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# Exchange Rate Pass-Through in an Emerging Market: The Case of the Czech Republic

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# Exchange Rate Pass-Through in an Emerging Market: The Case of the Czech Republic

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## Abstract:

We examine exchange rate pass-through, or how domestic prices respond to exchange rate shocks, in the Czech Republic from 1998 to 2013 by employing vector autoregression models. Using the aggregate consumer price index and its sub-components, we find that the degree of passthrough is incomplete except for food prices. The peak response occurs between 9 and 13 months after the exchange rate shock. The long-term pass-through is approximately 50% at the aggregate level. The degree of pass-through is greater for tradables than for non-tradables. The results also suggest that the exchange rate pass-through becomes slower but more complete during the financial crisis experienced in period considered.

**Keywords:** exchange rate pass-through, Czech Republic, inflation, vector autoregression

**JEL:** E31, E52, E58, F31

## Acknowledgements:

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# 1 Introduction

Because the Czech Republic has committed, by accepting the *acquis communautaire*, to adopting the common currency (the euro) at some future date, policy-makers should consider the conditions that this transition requires. The rules that specify entry into the euro zone are known as the Maastricht criteria, and they cover several macroeconomic variables – inflation, the long-term interest rate, public deficit (and overall debt) and a country’s exchange rate. Specifically, the exchange rate criterion stipulates that the applicant’s currency must enter the Exchange Rate Mechanism-II and remain there for at least two consecutive years without devaluing the domestic currency or departing from central parity by more than 15% in absolute terms. In contrast, the inflation criterion stipulates that the applicant’s inflation must be no more than 1.5% higher than the average of inflation rates in the three EU member states with the lowest inflation.

Many new EU member states experience real exchange rate appreciation induced by their catching-up processes (Coricelli and Jazbec, 2004). In this light, it is important for the applicant country to strike an optimal balance between price stability and exchange rate stability, set in opposition by the two criteria mentioned above. Therefore, in this paper, we examine the relationship between exchange rates and prices, specifically exchange rate pass-through into domestic inflation.

Exchange rate pass-through analysis is also an important tool for the monetary policy authority to achieve price stability. The Czech National Bank (CNB) adopted inflation targeting in 1998. After a period of disinflation, it currently maintains a 2% inflation target. The Czech Republic is one of the most open countries in the world, and exchange rate shocks may play an important role there, especially for certain components of the consumer basket. For example, the Czech Republic was affected by a large negative external shock at the outset of the global financial crisis that translated into a prolonged period of recession followed by slow growth. Previous estimates of exchange rate pass-through have been based on data from the period before the financial crisis. The Czech Republic experienced solid growth during that period. Therefore, it is vital to assess whether the degree of exchange rate pass-through has changed. In addition, it is interesting to observe how different sub-components of the consumer basket react to exchange rate changes to pinpoint which prices are more vulnerable to exchange rate shocks.

Importantly, the CNB introduced foreign exchange interventions in early November 2013 to reduce the risks of deflation and to achieve its inflation target. Unlike many other European countries, the Czech banking sector remained largely stable, liquid and well capitalized during the global financial crisis and did not receive government support (Czech National Bank's Financial Stability Report, 2014). Therefore, the central bank could not support the domestic economy by injecting additional liquidity into commercial banks and had to opt for other, unconventional measures. The domestic currency weakened by approximately 7% after this intervention, and the central bank announced that it would maintain a combination of inflation and exchange rate targeting at least until 2016. Clearly, this policy is based on the assumption that there is non-zero exchange rate pass-through, and the effectiveness of this policy increases at higher levels of pass-through. Therefore, updated estimates of exchange rate pass-through are of clear relevance for central bankers.

Our results suggest that the exchange rate pass-through in the Czech Republic is not complete, except in the case of food prices. We estimate the long-term exchange rate pass-through at the aggregate level to be approximately 50%. Exchange rate shocks are typically largely transmitted within a year. Therefore, our results indicate that the extent and speed of exchange rate pass-through have changed in the Czech Republic. In comparison to previous studies (especially Babecka-Kucharcukova, 2009), we find that during the current global financial crisis, exchange rate pass-through in the Czech Republic became slower but more complete. Our policy implication is that the foreign exchange interventions currently maintained by the CNB may be more effective than previous empirical evidence would suggest if these interventions were to be maintained for a sufficient time period. Our results point to what Shioji (2014) termed a revival in exchange rate pass-through. We contribute to evidence that exchange rate pass-through became more pronounced in recent years.

This paper is organized as follows. Section 2 discusses the related literature. Section 3 describes the data and introduces the econometric model. Section 4 presents the results. Concluding remarks are offered in section 5.

## 2 Exchange Rate Pass-Through in Central and Eastern Europe: Empirical Evidence

We provide a brief survey of existing studies that examine exchange rate pass-through in Central and Eastern Europe. We particularly focus on the Czech Republic. We refer the reader to Velickovski and Pugh (2011) for a quantitative survey (meta-analysis) of the exchange rate pass-through literature on transition economies. Useful surveys regarding exchange rate pass-through in Central and Eastern Europe (CEE) can be also found in Beirne and Bijsterbosch (2009) or Jimborean (2013). A survey of earlier studies is available in Menon (1995).

