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Transmission of Exchange Rate Shocks into Domestic Inflation: The Case of the Czech Republic*

Oxana BABECKÁ-KUCHARČUKOVÁ – Czech National Bank
(Oxana.Babetskaia-Kukharchuk@cnb.cz)

Abstract
This paper aims at estimating the exchange rate pass-through (ERPT) for the Czech Republic. The existing empirical literature does not come to a consensus about the degree of pass-through to Czech inflation. Since there is no unique approach regarding how to measure ERPT, we use 11 specifications, including some along the distribution chain in the spirit of McCarthy (2007). We try to explore the properties of exchange rate shock transmission by comparing impulse responses. In addition, we try to account for possible variation in time. Finally, we explore how the pass-through differs between tradable (3 sub-groups) and non-tradable goods. We find that the speed of exchange rate shock transmission to all prices is quite high. However, in absolute terms, ERPT does not exceed 25–30 %.

1. Introduction

By joining the European Union, the new EU members take on an obligation to adopt the euro at some point. This is preceded by a required minimum two-year membership in the ERM-II, which imposes certain exchange rate stability criteria. At the same time, the catching-up process in the new member states is reflected in higher productivity growth vis-à-vis the euro area, which, in turn, entails real exchange rate appreciation. Also, the exchange rate still represents a useful instrument of adjustment to various shocks. The new member countries that join the ERM-II might be viewed as balancing their monetary policy between low inflation, as required by the Maastricht criteria, and a stable exchange rate vis-à-vis the euro, as imposed by the ERM-II. In this context, the link between the exchange rate and inflation, or, more precisely, the *pass-through effect* of a variation in the nominal exchange rate on domestic inflation, receives particular attention. From a policy perspective, understanding the mechanism of transmission of exchange rate shocks into domestic inflation is vital for the implementation of a country's monetary and exchange rate policies. As a small open economy, the Czech Republic can be sensitive to external shocks. At the same time, the empirical literature finds low pass-through in a low inflation environment or when a country has inflation targeting.

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Given the high interdependence of economic factors, the mechanism of transmission of an exchange rate shock into the domestic economy does not appear simple. The literature on exchange rate pass-through comes to a consensus that the pass-through to domestic inflation is incomplete. However, the reasons are quite diverse. The low reaction of domestic prices is explained by strong competition, pricing to market, currency invoicing, degree of openness, and other factors. It is not surprising that there is no unique model to measure the pass-through effect, and the results vary significantly across studies and across countries.

The aim of the present paper, therefore, is to re-assess the dynamics and magnitude of exchange rate pass-through to Czech inflation. The existing empirical literature on pass-through for the Czech Republic reports estimates varying in the short run between 0 % and almost 40 %. However, these estimates are not always comparable. Since it is not clear which factor dominates, the present paper estimates ERPT using numerous specifications previously used in the literature applied to the same sample and time periods and using the same definitions of the exchange rate and inflation. This allows us to compare the pass-through estimates across models, to account for a large number of factors that could influence the transmission mechanism, as well as to check how sensitive the results are to alternative specifications and econometric procedures.

The paper has the following structure. The section 2 gives a definition of pass-through and discusses its properties. In the section 3, we explain the different approaches to modeling ERPT and take corresponding examples from the literature on ERPT to consumer prices estimated for the Czech Republic. The section 4 explains the estimation methods. The data and preliminary tests are described in the section 5. Section 6 shows the results. The main empirical findings are summarized in the conclusion.

2. Definition and Properties of ERPT

Traditionally, exchange rate pass-through is defined as "the percentage change in the local currency price of an imported good resulting from a 1 per cent change in the nominal exchange rate between the exporting and importing countries"[1]. Menon (1995) makes a survey of empirical studies on exchange rate pass-through conducted between 1974 and 1994. Most of these studies analyzed pass-through effects to export and import prices, estimated for large developed economies. Later, the analysis of exchange rate pass-through was extended to consumer and producer prices.

Exchange rate fluctuations impact on economic activity through two channels. Import prices transmit an exchange rate shock into domestic inflation directly, via imported goods, which constitute a part of final consumption, and indirectly, via imported inputs and intermediate goods for domestically produced products. A change in prices of imported goods may also cause a change in prices of goods produced domestically, even when they do not contain imported components. This effect may be substantial in a highly competitive environment. From the macro perspective, the indirect effect of an exchange rate shock can be considered as a change in the real exchange rate which has an impact on aggregate demand and the output gap.

[1] Bailliu and Fujii (2004)

ERPT to domestic inflation is lower than ERPT to prices of imported goods. An exchange rate shock affecting one stage of production is transmitted to consumer prices. Since the production and distribution process takes some time, the transmission mechanism is not likely to be immediate. Starting from McCarthy (1999), the majority of the ERPT studies focusing on domestic inflation base their analysis on the so-called distribution chain containing input prices, intermediate prices, and prices of final goods. The main advantage of this approach is its ability to compare the reaction of prices to an exchange rate shock at different stages of the distribution process. By and large, ERPT is expected to decline along the distribution chain, i.e., consumer prices are expected to react much less than import prices. When the reaction to a shock is less than the initial shock, the pass-through is incomplete. Most empirical studies find incomplete pass-through.

