First draft, comments welcome

Asymmetry of the exchange rate pass-through: An exercise on the Polish data[1]

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Abstract

In this paper we assess a level, linearity and symmetry of exchange rate pass-through to import and consumer prices (CPI) in Poland over the period 1997-2008. We distinguish four sources of nonlinearity: assigned to the business cycle – where the degree of the pass-through depends on the output gap, assigned to a direction of changes in the nominal effective exchange rate, i.e. appreciations and depreciations, assigned to the volatility of the nominal effective exchange rate, and finally – assigned to inflation environment.
We show that pass-through is incomplete even in the long run. The behaviour of import prices is affected by competitors' prices (pricing to market) in the long run and somewhat weaker in the short run.
We do not find a strong evidence of non-linearity in import prices reaction to the exchange rate. We also reject the hypothesis of an asymmetric response to appreciations and depreciations. On the other hand, we find out that there is 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; however it is mostly visible after such shocks like Russian crisis or the EU entry. We discuss potential outcomes for the monetary policy conduct[4].

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1. Introduction (non-technical summary)

Understanding how prices respond to the exchange rate is of key importance for a small open economy. In this paper we show the main properties of the exchange rate pass-through in Poland and asses their implications for the monetary policy. Our analysis covers a period 1997-2008 which is characterized by a rather homogenous monetary policy (inflation targeting) and a generally falling inflation rate. First we assess the degree of pass-through to import prices, examine if they exhibit pricing to market behaviour, 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 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 (1999 and 2001) where the impact of sequence of supply, demand and exchange rate shocks on the import, producer and consumer prices are examined, (see Przystupa (2002), Cholewiński (2008)). Since it is a popular method, for the sake of comparability with other studies we also provide the latest estimates we have obtained this way. They are shown in tables A1-A4 in the appendix. Generally, the pass-through of the exchange rate changes to the import prices did not alter between 2002 and 2008 and it is slightly over 0.7 after 8 quarters. 66% of the total effect takes place within the first two quarters. Pass-through to the consumer prices dropped from 0.42 in 2002 to 0.21 in 2007, and 52% of the shock has been absorbed in the first two quarters. 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 Gagnon, Ihrig 2008).

2. Theoretical considerations

Theoretical exchange rate pass-through literature is dominated by papers dealing with the degree of price adjustment and factors that it affect. The discussion started after numerous tests on variety of goods and across countries yielded very little evidence supporting a common in the earlier literature assumption of the absolute or relative Purchasing Power Parity (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 the seminal paper Dornbusch (1987) points 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 the 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. Devreux 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, firms choose a higher frequency of the adjustment the higher the rate of inflation, and the more volatile exchange rate. The higher the frequency of price adjustment, the higher is the pass-through effect. As a result Devreux and Yetman argue, that pass-through is endogenous to monetary policy.

Devreux, Engel and Storgaard (2003) analyze the determinants of an exporting firm 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 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 of a firm and therefore the degree of pass-through and that the degree of pass-through determines the volatility of exchange rate. On the other hand, Campa and Goldberg (2002) find that the higher inflation and exchange rate volatility are weakly associated with the higher pass-through.

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

Linearity and possible asymmetry are investigated less, 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. Though many papers used to assume linearity it does not have to be true. If there are some menu costs of price adjustment, then relatively small changes in the exchange rate may not be passed to prices. Only after exceeding a certain threshold these changes might be passed on customers. Moreover, if some changes in the exchange rate are perceived as transitory, they may be ignored by the price setters. On the other hand, if domestic prices react more to, say, depreciations than to appreciations, so if there is an asymmetry in the price reaction to the exchange rate changes, it may reflect distortions in the markets, in particular weak competition.

