THE RELATIONSHIP BETWEEN PRICE LEVEL, MONEY SUPPLY AND EXCHANGE RATE IN UKRAINE

by

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Abstract

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Monetary economists and policymakers in transition economies such as Ukraine are increasingly interested in how price level responds to changes in policy instruments or intermediate targets. In this paper, the relationships between CPI, money supply and exchange rate are estimated using Identified Vector Autoregression Approach. The results show that exchange rate shocks significantly influence price level behavior. Therefore, I conclude that exchange rate can serve as an efficient intermediate target for the monetary policy. There is some evidence that positive money supply shocks lead to a rise in the price level. However, this influence is not very strong, which can be explained by the fluctuations in the demand for hryvnia. Thus, there is a need for estimation of the money demand function in Ukraine. I also find strong evidence that money supply responds to the positive shocks in the price level by monetary contraction, which can be a sign of the conduct of the inflation-targeting policy by the National Bank of Ukraine.

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GLOSSARY

Identification Scheme. Set of explicit 1 or 0 restrictions on the coefficients of the matrix of contemporaneous shocks.

Impulse Response Function. Function that traces out the response of the dependent variable in the VAR system to shocks in independent variables.

Inflation Targeting. Monetary policy framework characterized by the announcement of official target ranges for the inflation rate and adjustment of monetary policy instruments such that to eliminate any discrepancies from the announced target.

Monetary Policy Framework. Targets, instruments, structure and mode of a monetary policy in a country.

Monetary Policy Instrument. Tool controlled by the monetary authority, using which it can influence intermediate targets of monetary policy.

Monetary Policy Intermediate Target. The monetary variable that has direct affect on ultimate target of the monetary policy and can be influenced by the monetary policy instruments.

Monetary Policy Ultimate Target. The monetary variable, control over which takes primary significance for the monetary policy decisions.

Chapter 1

INTRODUCTION

For a long time economists have been trying to find a variable that is easily controlled by monetary policy and related to economic activity on a stable basis. The greater effect such a variable has on the behavior of economic time series, the more effective monetary policy is.

The fundamental paper on the specification and estimation of behavioral relationships for monetary policy was written by Leeper and Sims in 1996 and concerned the case of the USA. The similar study was done for the case of transition economy, namely Poland, by Christoffersen and Wescott, 1999. But nothing was done for the case of Ukraine.

In my paper I extend the line of work on specification and estimation of behavioral relationships for monetary policy. In particular, I investigate the relationships between money supply, exchange rate and prices in the Ukrainian economy. Here money supply and exchange rate are variables that can be influenced by the monetary policy instruments and serve as intermediate targets of the monetary policy. The price level is considered as the ultimate target of monetary policy in Ukraine. In my analysis I will use identified vector autoregressions and impulse response functions to show how a shock in one of the variables influences the time behavior of others. If these time paths happen to diverge from those predicted by the theory, I will try to capture the peculiarities of Ukrainian economy that could acccount for such a divergence. The estimation will separate the effects of monetary policy on the economy from the response of monetary policy to the changes in economic conditions.

This study is of particular interest for the case of Ukrainian economy. For a long period of time the Ukrainian monetary authorities considered exchange rate stability as the primary goal of the monetary policy. Now exchange rate is still supported by the National Bank of Ukraine, but it is not the ultimate target of the monetary policy as that was before. Therefore, there is a need to specify a new framework for monetary policy in Ukraine. My study is supposed to produce a theoretically justified model of monetary relationships in the Ukrainian economy with good fit to the data. Knowing the structural behavioral relationships in the monetary sector of the economy it would be possible to say whether monetary policy affects inflation in Ukraine and whether the exchange rate and money supply are "good" intermediate targets for the monetary policy. On the other hand the model would show how quick (if any) is the response of monetary policy to changes in its targets. Definitely, such a model could be of help for the policymakers and the economists in their design of new monetary policy framework. Understanding the strength of the behavioral relationships for the monetary policy and their lags will help policymakers to better calibrate their monetary policy actions, improve their timing and better achieve their inflation targets.

The organization of the paper is as follows: Section II makes the survey of literature that compares the performance of different monetary policy regimes in fighting inflation and overviews the papers from the point of view of methodology used in the analysis of the monetary relationships. Section III presents the theory that justifies the relationships between price level, exchange rate and money supply. Section IV describes in details the data and methodology used in the paper. Section V discusses the results of the empirical analysis. Section VI concludes, emphasizing the main findings and their implications for the policymaking.

Chapter 2

SURVEY OF LITERATURE

As was mentioned in the Introduction, in my thesis paper I would like to build an appropriate VAR model of inflation in Ukraine, which would show the relationship between the price level and intermediate targets, controlled by the monetary policy. The existence of clear relationship between inflation rate and intermediate targets of monetary policy is the main operational condition for the successful conduct of inflation targeting framework of monetary policy. Therefore, in this paper I will try to verify the fulfillment of the main operational condition for inflation targeting in Ukraine.

The question arises why I consider inflation targeting as a possible strategy for Ukrainian monetary policy?