Focusing on the CEE countries, the prior literature finds that short-term exchange rate pass-through estimates are the lowest in the Czech Republic. The results for the Czech Republic are presented in Table 1. Korhonen and Wachtel (2005) find 3, 6, 9 and 18% pass-through effects for the Czech Republic, Hungary, Poland and Slovakia, respectively. María-Dolores (2008) estimates the effect at 11% for the Czech Republic, 32% for Hungary, 12% for Poland and 31% for Slovakia. In contrast, more recent studies suggest a potential change in this pattern. Beirne and Bijsterbosch (2011) estimate somewhat higher effects for the Czech Republic (25%) and Poland (36%) and somewhat lower effects for Slovakia (18%) and Hungary (24 %). Jimborean (2013) finds the lowest value for Poland (1%), followed by more or less the same estimates for the Czech Republic (7%), Hungary (8%) and Slovakia (8%). According to these figures, it appears impossible to declare that one country has consistently lower pass-through levels than another. Interestingly, Mihaljek and Klau (2008) find that the pass-through in the Czech Republic increased from 6% (1994-2000) to 13% (1994-2006).

The results for the long-term exchange rate pass-through are also presented in Table 1. Although the estimates differ somewhat, the pass-through is clearly less than complete, and the typical figure is approximately 50%.

Our study is closely related to Babecka-Kucharcukova (2009). Babecka-Kucharcukova (2009) follows the McCarthy (1999) specifications within the vector autoregression (VAR) framework and applies them to data from the Czech Republic over the 1996-2006 period. In the short-term horizon, she finds that pass-through is incomplete and fast. The maximum effect of the exchange rate shock is attained after approximately 6 months, and more than 50% of this effect occurs during the first 3 months. As expected, it is also confirmed that there is

Table 1: The exchange rate pass-through estimates for the Czech Republic

Author	Estimation method	Period	Frequency	Short-run ERP <sub>T</sub>	Long-run ERP <sub>T</sub>
Babecka-Kucharcukova (2009)*	VAR	1996-2006	(m)	0.10	0.25
Babecka-Kucharcukova (2009)	VECM	1996-2006	(m)	-	<0.30
Beirne, Bijsterbosch (2009)	VECM	1998-2008	(m)	0.25	0.51
Bitans (2004)	VAR	1993-1997	(m)	0.21	-
Bitans (2004)	VAR	1998-2003	(m)	0.13	-
Ca'Zorzi et al. (2007)	VAR	1993-2004	(q)	-	0.61
Campa, Goldberg (2005)**	OLS	N/A-2003	(q)	0.38	0.60
Coricelli et al. (2006)	VECM	1993-2002	(q)	-	0.46
Darvas (2001)	TVC-VAR	1993-2000	(q)	0.10	0.15
Egert, MacDonald (2009)*	N/A	1993-N/A	N/A	0.10	0.23
Egert, MacDonald (2009)***	N/A	1993-N/A	N/A	0.34	0.65
Jimborean (2013)	VAR	1996-2006	(q)	0.07	-
Korhonen, Wachtel (2006)	VAR	1999-2004	(m)	0.03	-
María-Dolores (2008)	OLS	2000-2006	(q)	0.11	-
Mihaljek, Klau (2001)	OLS	1994-2000	(q)	0.06	-
Mihaljek, Klau (2008)***	OLS	1994-2006	(q)	0.13	-
Vonnak (2010)*	VAR	1998-N/A	(m)	0.20	-

Notes: \*Figures representing the average of the estimated models. \*\*Figures related to import prices. N/A: not available. \*\*\*Figure representing the ERP<sub>T</sub> estimate when controlling for the strong trend appreciation of CZK. TVC-VAR: Time-varying cointegrated VAR. Most of the authors used the effective exchange rate. Mihaljek and Klau (2001) used bilateral exchange rates. Darvas (2001) excluded food, energy and administrated prices from the aggregated price index. Short-run pass-through represents either the peak impulse response or the value after the shortest period available in the papers (e.g., pass-through after 3 months). Long-run pass-through represents the total amount to be transmitted.

a substantial difference between the effect on tradables and non-tradables (i.e., the effect on non-tradables is much smaller and almost insignificant). After 6 months, the effect is almost fully transmitted into domestic consumer prices, and the effect on aggregate CPI does not exceed 25%.

Another area of interest is the pass-through evolution along the distribution chain (i.e., the effect of exchange rate shock to import prices, producer and consumer prices). The highest effect of approximately 85% (almost complete) is found for import prices. For the other two indices, the effect is much lower. This finding can be explained by the high competition in the domestic market, as Bacchetta and van Wincoop (2003) state. This result is in line with previous literature. In contrast, surprisingly, the estimates provided suggest a larger pass-through effect to consumer prices than to producer prices. This result is due to the substantial presence of foreign components in the consumption basket.

Franta et al. (2014) evaluate changes in the monetary transmission mechanism in 1996-2010 in the Czech Republic. Although it was not their primary concern, they find that exchange rate shocks produce long-lasting effects on prices and that there is little evidence of any changes in the nature of these price responses over time. Interestingly, Franta et al. (2014) do not confirm the trend of decreasing pass-through in the Czech Republic, as most of the previously published literature suggests. In addition to Mihaljek and Klau (2008) and Shioji (2014), this paper partially contradicts the common perception that pass-through is of a fading nature. To a certain extent, Beirne and Bijsterbosch (2011) fall into this category of papers because they also find a somewhat higher degree of pass-through.

In summary, there are some differences in the estimated results due to the various methodologies and different periods used in the papers. Nevertheless, empirical evidence suggests that the pass-through in the Czech Republic is incomplete. However, it is increasingly disputable whether the pass-through is of a fading nature. More recent papers show that it might not be a coincidence that their results indicate higher pass-through. Our aim is to provide more recent estimates of exchange rate pass-through.

### 3 Empirical Methodology and Data

#### 3.1 Vector autoregressions

We largely follow the previous literature and apply VAR models to examine the exchange rate pass-through in the Czech Republic. VAR models are well known. Therefore, we focus on discussing the important issues, such as the model specification and, particularly, the ordering of the variables. The impulse responses are identified using Choleski decomposition. As a result, the ordering of the variables matters.

