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Exchange market pressure and domestic credit evidence from Poland

Abstract. Starting from the Girton-Roper definition of the exchange market pressure index (*EMP*) we use the index to describe the Polish exchange rate system in transition 1994-2002. We also compare *EMP* indices calculated under two alternative methodologies. For that purpose we use first all foreign reserve changes and then pure official FOREX intervention data, which seems to be more relevant for assessing the actual exchange market stance. In fact, it better catches 'events' in the history of the Polish currency market. However, the narrower index performs worse than the broader one in the estimated linear *EMP* models. On the contrary, in the case of a VAR model the *EMP* index based on the intervention data produces more clear and long-lived signals, confirming the strong sterilization practice by the Polish central bank in the first sample subperiod.

Keywords: exchange market pressure, foreign exchange interventions, sterilization.
JEL Codes: E5, F3, F4.

1. Introduction

In the last quarter of the 20th century currency crises threatened economies and markets with a vast intensity and a growing frequency. Poland – unlike many other transition countries – did not have to experience a real currency crash, although internal problems and contagion from Russia, Asia and the Czech Republic could cause one. There were moments when the opposition (of whatever color) and the press saw a currency crash coming, but it never became reality. Were these visions a game or an illusion? Did the central bank control the situation by intervening in the currency market? What was the relationship between the exchange market situation and the monetary policy stance?

In order to answer these questions one can use instruments developed during a discussion among researchers started in the late 60's and developed till now, aimed at explaining the causes of currency crises, describing their mechanics and predicting them upon various sets of indicators. For all those purposes building an operational definition of a crisis event was crucial. One of the possible approaches to that problem (and a fairly widely used one) consists in building an exchange market pressure index (*EMP*), whose extreme values on the depreciation side indicate currency crisis events.

There are two main approaches in the empirical *EMP* literature: model-based and model-independent *EMP* indices. The former are introduced by the seminal paper by Girton and Roper (1977). They build up a monetary model, where the dependent variable is the *EMP* index, defined as a simple sum of the percentage depreciation of the currency and the (negative) change in the stock of international reserves scaled by base money. This framework is based on the consideration that an extreme speculative depreciation pressure can be neutralized by the monetary authorities either by letting the exchange rate fall or by selling out foreign exchange. This approach has been often used in the empirical literature. However, although derived from a model, the *EMP* index in the Girton-Roper approach is actually independent of model estimates, since by definition both components of the index contribute equally to its value. This point was subject to critique in a series of papers by Weymark (e.g. Weymark (1995) and Weymark (1997)). The author shares arguments of Girton and Roper on the necessary components of an *EMP* index, but she introduces and estimates a parameter (conversion factor) standing for the relative weight of exchange rate changes and FOREX flows in the *EMP* measure.

Many empirical papers that aimed to predict currency crises (e.g. the literature on early warning indicators) do not concentrate on a specific model for the exchange market pressure variable. Instead, they use a simpler measure, defined originally by Eichengreen, Rose, and Wyplosz (1995), which is fully model-independent. Their *EMP* index (hereafter ERW) is a weighted sum of exchange rate changes, international reserve changes and interest rate changes. However, the contrary to Weymark's approach, the weights are to be calculated from sample variances of those three components with no need to estimate any model. This simplicity made the ERW index widely used as the dependent variable in currency crisis models, but equally widely criticized by theoreticians for its strong a priori assumptions about the weighting scheme.

In this paper, we analyze exchange market pressure on the Polish zloty over the period from January 1994 to February 2002. Starting from the classic Girton-Roper approach, we adapt and apply it to the Polish currency market and then develop further to a dynamic (VAR) model under two alternative methodologies and data sets on the foreign reserve component of the *EMP* index.

There are three goals of this paper. The first one is to describe the Polish currency market stance using the exchange market pressure index that enables us to see market sentiments from a new perspective and to follow the really pursued (not only the officially announced) exchange rate system over the sample period.

The second aim is to analyze the relationship between the *EMP* (exchange market stance) and changes in domestic credit (monetary policy actions). Finally, the third goal is to compare the performance of the *EMP* models under two competitive methodologies. The first approach is equivalent to all previous empirical *EMP* contributions, where gross foreign reserve changes are used. However, such a variable may incorporate market irrelevant transactions, e.g. due to exchange rate changes, foreign debt repayments etc. Therefore we try out the second methodology that applies pure actual FOREX intervention data. This series describes truly the authorities' engagement in the currency market operations and thus seems to be more suitable for analyzing the exchange market pressure.

