The monetary transmission mechanism and the structural modelling of inflation at the National Bank of Poland

Bohdan Kłos, Research Department, National Bank of Poland, and
Ewa Wróbel, Monetary and Credit Policy Department, National Bank of Poland[1]

1. Introduction

The implementation of a direct inflation targeting (DIT) strategy creates the need for a deeper understanding of country-specific relations between monetary policy instruments and economic processes. The DIT strategy had been introduced before the Polish economy had achieved a sufficient level of macroeconomic stability and before the behavioural patterns of economic agents had matured, these patterns thus being subject to many changes. Permanent changes to market institutions in Poland also compelled agents to modify their methods of adjustment. It forced statistical offices to verify (and change) definitions of economic variables and their measurement methodology. In these circumstances any investigation of economic features based on statistical (econometric) techniques and available statistical data (in particular time series) has been very imprecise, and quite often misleading. However, the progress made in transforming the system in Poland and the development of market institutions have created the opportunity to enhance and intensify research, in particular modelling. Part of the research activity at the NBP aimed at supporting monetary policy in Poland can be classified into two groups:

- The study of monetary transmission mechanisms.

  This line of research focuses on examining the current state of the links between monetary policy instruments and the main economic variables such as inflation, money supply, industrial production, GDP growth, unemployment, and external and internal equilibrium indices. VAR modelling methodology is the main tool used in this area of research. An example is presented in the second section of this paper.

- Structural modelling of selected features of the Polish economy.

  Structural models of inflation attempt to describe a stylised version of the market economy rather than the current state of the transition process in Poland. These models mimic basic inflation-generating mechanisms and how the economy reacts to the policy instruments (in particular interest rates) used by decision-makers. In this area of modelling, data congruency is not a main criterion of the model quality, so that the model - primarily - reflects the author's way of thinking rather than providing a precise picture of the real economy. One of these models (MSMI-1) is described in the third section of the paper.

2. The role of interest rates in the monetary transmission mechanism in Poland (by E Wróbel)

Studies of the transmission mechanism in Poland using a VAR approach (Christoffersen and Wescott (1999), Kokoszczynski et al (1999), Wróbel (1999), Rybinski (2000)) have stressed the role of the exchange rate channel in the monetary transmission process. Using the Bernanke-Blinder restriction, they show that over the period 1992-99 the exchange rate channel strongly dominated the interest rate channel. The impact of exchange rate shocks on inflation, as well as on output growth and

[1] The paper, prepared for the workshop on modelling aspects of the inflation process and the monetary transmission mechanism in emerging market countries, expresses the authors' point of view.

nominal wage rates, was found statistically significant and fairly quick whereas interest rate shocks usually produced impulse response functions of nonsensical shape. This relatively strong impact of exchange rate shocks plausibly stemmed from the role the exchange rate traditionally played in inflationary expectations and from its direct impact on import prices. Unsatisfactory results in previous papers led me to repeat the transmission exercise with new assumptions, paying more attention to carefully isolating the monetary policy shock and skipping the period when, as one might suspect, the interest rate could not play any significant role in the monetary transmission mechanism.

2.1 Monetary policy in Poland

In Poland changes in monetary policy regimes and operating procedures were quite frequent. In particular, the exchange rate regime underwent multiple changes, evolving from a fixed to a pure float.

At the initial stage of the transformation, the exchange rate was fixed to the US dollar and then to a basket of five currencies. In late 1991, the fixed exchange rate regime was replaced by a preannounced crawling peg. In 1995, that was in turn replaced by a fixed rate with a crawling band. Central parity then ceased to be an official exchange rate and served only to set the band within which the currency could fluctuate. Instead, the fixing rate played the role of an official exchange rate. This regime survived until April 2000 but in the meantime the NBP gradually widened the band - from ±7% in 1995 to ±15% in 1999. Finally, in 1998 the NBP suspended interventions in the foreign exchange market and in April 2000 the złoty was fully floated. To avoid excessive exchange rate volatility and exchange rate appreciation independent from the current state of the economy, a special account was set up in 2000 for the incomes derived from privatisation.

Changes in the set of intermediate and operational targets add to the picture of continuous monetary policy modifications. An initial trial in the use of the interest rate as an operational instrument failed since, as Kokoszczynski and Stopyra (1996) point out, banks were accustomed to the credit limits applied in the 1980s and therefore were insensitive to the NBP interest rate policy. Banks sharply increased credit due to overoptimistic estimates of future aggregate demand. Insufficient skills on the part of banks' credit inspectors as well as inadequate NBP supervision and regulation also played an important role. This led the NBP to resort once again to credit ceilings. Thus, over 1990-93 the NBP targeted net domestic assets with credit limits serving as an operational instrument. They were in use up to 1992 and weakened agents' already weak sensitivity to the interest rate policy.

Over 1994-97 the NBP officially targeted the broad money supply. At first, the interest rate was adopted as an operational target, but then there was a two-year episode of monetary base targeting. In practice, the NBP put more stress on the exchange rate than on money and intervened in the exchange rate market whenever it considered that the current exchange rate of the złoty could jeopardise exports. On the other hand, it also tried to avoid an undesirable fall in the interest rates sterilising capital inflow. As a result, during this period monetary policy was eclectic with no clear-cut operational variable. Since 1999 Poland has abandoned intermediate targets and implemented direct inflation targeting, using the interest rate (28-day NBP bills) as the main instrument of monetary policy.

This short description of changes in monetary policy shows only a small portion of the difficulties, risks and challenges one faces when trying to build a structural model of inflation or to analyse the transmission mechanism using a VAR approach. When analysing the results obtained from the VAR presented in this paper, one must bear in mind that not only monetary policy but also fiscal policy underwent important changes that affected domestic demand. Due to the small sample these effects cannot be separated from the interest policy impact.

2.2 Estimation method and data

To examine the monetary transmission mechanism, I use a vector autoregression (VAR) approach and follow the Christiano, Eichenbaum and Evans (CEE 1994, 1998) identification method of a structural VAR (SVAR). SVAR is used to determine the monetary policy shock and then to examine the reaction of other endogenous variables to the defined monetary impulse.

The CEE identification procedure requires assumptions about variables the central bank looks at when setting an operating instrument and supposition about the nature of the interaction of the policy shock with the variables in the feedback rule. Namely, the monetary policy shock is identified with a disturbance term in a regression equation of the form:

$$S_t = \psi(\Omega_t) + \sigma\varepsilon_{St}$$

where S_t is the monetary policy instrument, ψ is a linear function, Ω_t is the information set available to the central bank when the monetary policy instrument is set, σ is a positive number, and ε_{st} is a serially uncorrelated shock that is orthogonal to the elements of Ω_t and has variance unity. The assumption of orthogonality means that variables of the information set react to a monetary policy shock only with a lag. This is a plausible assumption for high-frequency data. In the estimation I use monthly data. On the other hand, if Ω contains variables other than monetary variables, such as prices and output, the assumption that the central bank reacts to their contemporaneous values is controversial. In fact, the NBP obtains final data on retail prices and provisional data on output only two weeks after the end of a month.

Including too few variables in a VAR may lead to a misspecification problem; nonetheless, I decided to use a relatively modest set of variables, bearing in mind the small sample and the fact that long lag lengths in a VAR system quickly consume the degrees of freedom. These variables are the consumer price index (CPI), credit to the non-financial sector (in real terms) and the NBP intervention rate as a policy instrument. For pre-1998 this is the 14-day reverse repo rate converted for comparability reasons to a 28-day rate. Since 1998 this has been the 28-day NBP intervention rate.

I assume that, over 1995-2000, in setting the level of the interest rate, the NBP mainly considered the inflation rate and the rate of growth of credit to the non-financial sector. This set of variables has been important for the interest rate setting bodies at least since 1995, when the so-called "second" credit boom started (Figure 2.1). Including credit instead of production in the information set is untypical for that sort of analysis and therefore needs comment.

