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*The Effect of Inflation on Growth: Evidence from a  
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# The Effect of Inflation on Growth: Evidence from a Panel of Transition Countries\*

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## 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, full-information maximum likelihood, 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 of inflation on growth, and one that declines in magnitude as the inflation rate increases. These results include a role for a normalized money demand, by itself and as part of a nonlinearity in the inflation-growth effect. And these results derive from both a baseline single equation model and one that is then expanded into a three equation simultaneous system. This allows for possible simultaneity bias in the baseline model.

**JEL Classification:** C23, E44, O16, O42

**Keywords:** Growth, transition, panel data, inflation, money demand, endogeneity

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# 1 Introduction

Inflation still remains a stubborn problem in some transition countries. How this may affect these country's growth prospects is of considerable 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 country, for both panel and time series data (Gillman, Harris, and Matyas 2004, Fountas, Karanasos, and Kim 2006); how inflation affects transition countries is much less clear.

Theoretically, inflation can act as a tax on human capital by lowering the marginal product of human capital because of inflation-induced substitution from goods to leisure; with less use of human capital, because of more leisure, there is a lower return to capital, which causes a lower growth rate. (Gillman and Kejak 2005a, Gillman and Kejak 2005b). A striking feature of the inflation effect empirically is its non-linearity: it becomes smaller in magnitude as the inflation rate rises.<sup>1</sup> This can be explained theoretically as a rising sensitivity to the inflation tax that induces increasingly less holding of real money, more use of credit, and less substitution towards leisure (Gillman and Kejak 2005b).

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.<sup>2</sup> A priori, there is no certainty that transition countries would be exempt from the inflation tax effect on growth. While a transition country may be still 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, such as when transition countries have shaky federal tax financing that leads to fluctuating inflation rates. Such fluctuations can exacerbate possible feedback from the growth rate to the inflation rate, which creates endogeneity between inflation and growth.

This paper identifies the inflation effect on growth in a panel of transition countries by constructing models of growth, inflation, and money demand and estimating these using

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<sup>1</sup>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% for developed to 11% 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, Harris, and Matyas (2004) find a negative effect of inflation at all positive levels of inflation.

<sup>2</sup>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.

advanced panel techniques. The baseline econometric model is a single equation model; two-equation and three-equation simultaneous models are then built to account better for the possible endogeneity of inflation and normalized money demand. The extended models provide a significant robustness check to the results of the single equation model.

Money demand enters the model because of its role in determining the magnitude of the inflation-growth effect, theoretically as in Gillman and Kejak (2005a,b). The baseline model includes the ratio of the broad money stock to GDP; this is the income-normalized money demand, also equal to the inverse money velocity. This monetary aggregate has been included in growth estimations to proxy financial development<sup>3</sup>; but here it is included because the interest elasticity of money demand theoretically may determine the inflation-growth effect, and this elasticity can be captured in part in the econometric model using money demand.

An interaction term between normalized money demand and inflation is posited in the baseline econometric model. The rationale is that the product of normalized money demand and inflation is a measure of inflation tax revenues per unit of output, which in turn varies with the magnitude of the interest elasticity of money demand in a Cagan (1956) -type money demand function.<sup>4</sup> The interaction term is thereby designed to link the interest elasticity to the growth rate.<sup>5</sup>

Normalized M2 money demand also enters by itself within the model, as it can potentially further help explain growth. When the non-linear inflation effects on money demand are controlled for, the currency demand component as a fraction of GDP can indicate the degree to which tax evasion is occurring and how big is the shadow economy, which can affect growth; currency demand is often used as a measure of the shadow economy, and of how much avoidance there is of financial intermediation through the banking system. Similarly, the short term interest yielding aggregates that also are components of M2, as a fraction of GDP can indicate the extent to which assets are in short term interest yielding instruments rather than being in longer term credit instruments. Use of currency and short term investment, rather than long term investment, might hamper long run growth prospects.

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<sup>3</sup>M2/GDP (called "liquid liabilities") is one of three measures of financial development used in (Levine, Loayza, and Beck 2000); the other measures are more like credit aggregates than money aggregates and are not available in large panel data sets for transition countries.

<sup>4</sup>Mark and Sul (2003) have found empirical support for the Cagan function using international panel data. And such a money demand function, with a rising interest elasticity as the inflation rate rises, underlies the results in Gillman and Kejak (2005b).