The paper proposes a new perspective for investigation of the Polish exchange rate system in transition. This is particularly interesting when compared with alarming messages of a near currency crash, spread occasionally by the opposition (of whatever color) and the press. We also apply an original data set supplied by the National Bank of Poland with complete intervention data. This enables us to test the *EMP* model by using an alternative *EMP* component that catches much better currency market sentiments than the usually used gross foreign assets changes do. Finally, we are the first to analyze the relationship between the currency market stance and monetary policy measures in Poland by using the exchange market pressure variable.

2. Theoretical background

The concept of exchange market pressure was first put forward by Girton and Roper (1977). Their quite simple model bases on the monetary approach to the balance of payments posited by Johnson (1972). According to this idea, changes in exchange rates or balance of payments can be regarded as adjustments reflecting some monetary disequilibriums. Girton and Roper argue that any disequilibrium of the foreign exchange market must be resolved either by an exchange rate adjustment, or an official intervention, or both of them simultaneously. The dependent variable in their model is the exchange market pressure index, defined as a 'measure of the volume of intervention necessary to achieve any desired exchange rate target'. Numerically, it equals the sum of the percentage change in foreign assets of the relevant central bank (scaled by base money) and the percentage appreciation of the currency. Positive values of the index stand for appreciation pressure and negative *EMP* values indicate depreciation pressure.

According to Girton and Roper, such construction of the index ensures that the model holds for all exchange rate regimes. If the authorities keep the exchange rate fixed, they must neutralize exchange market pressure by foreign market interventions.

On the other hand, in case of a free float the possibility of exchange rate defense is by definition excluded and the whole speculative pressure is reflected by exchange rate changes. In all intermediate exchange rate systems some mixture of adjustments in official reserves and the exchange rate resolves the disequilibrium.

The central element of our model is the dynamic monetary equilibrium condition

$$M_s' = M_d'. \tag{1}$$

Money supply M_s is determined by the money multiplier A and the sum of domestic (D) and foreign (R) assets of the central bank:

$$M_s = A(D + R). \tag{2}$$

Money demand M_d is described by the classic representation

$$M_d = kPY^{\varphi(y)}e^{\varphi(i)i} \tag{3}$$

where k denotes a constant fraction of income held as money balances, Y is domestic real income and i domestic interest rate.

The last equation stands for the purchasing power parity condition linking the domestic price level P with foreign prices P^* and the bilateral exchange rate E[1]:

$$P = EP^*. \tag{4}$$

The monetary equilibrium condition is derived from equations (2)-(4) by substituting P in (3) by (4), equating the right-hand side of the outcome to (2), taking logarithms of both sides and differentiating the resulting expression. After some reordering we get

$$r - e = -d + \varphi(y)y + p^* - a + \varphi(i)i'$$

where each lowercase letter represents a percentage change in the corresponding variable (except from d and r which are percentage changes scaled by base money $D + R$ and i' which is a simple time derivative of interest rate).

Following Girton and Roper (1977) we define exchange market pressure index EMP as the sum of percentage changes in official foreign reserves r and the appreciation rate of the currency $-e$ in a given time period.

[1] E is defined as a price of a foreign currency in domestic currency units. Thus, positive changes in E represent depreciation of the domestic currency and negative changes – its appreciation.

$$EMP = -d + \varphi(y)y + p^* - a + \varphi(i)i'. \quad (5)$$

Since the PPP condition represented by (4) has been proved to hold rarely in reality (at least in the short run), it seems to be useful to withdraw it from the model. We therefore introduce a new variable z defined as the deviation from the relative PPP

$$z = p - p^* - e.$$

The final form of our model is:

$$EMP = -d + \varphi(y)y + p^* - a + z + \varphi(i)i'. \quad (6)$$

The coefficients of domestic credit and money multiplier changes are hypothesized to be negative 1. Thus, an increasing domestic money supply (relaxation of the monetary policy) has a negative impact on exchange market pressure, causing depreciation pressure in the currency market.

