Asymmetry of the exchange rate pass-through: An exercise on the Polish data

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Abstract

We propose a complex analysis of the exchange rate pass-through in an open economy. We assess the level, linearity and symmetry of exchange rate pass-through to import and consumer prices in Poland and discuss its implications for the monetary policy.
We show that the pass-through is incomplete even in the long run. There is pricing to market behavior both in the long and short run. We do not find a strong evidence of non-linearity in import prices reaction to the exchange rate and reject the hypothesis of an asymmetric response to appreciations and depreciations.
On the other hand, we find an asymmetry of CPI responses to the output gap, direction and size of the exchange rate changes and to the magnitude of the exchange rate volatility. The asymmetry is mostly visible after exogenous shocks. We reject the hypothesis of an asymmetric reaction of prices in a high and low inflation environment. [3]

JEL Classification: C22, E52, F31.
Key Words: Exchange Rate Pass-through, Non-linear Model.

Acknowledgments

We are thankful to Matthieu Bussiere, Michael Frömmel, Ryszard Kokoszczyński, Tomasz Łyziak and participants of the 13th ICMAIF at the University of Crete and XI CIE at the University of Barcelona for many helpful comments.

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1. Introduction (non-technical summary)

Understanding how prices respond to exchange rate is of key importance for any open economy. In our paper we propose a complex analysis of the exchange rate pass-through at the macroeconomic level. Basing on the Polish data we estimate and analyze the main properties of the exchange rate pass-through and assess their implications for the monetary policy. Our analysis covers a period 1997-2008, which is characterized by a homogenous monetary policy (inflation targeting, flexible exchange rate) and a generally falling inflation rate. We assess the degree of pass-through to import prices, examine if they exhibit pricing to market behavior and whether they react to the exchange rate symmetrically. We find that pricing to market exists, both in the long run and in the short run, but reject the hypothesis of asymmetric reaction to the exchange rate. Then, we pass to the CPI, show the level of pass-through and examine whether the process is symmetric. In contrast to import prices, in the case of CPI we find some asymmetries with respect to the output gap, direction and size of exchange rate change and its variability. We do not find asymmetry regarding inflation environment. Finally, we discuss implications for the monetary policy. To our knowledge, both pricing to market and asymmetric reactions of import prices and CPI have not been explored on the Polish data.

The existing Polish literature on the pass-through is not particularly abundant. It is mostly based on McCarthy (2000) where the impact of a sequence of supply, demand and exchange rate shocks on the import, producer and consumer prices is examined, see Przystupa (2002), Cholewiński (2008). Since it is a popular method, for the sake of comparability with other studies, we also provide results we have obtained this way. They are shown in tables A1-A4 in the appendix. Generally, pass-through of the exchange rate changes to the import prices do not vary over time and slightly exceeds 0.7 after 8 quarters. On the other hand, pass-through to the consumer prices exhibits a notable fall: it dropped by half over the period 2002-2008 from 0.42 to 0.21. Such high pass-through effect at the earlier stages of transformation can be interpreted as a result of fast structural changes in the economy, while the huge drop of the pass-through in the last years as an 'internationalization' of the Polish economy due to a massive inflow of the export-oriented foreign direct investment.

Figures for the pass-through effect to the import prices are close to results for other developed economies; whereas figures for the consumer prices differ considerably (they are close to the results estimated for 1971-1983 for the countries with the direct inflation targeting, see Ihrig et al. (2006).

Pass-through to the import prices, estimated with other methods gives similar results - we can safely say that the long-run pass-through for both nominal effective exchange rate and the bilateral exchange rate lies within the range of 0.7-0.8; moreover, a strong evidence of pricing to market is confirmed. Estimating a dynamic equation for import prices we show that instantaneous pass-through is 0.51 – much lower than in the long run and there is weaker evidence of pricing to market. Also, the error correction works quite efficiently: 46% of disequilibrium is eliminated within one quarter. Checking the nonlinearity of import prices reaction to appreciations and depreciations we find that if there is appreciation of the Polish currency with respect to the euro then the effect of the instantaneous pass-through is 0.55 and there is pricing to market. 65% of disequilibrium is eliminated within one quarter. A different picture emerges for the depreciation periods: neither pricing to market nor error correction mechanism seems to operate. The only factor affecting import prices is the exchange rate. The pass-through effect is 0.59. We cannot reject the hypothesis that pass-through in depreciations and appreciations is equal and tentatively conclude therefore, that there is no asymmetry in import prices' reaction to the exchange rate.

For the CPI we find the strong asymmetry of the pass-through effect along the business cycle: this effect may exceed 0.27 in the early expansion, and then it drops to 0.18-0.19 in the peak and to around zero in the early recession. During the late recession and the trough it is growing up to 0.18-0.19 and to over 0.27 in the early expansion. This is coherent with the behavior of enterprises in the business cycle, conditioning their investment decisions on expected profits with a maximum in the early expansion and a minimum in the early recession.

On the other hand, a strong asymmetric reaction was identified in the periods of appreciations and depreciations. If the zloty appreciates, the pass-through to the consumer prices declines and varies from 0.02 to 0.07. During depreciations or slight appreciations, the pass-through effect equals 0.24. Also regarding volatility the pass-through effect seems to be strongly asymmetric: for the volatility over 4.3% it is equal to 0.25, and 0.55 otherwise. The lower pass-through in the case of higher volatility can reflect the producers' reluctance to frequent price changes due to menu costs.

Examining the role of the inflation environment in the exchange rate pass-through behaviour we do not obtain a clear picture, hence we decide to reject the hypothesis that the asymmetry exists.

2. Brief review of the literature

Theoretical exchange rate pass-through literature is dominated by papers dealing with the degree of price adjustment and factors that affect pass-through. The discussion started after numerous tests on variety of goods and across countries yielded very little evidence supporting an assumption of the absolute or relative Purchasing Power Parity (Rogoff (1996), Ihrig et al. (2006).

One strand of the literature investigates pass-through stressing the role of market organization, product segmentation, pricing to market and competition as factors explaining why it is incomplete. In a seminal paper, Dornbusch (1987) points out that firms operating under imperfect competition may adjust mark-ups in response to the exchange rate shock. Froot and Klemperer (1989) show that if market share matters for future profits, then firms facing an exchange rate appreciation will decide whether to raise current or future profits, depending on their perception of durability of the appreciation. This strand of literature is closely related to the problem of pricing to market behaviour and we shall characterize it in more details in section 2, where we describe the model of import prices.

In the second strand of this literature, pass-through is treated as a phenomenon affected by the monetary policy. In a seminal paper Taylor (2000) suggests that price responsiveness to the exchange rate is positively related to the inflation rate. Bailliu and Fujii (2004) find that a transition to a low inflation environment induced by a shift in monetary policy is a cause of a declining pass-through. Devereux and Yetman (2002) build a model in which sticky prices result from menu cost of price adjustment. Monetary policy determines the average rate of inflation and exchange rate volatility. Firms are allowed to choose frequency of price adjustment and optimal frequency varies with the monetary policy regime. For a given menu cost, the higher the rate of inflation and the more volatile the exchange rate, the higher the frequency of price adjustment decisions taken by firms and the higher the pass-through effect. As a result Devereux and Yetman argue that pass-through is endogenous to monetary policy.

Devereux, Engel and Storgaard (2003) analyze the determinants of an exporting firm's choice of currency in which it pre-sets prices. With nominal price stickiness, the aggregate degree of exchange rate pass-through is determined by this decision. They develop a model of an endogenous exchange rate pass-through, in a framework in which the exchange rate itself is also endogenously determined. They find a two-sided relationship, namely that exchange rate volatility determines the price setting behavior of a firm, and therefore the degree of the pass-through, and that the degree of the pass-through determines the volatility of an exchange rate. On the other hand, Campa and Goldberg (2002) show that higher inflation and exchange rate volatility are weakly associated with higher pass-through.

To sum up this part of the literature overview, factors that explain an incomplete pass-through in the long run can be considered microeconomic, whereas these affecting its degree in the short run – macroeconomic.

