Economics of Transition

Economics of Transition
Volume 18(4) 2010, 697–714
DOI: 10.1111/j.1468-0351.2009.00389.x

The effect of inflation on growth

Evidence from a panel of transition countries[1]

Max Gillman* and Mark N. Harris**

*Cardiff Business School; and Institute of Economics, Hungarian Academy of Sciences.
E-mail: gillmanm@cf.ac.uk
**Monash University, Australia. E-mail: mark.harris@buseco.monash.edu.au

Abstract

The paper examines the effect of inflation on growth in transition countries. It presents panel data evidence for 13 transition countries over the 1990–2003 period; it uses a fixed effects panel approach to account for possible bias from correlations among the unobserved effects and the observed country heterogeneity. The results find a strong, robust, negative effect on growth of inflation or its standard deviation, and one that appears to decline in magnitude as the inflation rate increases, as seen for OECD countries. And the results include a role for a normalized money demand in affecting growth, as well as for a convergence variable, a trade variable and a government share variable. Robustness of the baseline single-equation model is examined by expanding this into a three-equation simultaneous system of output growth, inflation and money demand that allows for possible simultaneity bias in the baseline model.

JEL classifications: C23, E44, O16, O42.
Keywords: Growth, transition, panel data, inflation, money demand, endogeneity.

Received: March 25, 2008; Acceptance: December 21, 2009

[1] We are grateful for comments from Jan Kmenta, Lászlo Mátyás, Don Poskitt, Philippe Aghion and an anonymous referee, and thank Szilard Benk, Glenn Bunker and Isfaaq Timol for research assistance. This study was financially supported by a Monash University Faculty Research Grant.

Published by Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main St, Malden, MA 02148, USA

1. Introduction

Inflation remains a recurrent problem in some transition countries. How this may affect their growth prospects is of interest, given the widespread goal of achieving high economic growth. There is some robust evidence that inflation has been found to have a negative effect on growth within developed countries, for both panel and time-series data (Fountas *et al.*, 2006; Gillman *et al.*, 2004); how inflation affects transition countries is less clear.

A striking feature of the inflation effect empirically for developed countries is its non-linearity: it becomes smaller in magnitude as the inflation rate rises.[2] Theoretically, the negative effect on growth can be explained with inflation acting as a tax on human capital that lowers the marginal product of human capital because of inflation-induced substitution from goods to leisure; more leisure use induces a lower utilization rate of human capital, which causes a lower return to capital and a lower growth rate. The marginally diminishing nature of this negative effect can also be explained. With a type money demand endogenously generated within the general equilibrium, there is a rising sensitivity to the inflation tax that induces increasingly less holding of real money, more use of credit, and less substitution from goods towards leisure, resulting in a marginally decreasing inflation tax effect on growth (Gillman and Kejak, 2005).

For transition countries, a negative effect of inflation has been found in time-series evidence for Hungary and Poland, although this effect has not been established more broadly.[3] *A priori*, there is no certainty that transition countries would be exempt from the inflation tax effect on growth. While a transition country may still be deregulating its economy relative to more developed countries and building its market institutions, these factors have not been shown to cancel out the effect of inflation on the return to capital. However, it can be difficult to identify the effect of inflation on growth, especially during times when the stationary inflation rate is being shocked; for example, transition countries outside of the Euro can use spurts in money supply growth to finance government budget deficits. Such fluctuations can exacerbate possible feedback from the growth rate to the inflation rate, which can create endogeneity between inflation and growth.

This paper focuses on such potential endogeneity while estimating the effect of inflation on growth in a panel of transition countries. It does this by constructing models of growth, inflation and money demand, and estimating these

[2] The qualifying note is that a positive but insignificant effect of inflation on growth has been found for inflation rates below a certain threshold, in the range of 1 percent for developed to 11 percent for developing countries (Ghosh and Phillips, 1998). However, using instrumental variables to account for possible endogeneity of inflation and growth at low levels of inflation, when business cycle effects can make the price level procyclic, Gillman *et al.* (2004) find a negative effect of inflation at all positive levels of inflation.

[3] Gillman and Nakov (2004) find this negative effect for Hungary and Poland. Dawson (2003) examines growth in a panel of transition countries but without considering inflation.

simultaneously whilst also conditioning on any unobserved country and time heterogeneity. The baseline econometric model is a single-equation model; subsequent two- and three-equation simultaneous models are then built to account better for the possible endogeneity of inflation and money demand. The data period is the annual post-Soviet era from 1990 to 2003 and 13 transition countries are included. Econometric estimation uses a fixed effects, maximum likelihood, panel approach.

Besides the inflation level, we also include the standard deviation of inflation, which tends to be closely correlated with the level of inflation in order to include a measure of inflation uncertainty as in Judson and Orphanides (1999). The results show that both inflation and its standard deviation significantly reduce growth in the single-equation model, but the significance of the inflation level term goes down as the model is expanded to two and three equations, while the inflation standard deviation term remains robustly negative in impact. This feature of inflation uncertainty indicates a negative effect on growth in addition to, or even more significant than, the level of inflation itself.

