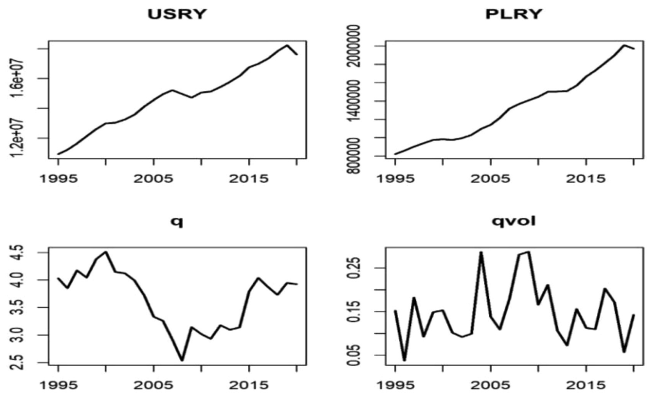
Another interesting time path appears for sector 4 (animal and vegetable oils, fats and waxes), which rises sharply after 2017. Sector 3 has a "hump" shape between 2000 and 2009, and sector 9 has its "hump" in the late 2000s. Sector 1 peaks in the early 2000s, followed by a steady decline. The three remaining sectors – 0, 5 and 6 – remain generally stable throughout the studied period.

We expect that idiosyncratic factors and major macroeconomic determinants can explain some of these fluctuations. These macro variables are depicted in Figure 2. Besides income growth and recessions, we may notice evidence of a zloty appreciation and volatility in the exchange rate after 2005. This is likely due to the large inflows of capital flows that were attracted to Central and Eastern Europe during this period (see Hegerty, 2020). Increased political stability and an improved investment climate led to appreciations of floating rates



Note(s): Horizontal lines – balanced trade: ln(2), in which X = M and X/M + 1 = 2; vertical lines: Bai–Perron structural breaks
Source(s): Own elaboration

Figure 1.
Trade balances and structural breaks



Source(s): Own elaboration

Figure 2.
Independent macroeconomic variables

and inflation in the region. The zloty began to depreciate – with increased volatility – around the time of the 2007–2008 financial crisis.

The GDP series are expected to be nonstationary and integrated of order one, while the real exchange rate and its volatility require a test to determine their orders of integration. The Phillips and Perron (1988) test suggests (Table 3) that these are indeed I(0); a visual inspection of differenced GDP suggests that these two series are I(1). Therefore, the ARDL model is highly appropriate for these data of mixed orders of integration.

Table 4 presents the ARDL and NARDL cointegration test statistics alongside the AIC-minimizing ARDL orders. Out of the 11 trade balances (ten sectors plus the total), half of the sectors are definitely cointegrated. This includes sectors 0, 3, 5, 7 and 9 but not total trade. Sector 1 is not cointegrated in any of the four models, while sector 2 is only in one model: the NARDL model without dummies. Markedly, one more trade balance, sector 8, has an

	Levels Stat. (p-Val.)	First difference Stat. (p-Val.)
Macro variables		
USRY	−1.985 (0.578)	−2.562 (0.358)
PLRY	−2.176 (0.505)	−2.577 (0.353)
q	−1.186 (0.883)	−4.975 (0.010)
qvol	−4.802 (0.010)	−10.533 (0.010)
Sectors		
0	−2.006 (0.570)	−5.868 (0.010)
1	−1.828 (0.638)	−5.796 (0.010)
2	−3.034 (0.178)	−6.322 (0.010)
3	−2.731 (0.294)	−7.157 (0.010)
4	−0.532 (0.972)	−5.793 (0.010)
5	−3.679 (0.044)	−5.936 (0.010)
6	−3.746 (0.040)	−5.467 (0.010)
7	−10.864 (0.010)	−11.635 (0.010)
8	−2.159 (0.512)	−3.481 (0.066)
9	−2.526 (0.372)	−5.448 (0.010)
Total	−3.026 (0.182)	−4.235 (0.015)

Note(s): All variables in natural logs; trade balances as $ln(TB+1)$
Source(s): Authors' own elaboration

Table 3.
Phillips–Perron stationarity test results

F-statistic just below the threshold to support cointegration. Additional trade balances with limited or conflicting results include sector 4, which only shows evidence of cointegration in the ARDL model without dummies. Sector 6 has significant F-statistics in two models and total trade might be cointegrated only via the linear ARDL model that includes dummies.