In Mishkin and Posen (1997), the primary goal of monetary policy is considered lowering inflation. The authors make such a conclusion by considering costs of inflation. One of the most apparent costs of inflation is that when it takes place people use non-interest bearing money, because otherwise inflation could offset their interest income. This requires increasing amounts of cash to conduct daily transactions, which is costly. But this cost is significant only for moderate and high levels of inflation and accounts for 1% of GDP. For the rates of inflation lower than 10% these cost are below 0.1% of GDP. In Ukraine, the inflation rate was above 20% for ten months of 1999 (Markiewicz, Dekhtiarchuk (1999)). Therefore the above costs of inflation can be significant in Ukraine. Another cost of inflation is that it becomes more profitable to invest in the financial rather than the productive sector, because opportunities to make profits acting on the financial market rather than investing in productive activities become greater with price instability. According to Mishkin and Posen (1997) the share of financial

market in GDP increases by 1% for each 10% increase in inflation, up to an inflation rate of 100%. The next cost of inflation is the distortion of productive decisions because of uncertainty in the future relative prices, which are crucial for planning investment expenditures. Finally, because taxes are rarely indexed for inflation, higher taxation results from inflation. In this case we mean tax brackets: as a result of inflation nominal income of the person rises and he comes to another tax bracket thus paying more tax, but real income is the same, so a person pays more taxes in real terms. These four costs reduce the level of productively employed resources thus slowing down economic growth. As a result of such considerations, economists and policymakers agreed that price stability should be the primary goal of monetary policy.

Taking this into account the authors consider three main monetary regimes in light of their ability to control inflation. Money growth targeting can keep nominal income growing that leads to the long-term price stability if the velocity of money is predictable (MV=PQ). But the main condition for the effectiveness of such a regime is the close and stable relationship between money growth and nominal income growth in the long run. If it is not the case, increase of money supply (according to the announced target) may be followed by the greater than predicted increase in nominal income at the expense of inflation. As a result we will get an increase in the price level, rather than price stability and will need to lower the money supply. So, the money supply may be used as an instrument, or intermediate target to control inflation rather than a target itself. It should be flexible to react to changes in the inflation rate. Therefore, the use of a monetary aggregate as a nominal anchor for monetary policy has become problematic in recent years. Another alternative is fixing the exchange rate of the national currency to the currency of another country. This regime is highly transparent and lowers inflation expectations thus reducing inflation. But the main disadvantage of such a regime is that it is not easy to maintain fixed exchange rate. Often this strategy leads to the depletion of foreign reserves and a balance of payment crisis. An

example of such a situation is Ukraine, where exchange rate targeting was recently abandoned because of the impossibility for the National Bank to undertake currency intervention. These considerations led economists to seek another nominal anchor, such as inflation target. An inflation targeting strategy, like exchange rate targeting, has the advantage of transparency that is it is easily understood by the public. This transparency reduces inflation expectations and inflation itself. It implies that we can use different intermediate targets such as the exchange rate or money supply to control inflation and change these targets from time to time according to their performance. The only ultimate goal is stabilizing the inflation rate, which is announced explicitly.

Mishkin and Posen (1997) describe the performance of four countries that adopted inflation targeting strategy and reach the conclusion that all four countries succeeded in maintaining low inflation rates without harming the real economy.

More advanced analysis of the success of inflation targeting framework is presented in Bernanke, Laubach, Mishkin, Posen (1999). The authors conclude that, all things considered, the inflation-targeting framework was a success in the countries examined. By success the authors mean that inflation levels and inflation expectations are below what would have been expected based on the predictions of the past. On the other hand, the costs of disinflation did not prove to be lower in comparison with other monetary regimes. But, in the opinion of the authors, the main strength of the inflation targeting regime is "…its ability to cope with and contain adverse inflationary developments, even though the policy of active disinflation remains costly"(Bernanke at. al., 1999 p.283). Thus, while inflation targeting may not reduce the costs of the transition to low inflation, it may help central banks to sustain price stability in the longer run by increasing the transparency of policy and the accountability of the monetary policymakers.

To sum up, we could conclude that, although rather new, inflation-targeting framework proved to be successful. As a result, some developing countries, such as Poland are now considering the possibility of using an inflation targeting strategy for their monetary policy. This strategy could also be a good alternative for Ukraine. But, for the inflation-targeting framework to be a success, some conditions should exist in a country.

Masson, Savastano and Sharma (1997) consider some necessary prerequisites that should exist in a country for the inflation targeting framework to be successful.

One of these prerequisites is the ability of the central bank to conduct independent monetary policy. It means that the central bank should be able to choose freely instruments for monetary policy, but it does not mean that there should be goal independence. For instance, the goal of the monetary policy, such as price stability, can be set by Verkhovna Rada in Ukraine, but which instruments to choose for the achievement of this goal should be decided by the National Bank. The authors argue that the main problem for developing countries could be the fiscal dominance over monetary policy. In other words, the authors claim that in developing countries the central banks are often required to automatically finance budget deficit. As a result there is a large level of seigniorage in these countries. The consequence of fiscal dominance and high inflation tax could be a fiscally driven inflation. In such circumstances monetary policy would fail to pursue any nominal target and would be rather accommodative. In Ukraine, according to the Law On Banks and Banking System, the National Bank is not required to automatically finance the budget deficit. It means that financing the fiscal deficit through seigniorage (printing money) is restricted in Ukraine. Indeed, the Ukrainian government mostly financed its deficit by issuing government bonds. This is the evidence of relatively independent monetary policy in Ukraine.