The coefficients associated with foreign inflation rate and deviation from the relative purchasing power parity are hypothesized to equal 1. These variables represent transmission channels of foreign disturbances. Both have an upward impact on international reserve holdings and/or the exchange rate level[2].

Domestic income growth rate and the change in domestic interest rates influence exchange market pressure through changes in the domestic money demand. The impact of the former is hypothesized to be positive, whereas the influence of the latter is negative.

3. Indices of exchange market pressure

One of the goals of this paper is to compare the performance of linear models of exchange market pressure using two alternative data series for international reserve changes, which are key elements of *EMP* index definition. The first series, hereafter denoted by r_1, covers changes in net foreign assets of the National Bank of Poland (NBP). Such a *global* approach has been widely used in earlier empirical studies. The alternative is r_2, a measure including only market relevant foreign transactions of the central bank – official interventions and transactions with banks. The rationale behind this *selective* approach is to capture only this part of interna-

[2] This statement may sound a bit controversial. For a detailed discussion refer to Wohar and Lee (1992).

tional reserve changes which are intended or just able to influence the exchange rate. Such events as foreign debt repayments from reserve resources, reserve gold revaluations or profits from investing reserve holdings seem to be irrelevant for the exchange market equilibrium and are therefore left out in r_2.

The problem of equivalence between actual intervention volume and foreign assets changes has not been widely recognized. Mastropasqua, Micossi, and Rinaldi (1988) and more recently Neely (2000) argue that low values of various relevant correlation measures cast doubt on the usefulness of central bank's foreign reserve changes as a proxy for the authorities' intervention activity. However, since the exact intervention data is usually unavailable even to researchers, such proxy can often be the only operational solution.

We apply and compare both measures of international reserve changes and their respective exchange market pressure indices (labeled *EMP1* and *EMP2*)[3]. The difference between the two alternative measures is apparent from Figures 1 and 2.

What both figures have in common is that appreciation pressure (positive index values) generally prevailed during the sample period. However, the behavior of *EMP1* and *EMP2* differs in details. The discrepancy between the two indices is obvious at 'events', characterized by extreme *EMP* values. The most striking examples are July 1997, August 1998, February 1999 and July 2001, when the zloty had a very hard time due to the flood catastrophe, the Russian crisis, the Brazilian crisis and an internal fiscal crisis combined with events in other emerging markets, respectively. In all four cases the zloty depreciated considerably and suddenly. In addition, the NBP intervened largely in the first case. All this should mirror in a good measure the exchange market pressure. The four events can be well observed on the *EMP2* graph, represented by large downward spikes with respective index values of -7.9, -8.0, -5.9 and -8.3. On the contrary, the global measure *EMP1* neglects fully all four events by attaching to them index values of 2.7, 7.6, 6.1 and 8.8, indicating actually periods of large appreciation pressure.

One probable reason for this failure is that sharp depreciations of the zloty lead to equally large end-of-month revaluations of reserves, expressed in zlotys. This effect cannot occur in *EMP2* by construction, since the latter is the sum of real FOREX transactions over the month expressed in zlotys. Another source of the distortion can be some large non-market reserve-boosting operations having place in the respective month.

Furthermore, application of *EMP1* as a measure of exchange market pressure leads to 'false alarms' at periods, when large portions of foreign debt are paid back. Fortunately for the analysis, there are not many such events in the sample period. But, the examples are striking again: September 1998, April 2001 and November

[3] Among empirical contributions to the *EMP* literature only Spolander (1999) compares the performance of the broad and the narrow measure of reserve changes. However, he estimates another type of *EMP* models.

2001 with *EMP1* values of -6.5, -8.0 and -21.5, respectively. *EMP2* counts for -0.1, 2.6 and 1.4 in those months.

An important argument against *EMP1* and in favor of *EMP2* can be put forward upon the relationship between *EMP* and actual exchange rate regimes. It is useful to look at the graphs of *EMP* indices and their components (Fig. 3 and 4). In the first part of the sample (until the summer 1998, when the last FOREX intervention took place) both *EMP* indices behave mostly parallel to changes in reserves. This suggests that changes in international reserves drive *EMP* during this period and that the authorities control the exchange rate by means of official interventions. In fact, at that time Poland pursued intermediate exchange rate regimes. However, in the second half of the sample this relationship breaks clearly for *EMP2*. Changes in the nominal exchange rate become the primary element of that measure, resulting in the mirror pattern of both variables since May 1999. However, this is not valid for *EMP1* – there is no obvious breakpoint attributable to the actual change in the Polish exchange rate regime[4].

