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Does Foreign Exchange Reserve Decumulation Lead to Currency Appreciation?
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ABSTRACT

Many developing countries have increased their foreign reserve stocks dramatically in recent years, often motivated by the desire for precautionary self-insurance. One of the negative consequences of large accumulations for these countries is the risk of valuation losses. In this paper we examine the implications of systematic reserve decumulation by the Czech authorities aimed at mitigating valuation losses on euro-denominated assets. The policy was explicitly not intended to influence the value of the koruna relative to the euro. Initially the timing and size of reserve sales was not predictable, eventually sales occurred on a daily basis (in three equal installments within the day). This project examines whether these reserve sales, both during the regime of discretionary timing as well as when sales occurred every day, had unintended consequences for the domestic currency. Our findings using intraday exchange rate data and time-stamped reserve sales indicate that when decumulation occurred every day these sales led to significant appreciation of the koruna. Overall, our results suggest that the manner in which reserve sales are carried out matters for whether reserve decumulation influences the relative value of the domestic currency.

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1. Introduction

China's official foreign exchange reserves hit $2.4 trillion in early 2010. Although China is currently the country with the largest foreign reserve accumulation, reserves have risen dramatically for many emerging market countries in recent years. A number of studies have attempted to understand the motives for reserve accumulation, as well as the costs and benefits of reserve stocks.[1] In this paper we examine what happens when a country decides to reduce its foreign reserve holdings. While reserve accumulation in some countries is thought to be the byproduct of a government strategy to keep the international value of the domestic currency low in order to boost export growth, does it follow that reserve decumulation leads to domestic currency appreciation? We test this hypothesis using unique intraday data on recent euro-denominated reserve sales by the Czech National Bank (CNB).

The Czech Republic became an independent state in January 1993 following the break-up of the Soviet Union. A decade later, in May 2004, it officially joined the European Union with a view toward eventually giving up the Czech Koruna (CZK) and joining the euro-zone.[2] Although the Czech Republic has yet to join the European Exchange Rate Mechanism (ERM II), a pre-condition for joining the euro-zone[3], the CNB intervened frequently in the CZK-EUR market through September 2002.[4]

[1] See Jeanne (2007) and Dominguez (2010).
[2] The Czech koruna (or crown) has been the currency of the Czech Republic since 8 February 1993 when it replaced the Czechoslovak koruna at par. The Czech Republic planned to adopt the euro in 2012, but its government suspended that plan in 2007.
[3] The Danish krone has been in the ERM II since the launch of the euro in 1999; the Estonian kroon, Lithuanian litas, and Slovenian tolar were included on 28 June 2004; the Cypriot pound, the Latvian lats and the Maltese lira on 2 May 2005; and the Slovak koruna on 28 November 2005.The currencies of the three largest countries which joined the European Union on 1 May 2004 (the Polish zloty, the Czech koruna, and the Hungarian forint) are expected to follow eventually. Slovenia joined the euro-zone in 2007, Cyprus and Malta joined in 2008, and Slovakia joined in 2009.

Throughout this period the CNB was largely engaged in leaning-against-the-wind operations to slow down the steady appreciation of the koruna relative to the euro (over the period 1999 through September 2002 the koruna appreciated by over 25% against the euro). The koruna abruptly reversed direction in the fall of 2002, and depreciated relative to the euro through early 2004 (during which time the CNB ceased intervening). In April 2004, as the koruna again began to appreciate against the euro, the CNB announced that it would begin to sell some its euro-denominated reserves. At that time, the euro value of its foreign reserve holdings was €21.9 billion (or $26.3b). The apparent rationale for the policy of reserve decumulation was to reduce the valuation losses that followed from the fact that Czech reserves are largely denominated in euros, the value of which was falling relative to the koruna. At the same time, the CNB was explicit in not wanting to influence, and in particular further appreciate, the koruna relative to the euro.[5]

The CNB decision to sell euro-denominated reserves starting in 2004 seems to have been well understood by market participants, but the timing and size of sales was not pre-announced. In June 2007 the CNB changed its discretionary approach to reserve sales; from this point on it sold €3m on a daily basis (in three equal installments within the day) through the end our data sample in November 2007.[6] This project examines whether these CNB reserve sales, both during the regime of discretionary timing as well as when sales occurred every day, had *unintended* consequences. We specifically test

[4] The CNB intervened on 1,247 occasions over the period 1997 through September 2002. See Disyatat and Galati (2007), Egert and Komarek (2006), Gersl and Holub (2006), and Scalia (2008) for analyses of these operations.

[5] See IMF Country Report No. 04/266 (http://imf.org/external/pubs/ft/scr/2004/cr04266.pdf) which states that the CNB recent decision to begin selling reserves was aimed solely at limiting further accumulation of reserves and "was not intended to influence the level of the exchange rate" (page 12).

[6] The daily sales amount of €3m is consistent with what can be inferred from the publicly available CNB data on unsettled foreign exchange transactions (http://www.cnb.cz/en/financial_markets/foreign_exchange_market/DEVOP_EUR_ENG.HTML).

whether these euro-denominated reserve sales influenced the CZK-EUR rate, while controlling for other factors that may have affected the relative value of the koruna.[7]

Our results suggest that over the full sample period, and the first (discretionary) regime, there is little evidence that euro reserve sales influenced the koruna. However, the decumulation in 2007, when the CNB sold euros every business day, led to a statistically significant appreciation of the koruna relative to the euro.

This finding that rules-based reserve sales lead to the relative appreciation of the domestic currency is surprising and intriguing. Economic theory generally suggests that "expected" policies are less likely to have an influence than "unexpected" ones.[8] Yet it is during the regime in which the CNB sold reserves every day that the sales seem to have influenced the value of the koruna.[9] The results are also surprising in the context of the intervention literature. It remains controversial whether traditional foreign exchange interventions operations, which are generally *intended* to influence currency values, are able to do so.[10] In this case reserve sales were explicitly not intended as

[7] The CNB has followed an inflation-targeting monetary regime since 1998. Actual Czech inflation generally kept well within its target range over our sample period (the CNB inflation target band was 3-5% in 2004, 2-4% in 2005, 3% in 2006 and 2% in March 2007). It is generally the case that countries that effectively target inflation sterilize their foreign currency operations. In the CNB case, sales of foreign reserves, if not sterilized with a matching increase in domestic assets, would result in a decrease in the monetary base. Our empirical specification controls for the possibility that reserve sales are not sterilized by including a daily (11am CET) Czech short-term interest rate (the 3-Month PRIBOR rate). The daily PRIBOR rate is statistically insignificant in all specifications estimated across the full sample period as well as the two subsamples, and inclusion of the interest rate does not influence any of the coefficient estimates on the other explanatory variables in the regressions, indicating that CNB reserve sales are sterilized. These results are available from the authors upon request.

[8] For an early example see Sargent and Wallace (1975) who show that if expectations are formed rationally (and there are no other sources of stickiness in the price mechanism) anticipated policies should have no real effects.

[9] Although reserves sales occurred every day it is worth noting that market participants at the time did not know whether this regime would continue indefinitely, as a consequence the sales can't be considered perfectly anticipated.

[10] See Dominguez and Frankel (1993), Dominguez (2006), Dominguez and Panthaki (2007), Fatum and Pedersen (2009), Fatum (2008) and Kearns and Rigobon (2005) for discussions of the efficacy of traditional intervention policy.

interventions in currency markets, but our results nonetheless suggest they did have an influence.