The second main condition for inflation targeting is the absence of commitment to any other nominal anchor, such as exchange rate. This may seem a bit controversial, because, as we said before, a fixed exchange rate lowers inflationary expectations and it seems unlikely that there is a trade-off between inflation targeting and exchange rate targeting. But actually the trade-off is possible, especially in the case of capital mobility. Suppose that the National Bank observes higher inflation than is targeted, say, because of overheating of the economy. In this case it decides to decrease money supply in order to decrease aggregate demand and thus reduce inflation. The fall of money supply causes an increase in the interest rate. If we have capital mobility, an increase of the interest rate will lead to the inflow of capital in the country, which in turn causes an increase of demand for national currency. If the National Bank has commitment to maintain fixed exchange rate, it should offset an increase of demand for national currency by an increase of the money supply. Thus the aggregate demand increases back, leading to inflation. In the IS-LM analysis this is called the endogenous movement of the LM curve. So, although fixing exchange rate is conducive to lowering inflation by means of lowering inflationary expectations, the inflation caused by other than expectations factors (e.g. demand inflation) can not be fought by monetary policy actions under fixed exchange regime. The authors claim that if a country chooses a fixed exchange rate it means that this country subordinates its monetary policy to this goal and thus becomes unable to pursue any other nominal anchor. Nevertheless, if the exchange rate is not fixed, but rather crawling then the coexistence of nominal exchange target and inflation target is possible as long as the priority is given to inflation target.

Ukraine has recently abandoned fixed exchange rate and is now going to switch to floating one. Therefore, this condition, like the condition of monetary independence, is also likely to hold in Ukraine.

But the main condition for the success of inflation targeting is the existence of an appropriate model of inflation at the disposal of the National Bank. In Debelle (1997) it is argued that such a model should explain the inflation path well. On the basis of such a model the policymakers should be able to make reliable forecasts of inflation. Actions of policymakers should be forward looking and they should know how changes in the instruments would influence the inflation rate and how long would it take for the inflation rate to respond to changes in instruments. Clearly, a good inflation model is of great importance for the inflation-targeting framework.

Taking into account that the previous two conditions can be considered fulfilled in Ukraine, the last condition becomes the key for the success of inflation targeting in Ukraine.

An attempt to find out how inflation responds to the changes in policy instruments was made by Christoffersen and Wescott (1999) for the case of Poland. The authors use a simple multivariate model of inflation or, in other words, variance autoregressive model (VAR). The authors use monetary policy instruments, activity variables and administered prices as explanatory variables. The immediate assessment of the dynamic relationship between inflation and the explanatory variables is done by using impulse response functions. As a result of the analysis it was found that among the monetary policy instruments there is a reasonable linkage between the exchange rate and the inflation, and there is some evidence that movements in money supply also influence inflation. The disappointing result of the analysis was that the interest rate failed to show any significant effect on the inflation rate. The authors explain this by the fact that both inflation and interest rate have been falling monotonically during the sample period.

The idea of analyzing monetary policy shocks by using small econometric, or VAR, models can be traced to Leeper, Sims, and Zha (1996). In this paper the authors use VAR framework for the analysis of monetary policy shocks in the

USA. In particular, the paper tries to find a policy variable, such as monetary aggregate or interest rate, that would be controlled by policy and at the same time would be closely related to economic activity. The main conclusion of this article is that not only the state of economy moves in response to changes in monetary policy instruments, but also monetary policy instruments respond to the state of the economy. This finding implies that treatment of monetary policy variables as exogenous is dangerous. In modeling the policy-setting process it is essential to assess accurately the effects of policy, in particular, policy endogeneity should be treated carefully.

As can be concluded from the survey of literature neither monetary aggregates nor the exchange rate can be used as the ultimate target of the monetary policy in Ukraine. However, they both can serve as intermediate targets or instruments in the conduct of inflation targeting policy, because money supply and exchange rate can influence the price level in the country significantly. This conclusion inspired the choice of the variables in my model: money supply and exchange rate as intermediate targets, and price level as ultimate target.

Another conclusion, drawn from the survey of literature, is that VAR techniques are widely used in the estimation of monetary relationships. Therefore, I will use VAR model in my paper.

Chapter 3

THEORETICAL BACKGROUND

As a theoretical framework for my research I chose the celebrated monetary approach to the relationships between money supply, price level and exchange rate described in Krugman, 1996. The monetary approach assumes that the price level in the economy is fully determined by changes in money supply and money demand. This assumption can be expressed as follows:

$$P_u = \frac{M_u^s}{L(i_u, Y_u)}$$

P_u - price level in Ukraine;

M_u^s - money supply in Ukraine;

L - money demand in Ukraine;

i_u - nominal interest rate in Ukraine;

Y_u - real national income of Ukraine.

The above equation tells us that increase in money supply should cause proportional increase in price level if money demand is unchanged.

Another assumption of monetary approach is that purchasing power parity (PPP) holds. According to absolute PPP prices in two different countries should be equal if expressed in the same currency:

$$P_{UAH} = P_{\$} * E_{UAH/\$}$$

P_{UAH} - price level in Ukraine expressed in Ukrainian currency

$P_{\$}$ - price level in the USA expressed in dollars

$E_{UAH/\$}$ - exchange rate expressed as number of hryvnias per dollar

After rearrangement:

$$E_{UAH/\$} = \frac{P_{UAH}}{P_{\$}}$$

We see that under PPP, an increase in Ukrainian prices should lead to proportional exchange rate depreciation (increase in the amount of hryvnias paid for a dollar). On the other hand, exchange rate depreciation should be accompanied by an increase in the Ukrainian price level to maintain PPP.

The last, but not the least, assumption of the monetary approach is that interest rate parity holds implying that the difference between domestic and foreign interest rates should be equal to the expected devaluation of the domestic currency:

$$i_u - i_{us} = \frac{E^e_{UAH/\$} - E_{UAH/\$}}{E_{UAH/\$}}$$

i_u - nominal interest rate in Ukraine;

i_{us} - nominal interest rate in the USA;

$E^{e}_{UAH/\$}$ - expected exchange rate;

$E_{UAH/\$}$ - current exchange rate.