We follow the ordering of the variables as in Babecka-Kucharchukova (2009), which corresponds to the distribution chain hypothesis, with variables approximating the supply and demand shocks placed before the distribution chain. This ordering is consistent with McCarthy (2007) and Ca’zozzi et al. (2007). Nevertheless, there are three differences of our approach compared to Babecka-Kucharchukova (2009). First, industrial production is used instead of GDP gap data because GDP gap data are provided only on a quarterly basis.<sup>1</sup> Second, the unit labor costs variable is dropped from the estimation because it is not available on a monthly basis. Third, keeping in mind the choice of industrial production over GDP, the ordering is adjusted to correspond to Beirne and Bijsterbosch (2011), who also used industrial production to approximate demand shocks. Beirne and Bijsterbosch (2011) argue that this “adjusted” ordering captures the functioning of the economy more realistically.

In this light, consider the following system<sup>2</sup>:

$$\Delta pm_{it}^{oil} = E_{t-1}(\Delta pm_{it}^{oil}) + \varepsilon_{it}^{supply} \quad (1)$$

$$\Delta s_{it} = E_{t-1}(\Delta s_{it}) + a_1 \varepsilon_{it}^{supply} + \varepsilon_{it}^s \quad (2)$$

$$\Delta ip_{it} = E_{t-1}(\Delta ip_{it}) + b_1 \varepsilon_{it}^{supply} + b_2 \varepsilon_{it}^s + \varepsilon_{it}^{demand} \quad (3)$$

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<sup>1</sup>There are several methods for data transformation from quarterly to monthly data, such as the quadratic method of interpolation, but it is difficult to assess whether these interpolation methods capture the output dynamics well. In contrast, industrial production captures only a certain part of economic activity.

<sup>2</sup>The chain structure of the model is similar to that of Blanchard (1983) and McCarthy (1999).

$$\Delta pm_{it} = E_{t-1}(\Delta pm_{it}) + c_1 \varepsilon_{it}^{supply} + c_2 \varepsilon_{it}^s + c_3 \varepsilon_{it}^{demand} + \varepsilon_{it}^{pm} \quad (4)$$

$$\Delta px_{it} = E_{t-1}(\Delta px_{it}) + d_1 \varepsilon_{it}^{supply} + d_2 \varepsilon_{it}^s + d_3 \varepsilon_{it}^{demand} + d_4 \varepsilon_{it}^{pm} + \varepsilon_{it}^{px} \quad (5)$$

$$\Delta py_{it} = E_{t-1}(\Delta py_{it}) + e_1 \varepsilon_{it}^{supply} + e_2 \varepsilon_{it}^s + e_3 \varepsilon_{it}^{demand} + e_4 \varepsilon_{it}^{pm} + e_5 \varepsilon_{it}^{px} + \varepsilon_{it}^{py} \quad (6)$$

$$\Delta pc_{it} = E_{t-1}(\Delta py_{it}) + f_1 \varepsilon_{it}^{supply} + f_2 \varepsilon_{it}^s + f_3 \varepsilon_{it}^{demand} + f_4 \varepsilon_{it}^{pm} + f_5 \varepsilon_{it}^{px} + f_6 \varepsilon_{it}^{py} + \varepsilon_{it}^{pc} \quad (7)$$

where  $\Delta$  is the difference operator (i.e.  $\Delta Y_t = Y_t - Y_{t-12}$ ),  $pm_{it}^{oil}$ ,  $s_{it}$ ,  $ip_{it}$ ,  $pm_{it}$ ,  $px_{it}$ ,  $py_{it}$  and  $pc_{it}$  stands for import price (oil only), exchange rate, industrial production, import price (all groups), export price, producer price and consumer price, respectively;  $E_{t-1}(\cdot)$  is the expectation of a variable based on the information set at the end of period  $t-1$ .  $\varepsilon_{it}^{supply}$ ,  $\varepsilon_{it}^s$ ,  $\varepsilon_{it}^{demand}$ ,  $\varepsilon_{it}^{pm}$ ,  $\varepsilon_{it}^{px}$ ,  $\varepsilon_{it}^{py}$  and  $\varepsilon_{it}^{pc}$  are the supply, exchange rate, demand, import price, export price, producer price and consumer price shocks, respectively.<sup>3</sup>

Equation (1) says that supply shocks are identified from the dynamics of oil price change. Equation (2) says that exchange rate shocks are identified from the dynamics of exchange rate change after taking into account the contemporaneous effect of the supply shock. As far as demand shocks are concerned, they are identified from the dynamics of industrial production change after taking into account the contemporaneous effects of the supply and exchange rate shocks as presents equation (3) and so on.

According to definition of the system, one may conclude that shocks in consumer price are identified from the dynamics of consumer price change after taking into account the contemporaneous effects of shocks of all variables that are placed before the consumer price (i.e. those that are defined in (1) - (6)).

Moreover, we ought to mention three other features about the models. First, the model allows domestic consumer prices to be affected by import prices in two channels - directly and indirectly via producer prices. Second, there is

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<sup>3</sup>In some specifications where  $pm_{it}^{oil}$  is included as exogeneous variable,  $pm_{it}$  is replaced by  $pm_{it}^{n-oil}$  that denotes import price (all groups except oil).

no contemporaneous feedback in the model (e.g. consumer price change may affect import price change only in future periods). Third, when estimating the exchange rate pass-through effect to prices of non-tradables we included variable for prices of tradables as well.<sup>4</sup>

The VAR specifications (and the ordering of variables) that we estimate are presented in Table 2. With the exception of specification 1, McCarthy (1999) argues that shocks along the distribution chain can be thought of as changes in the pricing power and markups of firms. Finally, we assume that the conditional expectations in all specifications can be replaced by linear projections of the lags of all endogenous variables included in the system.