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 and 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 literature assuming linearity and symmetry and that testing it has been shrinking. Early works on this topic are Mann (1986) and Goldberg (1995), who find asymmetries of consumer prices reaction to appreciations and depreciations. More papers appeared only after the year 2000. Devreux and Yetman in the paper mentioned above use a cross-section time series model to show that there is 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 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 find that in fact 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, non-symmetrical to the sign of the deviation and finally thresholds below which no adjustment takes place. Using data on the industries-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) do not find evidence of non-linearity in the reaction of import prices in the UK. On the other hand, 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 reaction to the former is bigger than to the latter. There is a weak asymmetry between reaction of import prices to appreciations and depreciations in Chile (Alvarez et al. (2008)). Bussière (2007) investigates whether export and import prices of G7 countries exhibit linear and symmetrical reaction the exchange rate movements. He finds that non-linear effect cannot be neglected, although the direction of the asymmetries and the magnitude of non-linearities vary across countries. 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. 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 short run pass-through is higher when the economy is growing faster, when the exchange rate depreciates above some threshold and when exchange rate volatility is lower. Goldfajn and Werlang (2000) use a panel of 71 countries and also report asymmetric reaction of pass-through over the business cycle. To sum up, there is 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 second 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. It 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 asymmetric reaction of the 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. 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 depends on competitor's prices. Thus, 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 persistent low degree of pass-through[5]. In this vein, Bergin and Feenstra (2001) using a general equilibrium model show that segmented markets with identical preferences cannot explain incomplete pass-through in contrast to segmented markets with different preferences, and therefore they consider translog preferences which have a property that 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 showed 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.

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

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:

(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 it seems to be in this case, then limiting 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, what 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 rather as guidelines than sharp point estimates.

Taking into account shortness of our sample and a 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.

But, what is important, however, 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 estimation easier and more reliable and therefore partially offsets 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 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))[6]. 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 confine the discussion of import prices behaviour with respect to the bilateral exchange rate (PLN/EUR[7]). One reason is the big role of imports from the EU in the total imports (about two thirds in 2007), another is the fact that imports from the euro area consists 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 rather a feature of manufacturing 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 in the dynamic equation quadratic and cubic terms are lacking. 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 data problems to the end of 1999 it is an overall index, since 2000 it comprises goods produced for the domestic market only. As it is clear from the 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

[6] The authors show changes in the exchange rate regime and the role of the exchange rate in the monetary transmission.
[7] Upside movement of the exchange rate means depreciation.

that seasonally adjusted data with 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[8].

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 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 behaviour 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 Chi-square test shows that we cannot reject this hypothesis. In the restricted version pass-through is approximately 0.8 for both NEER and the bilateral exchange rate. All variables are statistically significant, and 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 can be rejected at the 1% level the restriction $\alpha_1 = \alpha_2 = 1$, $\alpha_3 = 0$ (the law of one price) nor the restriction $\alpha_1 = \alpha_2$, $\alpha_2 + \alpha_3 = 1$ (unit homogeneity) and $\alpha_1 = \alpha_2 = 1$ (unit coefficients on the exchange rate and foreign prices) for the bilateral exchange rate. 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 PLN/EUR 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 in the unrestricted cointegrating vector all parameters but foreign prices are statistically significant, and that once again with except of foreign prices, 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 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

[8] 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.

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[9].

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 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[10]. 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 periods of appreciation and depreciation of the Polish currency. Thus we set:

$$A_t = \begin{cases} 1 & \text{if } \Delta e_t < 0 \\ 0 & \text{otherwise} \end{cases} \text{ and } D_t = \begin{cases} 1 & \text{if } \Delta e_t > 0 \\ 0 & \text{otherwise} \end{cases}$$

and in equation (7) 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 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, what means that exporters in the euro zone do not increase mark-ups, but rather care about future market share. The effect of instantaneous pass-through is 0.55, but it is estimated with a low T-statistics. A different picture emerges for 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 PLN/EUR appreciations only. When exporters' currency appreciates the exporters do not tend to lower their mark-ups. What can be a reason for such asymmetry? There are at least three, seemingly consistent, arguments. First, exporters expect rather appreciation than depreciation of the Polish zloty with respect to the euro and treat

[9] We do reproduce the results of Granger causality here.
[10] The same test is used in Herzberg et al. (2003)

depreciations as short-lived and therefore are not afraid of loosing 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: positive and 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 example too high transport costs, inclusion of other costs in the price, like insurance or hedging cost 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 behaviour, but its impact is very small. Depreciation of the PLN/EUR 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 transport 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 disequilibrium in one quarter; there is also a statistically significant and relatively big impact of pricing to market, what means that distribution and transport costs may be overpriced.

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

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

- 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);
- real marginal costs approximated by the output gap (y_t) – e.g. Woodford (2003);
- real exchange rate – contemporaneous (e_t^r) and expected ($E_t e_{t+1}^r$) – e.g. Woodford (2003).

For the monetary policy the response of the interest rates to inflation seems to be the key question. The optimal response depends on the slope of the Phillips curve. If the Phillips curve is linear, the slope is constant then the Taylor rule (Taylor, 1993) is applied. If the Phillips curve is non-linear, the slope is not constant, then the optimal response of interest rates to inflation is a function of the output gap.