This study examines the effects of Czech National Bank sales of euro-denominated reserves on the koruna. In the next section we describe the institutional context in which the Czech authorities decided to decumulate their foreign reserves. In section 3 we detail the intraday data that we use to test the hypothesis that reserve decumulation leads to an appreciation of the domestic currency. Section 4 describes the econometric methodology that we use to take into account the seasonal features of intraday exchange rate movements and section 5 provides estimation results from regressions of CZK-EUR returns on CNB reserve sales. Section 6 provides robustness checks and our conclusions are in section 7.

2. Institutional Aspects of CNB Reserve Sales

Figure 1 shows that Czech reserve holdings during our sample period were high relative to other emerging market countries with similar per capita GDP. However, if we compare Czech reserve holdings to other Eastern European countries and Russia (figure 2); they are closer to the median, well below Poland and Russia, but higher than Hungary and Bulgaria. At the end of 2007, foreign exchange reserves represented approximately 83% of the CNB's assets, 57.4% were denominated in euros, and the return on these reserves was the CNB's most significant revenue item.[11]

In their Annual Reports over the 2004-2007 period the CNB describes that it attempts to manage foreign exchange rate and interest rate risk on foreign reserves

[11] Annual Report of the Czech National Bank, 2004, 2005, 2006, 2007. http://www.cnb.cz/en/about_cnb/performance/annual_reports/index.html

based on the requirement that the euro portfolio should not record a loss (in absolute terms and relative to an unspecified benchmark portfolio) in any moving twelve-month period (the dollar portfolio criteria is that it not record a loss in any moving 36-month period). Figure 3 shows the evolution of the CZK-EUR rate from 1999 through the end of 2008. Over most of this period the koruna steadily appreciated against the euro. It is in this context that the CNB decided to sell euro-denominated reserve assets beginning in 2004.

While the CNB decision to sell euro-denominated reserves is documented in their Annual Reports starting in 2004 as well as IMF Article IV consultation reports, we were unable to find any publicly released detail on the implementation of this policy, in terms of the amount of reserves to be sold or the timing of the sales. The transaction data we obtained from the CNB indicates no discernable patterns of sales in terms of days of the week, time of day, or amounts in the first three years of our sample. We consequently describe the reserve sales in this period as belonging to a discretionary regime. Reserve sales occur on every business day by mid-2007, in three equal sized transactions, for identical amounts. The only unpredictable aspect of sales in this period is the intraday timing of the three transactions. We describe reserve sales in this subperiod as rules-based.

The koruna's appreciation trend briefly reversed in the first half of 2007. The use of the koruna as a funding currency for carry trade operations can explain most of this turnaround. The ECB started tightening monetary policy in 2006 and relatively low interest rates in the Czech Republic led investors to borrow in koruna to finance the purchase of debt instruments in higher-yielding currencies (such as the Icelandic krona).

In mid-2007 the CNB responded by tightening monetary policy, resulting in an unwinding of the koruna carry trade by mid-August. It is worth noting that the CNB continued to sell euro-denominated reserves under the rules-based regime during this brief period of koruna depreciation.

3. Data

The reserve data used in this study cover all CNB transactions over the 1 January 2004 to 23 November 2007 period. The data is provided by the CNB, and the sample period is determined by data availability. The data include transaction specific information: the euro value of each sale and the time-stamp to the nearest minute. During our sample period all CNB reserve transactions are sales of euro-denominated assets.

Table 1 provides descriptive statistics of the CNB reserve sales data.[12] Our sample includes 498 days with reserve sales, and 1,048 intraday reserve sale transactions. The maximum intraday transaction is €7 million in 2004 and the minimum intraday transaction amount is €1 million. The yearly cumulated amount of reserve sales ranges from €208 million in 2006 to €707 million in 2007. In percentage terms, relative to the total reserve stock, the CNB sales are quite small. For example, in 2007 the euro value of CNB reserves was €23.7 billion, so total euro sales of €707 million amounts to 3.5% of the total stock. Figure 4 shows that the koruna value of CNB reserve stocks fell by around 13% over this four year period, this decline in value is due both to the appreciation of the koruna and sales of reserves.

The high-frequency CZK-EUR exchange rate data is from GenesisFT, and covers the full 2004 to 2007 sample period. The data consists of quotes for the CZK-EUR

[12] Given the confidential nature of the intra-day reserve sales, we can't display or describe the data in greater detail.

spot rate at the end of every 15-minute interval over every 24-hour period. The rates are indicative quotes posted by traders. We follow Dacorogna, Müller, Nagler, Olsen and Pictet (1993) and filter the data for anomalies and bad quotes.[13]

Consistent with other intraday studies focusing on currency pairs with limited trading outside of local business hours (see Fatum and Pedersen 2009), we define a trading day in the Czech currency market to start at 8am (7.00 GMT+1) and finish at 6pm (17.00 GMT+1).[14] As a result, our analysis spans 1,005 trading days and a total of 41,205 15-minute observations. All CNB reserve sales transactions were carried out during Prague business hours, so that they are consistent with our trading day definition. While the exchange rate is quoted every 15 minutes, reserve transaction times were provided to the minute. We therefore cumulate reserve transactions in each 15-minute interval.

Czech and Euro-area interest rates, which are used as controls in our empirical analysis, are obtained from the websites of the CNB (www.cnb.cn/en) and the ECB (www.ecb.int), respectively. Time-stamped Czech and Euro-area macro announcements and preceding survey expectations are obtained from Bloomberg. Table 2 provides summary statistics for the CZK-EUR intraday exchange rate, the interest rates and the macro news.

4. Econometric Methodology

In order to take into account the long memory and intraday seasonality that characterizes high-frequency exchange rates, our baseline estimates of the response of the

[13] Intra-day transaction prices are not available for the CZK-EUR exchange rate market.
[14] This definition of a trading day carries over naturally to a definition of a weekend, i.e. we define a weekend to start at 17.15 GMT+1 Friday and finish at 7.00 GMT+1 Monday.

koruna exchange rates to CNB euro reserve sales follow the two-step weighted least squares (WLS) procedure developed by Andersen and Bollerslev (1998). Specifically, we model the response of the CZK-EUR exchange rate as a linear function of J lagged values of the exchange rate itself and the contemporaneous and K lags of the reserve sales variable, R_t:

$$(1) \qquad s_t = \beta_0 + \sum_{j=1}^{J} \beta_j s_{t-j} + \sum_{k=0}^{K} \gamma_k R_{t-k} + \varepsilon_t, t = 1...T$$

where s_t is the first-difference in logs of the CZK-EUR spot exchange rate. As noted earlier, T=41,205. We include 3 lags (45 minutes) of CZK-EUR returns (J=3) based on the Schwartz and Akaike information criteria and include prior reserves sales in the previous 75 minutes (K=5); we vary the number of time lags in our robustness checks. The estimation procedure is as follows: first, we estimate equation (1) by OLS and obtain the estimated residuals, $\hat{\varepsilon}_t$; next we model the volatility pattern using these estimated residuals. We follow Andersen, Bollerslev, Diebold and Vega (2003) in using the following parameterization:

$$(2) \qquad \left|\hat{\varepsilon}_t\right| = c + \alpha \frac{\hat{\sigma}_t}{\sqrt{n}} + \sum_{k=0}^{K} \beta_k R_{t-k} + \left(\sum_{q=1}^{Q} \delta_q \cos(\frac{q2\pi t}{40}) + \phi_q \sin(\frac{q2\pi t}{40}) \right) + u_t$$

where the absolute value of the residuals in equation (1) proxies for volatility in the 15-minute interval *t*, *c* is a vector of normalizing constants, *n* is the number of intervals in a day (in our case 40), $\hat{\sigma}_t$ is the one-day ahead volatility forecast for day *t* (i.e. the day that contains interval *t*), *q* is a specific intraday calendar effect, *Q* is the total number of calendar effects accounted for (*Q*=5, based on the Schwartz and the Akaike information criteria), and u_t denotes the residuals (assumed to be standard normal). We model the

lower frequency intraday pattern (the first term after the vector of constants) using realized volatility, and we model the higher frequency periodicity by inclusion of the Fourier flexible form (the terms in the parenthesis of equation 2).