Up to the present there has been no robust relationship between inflation and the output gap, obtained by the most common method such as HP and Kalman filters. The most plausible reason is that the Polish economy was undergoing rapid structural changes and that supply shocks were playing an important role in output behaviour. Moreover, deriving the output gap requires data covering at least one full business cycle. This condition was not fulfilled, making all estimates highly uncertain.

With uncertain and lagged information on the output gap,[2] credit growth was carefully analysed and used as an indicator of domestic demand pressure. Moreover, since consumer demand was heavily oriented towards imported goods, it served as a leading indicator of changes in the trade balance (the rate of growth of household credit Granger-causes changes in imports after nine months).

Over 1995-2000 the role of credit in financing investment and private consumption steadily increased - the amount of total assets due from the non-financial sector in relation to GDP rose from 18.4% to 30.1%. It should be stressed, however, that the share of credit in foreign currencies, ie credit that is independent of the domestic interest rate policy, amounted to about 12-22% of total credit.[3] In 1999 the private sector financed about 18% of investment outlays with domestic credit and about 63% from its own financial sources.[4] The share of consumer credit in private consumption more than quadrupled, increasing from as low as 2.5% in 1995 to 10.8% in 2000. Excluding long-term credit, ie credit with a maturity of over five years that was mostly utilised by households for financing expenditures for housing purposes, these figures drop to 2.2% in 1995 and 7.9% in 2000.

As the discussion in Section 2.1 shows, it is much easier to make assumptions about the NBP information set than to choose the operational variable. Changing monetary policy regimes together with increasing financial deregulation and rapid financial sector development leave the identification procedure open to criticism, since using it I cannot take into account all these factors. Due to the small sample I cannot test the sensitivity of the results to different sample periods. The Bernanke-Mihov (1998) identification method allowing for more than one operational variable may be a solution for a future study.

---

[2] In Poland quarterly data on GDP are released three months after the quarter-end.

[3] These data are for 1996-2000.

[4] The latest available data are for 1999 ("Investment and fixed assets in the national economy", *Information and Statistical Paper*s, CSO, Warsaw 2000). These data cover entities employing more than 20 staff.

To check the impact of monetary shocks on other variables, such as industrial output, retail sales, monetary aggregates and yields on T-bills, I included them in the VAR system one by one. Throughout the paper I ordered the variables as follows: CPI, credit in real terms, and the NBP intervention rate. Variables related to economic activity such as industrial output and retail sales are ordered just before the interest rate, since it is assumed that monetary policy has no contemporaneous impact on the real sector.

There is no agreement in the literature about what identification method to use to isolate monetary shock, but there is a broad consensus on the impact of a contractionary monetary policy shock. Short-term interest rates increase, while monetary aggregates as well as output, employment, profits and real wages fall. Price indices, with the exception of raw materials, respond with a considerable delay. To evaluate the identification method, I checked the impulse response functions accordingly. One can, however, easily imagine that in a transition economy some impulse response functions will not have a proper shape in spite of a well identified monetary policy shock. This may happen to variables characterising overregulated markets. The Polish labour market is a good example. At the initial stage of the transition, a system of wage control was aimed at preserving employment. Another factor enhancing temporary labour hoarding was a frequent privatisation clause pressing new owners to keep employment at a pre-privatisation level over a certain period. This period is in many cases coming to an end, depressing employment and increasing the unemployment rate. Moreover, during the period analysed, structural adjustments to some economic sectors such as coal mining and the steel industry were initiated, resulting in lower employment. There are also demographic factors considerably affecting labour supply (the baby boom of the early 1980s). Changes in the social security and health care systems in 2000 led those employed in the hidden economy to register as unemployed to be eligible for social benefits. Another important factor was a change in the national statistics in 2000 - since when CSO data have covered firms employing at least five staff. This very factor was responsible for a decrease of about 340,000 in official employment in January 2000. Thus, to avoid discarding a properly isolated monetary policy shock, I will be considering whether most of the impulse response it causes is reasonable.

Throughout the paper I shall be identifying monetary policy shocks with the exogenous shocks to the preferences of the monetary authority. CEE (1998) provide an appealing interpretation of this type of shock, saying that shocks to the preferences of monetary authorities may be due to stochastic shifts in the relative weight given to inflation and unemployment. There are at least two reasons why this explanation is appealing. The first is that, in countries undergoing transformation, monetary authorities learn on the job, accumulating experience and frequently facing new problems and challenges. This could affect and change the preferences. Second is the institutional change - since 1998 monetary policy in Poland has been conducted by the 10-member Monetary Policy Council.

The estimation covers a relatively short period - 1995.01-2000.12 - whereas transformation in Poland started as early as 1990. Discussion of changes in monetary policy should have shed some light on why I have confined the sample to the last six years. Other arguments, to recall the most important ones, are as follows:

- The first two years of transformation were dominated by so-called correctional inflation (considerable changes in relative prices).
- In limiting estimation to the period 1995-2000, I skip the fixed exchange rate regime period and almost totally the preannounced crawling peg period. Since May 1995 the exchange rate regime has gradually been growing more flexible.

All variables, except for interest rates and the unemployment rate, are in the log levels. Monetary data are from the NBP, and all other data from the CSO. To choose the lag length, the Akaike criterion was used. It suggested three lags, but due to problems with residual autocorrelation in most cases four lags were used. Data were seasonally adjusted with X-11; seasonal dummies were used to eliminate the remaining traces of seasonality. A temporary huge credit growth in the last days of June 2000 connected with the privatisation of one of the biggest Polish enterprises was removed from the data.

2.3 Estimation results

The estimation results are shown in Figures 2.2 and 2.3. VAR satisfies the stability condition (no root lies outside the unit circle). Residuals were examined for autocorrelation with the LM test up to 12 lags. The test indicates that the residuals are not serially correlated. Diagnostic statistics are presented in the Appendix.

Figure 2.2 shows that a contractionary monetary policy shock leaves industrial output practically intact: it falls with a considerable delay and the reaction is not statistically significant. A striking effect - not predicted by the theory - is a temporary increase in output after a shock; only after six months does output start to decline, becoming negative after nine months. A similar result is obtained by Millard (1998) for the United Kingdom.

Retail sales[5] react in a more conventional way - they fall temporarily after the shock. An ad hoc explanation is that this may be the result of exports cushioning for some time a fall in domestic demand. The Johansen test for cointegration of industrial output and retail sales rejects H0 of no cointegration at the 1% significance level; the LR test indicates one cointegrating equation at the 5% significance level. A forecast of industrial output from the short-term dynamic model shows that in some periods (such as the second half of 1999 and 2000, Figure 2.4) industrial output predicted from the level of sales was much lower than actual output in spite of a serious monetary policy tightening. Since the analysed sample is relatively small, it may be the case that periods of depressed domestic demand simply coincided with higher foreign demand. But another plausible explanation could be that a corporate sector faced with depressed domestic demand switched to exports.

A strong and relatively quick response from retail sales to monetary shocks at first glance stands in stark contrast to the common view that in Poland private consumption tends to be rigid. The simplest explanation is that the retail sales comprise not only private consumption but also sales of non-consumption goods, such as building materials and goods for agricultural production like seeds, fertilisers, agricultural machinery and equipment to name only a few. Investment goods are likely to react more readily to interest rate shocks, making the variable less stubborn than consumption towards the monetary policy shocks. Another reason is that in the aftermath of an interest rate shock consumers may switch to smaller retail outlets (bazaars) not fully covered by the official statistics.

There is a temporary price puzzle in Figure 2.2. It tends to become smaller but does not disappear if prices of other assets - such as the nominal exchange rate - are included in the VAR. The effect is well described in the literature and seems to be a common result in empirical works using the VAR method (Walsh (1998)). In Poland the maximal effect of a monetary policy shock on the price level appears 20 months after the shock. In Figure 2.2 the impulse response function of real wages in the corporate sector to a contractionary monetary policy shock is also presented. Real wages seem to increase temporarily after a shock. Millard (1998) reports the same result for the United Kingdom. Then they start to fall, but the overall reaction is statistically insignificant and short-lived. This result may suggest that wages are more rigid than prices, probably due to widespread explicit and implicit indexation mechanisms, the power of trade unions, and competition from imports in the goods market. The increase in industrial output that occurs after a shock can be another reason for the real wage increase. To check this result, a quarterly VAR was built, covering the period 1992-99 with the log of the consumer price index, logged wages and the index of labour productivity (the log of). The output gap, proxied by the difference between current and HP-filtered GDP, entered the VAR exogenously. Impulse response functions and variance decomposition showed that wages tended to be more responsive to prices than prices to wages.

