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Is inflation always and everywhere a monetary phenomenon?

Paul De Grauwe

Abstract

Using a sample of about 160 countries over the last 30 years, we test for the quantity theory relationship between money and inflation. When analysing the full sample of countries, we find a strong positive relation between long-run inflation and the money growth rate. The relation is not proportional, however. The strong link between inflation and money growth is almost wholly due to the presence of high- (or hyper-) inflation countries in the sample. The relationship between inflation and money growth for low-inflation countries (on average less than 10% per annumover the last 30 years) is weak.

I. *Introduction*

Is inflation always and everywhere a monetary phenomenon? [1] Many economists today will argue that when analysed over a sufficiently long period of time, inflation is indeed everywhere a monetary phenomenon. This "monetarist" view has not always been widespread, however. Prior to the upsurge of inflation in the 1970s, many economists were not inclined to look at the money stock when analysing the sources of the (low) inflation rates of that time. In this paper, we return to this issue using a sample of countries spanning the whole world over a period of 30 years. The key question we analyse concerns the link between inflation and the growth rate of money and how it depends on whether countries experience low or high rates of inflation.

The view that inflation is always and everywhere a monetary phenomenon has a long tradition based on the quantity theory of money (QTM). In

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[1] Friedman (1963) wrote these now famous words, not as a question but in the affirmative; see also Friedman and Schwartz (1963).

its simplest form, the QTM says that changes in money supply growth are followed by equal changes in the inflation rate and, through the force of the Fisher effect, in the nominal interest rate. The QTM is a measure of the extent to which inflation movements can be explained by purely monetary forces.

The starting point of the QTM is the well-known identity:

$$MV = YP, \tag{1}$$

where M is money supply, V is the velocity of money, Y is real output, and P is the price level. If we move to growth rates, we can express this equation as:

$$m+v=y+p,[2] \tag{2}$$

where lowercase letters denote growth rates. Thus, inflation – or the growth rate of the price level – can be expressed as:

$$p=m-y+v. \tag{3}$$

These identities are transformed into a theory, the quantity theory, by the following two propositions. First, in the long run, there is a proportionality relation between inflation and the growth rate of money, i.e., in a regression of inflation on money growth, the coefficient of money is estimated to be 1. Second, over a sufficiently long period of time, output and velocity changes are orthogonal to the growth rate of the money stock.

Thus, there are two aspects of the quantity theory. The proportionality prediction says that a permanent increase in money growth leads to an equal increase in the rate of inflation in the long run, while the orthogonality proposition – also referred to as the (super)neutrality of money – says that a permanent increase in the growth rate of money leaves output and velocity unaffected in the long run. If there is a positive effect of money growth on output, it only holds in the short run.

In this paper, we analyse these two propositions of the QTM. The way we proceed is to transform the identity into an econometric equation with testable propositions. Since we do not have independent estimates of ve-

[2] These are, of course, instantaneous rates, not average rates. For low growth rates, this should not pose a problem; for high growth rates, however, the inflation rate will be underestimated by just adding growth rates of money, velocity and output.

locity, we include velocity in the error term[3]. As a result, we estimate an equation of the form:

$$p_i = \beta_0 + \beta_1 m_i + \beta_2 y_i + \mu_i, \tag{4}$$

where p_i, m_i and y_i are the rate of inflation, the money growth and the output growth of country i, respectively, measured over a sufficiently long period of time (30 years). The QTM theory then predicts that $\beta_1 = 1$, $\beta_2 < 0$, and m_i and y_i are uncorrelated. We then test these propositions. Note that a potential bias may arise if the independent variables m_i and y_i are correlated with the error term (velocity). We provide indirect evidence that such a bias might exist.

The QTM does not specify which definition of money supply should be used in empirical tests of the theory. There is no theoretical reason why M1 or M2 should be used as the appropriate variable. Accordingly, many authors use both or other monetary aggregates to compare the results obtained for various definitions of money. Since the empirical literature is not consistent in its opinion as to which monetary aggregate is more correlated with the price level, we use both M1 and M2 in our study.

II. *Review of the Empirical Literature*

There is a vast empirical literature concerning the long-run relation between money growth and inflation. We begin by briefly describing some of its aspects. This literature can be divided into three groups. The first uses crosssection data on a large number of countries over a long time span. Usually, a long-run average of money supply (or its growth rate) and price level (or the inflation rate) is calculated and used to compute the correlation between the two. All countries are treated equally, and there is no distinction according to monetary or economic regimes.