On the other hand, the slope of the Phillips curve depends on determination whether the function is convex or concave. Filardo (1998) found that the Phillips curve is not purely convex or concave and 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 rise prices than to lower them, but the cost of fighting inflation is lowering – the slope of the Philips curve steeping) and if the output gap is negative, the Phillips curve is concave (firms are more reluctant to rise prices than to lower them, but the cost of fighting inflation is rising – the slope is flatting).

Accepting that the effectiveness of the monetary policy is determined by the slope of the Phillips curve, we investigate the possibility of non-linear reaction of inflation to the exchange rate changes along the business cycle.

4.1. Estimation methods

As it was shown in the Introduction, the exchange rate pass-through to the consumer prices in Poland seems to be relatively high (about 0.2), similar to that of the developed countries in the eighties of the last century. Under high average pass-through, an investigation whether and when a non-linearity of the pass-through occurs could facilitate monetary policy conduct.

The existence of the asymmetry in the exchange rate pass-through was investigated in relation to the business cycle approximated by output gap, to appreciations and depreciations of the nominal effective exchange rate of zloty, to volatility (standard deviation) of the nominal effective exchange rate and to inflation environment. Only two states (regimes) were discriminated for any economic process and output gap, NEER and inflation were set up as the variables caused transformation from one regime to another.

To divide the sample into properly defined sub-samples we use two methods. The first one splits the sample into classes, based on 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 (1996). Caner and Hansen (2004) develop an estimator which can be used for models with the endogenous variables but with an exogenous threshold variable. This allows estimating thresholds for dynamic models. Based on the procedure and program described in Caner and Hansen (2004) we estimated SETAR (**S**elf-**E**xciting **T**hreshold **A**uto**R**egresive) model of the general form:

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

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

Usually the threshold value is unknown and has to be estimated. Estimating the threshold by the ML method, maximum of the likelihood function has to be found, estimating by the TSLS or GMM method – the sum of the squared residuals shall be minimized.

Our sample consists of 46 observations and due to their small number we assumed the estimated threshold must split the data into sub-samples with minimum 15 observations. Franses and van Dijk (1999) show 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, nominal effective exchange rate (NEER), NEER volatility and inflation environment.

The second method based on Wolffram's (1971) idea, developed 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** then 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;

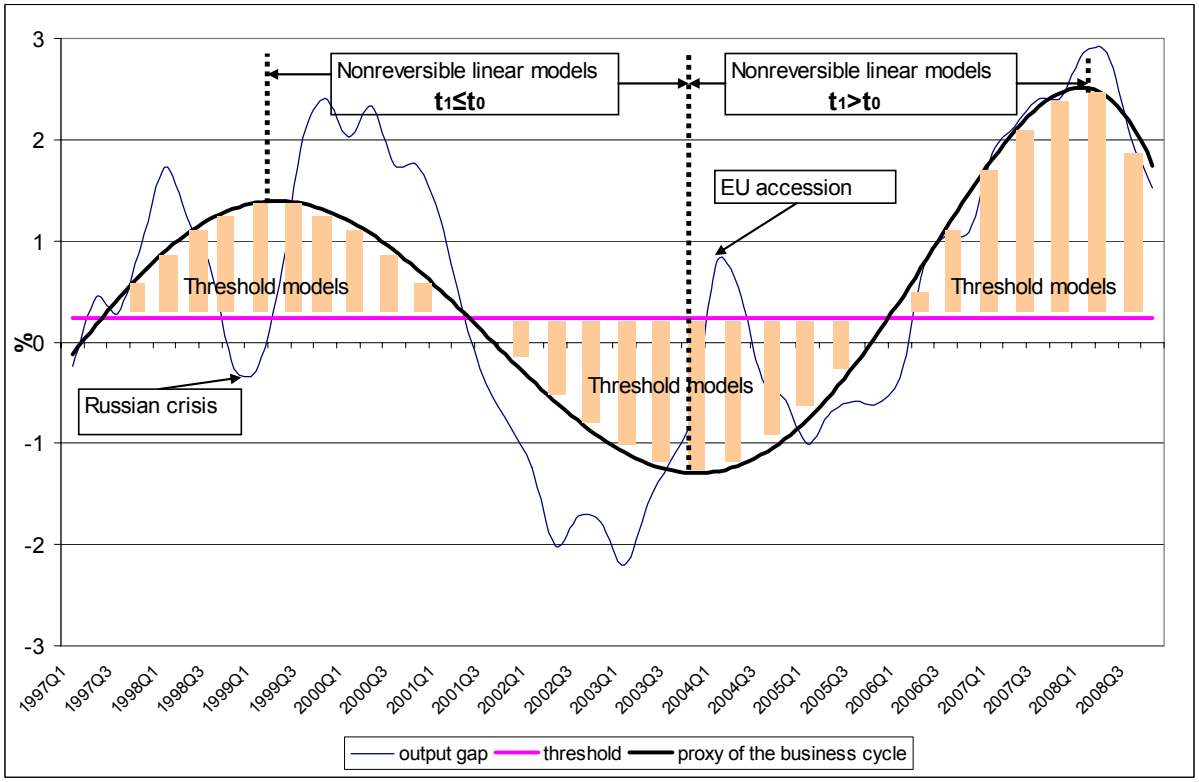
$j = 1,2,\ldots,T_1,T_2$; $T_1,T_2 < t$ (j – number of lags assigned to $\Delta X'_i, \Delta X''_i$).