The share of money demand in GDP is another variable that is postulated as entering the growth model. With a higher share of money to GDP, there is a lower GDP velocity of money. And then the inflation tax falls on a relatively higher money usage. This yields a higher inflation tax revenue for a given inflation rate, and leads to a larger growth rate decrease, as described in Gillman and Kejak (2005). Therefore, the higher the money-to-GDP ratio for a given inflation rate, the lower would be the expected growth rate; and our results are consistent with this interpretation. The inclusion of this variable compares most closely with the practice of including ‘liquid liabilities’ in the growth equation as a measure of financial development (Levine *et al.*, 2000), in that this variable is also defined in terms of the money-to-GDP ratio. An interaction term between this money-to-GDP variable and inflation is also posited in the growth equation to capture additional nonlinear effects; results show significance of this interaction in the baseline model.

Besides the growth equation, real money demand is also explained through a separate equation in the form of a Cagan (1956) money demand function that is consistent theoretically with Gillman and Kejak (2005). Inflation itself is also explained in a separate equation, where it depends on the money supply growth rate of current and past periods. This money supply determination of inflation is consistent with Cagan’s (1956) analysis; standard general equilibrium exchange economies, such as the cash-in-advance model; and the real business cycle models with money, such as Cooley and Hansen (1995). Moreover, money supply growth rates have previously been used as instrumental variables for inflation in econometric models (Gillman *et al.*, 2004). It is also consistent with the Crowder (1998) result that the US money supply growth rate Granger-causes inflation, along with similar results found for two transition countries in Gillman and Nakov (2004).

A growth convergence variable is also included and the expected significance is found for the baseline single- and full three-equation model. The leading per capita income country in the transition region is the Czech Republic and so this is chosen as the base country for the type of income ratio that is used in the literature. Here, this is defined as the per capita income level of the leading country (Czech Republic) to the per capita income level of each other country. This is designed to capture the transition dynamics, whereby the faster a country grows, the lower is its income level relative to the leading country. Variables reflecting the degree of trade, or openness, and the government share of output also have a certain degree of significance.

2. Data

The panel consists of 13 transition countries, the EU accession countries of east-central Europe: Bulgaria, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic and Slovenia; the EU Baltic accession countries of Estonia, Latvia and Lithuania; and the ex-Soviet nations of Russia, Moldova and Ukraine. The dataset is from the online World Bank Development Indicators (WBDI),[4] covering the annual period from 1990 to 2003. An alternative dataset is available from the online International Financial Statistics, but this does not include data for the Czech and Slovak republics before 1993, and so was not used. For further details about the definitions of the variables used, which are given below in Table 1, see the WBDI database. The inflation standard deviation is defined as in Judson and Orphanides (1999).

The first year of the sample, 1990, is used to compute growth rates. An additional year is used up when the lagged money supply growth rate is used as an instrument (i.e. as an explanatory variable for the inflation rate equation). For several countries, the money supply growth rate is not available until the mid-1990s; so, the sample is not restricted to a balanced panel and the largest possible number of years are used in each estimation. The sample size for each country is dictated by its first non-missing observation across all variables included in the model. Table 2 contains descriptive statistics for the (common) sample.[5]

From Table 2, we can see that although average growth for these transition countries over this period was a respectable 2 percent, this was volatile: ranging from a low of some −23 percent to a high of 10.5 percent. Inflation, in general, was both high and volatile. The average inflation rate was some 70 percent, dipping to a low of 1 percent and rising to a high of over 3,000 percent. This volatility in inflation is typified by the standard deviation of inflation variable, which showed a range from essentially zero to 184. On average, population growth rates were negative, as were trade shares, and investment rates were relatively stable around the mean of just over 20 percent. Similarly, government shares of GDP were relatively stable with a range of 6–27 percent around the mean value of 18 percent.

[4] This database is also used in Dawson (2003).

[5] Inflation rates of less than 1 percent were excluded, which meant dropping six data points; this was done in order to use the natural log functional form in the growth rate econometric models so as to employ the nonlinearity feature.

Table 1. Definitions of variables

Growth equation variables	
g	Real GDP growth rate, in local currency units (LCU).
$\ln(\pi)$	Natural log of the inflation rate (annual percentage change in the GDP deflator).
π	Inflation rate: annual percentage change in the GDP deflator.
$M2/y$	$M2$/GDP: real money demand divided by real GDP.
$\ln(\pi)\cdot(M2/y)$	Product of $\ln(\pi)$ and $M2/y$.
$\pi\cdot(M2/y)$	Product of π and $M2/y$.
y_c/y_i	[Real GDP, Czech Republic]/[real GDP, other country] in constant $US
I/y	Investment/GDP at market prices each in LCU.
PopGr	Population growth rate.
$\ln(\text{sd}(\pi))$	Natural log of standard deviation of the inflation rate.
$\text{sd}(\pi)$	Standard deviation of the four intra-year quarter-on-quarter inflation indices.
gov	Share of government expenditure in GDP.
trade	Share of trade balance in GDP.
Inflation equation variables	
σ, σ_{-1}	$M1$: money supply growth rate; current and lagged 1 period, annual, in LCU.
Money demand equation variables	
$\ln(M2)$	Natural log of real money: $M2$ divided by GDP deflator.
$\pi/100$	Inflation rate (annual percentage change in the GDP deflator), in decimals.
$\ln(y)$	Natural log of real GDP.

