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Effects of Monetary Policy on Output and Prices

by

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Martha A. Starr**

Abstract

In large industrial economies, changes in monetary policy affect real economic activity in the short-run, but in the long run affect only prices. In transition economies, little is known about whether monetary policy has such short-run effects: if so, maintaining independent policy preserves options of stimulating the economy when it is sluggish or cooling it down if it overheats -- but if not, other sorts of policy régimes that entail strong commitment to price stability may be more attractive, such as a monetary union, a currency board, or 'dollarization'. This paper uses time-series methods to examine real effects of monetary policy in Russia, Ukraine, Belarus, and Kazakhstan. There is only mixed evidence that 'money matters' in these countries, although its potential seems greater in Russia than elsewhere. This suggests a limited scope for activist use of monetary policy, at least in the near-term.

Key words: Post-Soviet economies, monetary policy, growth, price stability

JEL classification: P24, E5

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1. Introduction

There has been much discussion in recent years about potential benefits of relinquishing independent monetary policy in favor of alternative arrangements -- such as monetary unions, currency boards, or 'dollarization' -- that may favor international economic integration and commitment to price stability. A key advantage of independent policy is that the monetary authority can use monetary-policy instruments to offset adverse shocks to output, shifting policy to an expansionary stance when output is below potential or to a tighter one when it is above. For example, a key policy-controlled interest rate can be lowered to reduce commercial interest rates and stimulate aggregate spending. The liquidity of the banking system can be increased, potentially raising bank lending and again stimulating spending. Or a monetary expansion that lowers the real exchange-rate may improve the competitiveness of the country's products in domestic and world markets, boosting demand for national output.

The extent to which a given country can use monetary policy to affect output in the short-run is an open question. Findings for the U.S. are relatively well-accepted: a decline in the key interest rate controlled by the Federal Reserve tends to boost output over the next 2-3 years, but thereafter the effect dissipates, and the long-run effect is confined to prices (Christiano, Eichenbaum, and Evans 1999). Debates remain about precisely what factor or combination of factors account for this real effect, with lead candidates being sticky prices, sticky wages, and imperfect competition.[1] But this evidence of real effects is strongly consistent with the idea that monetary policy can be used to counter aggregate shocks.

In other types of economies, the potential for using policy in this way is less clear. In countries that have experienced high inflation or in which labor markets are chronically slack, prices and wages are unlikely to be particularly sticky, in which case monetary-policy changes may pass quickly through to prices, with little real effect. Where monetary policy has not been 'credible', the public's understanding of the government's incentives to enact 'monetary surprises' generally undermines the government's ability to use such surprises to boost output, and instead raises average inflation (Barro and Gordon 1983, Kydland and Prescott 1977). Additionally, the globalization of financial markets may erode the ability of small, open economies to move interest rates independently of world markets, again tending to undercut the potential value of independent policy (Dornbush 2001).

[1] For discussion, see Walsh (2003), Chapter 5.

Several studies have investigated whether short-run effects of monetary policy on output in other countries are similar to those in the United States.[2] To cite some recent examples, Hayo (1998) studies the money-output relation in 17 industrialized countries using Granger-causality tests, finding considerable variation in results across countries and time periods, and by model specification. In an analysis of 20 countries (predominantly OECD) based on vector-autoregressions, Hafer and Kutan (2002) find that interest rates generally play a relatively more important role than money in explaining output; however, estimated effects often differed significantly if the data were assumed to be trend- versus difference-stationary. In a study to be discussed further below, Ganev, Molnar, Rybiński, and Woźniak (2002) find no evidence that interest-rate changes affect output in 10 countries of Central and Eastern Europe (CEE), but find some indications that exchange-rate changes do.

This paper adds to the international evidence on real effects of monetary policy by examining the post-stabilization experiences of four core CIS countries -- Russia, Ukraine, Belarus, and Kazakhstan. For transition economies such as those of the CIS that are not slated to join the EU, understanding the extent to which policy can be used to affect output is particularly important. To continue the re-establishment of conditions favoring growth, these countries need to have in place monetary policy régimes that establish credibility, favor price stability, and facilitate international trade and capital flows. If policy variables can be used to affect output, then maintaining independent policy preserves options of stimulating the economy when it is sluggish or cooling it down if it overheats. But if monetary policy has no short-run effect on output, then other sorts of policy régimes that entail strong commitment to price stability may be more attractive, such as a monetary union, a currency board, or 'dollarization'.[3]

The structure of this paper is as follows. Section 2 reviews existing research on effects of monetary policy in CIS and other transition countries, and Section 3 discusses monetary factors of particular relevance to countries of the core CIS. Section 4 develops and implements a strategy for estimating Granger effects of policy-related variables on output and prices in the CIS, given that data on the post-stabilization period cover a short span (9 or so years), and that orders of integration of the time series are uncertain. Section 5 presents impulse response functions showing dynamic effects of unexpected changes in policy-related variables. Section 6 pulls together results, discusses their implications and concludes.

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[2] Note that there is little controversy over the long-run neutrality of money, at least when inflation is neither very high nor very low. See Barro (1996) or Bullard and Keating (1995).
[3] Throughout this paper the term 'dollarization' refers to replacement of the domestic currency with a strong international one, not necessarily the U.S. dollar.

2. Previous research on transition economies

There are some clear problems inherent in studying the effects of monetary policy on output and prices in transition economies. Because the inflationary dynamics of early transition were likely unique, the data series from which one can study post-stabilization macroeconomic dynamics are relatively short at present. The institutions and policies at work in intermediating relationships between money, output and prices -- such as the central bank and the foreign-exchange regime -- are themselves evolving, so that relationships between macroeconomic variables may not be stable over time.[4] Additionally, the mix of policy instruments used by the central bank may change over time, so that results for analysis of a given period may differ from those of sub-periods within it.[5] These factors suggest a need to be careful about empirical strategies that frame relationships between economic variables as constant in structure.

Several studies have examined relationships between money growth and *inflation* in the CIS, particularly in Russia. Early studies found that increases in money supply translated quite quickly into increases in prices, with lags estimated to be on the order of four months (Buch 1998). More recent studies find that the lag length has increased as inflation has fallen -- although, at 7 months, the lag remains quite short (Pesonen and Korhonen 1999, Nikolić 2000).[6] These results are broadly suggestive of flexible adjustments of wages and prices, which tend to limit the scope for activist use of monetary policy.

Research on the effects of monetary policy on output in the CIS is more limited. Ghosh (1996) examines effects of credit expansions on output in the Ukraine, finding that credit growth boosts output quickly (within 1-2 months), although the effect is transitory and small, and its eventual effect is to push output *below* its original level.[7] Studies of other transition economies

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[4] Thus, for example, in their study of CEE countries, Ganev et al. (2002) estimate Granger-causalities over 3-year rolling windows, finding notable changes over time.

[5] Baliño, Hoelscher, and Horder (1997) describe changes in monetary-policy instruments in Russia until 1997. Esanov, Merkl and Vinhas de Souza (2004) find some evidence that the Central Bank of Russia was aiming to reduce inflation before 1995, and thereafter shifted to exchange rate stabilization. Note, however, that the problem of changing instruments of monetary policy is not unique to analysis of transition economies; for example, Friedman and Kuttner (1992), among others, find a shift in U.S. monetary policy to an emphasis on interest rates at the outset of the Volcker/Greenspan era. See also Bernanke and Mihov (1998).

[6] Nikolić's (2000) careful study of the Russian data found that: (a) M2 is more closely correlated with inflation than M1; (b) a structural break in the relationship between money and inflation occurred around October 1994; (c) the dominant lag length rose from 4 to 7 months; and (d) the relationship between money and inflation is relatively unstable and sensitive to changes in the economic and institutional environment. See also Bahmani-Oskooee and Barry (1998).

[7] Ghosh (1996) argues that this expansionary effect results from a reduction in real wages; thereafter, output declines to below its original level so that the *net* effect on output is

also provide some evidence of real effects of monetary policy, albeit very mixed. Using monthly data on 10 CEE countries from 1995 to 2000, Ganev et al. (2002) examine effects of exchange rates and interest rates on output and inflation.[8] They find fairly robust evidence that exchange rates Granger-cause inflation, as many standard models would predict. However, effects of interest rates on inflation, and of both exchange- and interest-rates on output, varied considerably across countries and over time.[9] Using vector-autoregressions to characterize relationships between variables, they find that exchange-rate shocks (depreciations) raise output in the short-run in most countries, with effects dissipating after 12-18 months, and that such shocks also boost inflation. In contrast, effects of interest-rate shocks varied across countries and often were not significant. Thus, their research broadly suggests a scope for using exchange rates to affect output, with the caveat that structural analysis would be required to determine whether the relationship could be exploited for policy purposes (Lucas 1976). It should also be borne in mind that these transition countries are better developed financially, and better integrated into international capital markets, than those of the CIS.