Beginning with the linear ARDL model (Table 5), we can see that the traditional determinants – both partners' incomes and relative price as proxied by real exchange rate – are only significant in certain cases. The USA income is positive (driving Polish exports) while Polish income is negative (driving imports) for only sectors 0 and 3. Although coefficients for Sector 1 have the appropriate signs and significance, the F-test does not show that the variables in the model are cointegrated. Sector 7 (machinery and transport equipment) reveals that only Polish income has an impact, reducing the trade balance.

In this specification, the real exchange rate q is positive for sector 0, which implies that real zloty depreciation increases the trade balance. Real exchange rate volatility is significantly negative in sector 2, but this industry does not show evidence of cointegration among all macroeconomic variables. When dummies are added to the linear model, the results for sectors 0 and 3 hold. Moreover, the USA income is shown to increase the aggregate trade balance.

Applying the nonlinear model, sectors 0 and 3 again show the same income results, matching economic theory. One interesting finding is that nonlinear real exchange rates show much more evidence of cointegration when there are no structural break dummies in the model. Positive changes in q (real depreciations) increase the trade balance in sectors 1 and 7, while an increase in the negative component (a real depreciation) has a positive coefficient in Sector 4 and a negative one in Sector 7. Sector 1, again, does not show evidence of cointegration via the F-test.

Exchange rate volatility affects many more industries when structural breaks are not included. This supports the hypothesis that the real exchange rate already incorporates information on political and economic events through price mechanisms. Exchange rate risk reduces the trade balance in sectors 2 and 7 while increasing it in sectors 0 and 9. However, we cannot determine whether these stem from increases or decreases in imports and exports. It is

SECTOR	ARDL No dummies F (p-Val)	Order	W/dummies F (p-Val)	Order
0	*11.583 (0.000)*	(1,1,0,0,0)	*9.142 (0.000)*	(2,2,2,2,2)
1	2.143 (0.475)	(1,0,1,0,0)	2.105 (0.491)	(2,2,2,2,2)
2	3.920 (0.058)	(1,2,1,2,2)	3.147 (0.164)	(1,2,1,2,2)
3	*4.897 (0.013)*	(1,0,0,0,0)	*4.605 (0.020)*	(1,0,2,0,0)
4	*4.467 (0.025)*	(1,0,0,2,0)	3.211 (0.152)	(1,0,0,0,0)
5	*7.317 (0.001)*	(1,2,2,0,0)	*5.461 (0.005)*	(1,2,1,0,2)
6	*4.279 (0.034)*	(1,0,0,0,0)	3.215 (0.151)	(1,0,0,0,2)
7	*24.912 (0.000)*	(1,1,0,0,1)	*28.926 (0.000)*	(1,0,0,0,1)
8	1.777 (0.631)	(1,2,1,2,0)	2.054 (0.513)	(1,0,0,2,2)
9	*8.929 (0.000)*	(2,2,2,2,2)	*6.357 (0.001)*	(2,2,2,2,2)
Total	0.640 (0.975)	(1,0,2,0,0)	*5.116 (0.009)*	(1,1,1,1,0)
SECTOR	NARDL No dummies F (p-Val)	Order	W/dummies F (p-Val)	Order
0	*5.330 (0.003)*	(2,2,2,2,2,2)	*19.119 (0.000)*	(2,2,2,2,2,2)
1	2.346 (0.375)	(1,1,0,0,0,0)	0.839 (0.961)	(2,2,2,2,2,2)
2	*4.053 (0.033)*	(1,1,1,1,0,1)	2.318 (0.386)	(2,2,2,2,2,2)
3	*3.966 (0.039)*	(1,0,0,0,0,0)	3.792 (0.051)	(1,0,0,0,0,2)
4	3.721 (0.057)	(2,2,2,2,2,2)	2.522 (0.306)	(1,0,0,0,0,0)
5	*4.680 (0.010)*	(1,2,0,1,1,1)	*5.244 (0.004)*	(1,2,0,1,1,1)
6	3.483 (0.083)	(2,2,2,2,2,2)	*5.973 (0.001)*	(2,2,2,2,2,2)
7	*4.609 (0.012)*	(1,1,2,2,2,1)	3.641 (0.066)	(2,2,2,2,2,2)
8	3.694 (0.060)	(1,0,1,2,0,1)	2.759 (0.230)	(2,2,2,2,2,2)
9	*26.187 (0.000)*	(1,2,0,2,0,0)	*21.028 (0.000)*	(1,2,0,2,0,0)
Total	1.202 (0.875)	(2,2,2,2,2,2)	0.552 (0.990)	(2,2,2,2,2,2)

Note(s): ARDL specifications TB, USY, PLY, q and qVOL for the linear and TB, USY, PLY, qPOS, qNEG and qVOL for the nonlinear models, respectively
Items in italics are significant at alfa < 0.05
Source(s): Authors' own elaboration

Table 4. F-test results and ARDL orders

possible that a decrease in the trade balance occurs when exports are reduced more than imports, or when exports are increased more than imports.