Table 2. Descriptive statistics (common sample)

	Mean	Maximum	Minimum	SD	Observations
g	1.896871	10.5234	−22.9341	5.589493	136
$\ln(\pi)$	2.78647	8.112167	0.037361	1.380505	136
π	69.93154	3,334.798	1.038068	308.2055	136
$M2/y$	38.15849	79.7101	11.48738	17.29156	136
$\ln(\pi)\cdot M2/y$	99.44058	358.6315	0.858038	63.05809	136
$\pi\cdot M2/y$	2,217.248	108,284	23.84032	9,899.93	136
y_c/y_i	13.16398	127.4338	9.31E−08	34.57342	136
I/y	21.70542	36.05844	10.97662	4.73863	136
PopGr	−0.42507	1.613018	−2.57695	0.579078	136
$\ln(\text{sd}(\pi))$	0.710095	5.216945	−1.51413	1.104331	136
$\text{sd}(\pi)$	5.540882	184.37	0.22	18.26512	136
gov	18.11279	27.39892	5.690266	4.880563	136
trade	−3.57427	18	−24.7	5.579924	136
σ	0.296802	2.804887	−0.19807	0.357563	136
$\ln(M2)$	25.079	32.85384	11.32595	5.061315	136
$\pi/100$	0.699315	33.34798	0.010381	3.082055	136
$\ln(y)$	26.14311	33.69023	13.4379	4.894551	136

Notes: See Table 1 for variable definitions.

3. Econometric models and results

3.1 Baseline model

The baseline model is given as Model 1. With g_{it} being the dependent variable that denotes country i ($i = 1,\ldots,N$) GDP growth in year t ($t = \tau_i,\ldots,T_i$), and with $\ln(\pi_{it})$, $(M2/y)_{it}$, (y_{ct}/y_{it}) and $\mathbf{x}_{it}$ (a vector) denoting additional explanatory variables with unknown weights β_π, β_M, $\beta_{\pi M}$, β_c and $\boldsymbol{\beta}$, and with ε_{it} denoting the disturbance terms, we have:

$$g_{it} = \alpha_i + \lambda_t + \beta_\pi \ln(\pi_{it}) + \beta_M \left(\frac{M2}{y}\right)_{it} + \beta_c \left(\frac{y_{ct}}{y_{it}}\right) + \mathbf{x}'_{it}\boldsymbol{\beta} + \varepsilon_{it}. \tag{1}$$

The vector $\mathbf{x}_{it}$ is comprised of four variables. Three of these are always present: an interaction term that is the product of the money-to-output ratio and the log of inflation, $(M2/y)_{it} \ln(\pi_{it})$, the investment ratio, I and the population growth rate, *PopGr*. The fourth is the standard deviation of inflation, $\text{sd}(\pi)_{it}$, and the models are presented both without and with this variable included. This variable is included as a robustness check and allows for identification of the influence of both the first and second moments of inflation on growth. As in Judson and Orphanides (1999) the standard deviation of inflation was measured as the empirical standard deviation of the four quarterly inflation observations per year for each country. The final variant of this 'baseline model' is to enter the inflation rate in a level form, rather than log form. Note that when inflation entered the equation in log form, so did its standard deviation, and *vice versa*.

In addition, the panel nature of the data also requires conditioning on both unobserved country effects, given by α_i, and unobserved time effects, given by λ_t. The former will account for any remaining unobserved country heterogeneity; the latter will account for any remaining unobserved heterogeneity that is constant across countries and varying over time. As correlations among the unobserved effects and the observed country heterogeneity are likely in country data, and can result in biased estimates, a fixed effects approach in estimation is used for both single- and multiple-equation systems.

Thus, if there are correlations between the unobserved effects and the countries' observed heterogeneity, a fixed effects approach is typically advocated (Wooldridge, 2002). While estimations of such fixed effects models using maximum likelihood methods typically suffer from the well-known 'incidental parameters' problem (Neyman and Scott, 1948), Heckman (1981) suggests that a temporal sample size of $T = 8$ is sufficient for any significant fixed T bias to have essentially disappeared. Such updated evidence is provided by Greene (2004) who cites a significant reduction in biases from $T = 3$ onwards. So, here, with a temporal sample size of 14 (or 13 once the initial period has been removed), we are confident about using a fixed effects approach with little concern about any resulting small T bias, whilst accounting for any endogeneity bias arising from correlations between unobserved and unobserved heterogeneity.

3.2 Simultaneous system extension

If growth and inflation are jointly determined, then this renders these variables as potentially endogenous regressors in the usual panel estimation of equation (1). To allow for inflation being endogenous in the equations, we extend the baseline model first to a two-equation model 2: estimated

$$g_{it} = \alpha_i + \lambda_t + \beta_\pi \ln \pi_{it} + \beta_M \left(\frac{M2}{y}\right)_{it} + \beta_c \left(\frac{y_{ct}}{y_{it}}\right) + \mathbf{x}'_{it}\boldsymbol{\beta} + \varepsilon_{it}; \quad (2)$$

$$\ln \pi_{it} = \eta_i + \tau_t + \theta_\sigma \sigma_{it} + \theta_{\sigma-1}\sigma_{-1,it} + u_{it}. \quad (3)$$