A nonreversibility of the function ΔY_i occurs, i.e. 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 described above split the sample into different sub-samples with different economic interpretation. Output gap (approximation of the business cycle), 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: Own calculations.

The output gap for Poland was calculated as a percentage deviation of the GDP from the potential GDP[11]. Assuming that output gap approximates the economic activity along the business cycle, output gap values over the estimated threshold can be interpreted as periods of prosperity (late expansion, peak and early recession); values under the threshold – as a slump (late recession, trough and early expansion). The threshold estimated for 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 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.
The total sample contains 46 observations between 1q 1997 and 2q 2008 and seems to cover one and a half of the business cycles and two exogenous shocks: "Russian" crisis in 1998 and Poland's accession to the EU (2004)[12].

The exchange rate pass-through to the CPI inflation was estimated on the basis of the Philips curve similar to that which has been implemented in the small scale highly aggregated new-keynesian model that was developed at the NBP and served for inflation forecasting (see Kłos et al., 2005). The model was designed to capture inflation dynamics only. It was built on the standard assumptions of sticky prices and wages. Basic macroeconomic relationships included: the IS curve, uncovered interest parity (UIP) and the Phillips curve. The output gap in this model depends on its lagged value, the ex-ante real interest rate, the real effective exchange rate and the variable representing external demand. The nominal effective exchange rate (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.
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 $q_i \leq \tau$

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

[11] As in the case of the estimates for import prices, potential GDP was derived from the Hodrick-Prescott filter with λ=1600. In order to diminish the role of the last observations, the GDP sample was lengthen by the AR1 process.
[12] The approximate date of Poland's accession to the EU was known since 2002 but reaction of the economy could only be roughly predictable – therefore it can be treated as a shock.

The Phillips curve was estimated using the GMM method, where the instrumental variables were derived from a set of variables explaining the behaviour of the exchange rate of zloty since implementation of direct inflation targeting. Nominal effective exchange rate and the output gap were also included. Such procedure allows for relationships among the variables in the model of inflation. Having the shape of the Phillips curve set up, the instrumental variables were chosen in the manner assuring a proper sign at all explaining variables, correct value of the t-statistic and p-value of the J-statistic (to test overidentification of restrictions– if number of instruments exceeds the number of the estimated parameters; H_0: the overidentyfing restrictions are satisfied)). All things considered, 16 equations with the threshold and the nonreversibility method were estimated. Values of coefficients, t-statistic, J-statistic and number of observations are presented in the table A15 in the Appendix.

4.2. Estimation results.

If the relatively small number of observations, strictly connected with the changes in the structure of the Polish economy, is acceptable, the results of investigation of the asymmetric shocks are not inconsistent with the theoretical expectations and can help to better understand the nature of the asymmetry. The results are presented in Table 1 and Figure 2.

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.