These preliminary findings can be supported by an analysis of variances of *EMP* and its components. The variance of any of *EMP* indices consists of the variabilities of autonomous changes in both components (reserves and exchange rates) and an element describing their interrelationship. Formally,

$$\mathrm{var}(EMP) = \mathrm{var}(r) + \mathrm{var}(e) - 2\mathrm{cov}(r, e).$$

Thus, the individual shares of both *EMP* components in the behavior of the index can be represented by the ratios $\mathrm{var}(r) / \mathrm{var}(EMP)$ and $\mathrm{var}(e) / \mathrm{var}(EMP)$. Values of those ratios for the whole sample period and for some meaningful subperiods are listed in Table 1. The first subperiod (until July 1998) covers the time when the central bank did intervene in the FOREX market. During the second subperiod the central bank actually gave up actively influencing the exchange market.

In the last two columns of Table 1 an index of intervention activity INT is presented. It is defined as:

$$INT = \mathrm{var}(r) / (\mathrm{var}(r) + \mathrm{var}(e))$$

and calculated upon two alternative definitions of international reserve changes

[4] To be precise, the NBP did act in the FOREX market until the end of May, 1999, when the last 'fixing' transactions with commercial banks were made. However, these transactions were neither intended nor used as a policy instrument by the NBP because the authorities did not control the volume of 'fixing' trading. In fact, this volume was relatively small and it can be assumed that 'fixing' transactions did not influence the zloty rate significantly after the summer 1998. Since June 1999, when the 'fixing' was abandoned, the zloty actually floated freely, but the official announcement of the regime change was published in April 2000.

Table 1. Components of the variance of *EMP1* and *EMP2*

Period	var(r_1) as a fraction of var(*EMP1*)	var(e) as a fraction of var(*EMP1*)	var(r_2) as a fraction of var(*EMP2*)	var(e) as a fraction of var(*EMP2*)	INT1	INT2
1999:01-2002:02	1,426	0,158	0,794	0,222	0,901	0,781
1994:01-1998:07	0,993	0,056	0,814	0,062	0,947	0,930
1998:08-2002:02	1,963	0,315	0,071	1,051	0,862	0,063

discussed above. INT can be used to assess and classify exchange rate regimes. It takes values between 1 (pure peg) and 0 (pure float).

Although the Polish authorities withdrew from intervening in the exchange market early in August 1998, this important fact is neglected by the broad measure of changes in international reserves r_1. In the case of all three subperiods the variance of r_1 plays a leading role in the variability of the corresponding exchange market pressure index. On the other hand, the change in the real exchange rate regime is visible in the results obtained for r_2. This conclusion is equally apparent from the values of the intervention index which does not change after August 1998 for r_1 and falls sharply for r_2 to almost 0, indicating a substantial change in the exchange rate regime. Thus, the alternative measure of international reserve changes r_2 is expected to be more suitable for an exchange market pressure index, aiming to describe the real exchange market stance.

4. Empirical framework and estimation

4.1. The linear model

Besides comparing the performance of the model depending on the version of the *EMP* index, we want to check the applicability of linear *EMP* models to the Polish exchange market. The theoretical model (6) has been first tested in its static version by estimating three alternative linear equations. The first, fully unrestricted one, equals (6) and can be rewritten in the stochastic form as

$$EMP_t = \alpha_0 + \alpha_1 d_t + \alpha_2 y_t + \alpha_3 p^*_t + \alpha_4 a_t + \alpha_5 z_t + \alpha_6 i'_t + u_t . \qquad (7)$$

The second version of the model differs from (7) by setting the coefficient associated with domestic interest rate change i'_t to zero:

$$EMP_t = \alpha_0 + \alpha_1 d_t + \alpha_2 y_t + \alpha_3 p^*_t + \alpha_4 a_t + \alpha_5 z_t + u_t . \qquad (8)$$