The growth equation is the same; and in the new inflation equation, η_i and τ_t are unobserved effects. The new unknown coefficients are accordingly θ_σ and $\theta_{\sigma-1}$, and u_{it} is a random disturbance term. Similar to Gillman *et al.* (2004), where current and lagged values of the rate of growth of the $M1$ money supply are used as instruments for inflation, here the current and lagged money supply growth rates are the explanatory variables. To allow for possible endogeneity, the two error terms (ε,u) are allowed to follow a bivariate normal distribution (*BVN*) with correlation coefficient $\rho_{\varepsilon u}$, $(\varepsilon,u) \sim \text{BVN}(\mathbf{0},\Omega_{\varepsilon u})$ where $\boldsymbol{\Omega}_{\varepsilon u}$ is the variance–covariance matrix of (ε,u). The model is estimated by full-information maximum likelihood estimation (MLE) techniques under the assumption of multivariate normality.

Model 3 extends the simultaneous system to make money demand endogenous. Such endogeneity is plausible in that many studies indeed have estimated separate money demand functions that include the inflation rate or the nominal interest rate as an explanatory variable. Here, we use the Cagan (1956) form of the money demand as in the international panel study of Mark and Sul (2003). The Cagan (1956) form enters the log of (real) money demand on the left-hand-side of the equation and the inflation rate level, rather than its log, as the main substitution term on the right-hand side. With the log of real GDP also on the right-hand side, this gives a constant semi-interest elasticity of money demand and an income elasticity of money that is expected to be near unity.

The three-equation Model 3 is as follows:[6]

[6] We also experimented with a four-equation system, additionally treating investment as an endogenous variable; convergence problems were encountered here and, moreover, the investment ratio was never significant in the growth equation.

$$g_{it} = \alpha_i + \lambda_t + \beta_\pi \ln(\pi_{it}) + \beta_M \left(\frac{M2}{y}\right)_{it} + \beta_c \left(\frac{y_{ct}}{y_{it}}\right) + \mathbf{x}'_{it}\boldsymbol{\beta} + \varepsilon_{it}; \tag{4}$$

$$\ln(\pi_{it}) = \eta_i + \tau_t + \theta_\sigma \sigma_{it} + \theta_{\sigma-1}\sigma_{it}^{-1} + u_{it}; \tag{5}$$

$$\ln(M2)_{it} = \mu_i + \iota_t + \phi_\pi \pi_{it} + \boldsymbol{\phi}_y \ln y_{it} + e_{it}. \tag{6}$$

Again, the growth and inflation equations are the same. For the money demand equation, unknown coefficients are ϕ_π and ϕ_y, while μ_i and ι_t are unobserved effects and e_{it} is a random disturbance term. In allowing for the endogeneity of both $M2$ and inflation in the growth equation, it is assumed that all error terms are freely correlated (with coefficients $\rho_{\varepsilon u}$, $\rho_{\varepsilon e}$ and ρ_{ue}), with multivariate normal distributions (MVN) such that $(\varepsilon,u,e) \sim \text{MVN}(\mathbf{0},\Omega_{\varepsilon ue})$, where $\Omega_{\varepsilon ue}$ is the variance–covariance matrix of (ε,u,e). Note that as each equation has its own predetermined variable, the entire system is identified (Greene, 2008).

4. Results

Results are reported in Table 3 for model 1, Table 4 for model 2 and Table 5 for model 3 (unobserved country and time effects not reported). Unless explicitly modelled, all remaining explanatory variables here are treated as strictly exogenous. A full set of both time and individual dummies are available upon request. Results are presented in two sections in each table. The first section (column heading ' ln (π)') consists of two columns: estimated coefficients and standard errors (in parentheses) corresponding to the sole inclusion of the inflation variable; the second section of the tables (column heading ' ln (sd(π))' or 'sd(π)') is the same except that the standard deviation of the inflation rate is additionally included in the growth equation.

4.1 Single-equation baseline

Table 3 shows the results for the single-equation baseline model 1 (column heading ' ln (π)'). There is a strong negative significance of both the inflation rate and the $M2$ money-to-GDP ratio. Note that the coefficient on this variable here (and elsewhere) appears 'large' as it is defined as a ratio (that is, essentially in the zero–one interval), as opposed to investment, for example, which is expressed as a percentage (that is, essentially in the 0–100 interval). Capturing a nonlinear effect of these, the interaction term that is the product of these is also significant. Adding in the standard deviation of inflation shows that this also has a negatively significant effect, with the sum of the coefficients of the inflation term and the inflation standard deviation term equalling −7.05 versus −6.37 when the inflation term alone is

Table 3. Model 1 results

	ln(π)		ln(sd(π))	
	Coefficients	**SE**	**Coefficients**	**SE**
ln (π)	−5.837	(0.92)**	−3.214	(0.96)**
$M2/y$	−0.424	(0.13)**	−0.286	(0.11)**
ln(π)·($M2/y$)	0.091	(0.03)**	0.067	(0.02)**
y_c/y_i	0.405	(0.23)*	0.430	(0.19)**
I/y	−0.076	(0.18)	−0.098	(0.15)
PopGr	0.260	(0.97)	0.392	(0.76)
ln(sd(π))	–	–	−2.060	(0.56)**
gov	−0.310	(0.19)*	−0.076	(0.15)
trade	0.077	(0.11)	0.175	(0.09)*
Constant	27.172	(7.09)**	15.154	(5.96)**
$\overline{R}^2$	0.581		0.651	