<sup>5</sup>Such interactions terms have become more common in the growth literature, such as in Aghion, Howitt, and Mayer-Foulkes (2005).

In the simultaneous equations model, separate equations are added to the initial single equation growth model in order to explain each the money demand and the inflation rate, so as to allow for their possible endogeneity. The money demand equation follows the transition literature of including both the inflation rate and the nominal interest rate in the event that the Fisher equation of the nominal interest rate does not hold. For example Cziraky and Gillman (2006) found this was the case for Croatia; and by including both rates a stable money demand function was identified. The inflation equation is explained by the money supply growth rate, as based on standard general equilibrium exchange economies such as the cash-in-advance model (Gillman, Harris, and Matyas 2004). It is consistent with the Crowder (1998) result that the US money supply growth rate Granger-causes inflation, and with similar results found for two transition countries in Gillman and Nakov (2004).

To consider growth convergence, the leading per capita income country in the transition region, the Czech Republic, is chosen as the base country in the income ratio that is typically defined as the per-capita income level of leading country to the per-capita income level of each other country. This is to capture the transition dynamics whereby the growth rate is higher, the farther below is the income level of the particular country relative to the region leader's income level.<sup>6</sup>

The panel consists of 13 transition countries, ranging from the EU accession countries of East-Central Europe, including Bulgaria, the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia; the EU Baltic accession countries of Estonia, Latvia, and Lithuania; to the ex-Soviet nations of Russia, Moldova and Ukraine. The data period is the post-Soviet period of 1990 to 2003. Econometric estimation uses fixed effects, maximum likelihood, panel estimation that accounts for unobserved country and time effects.

The results indicate a significant negative inflation effect across all models, with the sign of the effect and its magnitude consistent with results reported for developed countries. And the magnitude is within a tight range across the four models presented, indicating robustness. Further this inflation effect tends to be diminishing in magnitude as the inflation rate rises, consistent with the non-linearity identified in this literature.

Normalized money demand acts to temper the negative inflation effect on growth, through its part in the interaction term, and when taken by itself it negatively affects growth. When allowed to be endogenously estimated in the three-equation model, the

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<sup>6</sup>Alternatively using a Western European country as the convergence leader, for example Germany, or even the US, yielded only insignificant results.

Table 1: Definitions of Variables

Growth Equation Variables	
$g$	Real GDP Growth Rate, in local currency units (LCU);
$\ln(\pi)$	Natural Log of GDP Deflator Percentage Growth Rate;
$MoneyD$	M2/GDP: income normalized Money Demand
$\ln(\pi) \cdot (MoneyD)$	Product of normalized Money Demand and $\ln(\text{inflation rate})$
$Czech/Other$	[Real GDP, Czech Republic]/[Real GDP, Other Country] in constant \$US;
$I/GDP$	Investment/GDP at market prices each in LCU;
$PopGr$	Population Growth Rate; each in LCU.
Inflation Equation Variables	
$M^s, M^s_{-1}$	M1 Money Supply Growth Rate; Current, Lagged 1 Period, annual, in LCU.
Normalized Money Demand Equation Variables	
$R$	Nominal Base Lending Rate;
$\ln(\pi)$	Natural Log of GDP Deflator Percentage Growth Rate;
$Trade$	(Trade Balance)/GDP;
$GDPpc$	Natural Log of GDP per capita in constant prices.

negative money demand effect rises substantially. Evidence for growth convergence is found in the baseline model but not the extended models.

## 2 Data

The data set is from the online World Bank Development Indicators (WBDI),<sup>7</sup> covering the annual period from 1990 to 2003. The countries included in the sample are: Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, Russia, the Slovak Republic, Slovenia and Ukraine. An alternative data set 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, please see the WBDI database.