In order to take into account the possibility that volatility is also influenced by macroeconomic news, we follow Andersen and Bollerslev (1998) and Andersen, Bollerslev, Diebold and Vega (2003), by including CNB reserve sales in the volatility equation.

5. Results

5.1 Baseline Estimations

We estimate the baseline WSL regression model over the full sample period, 1 January 2004 to 23 November 2007, as well as separately across the two sales regimes, the discretionary sales regime (1 January 2004 to 18 June 2007) and the rules-based regime (19 June 2007 to 23 November 2007 period). A positive reserve transaction indicates a sale of euros (EUR) against koruna (CZK) and the exchange rate is measured in terms of CZK per EUR. Therefore, a negative reserve sale coefficient estimate or a negative cumulative effect of reserve sales would imply that sales of euro-denominated reserves are associated with an appreciation of the CZK vis-à-vis the EUR.

Tables 3 and 4 display the results of the benchmark estimations of equations (1) and (2), respectively. The first column of Table 3 shows that for the full sample the coefficient estimates associated with the first, third, and fourth lags of euro-denominated reserves sales are significant at either 95 or 90% significance levels, and these coefficients are of the expected negative sign (sales of euro-denominated reserves are associated with a CZK appreciation). The Wald test of the hypothesis that the (negative)

sum of the estimated reserve sales coefficients is equal to zero is marginally rejected at 90% significance.

The discretionary sales regime (subsample 1) results shown in column 2 are similar to those found for the full sample, though we find that the cumulative (negative) effect of reserve sales is insignificant. These results suggest that during the first three years of discretionary reserve sales the CNB was able reduce its euro-denominated reserve holdings without adversely affecting the value, in domestic currency terms, of its remaining euro-denominated reserves.

However, this result is reversed in the rules-based regime in 2007. The sub-sample 2 results, shown in column 3, indicate that reserve sales significantly impact the CZK rate (at the 99% significance level). Further, the Wald test strongly rejects (again at the 99% significance level) that the (negative) sum of the estimated reserve sales coefficients is equal to zero. These estimates suggest that during sub-sample 2 CNB reserve sales influenced the CZK rate in the theoretically consistent but, from a policy perspective, undesired direction.

Table 4 displays the results of the estimation of the volatility model described in equation (2). Whether we estimate the volatility model across the full sample (column 1), sub-sample 1 (column 2), or sub-sample 3 (column 3), our results suggest that reserve sales are associated with reduced exchange rate volatility. While the realized volatility term associated with lower frequency periodicity is highly significant, the trigonometric terms are largely insignificant, suggesting an absence of intraday calendar effects in this market.

5.2 Reaction Functions and Unexpected Reserve Sales

It is possible that the specific timing of reserve sales transactions - for sub-sample 1 in terms of intraday timing as well as in terms of the specific days on which reserve sales occur, and for sub-sample 2 in regards only to intraday timing – is influenced by both the contemporaneous exchange rate movement (i.e. the change in the exchange rate that occurs over the 15-minute interval within which a reserve sale is carried out) and the recent (lagged) exchange rate movements. Furthermore, a close inspection of the reserve sales data reveals that reserve sales transactions tend to be episodic both across days and within days, suggesting that current reserve sales are significantly correlated with recent (lagged) reserve sales. As a result, our reserve sales variable may contain an expected component that, if unaccounted for, will lead to an underestimation of the true effect of reserve sales on exchange rates. In other words, despite the high-frequency of our data, our study may not be immune to endogeneity.

In order to control for this potential endogeneity, we follow a similar strategy as the daily data studies by Humpage (1999) and Namalendran and Naranjo (2000) and the intraday study by Fatum and Pedersen (2009). We first estimate a CNB reserve sales reaction function in order to capture the expected component of reserve sales. We then use the residuals from the reserve sales reaction function estimation (i.e. we subtract the expected component of reserve sales from the actual reserve sales) as a measure of unexpected reserve sales. In this way we can obtain an estimate of the influence of unexpected CNB reserve sales on the CZK-EUR exchange rate that is free of simultaneity bias.

The results of the reaction function estimation are provided in Table 5. The table shows that for sub-sample 1, the coefficient on the exchange rate is positive and highly significant, i.e. a depreciation of the CZK increases the odds of seeing a reserve sale transaction carried out within the following hour. The positive and significant coefficient on lagged reserve sales confirm the observed clustering of sales, i.e. once a reserve sale transaction is carried out the likelihood of another reserve sale increases. Interestingly, the sub-sample 2 reaction function results are markedly different, confirming that a change in CNB sale strategy took place. First, lagged exchange rate movements no longer help predict reserve sales, implying that sales are no longer aimed at timing the market. Second, while the first lag of reserve sales is still significant and positive, the remaining significant lags are negative, suggesting that unless a reserve sale is immediately followed by another transaction, the likelihood of seeing more sales decreases. These results are consistent with the fact that during sub-sample 2 it is always the case that three reserve sales occur on each business day (though the timing of these sales is not the same across days).

The results of the re-estimation of the conditional mean model described in Equation (1) using unexpected reserve sales in place of the actual reserve sales are provided in Table 6. The results are qualitatively similar to the baseline estimation results that are carried out without controlling for endogeneity (Table 3).[15]

5.3 Macro News

In order to ensure that the estimated effects of reserve sales are not tainted by the coincidental arrival of macro news, we extend our analysis to include time-

[15] This is not surprising given that the explanatory power of the reaction function regressions, as measured by goodness-of-fit, is low across both the sub-sample estimations.

stamped Czech and Euro-area macro news. Specifically, we include official macroeconomic announcements pertaining to changes in the Czech monetary policy rate (CZMONPOL) and surprises in Czech CPI (CZCPIYOY and CZCPIMOM), PPI (CZPPIMOM), industrial production (CZINDPROD), unemployment (CZUNEMP) and trade balance (CZTB); as well as changes in the Euro-area monetary policy rate (EURMONPOL) and surprises in Euro-area CPI (EURCPIYOY), PPI (EURPPIYOY and EURPPIMOM), GDP (EURGDP), and unemployment (EURUNEMP).

We measure macro surprises as the difference between the macro announcement and the preceding survey expectation obtained from Bloomberg. We follow Andersen, Bollerslev, Diebold and Vega (2003, 2007) and others by standardizing the macro news variables (i.e. for each news variable we divide the surprise by its sample standard deviation). Almeida, Goodhart, and Payne (1998) and Andersen, Bollerslev, Diebold and Vega (2003) show that the conditional mean of the exchange rate generally adjusts immediately in response to macro news, thus we only control for contemporaneous macro news. [16]

The estimated results of re-running equations (1) and (2) with the macro news variables included are shown in Table 7.[17] The estimated coefficients indicate that, with few exceptions, macro surprises exert no significant influence on the CZK-EUR exchange rate. Of more importance to our research question, the table also shows that the inclusion of macro news does not in any way change the previously reported results regarding the influence of reserve sales on currency values.

[16] In another set of estimations we include the first lag of macro news as well, to take into account the possibility of slower adjustment in this market, and find the results to be unchanged. These estimation results are not shown for brevity but are available from the authors upon request.

[17] Due to the relatively short duration of the second sub-sample only a limited number of non-zero macro news data points are included in the estimations.

