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The Output-Inflation Nexus in Ukraine:
Is there a Trade-off?

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Abstract

This paper examines whether expansionary credit policy can help sustain output growth in transition economies, with particular reference to Ukraine's experience since 1992. We find that, while *real* credit growth is indeed associated with higher output growth, an increase in the growth rate of *nominal* credit does not, in general equilibrium, stimulate output growth. Following a short-lived boom — caused by falling real wages — the increase in the growth rate of nominal credit leads to a *decline* in the level of output.

JEL Classification Numbers: E51, E52, C51

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Summary

Most countries embarking on the transition from planned to market economies have suffered steep, at times, precipitous declines in recorded output. Their experience has led many observers to question whether macroeconomic policy — particularly monetary policy — might not have been better directed at reducing the decline in output. This is particularly true of Ukraine, where industrial production fell by as much as 40 percent between 1992 and 1994, and real GDP declined by 35 percent over the same period. Against this background, this paper examines whether expansionary credit policy can help sustain output growth in transition economies, with particular reference to Ukraine's experience since 1992. The paper establishes a strong link between real credit growth and industrial output growth, with elasticities ranging from 0.2 to 1.1.

But real credit growth is not a policy variable — only nominal credit is under the control of the monetary authorities. In order to determine the general equilibrium effects on output of nominal credit growth, the paper develops a structural model of the Ukrainian economy. Using this model, it is found that an increase in the growth rate of nominal credit leads to a small increase in output growth during second month following the policy change. 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 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

I: Introduction

Most countries embarking upon the transition from planned to market economy suffered steep, at times precipitous, declines in recorded output. Their experience lead many to question whether macroeconomic policy — particularly monetary policy — could not have been better directed at ameliorating the output decline. While some countries have now weathered the output collapse — and several are enjoying robust growth — others appear mired in economic depression and stagnation. For these countries, the debate on the appropriate course of monetary policy remains both relevant and controversial.

Nowhere is this more true than in Ukraine, which saw its industrial production fall by as much as 40 percent between 1992 and 1994, and its real GDP decline by almost 35 percent over the same period. Concomitantly, inflation rates were extraordinarily high and volatile, at times bordering upon hyperinflation, and reaching more than 10,000 percent in 1993 and 400 percent in 1994. Confronted by this economic crisis, the government of Ukraine launched a comprehensive economic stabilization and reform program in late 1994. Although significant headway was made on lowering inflation, the continued decline of output — albeit at much slower rates than in previous years — sparked a heated debate within Ukraine about the appropriate course and objectives of macroeconomic policy. Critics of the current stabilization program attribute the fall in output to restrictive monetary policies and argue for a "correction" of monetary policy towards greater credit expansion as a means of boosting output. Proponents of the stabilization program argue that there is effectively no output-inflation trade-off, and that the arrest in the decline of output will only come about once macroeconomic stability has been achieved.

While the experience of other transition economies tends to support the latter view, most empirical studies are broad-brush panel data analyses of the reduced-form relationship between output and credit policy. This paper examines the specific mechanisms through which monetary policy can work in transition economies, using the illustrative — if extreme — example of Ukraine.

Our main conclusions may be summarized briefly. Section II establishes a strong link between (lagged) *real* credit growth from the banking system to the economy, and the growth rate of industrial production. Slightly more than one-half of industrial production appears to be sensitive to real credit growth, with elasticities ranging from 0.2 to 1.1. For industrial production as a whole, the elasticity is 0.4. Conversely, increases in real wages reduce industrial production, as do increases in real gas prices. Similar conclusions hold when real GDP is used instead of industrial production as the measure of output.

But of course, *real* credit growth is not a policy instrument: the authorities can, at best, influence *nominal* credit growth. Since an increase in the growth rate of nominal credit will affect prices, wages, and the exchange rate, determining the *general equilibrium* impact on output requires a full structural model. Section III presents econometric estimates of such a model. As the key macro variables in Ukraine are highly non-stationary, and are poorly captured by deterministic trends, particular emphasis is laid upon adequate modelling of the time-series properties of the stochastic processes.

Section IV uses this model to simulate the effect of a temporary increase in the *growth* rate of credit to the economy. The model suggests that a 10 percentage point increase in the growth rate of nominal credit during one month would, in the second month following the policy change, raise the growth rate of output by 1.7 percentage points. Thereafter, output declines sharply; so much so, that during the third and fourth months the *level* of output falls below its original level. Finally, output returns to roughly its original level.

The "recession" during the third and fourth months wipes out the output gain during the second month so that a policy of increasing credit growth in order to stimulate output is likely to prove self-defeating. Moreover, the increase in the growth rate of output during the second month comes from an unexpected source. The dynamics of the model imply that it is *not* the direct effect of real credit growth which boosts output. Rather, the stimulative effects of expansionary credit on output are at the expense of *real wages*, which decline following an increase in nominal credit. The paper concludes that increasing the growth rate of nominal credit is deleterious for output growth, and indeed was probably an important factor underlying the collapse in output during 1993 and 1994.

II: The Scope and Nature of the Output Decline

During the process of economic transformation it is perhaps inevitable that some sectors will need to contract while — if reform is successful — other sectors should expand. In Ukraine, however, the decline of industrial production has been virtually across the board, with none of the industrial sectors showing positive growth, either in 1994 or in 1995[1]. With the exception of natural gas production, which showed very modest declines in both 1994 and 1995, industrial production fell at rates ranging from 12 percent to almost 50 percent in 1994, and from 5 percent to 35 percent in 1995[2]. Particularly afflicted have been light industry, machine building, construction and — especially in 1993 — both ferrous and non-ferrous metallurgy. In total, industrial production fell by 28 percent in 1994, and by 14 percent during first ten months of 1995.

[1] A panel regression of (monthly) sectoral growth rates on time dummies and on individual industry intercepts shows that the later account for almost none of the observed variation. As argued by Borensztein, Demekas, and Ostry (1993) this provides some prima facie evidence that the decline in output is not related to restructuring of the economy.

[2] The figures for 1995 are for January-October and are relative to January-October 1994.

The evolution of total industrial production, and some of the key branches of industry, over the past three years is illustrated in chart 1. Industrial production in Ukraine typically exhibits some seasonality: most branches show a low level of activity at the beginning of the year, a sharp pick-up at the end of the first quarter, and another peak at the end of the third quarter. This seasonal pattern is particularly pronounced for food processing, which ranges from 22 percent of total industrial production in January to almost 30 percent of industrial production in September. As discussed below, in recent years part of this apparent seasonality also stems from monetary policy which was very expansionary at the end of the third quarter and the beginning of the fourth quarter and was then tightened significantly in the first quarter of the following year. This pattern of monetary policy was seen in 1993 and, albeit to a much lesser extent, in 1994 as well.

The factors underlying these observed declines are manifold. Ukraine's industrial products suffered from a sharp fall in demand — domestic, as real incomes fell, and external, as the break-up of the Soviet Union disrupted previous commercial relations and trade patterns. While changing demand undoubtedly played an important role, its effect is not easy to quantify and, at least for the domestic component, is difficult to disentangle from the output decline itself. The trend of declining output engendered by these developments has been exaccerbated by generally slow structural reforms. Until late 1994, price controls were pervasive, export controls — including compulsory surrender at a substantially overvalued exchange rate and quotas and licenses — were rife; and there had been virtually no headway made on privatization of the industrial sector. Again, the quantitative impact of these structural factors is difficult to determine, although qualitatively it seems clear that they have retarded growth.

At the same time, industrial enterprises started facing tighter credit conditions in an environment in which prices for inputs were often increasing more rapidly than output prices. Externally, this corresponded to the substantial terms of trade shock suffered by Ukraine as energy prices were raised to world levels[3]. More importantly, real credit growth became highly variable, ranging from 10 percent to -50 percent per month, as inflation eroded bouts of extraordinary credit expansion. While not depreciating the role of demand shocks and structural impediments to growth, this paper focuses on the impact of increasing costs, and the gyrations of real credit, on output growth in Ukraine.

To understand why real credit growth has been so important in determining industrial activity, it is useful to consider a stylized model of the "typical" enterprise[4].

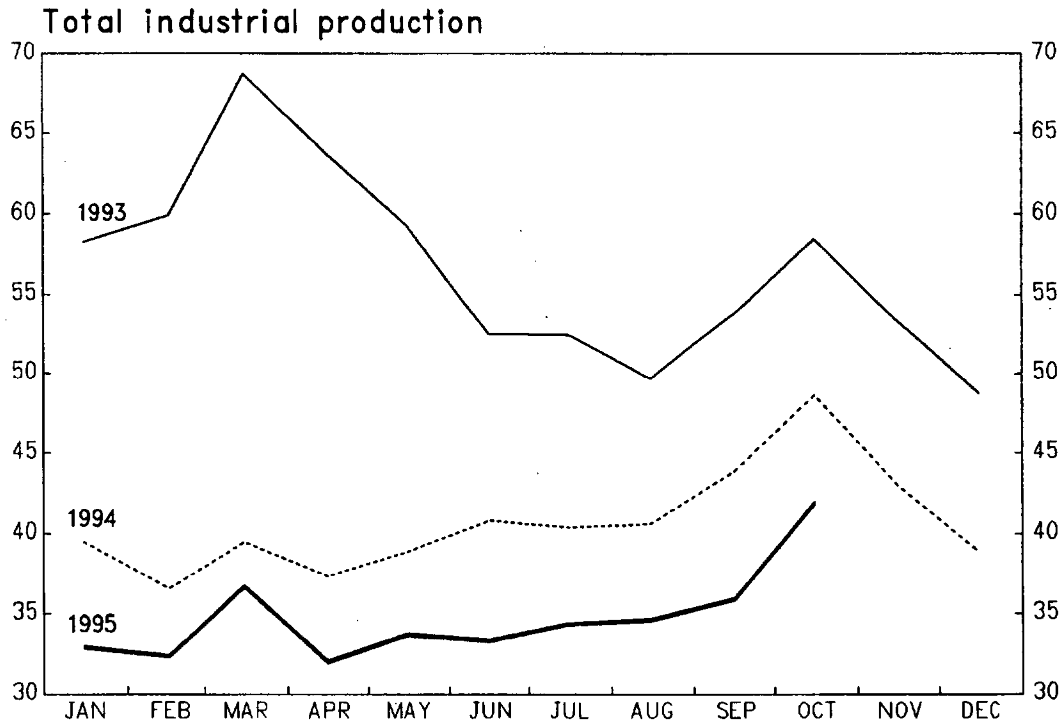
[3] There were considerable delays, however, in passing through the higher energy costs to enterprises and, *a fortiori*, to households. Until November 1994, gas was valued at an overvalued exchange rate and at a border dollar price which was below the world price (the lower dollar price was charged by Russia in lieu of payment of transit fees for Russian gas exports to Western Europe). Effective March 1995, industrial users pay the world price of gas, valued at market exchange rates.