A class of the New Open Economics Models (NOEM) assumes that exchange rate pass-through may be endogenous to the country's monetary policy and the country's inflation performance. Starting from Taylor (2000) numerous empirical studies find that exchange rate pass-through declines if the inflation environment turns low--inflationary, because this causes a "decline in the expected persistence of cost and price changes". Choudhri and Hakura (2006) test this relation empirically in a sample of 71 countries over 1979–2000. The authors argue that ERPT tends to be low in economies where inflation is low and monetary policy is more credible. This finding is also proved by Bailliu and Fujii (2004) and Gagnon and Ihrig (2004) in the long run. The authors use a macroeconomic model and Monte-Carlo simulations for parameterization of their model. Then, the model is fitted for 20 industrial countries using quarterly data over 1971–2003. Flamini (2004) proposes an analytical framework for incomplete or delayed pass-through to CPI inflation in a small-open economy. His approach is based on a dynamic stochastic general equilibrium model. Coricelli et al. (2006) explain differences in the completeness of pass-through also by differences in exchange rate regimes: countries with inflation targeting and flexible exchange rate arrangements have much smaller pass-through than those with less flexible exchange rate regimes. The authors find complete pass-through in Slovenia and Hungary. The impact of an exchange rate shock is smaller in Poland and the Czech Republic. The other possible explanations of low pass-through include a low share of imported goods, price stickiness of non-tradable goods in the consumption basket, the substitution effect (Burstein et al., 2002), the presence of intermediaries between exporters and consumers, currency invoicing and local distribution costs (Bacchetta and van Wincoop, 2003), and slow adjustment of consumer goods prices in a highly competitive environment. The signal from the exchange rate can also be distorted by menu costs and contracting costs (Devereux and Yetman, 2002) or firms' pricing-to--market strategy (Corsetti and Dedola, 2005). Notice, however, that changes in domestic prices are not necessarily caused by changes in the exchange rate. For this reason, Darvas (2001) proposes to decompose price changes into pass-through and price convergence effects.

Pass-through estimates on the aggregate consumer price index assume that pass-through is the same for all goods in the consumption basket. Parsley (1995), cited in Darvas (2001), criticizes the use of aggregated price indices for the estimation of exchange rate pass-through. Inference from the disaggregated level has some advantages. For example, different industries may have different sensitivities to

inflation changes. One explanation for this fact is a different degree of competition among market segments. The use of disaggregated price indices can, furthermore, let us take into account that prices of non-tradables grow faster than prices of tradables. However, due to data availability, most of the existing studies use aggregated price indices, and only a few studies, mostly performed on US data, analyze pass-through using disaggregated data. For developed countries this question was addressed, for example, in Pollard and Coughlin (2003). For transition economies, to our knowledge, there are only two studies on disaggregated pass-through. Dabusinskas (2003) estimates disaggregated pass-through for Estonia, and Bitāns (2004) shows impulse responses of various CPI sub-groups for Latvia. According to these results, the level of price aggregation affects the estimates of pass-through. Last but not least, ERPT is not necessarily symmetric and constant over time.[2]

Based on the general pass-through properties, we expect that the ERPT to Czech inflation is far from complete. This is due to both a low-inflation environment and inflation targeting. Import prices constitute about 25 % of the CPI. On the contrary, pass-through to import prices is likely to be very high for at least two reasons. First, the Czech Republic is a small open economy with a ratio of exports/imports to GDP exceeding 60 %. Second, according to Kamps (2006), during 1999–2004 around 90 % of contracts for imported goods were denominated in foreign currency (mostly in euro). In the empirical sections of the paper, we address most of the properties of ERPT, namely, the speed and magnitude of its transmission into domestic inflation. In addition, we try to test whether the pass-through varies over time. We show how different the reaction of price indices is along the distribution chain, and how different the results are when more disaggregated data are used instead of the aggregated index.

3. Approaches to Modeling ERPT: The Case of the Czech Republic

Pass-through to consumer prices is less transparent than pass-through to import prices. In its most basic form, the pass-through is obtained from interactions among the exchange rate, domestic consumer prices, and the most important transmission channel – import prices. Due to data problems, import prices are sometimes replaced by foreign consumer prices, reflecting the influence of the external economic environment. The advantage of such a model is its simplicity, which preserves the degree of freedom when the time series is short. However, it can suffer from misspecification due to neglect of the possible pass-through determinants. This criticism, however, can also be addressed even at sophisticated pass-through models.

Despite the relatively simple definition of exchange rate pass-through, in practice it is approximated and estimated by various approaches. One possible method is a simple one-equation regression. However, the most commonly applied method is VAR or structural VAR (SVAR).[3] In a VAR framework, short-run pass-through is measured as an impulse response to a given shock[4], which allows us to in-

[2] See, for example, Bussière (2006) for asymmetric pass-through and Darvas (2001), Rincon et al. (2005), and Sekine (2006) for time-varying pass-through estimates.

[3] Pass-through estimates can also be obtained from a calibrated structural model. On the one hand, the advantages of this model include its theoretical foundations and the inclusion of monetary policy or central bank reaction functions. On the other hand, one criticism of the structural models concerns the presence of pre-calculated parameters, frequently chosen on an *ad-hoc* basis.

Table 1 Pass-through Estimates for the Czech Republic and the Euro Area

author	estimation method	short-run and [long-run] ERPT	variables included in the model											
			supply shock pm^{oil}	demand shock			distribution chain					extern. monetary shock policy		
				gap	*dgp*	***s***	*w*	*pm*	*px*	*py*	***pc***	pc^f	*m*	*i*
EURO AREA														
McCarthy (1999)	VAR	0 [c]	X	X		**X**		X		X	**X**		X	X
McCarthy (2007)	VAR	0 [c]	X	X		**X**		X		X	**X**			
Faruqee (2006)	VAR	0.02				**X**	X	X	X	X	**X**			
Hahn (2003)	VAR	0.08	X	X		**X**		X		X	**X**			X
CZECH REPUBLIC														
Bitāns (2004)	VAR	0.21;0.13		X		**X**				X	**X**		X	X
Ca'Zorzi (2007)	VAR	[0.61;0.55]	X	X		**X**		X			**X**			X
Campa Goldberg (2006)	OLS	0; [0.60]			X	**X**					**X**	X		
Campa Goldberg (2006)	SVAR	0				**X**		X			**X**	X		
Coricelli et al. (2006)[a]	CVAR	[0.46]				**X**				X	**X**			X
Darvas (2001)[b]	VAR, EC	0–0.04; 0.15				**X**					**X**	X		
Darvas (2001)	TVEC	0.10;0.15				**X**					**X**	X		
Korhonen Wachtel (2006)	VAR	0.03;0.09	X			**X**					**X**	X		
Mihaljek Klau (2001)	OLS	0.06		X		**X**		X			**X**			
Beneš et al. (2003)		0.35-0.37	*Structural model*											

Notes: pm^{oil} – oil prices; *m* – broad money; *i* – interest rate; *gap* – output gap; *dgp* – real GDP; *s* – exchange rate; *w* – unit labor costs; pc^f – foreign CPI; *pm* – import prices; *px* – export prices; *py* – producer prices; *pc* – consumer prices – CP

[a] Coricelli et al. (2006) use inflation and interest rate differentials. Therefore, it is difficult to compare the model and the results with other estimations.