6. Robustness

In order to test the robustness of our results, we carry out the analysis using a different econometric procedure, a different reserve sales lag-structure, a different sub-sample demarcation point, and a different trading day definition. Additionally, we investigate whether the reserve sales are anticipated by traders by testing for lead effects.[18]

First, the gain in efficiency from the WLS procedure is potentially costly in terms of inconsistent estimates if the residuals from the initial estimation of equation (1) are improperly fitted in the volatility model described by equation (2). In order to address this potential concern we also estimate the baseline model using heteroskedasticity- and serial-correlation consistent (HAC) standard errors (i.e. we re-estimate equation (1) using HAC errors). The HAC results are qualitatively identical to the conditional mean results based on the two-step WLS procedure.

Second, in order to test for delayed effects of reserve sales beyond the 5th lag captured by our baseline model, we re-estimate our models with an additional 4 lags (60 minutes) of reserve sales included. These estimates confirm that reserve sales are only significantly associated with an appreciation of the CZK in subsample 2. Furthermore, none of the additional reserve sales lags (lags 6 through 9) are individually significant, and a separate test of the hypothesis that the sum of the reserve sales coefficients for lags 6 through 9 equals zero is not rejected.

Third, we change the sub-sample demarcation point. The hitherto employed demarcation point of June 19, 2007 is well-defined because, as discussed previously, it is

[18] Estimation results for the robustness analyses described in this section are available from the authors upon request.

based on when the CNB switched to a rules-based regime of carrying out exactly three reserve sales transactions of the same size on any given business day. However, since the reserve sales frequency increased substantially by the beginning of 2007 (although not to the point of daily sales of identical magnitudes), we test the robustness of our results by employing as an alternative demarcation point 7 January 2007. While the overall fit of the model deteriorates slightly when estimated across the alternatively defined (and thus extended) sub-sample 2, the results remain qualitatively unchanged: sub-sample 1 reserve sales have no detectable influence on the exchange rate while sub-sample 2 sales are, on average, systematically associated with an appreciation of the CZK vis-à-vis the EUR.[19]

Fourth, in order to ensure that the possibility of abnormal trading activity at either the beginning or the end of the trading day is not affecting our results we respectively shrink and expand our trading day definition by 60 minutes, i.e. we first redo the baseline estimations with a trading day defined to start at 7:30am (6.30 GMT+1) and finish at 6:30pm (17.30 GMT+1) and, subsequently, a trading day defined to start at 8:30am (7.30 GMT+1) and finish at 5:30pm (16.30 GMT+1).[20] The estimation results associated with these alternative trading day definitions are qualitatively identical to the previously discussed results.

Fifth, we address the possibility that the market anticipates and, therefore, systematically prices in the effect of the reserve sales prior to their occurrence by testing for the presence of lead effects of reserve sales. Specifically, we add two (30 minutes)

[19] We also momentarily disregard any institutional insights and visually detectable data structure in order to test for an unknown break-point (see Andrews 1993). The Andrews test identifies a break-point on 9 November 2006. When we use this demarcation point to distinguish our two subsamples our results remain robust. This is not surprising given that there are only two reserve sales days between 9 November 2006 and 7 January 2007.

[20] When we shrink the trading day definition two end-of-day reserve sales transactions are excluded from the analysis.

and, subsequently, five leads (75 minutes) of reserve sales to the baseline conditional mean model (Equation 1), and test whether the respective sums of leads (two or five leads) are significantly different from zero. Whether testing for lead effects of reserve sales across the full sample or separately across either of the two sub-samples, we find no evidence of cumulative lead effects.

7. Conclusion

Economists have long studied the question of optimal reserve holdings by governments. Foreign reserve stocks have risen dramatically for many developing countries in recent years, often motivated by the desire for precautionary self-insurance. However, one of the negative consequences of large accumulations of reserves denominated in foreign currency for these countries is the risk of valuation losses. In this paper we examine the implications of systematic reserve decumulation, intended to mitigate valuation losses, on domestic currency movements. Our findings are striking. We find little evidence that reserve decumulation influences the exchange rate when sales are carried out on a discretionary basis. By contrast, our results show that when these sales are carried out in a rules-based manner – identical amounts sold every business day – a significant appreciation of the domestic currency follows. The economic significance of this appreciation is not negligible. The estimates suggest that the cummulative effect on the CZK of Czech National Bank euro-denominated reserve sales in 2007 (of approximately €700 million) led to a 4.9% appreciation of the koruna relative to the euro.[21]

[21] The coefficient associated with the effect of reserve sales for sub-sample 2 is -72.42(10E6), which indicates that a €100 million reserve sale corresponds, on average, to a 0.7% appreciation of the CZK..

Our estimates of the effects of reserve decumulation by the Czech authorities are qualitatively similar to estimates in the literature of the effects of intervention in currency markets, even though the CNB explicitly did not intend to influence the value of the koruna with these operations. Dominguez and Frankel (1993) find that a $100 million purchase by the Fed leads to a 1.6% appreciation of the dollar, while Kearns and Rigobon (2005) find that a $100 million purchase of AUD by the Australian Central Bank leads to a 1.8% appreciation of the AUD, and a Bank of Japan purchase of $100 million JPY leads to a .2% appreciation of the JPY.

It is important to note that the reserve decumulation we study in this project occurs over a time period in which the CNB and its currency, the koruna, was not in crisis. Indeed, the reason the Czech monetary authority decided to impliment a decumulation strategy in 2004 was because the koruna was strong relative to the underlying currencies (particularly the euro) denominating the Czech reserve portfolio. Our results are therefore not indicative of what might happen in reaction to reserve depletion during a currency crisis.

While Czech foreign reserve stocks are large relative to other countries with similiar per capita GDP, they are dwarfed by China's massive stock of dollar-denominated reserves. Moreover, the potential valuation losses for China if its currency, the yuan, begins to appreciate relative to the dollar (something the Chinese government has recently suggested it may allow) are enormous. It is for this reason that it is interesting to consider what our coefficient estimates would suggest for China if it were to impliment the CNB's decumulation strategy for a fraction of its dollar-denominated reserve assets. On a daily basis CNB euro sales in 2007 were roughly .2 percent of

average CZK turnover in the euro market.[22] Daily average yuan (CNY) turnover in the dollar market was $9,153 million in 2007 (which was roughly 5 times higher than CZK turnover in the euro market). If we calibrate China's hypothetical dollar reserve sales to be similar in scale to those by the CNB in terms of the size of the yuan-dollar market, resulting in sales of $18 million per day, this decumulation policy would trigger a daily appreciation of .02% for the yuan. The annual effect of a years' worth of such daily sales would result in a 4.4% appreciation of the yuan (e.g. the CNY-USD rate would fall from 6.8 to 6.5).[23] These calculations are based on the assumption that the Chinese government publicly pre-announces the decumulation policy, that it systematically sells dollar assets every day, and that it allows the yuan to appreciate. On the other hand, if China instead followed the initial Czech approach to decumulation, selling reserves in a more discretionary manner, our findings suggest that it might be possible for China to likewise shed dollar assets without impacting the yuan exchange rate. Our priors are that the likely reaction of markets to a gradual decumulation of dollar-denominated reserve assets by China would likely lie somewhere between these two estimates.

[22] Average daily CZK turnover in the Euro market was $1,902 million in 2007. See, BIS Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity in 2007, http://www.bis.org/publ/rpfxf07t.htm Statistical Annex Table E.4, pp 66.

[23] A years' worth of $18 million sales is $4 billion (220 x $18m), or roughly .2% of China's $2.4 trillion reserve stock.

References

Almeida, Alvaro, Charles Goodhart and Richard Payne (1998). "The Effects of Macroeconomic News on High Frequency Exchange Rate Behavior," Journal of Financial and Quantitative Analysis 33, 383-408.