3. Monetary factors in the core CIS countries

This paper examines the experiences of the four core CIS countries: Russia, Ukraine, Kazakhstan, and Belarus. These countries represent about 90 percent of the output and 75 percent of the population of the CIS. Reflecting their Soviet legacy, their economies are relatively integrated: although tending to decline over time to varying degrees, for most countries of the core CIS, trade with other core CIS countries represents sizable shares of exports and imports; for Russia, intra-regional trade is far less important (see Figure 1).

Given their long association and close economic ties, some of these countries have at times discussed possibilities of monetary integration. Russia, Belarus, Kazakhstan, and Ukraine are in discussions of forming a 'Common Economic Space' (or Single Economic Space) that may at

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negligible. In the long run, hysteresis effects imply that prices increase by more than the increase in nominal credit, and output is slightly below its original level.

[8] They do not include a monetary aggregate because "money supply plays a far less significant role in monetary transmission mechanism than in developed economies amid low monetization" (p. 28)

[9] Results come from trivariate tests of effects of exchange- and interest-rates on output and inflation respectively. The exchange rate Granger-caused output in the Czech Republic, Estonia, and Romania in the first part of the 1995-2000 period; in Bulgaria and Hungary in second part; and in Latvia throughout. The interest rate Granger-caused output in Poland and perhaps the Czech Republic after 1997. In a study of Hungary and Poland, Gillman and Nakov (2004) find evidence of Granger causality from money to inflation -- but also, unexpectedly, from inflation to growth.

some point involve a common currency (Interfax 2004a). Russia and Belarus had planned for Belarus to adopt the Russian ruble in 2005, although presently this plan is on hold (Russia Journal 2003, Interfax 2004b). Additionally, the Eurasian Economic Community, which consists of Russia, Belarus, Kazakhstan, Kyrgyz Republic, and Tajikistan, has in principle agreed to work toward the introduction of a common currency in 2011 (Khetzeva 2002; Pravda 2003a, 2003b). The core CIS countries have also discussed ideas of a common economic space with the European Union (Samson 2002).[10]

The work of Robert Mundell (1961) and a vast body of recent research extending his ideas identify conditions favoring monetary union. Because the gains from eliminating transactions costs rise with the volume of trade, monetary unions are best formed among countries that trade heavily with each other. Additionally, as Alesina and Barro (2002, 2003) discuss, joining a monetary union is especially beneficial for small countries, since the decline in costs of international transactions improves their ability to realize economies of scale in production. In terms of macroeconomic considerations, members of a monetary union should be subject to similar aggregate fluctuations, so that a one-size-fits-all monetary policy would be reasonably appropriate for each member.[11] Joining a monetary union may have a particular value for a country that has struggled with chronic inflation, since the union-level commitment to low inflation can substitute for lack of national resolve; however, to be effective, unions of high- and low-credibility countries need to be dominated by large countries with high-credibility policies, so that low-credibility countries will not be able to compensate them for deviating from commitments (Alesina and Barro 2002, 2003).

This literature clearly has important implications for evaluating prospects for monetary integration in the CIS: for example, it suggests that Russia would stand to gain less than other CIS countries from forming a currency union, given that regional trade is less important to Russia than to other CIS countries; that benefits to small CIS economies, like Belarus, of forming a union would be greater than those for larger economies, like Ukraine; and that a currency union between Russia and Belarus could valuably assist Belarus in its struggle to reduce inflation. However, before these implications can be properly explored, it is important to determine whether the mechanisms in the CIS via which monetary policy is transmitted to output and prices resemble those assumed in standard models, given the reasons we have to suspect they may not be: namely that prices and wages may be more flexible, monetization is

[10] See Shagalov, Kivikari, and Brunat (2001) for discussion of the role of the euro in this regard.
[11] See Chaplygin, Hughes Hallett, and Richter (2004) for analysis of co-movements in aggregate shocks in the core CIS.

relatively low, credit markets are emergent, and interest rates for certain types of borrowing are affected importantly by conditions in world markets.

Thus, in what follows, we examine relationships between monetary policy and output and prices in Russia, Ukraine, Kazakhstan, and Belarus. Because the transmission mechanisms of monetary policy in CIS economies are not well-understood, we consider the effects of three policy instruments: money supply, interest rates, and the exchange rate. Money supply has of course been treated as the central policy-related variable in many studies of real effects. Narrow money -- defined as currency outside of banks plus demand deposits, and known as M1 -- can be more directly controlled by the government, and so would seem to be a better measure of monetary policy. Yet it is widely found that broad money -- equaling the sum of M1 and time and savings deposits, and known as M2 -- is more highly correlated with output and prices than M1, probably because substitution between M1 and time and savings deposits makes the former a relatively noisy measure of money supply (Christiano, Eichenbaum, and Evans 1999). However, factors other than policy contribute to fluctuations in M2, complicating its interpretation as a 'policy' variable. For one, velocity fluctuates in the short-run, so that relationships between money, output, and prices have some instability over short time horizons. For another, broad money may be partly endogenous to changes in economic conditions, as when a positive shock boosts business investment and triggers off monetary expansion (King and Plosser 1984). This may be a particular issue in CIS economies, which de-monetized substantially in early transition and are only now re-monetizing (see Figure 2).[12]

A second policy-related variable is the key interest rate under the control of the monetary authority. In advanced economies, this rate is the main instrument of monetary policy (e.g. the U.S. Federal Funds rate and the European Central Bank's refinancing rate). It is substantially less clear that changing the costs of funds to financial institutions has much real effect in CIS countries.[13] For one, credit markets and institutions tend to be thin and segmented, and the share of aggregate spending that is credit-sensitive is relatively small. Moreover, there may be an asymmetry in the monetary authority's ability to wield the interest-rate instrument: it may be able to use increases in banks' costs of funds to reign in aggregate demand, but may not be able to use rate reductions to stimulate demand in downturns, given that commercial borrowing rates may be hard to move down under risky business conditions (Dornbush 2001).

[12] Keller and Richardson (2003: 13) characterize Russia in 2001 and Ukraine in 2001/02 as periods when re-monetization unexpectedly accelerated; had the monetary authorities reduced liquidity to stay within monetary targets, they would have unnecessarily choked off economic growth.

[13] See Esanov, Merkl, and Vinhas de Souza (2004) for discussion of this point for Russia.

A third policy-related variable then is the exchange rate. Because the economies of the CIS are relatively open (Figure 3), policy moves that alter the competitiveness of domestic versus foreign goods at home and on world markets could have important effects on domestic production. Exchange-rate régimes in the CIS have in recent years mostly been managed floats, with governments intervening in foreign exchange markets to smooth through high-frequency fluctuations and limit real appreciations.[14] Of course, sharp shifts in market conditions -- as, for example, in the 1998 crisis triggered off by the Russian bond default -- can make it impossible to keep rates in desired ranges, in which case a government may have to let the exchange rate truly float. While depreciations are expected to be expansionary since they make domestic goods more competitive relative to foreign ones, they are not infrequently associated with contractions instead -- which may reflect not the exchange-rate change *per se*, but rather to circumstances that caused it, such as a 'sudden stop' in capital flows.[15]

4. Multivariate Granger-causality from monetary-policy variables to output

To characterize relationships between monetary-policy variables and output and prices in the post-stabilization period, we begin by using the notion of Granger causality, which indicates whether lagged values of policy variables are valuable for predicting future movements of output and prices (Sims 1972). Because we are unsure which policy variable or variables may have been appreciably related to output and prices, we include all three measures of monetary policy in the VAR: money supply, as measured by M1 or M2; the key policy interest rate, taken to be the central bank's refinancing rate;[16] and the exchange rate, measured in real effective terms. Output is measured as real GDP, and the general price level as the consumer price index. All data series are expressed in natural logs and have been seasonally adjusted using moving average methods.[17] To focus on macroeconomic dynamics during the post-stabilization years, we use quarterly data for 1995:1 to 2003:3 or 2003:4; beginning the analysis at this point is consistent with econometric studies findings significant breaks in macro dynamics in CIS

[14] In 2003, the IMF classified Russia, Kazakhstan, and Ukraine as having managed floats, while Belarus had a crawling band (Keller and Richardson 2003).
[15] For recent discussions, see Ahmed et al (2002) and Kamin and Klau (2003).
[16] There is some concern about using the refinancing rate as the appropriate interest-rate measure: central banks in the CIS have at times discouraged commercial banks from borrowing from central-bank lending facilities, so the amount of borrowing that occurs at this rate may be small (see, for example, Baliño 1998 on Russia). Alternative measures such as the inter-bank lending rate may provide a better indication of shifts in the costs of funds to banks; however, they are not necessarily good indicators of changes in monetary policy, since factors other than policy will affect these rates.
[17] Adjustment using ARIMA X12 was not possible in some cases, likely due to the relatively short span of the data. However, for series for which X12 adjustment was possible, Granger results were not qualitatively different from those using data adjusted with the MA method.

countries in 1994 and 1995 (e.g. Nikolić 2000; Esanov, Merkl, and Vinhas de Souza 2004).[18] Data are taken, wherever possible, from the International Monetary Fund's *International Financial Statistics* -- although when needed, the IFS data are supplemented with statistics from national agencies and central banks.[19] Details of data sources and variable definitions are given in Appendix A.