When structural breaks are included, exchange rate volatility increases the trade balance in sector 9. While this requires a more detailed analysis, one explanation may be that traders in these industries are particularly averse to risk. Another explanation is that the inclusion of structural breaks disproportionately reduces imports relative to exports, resulting in an overall reduction in the trade balance.

Further analysis needs to be done on industries 0 (food and live animals) and 3 (mineral fuels, lubricants and related materials). These natural resources are most sensitive to income. The descriptions above present stylized facts regarding specific industries, but more might be done to link economic growth with demand for these primary products.

Moreover, these results suggest that cointegration analysis is sensitive to the inclusion of structural breaks in the underlying model. Total trade flows are shown to be cointegrated only in the linear model that includes these dummies. However, this is atypical for both linear and nonlinear estimations, as there are slightly fewer cointegrated sectors when structural brakes are incorporated. For the linear model, seven sectors are cointegrated without dummies versus five with dummies; the corresponding numbers for the nonlinear model are six and four, respectively. Further research might show why this is the case.

Table 5.
ARDL and NARDL long-run coefficient estimates

ARDL model						
	No dummies					
Sector	INPT	USRY	PLRY	q	qVOL	$\bar{R}^2$
0	*−68.838 (0.000)*	*6.703 (0.000)*	*−2.975 (0.000)*	*1.045 (0.000)*	0.114 (0.074)	0.832
1	*−90.499 (0.010)*	*10.835 (0.003)*	*−6.137 (0.002)*	−0.415 (0.620)	0.106 (0.644)	0.725
2	*−5.578 (0.017)*	0.328 (0.157)	0.014 (0.905)	−0.063 (0.216)	*−0.072 (0.012)*	0.701
3	*−172.28 (0.000)*	*19.891 (0.000)*	*−10.917 (0.000)*	−1.453 (0.117)	−0.143 (0.578)	0.466
4	−3.944 (0.845)	−2.158 (0.297)	*2.656 (0.020)*	*2.151 (0.002)*	0.193 (0.310)	0.879
5	−1.126 (0.657)	0.077 (0.766)	0.007 (0.953)	−0.085 (0.113)	−0.039 (0.070)	0.529
6	−6.814 (0.699)	0.783 (0.667)	−0.423 (0.640)	0.758 (0.054)	0.100 (0.335)	0.239
7	*−15.536 (0.007)*	0.500 (0.340)	*0.553 (0.042)*	−0.14 (0.237)	−0.083 (0.109)	0.923
8	−14.867 (0.419)	0.363 (0.854)	0.615 (0.552)	0.887 (0.063)	−0.022 (0.842)	0.803
9	−281.83 (0.295)	34.435 (0.223)	−19.287 (0.167)	*−7.378 (0.015)*	1.990 (0.151)	0.811
ALL	−1.854 (0.962)	−0.500 (0.902)	0.754 (0.707)	0.411 (0.544)	0.074 (0.709)	0.883
	With dummies					
Sector	INPT	USRY	PLRY	q	qVOL	$\bar{R}^2$
0	*−76.928 (0.000)*	*6.97 (0.000)*	*−2.749 (0.000)*	*1.347 (0.000)*	0.037 (0.592)	0.891
1	34.686 (0.775)	−0.048 (0.996)	−2.850 (0.375)	2.642 (0.356)	−0.480 (0.613)	*0.874*
2	−5.842 (0.014)	0.262 (0.283)	0.110 (0.512)	−0.076 (0.155)	*−0.083 (0.009)*	0.702
3	*−188.98 (0.033)*	*21.948 (0.013)*	*−12.123 (0.006)*	−0.917 (0.586)	0.061 (0.864)	*0.468*
4	−6.157 (0.584)	0.433 (0.681)	−0.069 (0.912)	0.102 (0.793)	0.042 (0.624)	*0.885*
5	−2.886 (0.545)	0.228 (0.610)	−0.041 (0.826)	−0.070 (0.318)	−0.008 (0.832)	0.592
6	−9.907 (0.602)	0.680 (0.759)	−0.025 (0.986)	0.331 (0.498)	0.288 (0.189)	0.303
7	*−19.163 (0.001)*	*1.302 (0.032)*	−0.128 (0.708)	−0.119 (0.284)	−0.040 (0.453)	0.937
8	−1.516 (0.959)	1.003 (0.701)	−0.988 (0.536)	0.185 (0.858)	0.028 (0.870)	0.798
9	−269.78 (0.341)	22.746 (0.411)	−6.398 (0.652)	*−9.207 (0.026)*	2.047 (0.136)	0.817
ALL	*−24.795 (0.037)*	*2.633 (0.045)*	−1.296 (0.097)	0.092 (0.722)	0.028 (0.501)	*0.926*