Of course, the above three assumptions are very strong and unlikely to hold exactly in the real world. Nevertheless, this approach can give us the main ideas as to the relationships between money supply, price level and exchange rate in the economy. Furthermore, in those important situations where monetary changes are the dominant cause of economic fluctuations, the predictions of monetary approach are accurate over a long run (Krugman, 1996). In Ukrainian economy, this is likely to be the case.

Now based on monetary approach it is possible to figure out the expected form of time paths of price level and exchange rate following a change in the money supply.

If we assume flexible prices, that is prices responding immediately to the change in money supply, monetary expansion will lead to an increase in the price level, which, in turn, depreciates the exchange rate given that PPP holds in the short run. For sticky-price case, where it is assumed that PPP does not hold in the short run, monetary policy operates through the interest rate channel. Thus, positive domestic monetary policy shocks (implying an initial increase in the real money supply, given that prices are sticky in the short run) reduces the domestic interest rate. Given interest rate parity, the policy shocks instigate anticipation of an appreciation of the domestic currency in the long run. The fall in the domestic interest rate coupled with the expected appreciation of the domestic currency makes domestic assets unattractive. Domestic capital outflows and the domestic currency depreciates. A short run

equilibrium is reached when equality is attained between the expected returns on foreign and domestic assets (i.e. when interest rate parity holds). In the medium term, however prices begin to rise as a result of monetary expansion, the real money supply falls and domestic interest rate increases gradually appreciating the domestic currency and moving it to its long run PPP level. So, under sticky-price assumption the exchange rate overshoots its long run PPP level.

Thus, the expected time paths of price level and exchange rate following monetary expansion can be drawn as follows:

Figure 3.1. Expected path of exchange rate following monetary expansion (sticky-price case)

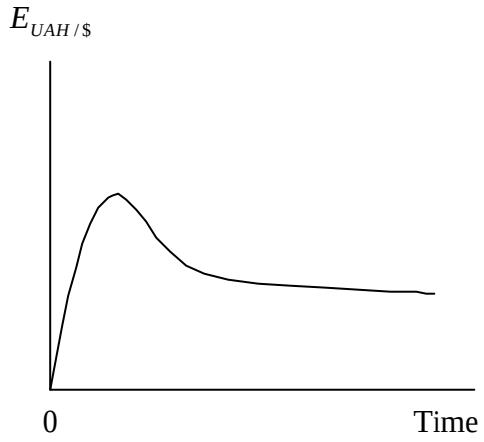


Figure 3.2. Expected path of exchange rate following monetary expansion (flexible-price case)

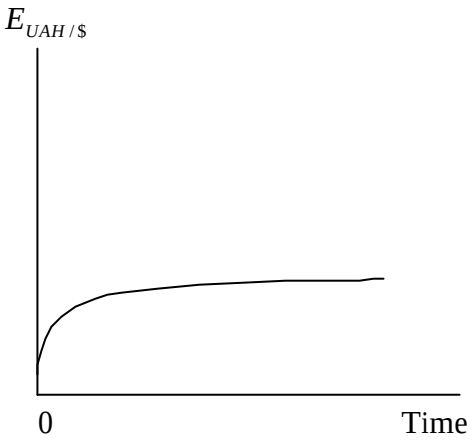


Figure 3.3. Expected path of price level following monetary expansion (sticky-price case)

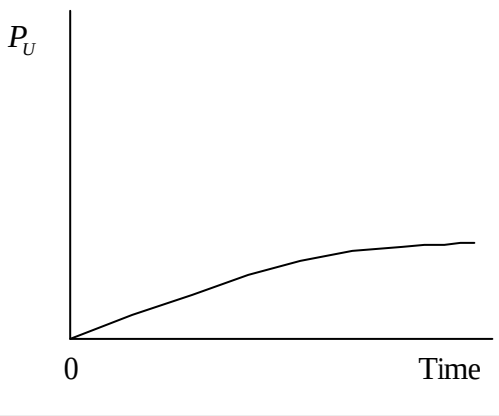
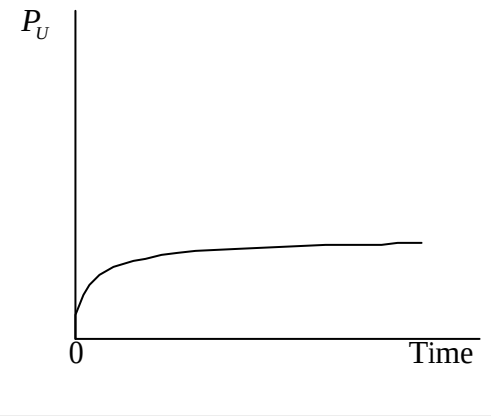


Figure 3.4. Expected path of price level following monetary expansion (flexible-price case)



Similarly, it is reasonable to expect the price level and the exchange rate to be positively correlated. Exchange rate depreciation should cause inflationary expectations and thus lead to an increase in the price level. On the other hand, a positive shock in the price level causes exchange rate depreciation, according to PPP.

Thus three variables – money supply, exchange rate and price level – are linked to each other, and those links are theoretically justified.

In this paper I am trying to build statistical model that would encompass the above variables, correspond to the theoretical predictions and fit the data well.

Next section describes data and methodology used in this paper.

Chapter 4

DATA AND METHODOLOGY

For the analysis of macroeconomic relationships, time series data are usually used. In this paper I follow this common practice. As was noted the aim of the analysis is to build a statistical model that would link such macroeconomic variables as the price level, money supply and exchange rate. Therefore, the time series data on these aggregates are used.

To ensure a large enough sample size as well as sufficient data variability I use monthly rather than quarterly or annual data. The sample will cover monthly data from 1995:01 to 1999:06.