A practical problem in characterizing relationships between output, prices and policy-related variables concerns the stationarity properties of the data. If some of the variables are stationary and others are non-stationary, the latter should be incorporated into the VAR in first-differences to avoid problems of spurious regression. However, in relatively short time-series, traditional unit-root tests (those of Dickey-Fuller and Phillips-Perron) have little power to distinguish between unit roots and stationary series that mean-revert but do so slowly, creating a bias towards non-rejection of unit roots; this is a particular problem in the present context because the span of the data is generally only nine years.[20] Moreover, while it might seem prudent to first-difference all variables to guard against the possibility of mishandling a non-stationary variable, Christiano and Ljungqvist (1988) demonstrate that series should not be differenced unnecessarily because of the low power of time-series tests on growth variables. Finally, from the work of Perron (1989) and Hafer and Kutan (1997, 2002), we know that structural breaks in data series can bias unit root tests towards non-rejection; this may be a problem in our context if, for example, breaks were associated with dramatic events like the 1998 Russian financial crisis. Appropriate treatment of the data is important for analysis: for example, Hafer and Kutan (2002) find that the relative importance of money versus interest rates, in explaining fluctuations in output, is often greater when the data are assumed to be trend- rather than difference-stationary.

Thus, to examine the stationarity properties of the data, we use a variety of tests for unit roots, including not only the traditional tests of Dickey-Fuller and Phillips-Perron, but also several alternatives intended to address problems of low power and size distortion.[21] Elliot, Rothenberg and Stock provide an asymptotically efficient test of the unit root hypothesis using quasi-differenced data de-trended via GLS. Given that unit root tests over-reject non-stationarity when residuals have a large negative moving-average root (as has been found for inflation), Ng and Perron develop four test statistics, also based on quasi-differenced data de-

[18] Also in 1995 was the legislation increasing the independence of the Central Bank of Russia.
[19] Of importance in this regard are the quarterly real GDP data from the State Committee on Statistics of the Russian Federation (Goskomstat).
[20] Dejong, Nankervis, Savin and Whiteman (1992). Perron and Shiller (1985) establish that it is the span, not the frequency, of the data that provides a basis for distinguishing between unit roots and slowly-reverting processes.
[21] See Maddala and Kim (1998), Chapters 3 and 4, for discussion of these tests and references.

trended via GLS, that have superior size and power. A test developed by Perron examines stationarity properties of the data, allowing for the possibility of structural breaks. Finally, whereas all of these tests have non-stationarity as their null hypothesis, the test of Kwiatkowski, Phillips, Schmidt and Shin instead has stationarity as its null.

Table 1 summarizes the results of the stationarity tests; detailed test statistics are given in Appendix B. Clearly there are very few cases where test results consistently indicate stationarity or nonstationarity: with the exceptions of output and prices in Russia, output and the interest rate in Ukraine, the exchange rate in Kazakhstan, and M1 in Belarus, almost all series have at least one test result that contradicts the others, with some having as many rejections of unit roots as they have failures to reject (such as M2 and the exchange rate in Russia). Perhaps interestingly, whereas earlier studies have found that Perron's test allowing for structural breaks often reverses findings of non-stationarity, this is not the case in our data: although almost all data series for all four countries show evidence of structural breaks in 1998 or 1999 (presumably related to the Russian financial crisis), in many cases the non-rejection of a unit root persists after allowing for a level shift or broken trend (or both). To some extent, these varied results are not surprising, given the short span of the data and known difficulties of distinguishing stationarity from nonstationarity in finite data sets. Still, the tests give us only mixed guidance on how to incorporate the series into VAR analysis, while neither over- nor under-differencing.

To accommodate uncertainties about correct orders of integration, we adopt a strategy as follows. For each country a baseline model is devised, in which variables for which test results fairly clearly indicate non-stationarity are first-differenced, while other variables are included in levels; decisions made in this regard are given in columns (b), (d), (f) and (h) of Table 1. However, many of the variables left in levels have a fair chance of being non-stationary. To address this problem, we use the modifications of the Granger-causality test proposed by Toda and Yamamoto (1995), which are robust to the order of integration of the variables. The tests are conducted as follows. Suppose one believes that the true lag length of the VAR is p; the standard Granger method tests the hypothesis that lags 1 through p of the i^{th} variable are jointly insignificant in the equation for the j^{th} variable. The Toda-Yamamoto test makes use of the fact that, although the order of integration of the endogenous variables may be uncertain, one usually has a reasonably good idea of the upper bound. Taking the maximum order of integration of the variables in the VAR to be k, the Toda-Yamamoto test estimates a VAR with $p+k$ lags, and then tests whether the first p lags of the variable i are significant in the j^{th} equation. An important advantage of this method is that, like the standard Granger-causality

tests, the test statistic has a χ^2 asymptotic distribution. Its disadvantage (of course) is that including the *k* additional lags of the endogenous variables reduces the power of the test.

To implement this method, we estimate VARs for each country taking the 'true' lag length to be 2 and the maximum order of integration to be 1; thus, VARs are estimated with three lags, but causality tests are based on the significance of the first two. Ideally, we would want to test for the optimal lag length preferred by the data, since VAR results can be sensitive to the lag length used.[22] However, in a short data set like ours, allowing for more lags quickly depletes degrees of freedom and reduces the precision with which effects can be estimated; also, having lag lengths vary across models makes it difficult to compare results.[23] Thus, we take the not uncommon approach of fixing the number of lags,[24] hoping in future work to be able to relax this restriction.

Table 2 presents results of the Toda-Yamamoto Granger tests, which show the significance of the lagged policy variables, individually and jointly, in explaining future movements in output and prices. The results suggest that money supply has not tended to be systematically related to output in the CIS. In Russia, Ukraine, and Belarus, there is no evidence of a Granger-causal relation between the monetary aggregates and output, regardless of whether the money measure is broad or narrow. In Kazakhstan, the hypothesis that money Granger-causes output can be rejected for M1, although not for M2; this is broadly consistent with findings from other studies that narrow money rarely matters for output, though broad money sometimes does.

The evidence on real effects of interest rates is also very thin. They have no significant predictive value for output in Ukraine, Kazakhstan or Belarus. In the model for Russia based on M1, they have some predictive value, but at a 10% significance level only. These findings support impressions that, to date, CIS monetary authorities have not been able to make much use of interest rates as a policy instrument, given that changes in banks' costs of funds may have only small influence on the pace of lending to businesses and consumers.

In contrast, the exchange rate has significant Granger effects in the model for Russia based on M2, and in both models for Kazakhstan, although it has not been significant in Ukraine or Belarus. Testing the joint significance of all three policy variables suggests that 'money

[22] See, for example, Hafer and Sheehan (1991). Toda and Yamamato (1995) demonstrate that, in their modification of the Granger test, usual lag selection procedures can still be applied, as long as the order of integration is not greater than the true lag length of the model.
[23] Note also that models for which lag-selection criteria called for 4 or more lags not infrequently had characteristic roots outside of the unit circle.
[24] For example, Hafer and Kutan (1997).

matters' in Russia and Kazakhstan, in the sense that the policy variables jointly have significant predictive value for output in both models, but that it is irrelevant for output in Ukraine and Belarus regardless of the measure of money.

Turning now to prices, the evidence that policy variables have Granger effects is patchy. In Belarus, M2 is estimated to Granger-affect prices at a significant level, as one might expect. M2 also has a significant effect in Kazakhstan, but at a 10% level only. Also in Kazakhstan, the interest rate Granger-causes prices. This is an unexpected result, given our sense that interest rates have been relatively weak instruments in the CIS; however, as will be discussed below, it may reflect a 'price puzzle,' rather than the use of interest rate hikes to curb inflationary pressures. There is some evidence that exchange rates Granger-cause prices: effects are significant in M1 and M2 models for Ukraine and in the M2 models for both Russia and Belarus, although in both cases at a 10% level only. In general, the monetary-policy variables have mixed effects on on prices: they are not jointly significant in either of the models for Russia and Kazakhstan, they are jointly significant in both models for Ukraine, and they are jointly significant in Belarus but in the M2 model only. However, it is important to stress that these results should not be taken to mean that monetary-policy variables are generally irrelevant for prices -- only that quarter-to-quarter shifts in policy variables are not systematically related to the ups and downs of prices in the quarters thereafter. This suggests a limited scope for using fine-tuning of policy instruments to smooth through price fluctuations in the short term.