(*continued*)

Table 5.

NARDL model

Sector	INPT	USRY	PLRY	qPOS	qNEG	qVOL	$\overline{R}^2$
	No dummies						
0	−41.902 (0.055)	*6.827 (0.000)*	*−4.957 (0.006)*	*1.863 (0.014)*	0.128 (0.810)	*0.239 (0.036)*	0.828
1	−50.705 (0.285)	*10.379 (0.010)*	*−8.569 (0.038)*	0.826 (0.593)	−1.541 (0.400)	−0.067 (0.822)	0.694
2	−11.188 (0.058)	0.395 (0.179)	0.341 (0.336)	−0.214 (0.253)	0.131 (0.426)	*−0.061 (0.033)*	0.604
3	*−139.742 (0.036)*	*21.575 (0.000)*	*−15.444 (0.007)*	0.292 (0.892)	−3.403 (0.155)	−0.039 (0.906)	0.447
4	−83.280 (0.100)	−1.609 (0.525)	8.012 (0.056)	−0.237 (0.877)	*4.936 (0.029)*	0.113 (0.671)	0.873
5	−8.253 (0.070)	0.151 (0.637)	0.435 (0.150)	−0.237 (0.057)	0.163 (0.265)	−0.011 (0.713)	0.612
6	27.124 (0.409)	5.169 (0.025)	−7.922 (0.034)	2.438 (0.066)	−2.232 (0.101)	0.786 (0.073)	0.399
7	11.467 (0.192)	0.601 (0.144)	*−1.562 (0.029)*	*0.723 (0.015)*	*−1.230 (0.003)*	*−0.092 (0.028)*	*0.958*
8	77.389 (0.266)	−1.588 (0.614)	−3.698 (0.100)	3.373 (0.078)	−1.663 (0.213)	0.127 (0.460)	0.829
9	*−866.133 (0.000)*	*54.832 (0.000)*	−1.592 (0.839)	*−20.804 (0.000)*	4.517 (0.231)	*2.187 (0.001)*	*0.920*
ALL	30.11 (0.631)	1.348 (0.435)	−3.764 (0.340)	1.603 (0.401)	−1.734 (0.355)	0.078 (0.710)	0.847
	With dummies						
Sector	INPT	USRY	PLRY	qPOS	qNEG	qVOL	$\overline{R}^2$
0	*−49.513 (0.014)*	*7.680 (0.001)*	*−5.420 (0.009)*	*2.147 (0.005)*	0.433 (0.253)	0.191 (0.154)	*0.954*
1	24.091 (0.955)	−7.095 (0.925)	6.495 (0.924)	1.998 (0.864)	7.580 (0.862)	−0.829 (0.884)	0.720
2	−121.127 (0.711)	3.042 (0.699)	5.254 (0.722)	−3.208 (0.722)	5.062 (0.725)	−0.026 (0.886)	*0.743*
3	−136.364 (0.117)	*20.209 (0.026)*	−14.047 (0.055)	−0.215 (0.930)	−3.616 (0.247)	0.050 (0.934)	0.378
4	−17.911 (0.446)	0.688 (0.636)	0.500 (0.813)	0.090 (0.907)	0.568 (0.596)	0.072 (0.588)	0.877
5	−3.185 (0.525)	−0.289 (0.486)	0.588 (0.056)	−0.174 (0.134)	0.213 (0.131)	−0.006 (0.820)	*0.643*
6	51.580 (0.338)	1.961 (0.551)	−5.930 (0.152)	2.135 (0.198)	−4.541 (0.142)	1.326 (0.133)	*0.685*
7	−8.545 (0.670)	1.218 (0.083)	−0.829 (0.502)	0.140 (0.813)	−0.495 (0.537)	−0.079 (0.104)	0.944
8	61.602 (0.171)	−7.35 (0.062)	4.071 (0.198)	4.079 (0.146)	0.071 (0.942)	0.133 (0.259)	*0.869*
9	*−643.498 (0.023)*	*40.477 (0.031)*	−0.949 (0.903)	*−16.33 (0.011)*	0.293 (0.963)	*1.894 (0.006)*	0.913
ALL	−23.061 (0.759)	−0.123 (0.991)	1.809 (0.869)	−0.280 (0.911)	−0.186 (0.958)	−0.115 (0.817)	0.809