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 or as an explanatory variable for the inflation rate. For several countries, the money supply

<sup>7</sup>This data base is also used in Dawson (2003).

growth rate is not available until the mid-1990s, so the sample is not restricted to be 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 4 in the Appendix contains descriptive statistics for the sample.<sup>8</sup>

## 3 Econometric Models

### 3.1 Baseline Model

The baseline model is given as Model 1. With  $g_{it}$  being the dependent variable that denotes the country  $i$  ( $i = 1, \dots, N$ ) GDP growth in year  $t$  ( $t = \tau_i, \dots, T_i$ ), and with  $\ln(\pi_{it})$ ,  $(MoneyD)_{it}$ ,  $\ln(\pi_{it})(MoneyD)_{it}$ ,  $(Czech/Other)_{it}$  and  $\mathbf{x}_{it}$  (a vector) denoting the explanatory variables with unknown weights  $\beta_\pi, \beta_M, \beta_{\pi m}, \beta_c$ , and  $\boldsymbol{\beta}$ , and with  $\varepsilon_{it}$  denoting the disturbance terms, its specification is as follows:

$$g_{it} = \alpha_i + \lambda_t + \beta_\pi \ln(\pi_{it}) + \beta_M (MoneyD)_{it} + \beta_{\pi m} [\ln(\pi_{it})(MoneyD)_{it}] + \beta_c (Czech/Other)_{it} + \mathbf{x}'_{it} \boldsymbol{\beta} + \varepsilon_{it}, \quad (1)$$

The vector  $\mathbf{x}_{it}$  is comprised of two variables, the investment ratio,  $I/GDP$ , and the population growth rate,  $PopGr$ . In addition, the panel nature of the data also requires conditioning on both unobserved country effects, given by  $\alpha_i$ , and unobserved time effects, given by  $\lambda_t$ . 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. Because 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 equation and multiple-equation systems.<sup>9</sup>

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<sup>8</sup>Inflation rates of less than 1% were excluded, which meant dropping 6 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.

<sup>9</sup>If there are correlations between the unobserved effects and the countries's observed heterogeneity, a fixed effects approach is typically advocated (Wooldridge 2002). While, estimation of such fixed effects models by MLE 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 can safely use 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.



The second model, Model 2, imposes the restriction that  $\beta_{\pi m} = 0$ , so that there is no interaction term between inflation and money demand. This is the more standard approach and it is included to clarify the role of the interaction term.

### 3.2 Model 3: Two Equation System

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 estimated equations, we extend the baseline model first to a two-equation system:

$$g_{it} = \alpha_i^* + \lambda_t^* + \beta_\pi^* \ln \pi_{it} + \beta_{\pi m}^* [\ln(\pi_{it}) (MoneyD)_{it}] + \beta_c^* (Czech/Other)_{it} + \mathbf{x}'_{it} \boldsymbol{\beta}^* + \varepsilon_{it}^* \quad (2)$$

$$\ln \pi_{it} = \eta_i + \tau_t + \theta_M M_{it}^s + \theta_{M-1} (M_{-1}^s)_{it} + u_{it} \quad (3)$$

The growth equation is the same, although the coefficient and error estimates are new and denoted with \* subscripts. In the inflation equation,  $\eta_i$  and  $\tau_t$  are unobserved effects; the unknown coefficients are  $\theta_M$  and  $\theta_{M-1}$ , and  $u_{it}$  is a random disturbance term. Similar to Gillman, Harris, and Matyas (2004), where current and lagged values of the rate of growth of the M1 money supply are used as instruments of inflation, here the current and lagged money supply growth rates are the explanatory variables.

To allow for possible endogeneity, the two error terms are allowed to follow a bivariate normal distribution (*BVN*) with correlation coefficient  $\rho_{\varepsilon u}$ ,  $(\varepsilon, u) \sim BVN(\mathbf{0}, \Omega_{\varepsilon u})$  where  $\Omega_{\varepsilon u}$  is the variance-covariance matrix of  $(\varepsilon, u)$ . The model is estimated by maximum likelihood estimation (MLE) techniques under the assumption of multivariate normality.

### 3.3 Model 4: Three Equation System

Model 4 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. The three-equation system is as follows:<sup>10</sup>

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<sup>10</sup>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.

$$g_{it} = \hat{\alpha}_i^* + \hat{\lambda}_t^* + \hat{\beta}_\pi^* \ln(\pi_{it}) + \hat{\beta}_m^* (MoneyD)_{it} + \hat{\beta}_{\pi m}^* [\ln(\pi_{it}) (MoneyD)_{it}] (4) \\ + \hat{\beta}_c^* (Czech/Other)_{it} + \mathbf{x}'_{it} \hat{\boldsymbol{\beta}}^* + \hat{\varepsilon}_{it}^*;$$

$$\ln(\pi_{it}) = \eta_i^* + \tau_t^* + \theta_M^* M_{it}^s + \theta_{M-1}^* (M_{-1}^s)_{it} + u_{it}^*; \quad (5)$$

$$(MoneyD)_{it} = \mu_i + \iota_t + \phi_\pi \ln(\pi_{it}) + \phi_R R_{it} + \mathbf{z}'_{it} \boldsymbol{\phi} + e_{it}. \quad (6)$$