5. Vector autoregressions and dynamic effects

Whereas the Toda-Yamamoto tests provide a scalar measure of the significance of policy variables for predicting future movements in output and prices, VAR models also provide insight into dynamic effects of unexpected changes in policy variables on macroeconomic outcomes. Here we use the standard approach of estimating unstructured VARS and identifying shocks through assumptions about variable ordering. This approach has known shortcomings, but also a number of advantages: it is helpful for characterizing 'stylized facts' about relationships between policy variables and output and prices; it requires minimal assumptions about underlying economic relationships, which is helpful for us given uncertainties about the evolving structures of CIS economies; and it enables us to compare results for CIS economies with a large body of findings for other countries.[25]

Here we estimate VAR models using the five variables of the Granger analysis (output, prices, money supply, interest rates, and exchange rates, expressed in levels or first-differences as

[25] See Christiano, Eichenbaum and Evans (1999) for general discussion.

determined above), and two lags of all variables.[26] To identify how shocks to given variables dynamically affect the other variables in the system, we following the standard for the literature and order the policy-related variables after output and price, which amounts to assuming that policy decisions can be made with knowledge of contemporaneous economic conditions, but that output and price respond to changes in policy variables with a lag. Specifically, we order output first, under the assumption that it adjusts most sluggishly, followed by price; while this departs from the usual assumption that prices are most sluggish, it seems more appropriate for the CIS context, where prices seem to be relatively flexible and such practices as just-in-time production methods are not at all common. Within the policy-related block, we order the variables as money supply, the interest rate, and the exchange rate, reflecting their likely degree of endogeneity to current economic conditions. Alternative orderings were also tried, and although some results are sensitive to variable ordering, the broad patterns of findings are not. Note that, since the order of integration of the variables is uncertain, long-run analysis using the resulting impulse responses should be treated with caution, but short-term responses should be less problematic (Phillips 1998).

The resulting impulse response functions show how output and prices are estimated to respond over time to a one-standard deviation 'shock' to the policy-related variable -- that is, a change that would not have been anticipated given the dynamics of the system. As Bernanke and Mihov (1998) explain, such changes have an intuitive interpretation as 'policy shocks,' that is, as moves to alter the ongoing dynamics of output and prices -- although it is also possible that 'unexpected' changes instead originate in factors omitted from the model.

Effects of the policy-related variables on output are shown in Figure 4. In Russia and Kazakhstan, a shock to the monetary aggregate has some tendency to raise output -- although the effect is fleeting and generally not statistically significant (i.e. zero falls within the 95% confidence interval, shown by the dotted lines). The profiles are not like the hump-shaped one often found for the U.S., where effects of monetary expansion on growth phase in over 9-12 months and peter out over 2-3 years; rather, they are more in line with Ghosh's (1996) result for the Ukraine, of a fast and highly transitory real effect. Our results show no significant effect of money supply on output in Ukraine or Belarus.

The most pronounced finding from the impulse responses is for Russia, where an unanticipated increase in the interest rate is associated with a significant drop in output in the next quarter. Of course the direction of this effect is consistent with expectations -- but the speed of

[26] Again, ideally one would want to select lag length using statistical criteria, but implementing such methods is problematic in the present context (see discussion above).

adjustment is surprising, since businesses and consumers might ordinarily be expected to adjust their spending moderately and gradually to changes in returns to saving and costs of investment, not substantially and immediately. The most likely explanation here seems to be that the estimated effect does not reflect a usual marginal adjustment to a marginal policy change, but rather the concurrence of dramatic changes in output and interest rates during times of such as the period leading up to the 1998 financial crisis. We return to this idea below.

Figure 5 shows estimated effects of the policy-related variables on prices. In all four countries, the basic profile is that an unanticipated shock to the monetary aggregate leads to higher prices in one or two quarters, although the effect is in a significant range for Ukraine and Kazakhstan only. This is consistent with the idea that prices in the CIS adjust relatively quickly to changes in the quantity of the medium of exchange; conceivably, the low precision with which effects are estimated may reflect changes noted by other authors in the speed of transmission of monetary shocks over the post-stabilization period (see above). Otherwise, consistent with findings from the Granger analysis, there is not much evidence of systematic effects of shocks to policy variables on prices. In Russia, there is a significant effect of interest rates on prices -- but it is the opposite of what would be expected: an unanticipated increase in the interest rate *boosts* the price level in the next quarter or two above the level it otherwise would have been. This effect resembles the 'prize puzzle' documented for the U.S.: in small VARs similar to ours, unexpected increases in interest rates seem to bring on higher prices, but the effect disappears once commodity prices are included in the model, apparently because commodity prices contain information about future inflation that policymakers considered at the time they raised interest rates, but that was omitted in the simple version of the model.[27] In the Russian case, again we suspect that the estimated association between price changes and prior unexpected movements in interest rates is rooted in the unusual events of 1997-98: interest rates were steadily increased in 1997 to stave off the brewing crisis, and inflation soared in 1998 after the exchange rate had to be floated, but as a consequence of the underlying imbalances that the interest rate changes were attempting to address, not of the changes *per se*.[28]

A final set of insights from the VAR analysis concerns the relative importance of monetary policy in the variance of output and prices. Gauging the contribution of policy variables in this respect is important because, even if their effects are estimated to be statistically significant, they may not be economically large. Table 3 shows the shares of the variances of output and

[27] Alternatively, Giordani (2001) argues that the price puzzle results from using the output level in the VAR instead of the output *gap*. In the case of economies in transition, however, the concept of the output gap is not well-defined, given the extent of ongoing structural change.
[28] On the subject of the ruble collapse, see Desai (1998).

prices associated with the policy-related variables, individually and jointly, over a 2 ½-year time horizon. In Russia, the policy-related variables are estimated to account for fairly large shares of variance in output -- 44% in the VAR based on M1, and 54% in that based on M2 -- with interest rates responsible for 2/3 or more of the contribution. In contrast, the policy variables account for only 10-20% of variance in output in Ukraine, Kazakhstan and Belarus. This difference is consistent with the idea that the power of monetary policy is likely to be greater in a relatively large, relatively closed economy than in smaller, more open ones.[29]

Findings are somewhat different with respect to prices. In Russia, the policy-related variables account for 25-31% of the variance in prices at the 2 ½-year time horizon, again with much of the contribution coming from interest rates. At 36-46%, the share of policy-related variables is higher in Kazakhstan, with the largest contribution associated with money supply. In Ukraine, the policy variables account for 30-34% of variance in prices, mostly due to the exchange rate. Broadly, this suggests that monetary policy plays an appreciable role in short-term price fluctuations in these countries, albeit via different instruments; however, other factors also play sizable roles, including dynamics related to output and prices themselves, suggesting limits on the scope of policy for controlling price changes in a high-frequency way. In Belarus, the policy-related variables play an even smaller role in the variance of prices, at 10-17%.

6. Overview and implications

In a nutshell, there is mixed evidence on real effects of monetary policy in the CIS. There are indications that interest rates affect output in Russia, and that money supply and exchange rates do in Kazakhstan; none of the policy-related variables seem to matter systematically in Ukraine or Belarus. Yet in general, effects of policy variables tend to be small and transitory and are often estimated imprecisely. Broadly, these findings confirm expectations of relatively modest real effects of monetary policy in present-day CIS contexts, where prices and wages are relatively flexible, monetization is low, credit markets are thin, and domestic interest rates are not independent of world capital markets.

However, there are notable differences across the four countries studied. In a sense, results for Russia resemble the pattern of the U.S. and some other advanced economies, in which adjustments in the key interest rate controlled by the central bank have significant effects on output.[30] This is consistent with expectations that monetary policy would be more influential in

[29] See, Wan Tai Wai (2000) for similar discussion of Singapore.
[30] Our result of a relatively important effect of the interest rate in Russia seems to differ from that of Esanov, Merkl, and Vinhas de Souza (2004), who find that the behavior of the Russian

a large, relatively closed economy than in small, relatively open ones. Still, the fact that estimated effects are immediate and fleeting, rather than phasing in over 9-12 months, suggests that the process underway is not the 'usual' one, whereby increased costs of credit marginally reduce interest-sensitive components of spending and so cool down economic growth. Instead, they seem to capture the dynamics of the major fluctuation of the post-stabilization period, the financial crisis, wherein hikes in interest rates and exchange-rate depreciations were used to eradicate excess demand for foreign exchange and were accompanied by real contraction. This highlights the value for Russia of maintaining independent monetary policy, not so much for 'fine-tuning' everyday shocks to output and prices, but as a 'safety valve' for dealing with sudden shifts in conditions such as this. Given that Russia is in the category of emerging market economies -- where intermittent turbulence in financial markets and risks of 'sudden stops' in capital flows seem to be inescapable facets of the growth trajectory (Kaminsky, Reinhart and Végh 2004) -- it seems critical to retain the flexibility that independent policy provides, especially for emergency response.