The unemployment rate and employment were the last variables from the real sector of the economy examined for their reaction to the contractionary monetary shock. The responses are not shown - both of them have a nonsensical shape (the unemployment rate decreases while employment increases after a brief and short-lived decline). It is not a totally unexpected result, bearing in mind the role of structural adjustment and administrative regulations in the labour market.

As presented in Figure 2.3, a contractionary interest rate shock affects narrow money (M1) and broad money (M2) as well as three-month and 12-month T-bill rates in a conventional way. Both M1 and M2 fall after a shock, but the fall of M2 is more prolonged. The short-term rate rises more than the long-term one.

The results of the VAR with the monetary policy shock identified in the spirit of CEE (1994, 1998) are in most cases reasonable even though monetary policy underwent several regime changes over the

[5] Data on retail sales cover the sale of consumer and non-consumer goods from retail sales outlets, catering entities and other sales outlets (ie warehouses, storehouses) in quantities indicating purchases to meet the needs of individual customers.

period examined. An interesting feature of Polish monetary transmission is that it seems to be evolving towards a mechanism with an increasing role for the interest rate. Moreover, there are signs that the transmission resembles more a textbook one than in the previous studies of monetary transmission. On the other hand, the labour market is the exception, but due to the reasons presented above it will probably never behave in a way the classical model predicts. It is also unclear if the labour market will come to resemble the Layard, Nickell and Jackman vision of the market. Therefore the labour market and its impact on inflation will need particularly careful analysis. Persistence in this market and the cost of disinflation in terms of unemployment seem to be a key issue. A brief assessment of unemployment persistence in Poland using the Cochrane test[6] shows that shocks to unemployment have a very long-lasting effect, suggesting the existence of hysteresis.

2.4 References

Bernanke, B and I Mihov (1998): "Measuring monetary policy", Quarterly Journal of Economics, vol 113.

Boguszewski, P and A Kocięcki (2000): "Wpływ polityki pieniężnej na zachowania przedsiębiorstw w świetle danych GUS i badań ankietowych - wybrane zagadnienia", Bank i Kredyt, nr 7-8.

Christiano, L J, M Eichenbaum and Ch L Evans (1994): "The effects of monetary policy shocks: some evidence from the flow of funds", *NBER Working Paper*, no 4699.

——— (1998): "Monetary policy shocks: what have we learned and to what end?", *NBER Working Paper*, no 6400.

Christoffersen, P F and R F Wescott (1999): "Is Poland ready for inflation targeting?", *IMF Working Paper*, no 41.

Cochrane, J H (1998): "How big is the random walk in GNP?", Journal of Political Economy, vol 96, no 5.

Kokoszczynski, R (ed) (1999): "Mechanizm transmisji impulsow polityki pieniężnej: przeglad glownych teorii oraz specyfika transmisji w Polsce", Materialy i Studia NBP, no 91.

Kokoszczynski, R and Stopyra, J (1996): "Dylematy wyboru celow posrednich i operacyjnych w polityce pieniężnej Narodowego Banku Polskiego", Bank i Kredyt, no 6.

Lyziak, T (2001): "Monetary transmission mechanism in Poland, theoretical concepts vs evidence", Materiały i Studia NBP, no 19.

Millard, S P (1998): "An examination of the monetary transmission mechanism in the United Kingdom", Bank of England, mimeo.

Millard, S, A Scott and M Sensier (1999): "Business cycles and the labour market, can theory fit the facts?", *Bank of England Working Paper*, no 93.

Rybinski, K (2000): "Wpływ polityki pieniężnej na proces dezinflacji w Polsce", Bank i Kredyt, no 7-8

Wróbel, E (1999): Mechanizm transmisji w Polsce w latach 1992-1999, materiały na konferencję ING Barings.

[6] Cochrane (1998) measures a random walk component in a series (originally GNP) from the variance of its long differences, in particular $(kVar(\Delta xt)/(\Delta kxk))$. I replicated an exercise with the unemployment rate from (Millard et al (1999)). As they point out, a simple explanation of the test is that if a variable is a random walk (ie the best forecast of the variable next period is equal to its current value), then the further ahead in time one goes, the more uncertainty there is about the variable. The variance of two-period changes in the variable should be twice the variance of one-period changes, the variance of three-period changes in the variable should be three times the variance of one period, etc. For Poland I used a small sample corrected version of the Cochrane test. If the test has a value near to zero, then the permanent shocks are of less importance. If the value is near one, then permanent shocks are important. If it is above one, the effect of shocks is amplified over time. The authors report that for the United Kingdom the test statistic is near five. The test statistic calculated for Poland on the basis of the sample 1992-2000 is even higher - between five and six for seasonally unadjusted (quarterly) data and between eight and nine for seasonally adjusted (quarterly) data.

Figure 2.1

Credit to private individuals and corporate sector in real terms (y/y)