Authors in the second group use long series of higher frequency data (annual or quarterly) referring to only one country to describe a long-run relationship between money and the price level. Sometimes, the results are compared with other single-country findings.

[3] We could, of course, use the definitional equation to derive velocity. But this would not be very sensible as we would then estimate an identity.

Table 1. *Main multi-country studies of long-run relationship between money supply and price level*

Author, year	Monetary aggregate	Prices	Data set	Time span	High–Low differentiation	Results
Vogel (1974)	Currency + demand deposits	CPI	16 Latin American countries	1950–69, annual data	No	Proportionate changes in inflation rate within two years of changes in money growth
Dwyer and Hafer (1988)	M2	GDP deflator	62 countries	1979–84, five-year averages	No	Strong positive correlation
Barro (1990)	Hand-to-hand currency	CPI	83 countries	1950–87	No	Strong positive "association"
Pakko (1994)	Currency + bank deposits	CPI	13 former Soviet republics	1992 and 1993, four-quarter averages	No	Positive relationship
Poole (1994)	Broad money	n.a.	All countries in World Bank tables	1970–80 and 1980–91, annual averages	No	Strong positive relationship
McCandless and Weber (1995)	M0, M1, M2	CPI	110 countries reported in IMF IFS	1960–90	No	Very strong positive correlation
Dwyer and Hafer (1999)	n.a.	GDP deflator	79 countries reported in IMF IFS	1987–97, two five-year averages	No	Strong and stable positive correlation

Note: "High–Low differentiation" indicates whether the author makes a distinction between low- and high-money growth countries.

The third group takes the shape of a historical investigation, sometimes reaching more than 200 years into the past. These studies often focus on one country only, but they suffer, as do studies of the second type, from the incomparability of the economic systems of a country across centuries.

Table 1 gives an overview of the representative articles of the first type of empirical studies, based on cross-sections of countries. The table also describes the data sets and the results. Authors of the articles listed in Table 1 try to either analyse data on the largest possible number of countries or focus on a smaller group of countries with similar economic systems. In the latter case, the results are only applicable to this particular group of countries, while the first method is supposed to yield universal results. In most cases, the relation between money supply and price level is strong and positive.

A common finding of these studies is that countries with low money growth (and low inflation) tend to create a horizontal cluster in a plot where inflation (vertical axis) is set against money growth (horizontal axis). However, none of the papers surveyed here has attempted to analyse this phenomenon or study how the level of inflation affects the relation between money growth and inflation.

An interesting conclusion can be drawn from the article by Dwyer and Hafer (1999). These authors compare the relation between average money growth and average inflation rate in two periods, 1987-1992 and 1993-1997. In the second period, the average inflation rate (across all countries in the sample) is lower. The reduction in the average inflation rate leads to the creation of two horizontal clusters of observations close to the origin. Thus, the weakening relation between money growth and inflation, as we progress towards zero money growth, may be associated with the average money growth of a country.

The second type of empirical study uses single country time-series analysis. Within this class of studies, an initial approach has been to analyse the long-term quantity theory relationship after transforming time series into the frequency domain. Representative papers are Lucas (1980) and Fitzgerald (1999). These studies tend to confirm the proportionality prediction of the quantity theory, although their methodology has been criticised by McCallum (1984) and Rolnick and Weber (1995). McCallum (1984) warns us that associating high-frequency time series with long-run economic propositions is not always warranted.

More recently, researchers have adopted another – more satisfactory – approach in analysing the time-series properties of inflation, output and money. This consists of explicitly testing coefficient restrictions implied by the quantity theory in vector autoregression models. Important papers using this approach are Geweke (1986), Stock and Watson (1988), Boschen and Mills (1995), and King and Watson (1997). These authors confirm the long-run neutrality of money on output for the US economy. Similar results for G7 countries were obtained by Weber (1994).

In this context, the empirical studies using the P-star model should also be mentioned. This model, suggested by Hallman, Porter and Small (1991), was further explored by Vega and Trecroci (2002) and Gerlach and Svensson (2004); see also Jansen (2004) for a recent exposition. The P-star model may be regarded as a modern monetarist approach to modelling inflation. It starts by defining the price gap as the difference between the price level and the long-run equilibrium price level, which is implied by the long-run quantity relation. The model then specifies a direct effect from the lagged price gap and the current price level.