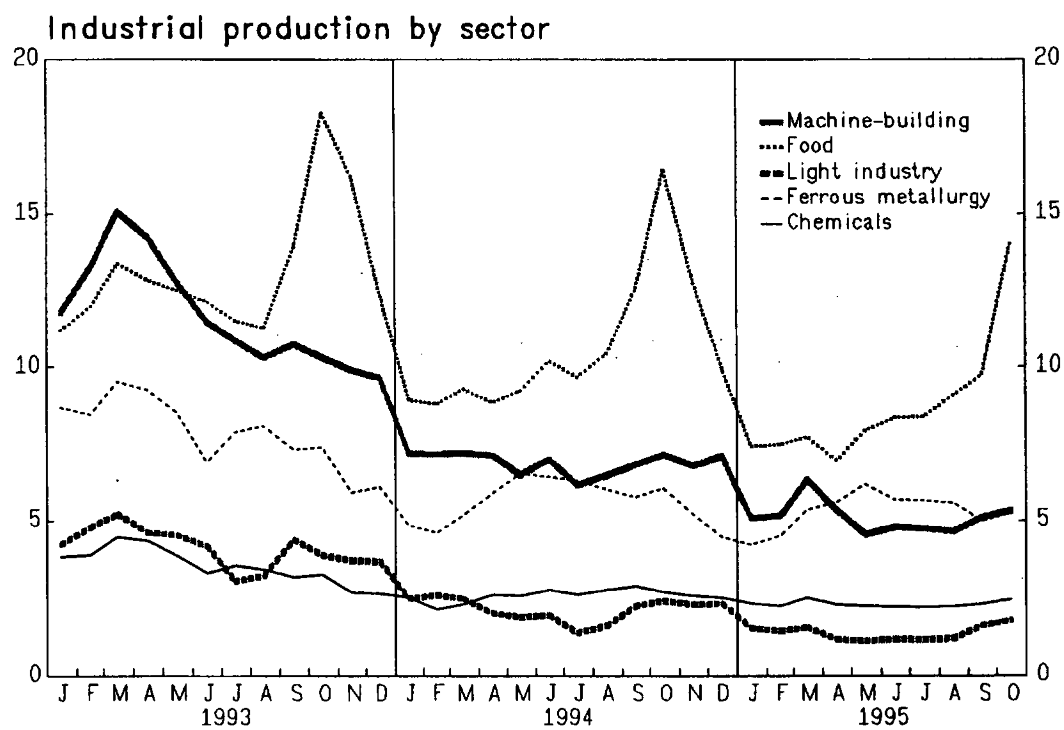
[4] This description is based upon Sundakov [1995]; Calvo and Kumar [1994] articulate a model of bank credit and enterprise performance in former socialist economies.

CHART 1

Industrial Production

(In prices of January 1, 1994; in Krb tln.)





Source: Ukrainian authorities.

As discussed in IMF [1996], the current legal framework in Ukraine implies that the enterprise has little say in the allocation of its existing assets (including the disposal of unproductive assets). Accordingly, an enterprise might be thought of as a collection of assets devoted to a particular purpose — maximal production of specific goods within the financing constraints, and the objective of providing employment to the incumbent work force[5]. Expenditure on current inputs, px, and wages, wL, must be financed by borrowing dC, incurring arrears, dA, or selling the stock of output produced previously, q_{-1}:

$$px + wL = dA + dC + pq_{-1}$$

If production is subject to a technology $q = f(x)$, $f_x > 0, f_{xx} < 0$ then output is given by:

$$q^s = f(\frac{dA}{p} + \frac{dC}{p} + q_{-1} - \frac{wL}{p})$$

There is thus a positive relationship between real credit expansion, dC/p, and output, and a negative relationship between real wages and output supply. For closure, a demand function is required. Assuming that demand is a function of real income: $q^d = g(wL/p)$, and imposing $q^s = q^d$, yields a simple model determining output and real wages as a function of real credit and real arrears[6].

The empirical importance of real credit as a determinant of output has been discussed by Calvo and Coricelli [1993] who examine the experience of 5 Eastern European countries during the early phases of their transition period (1990 to 1991)[7] . They argue that the availability of real credit is likely to become a binding constraint (even though the firm is viable) in an environment in which there are positive profit tax rates or faster growth rates of input prices than output prices. They estimate a statistical relationship between real credit and output growth for Poland. Depending upon the exact specification, they find real credit elasticities ranging from 0.2 to 0.6[8]

Chart 2 illustrates the evolution of nominal and real banking system credit to the economy in Ukraine over the period 1993-1995. During 1993 there were two sharp spikes in the growth rates of nominal credit to the economy, in March and in September, corresponding to financing needs for spring planting, and the procurement and processing of the harvest. Thereafter, there was a sharp fall in the growth rate of

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5 The goal of workers in enterprises appears to be preserving employment rather than raising real wages. Models of "excess wage claims" (e.g. Milesi-Ferretti [1992]) are, therefore, less relevant to Ukraine.

6 In what follows, we focus on real credit as the main determinant. Although arrears are certainly an important source of financing, it is hard to establish a strong correlation between output growth and arrears. This probably reflects limitations of the available data arising from imprecise accounting rules regarding the booking of arrears, a lack of distinction between flows and capitalization of existing arrears, and sproadic netting and clearing operations.

7 See Bofinger [1993] for a discussion of their results.

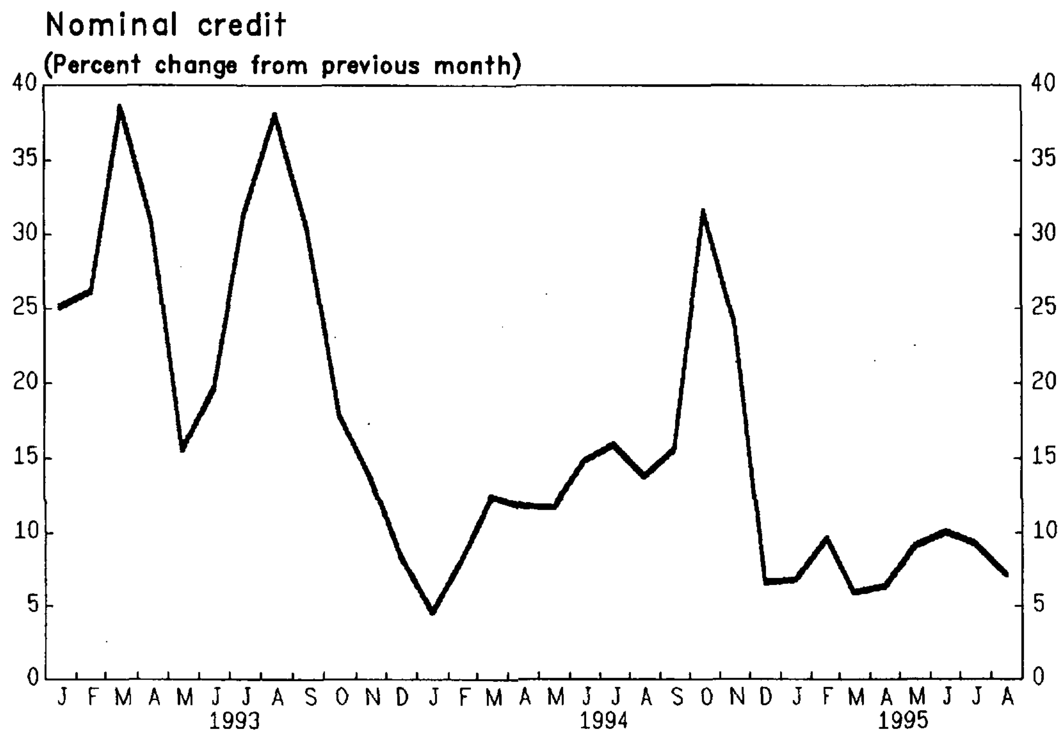
8 Their results cannot be compared directly to those presented below, however, because in their regressions Calvo and Coricelli do not control for other factors.