In contrast, in Ukraine, Kazakhstan and Belarus, monetary policy accounts for very small shares of the variance of output, consistent with the idea that activist policy has limited scope in smaller, more open economies. This suggests that the costs to them of relinquishing independent monetary policy in favor of high-credibility policy regimes like currency boards or 'dollarization' would not be particularly large. Still, policy does have significant, though modest real effects in Kazakhstan, whereas they seem to be absent in Ukraine and Belarus. It is likely that some part of this difference can be traced to differences in the credibility of monetary policy: notably, whereas Kazakhstan has made appreciable efforts to re-frame its central bank as a credible, independent institution committed to price stability, Belarus has taken a 'gradualist' approach to disinflation, leaving the central bank's monetary-policy functions co-mingled with the financing of fiscal deficits, and keeping its inflation the highest in the region. In this setting, where the public is accustomed to time-inconsistent use of monetary policy, money appears to be neutral not only in the long-run, but in the very short-run as well. As such, if credibility cannot otherwise be established, Belarus could conceivably gain from relinquishing monetary independence in favor of a high-credibility mechanism, such as adopting a strong international currency or entering a monetary union in which they are a small player.

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central bank from 1993-2002 is better characterized as targeting monetary aggregates (a McCallum rule) than interest rates (a Taylor rule). Some notable differences between our studies are: (a) whereas they investigate systematic movements of policy variables in response to output *gaps*, the present paper describes how *output itself* moves in response to policy variables; and (b) their analysis covers a longer period, including the post-liberalization years during which inflation and monetary indiscipline were front-burner issues.

Table 1. Summary of results of stationarity tests

	Russia		Ukraine		Kazakhstan		Belarus	
	(a) Findings from unit root tests	(b) Differenced in baseline model?	(c) Findings from unit root tests	(d) Differenced in baseline model?	(e) Findings from unit root tests	(f) Differenced in baseline model?	(g) Findings from unit root tests	(h) Differenced in baseline model?
Y	Consistently non-stationary	Yes	Consistently non-stationary	Yes	Non-stationary, exc. P-break	Yes	Stationary, exc. ADF and KPSS 10%	no
P	Consistently non-stationary	Yes	Non-stationary exc. ADF and PP	Yes	Non-stationary, exc. PP + ADF 10%	Yes	Non-stationary, exc. KPSS	yes
M1	Uncertain (non-stationary for all but PP, KPSS)	No	Uncertain (non-stationary but for PP, KPSS + ADF 10%)	No	Uncertain (stationary exc. for ADF and PP)	No	Consistently non-stationary	Yes
M2	Uncertain (stationary by ADF, ERS, KPSS; non-stationary by PP, NP, P-break)	No	Uncertain (stationary in PP, NP and ERS at 10%; non-stationary in ADF, P-break, KPSS at10%)	No	Stationary at 10% or better for all but PP	No	Mostly non-stationary, exc. ERS, and ADF and KPSS at 10%	No
Interest rate	Uncertain (non-stationary for PP, NP, ERS)	No	Consistently non-stationary	Yes	Non-stationary exc. for PP	No	Non-stationary, exc. KPSS	Yes
Exchange rate	Uncertain (stationary by ADF, ERS, NP, KPSS; non by PP and P-break)	No	Non-stationary ex. KPSS	Yes	Consistently non-stationary	Yes	Non-stationary, exc. KPSS	Yes

Notes: ADF= Augmented Dickey Fuller. PP = Phillips Perron. ERS = DF-GLS by the method of Elliot, Rothenberg, and Stock. NP = Ng-Perron. P-break = Perron's test allowing for structural break. KPSS = Kwiatkowski, Phillips, Schmidt and Shin. Detailed test statistics are given in Appendix B.

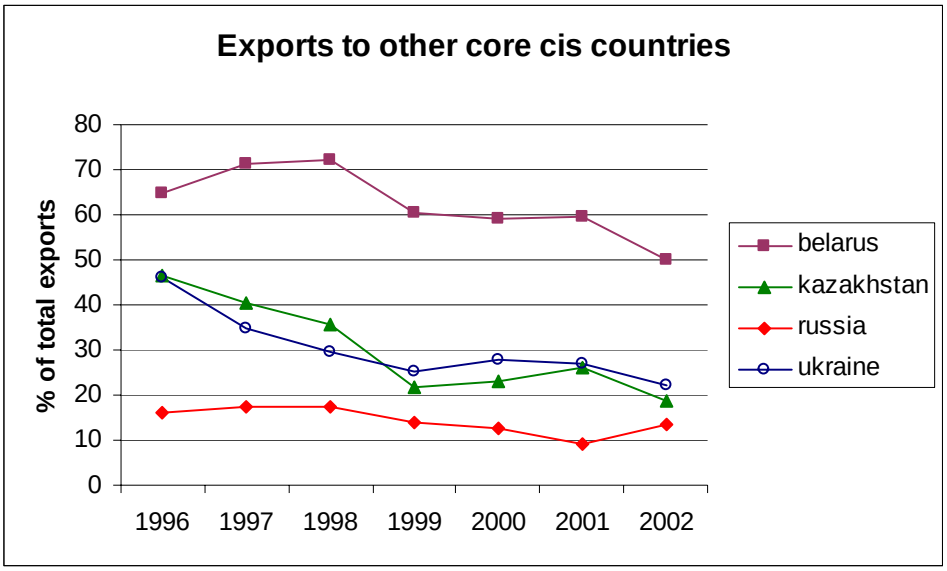
Table 2. Toda-Yamamoto estimates of Granger causalities: P-values of the significance of lagged monetary-policy variables for output and prices

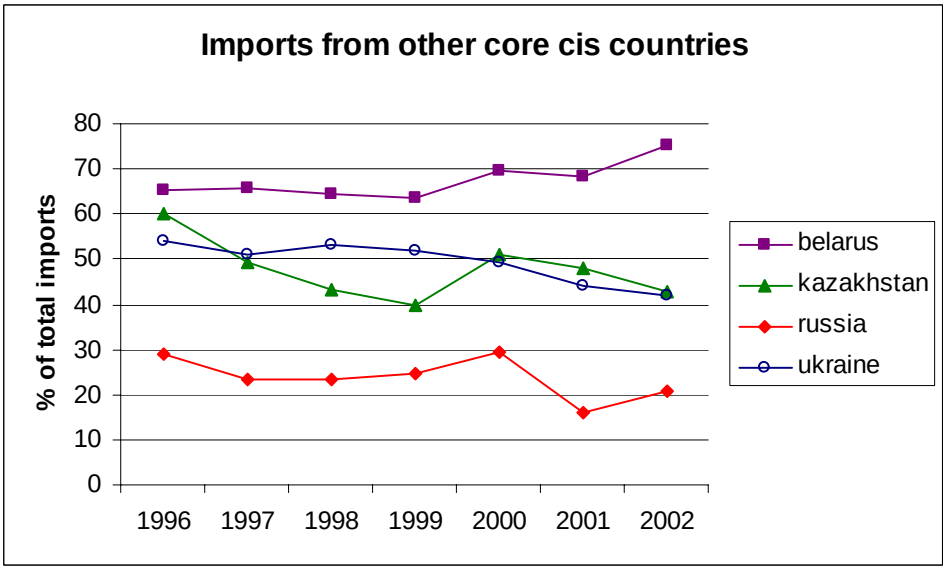
	Russia		**Ukraine**		**Kazakhstan**		**Belarus**	
	Measure of money		*Measure of money*		*Measure of money*		*Measure of money*	
	M1	M2	M1	M2	M1	M2	M1	M2
EFFECTS ON OUTPUT								
Money supply	.50	.20	.17	.97	.12	.00	.27	.19
Interest rate	.09	.14	.88	.53	.96	.18	.77	.77
Exchange rate	.17	.01	.95	.90	.00	.00	.29	.65
Policy variables jointly	.01	.00	.30	.79	.00	.00	.39	.28
EFFECTS ON PRICES								
Money supply	.79	.60	.65	.20	.39	.08	.16	.02
Interest rate	.78	.52	.32	.19	.74	.04	.44	.64
Exchange rate	.27	.09	.00	.00	.86	.21	.27	.08
Policy variables jointly	.77	.33	.00	.00	.69	.16	.42	.02

Table 3. Shares of variances of output and prices associated with policy variables, individually and jointly, in a 2 ½-year time horizon

	Russia		**Ukraine**		**Kazakhstan**		**Belarus**	
	Measure of money		*Measure of money*		*Measure of money*		*Measure of money*	
	M1	M2	M1	M2	M1	M2	M1	M2
OUTPUT								
Money	7.1	7.8	13.5	4.9	8.7	13.4	7.0	5.4
Interest rate	35.0	35.2	5.1	6.6	4.3	5.3	1.0	7.1
Exchange rate	8.6	10.6	0.7	2.2	1.3	1.3	2.4	1.5
Total policy	43.7	53.6	19.3	13.7	14.3	20.0	10.4	14.0
PRICES								
Money	5.5	6.3	2.7	3.3	23.1	26.0	10.1	15.3
Interest rate	17.9	22.0	7.6	13.2	10.9	12.4	0.1	0.5
Exchange rate	1.3	2.3	19.8	17.7	2.4	7.7	0.1	1.0
Total policy	24.7	30.6	30.1	34.2	36.4	46.1	10.3	16.8