We conduct a number of relevant statistical tests to assess whether the econometric models are correctly specified. We examine the stability of our VAR models. The results are available in the Appendix in Table A.2. The results suggest the stability of VAR models. We also examine the optimal lag length using the Schwarz Information Criterion (SIC). Ivanov and Killian (2005) suggest using the Schwarz Information Criterion (SIC) because it is the most accurate for small samples. The SIC typically recommends two lags. In certain cases, the SIC recommends one lag, but when we only used one lag, there was autocorrelation in the residuals. Therefore, we use two lags in all specifications. Finally, we also introduce an exogenous dummy variable that equals 1 during the crisis (2007:8-onwards) and 0 before the crisis (1998:1-2007:7). The results remain largely unchanged and are available upon request.

### 3.2 Data

We use data from January 1998 to August 2013. Our starting date is motivated by the change in the monetary policy regime, as the Czech Republic abandoned the fixed exchange rate regime in 1997 and adopted inflation targeting in January 1998. We use five different consumer price indexes and their subcomponents: aggregate CPI (PC), tradables only (PC-TT), food only (PC-TF), other tradables excluding food and beverages (PC-TO) and non-tradables excluding regulated prices (PC-NT). These data come from the Czech National Bank.

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<sup>4</sup>We believe the prices of nontradables do not react to exchange rate changes directly but mostly through the effect on tradables. More specifically, using nontradables in a VAR without including tradables at the same time is not correct. In terms of ordering, we place the prices of tradables in front of the prices of nontradables. We thank anonymous referee for this suggestion.

Table 2: Estimated VAR specifications

Model No.	Endogeneous variables					Exogeneous variables	
1	$s$	$pm$	$px$	$py$	$pc$		
2	$pm^{oil}$	$s$	$ip$	$pm^{n-oil}$	$py$	$pc$	
3	$s$	$ip$	$pm^{n-oil}$	$py$	$pc$		$pm^{oil}$
4	$s$	$ip$	$pm^{n-oil}$	$py$	$pc$		$pm^{oil}$
5	$s$	$ip$	$pm^{n-oil}$	$pc$			$pm^{oil}$
6	$s$	$ip$	$pc$				$pc^{EU}$
7	$s$	$pm$	$pc$				$pc^{EU}$
8	$s$	$pc$					$pc^{EU}$
9	$pm^{oil}$	$s$	$pc$				$pc^{EU}$
10	$s$	$pc$					$pc^{EU}$
11	$s$	$ip$	$pm$	$pc$			$pm^{oil}$

Notes:  $s$  - exchange rate,  $pm$  - import prices,  $px$  - export prices,  $py$  - producer prices,  $pc$  - consumer prices,  $pm^{oil}$  - import prices (oil only),  $ip$  - industrial production,  $pm^{n-oil}$  - import prices (all items except oil),  $i$  - interest rate,  $pc^{EU}$  - euro area consumer prices.

Next, we consider import and export price indexes and the EU aggregate CPI index. The sources of these data are the Czech Statistical Office and Eurostat. The 3-month Prague InterBank Offered Rate (PRIBOR) is used to capture the short-term interest rate. The source is Eurostat. The nominal effective exchange rate<sup>5</sup>, producer prices and industrial production index come from International Financial Statistics published by the IMF. The industrial production data are seasonally adjusted. Except for interest rates, the data are in logs. The descriptive statistics are available in Table A.1 in the Appendix.

## 4 Results

We provide the estimates of exchange rate pass-through in this section. As we have 11 different model specifications and 4 different consumer price indexes, 44 different VAR models have been estimated. Following Babecka-Kucharcukova (2009), we present them in a concise manner and select one specification for which we present the results in greater detail.

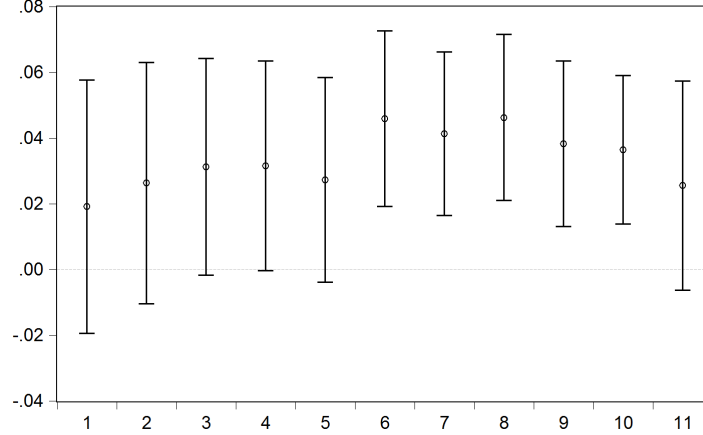
### Aggregate consumer prices

Figure 1 depicts the peak impulse responses of aggregate CPI to a 1% exchange rate shock. According to our results, the peak impulse response declined somewhat from 6%-7%, the figure reported by Babecka-Kucharcukova (2009), to 3%-4% on average. Babecka-Kucharcukova (2009) used data from 1996 to 2006, whereas we use more recent data from 1998-2013. Interestingly, the peak occurs between 8 to 11 months after the exchange rate shock, which is quite different from the findings of Babecka-Kucharcukova (2009), who report that the peak occurred approximately 2 months after the shock. This finding indicates that once we include the more recent data that cover the current global financial crisis, the rate of exchange rate pass-through is slower. This finding is confirmed by the results presented in Table 3, where the accumulated responses for 6, 12, 18, 24 and 60 months are presented.<sup>6</sup>

<sup>5</sup>The nominal effective exchange rate used in the estimation is defined according to the IMF definition of NEER.