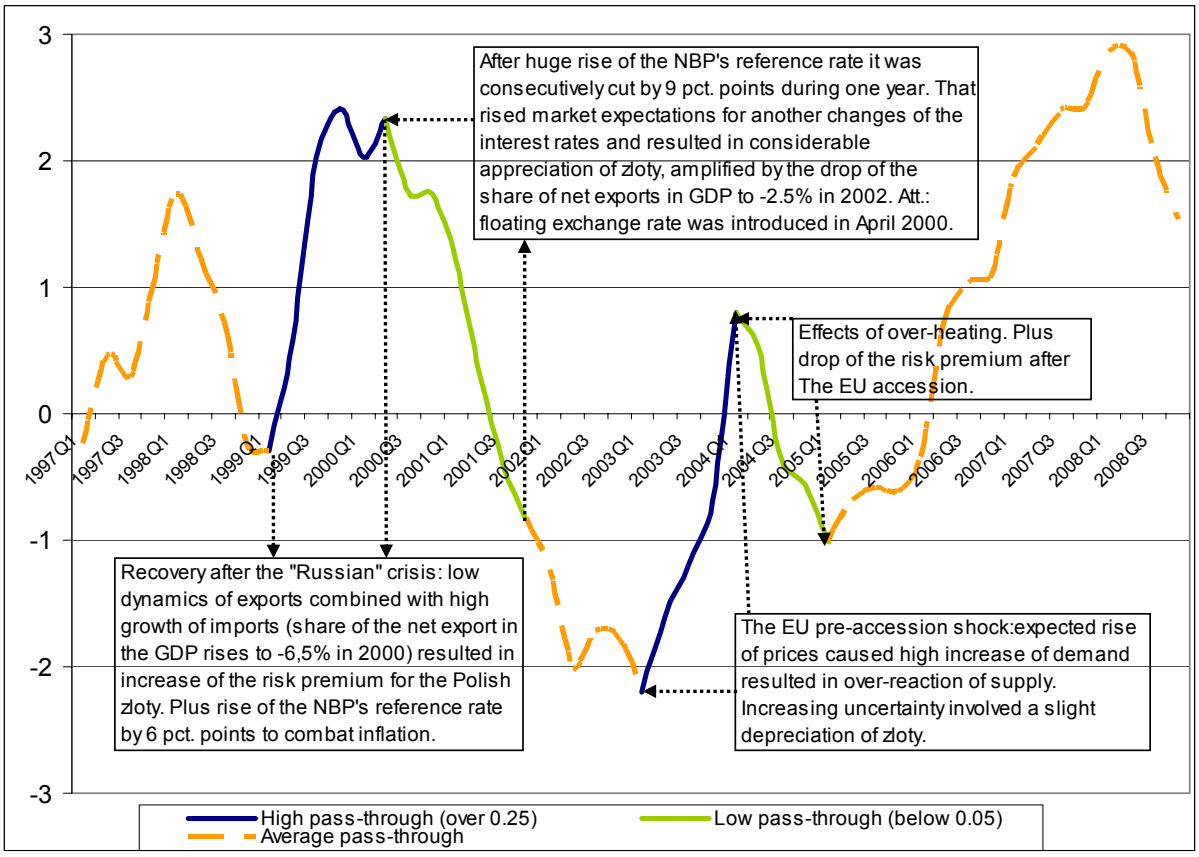
The estimation of the threshold for the output gap consistent with the Phillips curve shows its slight deviation from zero – 0.24%. Due to the fact that the analyzed period covers a relatively homogenous policy (inflation targeting), the difference may suggest a small inefficiency of the monetary policy, particularly during prosperity. In that period, a diminishing role of output gap in inflation explanation is combined with the higher role of inflation expectations. The respective coefficients are 0.14 and 0.71, compared to 0.22 and 0.49 during slump (table A16).

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

Combination of these two findings would suggest that the pass-through effect might be even over 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 behaviour of enterprises in the business cycle, conditioning their investment decisions on expected profits with maximum in the early expansion and minimum in the early recession (see, e.g. Kalecki (1943) or Mankiw (2006)). Inclination of the enterprises to price changes follows profit expectations.

On the other hand, a strong asymmetric reaction was identified in periods of appreciations and depreciations. If 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.

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



Source: Authors' estimations.

