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Money Growth, Output Growth, and Inflation: A Reexamination of the Modern Quantity Theory's Linchpin Prediction

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A testable implication of the modern quantity theory of money, when viewed as a theory of inflation, is the joint hypothesis that (i) there is a one-to-one positive relationship between inflation and the money stock growth rate, (ii) there is a one-to-one negative relationship between inflation and the aggregate output growth rate, and (iii) there are no other determinants of inflation besides the money stock and aggregate output expansion rates. This implication is the theory's linchpin prediction. A recent prior study published in this journal examines cross-country data and reports that this hypothesis cannot be rejected. The present study reexamines the prior study's data and finds that the joint hypothesis is decisively rejected, an unpleasant finding from a monetarist perspective. The article then goes on to propose an alternative to the prior study's model of the inflation process and reports findings that are, from the perspective of a monetarist, at least mildly pleasant.

JEL Classification: E31, E51

1. Introduction

Over the years, the quantity theory of money has been extended and refined. All versions, however, begin with the well-known equation of exchange, $MV = PQ$, where Q is the level of national output (real gross domestic product, GDP), P is the general price level, V is the velocity of money circulation, and M is the quantity of money. To convert this equation—actually an identity—into a theory, one of the four variables contained therein must be specified as functionally dependent on the other three. Monetarists argue that P is the dependent variable (Sprinkel 1971). Specifically, they argue that M is determined by the national monetary authority; that V is determined by a variety of both secular and cyclical factors;[1] that changes in V do not consistently offset changes in M; and that Q is determined by capital, labor, and technological advances (Sprinkel 1971).

The monetarist theory of inflation is a long-run theory; it does not purport to explain short-run increases in the general price level (Hafer and Wheelock 2001). Monetarists argue that short-run inflation stabilization is not feasible and, therefore, that monetary policy should be confined to inflation concerns over a relatively long horizon.[2]

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[1] See Meyer Burstein (1963) for an account of the velocity determinants of Irving Fisher (1911). An alternative version of the quantity theory makes velocity a function of the nominal interest rate (Fama 1982).

[2] Terry Fitzgerald (1999) presents evidence that this time period could be on the order of one decade.

John Moroney (2002, p. 399) asserts that in the traditional version of the quantity theory, "... a country's long-run inflation rate increases [one-to-one] with its money growth rate. The *modern* wrinkle is that inflation is mitigated by real GDP growth" (emphasis added). This assertion is consistent with the famous dictum of Milton Friedman (1968, p. 18) that "... inflation is always and everywhere a monetary phenomenon, produced *in the first instance* by an unduly rapid growth in the quantity of money" (emphasis added). Friedman's assertion is not that an increased money growth rate is the sole cause of inflation in the long run—just the most important cause (Friedman and Friedman 1980). An increase in inflation can also be caused by a decrease in the growth rate of Q (or, theoretically, even an increase in the growth rate of V), as is easily seen by solving the equation of exchange for P and then taking logs and first differences.

After taking logs and first differences,[3] Moroney (2002) obtains an estimating equation in which inflation is functionally dependent on the growth rates of the money stock and real GDP:

$$Y = \beta_0 + \beta_1 X + \beta_2 Z + u \qquad (\beta_0 = 0, \beta_1 = 1, \beta_2 = -1), \tag{1}$$

where Y is $\Delta \ln P$, X is $\Delta \ln M$, Z is $\Delta \ln Q$, and u is a random disturbance term that includes velocity changes. (Δ is the first difference operator.) The modern quantity theory's model-implied restrictions—which are testable predictions—are that the intercept is zero, the coefficient of the money stock growth rate is plus one, and the coefficient of the growth rate of real GDP is minus one. Arguably, this joint hypothesis is the *linchpin* prediction of the modern quantity theory: If the hypothesis is rejected by the data, the theory falls.