Andersen, Torben G. and Tim Bollerslev (1998). "Deutsche Mark-Dollar Volatility: Intraday Activity Patterns, Macroeconomic Announcements, and Longer-Run Dependencies," Journal of Finance 53, 219-265.

Andersen, Torben G., Tim Bollerslev, Francis X. Diebold, and Clara Vega (2003). "Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange," American Economic Review 93, 38-62.

Andersen, Torben G., Tim Bollerslev, Francis X. Diebold, and Clara Vega (2007). "Real-Time Price Discovery in Global Stock, Bond and Foreign Exchange Markets," Journal of International Economics 73, 251-277.

Andrews, D. W. K. (1993). "Tests for Parameter Instability and Structural Change with Unknown Change Point," Econometrica 61, 821-856.

Disyatat, Dis and Gabriele Galati (2007). "The Effectiveness of Foreign Exchange Intervention in Emerging Market Countries: Evidence from the Czech Koruna," Journal of International Money and Finance, 26, 383-402.

Dominguez, Kathryn (2010). "International Reserves and Underdeveloped Capital Markets," in NBER International Seminar on Macroeconomics 2009, edited by Lucrezia Reichlin and Kenneth West, University of Chicago Press for the NBER, 193-221.

Dominguez, Kathryn (2006). "When do Central Bank Interventions Influence Intra-daily and Longer-term Exchange Rate Movements?" Journal of International Money and Finance, 25, 1051-1071.

Dominguez, Kathryn and Freyan Panthaki (2007). "The Influence of Actual and Unrequited Interventions," International Journal of Finance and Economics, 12, 171-200.

Dominguez, Kathryn and Jeffrey Frankel (1993). Does Exchange Rate Intervention Work?, Institute for International Economics, Washington, D.C..

Egert, Balazs and Lubos Komarek (2006). "Foreign Exchange Interventions and Interest Rate Policy in the Czech Republic: Hand in Glove?" Economic Systems vol. 30, 121-140.

Fatum, Rasmus and Jesper Pedersen (2009). "Real-Time Effects of Central Bank Intervention in the Euro Market," Journal of International Economics 78(1), 11-20.

Fatum, Rasmus (2008). "Daily Effects of Foreign Exchange Intervention: Evidence from Official Bank of Canada Data," Journal of International Money and Finance 27(3).

Gersl, Adam and Holub, Tomas (2006). "Foreign Exchange Interventions under Inflation Targeting: The Czech Experience," Contemporary Economic Policy vol. 24, 475-491.

Humpage, Owen (1999). "U.S. Intervention: Assessing the Probability of Success," Journal of Money, Credit and Banking 31, 731-747.

Jeanne, Olivier (2007). "International Reserves in Emerging Market Countries: Too Much of a Good Thing?" Brookings Papers on Economic Activity, 1-55.

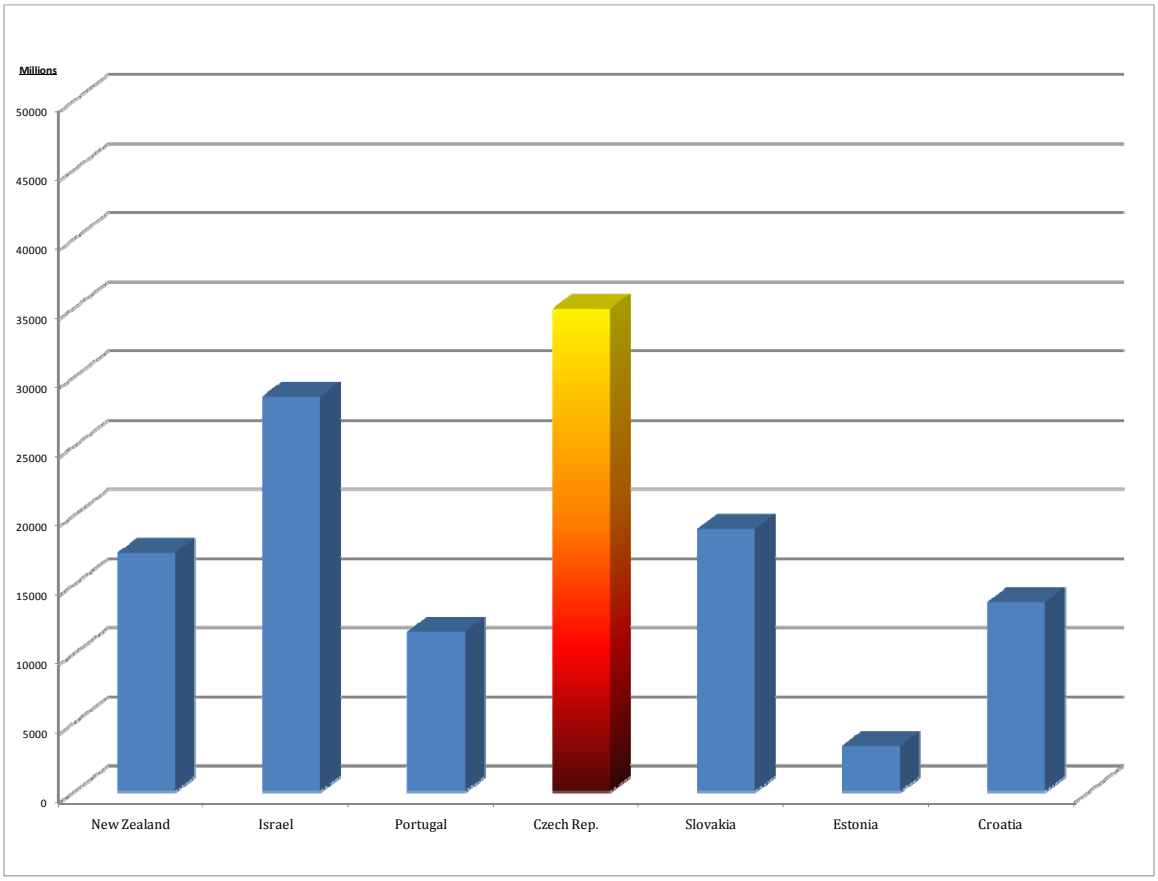
Kearns, Jonathan and Roberto Rigobon (2005). "Identifying the efficacy of central bank interventions: Evidence from Australia and Japan," Journal of International Economics, 66, 31-48.

Naranjo, Andy and Mahen Nimalendran (2000). "Government Intervention and Adverse Selection Costs in Foreign Exchange Markets," Review of Financial Studies 13, 453-477.

Sargent, Thomas and Neil Wallace (1975). "Rational Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule," Journal of Political Economy, 83, 2, 241-54.