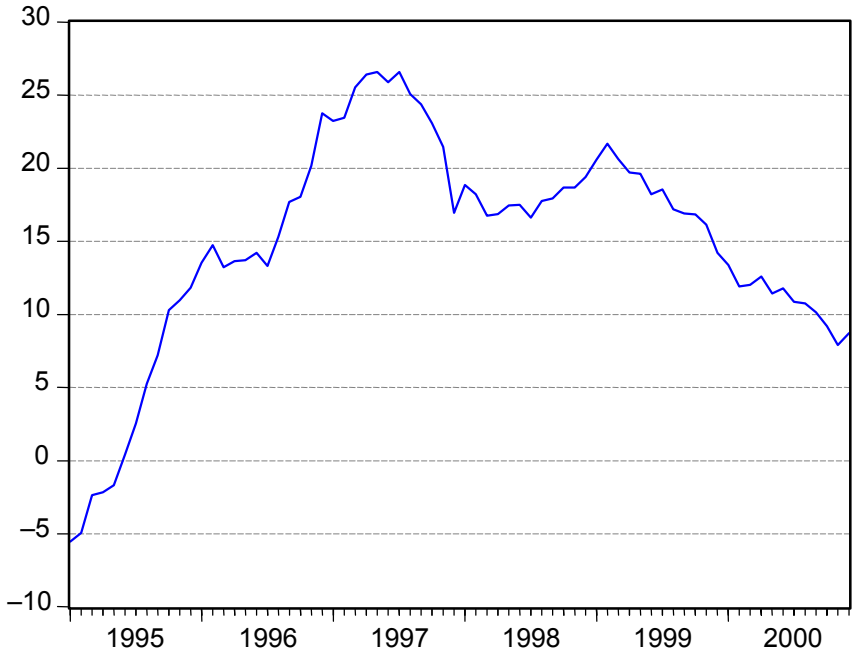


Figure 2.2

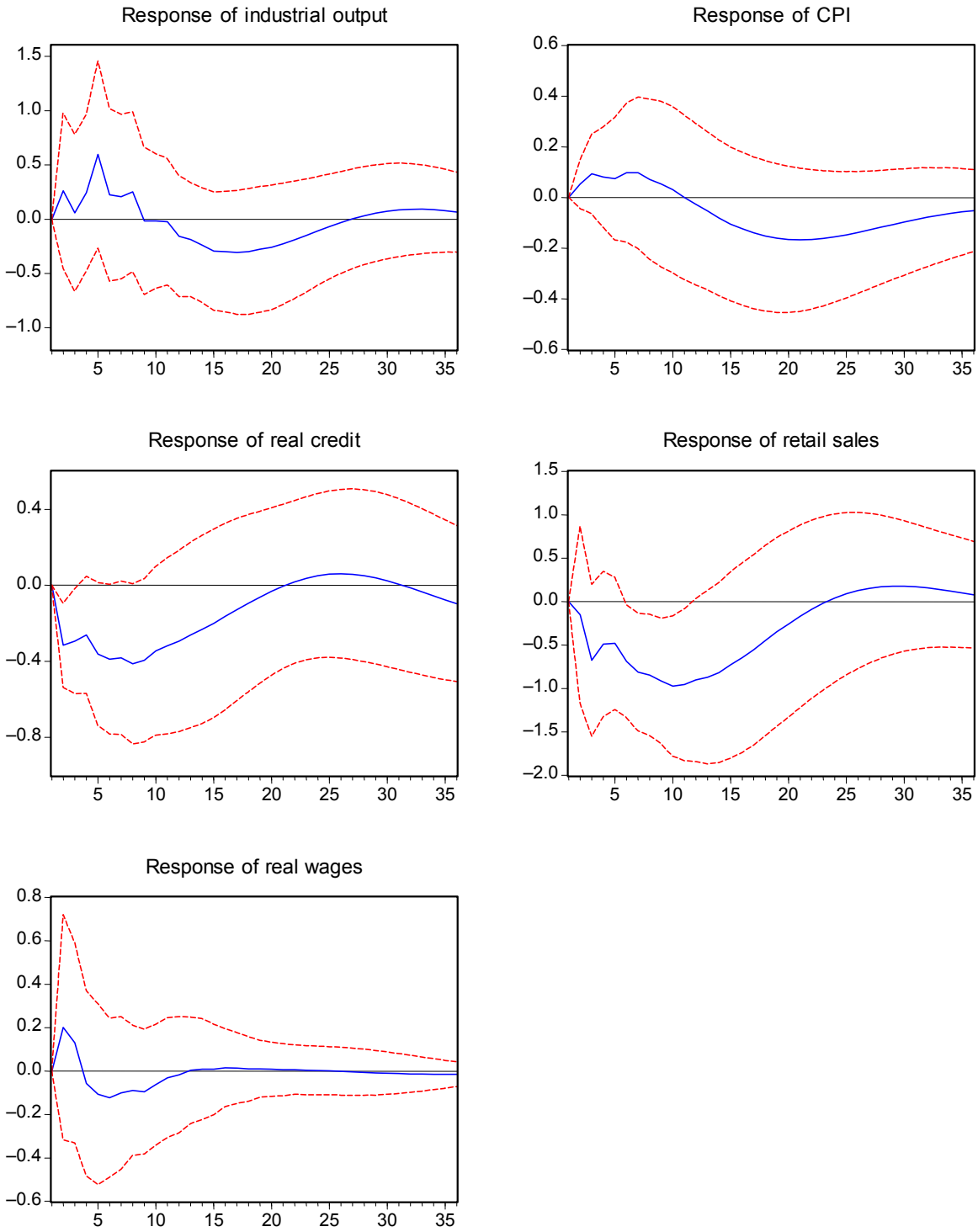

Response of industrial output
1.5
1.0
0.5
0.0
–0.5
–1.0
5
10
15
20
25
30
35
Response of CPI
0.6
0.4
0.2
0.0
–0.2
–0.4
–0.6
5
10
15
20
25
30
35
Response of real credit
0.4
0.0
–0.4
–0.8
5
10
15
20
25
30
35
Response of retail sales
1.5
1.0
0.5
0.0
–0.5
–1.0
–1.5
–2.0
5
10
15
20
25
30
35
Response of real wages
0.8
0.6
0.4
0.2
0.0
–0.2
–0.4
–0.6
5
10
15
20
25
30
35

Figure 2.3

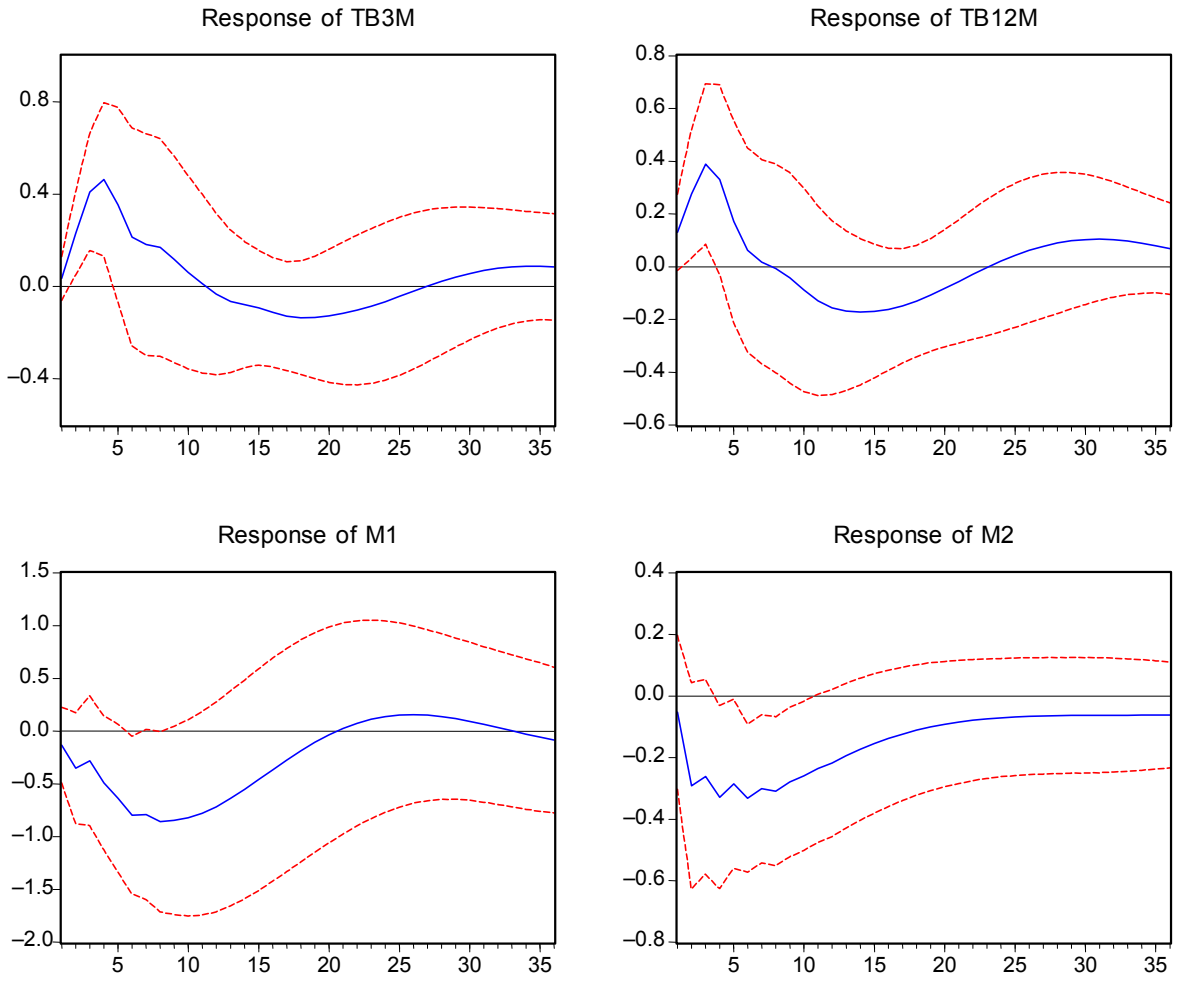
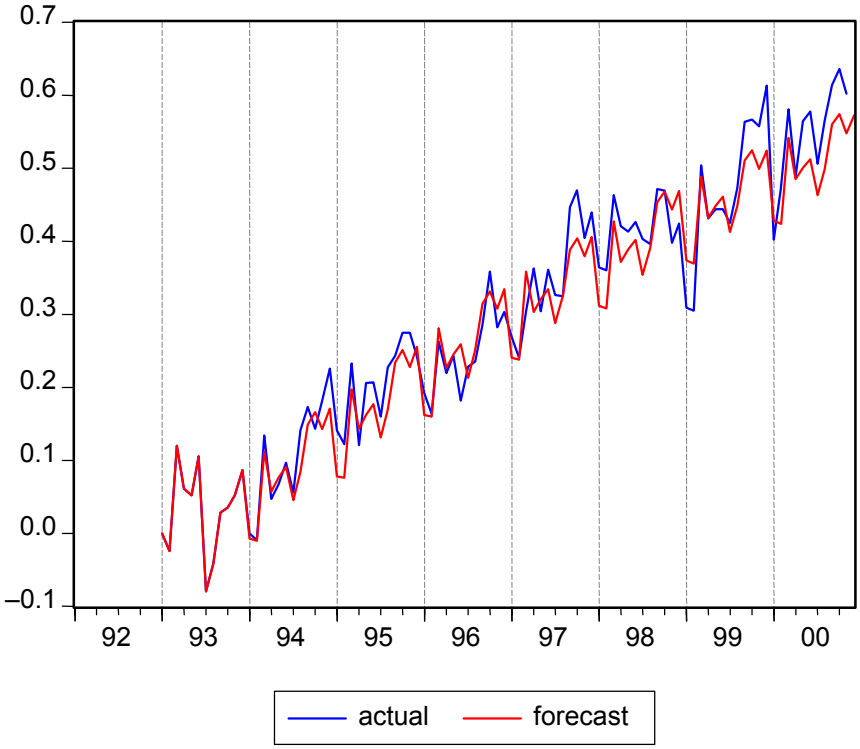