The growth and inflation equations are the same, although now the coefficients and errors again change, and these are indicated by an additional  $\hat{\phantom{x}}$  superscript for the growth equation, and a  $^*$  superscript for the inflation equation. For the money demand equation,  $\mathbf{z}_{it}$  is a vector of other explanatory variables, given below; unknown coefficients are  $\phi_\pi$ ,  $\phi_R$ , and  $\boldsymbol{\phi}$ ;  $\mu_i$  and  $\iota_t$  are unobserved effects, and  $e_{it}$  is a random disturbance term.

The specification of the money demand (*MoneyD*), defined as the ratio of *M2* to *GDP*, partly follows a traditional specification, by including the nominal interest rate and the inflation rate, the latter being included in that the Fisher equation of interest rates does not always hold and both the inflation and nominal interest rates can have separate effects on money demand (Cziraky and Gillman 2006).

The ratio *M2/GDP* is a monetary aggregate ratio, and the same and similar ratios have been estimated in the financial development literature. For example the ratio of private credit to *GDP* is used in this literature (but is not available for transition countries) and is also a type of monetary aggregate (but one that includes only the broad aggregates typically thought of as credit). This suggests using additional variables to explain money demand, as based on this other literature, such as in Rajan and Zingales (2003) and Boyd, Levine, and Smith (2001). In particular, we specify  $\mathbf{z}$  to contain the trade variable, *Trade*, and the level of per capita *GDP*, *GDPpc* (additional variables were experimented with but found consistently insignificant). Greater trade integration might be expected to increase money demand, although the direction of the effect is not obvious. A higher income level can affect the velocity of money demand, especially transitionally. For example, countries that are at the beginning of the transition have rudimentary banking industries, and tend to use more money and less banking; as the income level increases, the banking industry grows and less money is used relatively. This would give a negative relation between the per capita income and the money demand.

In allowing for the endogeneity of both *MoneyD* and  $\ln(\pi)$  in the growth equation, it is assumed that all error terms are freely correlated (with coefficients  $\rho_{\varepsilon u}$ ,  $\rho_{\varepsilon e}$  and  $\rho_{ue}$ ), with multivariate normal distributions (*MVN*) such that  $(\varepsilon, u, e) \sim MVN(\mathbf{0}, \Omega_{\varepsilon ue})$ , where  $\Omega_{\varepsilon ue}$  is the variance-covariance matrix of  $(\varepsilon, u, e)$ .

Table 2: Single Equation Estimation Results: Years 1990 to 2003

	Baseline: Model 1		Model 2	
	Coefficient	Std. Error	Coefficient	Std. Error
$\ln(\pi)$	-6.168	(0.78)**	-3.023	(0.56)**
$MoneyD$	-0.644	(0.13)**	-0.070	(0.07)
$\ln(\pi) \cdot MoneyD$	0.138	(0.03)**		
$Czech/Other$	0.430	(0.21)**	0.221	(0.23)
$I/GDP$	-0.078	(0.16)	-0.302	(0.17)*
$PopGr$	0.759	(0.93)	0.677	(1.03)
Constant	24.901	(5.23)**	16.103	(5.51)**
$N \cdot T$	144		144	
$N$	13		13	

\*Significant at 5% size.

## 4 Baseline Results

Results are reported in Table 2, for Models 1 and 2, and in Table 3, for Models 3 and 4 (unobserved country and time effects not reported). All explanatory variables here are treated as strictly exogenous. A full set of both time and individual dummies are available upon request.

### 4.1 Single Equation Estimation

Table 2 shows in the baseline Model 1 a significant negative effect of inflation on growth. Money demand also significantly affects growth, as does the interaction term between money demand and inflation. This interaction has a significant positive coefficient and acts to moderately reduce the negative effects of each inflation and money demand; this is quantified in the following subsection 4.2. Growth convergence is indicated by the significant positive coefficient for the transition dynamics variable (*Czech/Other*).