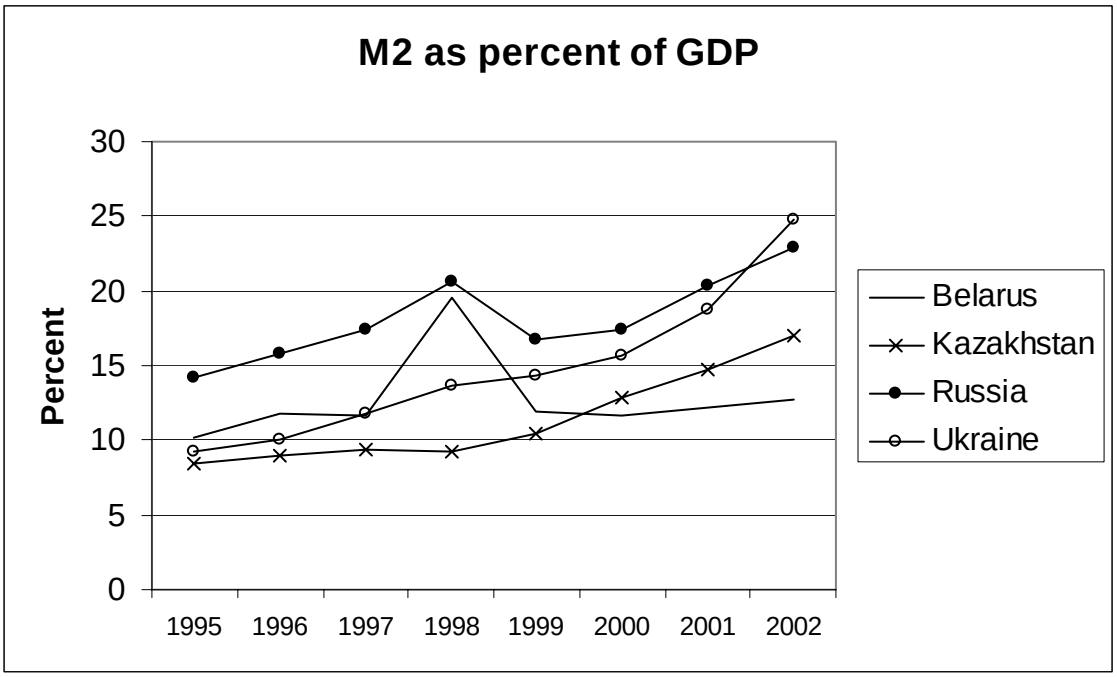
Figure 1. Share of exports to and imports from other core CIS countries





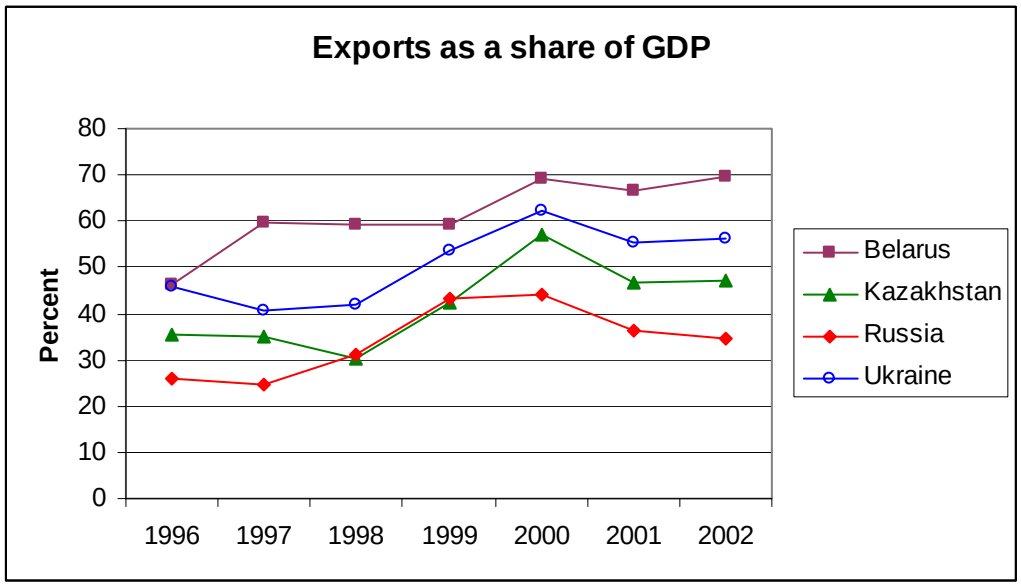
Source: IMF, *Direction of Trade Statistics*, 2003.

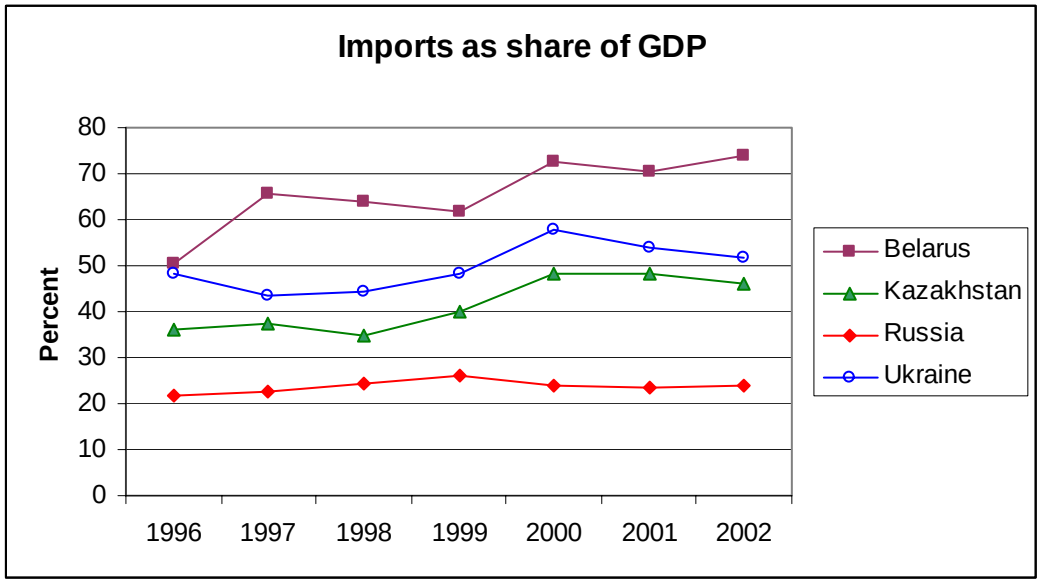
Figure 2. Monetization ratios in the core CIS



Source: World Bank, World Development Indicators.

Figure 3. Exports and imports as a share of GDP

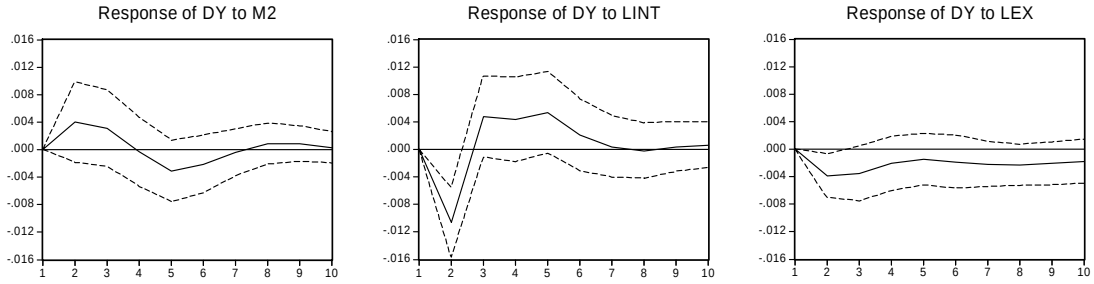




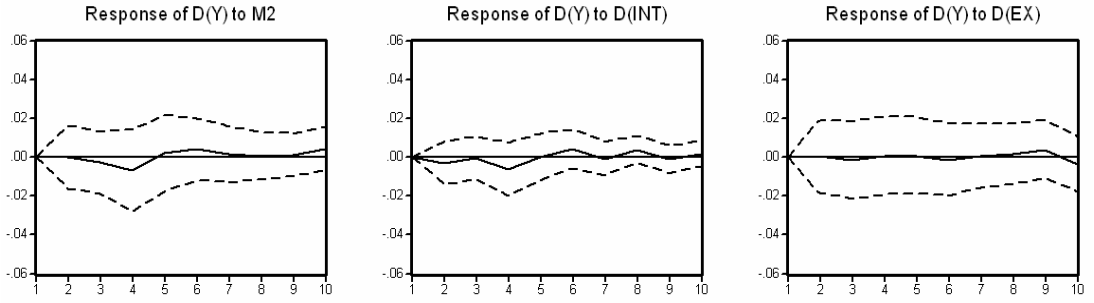
Source: World Bank, World Development Indicators.