	π		sd(π)	
	Coefficients	**SE**	**Coefficients**	**SE**
π	−0.016	(0.01)**	−0.009	(0.01)*
$M2/y$	−0.050	(0.07)	−0.029	(0.05)
π·($M2/y$)	3.0E−04	(2.E−04)*	2.5E−04	(1.4E−04)*
y_c/y_i	0.410	(0.26)	0.427	(0.19)**
I/y	−0.083	(0.21)	−0.164	(0.15)
PopGr	0.675	(1.11)	0.467	(0.81)
sd(π)	–	–	−2.860	(0.48)**
gov	−0.111	(0.20)	−0.029	(0.15)
trade	0.079	(0.13)	0.195	(0.09)**
Constant	2.409	(6.50)	4.357	(5.13)
$\overline{R}^2$	0.469		0.625	
NT	148		144	
N	13		13	

***Notes*:** Significance at the **5 and *10 percent levels.

in the model. This suggests that standard deviation is substituting for part of the inflation effect. Alternately specifying the inflation rate in level form [column headings 'π' and 'sd(π)'] results also in a significant negative coefficient, with the inflation standard deviation remaining negatively significant.

Another factor of significance is the convergence variable, the ratio of Czech income to the other countries, and this becomes more positively significant when

Table 4. Model 2 results

	$\ln(\pi)$		$\ln(sd(\pi))$	
	Coefficients	**SE**	**Coefficients**	**SE**
Growth				
$\ln(\pi)$	−5.794	(1.34)**	−3.092	(1.72)**
$M2/y$	−0.271	(0.23)	−0.079	(0.16)
$\ln(\pi)(M2/y)$	0.056	(0.05)	0.017	(0.04)
y_c/y_i	0.591	(0.45)	0.635	(0.46)
I/y	0.089	(0.32)	0.004	(0.24)
PopGr	0.578	(1.46)	0.568	(1.20)
$\ln(sd(\pi))$	–	–	−2.416	(0.93)**
gov	−0.428	(0.25)*	−0.211	(0.16)
trade	0.256	(0.17)	0.316	(0.12)**
Constant	29.983	(10.84)**	19.959	(8.85)**
log(Inflation)				
σ	1.695	(0.29)**	1.593	(0.34)**
σ_{-1}	0.531	(0.30)*	0.611	(0.28)**
Constant	2.869	(0.69)**	2.866	(1.23)**
$\rho_{g,\ \ln(\pi)}$	0.315		0.465	
Jarque–Bera	0.000		0.282	
NT	128		126	
N	13		13	

Notes: Significance at the **5 and *10 percent levels. *Jarque–Bera* is the *P*-value of the test for the null hypothesis of joint normality.

the inflation standard deviation is added. Further this convergence effect is of the expected sign.

The share of government spending in GDP is negatively significant without the inflation standard deviation but loses this significance when the inflation standard deviation is added. This can be because the inflation standard deviation is capturing some of the negative tax effect that is captured by the government share variable.

Finally, the trade variable becomes positively significant when the inflation standard deviation is added. The variable is of the expected sign in that the greater the engagement in trade, which this variable indicates, the more the technology adoption that takes place and the higher the growth rate tends to be. This explanation is referencing the learning-by-doing growth enhancement that export market engagement can induce as in Lucas (1988).

Table 5. Model 3 results

	ln(π)		ln(sd(π))	
	Coefficients	SE	Coefficients	SE
Growth				
ln(π)	−4.010	(1.19)**	−1.443	(1.42)
$M2/y$	−0.394	(0.26)	−0.291	(0.19)
ln(π)($M2/y$)	0.018	(0.05)	−0.005	(0.03)
y_c/y_i	0.577	(0.28)**	0.593	(0.23)**
I/y	−0.133	(0.26)	−0.028	(0.20)
PopGr	0.405	(1.24)	0.644	(0.82)
ln(sd(π))	–	–	−2.757	(0.70)**
gov	−0.329	(0.19)*	−0.184	(0.14)
trade	0.169	(0.11)	0.254	(0.10)**
Constant	39.990	(12.99)**	31.898	(8.57)**
ln(inflation)				
σ	1.926	(0.52)**	1.737	(0.62)**
σ_{-1}	1.026	(0.24)**	1.104	(0.25)**
Constant	2.278	(0.27)**	2.324	(0.37)**
ln(money demand)				
$\pi/10$	−0.006	(0.02)	0.009	(0.02)
ln(y)	0.941	(0.02)**	0.941	(0.02)**
Constant	0.643	(0.54)	0.612	(0.54)
$\rho_{g,\ln(\pi)}$	0.214		0.269	
$\rho_{g,M2}$	0.420		0.501	
$\rho_{M2,\ln(\pi)}$	−0.340		−0.334	
Jarque–Bera	0.000		0.121	
NT	128		126	
N	13		13	

***Notes*:** Significance at the **5 and *10 percent levels. *Jarque–Bera* is the *P*-value of the test for the null hypothesis of joint normality.