[b] Darvas (2001) also estimates an equilibrium real exchange rate model with time-invariant parameters.

[c] The original model was estimated for industrialized countries. The impulse response of the CPI to an exchange rate shock is insignificant for the majority of the euro area countries included in the sample. CVAR is cointegrated VAR and TVEC denotes threshold vector error correction model

infer the magnitude and dynamics of the pass-through. The accumulated impulse responses can be interpreted as long-run pass-through if the time horizon is sufficiently long (e.g., up to one year). The cointegrated VAR or error correction model allows us to measure equilibrium pass-through. Some time equilibrium pass-through is also called long-run pass-through. According to the definition of the error correction term, equilibrium pass-through represents the equilibrium to which the exchange rate coefficient tends to converge. The advantage of the VEC approach is that it keeps the information in levels taking into account causal relationships and non-stationarity issues.[5] However, the interpretation of equilibrium pass-through becomes very difficult when the number of cointegrated equations is greater than one. Finally,

[4] Shocks are usually normalized to one percent or to one standard deviation.

structural models may help in the assessment of pass-through properties. The different econometric methodologies and specifications lead to a variety of pass-through estimates for the Czech Republic.

Short-run pass-through varies from 0 % to almost 40 % (column 3 in *Table 1*). For comparison, the ERPT to the euro area HICP varies between 2 % (Faruqee, 2006) and 8 % (Hahn, 2003). It is mostly insignificant in McCarthy (1999 and 2007). Long--run pass-through is found to be around 0.5–0.6, which is far from complete. Studies with cross-country analysis find the lowest pass-through for the Czech Republic among the Central European countries (Coricelli et al., 2006, and Darvas, 2001) or the emerging economies (Mihaljek and Klau, 2001). In addition, Mihaljek and Klau (2001) find high inflation inertia for the Czech Republic (the highest in the sample). Most studies estimate pass-through using the effective exchange rate, but others, e.g., Mihaljek and Klau (2001), prefer the bilateral exchange rate, which is more transparent for firms in comparison with the effective exchange rate. Korhonen and Wachtel (2005) estimate pass-through using the euro and dollar exchange rates. Pass-through is found to be higher when the euro is used.

It is worth mentioning that such variation in the exchange rate pass-through results may be due to different estimation periods and differences in definitions of pass-through, as well as to different frequency of the data (monthly and quarterly). It may also be partially due to variation in the underlying price indices. For example, Beneš et al. (2003) and Darvas (2001) exclude food, energy, and administered prices from the aggregated price index. Coricelli et al. (2006) and Mihaljek and Klau (2001) use the aggregated index of CPI inflation.

4. General Estimation Strategy

None of the aforementioned approaches can be considered the best. Therefore, the alternative methods should rather be viewed as complementary to each other. While the single equation model may not account properly for possible endogeneity, the VAR approach allows us to account for both diversity of specifications and interactions among the variables. Therefore, it seems being the most appropriate estimation strategy. With a few exceptions[6] we replicate the specifications already applied to the Czech Republic data. In addition, we estimate McCarthy-type specifications with a distribution chain (see *Table 1*). Some of the variables we consider first as exogenous and then as endogenous. Only stationary specifications are used for the pass--through analysis. These 11 specifications are listed in *Table 2*. As the different specifications are based on different assumptions about the transmission mechanism, it is difficult to select the best one. We check the robustness of the results by comparing the pass-through estimates from all the specifications. To some extent this approach is

[5] Notice that the VAR approach is criticized by Coricelli et al. (2006) for inconsistency with the definition of pass-through. In particular, the authors emphasize that any type of shock can cause co-movements between the exchange rate and prices.

[6] We do not use, for example, broad money. Also, we do not replicate the model of Coricelli et al. (2006), estimated with inflation and interest rate differentials. Finally, Darvas (2001) estimates the time-invariant equilibrium real exchange rate, but there is no unique approach to estimating the equilibrium exchange rate (for different strategies of equilibrium exchange rate estimation for transition economies, see Égert et al., 2006). In addition, it is not necessarily the case that the equilibrium exchange rate is stable over time. Therefore, we do not follow this approach.

Table 2 Estimated VAR Specifications

VAR No.	endogenous variables						exogenous variables	
1	**s**	*pm*	*px*	*py*	**pc**	*w*		
2	pm^{oil}	*gap*	**s**	$pm^{non\ oil}$	*py*	**pc**		
3	*gap*	**s**	$pm^{non\ oil}$	*py*	**pc**		pm^{oil}	
4	*gap*	**s**	$pm^{non\ oil}$	*py*	**pc**		pm^{oil}	*i*
5	*gap*	**s**	$pm^{non\ oil}$	**pc**			pm^{oil}	*i*
6	*gap*	**s**	**pc**				pc^{EU}	
7	**s**	*pm*	**pc**				pc^{EU}	
8	**s**	**pc**					pc^{EU}	
9	pm^{oil}	**s**	**pc**				pc^{EU}	
10	**s**	**pc**					pc^{EU}	pm^{oil}
11	*gap*	**s**	*pm*	**pc**				

Notes: pm^{oil} – oil prices; $pm^{non\ oil}$ – non oil prices; *i* – interest rate; *gap* – output gap; *s* – exchange rate (NEER); *w* – unit labor costs; *pm* – import prices; *px* – export prices; *py* – producer prices; *pc* – consumer prices – CPI; pc^{EU} – euro area CPI

in line with Leamer's (1985) extreme bounds analysis (EBA).[7] According to Leamer (1985) the tested variable has no impact on the dependent variable when its lowest estimated coefficient minus two standard deviations is negative and the highest coefficient plus two standard deviations is positive. Leamer's approach was criticized as being too restrictive and rejecting variables relevant to the model. As an alternative, Sala-I-Martin (1997) suggests constructing the cumulative distribution function for the weighted coefficients with weights based on the estimated likelihoods of the individual models. Unfortunately, it is not obvious how to apply this approach to the system of equations.[8] Furthermore, it is not possible to have the same number of explanatory variables in all the tested specifications.