Table 1: Industrial Production by Branch

Branch	Growth rates 1994	Growth rates 1995	Share of industry
Energy	-12.4	-5.9	10.1
Fuel	-17.3	-15.0	13.7
Oil	-16.4	-13.5	11.1
Oil processing	-18.4	-16.1	9.7
Gas	-1.2	-2.8	0.7
Coal	-21.7	-16.0	2.5
Ferrous metallurgy	-28.3	-8.0	12.3
Non-ferrous	-24.2	-4.2	1.5
Chemicals	-26.3	-10.9	6.5
Machine building	-41.2	-25.5	18.2
Wood	-35.2	-19.6	3.0
Construction	-34.2	-25.7	3.8
Light	-47.5	-35.3	6.4
Food processing	-19.3	-16.5	22.7
Other	-22.6	-11.6	0.9
Total	**-28.1**	**-14.4**	**100.0**

CHART 2

Banking System Credit to Economy



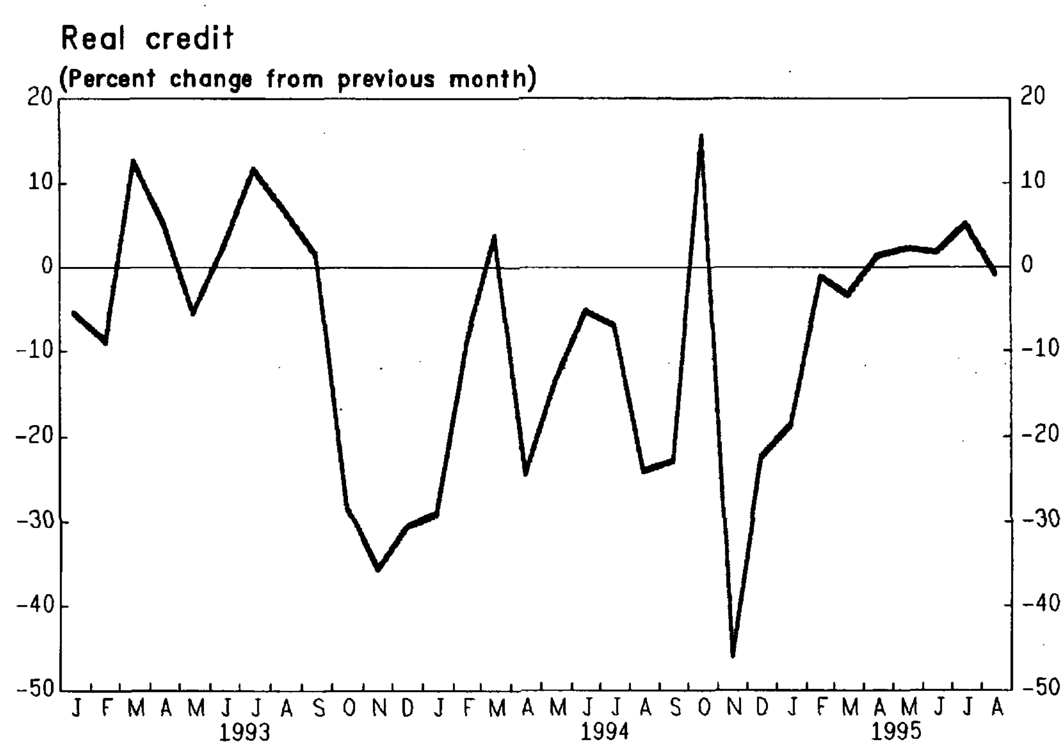


Table 2: Shares of Credit to Industry

Branch	Share
Power	7.1
Metallurgy and machine buildng	45.0
Light industry	12.7
Food processing	21.0
Other	14.1

nominal credit at the end of the year and at the beginning of 1994. The pattern was somewhat different during 1994, with a steady increase in the growth rate of credit throughout the year, peaking in October (when the monthly growth rate exceeded 30 percent) followed by a sharp fall towards the end of the year as the stabilization program was launched. In 1995 credit growth has been much more stable, and the seasonal pattern significantly muted.

Table 2 gives the breakdown, by different branches of industry, of industry's share of credit to the economy (which itself ranges from about 20 to 40 percent of total credit to the economy, with the remainder taken by agriculture, 10 percent; "other material sphere" — mainly defence related industries, 30 percent; and services, 20 percent). Food processing, and machine building and metallurgy, receive the largest share of credit to industry, and almost 6 and 12 percent respectively of total credit to the economy.

The second panel of chart 1 shows the evolution of real credit to the economy, where the nominal stocks have been deflated by the industrial production price deflator. Corresponding to the surges in nominal credit in 1993, real credit shows two spikes as well. By end-year, however, inflation caught up, and there was a very sharp contraction of real credit to the economy: in October real credit was falling at a monthly rate of 30 to 40 percent. These negative real rates of growth continued through much of 1994 with March and October being the only months during which real credit growth was positive. Again, the expansionary excesses during the summer eroded real credit at the end of the year, this time by as much as 50 percent in a single month. Following the first month of the stabilization program, the growth of real credit, though still negative, started increasing rapidly. Since March 1995, real credit growth has been modest, though generally positive.

Beyond the availability of real credit, the production costs incurred by the enterprise are likely to be important determinants of profitability and production. Two such costs are examined here. The first is the (producer) real wage. Changes in the real wage, if matched by corresponding increases in productivity, would not be associated with a decrease in profits or of real GDP. More typically, however, nominal wages might increase because of consumer price inflation or other wage bargaining factors, and the corresponding change in real producer wages might bear little relation to changes in productivity. The second is the cost of imported inputs, the most important of which is probably natural gas. Such cost increases naturally have a direct bearing on the profitability of enterprises.

How have these gyrations in real credit and changes in enterprise costs affected output? Table 3 reports the coefficient estimates, by branch, of a regression of output growth on growth rates of real credit to the economy, real wages, and real gas prices[9]:

$$\hat{q}_t = \beta_0 + \beta_1(\hat{c}^e_{t-1} - \hat{p}_{t-1}) + \beta_2(\hat{w}_{t-1} - \hat{p}_{t-1}) + \beta_3(\hat{p}^g_{t-1} + \hat{e}_{t-1} - \hat{p}_{t-1}) + v_t$$

where c^e is credit to the economy, p is the deflator, w is the wage rate, p^g is the price of gas in dollars, and e is the relevant exchange rate, and where, for any variable z_t, $\hat{z}_t \equiv \log(z_t) - \log(z_{t-1})$. This specification assumes that there is a one period lag in the effects of these variables; alternative specifications do not yield statistically significant coefficients.[10] The sample period is 1993:2 to 1995:9 (32 observations), heteroskedastic-consistent t-statistics are reported in parentheses with asterisks denoting significance at the 10, 5, and 1 percent levels; constants and seasonal dummies are not reported.

While the energy related sectors do not appear to depend upon real credit growth, machine building, wood work, construction, light industries, food processing, and other miscellaneous branches all appear to be highly sensitive to real credit growth. All together, these branches account for slightly more than one-half of Ukraine's industrial production. Taking industrial production as a whole, the real credit elasticity is estimated to be 0.37, and is highly statistically significant. These industries — which represent the more labor-intensive branches of industry — are also vulnerable to real wage increases, with elasticities ranging from -0.21 to -0.86. For total industrial production, the elasticity of output with respect to an increase in the real wage is -0.17 and is, again, statistically significant. Increases in real gas prices affect a wide range of industries, although the elasticity of total industrial production with respect to real gas price increases is only -0.08.

The results are suggestive: according to the econometric estimates, an increase in real credit growth can indeed help sustain output growth. But before concluding that monetary policy could be used to boost output and activity, it is important to recognize that real credit growth is not a policy instrument, only nominal credit growth can be controlled by the authorities. And in a dynamic context, the right hand side variables are themselves endogenous and are likely to be functions of credit policy[11].

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[9] The regressors are the same for each branch because time series on credit by branch are not available. Likewise, the wage rate used is the average for the industrial sector of the economy.

[10] Contemporaneous changes in real credit, real wages, or real gas prices are insignificant (whether one uses instrumental variables for endogeneity, or not) as are lags of more than one period.

[11] The regressors do not enter contemporaneously and therefore there is no econometric endogeneity problem in estimating the regression.

Table 3: Regression of industrial production growth on growth rates of real credit, real wages, and real gas prices

Branch	Real credit β_1	t_{β_1}	Real wage β_2	t_{β_2}	Real gas price β_3	t_{β_3}	R^2
Energy	0.28	(1.13)	-0.13	(0.90)	-0.03	(0.66)	0.56
Fuel	0.13	(0.39)	-0.19	(1.84*)	-0.22	(2.60**)	0.36
Oil	0.27	(0.65)	0.13	(1.02)	-0.29	(-2.71**)	0.31
Oil processing	0.37	(0.73)	0.11	(0.66)	-0.35	(2.68**)	0.29
Gas	0.01	(0.07)	0.02	(0.42)	-0.05	(2.00)	0.18
Coal	-0.09	(0.09)	0.12	(1.28)	-0.06	(3.52***)	0.40
Ferrous	0.28	(1.07)	-0.06	(0.42)	-0.07	(1.80*)	0.18
Non-ferrous	0.10	(0.40)	-0.06	(0.50)	-0.07	(1.18)	0.15
Chemicals	0.17	(1.16)	0.00	(0.13)	-0.05	(1.19)	0.21
Machine building	0.40	(2.62**)	-0.26	(3.58***)	-0.04	(1.19)	0.32
Wood	0.24	(1.65*)	-0.24	(3.00***)	-0.02	(0.48)	0.25
Construction	0.48	(2.47**)	-0.21	(2.17**)	-0.07	(2.01*)	0.32
Light	0.45	(2.48**)	-0.47	(4.90***)	-0.03	(0.54)	0.43
Food processing	0.59	(2.16**)	-0.27	(1.86*)	-0.10	(1.76*)	0.30
Other	1.14	(2.33**)	-0.86	(3.17***)	-0.04	(0.31)	0.44
Total	0.37	(2.27**)	-0.17	(2.05**)	-0.08	(2.73**)	0.34

Accordingly, in order to determine the general equilibrium effects of nominal credit growth on output and on activity, a full structural model of the economy must be specified.