Linearity and possible asymmetry are investigated less frequently, even though a question whether they exist is important if not crucial for the monetary authorities. Linear response means that prices react in the same way to "big" and "small" changes in the exchange rate. Many papers rather assumed linearity than tested it. But if there are some menu costs of price adjustment, then relatively small changes in the exchange rate may not be passed onto prices. Only after exceeding a certain threshold these changes might be passed on customers. On the other hand, if domestic prices react more to, say, depreciations than to appreciations, meaning there is an asymmetry in the price reaction to the exchange rate changes, it may reflect distortions in the markets, weak competition in particular.

Bussière (2007) provides assumptions and discusses the economic meaning of both quadratic and cubic non-linearities. The quadratic case relies on three assumptions: (i) that export prices are rigid downwards (ii) that quantities of exported goods are rigid upwards (exporting firms work at full capacities) and (iii) that exporting firms care about their market share. Exporters try to offset a fraction of exchange rate movements, and this fraction varies with the magnitude of the exchange rate changes. For a larger appreciation, the reaction of export prices decreases, whereas for a large depreciation – increases. Also, in appreciations exporters reduce their prices by a larger amount, because they fear losing market share. The cubic case relies on the assumption of the existence of menu costs on the side of both exporters and importers. If the former is true, then exporters only slightly adjust prices in their currency in response to the exchange rate changes, while these changes are reflected in the import prices. If the menu costs are at the side of importers, the exporting firms adjust prices to offset small changes in the exchange rate.

Recently the gap between empirical literature assuming linearity and symmetry and that testing it has been shrinking. Early works on this topic are Mann (1986) and Goldberg (1995); both find asymmetries in consumer prices' reaction to appreciations and depreciations. More papers appeared only after the year 2000. Devereux and Yetman in the paper mentioned above use a cross-section time series model to show that there is a non-linear relationship between the degree of pass-through and inflation rate. As inflation rises, pass-through increases too but at a decelerating rate. Pollard and Coughlin (2003) examine the symmetry in response of import prices in manufacturing to appreciations and depreciations as well as to the size of the change of the exchange rate in the US and show that there is some asymmetry in response of import prices in different industries. They find no clear direction of the asymmetry across industries, however, and conclude that pass-through is positively related to the size of the change in the exchange rate. Campa et al. (2006) examine non-linearity in import price adjustment in the EU (15). They explore three types of non-linearities: adjustments which are not proportional to the size of the deviation, adjustments which are non-symmetrical to the sign of the deviation and finally thresholds below which no adjustment takes place. Using data on the industry-level they obtain a strong evidence for the presence of nonlinearities in the adjustment towards long-run equilibrium in certain industries. They also find evidence for the existence of thresholds of no adjustment centred on zero. The thresholds seem to be much lower for the manufacturing than for the commodity industries. Herzberg et al. (2003) use aggregate data for the UK. They do not find evidence of non-linearity in the reaction of import prices. Bussière (2007) investigates whether export and import prices of G7 countries exhibit linear and symmetrical reaction to the exchange rate movements. He finds that a non-linear effect cannot be neglected, although the direction of the asymmetries and the magnitude of non-linearities vary across countries. Wickremasinghe and Silvapulle (2004) find that in Japan import prices of manufacturing display a statistically significant difference in their adjustment to appreciations and depreciations and that the reaction to the former is bigger than to the latter.

There is less evidence of import price reactions in the emerging markets. Alvarez et al. (2008) report a weak asymmetry between the reaction of import prices to appreciations and depreciations in Chile. They examine unit import values and wholesale import prices, the former aggregated into three subcomponents by end use: consumer, intermediate and capital goods; the latter distinguished imported goods from three sectors – mining, agriculture and industry. They find that coefficients for depreciations are higher than for appreciations, but null hypothesis that both coefficients are equal is not rejected only marginally for capital goods; for agriculture only depreciations are passed into import prices.

Literature dealing with the consumer price index is even scarcer. Goldfajn and Werlang (2000) use a panel of 71 countries and report an asymmetric reaction of pass-through over the business cycle. Correa and Minella (2006) investigate non-linearities in pass-through to consumer prices in Brazil. They estimate a Phillips curve with a threshold for the pass-through and show that the magnitude of a short run pass-through is higher when the economy is growing faster, when the exchange rate depreciates above a certain threshold and – surprisingly – when exchange rate volatility is lower. Posedel and Tica (2007) use a TAR model on Croatian data and find a single threshold of a monthly change in the exchange rate below which it does not affect consumer price inflation. Khundrakpam (2007) finds asymmetry of pass-through related to the direction of the exchange rate changes in India.

To sum up, there is a growing evidence showing the existence of various types of non-linearities both on the first stage of the pass-through, i.e. import prices, as well as on the last stage – i.e. consumer prices.

Our paper fits in this type of literature. The first part is devoted to the analysis of import prices: we start with a linear equation, and afterwards test whether it is mis-specified, i.e. whether it lacks non-linear terms. We do not find strong evidence for non-linearities, but it seems that in depreciations and appreciations different mechanisms of adjustment operate. In appreciations of the home currency with respect to the euro pricing to market seems to have some impact on import prices. However, this impact disappears in depreciations. The next part of the paper is focused on retail prices. We estimate threshold models and models based on nonreversibility of the linear functions and find an asymmetric reaction of consumer prices to appreciations and depreciations, to the volatility of the exchange rate, and, in the models based on nonreversibility, to the business cycle fluctuations. The impact of the inflation environment does not show any apparent asymmetry.

3. Import price model

There is a vast literature pointing that import prices can be affected by domestic prices. The phenomenon is known as pricing to market (henceforth PTM). It was perceived as a result of market imperfections (monopolistic power of price setters) and market segmentation, since in this case producers can charge a mark-up on costs. The mark-up depends on the elasticity of demand for a given product and this in turn is determined by competitors' prices. Facing a change in the exchange rate, producers can decide whether and to what degree the mark-up should absorb these changes. For example, if the domestic currency of an exporting firm depreciates, it can refrain from increasing its mark-up to build a future market share. Firms having a power to control their prices can charge different prices in different markets. Pricing to market can therefore explain why pass-through tends to be incomplete.

Further analyses of PTM show however, that imperfect competition together with market segmentation is not a sufficient condition for a persistently low degree of pass-through[4]. In this vein, Bergin and Feenstra (2001) use a general equilibrium model to show that segmented markets with identical preferences cannot explain incomplete pass-through in contrast to segmented markets with different preferences. Therefore, they consider translog preferences in which the elasticity of demand varies with the price a firm sets. Corsetti and Dedola (2002) analyze market segmentation resulting from a vertical interaction between monopolistic producers and retailers. They show that due to the presence of downstream retailers, upstream firms with monopoly power may face different demand elasticities in national markets even under symmetric constant elasticity preferences across countries. Monopolistic firms optimally set different prices to domestic and foreign dealers, and therefore the law of one price fails to hold at producer and consumer levels.

In this paper we use a model which is common in the literature on pass-through effect (e.g. Goldberg, Knetter (1997), Bache (2002), Bahroumi (2006). We assume that an exporting firm has some control over its price in the importing country. Namely, it sets the price as a mark-up over its marginal cost. In the importing country, import price expressed in its own currency is equal to the exporting firm's price multiplied by the exchange rate. Thus:

(1) $P_t^F = \lambda_t C_t^F$,

(2) $P_t^{IMP} = E_t P_t^F = E_t \lambda_t C_t^F$,

where P_t^F represents export prices of a foreign country, C_t^F is a marginal cost of production in a foreign country, λ_t is a firm's mark-up in the importing country, E_t is the exchange rate, and P_t^{IMP} stands for import prices of a home (importing) country.

Mark-up depends on the competitive pressure from importer's domestic production and demand pressure, Y_t. Competitive pressure can be expressed as a relation between domestic prices and foreign prices in terms of importer's currency:

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[4] For a more detailed discussion see for example Herzberg et al. (2003), or Bache (2007).

(3) $\lambda_t = K\left[\frac{P_t^H}{E_t C_t^F}\right]^{\alpha} (Y_t^H)^{\beta}$ $\qquad 0<\alpha<1,\ 0<\beta<1$ and K is constant.

Combining (2) and (3) gives:

(4) $P_t^{IMP} = K\left(E_t C_t^F\right)^{1-\alpha}\left(P_t^H\right)^{\alpha}(Y_t^H)^{\beta}$,

taking natural logs (depicted in lower case) we have:

(5) $p_t^{IMP} = \kappa + (1-\alpha)e_t + (1-\alpha)c_t^F + \alpha p_t^H + \beta y_t^H$.