The primary sources of the data are the databases of the National Bank of Ukraine and UEPLAC. In general, data on price level, exchange rates and money supply are monitored carefully and thoroughly by different institutions. Thus, access to these data is not problematic, which makes the analysis easier and, at the same time, more reliable, because no proxies are needed for the variables.

As was mentioned before in my thesis paper I want to answer the question of how the price level, money supply and exchange rate are linked. To put it differently, I want to know how a shock in one variable influences the other variables.

To answer this question I will use the variance autoregressive (VAR) analysis and the analysis of impulse response functions.

The general framework can be sketched as follows. We have three variables: consumer price index (CPI), exchange rate (ER) and money supply (M2). VAR model can be expressed as follows:

$$\underset{A}{\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}} \underset{Z_t}{\begin{bmatrix} CPI_t \\ ER_t \\ M2_t \end{bmatrix}} = \underset{B}{\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}} \underset{Z_{t-1}}{\begin{bmatrix} CPI_{t-1} \\ ER_{t-1} \\ M2_{t-1} \end{bmatrix}} + \underset{U_t}{\begin{bmatrix} e_t \\ u_t \\ v_t \end{bmatrix}} \quad (1)$$

Matrix A in this equation shows contemporaneous response or immediate response of variables to changes in other variables. For simplicity, I show only once lagged variables on the right hand side, but in the process of analysis, it is possible that some farther lags will be introduced. The relationship can be represented as follows:

$$\mathbf{AZ_t = BZ_{t-1} + U_t} \quad \mathbf{(2)}$$

To run regressions one needs dependent variable on the left-hand side and independent variables on the right hand side. After rearranging:

$$\mathbf{Z_t = A^{-1}BZ_{t-1} + A^{-1}U_t} \quad \mathbf{(3)}$$

Now if I denote $A^{-1}B$ by C and $A^{-1}U_t$ by W_t I will obtain the following regression:

$$\mathbf{Z_t = CZ_{t-1} + W_t} \quad \mathbf{(4)}$$

A problem now arises: running this kind of regression I can not separate the matrices A and B. The only thing I have is the estimated matrix C.

The solution for this problem is to make explicit restrictions on the coefficients of the matrix A, usually setting them equal to 1 or 0. These restrictions are made according to the theory and judgement. Having identified a matrix A in such a way and having the matrix C, it is possible to identify the matrix B = AC. After identification of the matrices I can construct so called impulse response functions, which show how a shock in one of the variables influences the behavior of other ones. Looking at the impulse response function I can say whether a variable behaves as was predicted by the theory or not. If the impulse response function is implausible, I should make other restrictions on the matrix A and try again to build impulse response function. This process continues until I get some different (or unique) plausible models. So the essence of this paper is to combine statistical skills with theoretical knowledge in building a model that would show how monetary shocks influence inflation and how inflation influences monetary policy.

Such a methodology may seem just data mining, but it proved to be successful in some empirical studies (e.g. Sims, Leeper, Zha (1996)). Making more formal restrictions on the matrix A and assessing the plausibility of impulse response functions by using more strict mathematical apparatus would be time consuming and would have great computational costs. At the same time, there is no guarantee that the results would be more accurate. Ultimately, what I need is that the model fit the data and be reasonable. This task can be successfully fulfilled by the above methodology.

In the previous paragraphs, I gave only the main idea about the methodology I am going to use in my research. Now I would like to emphasize in more details the major steps in approaching to the final version of the model I will test.

The first step is to define what number of lags are to be included in the model. This problem does not have unique solution for each situation. In this

paper I will use the approach of minimizing information criteria AIC combined with general judgment concerning the speed of adjustment taking into account the nature of the variables. The AIC approach to the determination of lag length has its disadvantage when applied to VAR models. It tends to find rather short lag length such as 1 or 2, because in VAR the number of parameters increases substantially with additional lags (pn^2) and, thus, the "penalty" for the introduction of the additional lag is high (Kunst, 2000). Therefore, I will also use general judgment based on theory in addition to minimizing AIC.

The next step is to test the data for stationarity. Broadly speaking, a stationary process is characterized by a constant mean and variance over time. Furthermore the covariance between the two time periods should not depend on the actual time at which it is computed (Gujarati, 1995). The assumption that data used in the model are stationary is very important. Stationarity of regressors is assumed in the derivation of standard inference procedures for regression models. Nonstationary regressors invalidate many standard results and require special treatment. If, for instance, one ignores this assumption and uses non-stationary data he can be misled by obtaining spurious regression, showing extremely high R^2. But in fact this kind of regression is unlikely to reflect true degree of association between the variables. I will test stationarity using the conventional Augmented Dickey-Fuller (ADF) Test. In case of stationary data it is possible to run VAR in levels. If, on the other hand, ADF test rejects the hypothesis of stationarity then I will take first differences of the data and check them for unit roots. If differenced series happen to be stationary then it is possible to run regressions in differences. In this case the original time series are integrated of order 1 (I(1)). The problem with regressions in differences is that it is rather difficult to interpret the coefficients on differenced variables. Most economic theory states the long-run relationship between the variables in level form and not first (or higher order) difference form. To tackle this problem I will use logarithms of time series rather than original data. It will make the interpretation of the

coefficients easier. For instance, the first difference of logarithms of price levels represents the inflation rate. Thus the coefficient will represent the elasticity of dependent variable to the change in price level. If, on the other hand, one runs regressions in differences of original data the estimated coefficients are semi-elasticities, which are harder to interpret.