III: A Simple Econometric Model

The rapidly changing structure of the Ukrainian economy, together with the scarcity of reliable data, precludes a very detailed econometric analysis. Nonetheless, it is possible to sketch out some key relationships of the economy. Since most economic time series are non-stationary, it is convenient, and indeed customary, to work in terms of first differences (or, when the data have been transformed into logarithms, in growth rates) of the variables. Yet economic theory should impose restrictions upon the *long-run* relationships between different variables and not simply upon the *short-run* dynamics. An analysis which ignores the restrictions on the *levels* of the individual time-series thus fails to test some of the implications of the economic theory. More importantly, the existence of a long-run relationship implies that the short-run dynamics cannot be independent of the instantaneous deviation of the variables from their long-run equilibrium. Technically, therefore, a regression estimated in first differences alone will suffer from omitted variable bias because it omits the "error-correction" term[12]. These error correction terms, moreover, can significantly affect the dynamic behavior of the structural model as a whole.

The econometric model outlined below draws on the theoretical model of section II. Output supply depends upon real wages, real credit, and real input prices. Output demand is determined by real wages[13]. Together these two equations determine the level of output and the real wage. Nominal wages, producer and consumer prices, and

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[12] Suppose that two variables, x and y, are individually I(1), (that is, they must be differenced once to be stationary), and that they have some long-run relationship given by:

$$y_t = \alpha_0 + \alpha_1 x_t + \epsilon_t$$

where ϵ is a stationary error term. Such a regression is called a co-integrating regression. The short-run dynamics between x and y must be of the form:

$$\Delta y_t = \beta_0 + \beta_1 \Delta x_t + \beta_2 \epsilon_{t-1} + u_t$$

where ϵ is the error term from the co-integrating regression, and where the coefficient β_2 should be negative. The term ϵ_{t-1} is known as the *error-correction* term. The interpretation of β_2 is straight-forward: if y is above its long-run relationship with x (so that ϵ is positive) then y should, *ceteris paribus*, tend to decrease (Δy is negative) for the long-run relationship to be preserved. This implies that a standard regression estimated in first-differences:

$$\Delta y_t = \beta_0' + \beta_1' \Delta x + u_t$$

will suffer from omitted variable bias, and the coefficients β_0' and β_1' will be biased estimates of the true parameters β_0 and β_1.

[13] Since output supply depends upon lagged real wages, the instantaneous supply-curve is vertical, and the demand function essentially determines the real wage.

the exchange rate are determined by ancillary equations.

1. Output

The econometric evidence presented above suggests three key determinants of industrial production or real GDP: real credit to the economy, real wages, and real gas prices (or other imported inputs). As table 4 shows, the null hypothesis of a unit root cannot be rejected for any of these variables.

The long-run relationship between real GDP, real credit, real wages and real gas prices may be written:

$$\log(q_t) = \alpha_0^1 + \alpha_1^1 \log(c_{t-1}^e/p_{t-1}) + \alpha_2^1 \log(w_{t-1}/p_{t-1}) + \alpha_3^1 \log(p_{t-1}^g e_{t-1}/p_{t-1}) + \epsilon_t^1 \quad (1)$$

where q_t is industrial production (or real GDP), c_t^e is banking system credit to the economy, p_t is the price index (industrial production deflator or GDP deflator), w_t is the average wage, p_t^g is the price of gas, and e_t is the exchange rate (the price of foreign currency).

The coefficients are reported in table 5 as equation (1) for the parameter estimates using real GDP and as equation (1') for the parameter estimates using total industrial production. The results are broadly consistent with those obtained above (estimated in growth rates). The long-run real-credit elasticity of real GDP is estimated to be 0.18 while the real-credit elasticity of industrial production is estimated to be 0.28. Increases in real wages reduce output and GDP as do increases in real gas prices. Not surprisingly, the impact on real GDP of an increase in real wages is smaller than the corresponding impact on industrial production; the effects of an increase in real gas prices are roughly the same.

Since the variables in (1) are non-stationary, the t-statistics on the individual coefficients are "spurious" in the sense of Engle and Granger [1987]. Equation (1), however, defines a co-integrating relationship and the existence of this co-integrating vector may be tested using a variety of methods. In table 4, two test statistics are reported: the co-integrating Durbin Watson statistics (CRDW) and the augmented Dickey-Fuller statistic (ADF).[14] Both statistics reject the null of no co-integration at the 5 percent level, or better.

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[14] The CRDW test rejects no co-integration (finds a co-integrating relationship) if the Durbin Watson statistic is sufficiently positive. The ADF test is a test of the stationarity of the error term from the co-integrating regression, with one lagged term in the regression (this lag, and all higher ones, were statistically insignificant). Critical values at significance level p are calculated from:

$$\Phi(p) = \phi_\infty^p + \phi_1^p/T + \phi_2^p/T^2$$

where $\phi_\infty^p, \phi_1^p, \phi_2^p$ depend upon the number of variables in the co-integrating regression and are taken from MacKinnon [1991] (see Banerjee et al. [1993], p. 213).

Table 4: Unit Roots and Co-integration Tests

Variable or Eqn.	ADF	CRDW
Variable		
$\log(q_t)$	-1.38	—
$\log(w_t/p_t)$	-0.35	—
$\log(e_t p_t^g/p_t)$	-1.75	—
$\log(m_t/p_t)$	-2.17	—
$\log(p_t)$	-0.25	—
$\log(w_t)$	-1.23	—
$\log(p_t^c)$	-0.33	—
$\log(e_t)$	-1.74	—
Equation		
(1)	-5.76**	1.40**
(1')	-4.10*	1.86**
(3)	-4.31*	1.40**
(3')	-4.38*	2.01**
(5)	-3.08	0.97**
(7)	-2.80	1.81**

Consider, next, the short-run dynamics around the long-run relationship (1). These are defined by:

$$\hat{q}_t = \beta_0^1 + \beta_1^1(\hat{c}_{t-1}^e - \hat{p}_{t-1}) + \beta_2^1(\hat{w}_{t-1} - \hat{p}_{t-1}) + \beta_3^1(\hat{p}_{t-1}^g + \hat{e}_{t-1} - \hat{p}_{t-1}) + \beta_4^1\epsilon_{t-1}^1 + v_t^1 \quad (2)$$

The coefficients of (2) are reported in table 5 where, as before, equation (2') refers to the estimates using industrial production. Comparing the coefficients α_1^1 and β_1^1 shows that real credit has a much larger effect on the short-run dynamics of GDP and industrial production than on the long-run elasticity. The short-run elasticity of real GDP with respect to real credit to the economy is estimated to be 0.49 (and, correspondingly, 0.46 for industrial production) with the effect being highly statistically significant. A one percent increase in real wages lowers real GDP by 0.21 percent and a one percent increase in real gas prices lowers real GDP by 0.11 percent. The effects on industrial production are similar. Finally, it is noteworthy that the coefficient on the residual from the co-integrating regression (β_4^1) is highly statistically significant. The coefficients of (2') may be contrasted to the corresponding regression with this term omitted (that is, a standard regression in growth rates), given in the last line of table 3 above.

Chart 3 shows the long-run trend in real GDP, as well both the actual and fitted dynamics around that trend. It bears emphasizing that the long-run trend here is a *stochastic* trend; that is, the long-run trend, *at any instant*, is that level of output to which the autonomous dynamics would return in the absence of further shocks; the trend itself, however, shifts over time as a function of the right hand side variables of (1). Real GDP was well above its long-run trend between August 1994 and November 1994, thereafter the sharp fall in real credit caused output to collapse to well below its long-run trend, where it remained until May 1995. A similar, though less pronounced pattern is observed for industrial production (chart 4).

2. Money Demand

As discussed above, in a dynamic context, the right hand side variables of (1) are themselves endogenous. In order to examine the general equilibrium effect of an increase in credit to the economy, therefore, the relationships determining $\hat{p}_t$ (the inflation rate of domestic prices), $\hat{w}_t$, and $\hat{e}_t$ must be specified. The equation determining domestic prices is simply a money demand function (which can be inverted to obtain the price level and the inflation rate). Again, it is useful to distinguish between the long-run relationship between real money, real activity and nominal interest rates from the short-run dynamics.