In practice it is often difficult to obtain in the empirical study equal parameters at the exchange rate and foreign prices that usually serve as a proxy for costs in the exporting country. Bache (2002) and Barhoumi (2006) stress that exchange rates are more volatile than costs, therefore the extent to which they are passed on prices may differ. One usually starts estimations without this restriction and tests it in the next step. Thus, the estimated equation is:

(6) $p_t^{IMP} = \alpha_0 + \alpha_1 e_t + \alpha_2 c_t^F + \alpha_3 p_t^H + \alpha_4 y_t^H + \varepsilon_t$.

We shall proceed this way. Some authors also point that domestic demand often turns out to be statistically insignificant (see for example Bussière (2007)). The rationale for that is simple: information that is contained in the measure of demand pressure can be already incorporated in another variable, notably in domestic prices. This is why this term is frequently omitted in estimations. To verify whether it is justified to allow for the output pressure in the dynamic (short-run) equation, we have checked the correlation between the output gap measure (a difference between actual and HP-filtered GDP) and the change in domestic prices – it was quite high, namely 0.538, therefore we decided not to plug the output gap into the equation.

3.1. Estimation method and data

Many studies of the pass-through effect are based on short-run dynamic equations. Such estimate has also been made for Poland (Przystupa (2002), Cholewiński (2008)). In this paper we present estimates of a long-run reaction of import prices to the exchange rate. If variables are cointegrated, as they seem to be in this case, then limiting the analysis to the short-run would reduce the information content. On the other hand, cointegration analysis requires data span that is sufficient for inferences on equilibrium levels of the variables. Our analysis covers an eleven-year period only (1997.Q1 2008.Q1). It is relatively short, which makes our conclusions somewhat risky. It needs to be stressed that estimation of asymmetry of exchange rate pass-through relies on an even smaller number of observations, since our sample must be divided into two sub-samples that reflect two different states, e.g. appreciation and depreciation or "big" and "small" changes of the exchange rate. Our results should therefore be treated as guidelines rather than sharp point estimates.

Taking into account the shortness of our sample and the small number of usable observations, we decided not to confine the analysis to one method only, but – whenever possible – to use more to reduce uncertainty concerning robustness of our results. Thus, in the case of import prices we use Johansen cointegration method and fully modified least squares. The latter is particularly well suited if there are problems with endogeneity and serial correlation.

It is important to note that the period covered in this paper is relatively homogenous in terms of a monetary policy regime, namely inflation targeting and flexible exchange rate. This makes the estimation easier and more reliable and therefore partially offsets the drawbacks of the time span shortness. On the other hand, the EU entry in 2004 constituted a significant disturbance to the real economy. There was an increase in inflation, but also – what is more important for this study – the role of exchange rate as a variable affecting the real sector of the economy has started to change since then. Due to an increasing role of intra-company trade, the impact of the exchange rate on the aggregate demand diminished (see also Łyziak et al. (2008) and Przystupa and Wróbel (2006)[5]. Moreover, Poland's foreign exchange market started to be increasingly impacted by the euro, whereas the position of the US dollar was falling.

We begin our estimations with the nominal effective exchange rate, but then restrict our discussion to the import prices' behavior with respect to the bilateral exchange rate (EUR/PLN[6]). One reason is the big share of imports from the EU in the total imports (about two thirds in 2007), another is the fact that imports from the euro area consist mostly of manufactured products. Pricing to market and asymmetries in the pass-through, i.e. the issues that are in the centre of our interest, are a feature of manufacturing rather than raw materials.

Since our aim is to check whether the exchange rate pass-through in Poland is linear and symmetric, we start with a linear equation and then test whether quadratic and cubic terms are lacking in the dynamic equation. Then we check whether import prices react asymmetrically to appreciations and depreciations.

In the estimation we use quarterly data. They are seasonally adjusted with X11. The only exception is the nominal exchange rate, which is not adjusted since, in the case of Poland, it is not significantly affected by seasonal factors. To assess the role of PTM, we use Producer Price Index (source: Main Statistical Office (GUS)); due to the data problems till the end of 1999 it is an overall index, whereas since 2000 it comprises goods produced for the domestic market only. As shown by graph A5 in the Appendix, the overall index and the index of prices for domestic market started to diverge mostly in 2004, thus we assume that this should not significantly influence our results. As a proxy for foreign prices we use euro area export prices (source: Eurostat). We do not employ unit export values of Poland's main trading partners. Silver (2007) points that unit export values can be substantially biased in representing export and import prices. Import price data come from GUS, whereas nominal exchange rate (quarterly average) - from the National Bank of Poland. All data are in logs, the base year for price indices is 2000.

As it is clear from table A9 foreign and domestic prices as well as the exchange rate are non stationary. One may have some doubts whether import prices are stationary. ADF test shows that seasonally adjusted data with an intercept can be considered as I(0), whereas raw data are rather non-stationary. Johansen test (Table A5 – A7) indicates that there is one cointegrating relation, therefore we treat import prices as an I(1) variable[7].

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[5] The authors show changes in the exchange rate regime and the role of the exchange rate in the monetary transmission.

[6] Upside movement of the exchange rate means appreciation.

[7] Hjalmarsson and Österholm (2007) show that Johansen's trace test and maximum eigenvalue test may bring erroneous results under the situation of nearly integrated variables. They suggest performing additional test which relies on a system of restrictions imposed on the cointegrating vector. We have performed this test and do not reject the hypothesis that the variables are cointegrated in the long run.

3.2. Estimation results

As we have mentioned above, there is one cointegrating equation of import prices, domestic prices, foreign prices and the exchange rate. Both nominal effective exchange rate (NEER) and the bilateral exchange rate give the cointegration. The cointegrating vector is presented in tables A8 and A9. We start estimates with the unrestricted vector – all variables have a proper sign. Contrary to domestic prices, foreign prices are not significant. Significance of domestic prices means that there is pricing to market behavior in the long run. The long-run exchange rate pass-through is 0.91 for the nominal effective exchange rate and 0.71 for the bilateral exchange rate.

Now we pass to the restricted version of the cointegrating relation. First we check whether the coefficients at NEER (or the bilateral exchange rate) and coefficients at foreign prices are equal. In both cases a Chi-square test shows that we cannot reject this hypothesis. In the restricted version the pass-through is approximately 0.8 for both NEER and the bilateral exchange rate. All variables are statistically significant, and the significance of domestic prices implies the existence of a pricing to market effect. Next, we check whether the pass-through effect is full. This hypothesis is not rejected at the 1% level for the bilateral exchange rate but rejected for the nominal effective exchange rate. Neither the restriction $\alpha_1 = \alpha_2 = 1$, $\alpha_3 = 0$ (the law of one price) nor the restrictions $\alpha_1 = \alpha_2$, $\alpha_2 + \alpha_3 = 1$ (unit homogeneity) and $\alpha_1 = \alpha_2 = 1$ (unit coefficients on the exchange rate and foreign prices) for the bilateral exchange rate can be rejected at the 1% level. For the nominal effective exchange rate only the law of one price cannot be rejected at the 1% level. All these restrictions, with exception of the law of one price for the bilateral exchange rate are rejected at 5% significance level; this however can be rejected at the 10% level. All in all, we conclude that while for the nominal effective exchange rate the results seem quite clear, for the EUR/PLN exchange rate we need a cross-check.

To have a clearer picture we estimate the model with FMLS and then impose the same set of restrictions. Table A9 (right hand panel) shows that, with the exception of foreign prices, in the unrestricted cointegrating vector all parameters are statistically significant, and all coefficients obtained with these two methods are similar. The point estimate of long-run pass-through is 0.68. Data show that there is long-run pricing to market. As previously, restriction $\alpha_1 = \alpha_2$ cannot be rejected. Once again, all parameters are statistically significant. Contrary to the results obtained with the Johansen method, all remaining restrictions are rejected at the 1% level of significance.