The last equation – and the most restricted one – is achieved by re-assuming the PPP condition and excluding the deviation term z:

$$EMP_t = \alpha_0 + \alpha_1 d_t + \alpha_2 y_t + \alpha_3 p^*_t + \alpha_4 a_t + u_t \,. \tag{9}$$

The validity of the PPP in the short run was rejected by several authors. The exclusion of z may therefore seem inappropriate. However, equations like (9) were frequently used in the empirical investigations of the Girton-Roper model (see e.g. Kim (1985), Mah (1995) and Thornton (1995)). Therefore, it can be an interesting exercise to look at its performance. Besides, the (in)significance of the coefficient α_5 will serve as sort of a test of the PPP condition.

The monetary model of exchange market pressure represented as in (6) assumes that the authorities do not sterilize their foreign market interventions. This assumption may be far from reality, but its failure has severe consequences for the credibility of model estimates. If official interventions were in fact fully sterilized, the domestic credit variable would be endogenous, influencing current and future values of exchange market pressure. This would cause a simultaneous equation bias, where OLS estimates are not only biased (towards –1), but also inconsistent.

In fact, the Polish authorities sterilized reserve flows extensively during the sample period. In order to test in a formal way, whether the impact of sterilization on the (OLS) regression properties is significant, the Godfrey and Hutton (1994) version of the Hausman (1978) simultaneity test is applied to all model forms (7)-(9). The suspected variable is domestic credit changes d, which may not be allowed to be treated as exogenous in the presence of sterilized official foreign market interventions. Alternatively to OLS we should use in this case instrumental variables (IV) methods taking into account interrelationships between some variables in the model. In performing the test a set of potential instrumental variables is used, including all exogenous variables from the corresponding *EMP* equation plus lagged values of both endogenous variables d and *EMP*[5].

The results (Table 2) show that all models but (9b) pass the first stage of the test. It means that there is no significant misspecification problem in these models and the instruments can be perceived as valid. Only exclusion of both interest rate

[5] Hausman (1983) stresses that in order to ensure consistency of IV estimators, all exogenous variables from the structural equation should be included in the instrumental variable set. In addition, lagged endogenous variables are necessary to identify the model (henceforth 'identifying instruments'). Bound, Jaeger, and Baker (1995) argue that if the relationship between instruments and the endogenous explanatory variable (here d) is weak enough, IV estimates can be biased even more than OLS results. They propose to choose the proper set of instruments by performing an F-test for excluded variables and inspecting the partial R^2 from regressing the endogenous explanatory variable on potential identifying instruments. Here, both diagnostic methods indicate that lagged *EMP* and d are relevant instruments.

Table 2. Results of the Hausman simultaneity test (Godfrey-Hutton framework, *p*-values)

Hypothesis \ model	(7a)	(8a)	(9a)	(7b)	(8b)	(9b)
H_0: no misspecification	0.969	0.953	0.941	0.246	0.263	0.050
H_0: d not endogenous	0.696	0.751	0.478	<.001	<.001	<.001

differential and PPP deviation term from the original *b*-type model results in a misspecified model form. In the case of all models basing on *EMP1* as dependent variable (*a*-type), no simultaneity problem can be concluded (second stage test). This somewhat surprising finding can be explained by the nature of the *EMP1* measure, which accounts for all reserve flows, whether related to sterilized FOREX interventions or not. By contrast, the domestic credit variable should be treated as endogenous in all models basing on *EMP2* (*b*-type). Consequently, the method of ordinary least squares proved to be efficient for the former type of models and multiple equations methods ought to be applied for the latter ones.

Estimation results for all six models are presented in Table 3. *b*-type models are estimated by the method of Two Stage Least Squares (2SLS). Instead of sample d we use a series of predicted domestic credit changes, calculated upon a regression of d on instrumental variables. Models basing on *EMP1* are estimated by both OLS and 2SLS for comparison, although OLS estimates are found more efficient in the previous tests. Since a significant yearly seasonal effect can be stated in all three *a*-type models, we re-estimate the corresponding equations iteratively with AR(12) terms included. A modified LM test (Davidson and MacKinnon (1993)) results do not indicate serial correlation problem in any of the models.