The dynamic properties of the model depend crucially upon the behavior of velocity. Since inflation is a tax on money holdings — which, even for broad money, is seldom adequately compensated by nominal interest rates — it is generally assumed that long-run velocity depends upon the inflation rate. This long-run velocity may be

Table 5: Output Growth Regressions

Coef.	Eqn. (1)	Eqn. (2)	Eqn. (1')	Eqn. (2')
α_1^1	0.18 (2.31**)	—	0.28 (7.81***)	—
α_2^1	-0.17 (1.96*)	—	-0.22 (4.04***)	—
α_3^1	-0.06 (1.31)	—	-0.08 (2.39**)	—
β_1^1	—	0.49 (5.83***)	—	0.46 (3.13***)
β_2^1	—	-0.21 (4.61***)	—	-0.23 (3.38***)
β_3^1	—	-0.11 (3.13***)	—	-0.08 (2.32**)
β_4^1	—	-0.78 (6.29***)	—	-0.48 (1.76*)
R^2	0.53	0.69	0.89	0.34
DW	1.40	2.00	0.85	1.76

CHART 3

Real GDP

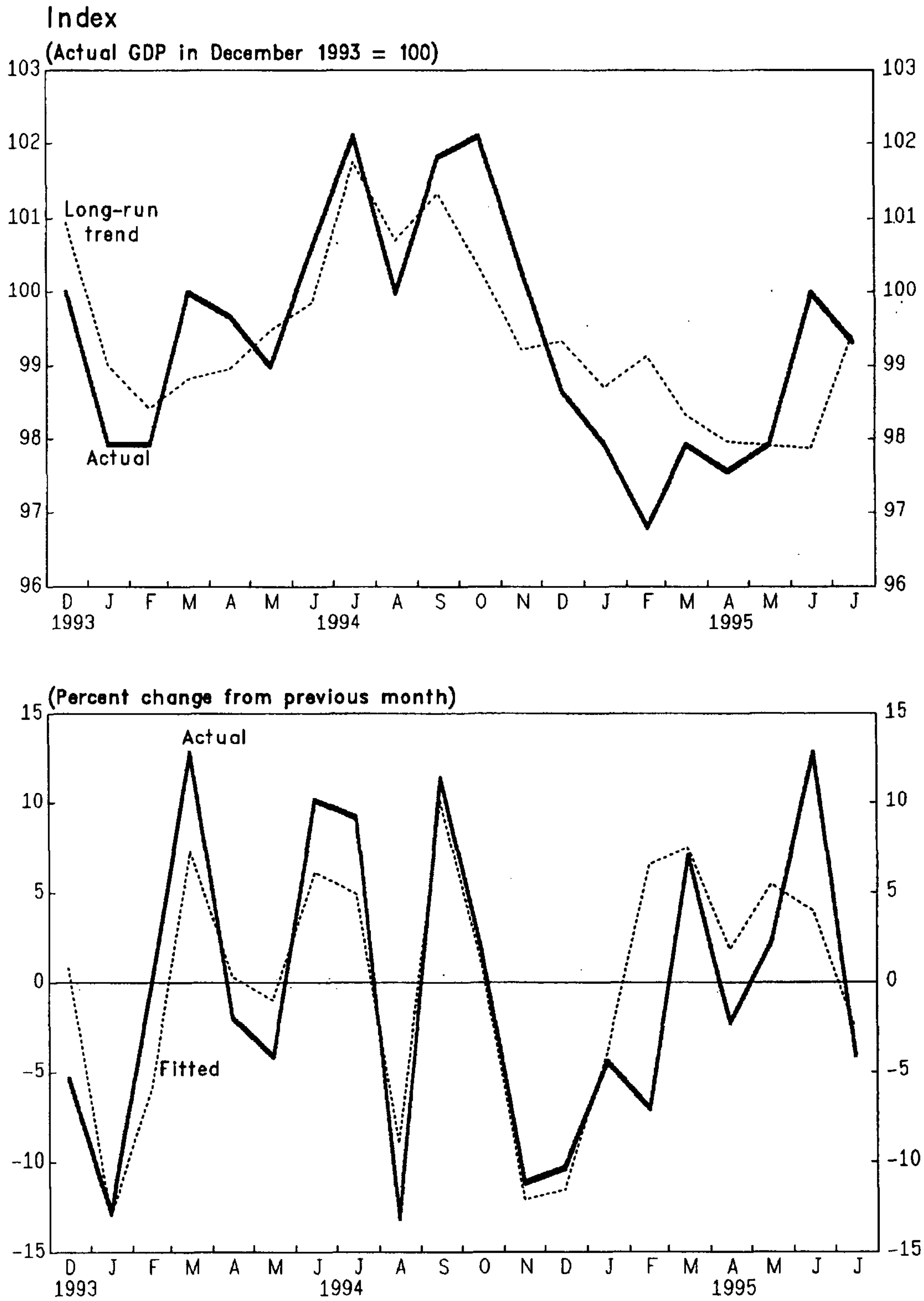
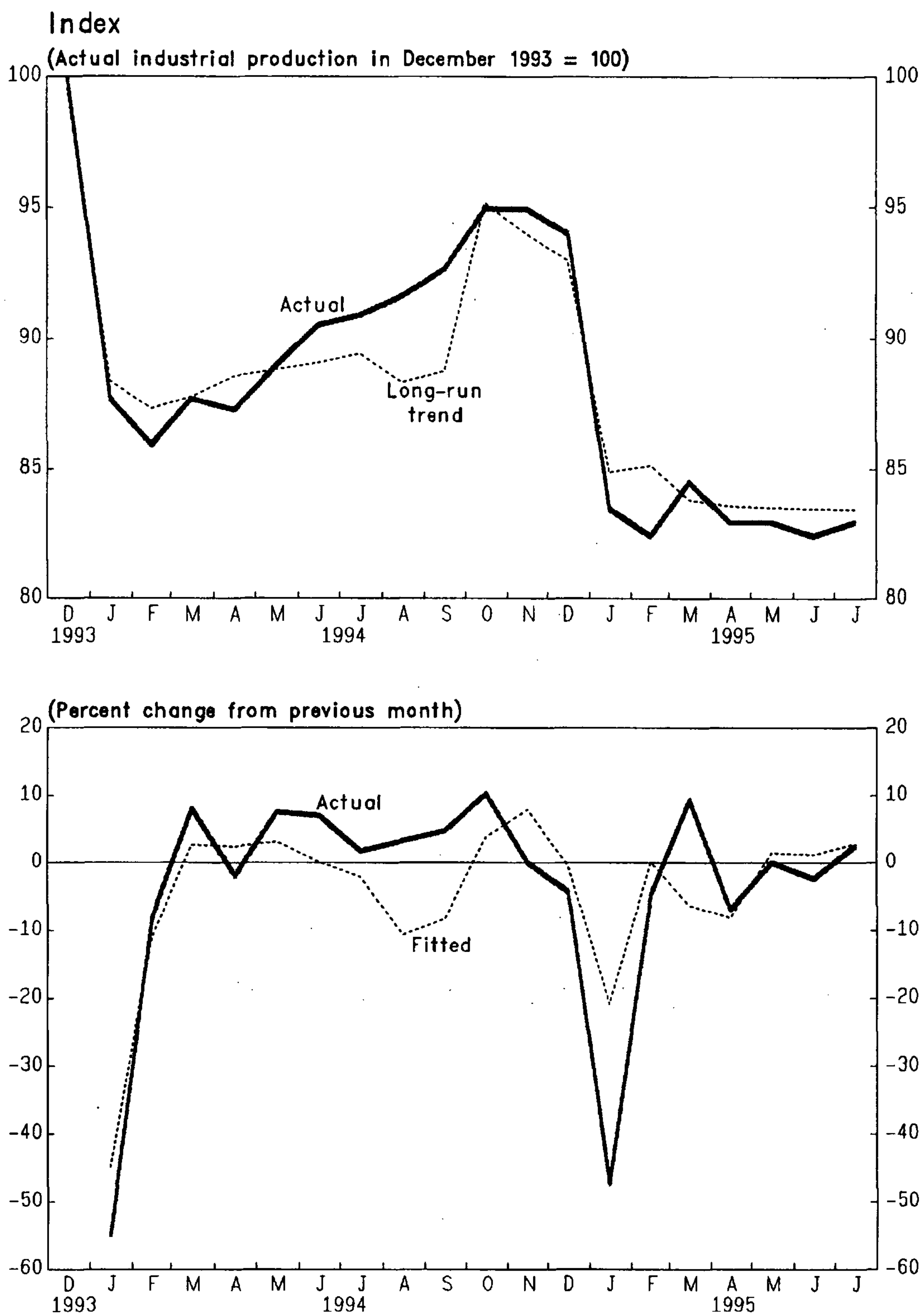


CHART 4

Industrial production



considered a "target" velocity towards which the dynamics of short-run money demand changes will tend. A natural assumption is that velocity depends upon *expected* inflation, where it is standard to assume that expectations are rational. Unfortunately, this assumption receives virtually no empirical support from Ukrainian data. Either expectations are being systematically violated, or perhaps more likely, individuals and enterprises need time to adjust their behavior, so *past* inflation determines the current long-run velocity. Such a relationship may be written:

$$\log(m_t) - \log(p_t) = \alpha_0^2 + \alpha_1^2 \log(q_t) + \alpha_2^2 \log(p_{t-i}^c / p_{t-i-1}^c) + \epsilon_t^2 \tag{3}$$

for some lag i, and where m_t is broad money.

Empirically, we find that the adjustment requires about one quarter, and the only lag which is statistically significant is $t - 4$.[15] Table 6 reports the coefficients (where equation (3') refers to the estimates using industrial production as the activity variable). The point estimate of the output elasticity is 1.51 using real GDP and 1.49 using industrial production. In both cases the coefficients are statistically significant and neither coefficient is significantly different from unity given the estimated standard errors. The coefficient α_2^2 is negative, and highly statistically significant, so that, indeed, past inflation reduces the long-run equilibrium money demand. Cointegration tests are reported in table 4.

The short-run dynamics determine the inflation rate, $\hat{p}_t$, given the growth in nominal broad money, and the growth in real income:

$$\hat{m}_t - \hat{p}_t = \beta_0^2 + \beta_1^2 \hat{q}_t + \beta_2^2 \epsilon_{t-1}^2 + v_t^2 \tag{4}$$

The coefficients are reported in table 6. The output elasticity of money demand is estimated to be 0.84 using real GDP, and 0.76 using industrial production (both are highly statistically significant).

Chart 5 illustrates the behavior of real money over the sample period. One noteworthy feature is the behavior of real money demand during the summer months of 1994. Real money demand was higher than expected, both in terms of the long-run relationship between output and real money and in terms of the short-run dynamics. This seems to be consistent with anecdotal evidence that price controls were being used during this period.