It is also worth talking about the possibility of cointegration in the data. Simply put, cointegration indicates the presence of long run equilibrium among time series data. In our case it is quite possible that the price level, money supply and exchange rate are cointegrated, that is have a long run relationship. Technically cointegration implies that even if the individual variables are nonstationary, a linear combination of these variables may be stationary (McNown and Wallace, 1994). It is this linear combination that we call cointegrating equation. If there is no cointegration in the data then standard VAR analysis applies. If, on the other hand, there exist one or more cointegrating equations, then the VAR should take them into account through an error correction term. The VAR that incorporates cointegration is called vector error correction (VEC) model. Thus testing for cointegration in the data is a necessary step in my analysis, because the presence of cointegration may influence the final form of the model. To test for cointegration I will use the conventional Johansen test procedure.

In the next section I will test the data for stationarity, cointegration and also find the optimal lag length thus arriving at the final version of the model to work with. I will then apply different identification schemes to the model and get different sets of impulse response functions. The interpretation of the impulse responses will be also done in the next section.

Chapter 5

EMPIRICAL RESULTS

Following the procedure mentioned in Section IV, I first define the number of lags I will include in the model. Appendix 1 shows the estimation outputs of VAR models using 1, 2, 3 and 6 lags. For convenience, Akaike Information Criteria (AIC) for the systems with different lags are presented in the following table.

Table 5.1. Akaike Information Criteria for the VAR systems with different lags

Lag Length	**1**	**2**	**3**	**6**
AIC	-19.91819	-20.09542	-19.81199	-19.41215

As can be seen from the Table 5.1, AIC is minimized when lag length is two. However, as was mentioned before, when applied to VAR AIC approach tends to produce rather short lag lengths. Since in the analysis I use monetary rather than real variables, it is reasonable to assume short lag length. But lag length of two is too short to capture the adjustment process. Therefore, I decided to use three lags (one quarter) in the estimation. This choice may seem rather arbitrary, but, unfortunately, economic theory says nothing about the optimal lag length. Consequently, the researchers have some freedom in choosing lag length.

Having defined lag length, I test data for stationarity using the ADF test. This test requires specifying the number of lagged differences to be included. The common procedure is to include p-1 lagged differences in the ADF equation.

Here *p* is the number of lags used in the model. In our case *p* is equal to three. Therefore, I will include two lagged differences in the ADF equations. Appendix 2 shows the results of the ADF test for logarithms of CPI, M2 and Exchange Rate. I included intercept (without trend) in the ADF equations. As can be seen from the results presented in Appendix 2, the logarithms of all time series are non-stationary, that is, the null hypothesis of the unit root can not be rejected even at 10% significance level.

Since the time series are non-stationary, they should be differenced until they become stationary. Appendix 3 shows the results of the ADF tests for the first differences of the logarithms of CPI, M2 and Exchange Rate. As can be seen the first differences of all time series are stationary. This means that all time series are I(1). So I will run the VAR's in first differences rather than in levels. To produce visual picture of the behavior of the time series I show the graphical representation of them in Appendix 3.

The final step is to define whether time series are cointegrated. The results of Johansen Cointegration Test are shown in Appendix 4. As can be seen likelihood ratio test indicates 1 cointegrating equation at 5% significance level. So, this cointegrating equation should be introduced in the model. It can be easily done by running Vector Error Correction (VEC) model rather than usual VAR.

To sum up, I will run VEC model on the first differences of the time series, with one cointegrating equation and with lag length three.

The VEC estimates are shown in Appendix 5. As can be seen, R^2 of the price equation is rather high (84.6%), which means that large portion of variation in inflation can be explained by the variation in exchange rate depreciation and money growth. Money supply equation has moderate R^2 (30.6%). Nevertheless, more than 30% of variation in money growth can be explained by the variation in inflation and exchange rate depreciation. Even such a small R^2 is a good sign, indicating that monetary authority somehow responds to

the changes in inflation and exchange rate depreciation. As for the exchange rate equation, R^2 is rather disappointing – 8%. But this equation is of minor interest in this paper. As was mentioned before, the paper focuses more on modeling inflation and investigating the response of monetary policy to changes in inflation and exchange rate.

It is possible now to analyze the impulse response functions obtained from the various identification schemes.

For the convenience, I reproduce the matrix equation (1) here:

$$\underbrace{\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}}_{A} \underbrace{\begin{bmatrix} CPI_t \\ ER_t \\ M2_t \end{bmatrix}}_{Z_t} = \underbrace{\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}}_{B} \underbrace{\begin{bmatrix} CPI_{t-1} \\ ER_{t-1} \\ M2_{-1} \end{bmatrix}}_{Z_{t-1}} + \underbrace{\begin{bmatrix} \dot{e}_t \\ u_t \\ v_t \end{bmatrix}}_{U_t} \quad (1)$$

Although this equation is the oversimplified version of the true model (it includes only one lag, it is in levels, it is not in logarithms and it does not incorporate countegrating equation), it can be used to demonstrate how different identification schemes are created.

As was mentioned in the previous section different identification schemes involve different matrixes (A's) of contemporaneous effects.

The underlying theory of monetary approach allows for both flexible and sticky prices. In terms of identification schemes flexible prices would mean that the coefficients a_{12} and a_{13} are equal to 1 that is prices respond immediately, within the same period, to changes in money supply and exchange rate. Sticky prices, on the other hand, would mean that the coefficients a_{12} and a_{13} are equal to 0 that is prices do not react immediately, but need some time to adjust.

Another criterion for discriminating between the different identification schemes is the speed of reaction of the monetary authority, represented by changes in the money supply, to changes in prices or exchange rate. For instance, if I assume that the monetary authority has full and on-line information about prices, then it is possible to assume that it can immediately respond to the changes in prices. In this case, the coefficient a_{31} in the matrix of contemporaneous shocks will be equal to 1. If, on the other hand, the information about prices goes to the monetary authority with a lag, then it can not immediately respond to the changes in the prices. Thus, the coefficient a_{31} will be equal to 0.