Response of TB3M
0.8
0.4
0.0
–0.4
5
10
15
20
25
30
35
Response of TB12M
0.8
0.6
0.4
0.2
0.0
–0.2
–0.4
–0.6
5
10
15
20
25
30
35
Response of M1
1.5
1.0
0.5
0.0
–0.5
–1.0
–1.5
–2.0
5
10
15
20
25
30
35
Response of M2
0.4
0.2
0.0
–0.2
–0.4
–0.6
–0.8
5
10
15
20
25
30
35

Figure 2.4

Actual and forecast industrial output



2.5 Appendix

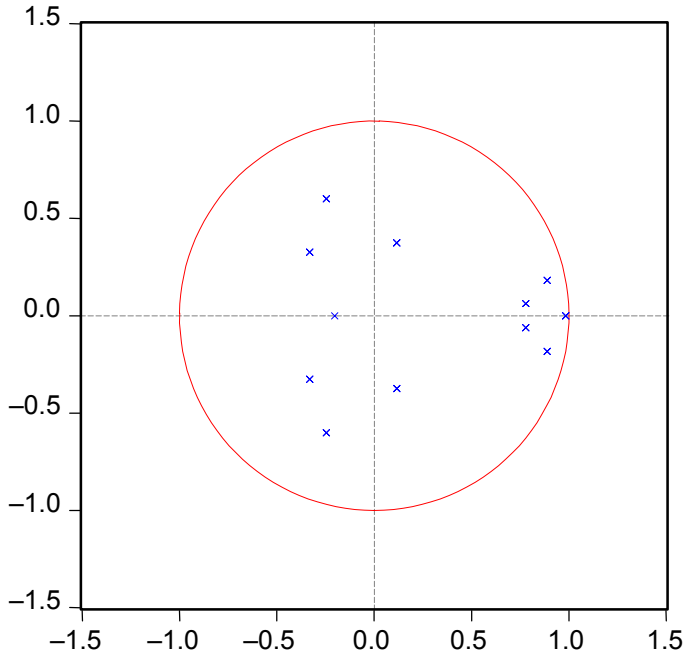
VAR residual serial correlation LM tests
H_0: no serial correlation at lag order h
Sample: 1995:01-2000: 12
Observations included: 67

Lags	LM-Stat	Prob
1	8.356672	0.4986
2	11.68689	0.2315
3	4.537902	0.8726
4	6.602488	0.6784
5	14.26531	0.1132
6	9.584925	0.3851
7	7.112851	0.6254
8	8.107002	0.5234
9	5.171880	0.8191
10	5.808371	0.7589
11	7.358047	0.5999
12	15.03845	0.0899

Note: Probs from chi-square with 9 df.

Figure 2.5

Inverse roots of AR characteristic polynomial



3. Structural modelling of inflation - some selected ideas concerning MSMI (by B Kłos)

3.1 Main assumptions of MSMI-1[7]

Ongoing structural changes in agents' behavioural patterns and a shortage of data are the main obstacles to the structural modelling of a transition economy. Econometric textbooks suggest several more or less sophisticated methods to model regime changes and structural breaks (for example, random or deterministic switching regression models, time-varying parameter or random parameter models) but the usefulness of these methods seems to be limited in the case of transition economies. All these methods require large samples in order to estimate parameters consistently. Besides, any estimates depict outdated (past) structure, so that a model is not very useful when policymakers consider changing the policy mix or analysing economic prospects. Therefore our structural model of inflation attempts to describe the future state of the economy. It is assumed that the transition process forces economic agents to learn and use market adjustment methods. The progress made with system transformation should make behavioural patterns more similar to those observed in developed market economies. The results of empirical investigation based on VAR methodology seem to support that point of view (see for example the previous section). The idea of modelling the future state of a transition economy rather than its current (interim) structure is accepted by several model builders but it usually has a hidden assumption.[8] This assumption simplifies the specification of equations because a stylised or even textbook description of the market economy may be used as theoretical background to the model. In addition, there are many empirical macromodels of small open market economies, and hence many good patterns to follow.

"Forward-looking" specification requires non-standard techniques to evaluate the structural parameters of the model since either statistical data do not contain information on parameters or the information is present in the sample but hidden by transition-specific phenomena. The idea of a calibration method applied to evaluate the parameters of the first version of the model (MSMI-1) is presented in the third part of this section.

Our understanding of the inflation process in a market economy suggests that sources of inflation cannot be reduced to just one root - say, exogenous money supply. There are several mechanisms responsible for inflation and the model of inflation should capture at least some of them.[9] MSMI-1 attempts to include the following inflation-generating mechanisms:

- The result of imperfect competition and wage bargaining in the labour market - a wage-price spiral.
- The result of tensions in product and labour markets when aggregate supply and aggregate demand are equalised. This is usually approximated by the concept of the output gap.
- The impact of expectations on inflation.
- The role of external supply and demand shocks transmitted into the economy directly and indirectly (by shifts in the endogenous exchange rate).

These mechanisms could influence inflation in the short and the medium run. It is assumed that the price level is determined by money supply in the long run. No attempt is made, however, to capture structural reasons for inflation specific to the transition process in Poland. The transition-specific events may be important but they are temporary. The mechanisms are interdependent and in order to take account of all these inflation-generating mechanisms, the model should describe the supply as well as the demand side of the economy. For this reason our small structural model of inflation is in

---

[7] This section shows the main characteristics of the first version of structural model inflation in Poland, MSMI-1 (see Kłos (2000) for more details). The model was put into practice in spring 2000. In late 2000 and early 2001 new versions of the model were developed. The latest version being used is MSMI-3.

[8] See, for example, Gionelly and Rovelly (1999) and Charemza (1996).

[9] See Brädsen et al (1999), Layard et al (1991), and Carlin and Soskice (1990).

fact a small structural model of the economy as a whole (a macromodel). The attempt to see inflation in the wider context of other macroeconomic features is also considered important by the author.

3.2 Stylised macroeconomic equilibrium

The macroeconomic context of the inflation process requires an answer to the question of how the different inflation-generating mechanisms are linked. It is therefore assumed that there are three markets in the economy: product market, labour market, and money and foreign assets market. These markets are interdependent but different, taking into account the type of competition and speed of adjustment. Adjustment is very fast in the money market because of free competition in this sector of the economy. Imperfect competition and nominal rigidities are responsible for the sluggish absorption of shocks in the labour market. In any case, unabsorbed disequilibrium spills over into other markets. Therefore the inflation process may be seen as a result of disequilibrium. This occurs in the product market.