3. Wage Setting Behavior

Real wages in Ukraine fell by more than 40 percent in 1993, followed by a further 16 percent in 1994. In 1995, however, real wages are expected to increase by about 9 percent. Through much of the sample period, an incomes policy limited increases in the nominal wage bill of enterprises to 80 percent of projected inflation for the current month. During periods of unexpectedly high or low inflation, the policy was

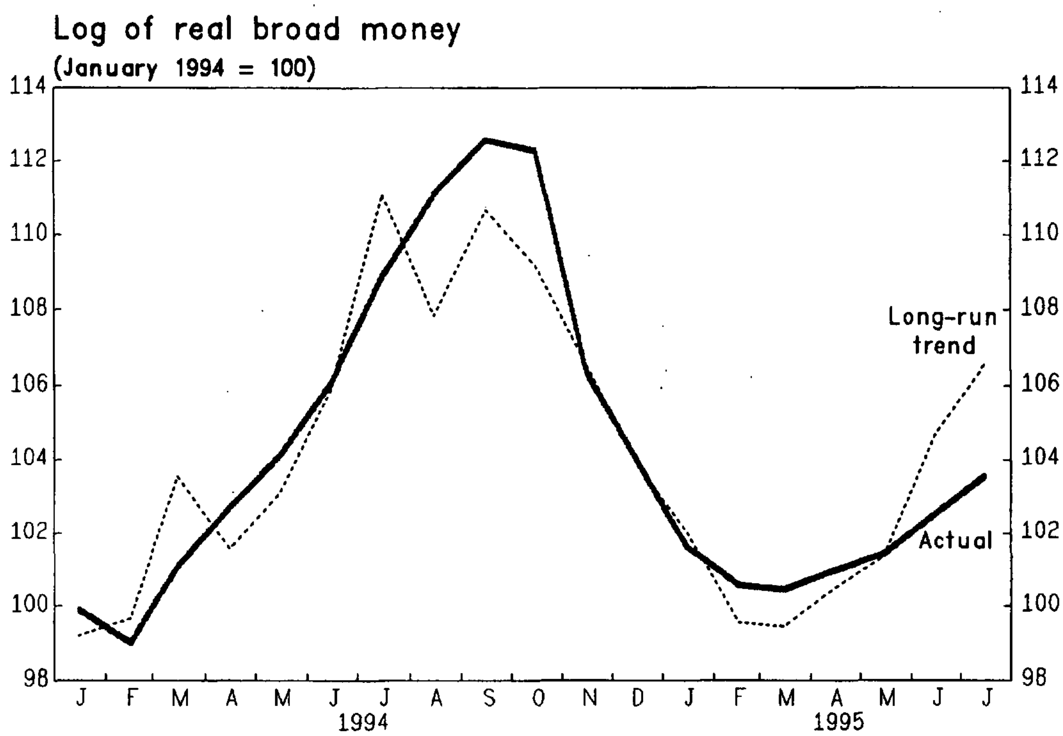
[15] The specification given in (3) uses consumer prices because a long-time series is available for the CPI than for the monthly GDP deflator. Using the GDP deflator yields a coefficient of -0.23 (t-statistic: 2.28**).

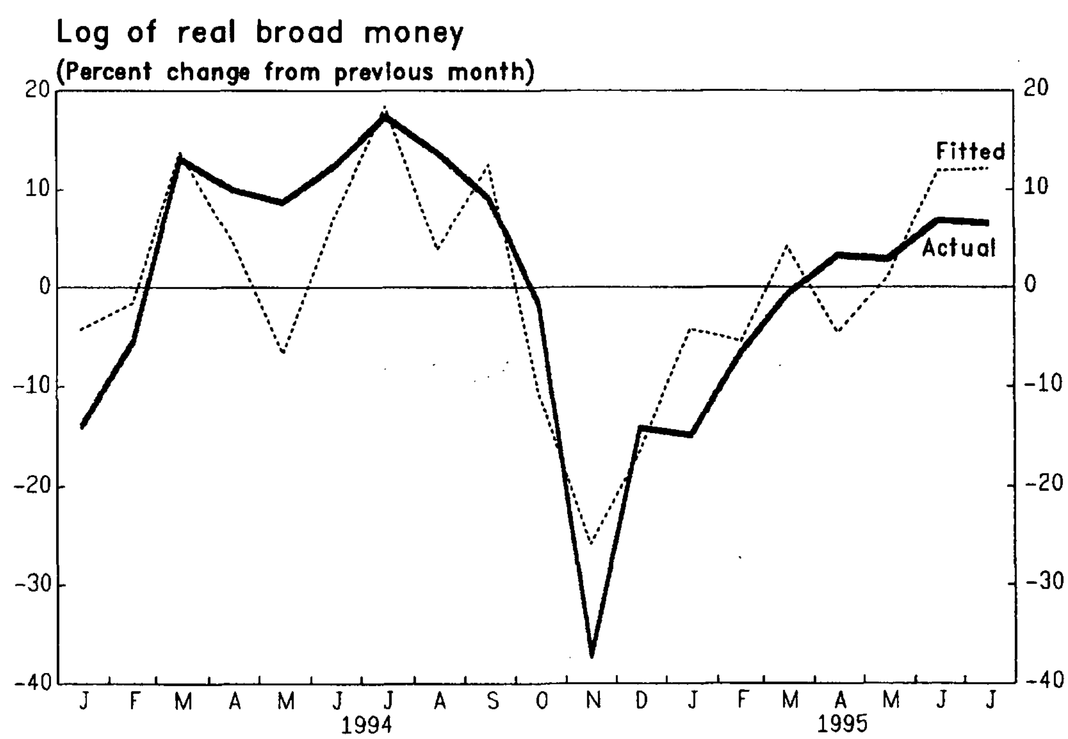
Table 6: Coefficients of Money Demand

Coef.	Eqn. (3)	Eqn. (4)	Eqn. (3')	Eqn. (4')
α_1^2	1.51	—	1.62	—
	(3.76***)		(3.54***)	
α_2^2	-0.27	—	-1.89	—
	(3.01***)		(3.32***)	
β_1^2	—	0.84	—	0.76
		(2.74**)		(2.37***)
β_3^2	—	-0.42	—	-0.40
		(1.79*)		(1.38)
R^2	0.79	0.84	0.78	0.86
DW	1.18	1.98	0.75	1.38

CHART 5

Real Broad Money





implemented on a "cumulative" basis so that there could be some real wage catch-up. The policy was enforced by direct administrative control of enterprises' bank accounts. In April 1995 the government discontinued this incomes policy, although it was re-instated in September 1995 (this time it was enforced through an excess wage tax).

Inevitably, there was some slippage in the implementation of this incomes policy and the long-run relationship between nominal wages and the consumer price index given by:

$$\log(w_t) = \alpha_0^3 + \alpha_1^3 \log(p_t^c) + \alpha_2^3 \log(q_t) + \epsilon_t^3 \qquad (5)$$

yields a coefficient of 1.07 for α_1^3 and 0.75 for α_2^3. Notice that, although written as a wage equation, (5) can also be considered the inverted form of a demand function for goods (where demand depends positively upon the real wage).

The short-run dynamics of nominal wages are assumed to be determined by:

$$\hat{w}_t = \beta_0^3 + \beta_1^3 \hat{p}_t^c + \beta_2^3 \epsilon_t^1 + \beta_3^3 \epsilon_{t-1}^3 \qquad (6)$$

where ϵ_t^1 is the residual from the co-integrating relationship for real GDP. According to (6), nominal wages increase in response to current CPI inflation, or whenever output is above its long-run level. Both coefficients are statistically significant, as reported in table 7.

4. Exchange Rate and Consumer Price Inflation

In order to close the model, relationships determining the nominal exchange rate and the consumer price inflation must be specified. In May 1993 a unified exchange rate was introduced, and by mid-summer the interbank auction market was showing rising volumes and growing market participation by commercial banks. Mainly as a result of the credit expansion during the summer, however, there was a continued depreciation of the exchange rate and the authorities responded by re-introducing a multiple exchange rate regime. Under this new regime, exporters had to surrender 50 percent of their foreign currency earnings at an over-valued official rate, and some of these receipts were administratively allocated for critical imports (mainly gas, medicines, and agricultural inputs) with the rest sold in the auction market (although participation in that market was restricted). There was also a street (cash) exchange rate and a substantial grey market. This multiple exchange rate regime, with ever widening wedges between the various rates, remained until November 1994 when the exchange rate was again unified. The estimates reported below use a combination of the various exchange rates for the period between August 1993 and November 1994, with weights equal to estimates of the volumes of transactions taking place at those exchange rates.[16]

[16] In calculating the gas price, above, the domestic price of gas was used. Since December 1994, this price has been indexed to the market exchange rate.

In the long-run, the real exchange rate is assumed to be stationary; that is, the exchange rate and the producer price index are assumed to be co-integrated[17]:

$$\log(e_t) = \alpha_0^4 + \alpha_1^4 \log(p_t) + \epsilon_t^4 \qquad (7)$$

While this is a much weaker condition than PPP, studies for industrialized countries often reject even this restriction on the long-run dynamics of the real exchange rate. The high inflation rates experienced in Ukraine, however, together with the limited capital mobility, makes it at least a reasonable assumption here. The CRDW for this relationship is 0.97 and the t-statistic on the ADF for the residual from (7) is -2.80. Thus while the CRDW rejects the null of no co-integration at the 10 percent level, the evidence is weak. Given the plethora of exchange rates prevailing between August 1993 and November 1994, however, this should scarcely be surprising.

In the short-run, the exchange rate is assumed to be determined by the expansion of total credit (to the economy plus government):[18]

$$\hat{e}_t = \beta_0^4 + \beta_1^4 \hat{c}_{t-1} + \beta_2^4 \epsilon_{t-1}^4 + v_t^4 \qquad (8)$$

Surprisingly, the contemporaneous increase in domestic credit has virtually no effect on the exchange rate, although the lagged growth rate has a substantial and statistically significant effect.