Studies designed to test the QTM using data on one or a few countries (the second group) often overlap with the third type of studies – very long-term historical analyses of the relation between money and prices, or investigations of this relation over a particular period in the past. One such long historical analysis was carried out by Smith (1988), who explores the relation between money and prices in the British colonies.

Studies analysing a large set of countries typically do not take differences between countries into account. However, Rolnick and Weber (1995) show that such disregard can change the results of estimations. They prove that the strength of the long-run relationship between money and prices differs across countries operating under different monetary standards. When compared with fiat standards, commodity standards result in lower correlations of money growth and inflation, a higher correlation with output growth and a lower correlation of various monetary aggregates with each other. Inflation, money growth and output growth are generally lower under commodity standards than under fiat standards.

III. *Cross-section Evidence: The Long Run*

We now turn to tests of the quantity theory using cross-section data on 30-year averages of money growth, inflation and output growth. (Later on, in Section IV, we use panel data to test the quantity theory.) We expect 30 years to be a sufficiently long period to be considered as “long run”. Therefore, we assume that our sample of data is sufficiently long to detect the type of relationship predicted by the quantity theory. We begin by presenting the data and then proceed to the regression analysis.

The Data

To explore the relationship between money growth and inflation, we chose the largest available sample of countries, covering the years 1969-1999. We used the International Financial Statistics of the IMF as the source of our data and tested the theory using two monetary aggregates, M1 and M2. Inflation is measured as a percentage increase in the consumer price index. Not all observations are shown in our graphs; five observations with an average inflation rate above 200% per annum were omitted. Including them would have compressed the remainder of the chart too much.

Figure 1 shows the full sample of observations on average annual inflation and money growth rates. As in the studies reviewed above, the observations are clustered around the 45° line. The correlation between average inflation and average M1 growth is 0.877, and 0.89 for the correlation with M2. Thus, the results are very similar to those obtained by Vogel (1974), Dwyer and Hafer (1988, 1999), Barro (1990), Poole (1994) and McCandless and Weber (1995). Note that our sample of countries is larger than the samples used in these studies.

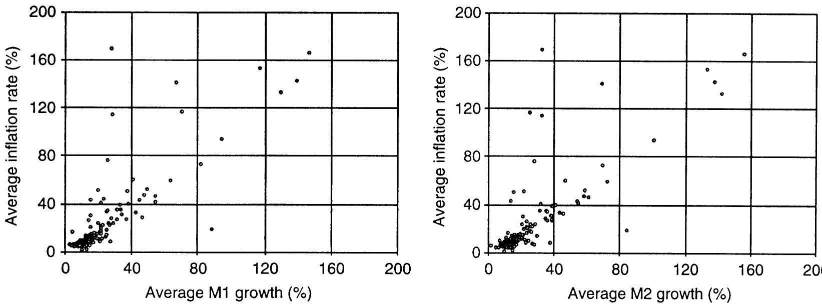

Fig. 1. Inflation and the average growth of M1 and M2, 1969–1999 (up to 200% p.a.)

Most of the observations are grouped in the lower-left part of the chart, close to the origin. To detect whether the relation between money supply growth and the inflation rate may vary between subsamples, we divided the set of all observations into groups in the following way. We started with a sample consisting of countries with inflation and money growth below 10%. Then, we progressively expanded the sample by adding the observations of the next classes, i.e., 10% to 20%, 20% to 30% and so on. A selection of scatter diagrams is shown in Figures 2-4. It is immediately evident fromthe successive scatter diagrams that the positive relation between inflation and money growth seems to become more pronounced as observations of high-inflation countries are added to the sample. For low-inflation countries (less than 10%), the scatter diagram forms a shapeless, almost horizontal cloud. Thus, the relation between inflation and money growth obtained for the lowest inflation countries appears to be quite different from the results for the full sample. This feature of the cross-section analysis which, to our knowledge, has not been analysed in the existing literature, is the focus of our analysis.

Cross-section Empirical Analysis

Here, we test both the proportionality and the neutrality (orthogonality) propositions of the QTM. We begin by examining the whole sample, and then try to obtain additional insights into the QTM relationships by analysing different subsamples.

Estimation over the Whole Sample

We start by estimating the regression equation (4) relating the long-term average inflation rate to the long-term average money supply growth, and the long-term growth rate of output (where the long term is 30 years)[4]. The first sample (M1) contains 116 countries, the second (M2) 109. Since there is evidence of heteroscedasticity, we use White standard errors. The results of an OLS estimation are shown in Tables 2 and 3. We observe that the growth rates of M1 and M2 have the right sign and are highly significant. But the coefficients of M1 and M2 exceed one, and significantly so. The size of this coefficient, as predicted by the quantity theory of money, should be one.