Figure 4. Impulse response functions: Effects on real output of a one standard-deviation shock to the policy variable over the next 10 quarters

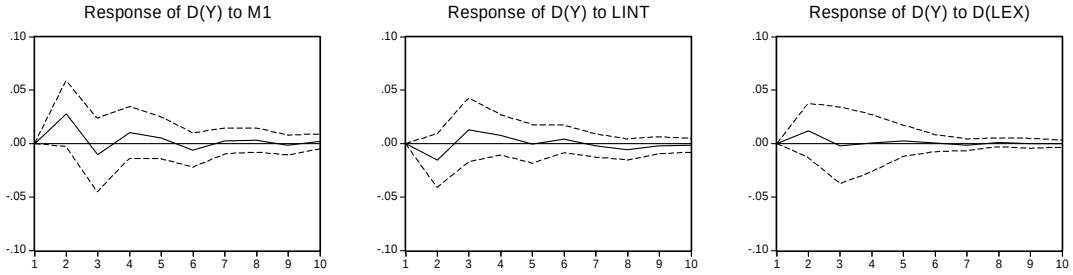
Russia



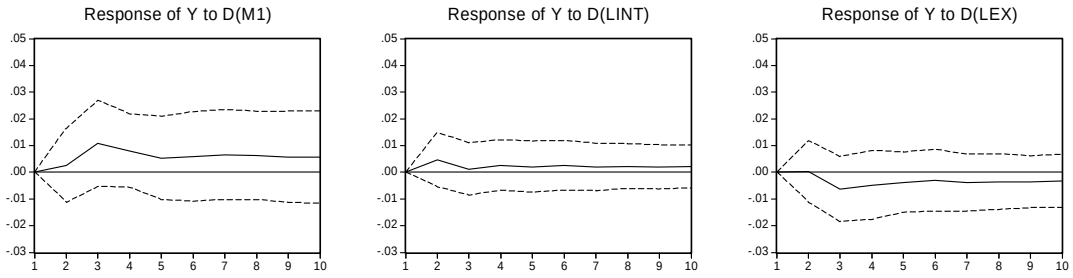
Ukraine



Kazakhstan



Belarus

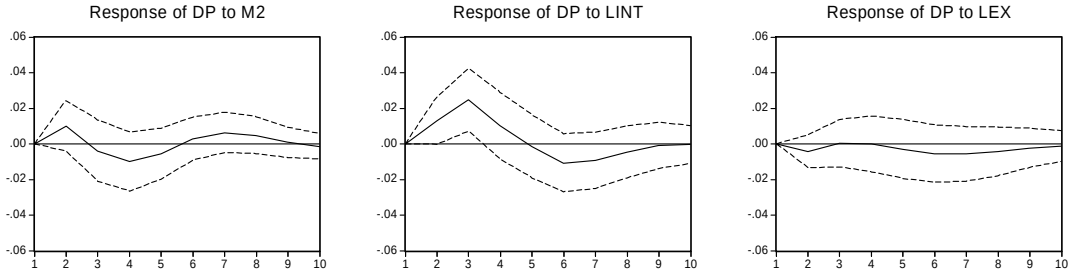


Notes:

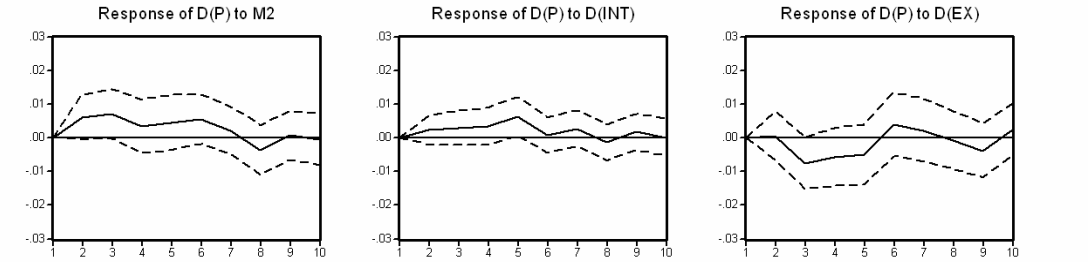
- Y=output, M1=narrow money, M2=broad money Lint=interest rate, Lex=exchange rate; models also included price.
- The horizontal axis shows the number of quarters since the shock to the policy variable: the vertical axis shows its effect on output relative to what it would have been in the absence of the shock.
- Dotted lines represent 95% confidence intervals.
- Results for Russia and Ukraine come from the model based on M2, while for Kazakhstan and Belarus they are from the model based on M1.

Figure 5. Impulse response functions: Effects on prices of a one standard-deviation shock to the policy variable, over the next 10 quarters

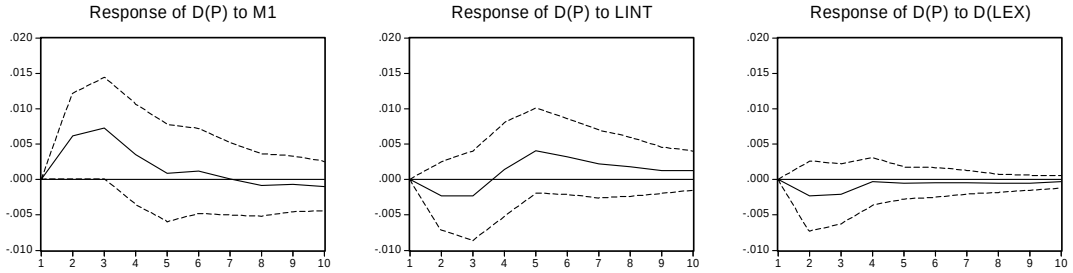
Russia



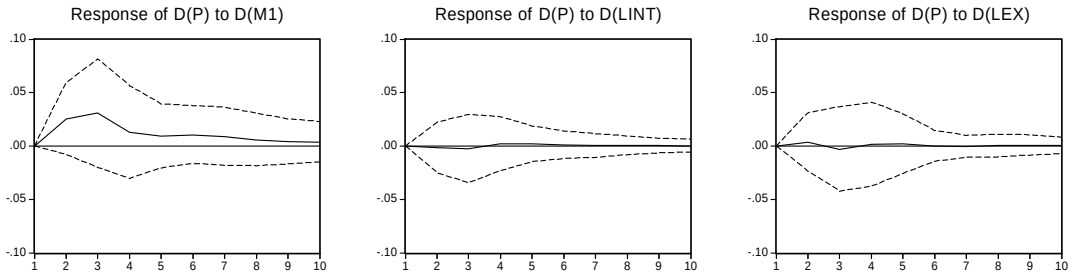
Ukraine



Kazakhstan



Belarus



Notes:

- Y=output, P=price, M1=narrow money, M2=broad money Lint=interest rate, Lex=exchange rate.
- The horizontal axis shows the number of quarters since the shock to the policy variable: the vertical axis shows its effect on output relative to what it would have been in the absence of the shock.
- Dotted lines represent 95% confidence intervals.
- Results for Russia and Ukraine come from the model based on M2, while for Kazakhstan and Belarus they are from the model based on M1.

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Appendix A. Variable definitions and data sources

Variable name	Definition	Data source
Real output (Y)	Real GDP, quarterly basis at an annual rate, expressed in constant units of local currency	IFS for Kazakhstan and Belarus; Russian data are from Goskomstat; Ukrainian data from State Committee of Statistics and Institute of Economic Policy Research and Consulting
Price (P)	Consumer price index, 1995=100	IFS
M1	Currency outside banks, plus demand deposits other than those of central government	IFS, line 34
M2	M1 plus time, savings, and foreign currency deposits of resident sectors other than the central government	M1, plus IFS line 35 ("quasi money")
Interest rate	Central bank's refinancing rate	IFS
Exchange rate	Real effective exchange rate: units of local currency per U.S. dollar, adjusting for differential rates of inflation	IFS for Russia and Ukraine; computed using U.S.-dollar exchange rate and relative CPIs for Kazakhstan and Belarus

In the econometric analysis, all variables are expressed in natural logarithms.

Appendix B. Unit root tests

Test	Abbrev.	Notes:
Augmented Dickey-Fuller	ADF	Lags chosen automatically using Aikake information criterion , max lag=8
Phillips-Perron	PP	Newey-West bandwidth using Bartlett kernel
Ng-Perron	NP	Spectral estimation method is AR-GLS detrended with lags chosen automatically using Aikake information criterion, max lag=8.
Dickey-Fuller GLS method of Elliott, Rothenberg and Stock	ERS	Lags chosen automatically using Aikake information criterion, max lag=8. Note that critical values are calculated for 50 observations and may not be accurate for samples of our size.
Perron's test for structural break	P-break	Models run with a shift term and/or broken trend as indicated by the data. Critical values of T-statistics are from Perron (1989).
Kwiatkowski-Phillips-Schmidt-Shin	KPSS	Newey-West bandwidth using Bartlett kernel

Note: All models included a constant term.