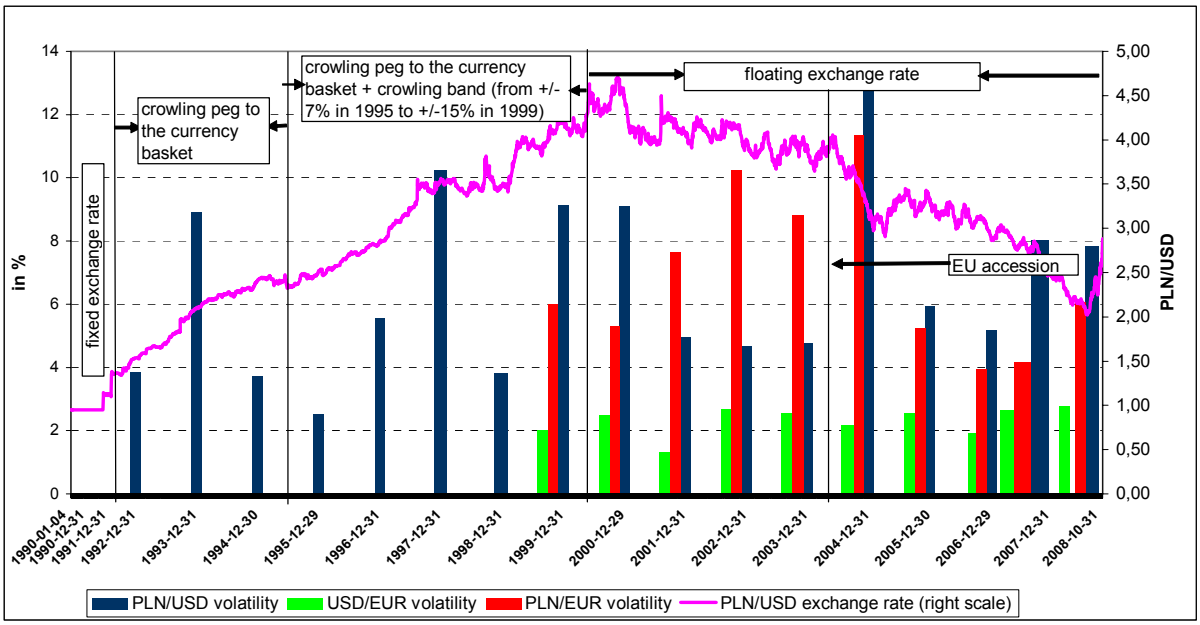
Combining the pass-through behaviour along the business cycle and during appreciations and depreciations, periods of the low and high pass-through were defined. The low pass-through can be identified when appreciation and contraction (recession) occurred simultaneously. For the high pass-through one needs a simultaneous occurrence of expansion and depreciation. In a business cycle the probability that such phenomenon takes place is low. However, identifying these periods for the Polish economy, we found two periods of high and low episodes of the pass-through effect (Figure 2).

The first one occurred in 1998, when the Russian economy contracted due to a severe financial crisis which burst out in this country 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, the pass-through remained at an average level. The coincidence of a faster growth and the depreciation, i.e. the high pass-through, occurred just after the shock and lasted about four quarters. The rapid recovery was followed by a slowdown and appreciation of zloty induced by market 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 of appreciation.

The second episode of such coincidence occurred before Poland's accession to the EU. The "ordinary" recovery was speeded up by the external positive shock. An excessive rise of demand resulted in an over-reaction of supply. Increasing uncertainty together with a diminishing interest rates disparity involved a slight depreciation of zloty. The period of high pass-through effect lasted from the 2nd quarter of 2003 until the 1st quarter of 2004, i.e. four quarters (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 1st quarter of 2005, i.e. 4 quarters.
It can suggest that episodes of high and low pass-through occur together and immediately after an exogenous shock. The direction of the shock does not matter.

The average volatility of the Polish zloty calculated for each quarter between 1997 and 2008 as the 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 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 to 0.25 and 0.55 otherwise. The lower pass-through in case of a higher volatility can reflect the producers' reluctance to frequent price changes due to the menu costs. These results are consistent with for example Pollard and Coughlin (2003) or Correa and Minella (2006); however, the last one got for Brazil similar results regarding volatility, but clearly opposite to ours in the case of the direction of the exchange rate changes. Generally, periods of high volatility of zloty are covered by periods of high pass-through effect; hence, they do not raise the total pass-through.

Figure 3. History of the Polish zloty exchange rate



Source: NBP data. Authors' calculation.

Looking for the role of the inflation environment in the exchange rate pass-through behaviour we do not estimate the threshold – it was set up at the level of the NBP inflation target. On the other hand, for the nonreversible linear function models, the sample was divided according to the ascending or descending periods of inflation. The results obtained do not produce a clear picture. In both methods used, the Wald test on the lack of asymmetry produces p-value at the level around 10%. Hence we decided to reject the hypothesis that the asymmetry exists, the more that it is close to the average level of the pass-through.