<sup>6</sup>We also tried to estimate this effect to net CPI in order to reflect specifics of the Czech economy. Based on statistically significant results, exchange rate pass-through to net CPI accounts roughly for 22% during the first 12 months. That is broadly similar to the results presented when using aggregate CPI.

Figure 1: **Peak impulse response of CPI inflation to a 1% exchange rate shock**



Notes: The numbers from 1 to 11 on the horizontal axis denote the specification number as defined in Table 2. The peak impulse response is presented with 95% confidence bands. The timing of peak impulse response is not identical across specifications. Typically, it occurs between 8 and 11 months after the exchange rate shock.

Table 3: **Accumulated response of CPI inflation to a 1% exchange rate shock**

VAR No.	6 months	12 months	18 months	24 months	60 months
1	0.00	0.10	0.21	0.31	0.48
2	0.03	0.18	0.29	0.31	0.21
3	0.05	0.22	0.38	0.46	0.46
4	0.05	0.23	0.38	0.45	0.45
5	0.05	0.20	0.33	0.39	0.39
6	0.11	0.37	0.56	0.67	0.92
7	0.10	0.33	0.47	0.52	0.41
8	0.11	0.37	0.57	0.67	0.77
9	0.07	0.29	0.42	0.44	0.31
10	0.07	0.28	0.44	0.52	0.61
11	0.05	0.20	0.29	0.30	0.13

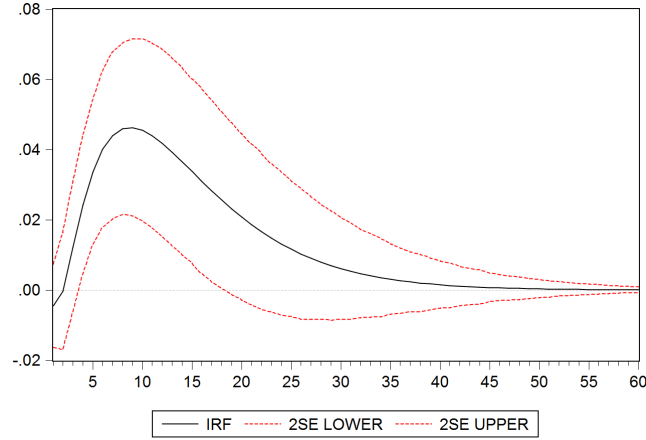
Notes: The numbers from 1 to 11 on the vertical axis denote the specification number as defined in Table 2.

Our results also indicate that the exchange rate pass-through is more complete than it was in the past. Babecka-Kucharcukova (2009) finds that the exchange rate pass-through is approximately 25% 6 quarters after a shock. Our results suggest that the corresponding figure is approximately 50%. Therefore, our results are more in line with Beirne and Bijsterbosch (2011), who report

an accumulated effect on aggregate consumer price of approximately 40%. The sample period used by Beirne and Bijsterbosch (2011) is 1995-2008. Franta et al. (2014) use time-varying VAR models to examine the changes in monetary policy transmission and demonstrate that the pass-through from the nominal effective exchange rate to the aggregate consumer price increased in the late 2000s in the Czech Republic.

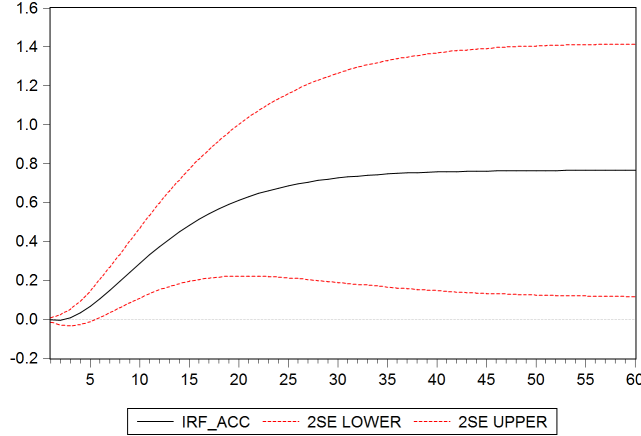
Finally, we choose specification 8 and report the impulse response and accumulated response to provide a more detailed view of the pass-through. Figure 2 depicts the impulse response of aggregate CPI to a 1% change in the exchange rate. The peak is achieved after 8 or 9 months with a maximum pass-through of 4.6% and then slowly decays toward 0. Figure 3 plots the accumulated response. The total effect transmitted to aggregate CPI is approximately 75%, and it is reached after approximately 2 years.

Figure 2: **Impulse response of CPI inflation to 1% exchange rate shock**



Notes: The numbers from 1 to 11 on the horizontal axis denote the specification number as defined in Table 2. The peak impulse response is presented with 95% confidence bands. The timing of peak impulse response is not identical across specifications. Typically, it occurs between 8 and 11 months after an exchange rate shock.

Figure 3: **Accumulated response of CPI inflation to a 1% exchange rate change**



Notes: The numbers from 1 to 11 on the horizontal axis denote the specification number as defined in Table 2. The peak impulse response is presented with 95% confidence bands. The timing of peak impulse response is not identical across specifications. Typically, it occurs between 8 and 11 months after an exchange rate shock.