All 11 specifications are estimated for five consumer price indices: *PC* – aggregated CPI, *PC-TT* – tradables only, *PC-TF* – food only, *PC-TO* – other tradables (excluding food and beverages), and *PC-NT* – non-tradables excluding regulated prices. In order to account for possible variation in time, all the estimates are performed for three periods: the whole period and two sub-periods. In total, this gives us 11*5*3 = 165 estimated VAR models. The price indices and the exchange rate are transformed into one-period log-differences.[9]

Short-run pass-through is computed as an impulse response from the VAR model. To compute the impulse responses, Cholesky ordering is selected. Cholesky decomposition implies a predetermined ordering of the impulse responses: in the first period the first variable is affected only by its own shock, the second variable is affected by the first variable's shock and its own shock, etc., and the last variable is af-

[7] The EBA approach suggests performing the estimation on a set of specifications containing a baseline model, the variable whose coefficient is tested for robustness, and up to three additional explanatory variables. The additional variables are taken from a large set of potential determinants of the dependent variable.

[8] An alternative technique to account for model uncertainty is Bayesian model averaging used, for instance, for out-of-sample forecasting of the exchange rate (Crespo Cuaresma, 2007) or inflation (Jacobson and Karlsson, 2004). The application of this method is not straightforward, and we leave it for further research.

[9] We complement the estimations on m-o-m changes with estimations done on the data transformed into annual growth rates: $(X_t - X_{t-12})/ X_{t-12}*100$. The results for annual growth rates are available upon request.

fected by the shocks from all the variables. Notice that the ordering of the endogenous variables matters. In practice, it is difficult to test all the possible combinations, e.g., a system of 6 variables gives 6! = 720 possibilities for ordering the variables. We selected the ordering of variables which corresponds to the distribution chain hypothesis. In the spirit of McCarthy (1999 or 2007) we place variables approximating demand and supply shocks before the distribution chain. Impulse responses estimated with Cholesky ordering are compared with generalized impulse responses proposed by Pesaran and Shin (1998). While there is no particular economic interpretation for generalized impulse responses, their major advantage is independence from the ordering of variables.

When series are non-stationary in levels but cointegrated, the VAR model may suffer from omission variable bias. In this case, the use of the vector error correction model (VECM) could be more appropriate. Once the model contains only one cointegrated equation, the error correction term provides information on the degree of equilibrium pass-through, estimated as the inverse of the exchange rate coefficient. At the same time, the dynamic part of the model can be used for computing short-run adjustments. All the specifications are tested for cointegration, but only the specifications with one cointegrated equation are considered for pass-through analysis based on the VECM.

5. Data Description and Preliminary Tests

Aggregated CPI, export, and import prices are obtained from the Czech Statistical Office. The nominal effective exchange rate[10] and the 3-month interest rate are taken from the ARAD database, while producer prices, labor costs, GDP, and the HICP for the euro area come from Eurostat. Sub-components of the Czech CPI are estimated by CNB staff. GDP, available on a quarterly basis, was converted to monthly frequency using the quadratic method of interpolation. The output gap is estimated from GDP data using the Hodrick-Prescott filter. In order to keep as much information as possible, we start with the estimations over the whole period. Then the data are split into sub-periods: 1996:1–2001:12 and 2002:1–2006:12. The second interval encompasses the period of CPI inflation targeting. It should also be noted that there were no FX interventions after 2002. We do not divide the second sub-sample into the pre- and post-EU accession periods, in order to keep the time series relatively long.

The original series, apart from GDP and the interest rate, are expressed in indices equal to 100 for the base year 2000. For the CPI, export, and import price indices, there was a methodological change in 2001: the number of representative price categories increased by approximately 20 %. Since there is no obvious way of combining the two methodologies, we merge the pre-2001 and post-2001 series using 2000 as the base year.[11]

[10] The effective exchange rate accounts for the fluctuation of the Czech koruna vis-à-vis the national currencies of 23 principal trade partners. Re-estimation of specification 1 with NEER, CZK/EUR, and CZK/USD shows that the pass-through results based on the specifications with NEER and the euro do not differ significantly from each other. This, in turn, is explained by a dominant share of trade with the euro area. By contrast, using the exchange rate against the US dollar gives substantially lower pass-through to Czech inflation.

[11] The same approach was applied in the Emerging Market Database (EMED) to construct the series of Czech export and import prices.

Before starting the econometric estimations, some commonly used tests are applied. First, the series are checked for stationarity. By and large, all the variables except the output gap are non-stationary in levels and stationary in first differences. The output gap is stationary by construction. For the interest rate, the ADF and KPSS tests generate controversial results. Since in the majority of pass-through studies the interest rate and the output gap are estimated in levels, we also include these variables in the VAR models in levels. The other variables are estimated in log differences. According to common practice, it is also possible to have some non-stationary variables if the whole model passes the stability test. We estimate all the VAR models with 2 lags. All 11 VAR models passed the stability test.[12] Furthermore, the Johansen cointegration test detects one cointegrated equation for specifications 2, 3, 8, and 11. In the other specifications the number of cointegrated equations varies from 0 to 3, but the results are sensitive to the assumptions of the test.

The VAR or VEC structure implicitly assumes that prices react to exchange rate appreciation and depreciation with the same magnitude and that the exchange rate coefficient is stable over time. First, we try to assess the time-varying pass-through by applying the Kalman filter.[13] We build a state and space model where changes in the CPI index are explained by changes in the exchange rate and the error correction term. By applying the Kalman filter, we allow the exchange rate coefficient to vary over time. The time-varying coefficient is found to be insignificant in all specifications. Second, the assumption of asymmetry in price adjustments could be important for the pass-through estimates. In general, prices can be more rigid downward,[14] i.e., the reaction to exchange rate appreciation is not the same as that to exchange rate depreciation. Some preliminary results indicate a possible asymmetry. It is not clear, however, how to define periods of appreciation and depreciation and how to distinguish temporary and permanent changes. We leave this for future research.