To sum up this part of our estimates, we can safely say that the long-run pass-through for both the nominal effective exchange rate and the bilateral exchange rate lies within the range of 0.7-0.8, and that there is equality of the coefficients of the exchange rate and foreign prices. There is no strong support in the data for the existence of the law of one price, unit long-run coefficients on the exchange rate and foreign prices, and long-run unit homogeneity in domestic and foreign prices. A final step in the cointegration analysis is the test of exogeneity. All tested variables - exchange rate, foreign prices and domestic prices - seem to be weakly exogenous. (Table A10). Exchange rate is strongly exogenous, but domestic producer prices are not[8].

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[8] We do reproduce the results of Granger causality here.

Then we estimate a dynamic equation for import prices using cointegrating vector obtained from the FMLS, namely:

(7) $$\Delta p_t^{IMP} = \beta_0 + \beta_1 EC_{t-1} + \sum_{i=0}^{4} \beta_{2,i}\Delta e_{t-i} + \sum_{i=0}^{4} \beta_{3,i}\Delta p_{t-i}^{F} + \sum_{i=0}^{4} \beta_{4,i}\Delta p_{t-i}^{H} + \sum_{i=1}^{4} \beta_{5,i}\Delta p_{t-i}^{IMP} + v_t ,$$

where EC is the error correction term and Δ stands for the first difference of a variable.

After elimination of statistically insignificant parameters we get the following results (Table A11): instantaneous pass-through is 0.51 – much lower than in the long run, there is weaker evidence of pricing to market in the short run than in the long-run. On the other hand, the error correction works quite efficiently: 46% of disequilibrium is eliminated within one quarter.

To check whether import prices react in a non-linear way to the exchange rate we perform a test similar to the Ramsey's RESET test, but with the Taylor expansion for the non-linear function[9]. It should reveal whether our equation lacks square or cubic terms. There is no strong evidence of the lacking square terms (Statistic F(1.39) =0.267 sign. level 0.61, LM(1)=0.299 sign. level 0.58). However, it is possible that there is a very weak cubic non-linearity (F(2,38) =2.001 sign. level 0.15, LM(2)=4.19 sign. level 0.12).
Our next step is to examine how changes in the exchange rate are transmitted to the import prices in the periods of appreciation and depreciation of the Polish currency. Thus we set:

$$A_t = \begin{cases} 1 & \text{if } \Delta e_t \prec 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{and} \quad D_t = \begin{cases} 1 & \text{if } \Delta e_t \succ 0 \\ 0 & \text{otherwise} \end{cases}$$

and in equation (7) we replace Δe_t with $\beta_1^A \left(A_t \Delta e_t\right) + \beta_1^D \left(D_t \Delta e_t\right)$ and estimate separately the equation for the appreciation and depreciation of the exchange rate.
The results are reproduced in tables A12 and A13. If there is appreciation of the Polish currency with respect to the euro the correcting mechanism is very efficient: 65% of disequilibrium is eliminated within one quarter. There is pricing to market, which means that exporters in the euro zone do not increase mark-ups, but rather care about future market share. The effect of the instantaneous pass-through is 0.55, but it is estimated with a low T-statistic. A different picture emerges for the depreciation periods: Neither pricing to market nor error correction mechanism seems to operate. The only factor affecting import prices is the exchange rate. The pass-through effect is 0.599. We could not reject the hypothesis that pass-through in depreciations and appreciations is equal. We tentatively conclude therefore, that there is no asymmetry in import prices' reaction to the exchange rate. Pricing to market manifests itself in periods of appreciations of the domestic currency only. When exporters' currency appreciates the exporters do not tend to lower their mark-ups. What can be the reason for such asymmetry? There are at least three, seemingly consistent, arguments. First, exporters expect appreciation rather than depreciation of the Polish zloty with respect to the euro and treat depreciations as short-lived and therefore are not afraid of losing market share. Second, prices are rigid downwards, exporters therefore are not eager to adjust them if their currency appreciates. Third, if exporters do not increase their mark-ups in favourable conditions, then they would incur losses if they decided to lower them in a case of the appreciation of their currency.

We have also checked how pass-through works in two additional cases: a positive and a negative sign of the error correction term. The former means that import prices are higher than the equilibrium level determined by exporters' prices and domestic prices due to, for

[9] The same test is used in Herzberg et al. (2003)

example, too high transportation costs, inclusion of other costs in the price (like insurance or hedging costs), or misperceived intensity of competition. If this is the case, a process of return to the equilibrium relies mostly on exchange rate adjustment. There is also statistically significant pricing to market behavior, but its impact is very limited. Depreciation of the domestic currency exchange rate is a factor that increases other prices (domestic prices). Pricing to market is small probably because in this case importers can involve only a small part of transportation and distribution costs in their prices. If import prices are lower than the equilibrium level, then the error correcting mechanism works quickly and efficiently eliminating 65% of the disequilibrium in one quarter; there is also a statistically significant and relatively big impact of pricing to market, which means that distribution and transportation costs may be overpriced.

4. Exchange rate pass-through models based on the Phillips curve.

In this chapter we examine a hybrid New-Keynesian Phillips Curve (NKPC) model. In the hybrid NKPC for an open economy inflation is a function of three factors:

(i) next period's expected inflation rate ($E_t\pi_{t+1}$) extended by the empirically observed persistence of inflation (backward looking inflation π_{t-1}) – e.g. Fuhrer and Moore (1995);

(ii) real marginal costs approximated by the output gap (y_t) – e.g. Woodford (2003);

(iii) real exchange rate – contemporaneous (e_t^r) and expected ($E_t e_{t+1}^r$) – e.g. Woodford (2003).

Accepting the NKPC, we admit that the behavior of inflation depends on the slope of the Phillips curve. If the Phillips curve is linear, the slope is constant. If it is non-linear, the slope is not constant and behavior of inflation is a function of the output gap and the exchange rate.

On the other hand, steepness of the slope of the Phillips curve depends on the determination whether the function is convex or concave. Filardo (1998) finds that the Phillips curve is not purely convex or concave and that convexity or concavity is determined by the output gap. If the output gap is positive, the Phillips curve is convex (firms are more inclined to raise prices than to lower them, but the cost of fighting inflation is falling – the slope of the Philips curve steeping) and if the output gap is negative, the Phillips curve is concave (firms are more reluctant to raise prices than to lower them, but the cost of fighting inflation is rising – the slope is flatting).

In this chapter we investigate the possibility of non-linear reaction of inflation to the exchange rate changes along the business cycle.

4.1. Estimation methods

As we have mentioned in the Introduction, the exchange rate pass-through to consumer prices in Poland seems to be relatively high (about 0.2). It is akin to that of the developed countries in the eighties of the last century. In such circumstances it is of key importance for the monetary policy to know whether the process is linear and symmetric. We check pass-through linearity with respect to (i) business cycle approximated by the output gap, (ii) appreciations and depreciations of the nominal effective exchange rate of the zloty, (iii) volatility of the nominal effective exchange rate and (iv) inflation environment. We distinguish two states

(regimes) for any economic process. The output gap, NEER and inflation are set up as the variables which cause a transition from one regime to another.
We use two methods to divide the sample into properly defined sub-samples. The first one splits the sample into classes, depending on the observation whether a given variable exceeds some threshold. If all explanatory variables are exogenous then **T**hreshold **A**uto**R**egresive (TAR) models can approximate a nonlinear autoregressive structure, where the number of regimes is small – see Tong (1990) or Hansen (2000). Caner and Hansen (2004) develop an estimator which can be used for models with the endogenous variables and an exogenous threshold variable. This allows estimation of thresholds for dynamic models. Basing on the procedure and a program described in Caner and Hansen (2004) we estimate a SETAR (**S**elf-**E**xciting **T**hreshold **A**uto**R**egresive) model of a general form:

$$Y_t + \theta_0 + \theta_1 Y_{t-1} + \ldots + \theta_p Y_{t-p} + I(Y_{t-d} \leq \tau)(\phi_0 + \phi_1 Y_{t-1} + \ldots + \phi_q Y_{t-q}) = \varepsilon_t$$

where:
Y – vector of explanatory variables;
d=1 and $0 \leq q \leq p$;
ε_t – white noise;
$\tau \in \mathrm{T}$ - threshold parameter: $I(y \leq \tau) = \begin{cases} 1 & \text{if } y \leq \tau \\ 0 & \text{otherwise} \end{cases}$

Usually the threshold value is unknown and has to be estimated. Estimation of the threshold with the ML method needs to determine the maximum of the likelihood function, whereas the estimation of the threshold with the TSLS or GMM method – to minimize the sum of the squared residuals.