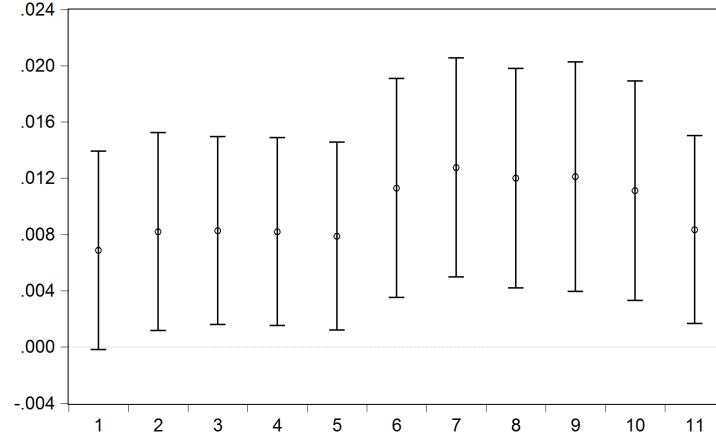
In addition, we perform variance decompositions and find that exchange rate fluctuations explain approximately 20% of variation in the aggregate prices on average (considering a horizon of two years). Finally, we also assess the performance of our VAR models by comparing their (pseudo out-of-sample) forecasting ability vis-a-vis a random walk. Using our VAR models and a random walk, we forecast the aggregate prices three months ahead and examine the forecasting performance by calculating the root mean square error. We present our results in A.3. Of our 11 specifications, 9 outperformed the random walk (in many instances considerably). The forecasts obtained from 2 specifications are marginally less accurate than a random walk. Overall, these results suggest that our VAR models have reasonable forecasting performance.

## Tradables

We examine the various elements of the consumer basket in greater detail. Figure 4 provides the estimates for the peak response for tradable prices. We find that the peak response is only 1%, and it occurs approximately 4 or 5 months after the shock. This finding suggests that the dynamics are substantially faster than in the case of aggregate CPI, although they are not as fast

as those found by Babecka-Kucharcukova (2009). The corresponding effect estimated by Babecka-Kucharcukova (2009) was approximately 8% on average, with a peak in approximately the 2nd month.

Figure 4: **Peak impulse response of tradables inflation to a 1% exchange rate shock**



Notes: The numbers from 1 to 11 on the horizontal axis denote the specification number as defined in Table 2. The peak impulse response is presented with 95% confidence bands. The timing of peak impulse response is not identical across specifications. Typically, it occurs between 8 and 11 months after an exchange rate shock.

Table 4: **Accumulated response of tradables inflation to a 1% exchange rate shock**

VAR No.	6 months	12 months	18 months	24 months	60 months
1	0.02	0.04	0.05	0.06	0.07
2	0.02	0.05	0.06	0.06	0.07
3	0.02	0.05	0.06	0.06	0.07
4	0.02	0.05	0.06	0.06	0.06
5	0.02	0.05	0.06	0.06	0.06
6	0.04	0.07	0.08	0.09	0.09
7	0.04	0.07	0.08	0.08	0.08
8	0.04	0.07	0.08	0.09	0.09
9	0.04	0.07	0.07	0.08	0.08
10	0.03	0.06	0.07	0.07	0.07
11	0.02	0.06	0.07	0.07	0.07

Notes: The numbers from 1 to 11 on the vertical axis denote the specification number as defined in Table 2.

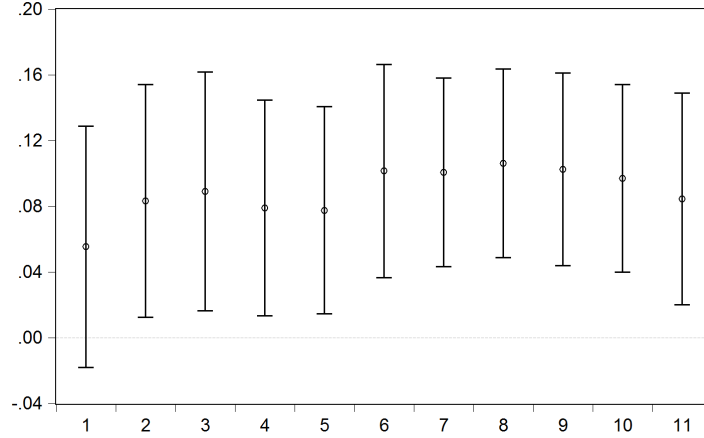
Table 4 presents the results for the accumulated response of tradable prices to an exchange rate shock. We find that most of the shock is transmitted during the first 12 months, reaching approximately 6%-7%, on average, as opposed to the estimate of 25% reported by Babecka-Kucharcukova (2009). Therefore, our results again indicate that exchange rate pass-through has slowed. Interestingly, we find that the pass-through to tradables is lower than in the case of aggregate CPI. Clearly, this finding is somewhat surprising, but it may be partly due to aggregation bias (Granger, 1980). An alternative explanation is that idiosyncratic shocks tend to cancel out when a substantial number of price series are aggregated (Altissimo et al., 2009). This pattern is also observed for Czech inflation data (Babecky et al., 2009). Babecky et al. (2009) find that inflation is more persistent when estimated at the aggregate level than when estimated using its underlying components.

### **Tradables (Food Only)**

Figure 5 presents the estimated short-term peak impulse responses. The peak response occurs 9 or 10 months after an exchange rate shock. The peak is approximately 9% on average. Although the peak of 9% is largely in line with Babecka-Kucharcukova (2009), from her sample, she estimated the peak to have already occurred around the second month after the shock.

Although we find that exchange rate shocks transmit to food prices rather slowly, the pass-through eventually becomes complete for this category. The results in Table 5 suggest that within 12-18 months, the exchange rate changes are fully transmitted into food prices. This finding contrasts with the previous findings of Babecka-Kucharcukova (2009), who suggests that approximately 25% of an exchange rate change transmits into food prices.

Figure 5: **Peak impulse response of food prices inflation to a 1% exchange rate shock**



Notes: The numbers from 1 to 11 on the horizontal axis denote the specification number as defined in Table 2. The peak impulse response is presented with 95% confidence bands. The timing of peak impulse response is not identical across specifications. Typically, it occurs between 9 and 10 months after an exchange rate shock.