6. Results

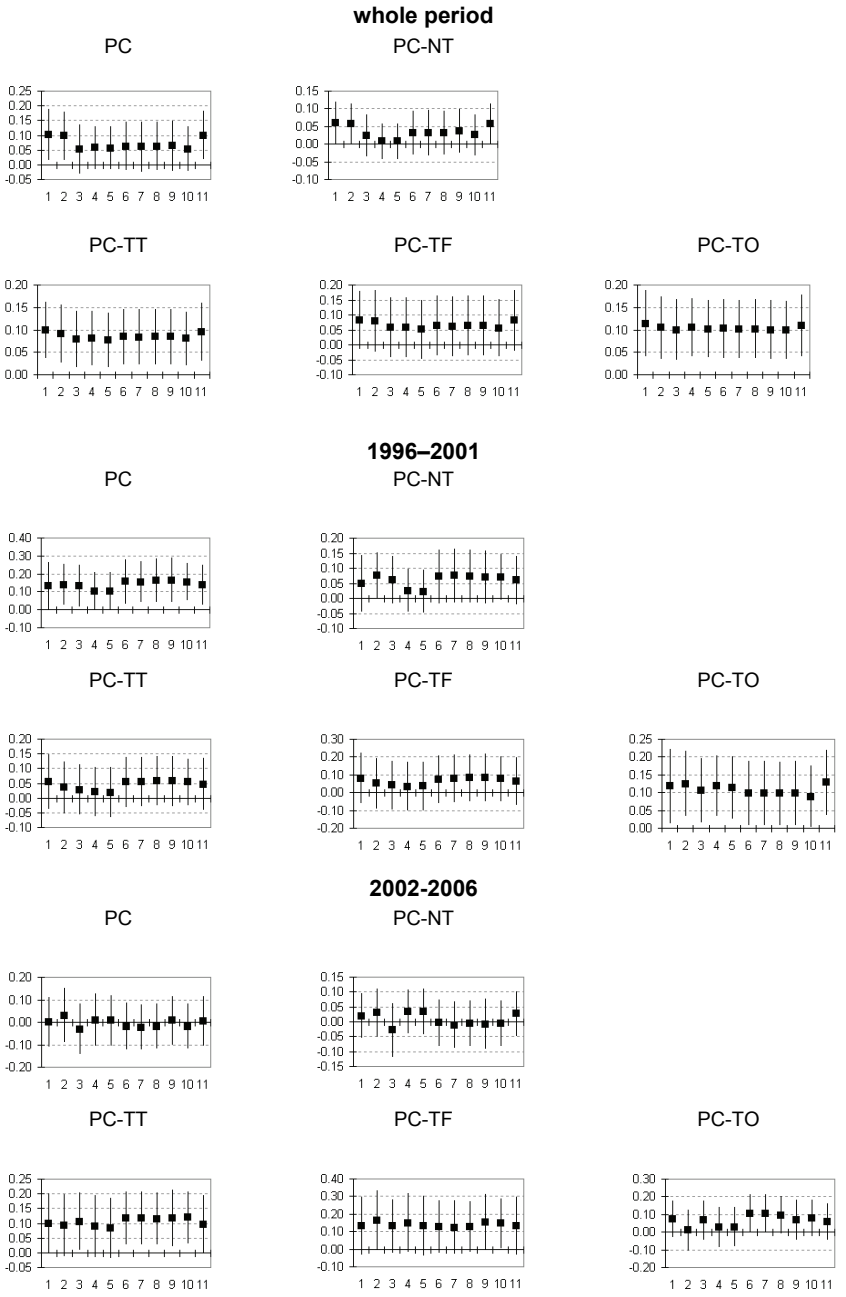
The measure of pass-through is based on the approach described in section 3. The impulse responses based on VAR models with Cholesky ordering of innovations show incomplete and fast short-run pass-through. The effect of the exchange rate shock to the CPI attains its maximum after roughly 6 months, and at least half of this

[12] Detailed results for the unit root tests and lag selection are available upon request. The optimal number of lags was selected using five information criteria. The Schwarz and Hannan-Quinn criteria suggest a minimal number of lags. In all other cases, the optimal number of lags increases with the number of lags in the VAR. The number of lags was set to 2 because one month seems to be a very short period. All the specifications, however, were re-estimated with 4 lags. The degree of ERPT does not differ significantly from that based on the 2-lag specification. Given that too many lags create additional noise in the impulse response functions and complicate their interpretation, the specifications with 2 lags turn out to be a reasonable choice.

[13] Darvas (2006) argues that the Kalman filter is the best technique for obtaining time-varying coefficients, since it preserves flexibility. By contrast, a smooth transition between the beginning and end of the period and the particular path assumed by the STAR (smooth transition threshold autoregression) model or the several regimes allowing for the possibility of returning to a previous regime (Markov switching process) seem to be unrealistic or too restrictive for countries like the Czech Republic.