The results show that the linear model of exchange market pressure is valid for the Polish case to some extent. The coefficients of domestic credit scaled changes, money multiplier changes and changes in deviation from PPP are highly significant and close to their theoretical values (an asymptotic F-test has been performed). Since α_5 is highly significant in all models where z is included, it is clear that deviations from PPP play a significant role in explaining *EMP*. Thus, PPP condition does not hold and the restricted versions (9) of the model are inferior to the other ones. Furthermore, the coefficient of the interest rate differential α_6 is insignificant in both representations of (7). This variable does not help to explain *EMP* movements and can be left out of the model. Consequently, equation (8) proves to be the best version of the linear exchange market pressure model regardless of the definition of the dependent variable.

It is apparent – particularly from all measures of goodness-of-fit – that *a*-type models are superior to their *b*-counterparts. The significance of parameter estimates is similar for all models, but in models based on *EMP2* not all coefficients have the correct hypothesized signs. Values of the estimated parameters are closer to the expected ones for all *a*-type equations, although *F*-tests of theoretical coefficient restrictions provided similar outcomes for both types of models.

To conclude, in the applied sample period the alternative measure *EMP2* seems not to comply with the monetary approach to exchange market pressure and with the linear representation formulated in the theoretical part of this paper. The alternative measure r_2 put into the model does not boost the explanation power of the linear model. The seemingly unrelated market-irrelevant elements of r_1 seem to matter in the estimation. This outcome could be subject to further research on the significance of individual components of the foreign asset changes r_1.

4.2. Dynamic interrelationship between EMP and domestic credit

The 2SLS estimation method is able to account for sterilization effects and to rectify the endogeneity problem associated with domestic credit variable *d*. However, it only technically eliminates the correlation between *d* and the disturbance term in the *EMP* equation. Thus, 2SLS does not fully take into account the dynamic interdependence between *EMP* and *d*. In order to analyze this interaction more in detail, we estimate two versions of VARX(2,0) models, again applying two alternative exchange market pressure indices *EMP1* and *EMP2*. In both cases the dependent variables *EMP* and *d* appear with 2 lags and are accompanied by a vector of exogenous variables taken from model (8), which was found to fit best in the 2SLS estimation[6].

Kamaly and Nese (2000) and Tanner (2001) also use the VAR methodology to assess the relationship between *EMP* and domestic credit. However, they include interest rate as the third endogenous variable in. The authors argue that in the case of a currency crisis followed by an interest rate defense, interest rate changes as a variable would react to changes in the *EMP* index, creating an endogeneity problem. Here, interest rates are not found to help to explain *EMP* or domestic credit changes. Interest rate changes in Poland still do not reflect as much market sentiment as they underlie structural adjustment to the lowering inflation rate. Neither were they used by the central bank as a short-term instrument to react to extreme to exchange market pressure. In order to justify our approach formally, Granger causality test for all the three variables under consideration is performed. The lag number of 2 has been chosen. The results (Table 3) show that there is a clear interrelationship between both *EMP* measures and *d*. On the other hand, the only significant test statistic involving *i* was the causality from domestic credit to interest rate.

The VAR coefficient estimates are not particularly useful for economic conclusions. A better tool are (orthogonalized) impulse response functions (IRF) that

[6] The number of lags in *EMP* and *d* is subject to optimization by minimizing the Akaike Information Criterion and by formal LR testing.

Table 3. Granger causality test _ *EMP*, domestic credit and interest rates (p-values in parentheses)

Hypothesis	*EMP1*	*EMP2*	*D*	*i*
EMP1 does not Granger-cause. . .			6.910	1.026
			(0.002)	(0.362)
EMP2 does not Granger-cause. . .			2.311	1.919
			(0.105)	(0.153)
d does not Granger-cause. . .	3.221	2.947		7.427
	(0.045)	(0.058)		(0.001)
i does not Granger-cause. . .	0.421	1.152	0.994	
	(0.657)	(0.321)	(0.374)	

describe reaction of one endogenous variable to one-standard-deviation shock in another endogenous variable throughout several time periods. In this framework we analyze the interrelationship between the exchange market pressure on the zloty and the monetary policy of the Polish authorities. The latter is represented by the policy variable *d*, i.e. the portion of monetary base controlled by policymakers.