4.2 *Two-equation model*

The two-equation model adds an equation that explains the inflation rate in terms of the current and lagged money supply growth rate, with a strong positive significance as theory suggests. Both terms in this second equation are significant. This indicates that both the current money supply growth rate and last period's money supply growth rate act to determine current inflation. This is consistent with real business cycles models with money, whereby the money supply shock is modelled with a high degree of autocorrelation as is standard, going back to Cooley and Hansen (1995).

The growth equation of the baseline model then becomes affected by having less significance of the $M2$-to-GDP ratio, and also insignificance of the interaction term between inflation and the $M2$-to-GDP ratio. The inflation term remains significant both with and without the inflation standard deviation term added, although again it can be seen that in some sense the addition of the inflation standard deviation is splitting the inflation effect between the two terms. Without the standard deviation, the coefficient of the log of inflation is −4.31. With the standard deviation, the coefficient on inflation is −1.80 and the coefficient on the inflation standard deviation is −2.59, for a sum of −4.39 compared with −4.31. With the inflation entered in level form in the growth equation, instead of in log form, the effect is no longer significant (not shown).

The convergence variable, y_c/y_i, has lost significance in the two-equation model, while the government and trade variables have the same effects as in the single-equation model. The investment ratio variable remains insignificant. The correlation between the error terms of the growth and the inflation equations is moderately high at 0.32 and 0.47, indicating that it is important to consider the model with inflation made endogenous. With regard to the *Jarque–Bera* test (which tests the maintained estimation assumption of multivariate normality of the disturbance terms), this clearly fails for the variant without $\ln(\mathrm{sd}(\pi))$, whilst passing comfortably for the $\ln(\mathrm{sd}(\pi))$ variant. On this basis, the latter would be preferred.

4.3 Three-equation model

The full three-equation model adds the Cagan (1956) money demand function to explain real money, which is here $M2$ as normalized by the inflation index, thus allowing the $M2$ term in the growth equation to be endogenous. In the money demand equation, the income term is significant with a 0.94 coefficient. This indicates an income elasticity near unity as expected. The inflation rate is not significant in the money demand equation. In the inflation rate equation, the second equation of the model, there is now greater significance of the past period money supply growth rates.

In the growth equation, making the money demand endogenous leads to the money-to-income ratio being more negatively significant in the growth equation, although its t-statistic is only −1.5. For the inflation effect, without the inflation standard deviation the inflation coefficient is −4.01, while with the inflation standard deviation this drops to −1.44 and is no longer significant. Meanwhile the inflation standard deviation now has a significant coefficient of −2.76; summing these two inflation coefficients together gives −4.20 compared with −4.01. Although the inflation coefficient is not significant, this still indicates some degree of splitting up of the inflation effect between the level and standard deviation variables. And multicollinearity remains a concern as these two variables are very highly related: the simple correlation coefficient between $\ln(\pi)$ and $\ln(\mathrm{sd}(\pi))$ is 0.8.

The convergence variable y_c/y_i re-establishes significance. And the government and trade variables show the same pattern, of government being marginally significant when excluding the inflation standard deviation, but insignificant when including the inflation standard deviation, while trade becomes positively significant when inflation standard deviation is included.

The correlation between the error terms of the growth and inflation equations now falls to 0.21 and 0.27, still indicating endogeneity of inflation now that money demand is also endogenous. The money demand and inflation equations show a high error correlation at −0.34 and −0.33, as do the growth and money demand equations at 0.42 and 0.50. This suggests that it is important to take into account the endogeneity of normalized money demand, and this makes model 3 preferred to the other models in this respect. And given the significance of the inflation standard deviation, the most preferred model is model 3 with this standard deviation included (the right-hand side panel). Indeed, further evidence of this is provided by the *Jarque–Bera* test which only passes for the latter.

5. Discussion of results

The three-equation model 3 with the inflation standard deviation would appear to be the preferred model, although the two-equation model 2 growth results are not much different. This shows robustness across the specifications with respect to the significance of most of the variables. The simultaneous equation extensions do make for more confidence in the overall view of the determinants of growth in the panel.

The results show that the inflation rate and/or its standard deviation negatively affect growth across all of the models. Both inflation and its standard deviation are significant in the baseline single-equation model and in the two-equation model; only the inflation standard deviation is significant in the three-equation model. The money-to-income ratio is significantly negative in the baseline and marginally insignificant in the three-equation model. This term can be interpreted as how heavily the inflation tax is striking the economy, with a greater money demand for a given inflation rate inducing a greater inflation tax burden and a lower growth rate.

The inflation standard deviation in the baseline growth model seems to be substituting for inflation. One interpretation is that some of the significant nonlinear inflation effects that are seen in the baseline single-equation model, with its significant interaction term, are being captured more directly by the inflation standard deviation in the three-equation model. Or it can be said simply that inflation uncertainty dominates the level effect once the endogeneity of the inflation rate and the money demand are accounted for (as in the three-equation simultaneous system).

Either way, these results validate the approach, for example, of Judson and Orphanides (1999), who include the inflation standard deviation.