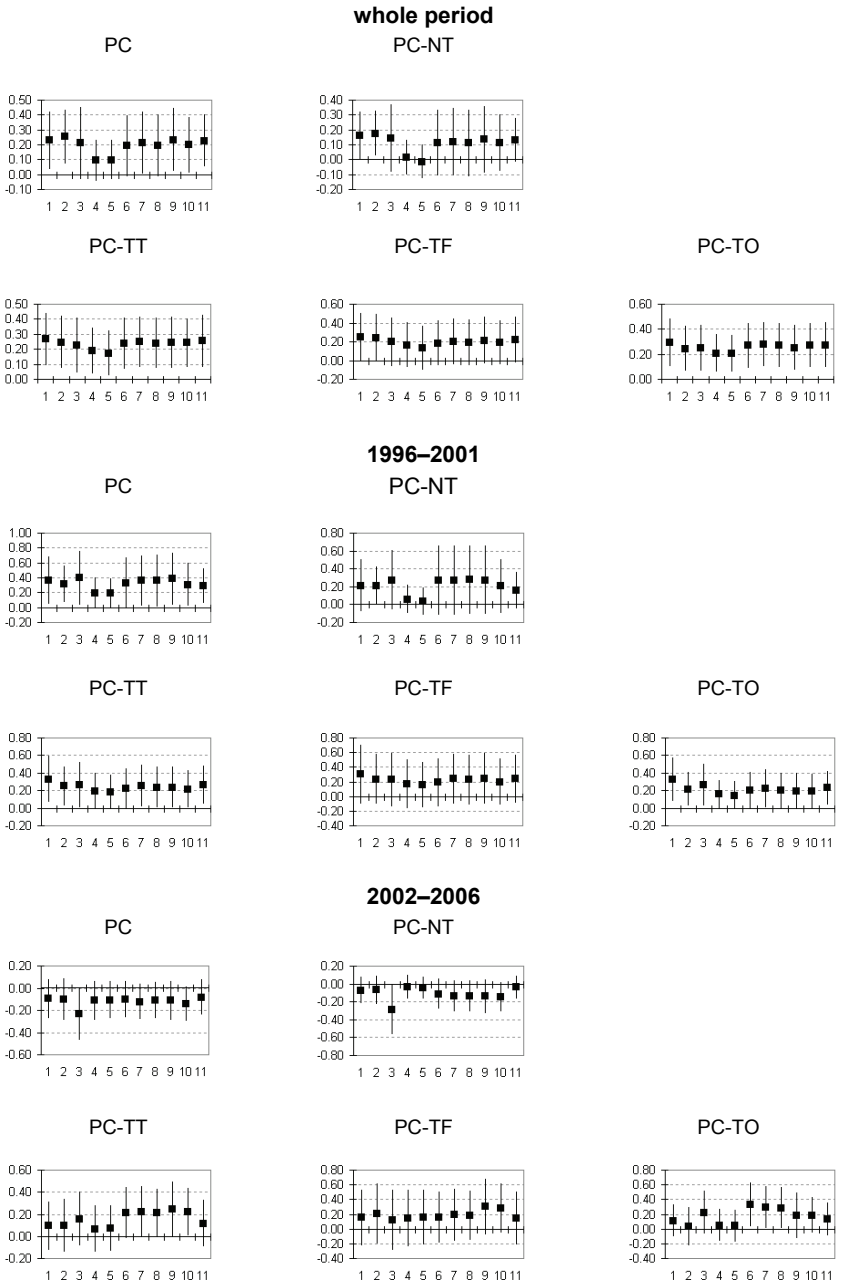
[14] See the menu-cost model of Ball and Mankiw (1994) for possible theoretical explanations of asymmetric price adjustments in the presence of positive trend inflation, and Pollard and Coughlin (2003) for estimates of asymmetric pass-through to import prices.

Figure 1 Peak Impulse Response to a 1% Exchange Rate Shock



Note: The numbers from 1 to 11 on the horizontal axis denote the specification number as in *Table 2*. The vertical line shows the 95% confidence interval. The peak impulse response is observed in the 2nd month for the sub-period 2002–2006 for all prices except other tradables. Otherwise, the peak impulse response occurs in the 3rd month.

Figure 2 Accumulated Impulse Response after 6 Periods



Note: The numbers from 1 to 11 on the horizontal axis denote the specification number as in *Table 2*. The vertical line shows the 95% confidence interval.

effect occurs during the first 3 months. In other words, if we consider the accumulated impulse response after 12 months as a complete response, the ERPT after 3 months accounts for at least 50% depending on the specification chosen. In order to check how sensitive our results are to the selected specification, we put the results obtained from different specifications in the same figure. *Figure 1* plots the peak impulse response and its confidence intervals for each specification estimated for 5 CPI indices[15] over 3 periods. The numbers from 1 to 11 on the horizontal axis correspond to the VAR numbering in *Table 2*. In other words, each small graph in *Figure 1* shows 11 peak impulse responses estimated from the 11 different VAR models.

According to our expectations, the magnitude of the pass-through is not the same for tradables and non-tradables. For non-tradables it is the smallest and is almost insignificant, in line with the theoretical literature. Among the three groups of tradable goods (total index, food, and other tradables), the peak impulse response has more or less the same magnitude. For some specifications it is slightly higher during the first period, but it becomes insignificant in the second period. The observed peak response is around 10 % for the estimates done on the whole sample. In the first period, only the aggregated index and selected specifications for other tradables have a statistically significant impulse response (around 10–15 %). In the second period, the peak impulse is significant in half of the specifications with the total tradables index.

After 6 months, the ERPT is mostly transmitted into consumer prices. *Figure 2* shows the accumulated impulse response in the 6th period. The ERPT to the aggregated CPI does not exceed 25 %. It is found to be higher in the first period (up to 40 %) and lower and insignificant in the second period. The lower pass-through in the second period is in line with the gradual decrease of the target level of inflation during 2002–2005. However, it is very unlikely that there is no ERPT to domestic inflation in a small open economy with a significant share of imported goods in the consumption basket. In the case of the estimations done on two sub-periods, the shorter data set and possible volatility in the data may hide the true magnitude of the pass-through. For this reason, the estimations performed on the whole sample seem to provide more reliable results. Notice that an insignificant accumulated impulse response means that the shock has already been transmitted and no longer affects the variable of interest. However, it can also be insignificant if all the instant impulse responses are insignificant.

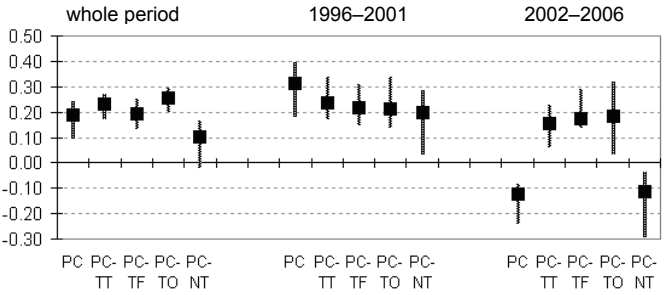
The robustness of the results is checked by replacing Cholesky ordering of innovations by generalized impulse responses (*Figure 3*). The pass-through estimates based on generalized impulse responses are broadly in line with the previous results.

Further, we show the pass-through evolution along the distribution chain. The vertical axis on *Figure 4* shows the magnitude of the pass-through (accumulated impulse responses) to import prices, producer prices, and consumer prices. The horizontal axis displays the periods of time. We show the results from the two VAR models where there is an aggregated import price index and the ERPT to consumer prices is significant. The estimations are done on the whole sample.