5. Conclusions for the monetary policy.

1. The exchange rate pass-through to the import prices varies between 0.7-0.9 and is similar to that of the other developed countries. Pricing to market exists, but reactions of import prices to the exchange rate seem to be symmetric.
2. Asymmetry arises in the domestic links of the distribution chain.
3. Defining periods of the high and low pass-through effect we find they occur together and immediately after an exogenous shock. The direction of the shock does not matter. Hence, during the "ordinary" economic fluctuations, the average level of the pass-through shall be taken into consideration.
4. In period of prosperity, a diminishing role of output gap in inflation explanation is combined with the higher role of inflation expectations. The respective coefficients are 0.14 and 0.71, compared to 0.22 and 0.49 during slump.

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: Reestimation of the SVAR described in: Przystupa J. (2002), *The exchange rate in the monetary transmission mechanism*, Materiały i Studia, nr 25, NBP

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: see table A1.

Table A3. Exchange rate pass-through for Poland.

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

Source: Based on works of the authors mentioned in the table. Details: in the References.

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	1990-2002	**VAR/VECM** H.Faruqee	0.42	1.17	0.01	0.02
	1983-2004	M.Ca'Zorzi et al.	0.55	0.72	0.06	0.13
	1990-2004	**Single eq. model** J.Campa, L.Goldberg, J.Gonzalez	0.66	0.81		
DIT countries	1971-1983 1984-2004	**Structural model** Gagnon i Ihrig				0.18 0.03
USA	1990-2002	**VAR/VECM** H.Faruqee	0.15	0.30		
	1983-2004	M.Ca'Zorzi et al.	0.21	0.38	0.01	0.02
	1990-2004	**Single eq. model** J.Campa, L.Goldberg, J.Gonzalez	0.26	0.41		

Source: see table A3.

Table A5. Unit root test (Augmented Dickey-Fuller)

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 (nominal effective exchange rate)

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, exchange rate - 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]
α_0	1.86 [1.45]
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]
α_0	2.95 [4.44]
restricted: $\alpha_1 = \alpha_2 = 1$	Chi-square=9.64, p. 0.008
restricted: $\alpha_1 = \alpha_2 = 1,\ \alpha_3 = 0$	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 PLN/EUR

	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]
α_0	2.03 [0.51]	-3.51 [-1.45]
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]
α_0	-3.25 [-4.91]	-3.26 [-6.76]
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 PLN/EUR, 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 PLN/EUR, 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