Using long-run (1980–1993) cross-section data on 81 countries, which he takes from the World Bank's *World Development Report 1995*, Moroney (2002) tests the joint hypothesis ($\beta_0 = 0$, $\beta_1 = 1$, $\beta_2 = -1$) and incorrectly claims that the hypothesis cannot be rejected at even the 0.01 level of significance.[4] As will be shown in the next section, the joint hypothesis is rejected decisively. Fortunately, however, it will also be shown that a modification to Moroney's model specification helps to salvage the most substantive part of the modern quantity theory's implied restrictions.

2. Modification to the Quantity Theory Setup

In contrast to the conventional quantity theory setup, in which the economy's real activity is determined entirely outside its monetary sector (Fama 1982; Moroney 2002)—that is, in which no provision is made for the possibility that the monetary authority's actions could have an adverse effect on output[5]—the present article entertains the possibility that Y and Z are jointly determined. The motivation for exploring this possible joint determination is that some researchers, most notably Robert Barro (1997), have demonstrated that a negative correlation emerges when the long-run average rate of growth of GDP per capita is regressed on the long-run average inflation rate (and a set of control variables). While some argue that this evidence is far from conclusive (Bruno and Easterly 1998),[6] it is suggestive. Formally, Barro's regression equation is

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[3] Actually, Moroney writes the expression in terms of first-order differentials, but the inflation equation he estimates is one that is expressed in first differences.

[4] In a December 16, 2003, E-mail to the author, John Moroney graciously acknowledged that his claim is erroneous.

[5] The quantity theory setup notwithstanding, inflation—whether anticipated or unanticipated—can impose *real* costs (Abel and Bernanke 1991; Briault 1995).

[6] However, see Gylfason and Herbertsson (2001).

$$\Delta \ln(\text{GDP}/\text{POP}) = \gamma_0 + \gamma_1 Y + \gamma_2 W_2 + \cdots + \gamma_k W_k + \varepsilon_1, \quad (2)$$

where Δ ln (GDP/POP) is the average annual growth rate of real GDP per capita over a long-run period, Y is (as in the quantity theory inflation equation) the average inflation rate over the period, the Ws are controls, and ε_1 is the usual disturbance term.

In their oft-cited critique of the cross-country economic growth regression literature, Ross Levine and David Renelt (1992) employ the following base regression equation:[7]

$$\Delta \ln(\text{GDP}/\text{POP}) = \delta_0 + \delta_1 \text{INITIAL} + \delta_2 \text{SCHOOL} + \delta_3 \text{INV} + \delta_4 \Delta \ln \text{POP} + \varepsilon_2, \quad (3)$$

where INITIAL is the initial level of real GDP per capita, SCHOOL is a measure of the population's educational attainment that proxies for the stock of human capital, INV is the average investment share of GDP, and Δ ln POP is the average population growth rate. If the latter equation is expanded to include Y as a regressor, and if Δ ln POP is added to both sides of the resultant equation, the following equation is obtained:

$$Z = \delta_0 + \delta_1 \text{INITIAL} + \delta_2 \text{SCHOOL} + \delta_3 \text{INV} + (1 + \delta_4)\text{POPRATE} + \delta_5 Y + \varepsilon_3, \quad (4)$$

where POPRATE is Δ ln POP and Z is (as before) Δ ln GDP. There is no pretense here that the latter equation is a structural relation.[8] The purpose of expanding the modern quantity theory's model of inflation to include the latter equation along with Moroney's inflation equation is merely to allow for the possibility that Y and Z are jointly determined, and then to see what the effect might be on the theory's joint hypothesis ($\beta_0 = 0$, $\beta_1 = 1$, $\beta_2 = -1$).