The results support the general findings of a fading pass-through effect along the distribution chain: the highest – close-to-complete – pass-through is found for im-

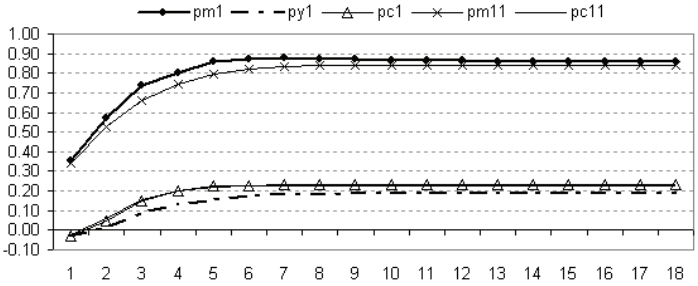
[15] We assume that the exchange rate shock may be transmitted through intermediate inputs that do not necessarily belong to the same group as the final product. Therefore, we keep all other variables unchanged when the disaggregated consumer price index is used instead of the aggregated one.

Figure 3 Accumulated Generalized Impulse Responses After 6 Periods



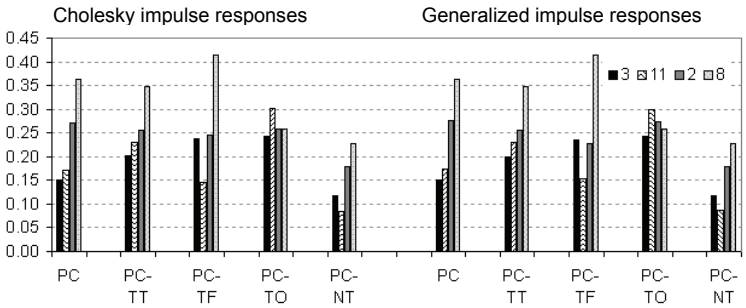
Note: The vertical bars show the minimum and maximum pass-through from the 11 specifications for the given price index. Black points show the average.

Figure 4 Pass-through Along the Distribution Chain (Accumulated Impulse Response)



Note: pc is the aggregated consumer price index, *py* is the producer price index, and *pm* is the import price index. The numbers 1 and 11 in the legend denote the specification number as in *Table 2*. The periods (months) are plotted on the horizontal axis.

Figure 5 Pass-through Estimates Based on the VECM; Impulse Response After 6 Periods



port prices; the pass-through is much lower for the PPI and CPI. The pass-through to import prices is around 85 %, which is close to Faruqee (2006) for the euro area. Interestingly, the reaction of producer prices to the exchange rate shock is lower than the reaction of consumer prices to the same shock. Bacchetta and van Wincoop (2003)

explain the high pass-through to import prices and the low pass-through to domestic prices by high competition in the domestic market. In other words, foreign exporting firms sell intermediate goods to domestic firms and set their prices in the foreign currency. Domestic firms produce final goods, which include foreign components. If the degree of competition among local producers in the local market is high, the domestic firm prefers to set its prices in the local currency, which leads to a high pass--through to import prices and low pass-through to consumer prices. Therefore, the main absorption of the exchange rate shock occurs during the production process. The higher pass-through to consumer prices relative to producer prices in this case is a result of the foreign component in the consumption basket.

Figure 5 shows the impulse responses based on the VECM estimated for 4 specifications (2, 3, 8, and 11). The average impulse response is about 24–27 % for tradables and the aggregated CPI, and about 15 % for non-tradables.

The pass-through estimates based on the whole period are in line with the previous literature. The pass-through is less than 30 %, which is somewhat lower than found in the literature for other countries in the region. For instance, Égert and McDonald (2006) estimate the pass-through to CPI inflation in Hungary, Poland and Slovakia at between 30 % and 35 %; for Slovenia it is about 50 %.

7. Conclusion

In this paper, we measure the dynamics and completeness of the pass-through for the Czech Republic by applying alternative specifications and econometric procedures. The speed of the exchange rate shock transmission to all prices is quite high (at least 50 % of the shock is transmitted during the first 3 months and 100 % after 6 months), which is usual for a small open economy. However, in absolute terms, the peak impulse response does not exceed 25 %, and the total reaction to the exchange rate shock is likely to be less than 30 % for the data estimated on the whole sample. The pass-through is found to be somewhat higher than 30 % during 1996––2001, but it is mostly insignificant between 2002 and 2006. The lower pass-through may reflect the fact that the inflation targeting policy brought inflation down significantly. This, in turn, had a downward effect on ERPT, as pass-through is generally lower in a low inflation environment than in a high inflation environment. Though the lower pass-through in the second period is in line with the decrease in the level of target inflation during 2002–2005, it is unlikely to be zero due to a substantial share of imported goods in the consumption basket. Shorter time-series and possible volatility in the data may be responsible for the insignificant pass-through estimates. Estimations based on the whole sample seem to provide more reliable results. We also find that tradable goods react much more to an exchange rate shock than do non--tradable goods, in line with the theoretical foundations. Furthermore, the magnitude of the exchange rate pass-through decreases from the initial stage of production to final goods. However, we found lower pass-through to producer prices than to consumer prices. High competition on the domestic market or the presence of imported goods in the consumption basket could be a possible explanation for this result. Last but not least, as the present research is based on relatively short time series of a fast transforming economy, the estimated exchange rate pass-through should be interpreted in relative terms rather than in absolute values. The results are viewed as

emphasizing the general tendencies in pass-through behavior, but thanks to easily updatable data it will be possible to survey further pass-through developments in the future.

REFERENCES

Bacchetta P, Wincoop E van (2003): Why Do Consumer Prices React Less Than Import Prices to Exchange Rates? *Journal of the European Economic Association*, 1(2–3):662–670.

Bailliu J, Fujii E (2004): Exchange Rate Pass-Through and the Inflation Environment in Industrialized Countries: An Empirical Investigation. *Bank of Canada Working Paper*, no. 2004-21.

Ball L, Mankiw NG (1994): A Sticky-Price Manifesto. *Carnegie-Rochester Conference Series on Public Policy*, 41:127–151.

Beneš J, Hlédik T, Vávra D, Vlček J (2003): The Quarterly Projection Model and its Properties. In: CoatsW, Laxton D, Rose D (Eds.): *The Czech National Bank's Forecasting and Policy Analysis System*. Czech National Bank, Prague.