Model 2 shows the results when the nonlinearity is ignored. Inflation still significantly negative affects growth, but with a coefficient of about half the magnitude as in the baseline. And no other variable is significant at the 5% level of confidence.

## 4.2 Inflation and Money Demand Effects

The effect of inflation on growth, and of normalized money demand, on growth can be determined in Models 1 and 2 by taking the derivative of growth with respect to each inflation and normalized money demand, using the estimated equation. To simplify this analysis, re-write the estimated equation (1) as

$$g = A \ln(\pi) + B(\text{MoneyD}) + C [\ln(\pi) \cdot (\text{MoneyD})] + (\text{Other}), \quad (7)$$

where *Other* indicates the rest of the variables of equation (1).

### 4.2.1 Inflation

The interaction term between inflation and normalized money demand enters into Model 1 and makes the derivative:  $\partial g / \partial \pi = [A + C(\text{MoneyD})] / \pi$ . From Table 2, and using the mean value for *MoneyD* from Table 4,  $\partial g / \partial \pi = [-6.17 + (0.138)(34.62)] / \pi = -1.39 / \pi$ . With the mean of  $\ln \pi = 2.58$ , as given in the Appendix Table 4, this implies that the mean  $\pi = 13.20$ , and so  $\partial g / \partial \pi = -0.105$ . Note that the negative effect on inflation on growth falls in magnitude as the inflation rate rises.

The derivative of  $g$  with respect to inflation  $\pi$  for Model 2 is simply  $\partial g / \partial \pi = A / \pi$ . By Table 2,  $\partial g / \partial \pi = -3.023 / \pi$ . Evaluated at the mean  $\pi$ , this effect is  $-0.23$ .

### 4.2.2 Money Demand

In Model 1, with the interaction term, the effect of normalized money demand is now  $\partial g / \partial (\text{MoneyD}) = B + C \ln \pi$ . From Table 2, and using the mean value for  $\ln \pi$  from Table 4,  $\partial g / \partial (\text{MoneyD}) = -0.644 + (0.138)(2.58) = -0.29$ . Thus the effect is negative. The effect of normalized money demand in Model 2 is given by  $\partial g / \partial (\text{MoneyD}) = B$ . Since  $B$  is insignificant in Table 2, there is no discernible effect.

## 5 Extension to Simultaneous Systems

The econometric model is extended to the multiple-equation, simultaneous, systems of equations (2)-(3) and (4) to (6) in order to more fully account for endogeneity among inflation, normalized money demand and growth. Model 3 (equations (2)-(3)) has growth and inflation as endogenous, and Model 4 (equations (4)-(6)) also has normalized money demand as endogenous. Table 3 presents two-way fixed effects results.<sup>11</sup>

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<sup>11</sup>Due to convergence problems, the time effects were omitted from the Model 4 estimation.

The Model 3 results indicate that for the growth equation, the significance, sign, and coefficients of normalized money demand, inflation, and the interaction terms are not much affected by the additional equation, as compared to the baseline Model 1. One change is that the *Czech/Other* term loses significance.

The Model 3 inflation equation, in line with the literature that finds that money supply growth rate changes cause inflation rate changes (Crowder 1998), we let inflation be determined by the current, and the one-period lagged, annual growth rate of the M1 money supply aggregate. Adding the growth rate to this equation can be justified either by output gap approaches involving a short run Phillips curve, or with a quantity theoretic determination of inflation, as in Benk, Gillman, and Kejak (2008). However experiments with this growth rate term always found it insignificant.

In Model 4, the growth rate, inflation rate and normalized money demand are treated as endogenous variables. This has the effect of leaving the inflation rate a significant and negative determinate of growth, as well as keeping money demand a significant negative determinate of growth. But the interaction term between inflation and growth loses some significance and is only accepted at a 10% level of confidence. Also, the *Czech/GDP* variable becomes significant, as in the baseline model, but with a negative sign in contradiction with growth convergence theory.

The inflation equation shows a change towards greater significance for the lagged money supply growth rate, now at a 5% confidence level.