Following the above logic, I considered four identification schemes:

Identification scheme 1. Prices are assumed fully flexible. Monetary authority does not react immediately to changes in the prices and exchange rate. Exchange rate responds immediately to the changes in the money supply. The matrix A of contemporaneous effects under this identification scheme will be as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

Identification scheme 2 Prices are assumed sticky. Monetary authority responds immediately to the changes in prices but not to the changes in exchange rate. Exchange rate responds immediately to the changes of both prices and money supply. The matrix A of contemporaneous effects under this scheme will be as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 0 & 1 \end{bmatrix}$$

Identification scheme 3. Prices are assumed fully flexible. Monetary authority responds immediately to the changes in exchange rate, but not to the changes in prices. Exchange rate does not respond immediately to the changes in prices and money supply. The matrix A will be as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix}$$

Identification scheme 4 Prices are assumed sticky. Monetary authority responds immediately to the changes in both prices and exchange rate. Exchange rate responds immediately to the changes in prices but not in the money supply. The matrix A will be as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

As you can see, all the above schemes include only 3 zero elements, that is the matrix A in each case is exactly identified. Furthermore, the schemes are made in such a way that the matrix A can be presented in the upper triangular form by reordering the variables. These two kinds of limitations are imposed by E-Views software. Unfortunately, E-Views can not deal with overidentified and non-recursive schemes. Therefore, it is impossible to introduce the scheme, in which, say, prices are assumed to be sticky and monetary authority does not respond immediately to neither exchange rate nor price changes (this scheme would require 4 zero restrictions). Of course, these limitations significantly reduce the power of the analysis, but I have no option but to go with them.

The impulse response functions obtained using different identification schemes are shown in Appendix 6. Although the VEC model is run in the first differences, the shocks are made to the levels of the variables. Thus, impulse responses depicted in Appendix 6 show the responses of the levels of the variables to the shocks in the levels of other variables.

As can be seen from the Figure 1 of Appendix 6 all identification schemes exhibit approximately the same pattern of behavior of the price level upon the shock in the price level. On impact the price level increases and this increase is preserved in the long run.

All four identification schemes show that a positive shock to the exchange rate (exchange rate depreciation) leads to a permanent increase in the price level. But the speed of reaction of prices on exchange rate depreciation varies with different identification schemes. For the schemes 1 and 3 prices increase immediately, on impact, while for the schemes 2 and 4 there is no increase in the price level on impact. This is quite natural, because schemes 1 and 3 assume flexible prices while schemes 2 and 4 allow for some stickiness in the prices. In any case, there is strong evidence that exchange rate positively influences price level. It can be explained by the fact that exchange rate serves as an anchor in people's inflationary expectations. Exchange rate stability in Ukraine is an indicator of the credibility of the National Bank. Thus exchange rate depreciation triggers inflationary expectations, which, in turn influence actual price level. Another reason for the positive influence of exchange rate on the prices in Ukraine is that imports to GDP ratio is quite high in Ukraine. Although the major part of imports is gas and oil – goods that are not included in the CPI calculations – the prices of these goods significantly influence the prices of consumer goods. Therefore, exchange rate depreciation, which raises the prices of gas and oil, indirectly raises the prices of consumer goods.

The effect of a shock in the money supply on the time behavior of the prices is more controversial. As can be seen from the Figure 1 of Appendix 6 the identification schemes 1, 3 and 4 exhibit so called "price puzzle" – positive shock in money supply leads to the fall in the price level. This apparently contradicts the theory of the monetary approach described in the Theoretical Background Section. Usually puzzles are solved by adopting another identification scheme. In our case scheme 2 produces more plausible result: a

positive shock in the money supply leads to a permanent increase in the price level. But as can be seen this increase is rather small. This fact is surprising and disappointing, because it means that by changing money supply monetary authority can not influence significantly the price level in the country. There is, however, an explanation to this feature of the Ukrainian economy. The problem lies in the fluctuations in the demand for money in Ukraine. According to the monetary approach, the price level is determined by the ratio of the money supply to the money demand. If money supply increase does not lead to an increase in the price level, it means that money demand increased too. And this was the case for the Ukrainian economy. In particular, the demand for the national currency increased in 1996, when hryvnia was introduced. Furthermore, the demand for hryvnia rose among foreign investors buying Ukrainian T-bills in the period from 1996 to 1998. Thus, money demand increase reduced the effect of the monetary expansion on the price level.

Figure 2 of the Appendix 6 depicts the responses of exchange rate to the shocks in CPI, exchange rate and money supply.

Schemes 1 and 3 exhibit implausible responses of exchange rate to the shock in the prices. These schemes show that exchange rate appreciates following an increase in the domestic price level. Such a result apparently contradicts the theory of purchasing power parity described in Chapter 3. Schemes 2 and 4, on the other hand, fit theoretically predicted pattern of the exchange rate behavior following the price shock. As can be seen from the Figure 2, a positive price shock leads to exchange rate depreciation, as predicted by the PPP.

The response of exchange rate to the shock in exchange rate is the same for all identification schemes. There is an increase in exchange rate, which is the shock itself, but in the long run exchange rate rises even greater.