Our sample consists of 46 observations and due to their small number we assume that the threshold should split the data into sub-samples with minimum 15 observations. Franses and van Dijk (1999) show that a safe choice is min. 15% of observations in the sub-sample. In order to estimate threshold values we use four specifications of the threshold model (based on the Phillips curve), differing basically by the variables used as the threshold for the pass-through: output gap, NEER, NEER volatility and inflation environment.

The second method refers to Wolffram's (1971) idea, developed further by Houck (1977), for investigating nonreversibility of the linear functions through segmenting the variables involved.

Let us assume the variable **Y** depends on the values of **X** being suspected for asymmetry, and on the set of other variables **Z.** We want to examine whether one-unit increases of **X** from period to period have a different impact on **Y** than one-unit decreases of **X:**

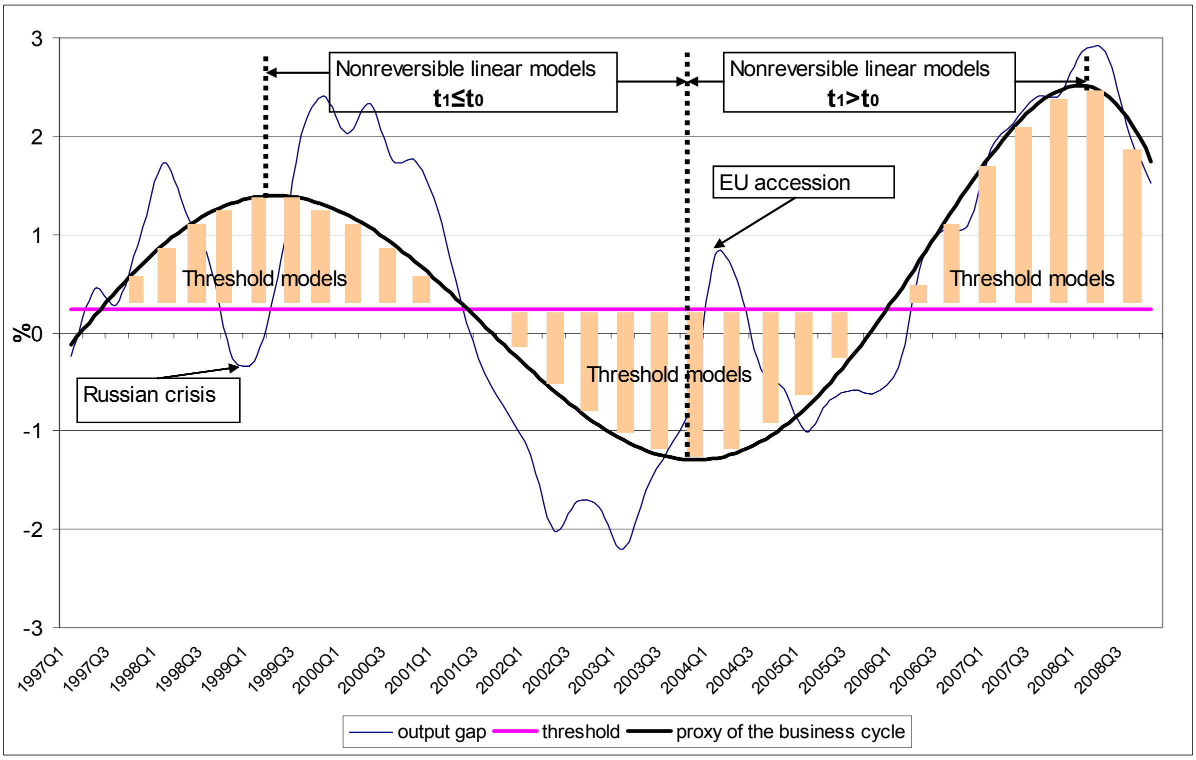
$$\Delta Y_i = a_0 + \sum_{j=0}^{T_1} a_{1,j} \Delta X'_{i-j} + \sum_{j=0}^{T_2} a_{2,j} \Delta X''_{i-j} + a_3 Z_i$$

where for $i = 1,2,\ldots,t$:
$\Delta Y_i = Y_i - Y_{i-1}$
$\Delta X'_i = X_i - X_{i-1}$ if $X_i > X_{i-1}$ and $= 0$ otherwise;
$\Delta X''_i = X_i - X_{i-1}$ if $X_i < X_{i-1}$ and $= 0$ otherwise;
$j = 1,2,\ldots,T_1,T_2$; $T_1,T_2 < t$ (j – number of lags assigned to $\Delta X'_i, \Delta X''_i$).

A nonreversibility of the function ΔY_i occurs, i.e. the reaction is asymmetric, if $\left|\sum_{j=0}^{T_1} a_{1,j}\right| \neq \left|\sum_{j=0}^{T_2} a_{2,j}\right|$

Both methods divide the sample into different sub-samples with different economic interpretation. Output gap, suspected of the asymmetric impact, can serve as an example (Figure 1).

Figure 1. The economic interpretation of the threshold model and model based on nonreversibility of the linear functions



Source: Authors` calculations.

The output gap was calculated as a percentage deviation of the actual GDP from a potential[10]. Assuming that the output gap is a proxy for the economic activity along the business cycle, its values exceeding the estimated threshold can be interpreted as periods of prosperity (late expansion, peak and early recession), whereas the values below the threshold – as a slump (late recession, trough and early expansion). The threshold estimated for the output gap identifies 25 periods of prosperity and 21 periods of slump (Figure 1).

The sub-sample derived from the nonreversibility of the linear function, for $\mathbf{t_{i+1}>t_i}$, points out periods of expansion or recovery (early expansion, late expansion and peak), while the sub-sample for $\mathbf{t_{i+1}\leq t_i}$ describes periods of contraction or recession (early recession, late recession and trough). This method identifies 24 periods of expansion and 22 periods of contraction.

[10] As before, potential GDP was derived from the Hodrick-Prescott filter with λ=1600. To diminish the role of the last observations, the sample was lengthen by an AR(1) process.

The total sample contains 46 observations between 1q 1997 and 2q 2008 and seems to cover one and a half business cycles and two exogenous shocks: "the Russian crisis" in 1998 and Poland's accession to the EU (2004)[11].

The exchange rate pass-through to the CPI was estimated on the basis of the Philips curve similar to the one in a highly aggregated New-Keynesian model developed at the National Bank of Poland for inflation forecasting (see Kłos et al., 2005). The model was built on the standard assumptions of sticky prices and wages. Basic macroeconomic relationships include: the IS curve, uncovered interest parity (UIP) and the Phillips curve[12]. The shape of the Phillips curve used to estimate the pass-through effect is as follows:

$$\pi_{t,k}^{q_i} = \alpha_{1,k}^{q_i} E_t \pi_{t+1} + (1 - \alpha_{1,k}^{q_i} - \alpha_{2,k}^{q_i})\pi_{t-1} + \alpha_{2,k}^{q_i}(\Delta e_{t-1}^{r}) + \alpha_{3,k}^{q_i} y_{t-2} + \varepsilon_t$$

where π stands for inflation (CPI),

q_i is a threshold variable (i=1…4);

i=1 → output gap (y);

i=2 → Δ nominal effective exchange rate (Δe);

i=3 → volatility of the nominal effective exchange rate (s);

i=4 → inflation (π): actual inflation – inflation target (τ);

k=1,2; k=1 for $q_i > \tau$ (τ = threshold);

k=2 for $q_i \leq \tau$

and e^r is a nominal effective exchange rate plus foreign inflation.

We estimate the Phillips curve using the GMM method. The instrumental variables were derived from a set of variables explaining behavior of the exchange rate of the zloty (see the recalled NBP model). Nominal effective exchange rate and the output gap were also included. Such procedure allows for relationships among the variables as in the model of inflation. The instrumental variables were chosen in the manner assuring proper sign at all explanatory variables, correct value of the t-statistic and p-value of the J-statistic. Finally, we estimate 16 equations with the threshold and the nonreversibility method. All details are presented in table A15 in the Appendix. When interpreting the results, one must bear in mind a small number of observations used in the estimation.