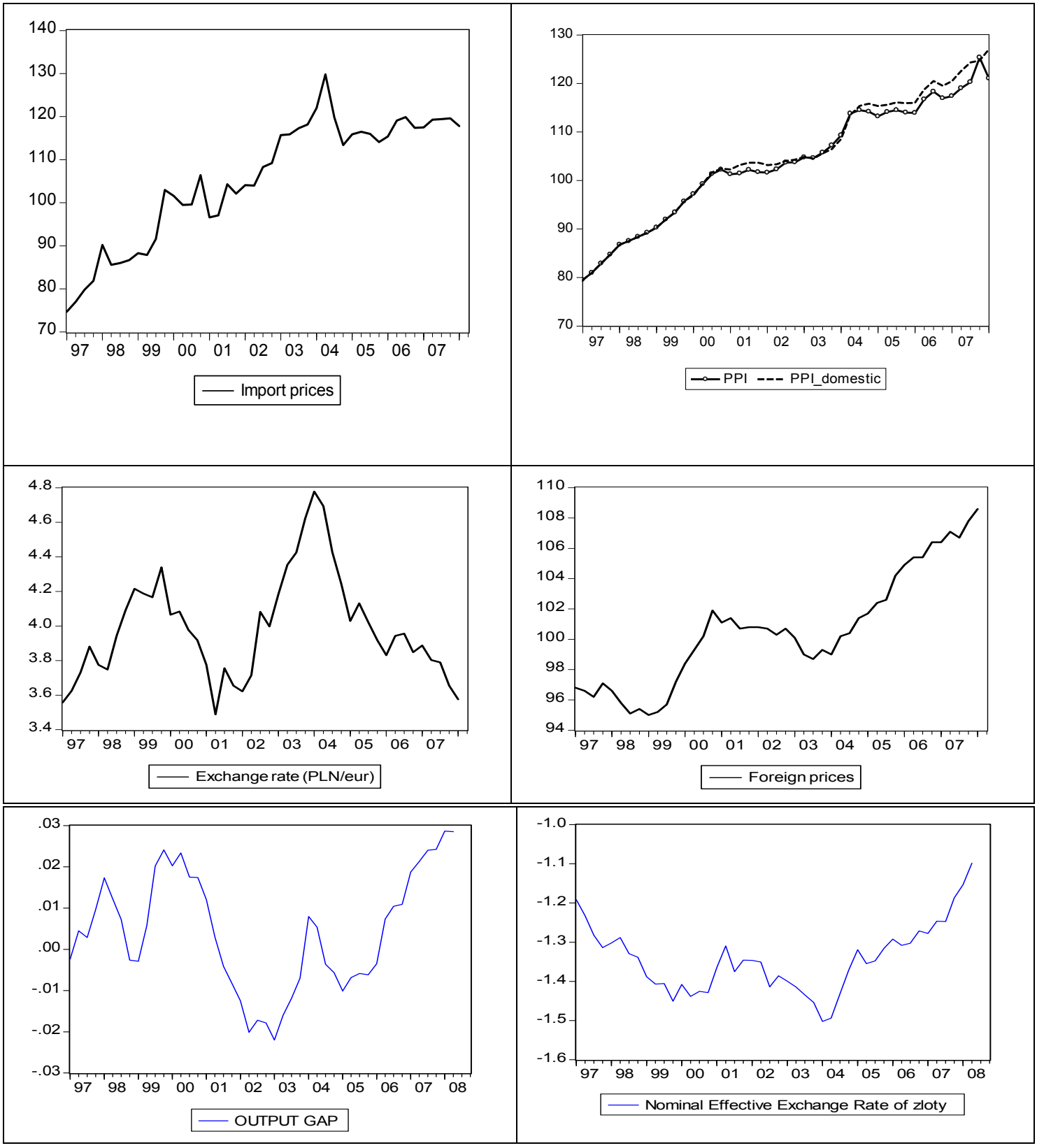
Table A16. Results of the Phillips curve estimation.

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

	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)						
$q_i > \tau$ Output gap	0.708 (7.16)	0.484	-0.192 (2.50)	0.138 (1.81)	22	0.59
$q_i \leq \tau$	0.497 (4.80)	0.682	-0.179 (2.43)	0.219 (1.79)	19	0.64
$q_i > \tau$ ΔNEER	0.476 (3.98)	0.589	-0.065 (5.19)	0.318 (2.79)	21	0.19
$q_i \leq \tau$	0.450 (3.26)	0.789	-0.239 (3.24)	0.236 (2.67)	19	0.99
$q_i > \tau$ Volatility NEER	0.931 (2.32)	0.316	-0.247 (2.63)	0.271 (1.75)	25	0.23
$q_i \leq \tau$	0.611 (3.76)	0.938	-0.549 (2.56)	0.548 (1.81)	15	0.68
$q_i > \tau$ Inflation	0.700 (2.88)	0.495	-0.195 (3.17)	0.425 (2.08)	15	0.37
$q_i \leq \tau$	0.738 (8.01)	0.463	-0.201 (1.98)	0.064 (1.74)	26	0.46
Nonreversible linear models						
$t_{i+1} > t_i$ Output gap	0.568 (2.30)	0.706	-0.274 (1.96)	0.563 (2.11)	21	0.44
$t_{i+1} \leq t_i$	0.499 (3.78)	0.562	-0.091 (1.88)	0.306 (1.82)	20	0.52
$t_{i+1} > t_i$ ΔNEER	0.577 (3.73)	0.441	-0.018 (1.63)	0.543 (1.68)	21	0.29
$t_{i+1} \leq t_i$	0.389 (1.73)	0.849	-0.238 (1.69)	0.151 (1.61)	19	0.98
$t_{i+1} > t_i$ Volatility NEER	0.576 (5.21)	0.564	-0.140 (2.36)	0.132 (1.68)	20	0.21
$t_{i+1} \leq t_i$	0.619 (3.34)	0.522	-0.141 (2.17)	0.359 (1.90)	21	0.99
$t_{i+1} > t_i$ Inflation	0.922 (2.78)	0.238	-0.160 (1.72)	0.287 (1.98)	21	0.61
$t_{i+1} \leq t_i$	0.949 (5.17)	0.417	-0.183 (1.87)	0.262 (1.63)	20	0.27

Source: Authors' estimation.

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



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