Calculation of IRF's is based on a causality ordering of relevant variables, which is necessary to identify the underlying structural model. In the case of a two-equation model one restriction must be imposed. It means we have to exclude either the contemporaneous impact of *EMP* shocks on *d* or the reverse. We choose the ordering *EMP–d*, which means that shocks to exchange market pressure have no instantaneous impact on domestic credit changes, but shocks to *d* may influence *EMP* immediately[7].

In this setting impulse response functions are able to describe the response of domestic credit to current and past innovations to exchange market pressure and the reaction of the *EMP* index to past (but not current) shocks to domestic credit component of the monetary base.

The results (Table 4) show that both instantaneous and lagged responses of domestic credit to innovations in the exchange market pressure index are significant and negative. This would mean that a sudden depreciation pressure on the Polish zloty results in loosening the monetary policy and/or that the extent of sterilization of FOREX interventions by the NBP is large. A precise separation of both effects may be difficult. In order to interpret these findings one should take into account general tendencies in the Polish money market over the sample period. As discussed abo-

[7] This approach differs from that applied by Tanner (2001), Tanner (2002) and Kamaly and Nese (2000), who place *d* first, and thus treat domestic credit changes as exogenous to the system in the lag 0. However, we find it more plausible to allow for immediate reactions of *d* after an innovation in *EMP*, e.g. in form of sterilizing open market operations by the central bank. Domestic credit is here assumed to have only a lagged effect on *EMP*.

ve, appreciation pressure prevails throughout a large part of this period. There are only several events, when *EMP* is negative. At the same time, there is a long-term tendency in the domestic credit to fall in the first half of the sample period – first of all due to the main policy goal of dampening high inflation rates, but also because of sterilization of the rapid increase in international reserves of the NBP in the mid-90's. Hence, the significance of negative responses of domestic credit to shocks to *EMP* may be not necessarily attributable to some policy reactions to the latter in crisis-like periods of high depreciation pressure, but maybe more to structural processes in the Polish economy having taken place during the sample period.

Table 4. Impulse responses to one s.d. innovations (t-statistics in parentheses)

Lag	Model *a*		Model *b*	
	$EMP1 \rightarrow d$	$d \rightarrow EMP1$	$EMP2 \rightarrow d$	$d \rightarrow EMP2$
0	-4.853***		-2.763***	
	(-12.51)		(-5.912)	
1	-1.065**	0.219	-0.725*	0.005
	(-2.060)	(1.586)	(-1.711)	(0.036)
2	-1.130**	0.252*	-1.392***	-0.259
	(-2.246)	(1.786)	(-3.647)	(-1.616)
3	-0.412	0.088	-0.733***	-0.099
	(-1.533)	(1.560)	(-2.681)	(-1.008)
4	-0.280	0.067	-0.690**	-0.108
	(-1.170)	(1.355)	(-2.470)	(-1.247)
5	-0.127	0.029	-0.472**	-0.068
	(-0.942)	(1.094)	(-2.016)	(-1.045)
6	-0.074	0.018	-0.384*	-0.059
	(-0.769)	(0.913)	(-1.754)	(-1.049)

However, the effect of *EMP* on *d* is much longer for the *EMP2* measure, where it lasts up to the sixth lag. It means that official interventions have a greater long-run impact on domestic credit than non-market FOREX operations of the central bank. Here we can guess some monetary policy reaction taking place after those shocks in the exchange market that need resolution by the means of FOREX interventions.

An opposite relation is not established – none of the responses of *EMP* to innovations in *d* is found statistically significant at the 5% level for none of *EMP* measures. This finding suggests that shifts in monetary policy represented by domestic credit changes have no greater influence on speculators' decisions over their zloty positions. Market participants trust much more the long-run positive effects of economic transformation in Poland, undertaken in the 90's.

The results of impulse response function estimation are finally subject to sensitivity analysis. The main point is to check the importance of the assumed initial ordering of endogenous variables, which is crucial for final estimates. IRF's are re-estimated using the competing ordering *d-EMP*, which allows no contemporaneous reaction of domestic credit to innovations in the *EMP* index. Effects of sterilization of official interventions are assumed to occur in later periods. Furthermore, domestic credit changes are supposed to be able to instantaneously influence speculative pressure *EMP*.