3. Ordinary Least Squares Results

As mentioned, Moroney's 81-country sample data are from the *World Development Report 1995* (World Bank 1995). X is average annual nominal growth rate (%) of money, broadly defined, over the period 1980–1993; Y is average annual growth rate (%) of the GDP deflator, 1980–1993; and Z is average annual growth rate (%) of real GDP, 1980–1993. The first column of results in Table 1 is the output of an attempt to replicate table 1a of Moroney (2002). That output includes ordinary least squares (OLS) estimates of the coefficients and coefficient standard errors for Moroney's inflation equation. (Moroney does not report the estimated intercept and its standard error.) The estimate for the coefficient of X and its standard error are identical to Moroney's, but the same is not quite true for the estimated coefficient of Z and its standard error.[9] Also reported, at the bottom of Table 1's first column of results, are two Wald (1943) test results.[10] The first tests the *strong* joint hypothesis, H_0: $\beta_0 = 0$, $\beta_1 = 1$, $\beta_2 = -1$. The calculated value of the chi-square test statistic, 39.3474, is far greater than the

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[7] The term "base regression" is from Levine and Renelt (1992).

[8] As Xavier Sala-i-Martin (1997) points out, a problem faced by empirical growth economists is that growth theories are not explicit enough about what explanatory variables belong in the "true" growth regression equation.

[9] The data used to generate these estimates were provided in hard copy attached to an April 9, 2003, E-mail received by the author from John Moroney. The author carefully checked (and rechecked) to ensure that no transcription errors were made when the data were used as input for his regressions. The author cannot explain why his results differ (slightly) from Moroney's.

[10] An exposition of the Wald test can be found in several econometrics textbooks, for example, Greene (2000).

Table 1. Inflation Regression: OLS Results

Explanatory Variable	Regression (I)	(II)	(III)
Intercept	−0.0574 (0.8762)	−0.1223 (0.2274)	−0.2342 (0.6196)
X	1.0333 (0.0087)*	1.0248 (0.0302)*	1.0331 (0.0236)*
Z	−1.7210 (0.2123)*	−1.4737 (0.1555)*	−1.6620 (0.1759)*
Adjusted R^2	0.9946	0.9526	0.9946
Chi-square for strong Wald (1943) test	39.3474*	33.7463*	36.8017*
Chi-square for weak Wald (1943) test	31.9407*	12.9112*	14.2552*
Sample size	81	81	76

Estimated coefficient standard errors are in parentheses. As in table 1a of Moroney (2002), the estimated standard errors for regression (I) are not White (1980) heteroskedasticity consistent. For regression (II), as in table 1b of Moroney (2002), heteroskedasticity is accounted for by dividing the variables by the square root of X, that is, the regressand is $Y/\sqrt{X}$ and the regressors are $X/\sqrt{X}$ and $Z/\sqrt{X}$. For regression (III), the estimated standard errors are White (1980) heteroskedasticity consistent.
* Statistically significant at the 0.01 level.

critical value of that statistic for any conventional level of significance, signaling decisive rejection of the strong joint hypothesis. However, because the intercept is not statistically significant,[11] this test may be too demanding. The null hypothesis for the second Wald test is less stringent; it is the *weak* joint hypothesis, H_0: $\beta_1 = 1$, $\beta_2 = -1$. This hypothesis, also, is soundly rejected.[12]

The second column of results in Table 1 is the output of an attempt to replicate table 1b in Moroney (2002). To correct for heteroskedasticity, Moroney divides all of the original variables by the square root of X: The regressand is $Y/\sqrt{X}$, and the regressors are $X/\sqrt{X}$ and $Z/\sqrt{X}$. The estimated coefficients and standard errors, although not identical to Moroney's, are not much different. Moroney (2002, p. 405) incorrectly claims that the null hypothesis "... $\beta_0 = 0$, $\beta_1 = 1$, $\beta_2 = -1$ cannot be rejected at $p \leq .01$." For the strong Wald test (of $\beta_0 = 0$, $\beta_1 = 1$, $\beta_2 = -1$), the calculated value of the chi-square statistic is 33.7463, which exceeds the critical value of the test statistic for any conventional level of significance. This result is the exact opposite of Moroney's interpretation of his Wald test result. The calculated value of the chi-square test statistic for the weak Wald test (of $\beta_1 = 1$, $\beta_2 = -1$), 12.9112, also exceeds the critical value. Thus, for both Wald tests the modern quantity theory's prediction is rejected.