Table 5: **Accumulated response of food prices inflation to a 1% exchange rate shock**

VAR No.	6 months	12 months	18 months	24 months	60 months
1	0.07	0.37	0.67	0.89	1.29
2	0.17	0.64	1.01	1.14	1.03
3	0.20	0.72	1.14	1.37	1.50
4	0.20	0.65	0.99	1.15	1.22
5	0.18	0.63	0.98	1.16	1.07
6	0.25	0.83	1.28	1.48	1.60
7	0.24	0.82	1.24	1.43	1.21
8	0.23	0.85	1.33	1.58	1.72
9	0.22	0.81	1.23	1.43	1.25
10	0.21	0.78	1.22	1.49	1.76
11	0.19	0.68	1.07	1.22	0.87

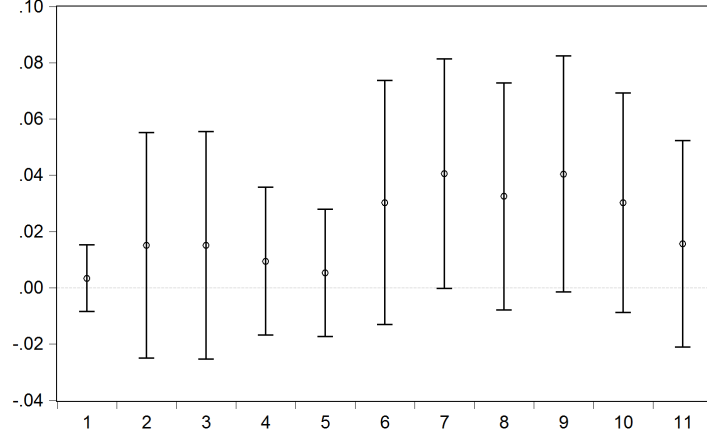
Notes: The numbers from 1 to 11 on the vertical axis denote the specification number as defined in Table 2.

## Non-tradables

We estimate the peak response of non-tradables to be approximately 2%, which corresponds to the previous estimates of Babecka-Kucharcukova (2009). Ac-

cording to the results depicted in Figure 6, the response is not statistically significant at conventional levels. This finding applies to the case of peak impulse response and to the case of accumulated responses. The estimated accumulated response varies substantially across model specifications; see Table 6.

Figure 6: **Peak impulse response of non-tradables inflation to a 1% exchange rate shock**



Notes: The numbers from 1 to 11 on the horizontal axis denote the specification number as defined in Table 2. The peak impulse response is presented with 95% confidence bands. The timing of peak impulse response is not identical across specifications. Typically, it occurs between 11 and 13 months after an exchange rate shock.

Table 6: **Accumulated response of non-tradables inflation to a 1 % exchange rate shock**

Var No.	6 months	12 months	18 months	24 months	60 months
1	-0.02	-0.03	-0.01	0.00	0.03
2	-0.01	0.05	0.13	0.19	0.22
3	0.01	0.07	0.16	0.22	0.27
4	0.01	0.05	0.10	0.12	0.09
5	0.01	0.01	0.04	0.06	0.07
6	0.05	0.21	0.38	0.52	0.84
7	0.08	0.30	0.53	0.72	1.17
8	0.04	0.22	0.40	0.56	0.89
9	0.06	0.27	0.50	0.68	1.08
10	0.05	0.21	0.38	0.52	0.81
11	0.00	0.06	0.15	0.24	0.41

Notes: The numbers from 1 to 11 on the vertical axis denote the specification number as defined in Table 2.

## Policy Implications

We discuss our results in the context of the recently introduced Czech National Bank policy (introduced in early November 2013), which uses the exchange rate as an additional instrument to ease monetary conditions. The central bank commits itself to preventing the Czech currency from depreciating above 27 CZK/EUR. It operationalizes its commitment as 'forward guidance' given the bank's announcement that it will maintain this policy of a weakened currency at least until 2016. The CNB adopted this policy to maintain price stability, as defined by its 2% inflation target. Coping with global financial crisis, the CNB decreased its main monetary policy rate to effectively zero, while deflationary risks remained (the current inflation rate was approximately 1%, but the central bank's forecast indicated that it would further decline to zero in the absence of intervention). Seeking an alternative policy instrument in a small open economy characterized by a well-capitalized and liquid banking sector, the CNB introduced the exchange rate as this additional instrument. In early November 2013, the CNB heavily intervened in the foreign exchange market for several days, depreciating the currency from 25.7 EUR/CZK to more than 27 EUR/CZK. Therefore, the domestic currency depreciated by approximately 7%. The domestic currency fluctuated around a value of 27.5 CZK/EUR thereafter without requiring further foreign exchange interventions. The details regarding the Czech National Bank's exchange rate policy are available in its Inflation Report IV/2013.

According to our results, a 1% exchange rate depreciation shock is associated with an approximately 0.25% increase in aggregate prices within the year. As a consequence, weakening the currency by 7% could contribute to inflation by some 1.75%, other things being held constant. This is interesting to compare to the official CNB estimates. CNB (2014b) uses input-output tables for the Czech economy to assess the impact of exchange rate depreciation and provides estimates that the direct (short-term) effect of a 5% depreciation on prices is 1.2%, while the long-term effect is 1.6%. As a result, the CNB estimates for 7% depreciation are 1.68% in the short-term and 2.31% in the long-term. Although our method and that applied by the CNB differ, the estimates are broadly consistent with one another. Importantly, both methods imply that the effect of exchange rate depreciation is economically significant. This finding suggests that if the exchange rate were to remain at the level preferred by the CNB, it would substantially reduce deflationary risks.