Given relationships determining increases in domestic prices (4), and the exchange rate (8), the consumer price inflation is simply a linear combination of the two:

$$\hat{p}_t^c = \beta_0^5 + \beta_1^5 \hat{p}_t + \beta_2^5 \hat{e}_t \qquad (9)$$

the unrestricted estimates of β_1^5 and β_2^5 are 0.17 and 0.84 respectively, which yields a reasonable share of imported goods in the consumer price basket.

IV: Sustaining Output through Credit Growth

With the econometric model estimated above, it is possible to examine the macroeconomic effects of an increase in nominal credit and, in particular, whether such a policy could be used to sustain output. The policy experiment under consideration is an increase in the *growth rate* of *nominal* credit to the economy by ten percentage points for a single month, after which the growth rate is assumed to return to its steady-state value. For convenience, and without loss of generality, all growth rates are measured *relative* to their steady state values so that eventually all of the growth rates in the simulation model return to zero. Naturally, this does not assume that the underlying steady state growth rates are themselves zero. Nominal credit, for example,

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17 This is a long-run version of PPP (using producer prices) but it does not preclude instantaneous deviations from PPP, nor does it preclude a deterministic trend in the real exchange rate.

18 Nominal interest rates do not appear to have much effect on the exchange rate, suggesting that capital mobility is low.

Table 7: Wages, Exchange Rate, and Inflation

Coef.	Eqn. (5)	Eqn. (6)	Coef.	Eqn. (7)	Eqn. (8)	Coef.	Eqn. (9)
α_1^3	1.07 (35.0***)	—	α_1^4	0.45 (29.2***)	—		—
α_2^3	0.75 (2.88**)						
β_1^3	—	0.82 (4.39***)	β_1^4	—	1.19 (2.50**)	β_1^5	0.84 (4.69***)
β_2^3	—	0.70 (2.26**)	β_2^4	—	-0.48 (2.07*)	β_2^5	0.17 (0.50)
β_3^3	—	-0.61 (2.89***)					
R^2	0.98	0.60		0.97	0.61		0.90
DW	0.97	2.19		0.84	1.29		1.35

can grow at the growth rate of real money demand plus the steady-state inflation rate. The results should thus be interpreted as being relative to some baseline scenario.

An increase in nominal credit is not, of course, necessarily equivalent to an increase in the money supply. Yet the model assumes a money demand function for broad money, (3)-(4) so an assumption regarding the effect of an increase in credit on the money supply is required. Given the flexible exchange rate policy pursued by the National Bank of Ukraine, the offset from the decline in reserves following a credit expansion should be small. In fact, the correlation between increases in the growth rate of credit to the economy and broad money exceeds 0.96 so increases in credit growth and money supply growth are treated as equivalent here.

If attention is confined to the short-run dynamics of the model then simulating the effects of an increase in credit growth is straightforward. Defining $x_t = \{\hat{q}_t, \hat{p}_t, \hat{e}_t, \hat{p}^c_t, \hat{w}_t, c^e_t\}$ the model may be written in its state-space representation:

$$x_t = \Phi x_{t-1} + \Gamma c^e_t \tag{10}$$

if $E_t\{c^e_{t+k}\} = 0$ (the increase in the growth rate of credit is temporary) then the k-period ahead projection is simply $E_t\{x_{t+k}\} = \Phi^k x_t$.

The dynamics of a model which ignores the long-run relationships between the variables, however, will, in general, be mis-specified and could differ significantly from the true dynamics. For example, the effect on output growth of an increase in real wages will not be independent of the current *level* of output and its relation to the current *level* of real wages. The presence of these long-run relations means that the state vector x_t defined above in terms of *growth* rates of the variables cannot capture the full dynamics of the model.

Nonetheless, it *is* possible to take account of the long-run relations within a state-space representation. Consider, for example, the short-run dynamics of real output growth; the problem arises from the term $\beta^1_4\epsilon^1_{t-1}$. Using (1) ϵ^1_t may be written:

$$\begin{aligned}\epsilon^1_t &= \log(q_t) - \{\alpha^1_0 + \alpha^1_1\log(\frac{c^e_{t-1}}{p_{t-1}}) + \alpha^1_2\log(\frac{w_{t-1}}{p_{t-1}}) + \alpha^1_3\log(\frac{p^g_{t-1}e_{t-1}}{p_{t-1}})\} \\ &= \epsilon^1_{t-1} + \hat{q}_t - \{\alpha^1_1\hat{c}^e_{t-1} + \alpha^1_2\hat{w}_{t-1} + \alpha^1_3\hat{p}^g_{t-1} + \alpha^1_3\hat{e}_{t-1} - (\alpha^1_1 + \alpha^1_2 + \alpha^1_3)\hat{p}_{t-1}\}\end{aligned}$$

Thus, the dynamics of the error-correction terms themselves may be written as functions of the growth rates of the variables. Similarly, the other long-run relationships (3), (5), and (7) may be inverted to yield $\epsilon^2_t, \epsilon^3_t, \epsilon^4_t$. The augmented state vector then becomes:

$$x_t \equiv [\ \hat{q}_t \ \ \hat{p}_t \ \ \hat{w}_t \ \ \hat{e}_t \ \ \hat{p}^c_t \ \ \hat{c}^e_t \ \ \epsilon^1_t \ \ \epsilon^2_t \ \ \epsilon^3_t \ \ \epsilon^4_t \ \ \hat{p}^c_{t-1} \ \ \hat{p}^c_{t-2} \ \ \hat{p}^c_{t-3}\ ]'$$

and the model's dynamics are simply:

$$x_t = \Theta x_t + \Phi x_{t-1} + \Gamma c^e_t \tag{11}$$

$$= (I - \Theta)^{-1}(\Phi x_{t-1} + \Gamma c_t^e)$$

Explicit expressions for the matrices $\Theta, \Phi,$and Γ are given in appendix 1.

The system defined by (11) will be dynamically stable (will have eigenvalues strictly within the unit circle) as long as the variables in x_t are stationary.[19] This requires that the levels of $\log(q_t)$, $\log(p_t)$, $\log(w_t)$, $\log(e_t)$, $\log(p_t^c)$,and $\log(c_t^e)$ be at most I(1), and that the long-run relationships represent co-integrating vectors (so that the error correction terms are I(0)).

The solid lines in chart 6 show the effects on the *levels* of output and consumer prices following a temporary increase in the growth rate of credit to the economy, by 10 percentage points, during period 1 (thereafter the growth rate returns to its baseline level).

The output variable we use is monthly real GDP; similar conclusions are obtained using monthly industrial production[20]. Output is unaffected in the first period because none of the regressor variables in (2) enter contemporaneously. Producer price inflation jumps to 10 percent but the consumer price inflation in the first period is only 8 percent, reflecting the lagged effect of the credit expansion on the exchange rate. It is noteworthy the since output is constant in the first period, the money demand function (4) necessarily implies that *real* credit cannot increase in the first period.[21] With wages increasing by only 82 percent of the consumer price inflation, the nominal wage increase is around 7 percent. The real wage decline in terms of the consumer price index is about 1.5 percent, while the decline in terms of producer prices is about 3 percent.

Output increases in period 2, by about 1.7 percent. This effect, though, does not reflect the direct impact of higher credit to the economy since, in real terms, credit did not increase at all in period 1.[22] Rather, the boost in output stems entirely from the fall in *real wages* in period 1, and the fall in real gas prices (because the exchange rate

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19 The non-zero eigenvalues are $\{-0.35 \pm 0.35, 0.37 \pm 0.57, 0.85, 0.12, 0.45, 0.48\}$

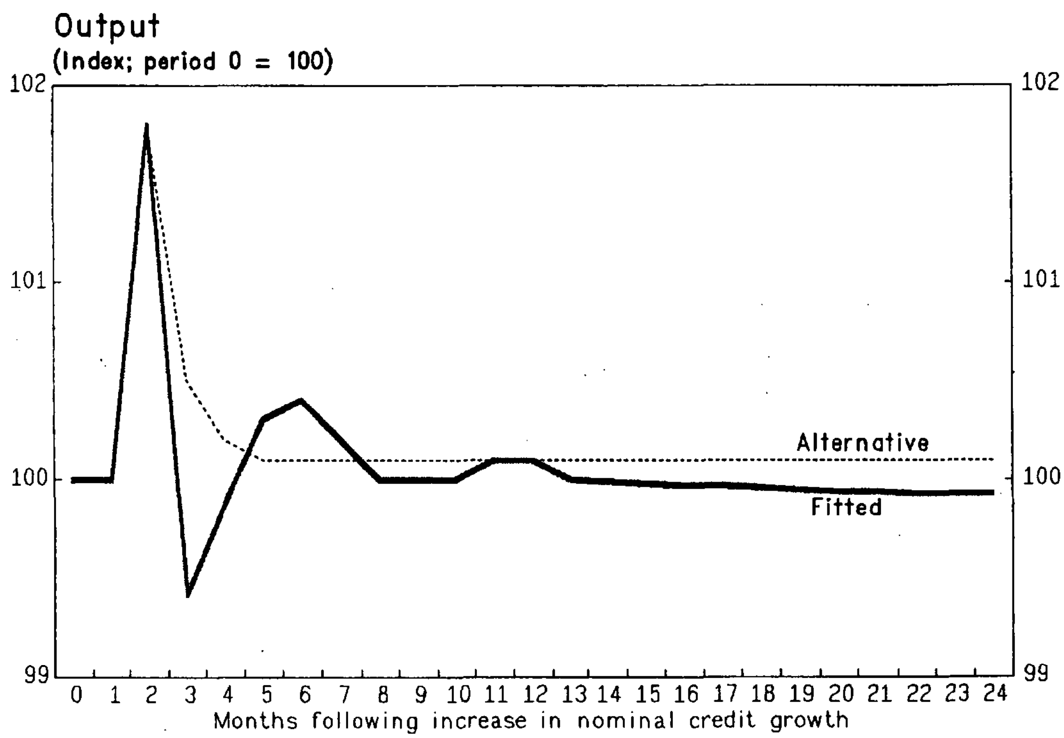
20 Industrial production is measured from the output side, while the monthly real GDP uses data on wages and profits.