The way in which the inflation rate affects output growth is consistent, to some extent, with studies finding a marginally decreasing growth effect as inflation increases. In the baseline model 1, with the log of inflation as the variable in the growth equation, the smaller the significant negative growth effect, the higher is the inflation rate; and this diminishing marginal effect is also found in the two-equation system of model 3. In these models the derivative of the growth rate with respect to inflation equals the estimated coefficient on the log of inflation term, divided by the inflation rate, and so the effect decreases in magnitude as the inflation rate increases. This form of the specification is more robust than when the inflation variable enters the growth equation in level form rather than log form. Entering both the inflation rate and its standard deviation in level form as an alternative specification in the baseline model 1 also gives a significant negative effect, and here it is a constant change in the growth rate as the inflation rate rises. However, this level form of the inflation effect is not significant in model 2 or 3. In the three-equation model 3, the log of the standard deviation alone is the significant inflation effect. In this case, given the well-known high correlation between the mean and standard deviation of inflation, this result may not be inconsistent with a marginally decreasing inflation effect on growth.

The ratio $M2/y$ is a monetary aggregate ratio, and similar ratios have been included in growth rate estimations found in the financial development literature, such as in Rajan and Zingales (2003) and Boyd *et al.* (2001). We experimented with financial development specifications of this equation, but these were not successful. Instead, the money demand approach is used as it is internally consistent with the theory presented here of why the money–output ratio affects the growth rate negatively, in terms of its indication of the magnitude of the inflation tax burden on growth. Also the money demand estimation is plausible given its near unity income elasticity. The lack of significance of the inflation rate in the money demand equation can be a result of using a relatively broad aggregate, $M2$, for the money demand aggregate. As the aggregate becomes broader, it goes from being more of a money aggregate towards being a credit aggregate. And the effect of inflation or the interest rate on money demand empirically has been found to turn from being a negative effect to being a positive one. For example, for the US postwar 1946–1999 sample, Haug and Tam (2007) use error-correction methods and find that $M2$ money demand has a significant positive sign on the interest rate; over the same period for $M1$ money demand they find cointegration with a Cagan (1956) negative semi-interest elasticity; and they also find a negative interest elasticity for $M0$ money demand. We also experimented with entering the inflation rate in its log form into the money demand equation (giving a constant interest elasticity), and with using the nominal interest rate in addition to, or instead of, the inflation rate, but these experiments had little effect on the results of the three-equation system.

Dawson (2003) finds in his panel study of growth in transition countries that the ratio of investment-to-GDP is significant, although he does not include inflation in the growth equation. While this is also significant in the OECD panel study of Gillman *et al.* (2004), here it is not found to be significant in any of the models. An interpretation of this result is that the investment ratio can capture the effect of the real interest rate on growth to some extent. And it could be that in the transition data of this study the tax effects of inflation on growth swamp the real interest rate effects on growth. However, the investment ratio may well be significant for a different set of countries or a different time period.

The results taken altogether can be interpreted as a finding in support of endogenous growth over exogenous growth. Kocherlakota and Source (1996) find that certain types of government capital spending causes permanent changes in the level of GDP, and that this supports endogenous growth models. And in Kocherlakota and Yi (1995) they show how the sign of the coefficient on initial income in growth regressions does not by itself indicate whether growth is exogenous or endogenous in nature. Here, the sign on the convergence variable in the full model 3 is positive, so that countries with relatively low income have a higher growth rate.

We would need to include additional variables on initial human or physical capital in order to categorize precisely the convergence result as supporting exogenous or endogenous growth according to Kocherlakota and Yi (1995). Due to data scarcity we are unable to take this approach. However, we do include the share of government spending in GDP. This variable indicates the degree of the overall tax burden that in endogenous growth theory can cause a lower growth rate. And this is found to have a significant negative effect as would be expected when omitting the inflation standard deviation. The government ratio become less significant when including the inflation standard deviation and again this may be that the negative inflation tax effect, or inflation uncertainty effect, is swamping in significance the overall tax effect indicated by the government ratio variable.

These results provide support of endogenous growth from the monetary perspective. The negative effect of inflation on growth is strong either through the level of inflation or its standard deviation. And in monetary models of endogenous growth the inflation rate can act as a tax on human capital and so lower growth. Albeit the effect of uncertain inflation on growth is not well established either empirically for developed countries or theoretically within endogenous growth economies. Some arguments about precautionary savings can lead to a conclusion that inflation uncertainty increases economic growth. However, the effect of certain inflation is clear in it leading to lower growth in Lucas (1988)-type models. And our empirical results on the inflation standard deviation likewise support a negative effect of such uncertain inflation on growth in this sample, as in Judson and Orphanides (1999) for postwar OECD data.

6. Conclusion

We present a baseline model of growth that depends in part on inflation and normalized money demand. We account for the possibility that both inflation and normalized money demand may be endogenous variables, by estimating a system of three equations, for growth, inflation and normalized money demand, using full-information MLE techniques. The estimated error correlations suggest that both are endogenous in the growth equation. The results also suggest that it is important to include the inflation standard deviation.

Extensions to include public capital would be useful, both to see the effect of certain types of government expenditure and to enable further testing of exogenous versus endogenous growth. However, detailed data on different public capital are difficult to gather in a way that the data are homogenous. It would also be useful to bring to bear how research and development expenditure affects growth in transition countries, again an issue of data availability, following the theory, for example, of Aghion and Howitt (2007). And this may prove a better alternative, for example, to the investment-to-output ratio.