Chart 3.1 presents a stylised and simplified picture of (static) short- and medium-run general equilibrium in MSMI-1. This version of the model assumes exogeneity of the short-term interest rate and endogeneity of the exchange rate; therefore the exchange rate is acting as a money market clearing price (see the lower part of the diagram). Certainly, inflation (a result of spillover effects) and (exogenous) interest rate policy may influence the way shocks are absorbed by the money and foreign assets market. Money market conditions impact on aggregate demand. Exports, imports and household incomes are not shown in the chart but exist in the model and influence aggregate demand and the equilibrium point.

The labour market and product market seem to be fairly standard (see the upper part of the diagram). Labour market conditions define the aggregate supply curve. Producers set their prices using a mark-up formula, and the bargained real wage (or expected real wage) rises with the level of employment. In those circumstances, the labour market exhibits features similar to those described by Layard et al (1991). The chart shows static equilibrium, so acceleration of inflation cannot be noticed.

3.3 Formal structure of MSMI-1

The formal structure of MSMI-1 is similar to many contemporary macroeconometric models, which mimic the short-run dynamics of variables as well as depict (local) long-run equilibrium (steady state) using a direct error correction mechanism (DECM).[10] The use of global long-run equilibrium equations and indirect error correction mechanisms (IECM) is less common.[11]

A long-run static equation often does not define causality in the economic sense. It is up to the researcher to assign the endogeneity (exogeneity) status of variables included in the equation.[12] It is also up to the researcher to investigate or to assume the direction of causality. If a static equation contains just one endogenous variable, an error correction mechanism specific to that particular endogenous variable may be built. Hence, there are local long-run equilibrium and direct error correction mechanisms. The static equation may, however, include two or more endogenous variables. At the point of long-run equilibrium the causality could be undetermined. In that case, the long-run relation defines global equilibrium and one has an opportunity to build direct (DECM) as well as indirect error correction mechanisms (IECM). The idea of the DECM and IECM is shown by the following example:

$$y_t = \alpha_0 + \alpha_1 x_{t1} + \alpha_2 x_{t2} + \varepsilon_t \qquad \text{(Static long-run equation)}$$

$$ECM_{t-j} = y_{t-j} - (\alpha_0 + \alpha_1 x_{t-j1} + \alpha_2 x_{t-j2})$$

[10] See, for example, Whitley (1994) and Chan et al (1995).

[11] Of course, the idea of global, direct and indirect error correction mechanisms is taken from the Johansen procedure. See also Charemza (1996), Garratt et al (1998), and Kłos (1999).

[12] In the framework of the Johansen procedure, the weak exogeneity of the variables may be tested. Weak exogeneity is a statistical (econometric) term, however. In this paper a specific meaning of this term is used, namely the endogenous and exogenous status of variables implies direction of causality (in the general, not statistical, sense).

$$\Delta y_t = \beta_1 \Delta x_{t1} + \beta_1 \Delta x_{t2} - \delta_d \, ECM_{t-j} + ... + u_t \qquad j = 1,... \qquad \text{(DECM)}$$

$$\Delta x_{t1} = \beta_1 \Delta x_{t2} + \beta_2 \Delta y_t + \delta_i \, ECM_{t-j} + ... + u_t \qquad j = 1,... \qquad \text{(IECM)}$$

The ECM variable, by definition, is a measure of disequilibrium, so that variable may be used as an indicator of spillover effects. The formal scheme of the mechanism, called spillover disequilibrium mechanism (SDM), is as follows:

$$\Delta w_{t1} = \beta_1 \Delta z_{t1} + \beta_2 \Delta z_{t2} \pm \delta \, ECM_{t-j} + ... + u_t \qquad j = 0,... \qquad \text{(SDM)}$$

Direct and indirect error correction mechanisms stabilise the model, but the SDM indicates a need for adjustment, so it usually pushes the left-hand variable out of the long-run equilibrium point. Applying the SDM requires some caution. The SDM usually does not define the proper steady state solution of the left-hand variable, so the equation should contain some additional factors or have a feature maintaining the desired long-run solution.

The MSMI-1 model is composed of 12 stochastic equations; two of them are static (long-run). The full list comprises:

- Static (long-run) equations: production function and money-price relationship.
- Dynamic (short-run) equations: internal demand, exports, imports, demand for money, import prices, consumer prices, producer prices, wages, employment, exchange rate.

There are 15 identities and deterministic equations. These equations define expectations (consumer prices and nominal wages), the index of fixed assets, some specific quantity indices and GDP. Expectations concern consumer prices, nominal wages and the złoty/dollar exchange rate. None of these is forward-looking.

The list of exogenous variables comprises: the internal short-run interest rate, effective tax rates (indirect taxes, personal income taxes, corporate income taxes), nominal government expenditures, the short-run external interest rate, world prices, world production, world oil prices, and the euro/dollar exchange rate. The model does not impose any balancing constraints except GDP identity. There is no state budget balance or balance of payments account, nor is public debt explained.

3.4 The technique of parameter calibration

The calibration procedure is based on an idea of M-estimators. Many standard estimators are examples of unconditional optimisation. For example, the ordinary least square technique uses a sum of squared residuals as a loss function and that function is minimised to obtain estimates of parameters. The method applied to calibrate parameters of MSMI-1 is also a case of seeking minima. The loss function is taken from the generalised method of moment (GMM), namely I use a form of the GMM loss function suitable for M-equation non-linear systems:[13]

$$H(a,b) = \sum_{i=1}^{M} \sum_{j=1}^{M} \sigma_{ij} \left(y_i - f_i\left(a_i(L)Y, b_i(L)X\right)\right)' Z \, A \, Z' \left(y_j - f_j\left(a_j(L)Y, b_j(L)X\right)\right)$$

where:

σ_{ij} = a component of the inverted error term covariance matrix,

Z = a matrix of instrumental variables,

A = a positive defined matrix,

y_i, Y = a vector (matrix) of endogenous variables,

X = a matrix of exogenous variables,

a_i, b_i = vectors of parameters to be calibrated,

[13] See Davidson and McKinnon (1993).

$f_i(.,.)$ = a structural equation of the model.

The standard GMM method minimises the loss function *H(.,.)* unconditionally. The calibration method is the case of conditional optimisation. The parameter space is restricted and the restrictions supplement the statistical sample. This is a standard method of including non-sample information in the estimation process. However, a typical estimation procedure uses a very limited number of restrictions (but so-called null restrictions). In the case under consideration, a single solution (in the formal sense) to the unconstrained problem may not exist since the sample is very small. Therefore restrictions are also necessary to identify parameters.

The constraints applied in this exercise define the lower and upper limits of each parameter (but constants and dummies). The limits are taken from a comparison of estimated models of developed market economies (France, Finland, the United Kingdom, etc). Some of the constraints are the results of multiplier analysis. Certainly, there are some constraints which cannot be justified on theoretical grounds, but just express the author's point of view.

In practice, the calibration procedure is more sophisticated and it is composed of several steps. The model contains some long-run (static) equations (used to define the global ECM) and some deterministic equations. In order to calibrate the system as a whole, parameters of static and deterministic equations of the model as well as the matrix of σ_{ij} should be given. Therefore, one calibrates parameters of deterministic equations and estimates static equations in the first step. In the second step, each behavioural (dynamic) equation is calibrated separately to compute residuals. These residuals are used to evaluate the covariance matrix [σ_{ij}]. The calibration of the system as a whole is carried out in the final step.

3.5 The results of calibration

In the case under review the parameters of the model were calibrated over the quarterly sample 1994:3-1999:4 (2000:1). The equations fit the sample data fairly well and the model was able to replicate past events of the Polish economy quite well too.[14] Charts 3.2 to 3.4 show the results of some simulation exercises performed to analyse dynamic features of MSMI-1. In all cases an exogenous variable was changed permanently and the results are measured as a percentage difference from the baseline value.

The first chart (3.2) shows the impact of changes in effective tax rates on inflation and GDP. In each case the effective rate of taxes rises by one percentage point. The pattern of time paths suggests that the rise in the indirect tax rate (*txo*) and that in the corporate income tax rate (*txp*) are the cases of supply shocks since the shift in rates pushes GDP and prices in opposite directions. The increase in the personal income tax rate (*txd*) seems to be a demand shock in the MSMI-1 model. The rise in personal taxes reduces disposable income, so aggregated demand declines as well as inflation. The magnitudes of the effects are interesting. The charts prove that indirect taxes have the strongest impact on inflation and GDP but GDP is more sensitive to change in personal income tax than to change in corporate income tax.