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[4] Some of the time series used in the calculations of averages differ in length. We have reestimated all equations using a sample consisting of time series with at least 20 observations. The results are very similar to those obtained for the full sample and are not reported here. They can be obtained from the authors on request.

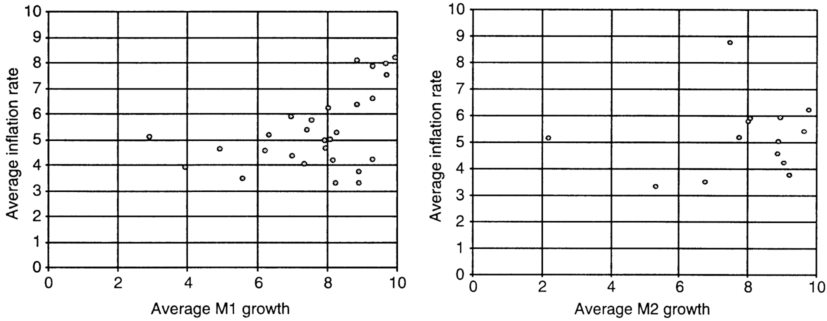

Fig. 2. Inflation and money supply growth lower than 10%

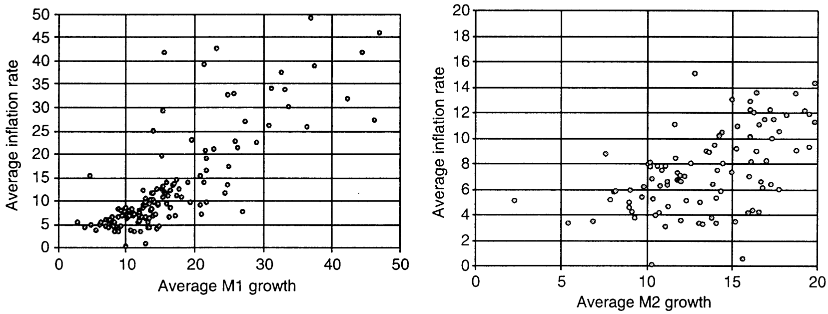

Fig. 3. Inflation and money supply growth from 0% to 20%

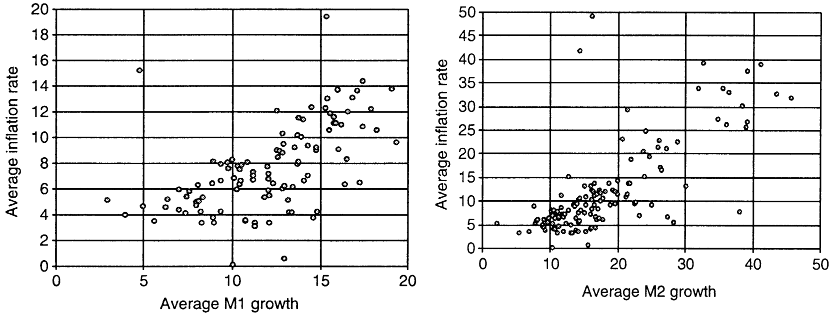

Fig. 4. Inflation and money supply growth from 0% to 50%

Table 2. *Results of the OLS estimation of* $p_i = \beta_0 + \beta_1 m1_i + \beta_2 y_i + \mu_i$

White HCSE&Covariance				Included observations: 116	
Variable	Coefficient	Std. error	t-Statistic	p-Value	Test $\beta_1 = 1$
Constant	4.134	17.534	0.236	0.814	p-Value
m1	1.639	0.161	10.195	0.000	0.0001
y	−2.826	3.476	−0.813	0.418	
Adjusted R-squared		0.858	Akaike information criterion	11.439	
Durbin–Watson statistic		1.793	p-Value (F-test)	0.000	

Note: The econometric package used for the regressions reported here and in the other tables is Eviews.

However, for the full sample of countries analysed over the 30-year period, this hypothesis is rejected. Later on, we return to this result, and argue that this coefficient is greatly influenced by hyperinflationary dynamics in the high-inflation countries, which leads to a positive correlation between money growth and velocity. This could then give rise to an upward bias in the coefficient of money growth.

The estimated coefficient of output growth has the expected sign and is surprisingly large in value, but it is not significant. Therefore, we cannot decisively confirm that output has no impact on inflation in any country.