4.2. Estimation results.

The results seem to be consistent with these obtained by Mann (1986), Goldberg (1995), Goldfajn and Verlang (2000), and Correa and Minella (2006). They are presented in Table 1 and Figure 2.

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[11] The approximate date of Poland's accession to the EU was known since 2002 but the reaction of the economy was hardly predictable – therefore it can be treated as a shock.

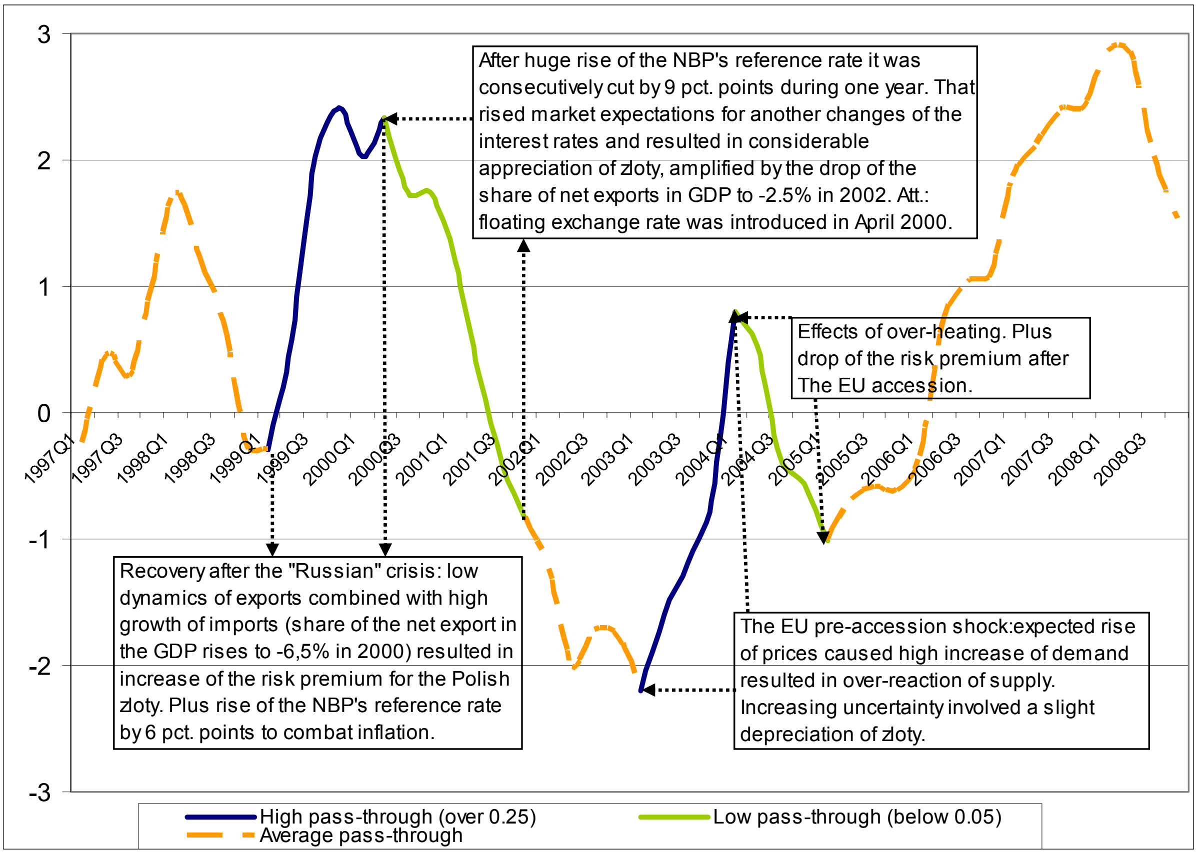
[12] The output gap in the model depends on its lagged value, the ex-ante real interest rate, the real effective exchange rate and the external demand. NEER is determined — in line with the arbitrage condition — as a function of the USD/PLN exchange rate and the EUR/USD cross rate (exogenous variable), while the USD/PLN exchange rate is modelled within the concept of the UIP. The explanatory variables of the USD/PLN exchange rate are the lagged value of this variable, the interest rate disparity, the term structure of interest rates, the EUR/USD cross rate and risk factors. The list of risk factors includes the output gap, budget deficit, net exports, current account deficit and foreign direct investment.

Table 1. The asymmetry of the exchange rate pass-through to the consumer prices

Asymmetry of the exchange rate pass-through to CPI related to:	Threshold models (τ = threshold)		Nonreversible linear models	
	variable > τ	variable ≤ τ	$t_1 > t_0$	$t_1 \leq t_0$
Output gap (y)	τ = 0.24%		0.274	0.091
	0.192	0.179		
Δ nominal effective exchange rate (Δe)	τ = 2.08%		0.018	0.238
	0.065	0.239		
Volatility of the nominal effective exchange rate (s)	τ = 4.32%		0.139	0.141
	0.247	0.549		
Inflation (π)	τ = level of official inflation target		0.160	0.183
	0.195	0.201		
Pass-through (general)	0.229			

Source: Authors' estimation.

Figure 2. The cross-reaction of the asymmetric shocks of the output gap and the nominal effective exchange rate.



Source: Authors' estimations.

The threshold for the output gap shows a slight deviation from zero (0.24) suggesting a small inefficiency of the monetary policy, particularly during prosperity. In that period, a smaller role of output gap in the explanation of inflation is combined with the bigger role of inflation expectations. The respective coefficients are 0.14 and 0.71, compared to 0.22 and 0.49 during the slump (table A16). It may reflect an increasing power of employees in wage negotiations during prosperity, resulting in a higher propensity of producers to price increases. It is directly transferred to consumers` expectations, which become more and more forward-looking.

The Wald test shows no statistically significant differences in the exchange rate pass-through between the periods of prosperity and the periods of slump. However, there is a huge difference in the pass-through effects between the periods of expansion (0.27) and contraction (recession): 0.09.

Combination of these two findings would suggest that the pass-through effect may even exceed 0.30 in the inflexion point between early and late expansion. Then it drops to 0.19-0.21 in the peak and to around zero in the inflexion point between early and late recession. During the late recession and the trough it is growing up to 0.19-0.21 and exceeds 0.30 in the early expansion. This is coherent with the behavior of enterprises in the business cycle, conditioning their investment decisions on expected profits with a maximum in the early expansion and a minimum in the early recession (see, e.g. Kalecki (1943) or Mankiw (2006). The enterprises' propensity to change prices follows profit expectations.

On the other hand, there is a strong asymmetric reaction in the periods of appreciations and depreciations. If the zloty appreciates (or, according to the threshold model, the appreciation rate is over 2%), the pass-through to the consumer prices declines and varies from 0.02 to 0.07. During the depreciations or slight appreciations (below 2%) and depreciations, the pass-through effect equals 0.24.

Combining the pass-through effect over the business cycle and during appreciations and depreciations we can define periods of low and high pass-through. It is low if appreciation and contraction occur simultaneously. The high pass-through is characteristic for periods of a simultaneous occurrence of expansion and depreciation. However, the probability that such phenomenon appears over the business cycle is relatively low. Examining the data for Poland, we find two periods of high and low pass-through (Figure 2).