Now let's look at the response of the exchange rate to a shock in the money supply. As can be seen from Figure 2 of Appendix 6 the effect of a monetary expansion on the behavior of the exchange rate is controversial. All identification schemes show that in the long run monetary expansion leads to the exchange rate depreciation – result predicted by the theory. But in the short run, schemes 1, 3 and 4 exhibit "exchange rate puzzle" – appreciation of exchange rate following monetary expansion. As Kumah (1996) suggests the "exchange rate puzzles" could be attributable to the particular identification schemes. Changing identification scheme may solve the problem. Indeed, scheme 2 exhibits quite plausible pattern of exchange rate behavior following monetary expansion. As Figure 2 shows, on impact exchange rate depreciates sharply but by the end of the second period it partly appreciates. This overshooting is consistent with the prediction of the monetary approach for the case of sticky prices (note that scheme 2 implies sticky prices). After the second period exchange rate again depreciates sharply and then again partly appreciates, arriving to its long run equilibrium level.

The least controversial response is that of money supply to the shocks in prices, exchange rate and money supply. Figure 3 of the Appendix 6 depicts the responses of money supply.

As revealed by the graph, all four identification schemes show that money supply falls following an increase in the price level. It should be noted that schemes 2 and 4 produce immediate response of money supply, while schemes 1 and 3 show less rapid reaction. It is natural, because the contemporaneous effect of CPI on money supply was explicitly assumed in schemes 2 and 4. Nevertheless, money supply unambiguously falls in the long run following positive shock in the price level. It could mean that monetary authority of Ukraine – the National bank of Ukraine – pursued a kind of inflation targeting policy, responding to inflation by monetary contraction.

As can be seen from the Figure 3, exchange rate depreciation causes a long run increase in money supply. This result is supported by all schemes. Scheme 3, however, shows immediate fall in money supply, but this fall is too small to be considered. The fact that the money supply increases following exchange rate depreciation is technical rather than behavioral. As was mentioned before, I included foreign currency deposits (denominated in the national currency) in the measure of money supply. Therefore, exchange rate depreciation automatically increases the national currency value of the foreign currency deposits, thus increasing money supply.

The response of the money supply to a shock in the money supply is unambiguous. All identification schemes show an increase in money supply following positive shock in money supply (see Figure 3).

To sum up, the most plausible impulse responses are revealed by identification scheme 2, which assumes that prices are sticky, money supply responds immediately to changes in prices, and exchange rate responds immediately to changes in both prices and exchange rate. These assumptions are quite reasonable for Ukraine. Indeed, prices in Ukraine are subject to government control and, therefore, are unlikely to react to the changes in the money supply and exchange rate within a month. It is possible that the monetary authority, willing to fight inflation, immediately responded to the price shocks by changing money supply. Finally, it is quite reasonable to assume that the exchange rate reacts immediately to the changes in both prices and money supply, because foreign exchange markets usually use efficiently and quickly any incoming information.

On the basis of identification scheme 2 it is now possible to revise the main finding. There is strong evidence that exchange rate shocks influence price level in the country. In particular, exchange rate depreciation leads to the long run rise in the price level. There is some evidence of the positive effect of money supply on the price level, but this effect is not very strong. It can be

explained by the rise in the demand for money in the sample period. Nevertheless, the reverse effect of price level on money supply is a strong one, indicating the attempts of the monetary authority to fight inflation. Reaction of exchange rate to the positive shocks in prices and money supply is natural – depreciation. An increase in money supply upon exchange rate depreciation is rather technical issue, because money supply measure includes foreign currency deposits.

Chapter 6

CONCLUSIONS

The paper aimed at estimating the relationship between possible intermediate targets of monetary policy and an ultimate target. As intermediate targets, money supply and exchange rate were chosen. The price level served as the ultimate target. Therefore, I estimated the relationship between the price level, exchange rate and money supply. For the estimation I used Vector Error Correction model. To make the analysis more rigorous I compared the performance of impulse response functions obtained from the different identification schemes – sets of explicit restrictions on the matrix of contemporaneous shocks.

The identification scheme that assumed sticky (within a month) prices, quickly responding to the shocks in prices and money supply exchange rate and quickly responding to the shocks in prices money supply, proved to produce the most plausible results.

The main finding is that exchange rate shocks significantly influence the behavior of the price level. In particular, exchange rate depreciation leads to a permanent increase in the price level. This could be explained by the influence of the prices if imported goods, which are linked to the exchange rate, on the prices of consumer goods. Furthermore, the exchange rate serves as a nominal anchor for Ukrainians in the formulation of their inflationary expectations.

There is some evidence that money supply shocks effect the price level behavior, but this effect is not very strong. This can be explained by the changes in the demand for money during the sample period.

On the other hand, the money supply responded significantly to the shocks in the price level. In particular, an increase in the price level was usually followed by the monetary contraction. This could be a sign of the attempts of the National Bank of Ukraine to conduct inflation-targeting policy.

The main message for the policymakers is that the exchange rate, although undesirable as an ultimate target for the monetary policy, could serve as an efficient intermediate target for the inflation targeting policy. Money supply, on the other hand, should be treated with caution. Fluctuations in the demand for money may significantly reduce the power of the money supply as an intermediate target. Therefore, there is a need for estimation of the demand for money in Ukraine. Obviously, there is a room for further research on this issue.

This paper is clearly far from the final point on the issues discussed. There are some limitations of my approach. As I mentioned before, I used exactly identified recursive matrixes of contemporaneous shocks in my estimations. But the introduction of the overidentified and non-recursive matrixes could considerably increase the power of the analysis. In this aspect there is a possibility of further research. Also it is possible to include other intermediate targets, such as the interest rate, in the specification and estimate their effectiveness. Finally, as I mentioned in the previous paragraph, there is a need for estimation of the demand for money in Ukraine. All the above issues could be the subjects of further research.

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