Table 3. *Results of the OLS estimation of* $p_i = \beta_0 + \beta_1 m2_i + \beta_2 y_i + \mu_i$

White HCSE&Covariance				Included observations: 109	
Variable	Coefficient	Std. error	t-Statistic	p-Value	Test $\beta_1 = 1$
Constant	18.888	18.734	1.008	0.316	p-Value
m2	1.451	0.164	8.836	0.000	0.007
y	−5.122	3.556	−1.440	0.153	
Adjusted R-squared		0.823	Akaike information criterion	11.716	
Durbin–Watson statistic		1.638	p-Value (F-test)	0.000	

As mentioned earlier, the quantity theory predicts that over a sufficiently long period, changes in the growth rate of money do not affect output growth. If a rise in money growth increases output growth, this effect is temporary. Over the time horizon of 30 years considered here, these temporary output effects of monetary expansions seem to have disappeared. To test the neutrality proposition, we estimated the following equation:

$$y_i = \gamma_0 + \gamma_1 m_i + \eta_i, \quad (5)$$

where the variables are defined as in (4). The results are reported in Tables 4 and 5. We find that although very small in absolute value, the effect of higher money growth on output growth is negative, and significantly so. This suggests two conclusions. First, the QTM prediction that an expansion of the money stock does not increase output in the long run is confirmed. Second, considering that the estimate is significant, countries having experienced higher money growth also experienced a lower output growth – a finding in line with the empirical evidence on the determinants of economic growth; see Barro and Sala-i-Martin (1995). However, this effect is quantitatively very small for low- and intermediate-inflation countries. For example, an increase in the yearly growth rate of money (m1) of 10 percentage points sustained over a 30-year period reduces yearly growth of output by 0.054%. For high-inflation countries which experience yearly growth rates of money of several hundred percentage points, this effect is quantitatively much more important. To gain insight into the quantitative importance of this effect, we multiplied the coefficients of money growth by one standard deviation of money growth observed in the sample. Due to the presence of very highinflation countries in the sample, one standard deviation in the yearly rates of the money stocks is very high, i.e., 85% (for M1) and 122% (for M2). We find that a one-standard deviation increase in the average money growth reduces average output growth by approximately 0.5%.

Table 4. *Results of the OLS estimation of* $y_i = \gamma_0 + \gamma_1 m1_i + \eta_i$

White HCSE&Covariance					Included observations: 116
Variable	Coefficient	Std. error	*t*-Statistic		*p*-Value
Constant	4.0508	0.2553	15.8615		0.0000
m1	−0.0054	0.0022	−2.5119		0.0134
Adjusted *R*-squared	0.0441		Akaike information criterion		4.6993
Durbin–Watson statistic	1.8769		*p*-Value (*F*-test)		0.0134

Table 5. *Results of the OLS estimation of* $y_i = \gamma_0 + \gamma_1 m2_i + \eta_i$

White HCSE&Covariance					Included observations: 109
Variable	Coefficient	Std. error	*t*-Statistic		*p*-Value
Constant	4.0736	0.2707	15.0459		0.0000
m2	−0.0046	0.0020	−2.2285		0.0279
Adjusted *R*-squared	0.0354		Akaike information criterion		4.7615
Durbin–Watson statistic	1.7961		*p*-Value (*F*-test)		0.0279

Estimation over Subsamples

One of the main hypotheses we want to test is whether the quantity theory holds better (or less so) for different levels of inflation. To analyse this issue, we estimated the model for different subsamples. The intuitive choice would have been to use the level of inflation to define the subsamples; however, using the level of inflation (the LHS variable) to group observations creates a potential bias. Therefore, we grouped observations using money growth (a RHS variable). We performed the estimation in a recursive manner, i.e., enlarging the samples by adding observations with increasing values of money growth. The results are shown in Table 6. However, we also carried out all estimations dividing the countries according to their inflation rate, and obtained very similar results.

We observe that in the sample of low money growth countries (on average, a growth of M1 and M2 lower than 15% p.a.), the coefficients of the money variable are close to zero and not statistically different from zero. As we add observations of countries with high money growth, these coefficients increase in value and become significantly different from zero (already in the second subsample). Note that when we add the countries with the highest money growth, the coefficients of money growth become significantly higher than 1.