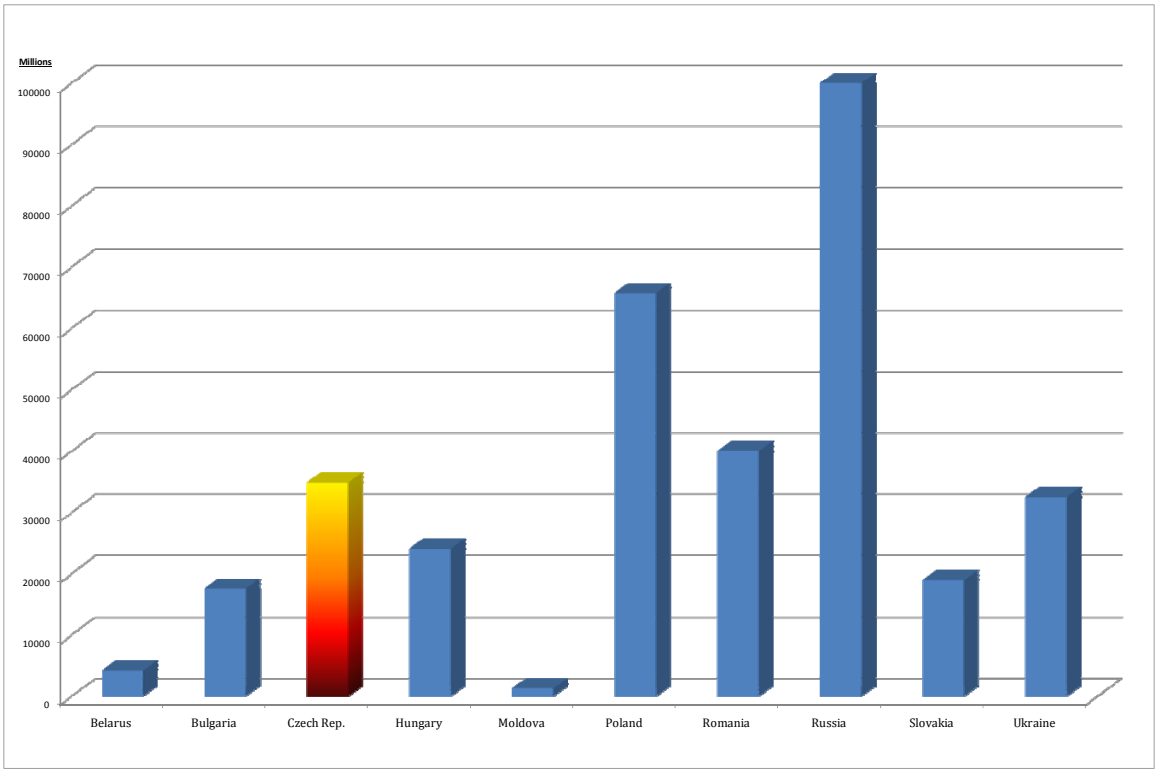
Scalia, Antonio (2008). "Is Foreign Exchange Intervention Effective? Some Micro-Analytical Evidence from Central Europe," Journal of International Money and Finance 27, 529-546.

Figure 1
Foreign Reserve Assets (in US Dollars) held by Countries with similar GDP per capita as the Czech Republic (December 2007)



Source: IMF, IFS Statistics

Figure 2
Foreign Reserve Assets (in US Dollars) held by Eastern European Countries and Russia (December 2007)

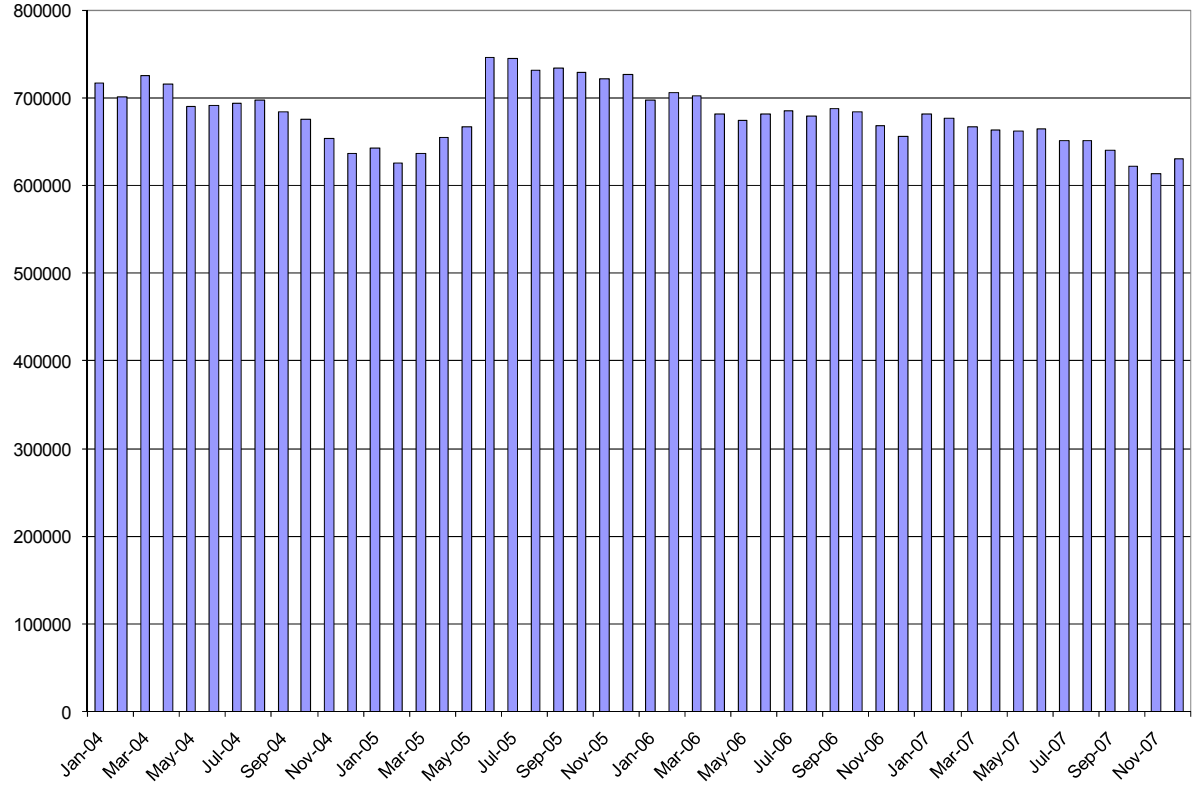


Source: IMF, IFS Statistics

Figure 3
CZK-EUR rate (1999-2008)

Data source: GenesisFT

Figure 4
CNB Foreign Reserve Stock (monthly, in millions of koruna)



Data source: Czech National Bank

Table 1	CNB Euro Reserve Sales			
	2004	2005	2006	2007
Total Number of Days with Reserve Sales	105	114	72	207
Total Number of Intraday Reserve Sales Transactions	193	231	104	520
Maximum Transaction Amount (Intraday)	€7	€2	€2	€2
Minimum Transaction Amount (Intraday)	€1	€1	€2	€1
Cumulated Euro Value of Reserve Sales	€439	€461	€208	€707

Notes:
(a) Data source: Czech National Bank
(b) Reserve transaction amounts in millions of EUR
(c) Sample ends November 23, 2007.

Table 2	Summary Statistics				
	Mean	Std. Dev.	Maximum	Minimum	Non-Zero Observations
CZK/EUR Spot Rate	29.51555	1.640642	33.555	26.516	96480
CZ Monetary Policy Rate	0.000013	0.002669	0.25	-0.25	11
CZ CPI MoM	-0.00000259	0.005273	1.1	-0.5	37
CZ 3-Month PRIBOR	0.0000449	0.002916	0.22	-0.25	427
CZ CPI YoY	-0.00000622	0.005426	1.1	-0.5	34
CZ PPI MoM	0.000000207	0.006519	0.8	-0.8	40
CZ Industrial Production	0.000292	0.073318	7.40	-6.7	47
CZ Unemployment	-0.0000166	0.001985	0.2	-0.2	26
CZ Trade Balance	0.537376	84.83538	11212	-5776	44
EUR Monetary Policy Rate	0.0000311	0.002788	0.25	0	12
EUR CPI YoY	-0.00000311	0.001327	0.1	-0.1	17
EUR PPI YoY	0.0000207	0.002535	0.5	-0.2	26
EUR PPI MoM	0.00000415	0.002184	0.4	-0.2	22
EUR GDP YoY	0.00000316	0.00216	0.3	-0.3	20
EUR Unemployment	-0.00000829	0.002184	0.4	-0.2	22

NOTES:
(a) All data series run from January 1, 2004 to November 23, 2007.
(b) The exchange rate series contain a quote every 15-minutes; the macro surprises are measured as the difference between the time-stamped announcement and preceding median survey value. The Czech 3-Month PRIBOR rate as well as the Czech and Euro-area monetary policy rate series measure actual changes.
(c) The intraday exchange rate data is from GenesisFT. The reserve sales and PRIBOR data are provided by the Czech National Bank. The macro news is obtained from Bloomberg.