The results in the last column of Table 1 are for 76 of Moroney's 81 countries. In the study's next section, Y and Z are treated as jointly determined. Data on some of the determinants of Z are missing for five countries.[13] The purpose of reporting the results that appear in the last column is to make possible an "apples-to-apples" comparison of Moroney's single-equation quantity theory specification with the two-equation specification examined in section 4. The estimated coefficients, coefficient standard errors, and Wald test statistics reported in the last column of Table 1 are qualitatively the same as those reported in the first column of results, indicating that the five countries dropped do not exert an undue influence on the results obtained for the 81-country sample. The Wald

[11] An anonymous referee has asserted that "[t]he intercept in the basic regression might be nonzero if, as Moroney suggested, inflation is measured with error."

[12] An anonymous referee has also asked if a Hausman (1978) test was used to test the "... hypothesis that the OLS specification is inconsistent." Presumably this concern is whether or not Z is exogenous; if Z is endogenous, OLS estimation would yield inconsistent coefficient estimates. The results of the Hausman test did suggest that the null hypothesis that Z is exogenous could not be rejected. Nonetheless, it was decided to proceed as if Z were endogenous because nonrejection of a null hypothesis does not necessarily mean that the null is true, and because Barro (1997) and others have provided empirical support for the view that inflation is a (negative) determinant of economic growth.

[13] The five countries are Burkina Faso, China, Oman, Poland, and Romania.

Table 2. Inflation and Output Growth Regressions: 2SLS Results

Explanatory Variable	Dependent Variable Y	Dependent Variable Z
Intercept	−1.0949 (1.2186)	2.5188 (1.3045)**
X	1.0350 (0.0247)*	—
Z	−1.3938 (0.3341)*	—
INITIAL	—	−0.2668 (0.1401)**
SCHOOL	—	−1.1591 (0.9942)
INV	—	12.8562 (4.5320)*
POPRATE	—	−0.4334 (0.2658)
Y	—	−0.0045 (0.0027)***
Adjusted R^2	0.9945	0.1997
Chi-square for strong Wald (1943) test	29.2311*	—
Chi-square for weak Wald (1943) test	4.6002	—
Sample size	76	76

White (1980) heteroskedasticity-consistent estimates of coefficient standard errors are in parentheses. Strictly speaking, R^2 is not a meaningful statistic when the estimation method used is 2SLS (Basmann 1962).
* Statistically significant at the 0.01 level.
** Statistically significant at the 0.05 level.
*** Statistically significant at the 0.10 level.

test results indicate that the bottom line remains the same: The quantity theory's model-implied prediction is rejected by all of the OLS results. However, these results should not be accepted uncritically, for reasons explained in the next section.

4. 2SLS Results

This section treats the output growth equation—the last equation in section 2—and Moroney's inflation equation as a simultaneous system. Data for, and definitions of, the inflation equation's variables are discussed above. For the variables in the output growth equation that are not also included in the inflation equation, the data come from two sources. Data on POPRATE, the average annual population growth rate (%) for 1980–1993, are from the *World Development Report 1995* (World Bank 1995). Data on the remaining three explanatory variables are from the data set of Levine and Renelt (1992).[14] INITIAL is real GDP per capita in 1960, Levine and Renelt's RGDP; SCHOOL is primary enrollment rate in 1970, Levine and Renelt's PRJ; and INV is the 1974–1989 investment share of GDP, Levine and Renelt's INV also.

The results anticipated for the output growth equation are largely confirmed by the results reported in Table 2. The estimated coefficient of the initial level of real output is significantly negative, a result that mirrors the so-called convergence hypothesis (Barro and Sala-i-Martin 1995), which asserts that, other things equal, poor economies tend to grow faster than rich ones. The estimate of the coefficient of investment is positive and significantly different from zero. On the other hand, the educational attainment variable does not enter significantly, a result that is consistent with the findings of some previous studies (Temple 1999). Finally, the estimated coefficient of inflation also is statistically significant (albeit weakly significant).