The second chart (3.3) shows the results of a 1% rise in nominal government expenditures. This exercise is not very informative since, in the period under consideration, the real value of expenditure changes as well the ratio of expenditures to GDP. Nevertheless, some pieces of information may be recovered. There is no budget constraint in the model, so it may be assumed that the increase in government expenditures should increase GDP permanently and the inflation cost may not be important. This is not the case due to supply constraints. Moreover, the maximum value of the government spending (interim) multiplier is around 1.08, hence the balance of costs (in terms of GDP) may be negative.

The last exercise depicts the influence of the nominal short-term interest rate on GDP and inflation. The permanent rise in the short-run interest rate (by one percentage point) suppresses inflation, but this effect is not permanent. The rise in the interest rate suppresses GDP, but this is not an efficient method to compress internal demand as well. After six to eight quarters, due to substitution effects,

[14] The employment equation is an exception.

cheaper imported goods replace internal production. Clearly, this is the result of a rise in real government expenditures. Nominal expenditures are kept at the level of base simulation but the drop in inflation raises real expenditures. The rise in internal demand increases the general price level in subsequent quarters. This is shown in Chart 3.4.

The calibration technique gives values of structural parameters but standard errors of estimates are not available. Most of them cannot be computed because they do not exist. This is a major drawback of many calibration procedures, so the only way to validate the model is perhaps to analyse goodness-of-fit measures and the responses of the model to standard shocks. Reasonable dynamic multipliers and data congruency of the variables do not prove the relevance of the ideas applied in a model or of the model as a whole. Moreover, it may be suggested that data congruency is a disadvantage of the model, since it proves the "backward-looking" specification of the model. Nevertheless, provided that the economic background of the model is accepted, the model may be a useful tool for medium-term scenario analyses. Calibrated structural models may not paint a precise picture of the real economy. These models are also not very precise forecasting tools as far as short-term predictions are concerned. Nonetheless, the calibrated structural macromodels (including MSMI-1) can be used to build medium-term scenarios and detect the possible effects of external and internal shocks. They can also be used to design a slightly better macroeconomic policy mix.

3.6 Further development of the structural models

A better understanding of transition-specific events, a slightly more informative sample,[15] and wealth of experience gained since the first version (MSMI-1) was put into practice allowed the author to change the modelling methodology and the specification of the model. Both are more standard now. Newer versions of the model (MSMI-2 and MSMI-3) still attempt to describe the future rather than the current (interim) behavioural patterns of agents. However, using a limited information version of the GMM technique, it is now possible to estimate the short-run dynamics of the equations (but this is not very sophisticated). The long-run part, error correction mechanisms, is still assumed or calibrated.[16] There are some changes in the macroeconomic background of the model as well. The most important one concerns the long-run roots of inflation. MSMI-3 assumes a very limited long-run impact of money supply on inflation but links inflation to the condition of external markets through a version of the PPP paradigm. MSMI-3 allows an interest rate rule to be chosen, so the interest rate and inflation define the money market clearing mechanism. The role of the exchange rate is now very standard. Newer versions of the model introduce the forward-looking behaviour of the money and foreign assets market as well.

The MSMI parameters are re-estimated at least every quarter. The volatility of estimates suggests, however, that the economy (the adjustment method applied by agents) is still far from mature. Nevertheless, if allowance is made for the disadvantages of this model, and the limitations of models in general, it is an indispensable tool for scenario and policy analyses. Despite a lack of data and permanent structural shifts, which constrain the credibility of our models, structural models are becoming an important component of the toolkit of decision-makers.

---

[15] The Polish economy has been exposed to several supply and demand shocks during the last two years. The impact of the shocks on the economy has been rather destructive but, paradoxically, it has provided an additional opportunity to observe how economic agents attempt to absorb shocks and adjust. It made the sample more informative. On the other hand, some institutional changes were introduced in 1999 and 2000 and, for this reason, many macroeconomic variables are now measured less precisely.

[16] There are some exceptions. For example, long-run import prices are estimated in an error correction equation and long-run demand is estimated using the Johansen procedure.

3.7 References

Brådsen G, E S Jansen and R Nymonen (1999): "Econometric inflation targeting", Arbeidsnotat no 1999/5, Norges Bank, Oslo, June 22.

Brillet J-L (1997): "Analysing a small French ECM model", INSEE, Document de travail, G9709.

Britton E and J D Whitley (1997): "Comparing the monetary transmission mechanism in France, Germany and the United Kingdom: some issues and results", Bank of England Quarterly Bulletin, May.

Carlin W and D Soskice (1990): "Macroeconomics and the wage bargain, a modern approach to employment, inflation, and the exchange rate", OUP.

Chan A, D Savage and R Whittaker (1995): "The new treasury model", HM Treasury, London, December.

Charemza W W (1996): "Project PL 9214-21, programme for rebuilding tools for quantitative economic analyses for the ministry of finance, final report", Department of Economics, University of Leicester, December 1996 (unpublished).

Davidson R and J McKinnon (1993): "Estimation and inference in econometrics", OUP, Oxford.

Garratt A, K Lee, M H Pesaran and Y Shin (1998): "A long-run structural macroeconometric model of the UK", June-August, 1998 (unpublished).

Gionelly R and R Rovelly (1999): "Monetary policy and the convergence to low inflation: a small macromodel for Poland and Hungary 1991-1998", Università di Bologna, Phare-ACE Programme 1996, Project No P96-6114-R: Central Banks, Financial Structure and Monetary Policy in the Economies in Transition in Central and Eastern Europe (unpublished).

Giorno C, P Richardson, D Rosenveare and P Noord (1995): "Estimating potential output, output gaps, and structural budget balances", OECD ECO Working Papers no 152.

Hall S G and S G B Henry (1988): "Macroeconomic modelling", North-Holland, Amsterdam.

Kłos B (1999): MF-2.15 Kwartalny model gospodarki polskiej. Charakterystyka teoretycznych podstaw specyfikacji równań, Metody oceny parametrów, Lista równań, Departament Polityki Finansowej i Analiz, Ministerstwo Finansów, Grudzień 1998 - Styczeń 1999 (unpublished).

——— (2000): Empiryczny model inflacji, Bank i Kredyt, September.

Layard R, D Nickell and R Jackman (1991): Unemployment, Macroeconomic Performance and the Labour Market, OUP, Oxford.

Turner D, P Richardson and S Rauffet (1996): "Modelling the supply side of the seven major OECD economies", OECD ECO Working Papers no 167.

Welfe A and W Welfe (1999): "Mechanizmy ekonomiczne okresu transformacji (analiza na podstawie ekonometrycznego modelu gospodarki narodowej Polski WK98)", Ekonomista, nr 2.

Whitley J D (1994): "A course in macroeconomic modelling and forecasting", Harvester, Aldershot.

"Economic models in the Bank of England", Bank of England, London 1999.

"The transmission mechanism of monetary policy", The Monetary Policy Committee, Bank of England, 1999.

User manuals of NiGEM and NiDEM models worked out by NIESR, London 1999-2000.