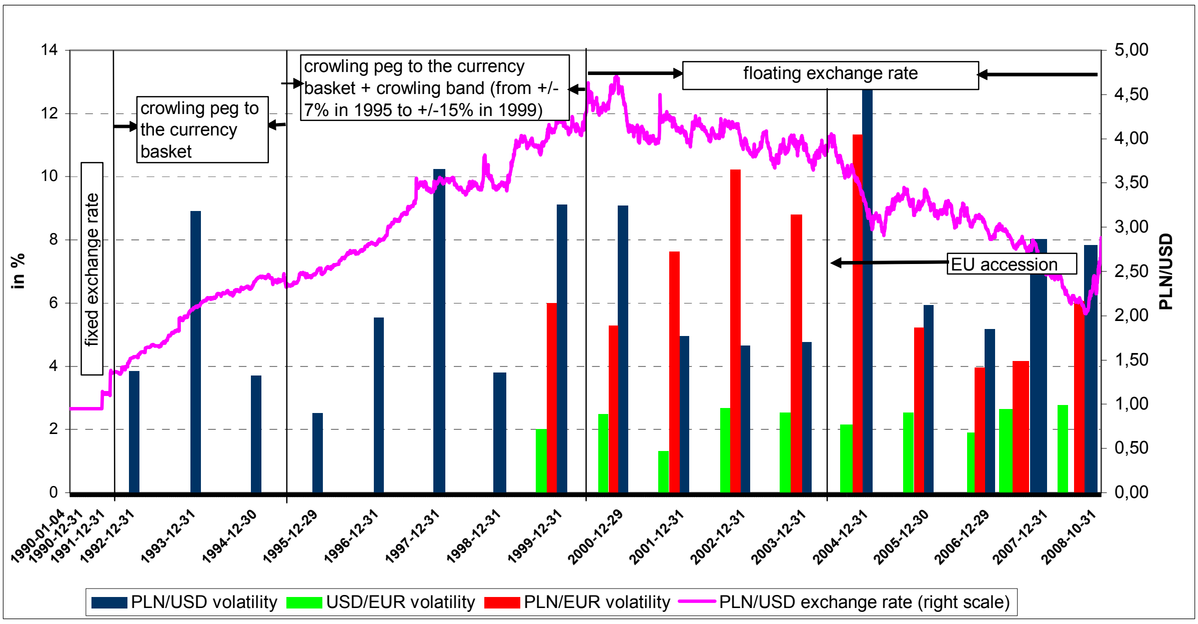
The first one occurred in 1998, when the Russian economy contracted due to a severe financial crisis which burst out in the last quarter of 1997. Poland, being in the ascending phase of the business cycle, was therefore affected by a negative external shock. During the fall of the GDP growth rate, pass-through remained at an average level. The coincidence of a faster growth and the depreciation, i.e. the high pass-through effect, occurred just after the shock and lasted about four quarters. The rapid recovery was followed by a slowdown and the appreciation of the zloty induced by expectations for successive cuts in the interest rates. The period of the low pass-through effect lasted about 7 quarters and ended up together with the slowdown of the exchange rate appreciation.

The second episode of such a coincidence occurred before Poland's accession to the EU. The "ordinary" recovery was accelerated by the external positive shock. An excessive rise in demand induced by a fear of future price increases resulted in an over-reaction of supply. Increasing uncertainty together with a diminishing interest rates disparity caused a slight depreciation of the zloty. The period of high pass-through effect lasted from the 2q 2003 until

the 1q 2004 (Poland joined the EU in May 2004). It was followed, similarly to the first episode, by a period of a low pass-through, lasting till the 1q of 2005.
This can suggest that episodes of high and low pass-through occur together and immediately after an exogenous shock. Seemingly, it does not matter whether the shock is positive or negative.

The average volatility of the Polish zloty calculated for each quarter between 1997 and 2008 as a standard deviation of the daily data is equal to 7.1%, and varies from 2.8% in 2007 to over 10% in 2003 and 2004 (Figure 3). The threshold value for the volatility of the nominal effective exchange rate of the zloty was estimated at the level of 4.3%, with 29 observations over the threshold and 17 below. The pass-through effect seems to be strongly asymmetric: for the volatility over 4.3% it is equal 0.25 and 0.55 otherwise. The lower pass-through in the case of higher volatility can reflect the producers' reluctance to frequent price changes due to the menu costs. These results are consistent with Pollard and Coughlin (2003) or Correa and Minella (2006).[13] Generally, the periods of high volatility of the zloty are simultaneously these of high pass-through; hence they do not raise the total effect.

Figure 3. History of the Polish zloty exchange rate



Source: NBP data. Authors' calculation.

Examining the role of the inflation environment in the exchange rate pass-through we do not estimate the threshold – it was set up at the level of the NBP inflation target. For the nonreversible linear function models the sample was divided according to the ascending or descending periods of inflation. The results are not clear – Wald test on the lack of asymmetry produces p-value at the level around 10%. Hence we decided to reject the hypothesis of asymmetric reaction.

[13] However Correa and Minella got different results for appreciations and depreciations.

5. Conclusions for the monetary policy.

In the paper we do an ‘exchange rate pass-through exercise’ on the Polish data, so the results can be country-specific. We find no evidence of a non-linear reaction of import prices with respect to the exchange rate changes. Due to the market imperfections asymmetry arises in the domestic links of the distribution chain. Our estimations of the consumer prices’ reaction show that the exchange rate pass-through tends to vary alongside the business cycle. It is relatively small during contractions and high during expansions. It also differs for changes in the nominal effective exchange rate below and above a threshold level, which is about 2%. In periods of increased exchange rate volatility, the pass-through effect becomes lower and tends to rise in the time of lower volatility.

Defining periods of the high and low pass-through effect (as a combination of the pass-through over the business cycle and during appreciations and depreciations) we find that the high pass-through occurs together with exogenous shocks and the low pass-through - immediately after such shocks, no matter if they are positive or negative. Hence, during the “ordinary” economic fluctuations, monetary policy faces average level of the pass-through rather than an asymmetric one.

The Polish example shows that even if there is some evidence of asymmetries with respect to, say, the output gap and appreciations and depreciations, to have a proper overview of its potential impact on the monetary policy, *all* sources of possible asymmetries should be considered.

Statistical Appendix

Table A1: Exchange rate pass-through. Estimation based on the McCarthy's SVAR.

Pass-through effect after → for ↓	**2 quarters**		**4 quarters**		**8 quarters**	
	Est.02	**Est.08**	**Est.02**	**Est.08**	**Est.02**	**Est.08**
Import transaction prices (PM)	**0.51**	**0.50**	**0.69**	**0.65**	**0.79**	**0.73**
Price index of the sold production of industry (PPI)	0.27	0.24	0.50	0.44	0.59	0.51
Consumption price index (CPI)	0.17	0.11	0.36	0.19	0.42	0.21

Source: Authors' calculations

Table A2: Time decomposition of the pass-through effect.

Time decomposition of the pass-through effect for ↓ (total P-T=100)	**Quarter after shock**				
	Q_0	Q_1	Q_2	Q_3	Q_4 to Q_8
Import transaction prices (PM)	17	49	25	4	5
Price index of the sold production of industry (PPI)	12	35	29	10	14
Consumption price index (CPI)	10	42	31	7	10

Source: Authors' calculations

Table A3. Exchange rate pass-through for Poland.

Period of estimation	**Method applied**	**Exchange rate pass-through to:**			
		Import prices		**Consumer prices**	
		Short-term	**Long- term**	**Short- term**	**Long- term**
1998-2008	VAR/VECM Przystupa,Wróbel		0.81		
1991-2004	Ca'Zorzi et al.	~ 0.70	1.30	~ 0.25	0.56
1999-2004	Korhonen, and Wachtel			0.09	0.09
1998-2008	Model based on the Phillips curve Przystupa and Wróbel			0.22	
1998-2008	Model NSA used at the NBP			0.27	
1990-1999	One-equation models Campa and Goldberg	0.50	0.99		

Table A4: Exchange rate pass-through.

	Period of estimation	Method used	Pass-through effect for:			
			Import prices		Consumer prices	
			After 2 q	After 8 q	After 2 q	After 8 q
Euro zone		**VAR/VECM**				
	1990-2002	Faruqee	0.42	1.17	0.01	0.02
	1983-2004	Ca'Zorzi et al.	0.55	0.72	0.06	0.13
		Single eq. model				
	1990-2004	Campa et al.	0.66	0.81		
DIT countries		**Structural model**				
	1971-1983 1984-2004	Gagnon and Ihrig				0.18 0.03
USA		**VAR/VECM**				
	1990-2002	Faruqee	0.15	0.30		
	1983-2004	Ca'Zorzi et al.	0.21	0.38	0.01	0.02
		Single eq. model				
	1990-2004	Campa et al.	0.26	0.41		

Table A5. Unit root test (ADF)

Variable, in logs, nsa	Trend and intercept, t-statistic, p-values in ( )	Intercept, t-statistic, p-values in ( )
p_t^{IMP}	-2.450 (0.350)	-2.36 (0.158)
p_t^{H}	-2.941 (0.160)	-1.386 (0.580)
p_t^{F}	-2.237 (0.458)	0.754 (0.992)
e_t	-1.525 (0.806)	-1.750 (0.400)
e_t^{NEER}	-0.983 (0.936)	-0.524 (0.877)
Variable, in logs, sa	Trend and intercept, t-statistic, p-values in ( )	Intercept, t-statistic, p-values in ( )
p_t^{IMP}	-2.640 (0.266)	-2.699 (0.082)
p_t^{H}	-3.085 (0.122)	-1.607 (0.720)
p_t^{F}	-2.756 (0.221)	0.275 (0.974)