The 2SLS results for the inflation equation are an improvement over the OLS results. The 2SLS-estimated coefficient of X is virtually identical to the estimate obtained from the OLS estimations,

[14] This data set is available at www.worldbank.org/research/growth/ddlevren.htm on the World Bank's Web site.

all being close to the quantity theory prediction, $\beta_1 = 1$. Importantly, the 2SLS estimate of the coefficient of *Z*, −1.39, is closer to the quantity theory prediction than are the OLS estimates. In fact, the 2SLS estimate is close enough to the quantity theory's predicted value that the second Wald test result reported in Table 2 cannot reject the weak joint hypothesis, not even at the 0.10 level of significance. This result salvages the most substantive part of the modern quantity theory's model-implied restrictions, namely (i) that there is a one-to-one positive relationship between inflation and the money stock growth rate, and (ii) that there is a one-to-one negative relationship between inflation and the aggregate output growth rate.

The results presented in Table 2 also permit an assessment of the famous assertion of Friedman (1968) that inflation is primarily a monetary phenomenon. This assessment can be made by comparing the *beta coefficients* of the explanatory variables (Goldberger 1964). Beta coefficients are standardized parameters that provide a dimensionless gauge of the relative influence of the explanatory variables, *X* and *Z*, on the affected variable, *Y*. If *X* and *Z* had the same units of measurement, then a comparison of their unstandardized coefficients would provide an idea of their relative influence on *Y*. Of course, this is not the case for *X* and *Z*—their scales differ. Beta coefficients can be used to circumvent this problem. The beta coefficient for *X* is the 2SLS-estimated coefficient of *X* multiplied by the sample standard deviation of *X* divided by the sample standard deviation of *Y*. The beta coefficient for *Z* is similarly defined. For the 76-country sample, the standard deviation of *Y* is 58.95, of *X* is 56.17, and of *Z* is 2.03. Thus, the beta coefficients of *X* and *Z* are 0.9863 and –0.0479, respectively. Since the beta coefficient for *X* is numerically much larger than that for *Z*, Friedman's assertion is supported by the data.

In his table 6, Moroney (2002) reports OLS results for 21 low-inflation, low–money-growth countries.[15] Although he obtains coefficient estimates that are statistically significant at the 0.05 level, his adjusted R^2 is relatively small (0.308), which leads him to conclude that the quantity theory is inadequate, or at least incomplete, for explaining inflation in those countries. The expanded two-equation model also performs poorly for the sample of low-inflation, low–money-growth countries, with one country (Oman) deleted due to missing data (on INITIAL). None of the 2SLS-estimated coefficients in either the inflation equation or the growth equation is significantly different from zero.

5. Conclusions

Empirical results reported in economics journals should naturally invite skepticism—scientific inquiry embodies dubiety. Replication is an essential part of scientific methodology (Dewald, Thursby, and Anderson 1986).

This article has attempted to replicate the empirical results reported in Moroney (2002). This effort was only partially successful. Most importantly, the article has called attention to a serious reporting error, that is, Moroney's claim that the modern quantity theory's model-implied restrictions are consistent with his 81-country sample evidence. To rectify this situation, the article has proposed appending an output growth equation to Moroney's inflation equation.

Except for low-inflation, low–money-growth countries, the empirical evidence obtained by treating inflation and output growth as jointly determined salvages the modern quantity theory's two most important model-implied restrictions: (i) that there is a one-to-one positive relationship between

[15] An attempt to replicate exactly these results was successful, unlike the attempt to replicate full sample results of Moroney (2002) reported in his table 1.

inflation and the money stock growth rate and (ii) that there is a one-to-one negative relationship between inflation and the aggregate output growth rate. Moreover, the empirical evidence presented in this article provides support for Friedman's dictum that inflation is primarily a monetary phenomenon.

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