Table 3	Exchange Rate Responses to Reserve Sales: Conditional Mean Equation		
	Full Sample	Sub-Sample 1	Sub-Sample 2
Constant	1.84 (1.45)	2.10 1.61	2.96 (4.15)
DLNCZKEUR(-1)	-0.27*** (0.00)	-0.29*** (0.00)	-0.17*** (0.01)
DLNCZKEUR(-2)	-0.07*** (0.00)	-0.08*** (0.00)	-0.05*** (0.01)
DLNCZKEUR(-3)	-0.04*** (0.00)	-0.05*** (0.00)	0.01 (0.01)
RESSALE	3.57 (4.07)	5.72 (4.46)	-13.24 (10.49)
RESSALE(-1)	-10.45** (4.39)	-9.83** (4.84)	-10.90 (10.20)
RESSALE(-2)	5.06 (4.19)	6.27 (4.69)	-0.77 (9.78)
RESSALE(-3)	-6.67* (3.99)	-7.81* (4.49)	5.29 (8.94)
RESSALE(-4)	-10.57** (4.85)	-7.70 (5.43)	-33.58*** (10.49)
RESSALE(-5)	0.16 (4.86)	4.48 (5.29)	-19.22 (12.56)
Sum of RESSALES	-18.90	-8.87	-72.42
Wald Statistic	3.30*	0.59	7.84***
Observations	41180	36547	4633

NOTES:
(a) * Denotes significance at 90%; ** denotes significance at 95%; *** denotes significance at 99%.
(b) Standard errors in ( ) below the point estimates.
(c) Estimations are defined in Equation (1) in the text, and carried out using 2WLS.
(d) The dependent variable, DLNCZKEUR, is the first difference of the log of the 15-minute CZK/EUR spot exchange rate.
(e) RESSALE denotes reserve sales of EUR carried out by the CNB. RESSALE is measured in millions of EUR.
(f) Point estimates and standard errors associated with Constant, RESSALE, and Sum of RESSALES are multiplied by 10(E6) for readability.
(g) Sum of RESSALES refers to the cumulative effect of contemporaneous and five lags of reserve sales.
(h) Sub-sample 1 runs from January 1, 2004 to June 18, 2007; Sub-sample 2 runs from June 19, 2007 to November 23, 2007.

Table 4	Exchange Rate Responses to Reserve Sales: Volatility Equation		
	Full-sample	Sub-sample 1	Sub-sample 2
Constant	4.4681*** (0.48202)	4.4259*** (0.52754)	5.5213*** (1.3573)
Realized Volatility	0.57415*** (0.008069)	0.57426*** (0.0085997)	0.55597*** (0.031715)
RESSALE	-1.601** (.70367)	-1.4058* (0.76247)	-2.927* (1.6435)
RESSALE(-1)	-.83874 (0.7041)	-0.61256 (0.76285)	-3.1001* (1.6447)
RESSALE(-2)	-1.3077* (0.70409)	-0.93504 (0.76271)	-3.6178** (1.6466)
RESSALE(-3)	-1.7565** (0.70409)	-1.3378* (0.76271)	-5.2815*** (1.6466)
RESSALE(-4)	0.26497 (0.70437)	0.63672 (0.76285)	-2.6724 (1.6509)
RESSALE(-5)	0.22122 (0.70557)	0.28121 (0.76387)	-0.026462 (1.6604)
$\delta(1)$	2.4858 (2.9144)	2.8846 (3.1796)	-1.0071 (6.3943)
$\delta(2)$	-1.4757 (2.9144)	-0.33122 (3.1791)	-8.9307 (6.3988)
$\delta(3)$	3.9579 (2.9142)	4.3334 (3.1789)	5.8841 (6.3926)
$\delta(4)$	0.75642 (2.9142)	0.77641 (3.1789)	0.029398 (6.3985)
$\delta(5)$	-0.94428 (2.9143)	-0.083674 (3.1789)	3.428 (6.3957)
$\varphi(1)$	-0.1573 (2.9143)	-0.5494 (3.1788)	2.4482 (6.3931)
$\varphi(2)$	-0.73456 (2.9146)	-1.7634 (3.1793)	-10.258 (6.4027)
$\varphi(3)$	3.4246 (2.9141)	4.7982 (3.1789)	5.2266 (6.3934)
$\varphi(4)$	-3.8461 (2.9141)	-3.9839 (3.1789)	4.3773 (6.4003)
$\varphi(5)$	2.0185 (2.9142)	3.8104 (3.1789)	12.329* (6.3951)
R^2	0.11029	0.10925	0.069477

NOTES:
(a) * Denotes significance at 90%; ** denotes significance at 95%; *** denotes significance at 99%.

(b) Standard errors in ( ) below the point estimates.
(c) Estimations are defined in Equation (2) in the text.
(d) The dependent variable is the absolute residual from the auxiliary regression defined in Equation (1).
(e) The independent variables are the constant, a realized volatility measure, reserve sales (RESSALE), and trigonometric terms (cosine terms denoted by δ, sine terms denoted by φ). RESSALE is measured in millions of EUR.
(f) Constant and reserve sales point estimates and standard errors are multiplied by 10(E5); point estimates and standard errors associated with trigonometric terms are multiplied by 10(E6).
(g) Sub-sample 1 runs from January 1, 2004 to June 18, 2007; Sub-sample 2 runs from June 19, 2007 to November 23, 2007

Table 5	Reserve Sale Reaction Function			
	Sub- Sample 1		Sub-Sample 2	
	all lags	selected lags	all lags	selected lags
Constant	0.04*** (0.00)	0.04*** (1591.02)	0.08*** (0.00)	0.08*** (0.00)
DLNCZKEUR(-1)	2.15 (2.07)	-	-2.25 (8.86)	-
DLNCZKEUR(-2)	2.48 (2.14)	-	-13.88 (8.94)	-
DLNCZKEUR(-3)	-1.58 (2.45)	-	11.57 (8.94)	-
DLNCZKEUR(-4)	7.58*** (2.93)	7.62*** (2.71)	-1.68 (8.21)	-
DLNCZKEUR(-5)	1.00 (2.86)	-	-4.39 (8.83)	-
DLNCZKEUR(-6)	-0.38 (2.51)	-	-12.92 (8.94)	-
DLNCZKEUR(-7)	3.09 (2.57)	-	5.04 (9.44)	-
DLNCZKEUR(-8)	0.71 (2.52)	-	-3.50 (9.12)	-
RESSALE(-1)	0.035*** (0.012)	0.035*** (0.012)	0.045** (0.018)	0.044** (0.018)
RESSALE(-2)	0.003 (0.06)	-	-0.008 (0.014)	-
RESSALE(-3)	0.013** (0.006)	0.014** (0.006)	-0.010 (0.012)	-
RESSALE(-4)	0.019*** (0.007)	0.019*** (0.007)	-0.012 (0.012)	-
RESSALE(-5)	0.014** (0.007)	0.015** (0.007)	-0.022** (0.011)	-0.023** (0.011)
RESSALE(-6)	0.006 (0.006)	-	-0.025** (0.010)	-0.023** (0.010)
RESSALE(-7)	0.006 (0.006)	-	-0.030*** (0.010)	-0.030*** (0.010)
RESSALE(-8)	0.012* (0.012)	-	-0.012 (0.013)	-
Observations	36547	36547	4633	4633
R-Squared	0.003	0.002	0.006	0.004
S.E. of Regression	0.29	0.29	0.28	0.28
F-Statistic	6.13***	17.22***	1.75**	4.78***