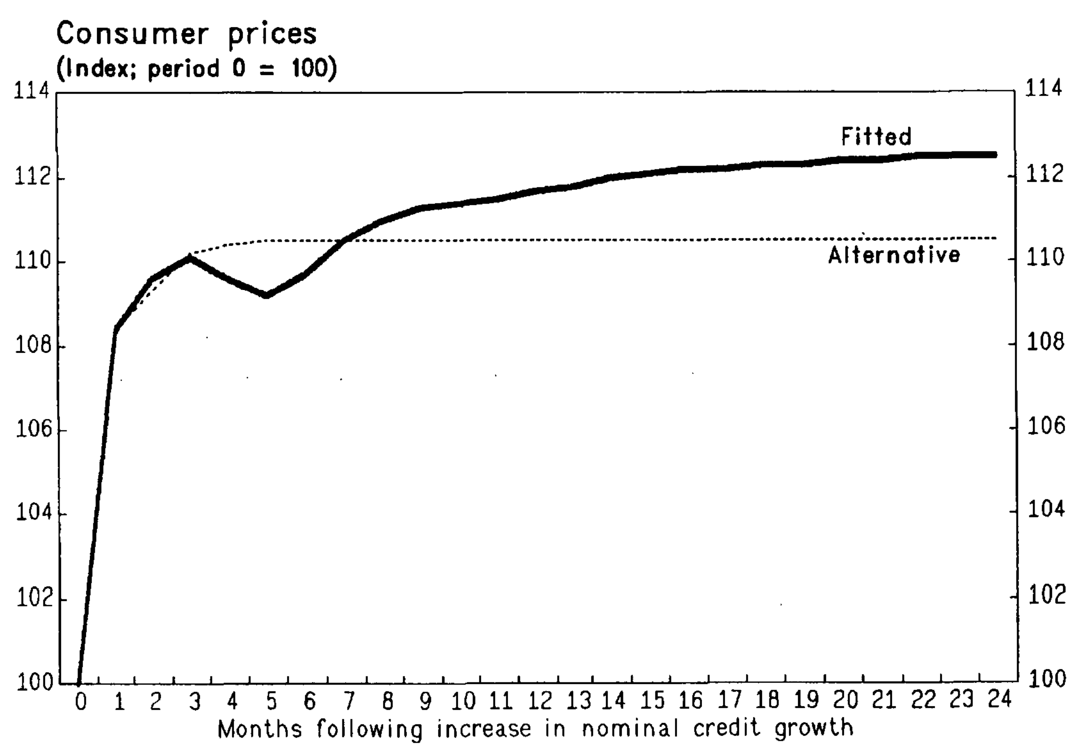
21 This property of the model stems entirely from (i) the money demand function and (ii) the empirical finding that increases in real credit require at least one month to affect output. As such, this property is quite robust to alternative specifications of the empirical model. Empirically, of course, the correlation between nominal and real credit growth will not be zero because, for example, seasonal increases in output might raise money demand at time at which nominal credit is also increasing. Nonetheless, this correlation is low: the simple correlation between nominal and real credit growth is 0.01, and the correlation between *changes* in nominal and real credit growth is 0.3.

22 That is, the effect is entirely through the terms β_2^1 and β_3^1 rather than β_1^1.

CHART 6

Simulated Effects of Increase in Growth Rate of Nominal Credit





does not react immediately)[23]. The increase in output raises money demand and causes producer prices to fall (relative to period 1) and this, in turn, raises real credit to the economy (even though there are no further increases in nominal credit). At the same time, the exchange rate depreciates in period 2 and this causes a further 1.2 percent consumer price inflation.

The higher real credit — which should, *ceteris paribus*, raise output in the third month — is more than offset, however, by the effect of the depreciating exchange rate (combined with falling producer prices) and the increase in real wages (stemming from higher consumer price inflation but falling producer prices) that occurs in the second month. The decline in output is sufficiently sharp that the *level* of output falls below its original level in periods 3 and 4. The fall in output in period 3 reduces money demand and causes a 1.4 percent increase in producer prices, which then reduces the stock of real credit to the economy and keeps output depressed in period 4, as well.

Beyond period 4, the dynamics reflect primarily the effects of the error correction terms which bring the economy back towards its new long-run equilibrium, including the decline in real money demand in response to past inflation. This new long-run equilibrium is characterized by producer and consumer prices being 12 to 13 percentage points higher, and output being about 0.1 percentage points lower than in the original baseline scenario[24].

Finally, it is interesting to compare the dynamics of this model with one in which the long-run co-integrating relationships are — incorrectly — ignored. The dynamics of output and inflation with the error-correction terms set identically equal to zero are illustrated in chart 6 by dotted lines In such a model, there is no "recession" and, in the long-run, the levels of all of the variables return to their original baseline values.

To summarize, the dynamics of the model imply that an increase in the growth rate of real credit has an immediate inflationary impact, and a lagged stimulative effect on output, the counterpart of which is the fall in real wages. Thereafter, the increase in credit growth causes output to fall below its original level and this offsets the output gain during the second period. As a result, the average level of output over the three months following the increase in nominal credit is only 0.3 percent higher than in the baseline. The results hold, *a fortiori*, of course, when the expansion of credit is not to the economy but is used to finance the budget deficit instead. In that case, the recession is yet sharper as there is no direct beneficial effect of the credit expansion for enterprises.

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[23] More generally, this represents an appreciation of the real exchange rate which reduces the real cost of imported inputs.

[24] An alternative policy shock is a *permanent* increase in the *growth* rate of credit. In such a scenario, the growth rate of output becomes negative in the third and fourth months although the level remains about 1.2 percent higher than baseline. Thereafter the growth rate of output is very low, although inflation is about 10 percent per month. At the end of one year, consumer prices are 220 percent higher than their baseline level and output is 2.6 percent higher than baseline.

V: Conclusions

This paper addresses a simple question: Can expansionary credit policy help sustain output? The lack of adequate data — and the rapidly evolving economic structure — implies that any analysis is likely to be little more than illustrative. Yet the main message seems clear.

Notwithstanding the strong relationship between real credit growth and output growth, the dynamics of the Ukrainian economy imply that increasing credit growth to the economy — beyond the rate sustainable by money demand — is likely to prove self-defeating. In the first instance, even the impact effect on output growth is minimal: a 10 percentage point increase in the growth rate of nominal credit would raise the growth rate of output by only 1.7 percentage points. More importantly, the boost in output would be followed by a sharp recession which lowers the *level* of output below its original level. The net output gain of such a policy is therefore minuscule. Interestingly, this conclusion holds whether one uses industrial production as the output variable or, (as above) monthly GDP. Thus a policy of trying to reduce the pace of contraction by providing more credit to enterprises — including those that are currently loss-making — is futile in the sense that the increase in net real value added is negligible.

Expansionary credit policy, moreover, works mainly by cutting real wages. At a time when real wages in Ukraine are already low by international standards, such a policy is unlikely to prove popular or sustainable. And as Lucas [1976] points out in a similar context, a systematic attempt by the government to cut real wages through inflation would soon be vitiated by rational wage setters.

These conclusions are also borne out by a casual look at Ukraine's experience over the past few years. Both in 1993 and in 1994, there was a collapse of real credit as the demand for money was unable to sustain the massive increases in nominal credit. Far from boosting output, those excesses resulted in steep declines of output and ever decreasing demand for money, as income fell and confidence was eroded. Stability of the macroeconomic environment is thus a *sine qua non* for sustained economic growth. And stimulating output growth is perhaps best left to structural measures, after all.

Appendix

In the text, reference is made to the state-space representation of the model. Using equations (11) - (9), the model may be written:

$$
\begin{aligned}
x_t &= \Theta x_t + \Phi x_{t-1} + \Gamma c_t^e \\
&= (I - \Theta)^{-1}(\Phi x_{t-1} + \Gamma c_t^e)
\end{aligned}
$$

where:

$$
\Theta = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\beta_1^2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \beta_1^3 & 0 & \beta_2^3 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \beta_1^5 & 0 & \beta_2^5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-\alpha_1^2 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & -\alpha_1^3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -\alpha_1^4 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

$$
\Phi = \begin{bmatrix}
0 & -(\beta_1^1 + \beta_2^1 + \beta_3^1) & \beta_2^1 & \beta_3^1 & 0 & \beta_1^1 & \beta_4^1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -\beta_3^2 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \beta_3^3 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \beta_1^4 & 0 & 0 & 0 & \beta_3^4 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & (\alpha_1^1 + \alpha_2^1 + \alpha_3^1) & -\alpha_2^1 & -\alpha_3^1 & 0 & -\alpha_1^1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -\alpha_2^3 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0
\end{bmatrix}
$$

and

$$\Gamma = \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}; \; x_t = \begin{bmatrix} \hat{q}_t \\ \hat{p}_t \\ \hat{w}_t \\ \hat{e}_t \\ \hat{p}_t^c \\ \hat{c}_t^e \\ \epsilon_t^1 \\ \epsilon_t^2 \\ \epsilon_t^3 \\ \epsilon_t^4 \\ p_{t-1}^c \\ p_{t-2}^c \\ p_{t-3}^c \end{bmatrix}$$

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