The normalized money demand equation shows significance of the inflation rate, with a negative sign, of the nominal interest rate, with a positive sign, and of the GDP per capita, with a negative sign as suggested in Section 1. This suggests a reasonable specification. The positive nominal interest rate effect may indicate the effect of the real interest rate, which can be interpreted in terms of a substitute price to holding money. With a higher real interest rate, the cost of producing banking services is higher, and supply of credit used for exchange is lower (trade credit), and so the money demand would be higher.<sup>12</sup>

The correlation between the error terms of the growth and inflation equations drops from 0.14 in Model 3 to 0.09 in Model 4, both indicating little endogeneity. And for the money demand and inflation equations, the error correlation is also low, at -0.026. However, for the growth and money demand equations the error correlation is high, at 0.95. This suggests that it is important to take into account the endogeneity of normalized money demand in the growth regression. And this also makes Model 4 preferred to the

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<sup>12</sup>This can be derived theoretically by including capital in the specification of the credit production sector, as postulated in Gillman and Kejak (2005a).

Table 3: Systems Estimation Results: Years 1990 to 2003

	Model 3		Model 4	
Growth	Coefficient	Std. Error	Coefficient	Std. Error
$\ln(\pi)$	-5.662	(1.10)**	-7.368	(2.72)**
<i>MoneyD</i>	-0.555	(0.21)**	-1.788	(0.75)**
$\ln(\pi) \cdot (MoneyD)$	0.121	(0.04)**	0.046	(0.03)*
<i>Czech/Other</i>	0.566	(0.42)	-0.288	(0.12)**
<i>I/GDP</i>	-0.102	(0.26)	0.202	(0.24)
<i>PopGr</i>	0.782	(1.30)	0.522	(1.06)
Constant	23.610	(10.13)**	91.692	(39.67)**
Inflation	Coefficient	Std. Error	Coefficient	Std. Error
$M^s$	1.748	(0.30)**	1.777	(0.67)**
$M_{-1}^s$	0.484	(0.29)*	1.096	(0.27)**
Constant	2.873	(0.46)**	2.146	(0.29)**
Money Demand	Coefficient	Std. Error	Coefficient	Std. Error
$\ln(\pi)$	-	-	-2.633	(0.88)**
<i>R</i>	-	-	0.026	(0.01)**
<i>GDPpc</i>	-	-	-2.365	(1.17)**
<i>Trade</i>	-	-	-0.179	(0.13)
Constant	-	-	68.298	(9.63)**
Error Correlations				
$\rho_{g, \ln \pi}$	0.1432		0.0867	
$\rho_{g, MoneyD}$	-		0.9513	
$\rho_{MoneyD, \ln \pi}$	-		-0.0244	
$N \cdot T$	128		120	
$N$	13		13	

\*\*Significant at 5% size; \*Significant at 10% size.

other models in this respect. The exact effects of money demand and inflation on growth can be determined in Models 3 and 4 much as was done in Section 4.2, as follows below.

## 5.1 Inflation and Money Demand Effects

The general simplified model, from the system in equations (4)-(6), now is

$$g = A \ln(\pi) + B(\text{Money}D) + C [\ln(\pi) \cdot (\text{Money}D)] + \text{Other}; \quad (8)$$

$$\ln \pi = \text{Other}2; \quad (9)$$

$$\text{Money}D = D \ln \pi + \text{Other}3. \quad (10)$$

### 5.1.1 Inflation

The effect of inflation on growth in Model 3 is similar to the effect in Model 1:  $\partial g/\partial \pi = [A + C(\text{Money}D)]/\pi$ . Using Table 3, and the mean value of  $\text{Money}D$  from Table 4,  $\partial g/\partial \pi = [-5.66 + (0.121)(34.62)]/\pi = -1.47/\pi$ , similar to the  $-1.39/\pi$  in Model 2. Evaluated at the mean of  $\ln \pi = 2.58$ , with  $\pi = 13.20$ , then  $-1.29/\pi = -0.111$ , almost the same as the  $-0.105$  in Model 1. Again, the negative inflation effect on growth falls in magnitude as the inflation rate increases.