NOTES:
(a) * Denotes significance at 90%; ** denotes significance at 95%; *** denotes significance at 99%.
(b) Standard errors in ( ) below the point estimates.
(c) Estimations are carried out using OLS with heteroskedasticity and autocorrelation consistent (HAC) standard errors and covariances .
(d) The dependent variable, RESSALE, denotes reserve sales of EUR carried out by the CNB and is measured in millions of EUR. The variable DLNCZKEUR is the first difference of the log of the 15-minute CZK/EUR spot exchange rate
(e) Sub-sample 1 runs from January 1, 2004 to June 18, 2007; Sub-sample 2 runs from June 19, 2007 to November 23, 2007

Table 6	Exchange Rate Responses to Unexpected Reserve Sales	
	Sub-Sample 1	Sub-Sample 2
Constant	-1.15 (3.18)	-3.51 (7.02)
DLNCZKEUR(-1)	-0.31*** (0.01)	-0.16*** (0.03)
DLNCZKEUR(-2)	-0.10*** (0.01)	-0.04* (0.03)
DLNCZKEUR(-3)	-0.05*** (0.01)	0.03 (0.02)
UNEXRESSALE	16.02 (10.19)	-8.05 (22.91)
UNEXRESSALE(-1)	-0.40 (0.94)	-28.46 (20.95)
UNEXRESSALE(-2)	8.17 (10.11)	-9.28 (20.03)
UNEXRESSALE(-3)	-9.94 (8.84)	10.90 (16.80)
UNEXRESSALE(-4)	-10.61 (10.58)	-19.89 (18.82)
UNEXRESSALE(-5)	2.33 (9.64)	-37.71* (22.56)
Sum of RESSALES	5.57	-92.49
Wald Statistic	0.04	3.60*
Observations	36547	4633
R-Squared	0.09	0.03
S.E. of Regression	0.00	0.00
F-Statistic	332.35***	13.08***

NOTES:
(a) * Denotes significance at 90%; ** denotes significance at 95%; *** denotes significance at 99%.
(b) Standard errors in ( ) below the point estimates.
(c) Estimations are defined in Equation (1) in the text, and carried out using OLS with heteroskedasticity and autocorrelation consistent (HAC) standard errors and covariances .
(d) The dependent variable, DLNCZKEUR, is the first difference of the log of the 15-minute CZK/EUR spot exchange rate.
(e) UNEXRESSALE denotes unexpected reserve sales of EUR carried out by the CNB and is measured in millions of EUR. Unexpected reserve sales are proxied by the residuals of the reserve sale reaction function.
(f) Constant point estimates and standard errors are multiplied by 10(E6); point estimates and standard errors associated with UNEXRESSALE, as well as sum of UNEXRESSALES, are multiplied by 10(E11).
(g) Sum of RESSALES refers to the cumulative effect of contemporaneous and five lags of reserve sales
(h) Sub-sample 1 runs from January 1, 2004 to June 18, 2007; Sub-sample 2 runs from June 19, 2007 to November 23, 2007

Table 7	Exchange Rate Responses to Reserve Sales and Macro News		
	Full Sample	Sub-Sample 1	Sub-Sample 2
Constant	-0.72 (2.91)	-0.86 (3.11)	3.81 (7.76)
DLNCZKEUR(-1)	-0.30*** (0.01)	-0.31*** (0.01)	-0.17*** (0.03)
DLNCZKEUR(-2)	-0.09*** (0.01)	-0.10*** (0.01)	-0.05** (0.02)
DLNCZKEUR(-3)	-0.04*** (0.01)	-0.05*** (0.02)	0.04* (0.02)
RESSALE	12.48 (9.19)	14.96 (9.91)	-11.06 (21.59)
RESSALE(-1)	-4.12 (8.59	-0.79 (0.94)	-29.20 (20.70)
RESSALE(-2)	6.33 (9.30)	8.21 (10.10)	-5.28 (19.99)
RESSALE(-3)	-8.62 (8.13)	-10.58 (8.86)	11.83 (16.56)
RESSALE(-4)	-10.61 (9.77)	-9.93 (10.65)	-18.62 (18.58)
RESSALE(-5)	-0.53 (0.90)	3.34 (9.63)	-35.41 (22.26)
CZMONPOL	0.56 (3.65)	3.54 (3.43)	-13.19 (8.66)
CZCPIYOY	-7.07 (6.31)	-8.36 (6.48)	-9.06 (8.92)
CZCPIMOM	8.46 (6.52)	10.46 (6.65)	-14.43 (9.34)
CZPPIMOM	0.16 (1.40)	0.11 (1.50)	0.10 (2.53)
CZINDPROD	0.02 (0.16)	-0.06 (0.16)	0.14 (0.24)
CZUNEMP	-1.60 (4.58)	-3.20 (4.46)	19.37 (13.09)
CZTB	0.00 (0.00)	-0.00 (0.00)	0.00* (0.00)
EURMONPOL	-4.87 (7.23)	-4.99 (7.82)	-2.01 (12.11)
EURCPIYOY	1.41 (8.79)	1.81 (9.34)	-3.17*** (0.95)
EURPPIYOY	-0.12 (1.19)	-6.41 (11.15)	15.86 (12.21)
EURPPIMOM	2.26	12.00	-16.24

	(10.13)	(10.68)	(12.14)
EURGDP	-14.99** (6.01)	-18.04** (7.44)	-4.40*** (1.11)
EURUNEMP	3.90 (5.48)	6.37 (7.93)	-2.03 (1.98)
Sum of RESSALES	-5.07	5.21	-87.74**
Wald Statistic	0.07	0.06	4.22
Observations	41180	36547	4633
R-Squared	0.09	0.09	0.03
S.E. of Regression	0.0006	0.0006	0.0004
F-Statistic	174.65***	164.29***	7.55***

NOTES:
(a) * Denotes significance at 90%; ** denotes significance at 95%; *** denotes significance at 99%.
(b) Standard errors in ( ) below the point estimates.
(c) Estimations are defined in Equation (1) in the text, and carried out using OLS with heteroskedasticity and autocorrelation consistent (HAC) standard errors and covariances .
(d) The dependent variable, DLNCZKEUR, is the first difference of the log of the 15-minute CZK-EUR spot exchange rate.
(e) RESSALE denotes reserve sales of EUR carried out by the CNB. RESSALE is measured in millions of EUR.
(f) Czech macro news variables control for monetary policy rate changes (CZMONPOL) and surprises in CPI year-on-year (CZCPIYOY), CPI month-on-month (CZCPIMOM), PPI month-on-month (CZPPIMOM), industrial production (CZINDPROD), unemployment (CZUNEMP), trade balance (CZTB); Euro-area macro news variables control for monetary policy rate changes (EURMONPOL) and surprises in CPI year-on-year (EURCPIYOY), PPI year-on-year (EURPPIYOY), PPI month-on-month (EURPPIMOM), GDP (EURGDP), and unemployment (EURUNEMP).
(g) Constant point estimates, RESSALE, sum of RESSALES, and associated standard errors are multiplied by 10(E6); point estimates and standard errors associated with the macro news are multiplied by 10(E4).
(h) Sum of RESSALES refers to the cumulative effect of contemporaneous reserve sale and the five lags of reserve sales
(i) Sub-sample 1 runs from January 1, 2004 to June 18, 2007; Sub-sample 2 runs from June 19, 2007 to November 23, 2007