Chart 3.1
Short- and medium-run equilibrium

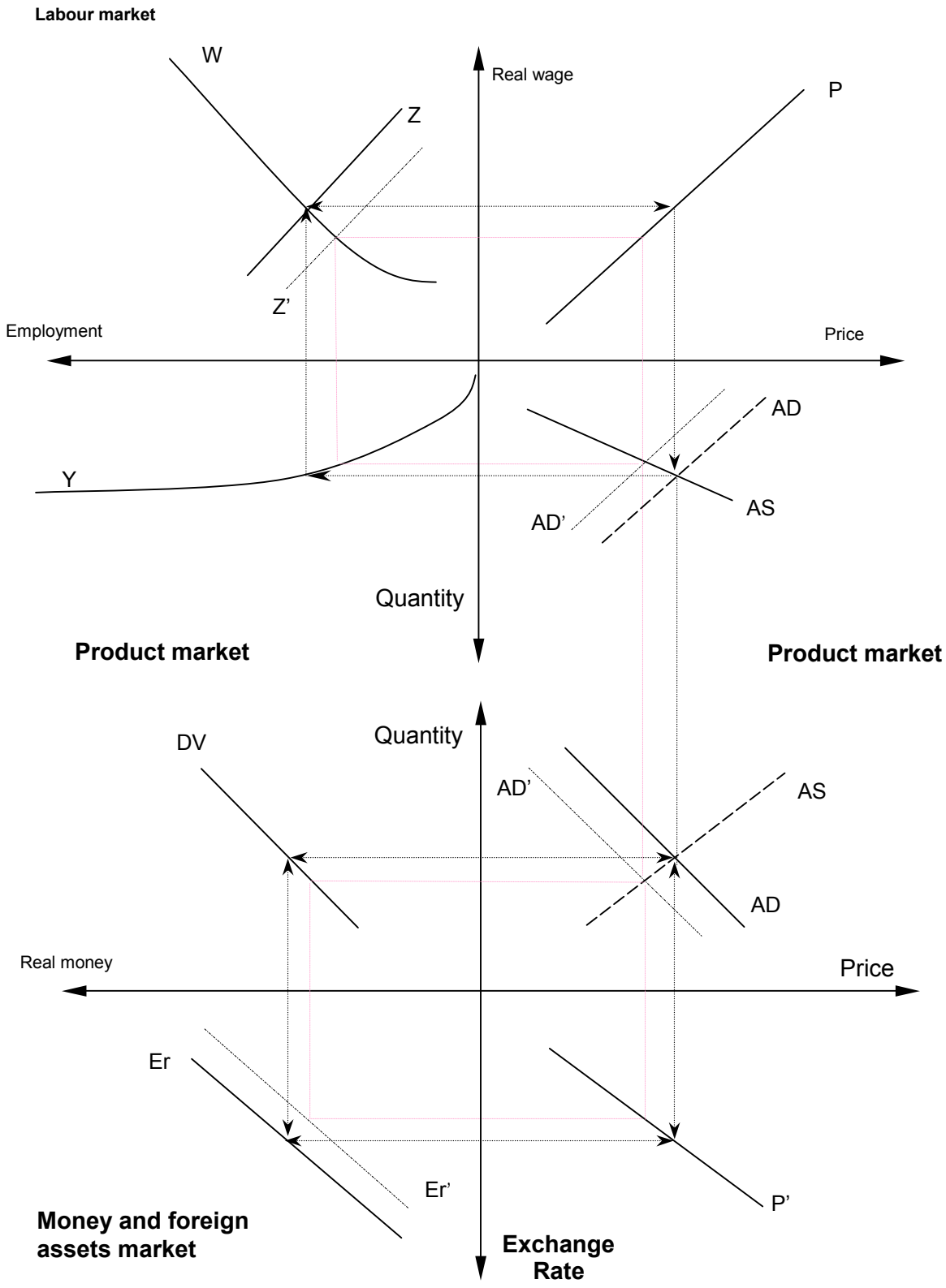


Chart 3.2
Change in inflation (left-hand panel) and GDP (right-hand panel) due to changes in tax rates

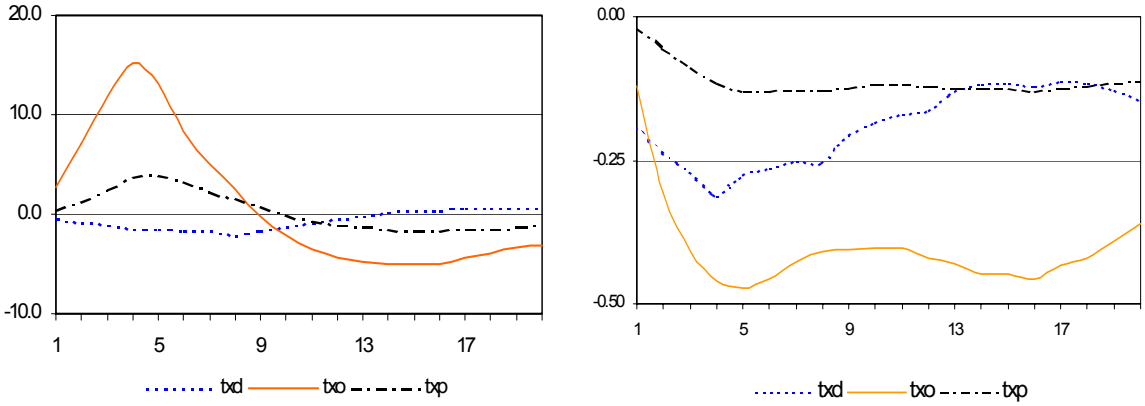


Chart 3.3
Change in inflation and GDP due to rise in government expenditures shock

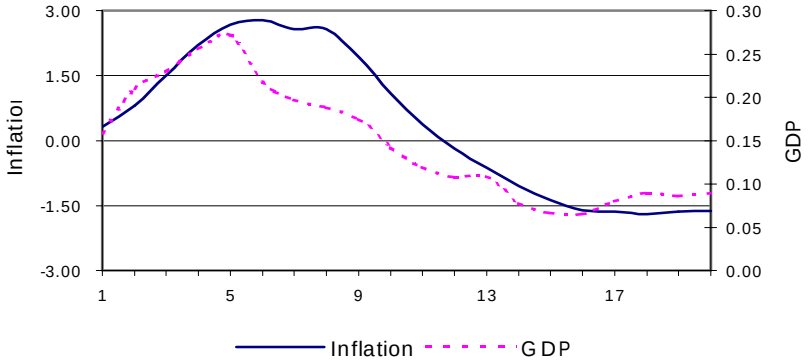
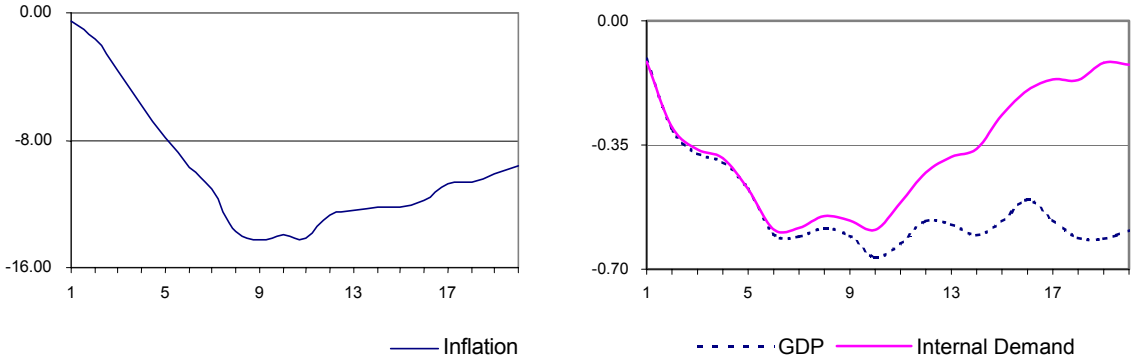


Chart 3.4
Changes in inflation and GDP due to rise in short-term interest rate



4. Final remarks

The important branch of research carried out at the National Bank of Poland aimed at supporting monetary policy attempts to study the current state of monetary transmission. This line of research monitors the evolution of the immediate and delayed responses of the economy to standard shocks. The results of these investigations suggest that the Polish economy is slowly resembling a typical market economy. Obviously, there are some country-specific features and some reactions to standard

shocks are also country-specific. The VAR analyses provide us with a kind of benchmarking, even though the author finds some of the results not fully reliable, in particular the reaction function of industrial production and unemployment rate. However, it is quite a good starting point to develop the second line of research, namely structural modelling. Our structural macromodels still, primarily, exhibit the authors' view of the economy. It is not a "true" picture of the economy since the sample is still too small and the structure investigated still too volatile. However, having such benchmarking at least makes it possible to evaluate the dynamic multipliers of structural models and check the validity of calibrated (or conditionally estimated) structural models of the economy.