The results provide robust new panel evidence that inflation and/or its standard deviation significantly and negatively affects economic growth in transition countries. These results indicate that this region's growth, inflation and normalized money demand experience may not be so different from more developed countries. And significant growth convergence evidence is found in the full simultaneous system model.

The results of the simultaneous systems include the determination of inflation by the money supply growth. And such money supply growth occurs across different monetary policy regimes, be they Taylor rule guided with a residual money supply process, inflation targeting or other regimes. This suggests that monetary policy, through the inflation rate, may affect growth as perversely in transition as in developed countries. And if so, then this should make adoption within the region of the relatively low-inflation Euro, or some other low inflation policy such as inflation targeting, beneficial for growth in this region. From this perspective, as far as the adoption of such low inflation policies is concerned, the sooner the better. However, fiscal policy needs to keep budget deficits within reasonable ranges in order for such pro-growth policies to be successful. And results also suggest to some extent that more trade and a lower government share in output are good for transitional countries' growth.

References

Aghion, P. and Howitt, P. (2007). 'Capital, innovation, and growth accounting', *Oxford Review of Economic Policy*, 23(1), pp. 79–93.

Boyd, J. H., Levine, R. and Smith, B. D. (2001). 'The impact of inflation on financial sector performance', *Journal of Monetary Economics*, 47(2), pp. 221–249.
Cagan, P. (1956), 'The monetary dynamics of hyperinflation', in Friedman, M. (ed.), *Studies in the Quantity Theory of Money*, Chicago, IL: The University of Chicago Press, pp. 25–120.
Cooley, T. F. and Hansen, G. D. (1995). 'Money and the business cycle', in Cooley, T. F. (ed.), *Frontiers of Business Cycle Research*, chapter 7, Princeton, NJ: Princeton University Press, pp. 175–216.
Crowder, W. J. (1998). 'The long-run link between money growth and inflation', *Economic Inquiry*, 36(2), pp. 229–243.
Dawson, P. J. (2003). 'Financial development and growth in economies in transition', *Applied Economic Letters*, 10, pp. 833–836.
Fountas, S., Karanasos, M. and Kim, J. (2006). 'Inflation uncertainty, output growth uncertainty and macroeconomic performance', *Oxford Bulletin of Economics and Statistics*, 68(3), pp. 319–343.
Ghosh, A. and Phillips, S. (1998). 'Inflation, disinflation and growth', *IMF Working Paper WP/98/68*, Washington, DC: IMF.
Gillman, M. and Kejak, M. (2005). 'Inflation and balanced-path growth with alternative payment mechanisms', *Economic Journal*, 115(500), pp. 247–270.
Gillman, M. and Nakov, A. (2004). 'Causality of the inflation-growth mirror in accession countries', *Economics of Transition*, 12(4), pp. 653–682.
Gillman, M., Harris, M. N. and Matyas, L. (2004). 'Inflation and growth: Explaining a negative effect', *Empirical Economics*, 29(1), pp. 149–167.
Greene, W. (2004). 'The behaviour of the maximum likelihood estimator of limited dependent variable models in the presence of fixed effects', *Econometrics Journal*, 7(1), pp. 98–119.
Greene, W. (2008), *Econometric Analysis*, 6th edn, Englewood Cliffs, NJ: Prentice-Hall.
Haug, A. A. and Tam, J. (2007). 'A closer look at long-run US money demand: Linear or nonlinear error-correction with M0, M1, or M2?' *Economic Inquiry*, 45(2), pp. 363–376.
Heckman, J. (1981), 'Statistical models for discrete panel data', in Mansky, C. and McFadden, D. (eds), *Structural Analysis of Discrete Data with Econometric Applications*, Cambridge, MA: MIT Press.
Judson, R. and Orphanides, A. (1999). 'Inflation, volatility and growth', *International Finance*, 2(1), pp. 117–138.
Kocherlakota, N. R. and Source, K.-M. Y. (1996). 'A simple time series test of endogenous vs. exogenous growth models: An application to the United States', *The Review of Economics and Statistics*, 78(1), pp. 126–134.
Kocherlakota, N. R. and Yi, K.-M. (1995). 'Can convergence regressions distinguish between exogenous and endogenous growth models?' *Economics Letters*, 49, pp. 211–215.
Levine, R., Loayza, N. and Beck, T. (2000). 'Financial intermediation and growth', *Journal of Monetary Economics*, 46, pp. 31–77.
Lucas, R. E., Jr (1988). 'On the mechanics of economic development', *Journal of Monetary Economics*, 22, pp. 3–42.
Mark, N. C. and Sul, D. (2003). 'Cointegration vector estimation by panel DOLS and long run money demand', *Oxford Bulletin of Economics and Statistics*, 65(5), pp. 655–680.
Neyman, J. and Scott, E. (1948). 'Consistent estimates based on partially consistent observations', *Econometrica*, 39, pp. 359–382.

Rajan, R. G. and Zingales, L. (2003). 'The great reversals: The politics of financial development in the 20th century', *Journal of Financial Economics*, 69(1), pp. 5–50.
Wooldridge, J. M. (2002), *Econometric Analysis of Cross Section and Panel Data*, Cambridge, MA: MIT Press.