## 5 Concluding Remarks

We estimate exchange rate pass-through in the Czech Republic in the 1998-2013 period. We use aggregate consumer prices and their sub-components to analyze whether exchange rate shocks influence different components of the consumer basket differently.

In line with the survey by Velickovski and Pugh (2011), we find that the exchange rate pass-through is not complete; that is, an exchange rate shock does not fully translate into prices. The exception is food prices, for which our results indicate complete pass-through. Specifically, we find that approximately one-half of exchange rate changes are transmitted into aggregate prices and that this process takes approximately one year. Therefore, our results are in contrast with previous evidence, which was based on data from before the financial crisis. The typical finding in the exchange rate literature was that exchange rate pass-through is declining and is typically fast. For example, using a similar econometric framework and Czech data, Babecka-Kucharcukova (2009) estimates the long-term exchange rate pass-through to be approximately 25% and the peak response of prices to exchange rate shocks to occur approximately 2 months after the shock. In contrast, our findings based on more recent data indicate slower but more pronounced exchange rate pass-through. This finding is in line with other studies, such as Franta et al. (2014) and Shioji (2014). In terms of policy implications, our results suggest that the foreign exchange interventions adopted in late 2013 by the Czech National Bank to reduce the risks of deflation may be more effective than previously thought.

In terms of further research, we believe it would be worthwhile to analyze exchange rate pass-through in the Central and Eastern European countries at the disaggregate level to quantify the extent of aggregation bias (Granger, 1980). Furthermore, it would be interesting to determine whether there are asymmetries in exchange rate pass-through. Specifically, prices may be sticky downward; therefore, the extent and the speed of the reaction to exchange rate shocks may differ depending on whether the exchange rate depreciates or appreciates. Finally, it may be interesting to employ time-varying vector autoregression models (or time-varying parameter models in general) to assess the potential changes in exchange rate pass-through in a more coherent framework.

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## Appendix

Table A.1: Descriptive statistics

	Mean	Median	Min	Max	Stand. dev.	Skewness	Observations
<i>PC</i>	102.85	100.65	84.10	122.50	11.07	0.143	188
<i>PC-TT</i>	103.22	102.30	98.36	112.74	3.674	0.767	188
<i>PC-TF</i>	107.44	100.58	92.01	138.96	13.15	0.758	188
<i>PC-NT</i>	98.37	100.80	69.78	117.92	14.50	-0.365	188
<i>s</i>	101.72	101.19	74.80	129.36	15.51	-0.078	188
<i>px</i>	98.74	98.75	91.70	105.90	3.062	0.188	188
<i>pm</i>	99.81	99.50	88.60	114.20	4.819	0.634	188
<i>ip</i>	98.58	99.85	61.50	134.50	18.47	-0.089	188
<i>py</i>	100.62	100.39	84.27	117.87	10.28	0.087	188
<i>pm<sup>oil</sup></i>	99.49	97.95	29.10	175.00	37.17	0.206	188
<i>pm<sup>n-oil</sup></i>	99.80	99.22	88.38	115.48	6.43	0.497	188
<i>pc<sup>EU</sup></i>	101.01	100.76	86.29	117.61	9.46	0.086	188
<i>i</i>	3.662	2.545	0.460	16.590	3.313	2.272	188

Notes: *PC* - aggregate CPI, *PC-TT* - consumer prices for tradables, *PC-TF* - consumer prices for traded food only, *PC-TO* - consumer prices for other tradables, *PC-NT* - consumer prices for non-tradables, *s* - exchange rate, *pm* - import prices, *px* - export prices, *py* - producer prices, *pc* - consumer prices, *pm<sup>oil</sup>* - import prices (oil only), *ip* - industrial production, *pm<sup>n-oil</sup>* - import prices (all items except oil), *i* - interest rate, *pc<sup>EU</sup>* - euro area consumer prices. Data included are before log-transformation.

Table A.2: VAR Stability

VAR No.	PC	PC-TT	PC-TF	PC-NT
1	0.9384	0.9280	0.9438	0.9332
2	0.9438	0.9477	0.9452	0.9533
3	0.9147	0.9250	0.9235	0.9508
4	0.9156	0.9225	0.9193	0.9219
5	0.9312	0.8803	0.9297	0.8814
6	0.9769	0.9746	0.9658	0.9818
7	0.9271	0.9045	0.9354	0.9495
8	0.8534	0.8402	0.8784	0.9437
9	0.9297	0.9139	0.9353	0.9441
10	0.8745	0.8180	0.8642	0.9448
11	0.9308	0.9097	0.9296	0.9279

Notes: *PC* - aggregate CPI, *PC-TT* - consumer prices for tradables, *PC-TF* - consumer prices for food only, *PC-NT* - consumer prices for non-tradables. Figures represent the modulus of the root closest to the unit circle boundary. If below 1, the null of stability cannot be rejected.

Table A.3: Forecasting ability of VAR specifications: comparison with random walk

VAR No.	Our model	Random walk	Our model/Random walk
1	0.0034	0.0032	1.0530
2	0.0019	0.0032	0.6057
3	0.0016	0.0032	0.5040
4	0.0023	0.0032	0.7158
5	0.0020	0.0032	0.6336
6	0.0028	0.0032	0.8784
7	0.0030	0.0032	0.9402
8	0.0029	0.0032	0.9211
9	0.0025	0.0032	0.7833
10	0.0015	0.0032	0.4601
11	0.0034	0.0032	1.0597

Notes: The forecast of aggregate CPI performed for the period between May 2013 and August 2013. Forecasting ability measured using the root mean squared error (RMSE) of our models vis-a-vis a random walk. A value in the last column smaller than 1 indicates that the RMSE is lower when our models are used instead of a random walk.

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