Bitāns M (2004): Pass-Through of Exchange Rates to Domestic Prices in East European Countries and the Role of Economic Environment. *Bank of Latvia Working Paper*, no. 4/2004.

Burstein AT, Eichenbaum M, Rebelo S (2002): Why Are Rates of Inflation So Low After Large Devaluations? *CEPR Discussion Paper*, no. 8748.

Bussière M (2006): Exchange Rate Pass-Through to Trade Prices – The Role of Nonlinearities and Asymmetries. *ECB Working Paper*, no. 822.

Ca'zorzi M, Hahn E, Sánchez M (2007): Exchange Rate Pass-Through in Emerging Markets. *ECB Working Paper*, no. 739.

Campa J, Goldberg L (2006): Distribution Margins, Imported Inputs, and the Sensitivity of the CPI to Exchange Rates. *NBER Working Paper*, no. 12121.

Campa JM, Gonzalez Minguez JM (2006): Differences in Exchange Rate Pass-Through in the Euro Area. *European Economic Review*, 50(1):121–145.

Choudhri EU, Hakura DS (2006): Exchange Rate Pass-Through to Domestic Prices: Does the Inflationary Environment Matter? *Journal of International Money and Finance*, 25(4):614–639.

Choudhri EU, Faruqee H, Hakura DS (2005): Explaining the Exchange Rate Pass-Through in Different Prices. *Journal of International Economics*, 65(2):349–374.

Coricelli F, Jazbec B, Masten I (2006): Exchange Rate Pass-Through in EMU Acceding Countries: Empirical Analysis and Policy Implications. *Journal of Banking & Finance*, 30(5):1375–1391.

Corsetti G, Dedola L (2005): A Macroeconomic Model of International Price Discrimination. *Journal of International Economics*, 67(1):129–155.

Crespo Cuaresma J (2007): Forecasting euro exchange rates: How much does model averaging help? *University of Innsbruck*, *Working papers in economics and statistics*, no. 2007-24.

Dabusinskas A (2003): Exchange Rate Pass-Through to Estonian Prices. *Eesti Pank Working Paper*, no. 1003.

Darvas Z (2001): Exchange Rate Pass-Through and Real Exchange Rate in EU Candidate Countries. *Economic Research Centre of the Deutsche Bundesbank, Discussion Paper*, no. 10/01.

Darvas Z (2006): Monetary Transmission in the New EU Member States: Evidence from Time--Varying Coefficient Vector Autoregression. *OENB Focus on European Economic Integration*, (1):140–156.

Devereux MB, Yetman J (2002): Price-Setting and Exchange Rate Pass-Through: Theory and Evidence. *Proceedings of a conference held at the Bank of Canada, November 2002*. Ottawa, Bank of Canada.

Égert B, Halpern L, MacDonald R (2006): Equilibrium Exchange Rates in Transition Economies: Taking Stock of the Issues. *Journal of Economic Surveys*, 20(2):257–324.

Égert B, MacDonald R (2006): Monetary Transmission Mechanism in Transition Economies: Surveying the Surveyable. *Magyar Nemzeti Bank Working Paper*, no. 5.

Faruqee H (2006): Exchange Rate Pass-Through in the Euro Area. *IMF Staff Papers*, 53(1):4.

Flamini A (2004): Inflation Targeting and Exchange Rate Pass-Through. Geneva, The Graduate Institute of International Studies, Economics Section, *HEI Working Paper*, no. 04.

Gagnon JE, Ihrig JE (2004): Monetary Policy and Exchange Rate Pass-Through. (Up-dated version of FRB International Finance Discussion Paper, no. 704, July 2001.) *International Journal of Finance & Economics*, 9(4):315–338.

Hahn E (2003): Pass-Through of External Shocks to Euro Area Inflation. *ECB Working Paper*, no. 243.

Jacobson T, Karlsson S (2004): Finding Good Predictors for Inflation: A Bayesian Model Averaging Approach. *Journal of Forecasting*, 23:479–496.

Kamps A (2006): The Euro as Invoicing Currency in International Trade. *ECB Working Paper*, no. 665.

Korhonen I, Wachtel P (2006): A Note on Exchange Rate Pass-Through in CIS Countries. *Research in International Business and Finance*, 20(2):215–226.

Leamer E (1985): Sensitivity Analyses Would Help. The *American Economic Review*, 75(3):308––313.

McCarthy J (1999): Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies. *BIS Working Paper*, no. 79.

McCarthy J (2007): Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in Some Industrialized Economies. *Eastern Economic Journal*, 33(4):511–537.

Menon J (1995): Exchange Rate Pass-Through. *Journal of Economic Surveys*, 9(2):197–231.

Mihaljek D, Klau M (2001): A Note on the Pass-Through from Exchange Rate and Foreign Price Changes to Inflation in Selected Emerging Market Economies. In: *BIS Papers*, no. 8 ("Modelling Aspects of the Inflation Process and the Monetary Transmission Mechanism in Emerging Market Countries"), pp. 69–81 (Bank for International Settlements, Basel, ISSN 1609-0381, ISBN 92-9131--629-6).

Pesaran MH, Shin Y (1998): Impulse Response Analysis in Linear Multivariate Models. *Economics Letters*, 58:17–29.

Pollard PS, Coughlin CC (2003): Pass-Through Estimates and the Choice of an Exchange Rate Index. *Federal Reserve Bank of St. Louis Working Paper*, no. 2003-004B.

Rincon H, Caicedo E, Rodríguez N (2005): Exchange Rate Pass-Through Effects: A Disaggregate Analysis of Colombian Imports of Manufactured Goods. *Central Bank of Colombia Working Paper*, no. 330.

Sala-I-Martin X (1997): I just ran two million regressions. The *American Economic Review*, 87(2): 178–183.

Sekine T (2006): Time-Varying Exchange Rate Pass-Through: Experiences of Some Industrial Countries. *BIS Working Paper*, no. 202.

Taylor J (2000): Low Inflation, Pass-Through, and the Pricing Power of Firms. *European Economic Review*, 44(7):1389–1408.