Re-estimation of IRF coefficients supports the consistency of a long-lasting significant negative impact of *EMP* innovations on domestic credit. Similarly to the previous results, the effect is longer for *EMP2* (6 lags) than for *EMP1* (3 lags). The main message of the relationship can thus remain unchanged. On the contrary, responses of *EMP* indices to innovations in *d* turn to be significant (and negative) after the change in the selected causal ordering. Also in this case the effect is longer for *EMP2* (6 lags) than for *EMP1* (2 lags).

5. Conclusions

The three main goals of our paper are spelled out in the introduction. The first was to apply the exchange market pressure index to describe the Polish currency market stance during the period 1994:01-2002:02 from a new perspective. The second intention was to look at the dynamic interrelationship between the two central variables of the model: the *EMP* index and domestic credit changes *d*. The third question was, what is the difference in estimation results, when two alternative measures for exchange market pressure are used: the first considering all shifts in foreign assets of the central bank and the second eliminating 'market irrelevant' operations.

A general conclusion can be drawn from the first exercise that the *EMP* index very well illustrates changes in the pursued exchange rate system. It depictures the 'real' exchange rate system, as opposed to the officially declared exchange rate system that can differ from the former one, if the central bank does not release information about the foreign exchange intervention. In the case of Poland there are two clear breakpoints (August 1998 and May 1999), when the Polish central bank seized from further intervening and gave up 'fixing' transactions, consequently. We can also see periods of large exchange market pressure that did not end with a currency crisis though. The most striking message from this descriptive part of the analysis is that the application of the broader *EMP* measure based on the foreign assets changes passes over some important currency market events and produces a certain amount of 'false alarms', making itself useless as a potential dependent variable in an analysis of early warning signals of currency crises. It would certainly be much more plausible to use for such purpose our narrower version of the *EMP* index, consisting of the pure intervention data.

In order to solve the second problem formulated, the Vector Autoregression technique is applied. Interpreting the results of the orthogonalized impulse response functions we can state that domestic credit reacts counterdirectionally to innovations to *EMP*. This effect lasts between 2 and 6 periods, depending on the *EMP* measure used. For the opposite relation we find no consistent evidence about the reaction of *EMP* to shocks to domestic credit. These findings confirm that the monetary authorities regularly sterilized reserve flows. Besides, due to the necessary economic reforms the domestic component of the monetary base was systematically contracting during the sample period, while the exchange market pressure remained mostly on the appreciation side.

A comparison of model estimation results for models basing on alternative *EMP* indices leads us to the conclusion that the narrower measure (including only official interventions and other currency market operations with commercial banks) did not come off better than the usually applied broader measure in our data sample. The exclusion of 'market irrelevant' operations – which might seem justifiable in the light of the logic of speculative pressure – does not boost the explanation power of the linear model. The application of the narrower measure for foreign reserve changes in the dynamic VAR models produces more clear results about the relationship between the exchange market pressure and domestic credit changes. The most important difference between the results for both measures is that the negative response of domestic credit to *EMP* innovations is significantly longer when the narrower *EMP* index is applied. This suggests that FOREX interventions have a longer-lived impact on the de facto monetary policy (e.g. sterilization) than other FOREX operations of the central bank which are not directly relevant for the currency market.

Data appendix

D – net domestic assets of the National Bank of Poland (NBP), PLN bn; source: NBP

R_1 – net foreign assets of the NBP, PLN bn; source: NBP

R_2 – foreign transactions of the NBP excl. scheduled transactions, PLN bn; source: NBP

A – ratio M2 to reserve money; source: NBP

Y – industrial production index; source: Main Statistical Office, Warsaw

P – Producer Price Index (PPI); source: Main Statistical Office

P^* – weighted PPI of the EU (55%, industry excl. construction) and the USA (45%, finished goods); sources: Eurostat and the US Bureau of Labor Statistics

E – nominal effective exchange rate of the zloty with respect to a currency basket

(EUR – 55%, USD – 45%), end of month; source: NBP, own calculations of the index

i – interest rate differential between the 3-month WIBOR and the weighted 3-month euro (55%) and dollar (45%) LIBOR rates, average of month; source: NBP

The sample period was 1994:01 to 2002:02. Following the suggestions of Davidson and MacKinnon (1993) none of the series was seasonally adjusted.

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