Note(s): Coefficient estimates in italic – significant at 5%; *F*-statistic in italic – highest among the four models
Source(s): Authors' own elaboration

6. Conclusion

Since the advent of cointegration and other time-series methodologies, numerous studies have investigated the impact of exchange rate fluctuations and exchange rate risk on trade flows around the world. While these introduced many advances to the field – particularly in the application of nonlinear techniques that can separate the impact of appreciations from those of depreciations – the role of structural breaks has been the focus of considerably less attention. These breaks have the potential to incorporate the same information as relative prices do, therefore weakening the importance of exchange rate variables. At the same time, while nearly every country pair has been examined – for both aggregated and sectoral data – much less scholarly scrutiny focused on Poland–USA trade relations. Therefore, this article fills a pronounced gap in the literature.

After examining monthly trade balances for ten sectors as well as total trade, we found structural breaks in each trade balance by using the Bai–Perron test (1998). However, these tend not to correspond to major events such as Poland's 2004 accession to the EU or the 2007–2008 financial crisis. Next, we applied both the linear ARDL method of Pesaran *et al.* (2001) and the nonlinear approach of Shin *et al.* (2014) to a macroeconomic model that included Polish and USA industrial production, real exchange rate and real exchange rate volatility. Overall, evidence for overall cointegration – as well as the specific impacts of exchange rate changes and volatility – proved to differ depending on the industry. Two modifications to the basic ARDL cointegration model tend to show less evidence of cointegration; the two modifications were the incorporation of structural breaks in the trade balance time series and the separation of positive and negative exchange rate changes via a nonlinear ARDL model. While there are few "asymmetric" effects, neither positive nor negative exchange rate changes showed significant effects in most industries, while income played a role in certain natural resources sectors. Most importantly, we found evidence that including structural breaks in the model results in fewer significant coefficients – particularly negative ones – for real exchange rate. In general, sector 0 (food and live animals) seems to be most affected by this relative price.

Our conclusions are consistent with Sy-Hoa *et al.* (2021), who concludes that volatility influences total trade between the USA and Vietnam to a different extent for specific industries, and it does not influence most industries at all. Baum *et al.* (2004) and Bahmani-Oskooee and Saha (2020) prove that this relationship may depend on the country and that for some of them it does not exist; so we show that for Poland–USA trade relations, it depends on both the studied sector and the employed methodology. Contrary to Aftab and Ismail (2018), who argue that there is no significant effect of exchange rate volatility on the Chinese trade balance, we show that for Poland–USA trade relations, it does exist but for some sectors only. Similar to Bahmani-Oskooee and Aftab (2017) who studied the same effect on Malaysia–Korea trade relations, we conclude that the influence of exchange rate volatility differs depending on the analyzed industry. Although Ollivaud *et al.* (2015) and Swarnali *et al.* (2017) notice that the relationship between exchange rate and trade has been reduced over time, we show that it continues to exist for some industries. We confirm that between the USA and Poland the inclusion of structural breaks also changes the relationship between the exchange rate and trade, as in Kang and Dagli (2018) and Dincer and Kandil (2011) for other countries.

Therefore, when acting to manage the economy, policymakers should keep in mind several differences between sectors – in terms of key macroeconomic determinants of trade. Trade in certain natural resources – particularly in sectors 0 and 3 – is driven by both partners' incomes. The former sector is also more affected by changes in real exchange rate. On the other hand, manufacturers are less affected overall. This might affect policy if one sector is favored over another one. There might also appear regional impacts, should areas such as Silesia depend more on manufacturing than other regions. Nevertheless, central bankers should also pay attention to the political and other events that might lead to "regime shifts" in trade, since the econometric models used to estimate these trade flows are sensitive to their inclusion.

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