Table A6. Johansen cointegration test - trace statistics (NEER)

Hypothesized no of ce(s)	Eigenvalue	Trace statistics	0.05 critical value	Probability
None	0.493755	60.42062	54.07904	0.0219
At most 1	0.317904	31.14904	35.19275	0.1009
At most 2	0.207372	14.69788	20.26184	0.5615
At most 3	0.103637	4.704618	9.164546	0.5125

Table A7. Johansen cointegration test - trace statistics (bilateral exchange rate)

Hypothesized no of ce(s)	Eigenvalue	Trace statistics	0.05 critical value	Probability
None	0.457465	57.91189	54.07904	0.0219
At most 1	0.399639	32.22877	35.19275	0.1009
At most 2	0.161961	10.79939	20.26184	0.5615
At most 3	0.077288	3.378395	9.164546	0.5125

Table A8. Cointergating vector - NEER

	VECM (cointegration Johansen), t-stat in [ ]
unrestricted	
α_1	-0.91 [5.92]
α_2	1.44 [2.21]
α_3	0.95 [5.19]
restricted: $\alpha_1 = \alpha_2$	Chi-square=0.56, p. 0.45
α_1	-0.81 [7.50]
α_2	0.81 [7.50]
α_3	1.13 [17.65]
restricted: $\alpha_1 = \alpha_2 = 1$	Chi-square=9.64, p. 0.008
restricted: $\alpha_1 = \alpha_2 = 1$, α_3=0	Chi-square=11.1, p. 0.011
restricted: $\alpha_1 = \alpha_2$, $\alpha_2 + \alpha_3$=1	Chi-square=10.21, p. 0.006

Table A9. Cointegrating vector, bilateral exchange rate EUR/PLN

	VECM (cointegration Johansen), t-stat in [ ]	Fully modified least squares t-stat in [ ]
unrestricted		
α_1	-0.71 [2.47]	0.68 [4.73]
α_2	0.41 [0.35]	0.74 [1.09]
α_3	0.83 [2.27]	0.82 [4.14]
restricted: $\alpha_1 = \alpha_2$	Chi-square=0.03, p. 0.86	Chi-square=0.018, p. 0.91
α_1	-0.78 [5.28]	0.67 [7.15]
α_2	0.78 [5.28]	0.67 [7.15]
α_3	0.71 [7.22]	0.84 [15.29]
restricted: $\alpha_1 = \alpha_2 = 1$	Chi-square=7.24, p. 0.026	Chi-square=12.46, p. 0.002
restricted: $\alpha_1 = \alpha_2 = 1$, $\alpha_3 = 0$	Chi-square=7.49, p. 0.058	Chi-square=260, p. 0.000
restricted: $\alpha_1 = \alpha_2$, $\alpha_2 + \alpha_3 = 1$	Chi-square=6.87, p. 0.032	Chi-square=40.0, p. 0.000

Table A10. Test of weak exogeneity

Variable	Chi-square (1)	Probability
p^H	2.49	0.11
e	0.011	0.92
p^H	2.67	0.102

Table A11. Dynamic import price equation

Variable	Coefficient	t-stat
β_0	0.0011	0.16
β_1	-0.464	-3.02
$\beta_{2,0}$	0.51	3.94
$\beta_{4,0}$	0.898	1.82

Table A12. Dynamic import price equation: appreciation of the EUR/PLN, usable obs.: 24.

Variable	Coefficient	t-stat, p-value in ( )
β_0^A	-0.0023	-0.16 (0.874)
β_1^A	-0.654	-2.96 (0.008)
$\beta_{2,0}^A$	0.55	1.58 (0.131)
$\beta_{4,0}^A$	1.29	1.8 (0.091)

Table A13. Dynamic import price equation: depreciation of the EUR/PLN, usable obs.: 20

Variable	Coefficient	t-stat
β_0^D	-0.0055	-0.39
β_1^D	-0.225	-1.03
$\beta_{2,0}^D$	0.599	2.07
$\beta_{4,0}^D$	0.77	1.12

Table A14. Dynamic import price equation: positive EC, usable obs.: 21.

Variable	Coefficient	t-stat
β_0^{EC+}	0.00183	0.08
β_1^{EC+}	-0.31	-0.63
$\beta_{2,0}^{EC+}$	0.66	4.27
$\beta_{4,0}^{EC+}$	0.003	0.0031

Table A15. Dynamic import price equation: negative EC, usable obs.: 23.

Variable	Coefficient	t-stat
β_0^{EC-}	-0.019	-1.62
β_1^{EC-}	-0.65	-2.01
$\beta_{2,0}^{EC-}$	0.16	0.82
$\beta_{4,0}^{EC-}$	2.0	3.39

Table A16. Phillips curve

$$\pi_{t,k}^{q_i} = \alpha_{1,k}^{q_i} E_t \pi_{t+1} + (1 - \alpha_{1,k}^{q_i} - \alpha_{2,k}^{q_i}) \pi_{t-1} + \alpha_{2,k}^{q_i} (\Delta e_{t-1}^{r}) + \alpha_{3,k}^{q_i} y_{t-2} + \varepsilon_t$$

	Coefficients				No. of obs. after adj.	p-value of J-statistic
	α_1	$1-\alpha_1-\alpha_2$	α_2	α_3		
Threshold models (τ = threshold)						
Output gap $q_i > \tau$	0.708 (7.16)	0.484	-0.192 (2.50)	0.138 (1.81)	22	0.59
Output gap $q_i \leq \tau$	0.497 (4.80)	0.682	-0.179 (2.43)	0.219 (1.79)	19	0.64
ΔNEER $q_i > \tau$	0.476 (3.98)	0.589	-0.065 (5.19)	0.318 (2.79)	21	0.19
ΔNEER $q_i \leq \tau$	0.450 (3.26)	0.789	-0.239 (3.24)	0.236 (2.67)	19	0.99
Volatility NEER $q_i > \tau$	0.931 (2.32)	0.316	-0.247 (2.63)	0.271 (1.75)	25	0.23
Volatility NEER $q_i \leq \tau$	0.611 (3.76)	0.938	-0.549 (2.56)	0.548 (1.81)	15	0.68
Inflation $q_i > \tau$	0.700 (2.88)	0.495	-0.195 (3.17)	0.425 (2.08)	15	0.37
Inflation $q_i \leq \tau$	0.738 (8.01)	0.463	-0.201 (1.98)	0.064 (1.74)	26	0.46
Nonreversible linear models						
Output gap $t_{i+1} > t_i$	0.568 (2.30)	0.706	-0.274 (1.96)	0.563 (2.11)	21	0.44
Output gap $t_{i+1} \leq t_i$	0.499 (3.78)	0.562	-0.091 (1.88)	0.306 (1.82)	20	0.52
ΔNEER $t_{i+1} > t_i$	0.577 (3.73)	0.441	-0.018 (1.63)	0.543 (1.68)	21	0.29
ΔNEER $t_{i+1} \leq t_i$	0.389 (1.73)	0.849	-0.238 (1.69)	0.151 (1.61)	19	0.98
Volatility NEER $t_{i+1} > t_i$	0.576 (5.21)	0.564	-0.140 (2.36)	0.132 (1.68)	20	0.21
Volatility NEER $t_{i+1} \leq t_i$	0.619 (3.34)	0.522	-0.141 (2.17)	0.359 (1.90)	21	0.99
Inflation $t_{i+1} > t_i$	0.922 (2.78)	0.238	-0.160 (1.72)	0.287 (1.98)	21	0.61
Inflation $t_{i+1} \leq t_i$	0.949 (5.17)	0.417	-0.183 (1.87)	0.262 (1.63)	20	0.27

Figure A1. Import prices (year 2000=100), overall PPI and PPI for the domestic market (year 2000=100), bilateral exchange rate, foreign prices (deflator of euro area export prices of manufacturing, year 2000=100).

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