For the effect of inflation in Model 4, the equation for  $\text{Money}D$  depends on inflation and so must be substituted into the growth equation. Making this substitution using equations (8) and (10), the growth equation (8) can now be expressed as  $g = A \ln \pi + [B + C \ln \pi][D \ln \pi] + \text{Other}4$ ; and so  $\partial g/\partial \pi = [A + BD + 2CD \ln \pi]/\pi$ . Using Table 3, and the mean value of  $\ln \pi$  from Table 4,  $\partial g/\partial \pi = [-7.37 + (-1.79)(-2.63) + 2(0.046)(-2.63) \ln \pi]/\pi = -2.90/\pi$ ; evaluated at  $\pi = 13.20$ ,  $\partial g/\partial \pi = 0.22$ . This is a stronger negative effect of inflation than in Models 1 and 3, but about equal to that of the single equation Model 2, where without the interaction term, the result was  $-0.23$ . Using only variables with significance at a 5% level,  $C$  is not significant. Then the computation becomes  $\partial g/\partial \pi = [A + BD]/\pi = [-7.37 + (-1.79)(-2.63)]/\pi = -2.66/\pi = -0.20$ , again close to the result of Model 2.

### 5.1.2 Normalized Money Demand

The effect of the normalized money demand on growth in Model 3 is similar to that in Model 1:  $\partial g/\partial (\text{Money}D) = B + C \ln \pi$ . Using Table 3, and the mean value of  $\ln \pi$  from Table 4,  $\partial g/\partial (\text{Money}D) = -0.56 + (0.121)(2.58) = -0.25$ , as compared to  $-0.29$  in Model 1.

For the three equation system in Model 4, again  $\partial g/\partial (MoneyD) = B + C \ln \pi$ ; and from Table 3 and the mean value of  $\ln \pi$  from Table 4,  $\partial g/\partial (MoneyD) = -1.79 + (0.046)(2.58) = -1.67$ . This is at the 10% level of confidence. At the 5% level, the interaction term is not significant and  $\partial g/\partial (MoneyD) = -1.79$ . These effects are more strongly negative than in Models 1 and 3.

## 6 Discussion of Results

We conducted additional experiments excluding hyperinflation data to test for sensitivity to this. To do this, we used Model 4 and allowed for interaction of a dummy for inflation rates over 100% with appropriate variables. These resulting new coefficients gave us the differential effect of inflation when it's over 100%. This was done first, with such dummies for every variable in which inflation appears in the entire three-equation system; second this was employed with dummies only on the inflation variables that appear in the growth equation. Also we tried a simple dummy variable for inflation rates over 100%, again in the entire three-equation system and in only the growth equation. None of these extra variables were ever individually significant. Therefore we included all hyperinflation data.

The negative effect of inflation can be summarized by the point estimates at the mean inflation rate, of  $-0.23$  for the simplest one-equation model with no interaction term, of  $-0.105$  with the interaction term, of  $-0.11$  in the two-equation model with inflation endogenous, and of either  $-0.23$  or  $-0.20$  in the three-equation model, depending on the level of confidence. The 5% confidence range of  $(-0.105, -0.20)$  is within the  $(-0.13, -0.25)$  range found in a related study by Gillman and Harris (2004) for a single equation system with an OECD country sample.<sup>13</sup> As these point estimates are found within a model in which the negative inflation effect becomes increasing weaker as inflation increases, the inflation effect is qualitatively similar to that of developed countries, though perhaps of somewhat smaller magnitude. A smaller magnitude of the inflation results is consistent with our panel data work (Gillman, Harris, and Matyas 2004), in which the less developed sub-sample shows a significantly smaller magnitude of the inflation effect on growth, than does the OECD sub-sample.

The "liquid liabilities" variable, also called the "financial depth" variable, in Levine, Loayza, and Beck (2000) is the same as the measure of normalized money demand,

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<sup>13</sup>Of the eight alternative estimated models considered by Gillman and Harris (2004), the effect of inflation on growth was between  $-0.19$  and  $-0.25$  for seven of the eight models, and  $-0.13$  for one model. However, this is the effect without factoring in the interaction term between inflation and financial development, which would make these estimates somewhat more negative.



$M2/GDP$ ; and this variable is also used in the transition growth estimation of Dawson (2003). The estimation of the normalized money demand equation, in the three-equation system of Model 4, acknowledges this use of this variable in different literatures by including variables related to openness, such as trade, as well as per-capita GDP, as additional variables that can explain  $M2/GDP$  besides the standard money demand variables. While trade is not significant, the per-capita GDP variable is significant and negative in effect; in comparison Rajan and Zingales (2003) find mixed evidence of the sign of this latter effect, both positive and negative. Conversely, the financial development literature uses the key money demand "own price" variable, the inflation rate, to explain liquid liabilities, as in Boyd, Levine, and Smith (2001).