Appendix Table B1. Unit root tests: RUSSIA

			Level								
			H0: Variable has unit root								H0: variable is stationary
	Trend included in tests?		ADF	Phillips-Perron	Ng-Perron				DF-GLS (ERS)	Perron test for break	KPSS
					MZa	MZt	MSB	MP			
Y	yes	Test stat	-1.83	-1.38	-4.66	-1.39	0.30	18.65	-1.46	- 3.59	0.192*
		5%	-3.55	-3.54	-17.3	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.21	-3.20	-14.2	-2.62	0.19	6.67	-2.89		0.119
P	no	Test stat	-1.30	-2.13	0.41	0.29	0.71	34.17	0.31	- 2.90	0.703*
		5%	-2.95	-2.95	-8.10	-1.98	0.23	3.17	-1.95	-4.24	0.463
		10%	-2.62	-2.61	-5.70	-1.62	0.28	4.45	-1.61		0.347
M1	yes	Test stat	-3.22	-3.96*	-5.96	-1.69	0.28	15.25	-2.65	(no break)	0.067
		5%	-3.59	-3.54	-17.3	-2.91	0.17	5.48	-3.19	-	0.146
		10%	-3.23	-3.20	-14.2	-2.62	0.19	6.67	-2.89		0.119
M2	yes	Test stat	-4.36*	-2.47	-6.62	-1.81	0.27	13.76	-3.79*	- 2.14	0.091
		5%	-3.59	-3.54	-17.3	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.23	-3.20	-14.2	-2.62	0.19	6.67	-2.89		0.119
Int	yes	Test stat	-4.90*	-2.33	-796.5*	-19.95*	0.03*	0.12*	-3.59*	- 2.60	0.078
		5%	-3.57	-3.54	-17.3	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.22	-3.20	-14.2	-2.62	0.19	6.67	-2.89		0.119
Exch	no	Test stat	-2.66+	-2.03	-11.01*	-2.30*	0.21*	2.41*	-2.27*	- 3.82	0.125
		5%	-2.95	-2.95	-8.1	-1.98	0.23	3.17	-1.95	-4.24	0.463
		10%	-2.61	-2.61	-5.7	-1.62	0.28	4.45	-1.61		0.347

See above for notes. * = null hypothesis can be rejected at 5% level; + = null can be rejected at 10% level

Appendix Table B2. Unit root tests: UKRAINE

	Trend included in tests?		Level								
			H0: Variable has unit root								H0: variable is stationary
			ADF	Phillips-Perron	Ng-Perron				DF-GLS (ERS)	Perron test for break	KPSS
					MZa	MZt	MSB	MP			
Y	yes	Test stat	-2.29	-2.10	-6.71	-1.68	0.25	13.66	-2.12	-3.92	0.199*
		5%	-3.54	-3.54	-17.3	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.20	-3.20	-14.2	-2.62	0.19	6.67	-2.89		0.119
P	no	Test stat	-3.22*	-4.88*	0.15	0.11	0.72	32.99	0.07	-3.38	0.694+
		5%	-2.98	-2.95	-8.1	-1.98	0.23	3.17	-1.95	-3.96	0.739
		10%	-2.63	-2.61	-5.7	-1.62	0.28	4.45	-1.61		0.463
M1	yes	Test stat	-3.28+	-4.93*	-3.07	-1.20	0.39	28.76	-1.32	-3.21	0.093
		5%	-3.59	-3.54	-17.3	-2.91	0.168	5.48	-3.19	-3.72	0.146
		10%	-3.23	-3.20	-14.2	-2.62	0.185	6.67	-2.89		0.119
M2	yes	Test stat	-1.77	-3.72*	-49.17*	-4.95*	0.10*	1.88*	-3.29+	-2.66	0.139+
		5%	-3.58	-3.54	-17.3	-2.91	0.17	5.48	-3.77	-4.24	0.146
		10%	-3.22	-3.20	-14.2	-2.62	0.19	6.67	-3.19		0.119
Int	Yes	Test stat	-1.93	0.11	-10.59	-2.30	0.22	8.61	-2.06	-3.45	0.111
		5%	-3.54	0.15	-17.3	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.20	0.12	-14.2	-2.62	0.19	6.67	-2.89		0.119
Exch	No	Test stat	-1.14	-1.14	-2.78	-1.06	0.38	8.43	-1.14	-4.15	0.201
		5%	-2.95	-2.95	-8.1	-1.98	0.23	3.17	-1.95	-4.24	0.463
		10%	-2.61	-2.61	-5.7	-1.62	0.28	4.45	-1.61		0.347

See above for notes. * = null hypothesis can be rejected at 5% level; + = null can be rejected at 10% level

Appendix Table B3. Unit root tests: Kazakhstan

	Trend included in tests?		Level								
			H0: Variable has unit root								H0: variable is stationary
			ADF	Phillips-Perron	Ng-Perron MZa	Ng-Perron MZt	Ng-Perron MSB	Ng-Perron MP	DF-GLS (ERS)	Perron test for break	KPSS
Y	yes	Test stat	-1.78	-2.64	-6.41	-1.78777	0.28	14.2153	-1.99101	- 7.23*	0.189*
		5%	-3.56	-3.55	-17.30	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.21	-3.21	-14.20	-2.62	0.19	6.67	-2.89		0.119
P	yes	Test stat	-3.21+	-6.01*	-5.18	-1.49	0.29	17.01	-1.56196	- 3.55	0.167*
		5%	-3.55	-3.55	-17.30	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.21	-3.21	-14.20	-2.62	0.19	6.67	-2.89		0.119
M1	yes	Test stat	-2.73	-1.95	-32.20*	-3.98*	0.12*	3.02*	-2.95+	- 4.50*	0.143+
		5%	-3.56	-3.55	-17.30	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.21	-3.21	-14.20	-2.62	0.19	6.67	-2.89		0.119
M2	yes	Test stat	-3.39+	-2.08	-41.86*	-4.57*	0.11*	2.20*	-3.04+	na	0.110
		5%	-3.61	-3.59	-17.30	-2.91	0.17	5.48	-3.19		0.146
		10%	-3.24	-3.23	-14.20	-2.62	0.19	6.67	-2.89		0.119
Int	yes	Test stat	-3.40	-15.73*	-1.67	-0.80	0.48	44.93	-1.65	na	0.174*
		5%	-4.34	-3.55	-17.30	-2.91	0.17	5.48	-3.19		0.146
		10%	-3.59	-3.21	-14.20	-2.62	0.19	6.67	-2.89		0.119
Exch		Test stat	-1.97	-1.70	-10.50	-2.21	0.21	9.06	-2.10	- 3.94	0.095
		5%	-3.55	-3.55	-17.30	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.21	-3.21	-14.20	-2.62	0.19	6.67	-2.89		0.119

See above for notes. * = null hypothesis can be rejected at 5% level; + = null can be rejected at 10% level

Appendix Table B4: Unit root tests: BELARUS

	Trend included in tests?		Level								H0: variable is stationary
			H0: Variable has unit root								
			ADF	Phillips-Perron	Ng-Perron MZa	Ng-Perron MZt	Ng-Perron MSB	Ng-Perron MP	DF-GLS (ERS)	Perron test for break	KPSS
Y	yes	Test stat	-2.73	-4.06*	-25.92*	-3.59*	0.14*	3.58*	-3.29*	- 5.66*	0.130+
		5%	-3.57	-3.55	-17.3	-2.91	0.17	5.48	-3.19	- 4.24	0.146
		10%	-3.22	-3.21	-14.2	-2.62	0.19	6.67	-2.89		0.119
P	yes	Test stat	-2.31	-1.27	-10.34	-2.19	0.21	9.22	-2.32	- 2.05	0.106
		5%	-3.55	-3.55	-17.3	-2.91	0.17	5.48	-3.19	-4.24	0.146
		10%	-3.21	-3.21	-14.2	-2.62	0.19	6.67	-2.89		0.119
M1	no	Test stat	-0.91	-1.20	-4.49	-1.28	0.29	5.82	-0.42	- 1.84	0.689*
		5%	-2.96	-2.95	-8.10	-1.98	0.23	3.17	-1.95	-3.72	0.463
		10%	-2.62	-2.61	-5.70	-1.62	0.28	4.45	-1.61		0.347
M2	yes	Test stat	-3.35+	-1.11	-0.51	-0.31	0.59	74.02	-4.14*	- 2.80	0.113
		5%	-3.59	-3.55	-17.3	-2.91	0.17	5.48	-3.19	-3.72	0.146
		10%	-3.23	-3.21	-14.2	-2.62	0.19	6.67	-2.89		0.119
Int	no	Test stat	-2.09	-2.31	-4.78	-1.52	0.32	5.18	-1.21	- 3.20	0.178
		5%	-2.96	-2.95	-8.1	-1.98	0.23	3.17	-1.95	-3.96	0.463
		10%	-2.62	-2.61	-5.7	-1.62	0.28	4.45	-1.61		0.347
Exch	yes	Test stat	-2.05	-3.02	-7.58	-1.92	0.25	12.07	-1.80	- 3.25	0.110
		5%	-3.56	-3.55	-17.3	-2.91	0.17	5.48	-3.19	-3.72	0.146
		10%	-3.21	-3.21	-14.2	-2.62	0.19	6.67	-2.89		0.119

See above for notes. * = null hypothesis can be rejected at 5% level; + = null can be rejected at 10% level