Our results indicate that normalized money demand has a significantly negative effect on the growth rate, by itself and through the interaction term with inflation, for all models that include some interaction between inflation and normalized money demand (Models 1, 3, and 4). For Model 2, with no interaction with the inflation rate, the effect of normalized money demand is insignificant. Thus the money demand factor proves to be important, but only when including the nonlinearity through the interaction term.

The novel feature of including the interaction term is based in capturing the non-linear effect of inflation on growth that is found empirically and has been explained theoretically. Gillman and Kejak (2005a,b) show that, in a model restricted to a unitary velocity, money demand variation is limited to consumption variation, and the inflation-growth effect is almost linear. This contradicts the evidence that the growth rate falls at a decreasing rate as inflation rises. They go on to show that endogenizing money velocity implies a money demand interest elasticity that rises with the inflation rate (similar to the Cagan (1956) function), and gives the desired nonlinear growth effect of inflation.

Econometrically the nonlinearity in the inflation-growth effect is captured in part with the level-log formulation of the Models 1-4, with the growth rate in levels and the inflation rate in logs. The magnitude of the change in the growth rate from an inflation increase, as in Sections 4.2, and 5.1, falls as the level of the inflation rate rises. However by including the interaction term between money demand and inflation, this inflation-growth effect is modified somewhat. Because the product of money demand and inflation is equal to the tax revenues from the inflation tax, and this varies with the interest elasticity of money demand, the inclusion of the interaction term modifies the shape of inflation-growth profile in a way that can be interpreted as capturing an additional effect of the magnitude of the interest elasticity of money demand. With the interaction term in this data sample being found to be consistently positive, our interpretation of the result is that the interest

elasticity is somewhat higher than that implicit in the inflation-growth relation implied when the interaction term is excluded and money demand plays no role (as in Model 2). The higher money interest elasticity causes the growth effect to be not as negative in the sample. Conversely, a negative effect of the interaction term would have been interpreted as implying that the money demand interest elasticity was lower than that implicit in the inflation-growth effect that would be estimated when excluding the interaction term. Such differences may arise when the data samples represent developing versus developed countries, which have different inflation growth profiles as in Gillman, Harris and Matyas (2004).

The results of a negative effect of money demand on growth, as taken by itself, is interpreted as the effect either of a more rudimentary banking system which intermediates finance less efficiently, or the effect of the underground economy that uses cash more heavily and can be detrimental to growth. These two causes can be interrelated.

## 7 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 maximum likelihood estimation techniques. The estimated correlations suggest that money demand is endogenous in the growth equation, but inflation much less so. An interaction term between inflation and money demand is important to include in order to get unbiased results.

The results provide robust new panel evidence that inflation significantly and negatively affects economic growth in transition countries. And this effects decreases in magnitude as the inflation rate rises, as has been found for developed countries. Inflation also causes less normalized money demand, a finding consistent with standard results. These results suggest that this region's growth, inflation, and normalized money demand experience may not be so different from more developed countries. A caveat is that the growth convergence evidence was found to be mixed.

The results suggest that monetary policy, through the inflation rate, may affect growth and money demand 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.

Table 4: Descriptive Statistics

1990-2003 Sample; Model 4	Mean	Maximum	Minimum	Std. Dev.
$g$	2.63	10.52	-22.93	4.84
$I/GDP$	21.87	36.06	10.98	4.81
$gl$	-0.44	1.61	-2.58	0.58
$MoneyD$	34.62	70.36	9.31	16.36
$Czech/GDP$	8.72	124.87	0.00	26.87
$\ln(\pi)$	2.58	6.86	0.04	1.24
$\ln(\pi) \cdot MoneyD$	80.90	267.09	0.80	46.86
$M^s$	0.25	1.88	-0.20	0.27
$Trade$	-3.68	18.00	-24.70	5.82
$GDP_{pc}$	9.82	16.74	-4.29	4.94
$R$	31.67	320.31	5.51	41.19
$N$	13			
$NT$	120			

From this perspective, the sooner is the adoption of such low inflation policies, the better. However, fiscal policy needs to keep budget deficits within reasonable ranges in order for such pro-growth policies to be successful.

## A Appendix: Descriptive Data Statistics

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