We conclude this section by noting that in the long term (30 years), the neutrality proposition of the quantity theory is confirmed, i.e., higher money growth has no permanently positive effect on output growth. For highinflation countries, an increase in money growth reduces output growth. The prediction of proportionality is not maintained, however. For the sample as a whole, we find the coefficient of money to be systematically higher than 1. When we split the sample into subsamples according to the level of money growth, we find a very low and insignificant coefficient of money in the class of low-inflation countries. Thus, for low-inflation or low money growth countries, the quantity theory prediction that inflation is a monetary phenomenon is not confirmed. The situation is very different in the class of high-inflation, high money growth countries. There, we find a coefficient of money growth significantly higher than 1. Thus, in this group of countries, money growth has a more than proportional effect on inflation.

The picture emerging from this analysis is as follows:

1. In the class of low-inflation countries, a higher growth rate of money does not lead to a proportional increase in inflation in the long run, nor

Table 6. *Results of estimation of the equations:* $p_i = \beta_0 + \beta_1 m_i + \beta_2 y_i + \mu_i$

Variable	Coefficient	Std. error	t-Statistic	p-Value	Test $\beta_1 = 1$
M1					
Interval (*m1* < 15% p.a.; #obs. = 46)					
Constant	6.181	2.704	2.285	0.027	p-Value
m1	0.224	0.262	0.856	0.397	0.003
y	−0.459	0.237	−1.943	0.059	
Interval (*m1* < 20% p.a.; #obs. = 70)					
Constant	2.398	2.314	1.036	0.303	p-Value
m1	**0.795**	0.276	2.882	0.005	0.456
y	−0.874	0.509	−1.718	0.090	
Interval (*m1* < 30% p.a.; #obs. = 88)					
Constant	0.636	3.385	0.188	0.851	p-Value
m1	**1.243**	0.322	3.859	0.000	0.451
y	**−1.784**	0.754	−2.364	0.020	
Interval (*m1* < 100% p.a.; #obs. = 106)					
Constant	6.919	5.003	1.383	0.169	p-Value
m1	**1.344**	0.289	4.657	0.000	0.233
y	**−3.118**	1.191	−2.618	0.010	
Full sample (#obs. = 116)					
Constant	4.134	17.534	0.236	0.814	p-Value
m1	**1.639**	0.161	10.195	0.000	0.000
y	−2.826	3.476	−0.813	0.418	
M2					
Interval (*m2* < 15% p.a.; #obs. = 32)					
Constant	4.75	4.745	2.145	0.035	p-Value
m2	0.25	0.245	0.187	0.200	0.001
y	−0.28	−0.282	0.219	0.209	
Interval (*m2* < 20% p.a.; #obs. = 58)					
Constant	0.592	2.212	0.268	0.790	p-Value
m2	**0.888**	0.299	2.969	0.004	0.709
y	−1.095	0.613	−1.787	0.079	
Interval (*m2* < 30% p.a.; #obs. = 79)					
Constant	1.012	2.479	0.408	0.684	p-Value
m2	**1.059**	0.233	4.548	0.000	0.798
y	**−1.738**	0.756	−2.298	0.024	
Interval (*m2* < 100% p.a.; #obs. = 101)					
Constant	11.250	6.685	1.683	0.096	p-Value
m2	**1.316**	0.248	5.311	0.000	0.202
y	**−3.958**	1.113	−3.555	0.000	
Full sample (#obs. = 109)					
Constant	18.888	18.734	1.008	0.316	p-Value
m2	**1.451**	0.164	8.836	0.000	0.006
y	−5.122	3.556	−1.440	0.153	

does it affect the rate of output growth. This suggests that there must be a negative correlation between money growth and velocity growth, a conclusion following from the fact that $m + v = p + y$ is an identity.

This negative correlation between money growth and velocity growth in the class of low-inflation countries has two possible interpretations. One relies on the liquidity effect of an increase in money growth, i.e., when the growth of money increases, this leads to a decline in the nominal interest rate which, in turn, increases the demand for money (reduces velocity). This liquidity effect only occurs in the short run, however. In our sample, we relate 30-year average growth rates of money and velocity. It is difficult to believe that the short-term liquidity effect can be sustained over 30 years, so we discard this interpretation.

A second interpretation is that, in the class of low-inflation countries, velocity changes are exogenously driven. They are determined by technological and institutional changes in the payments system, most of which are unrelated to the growth rate of the money stock. Since, according to our previous results, output growth and inflation rates are disconnected from money growth, it follows that money growth adjusts to exogenous shocks in velocity in the class of low-inflation countries. If this interpretation is correct, the negative correlation between velocity (the error term) and money growth creates a downward bias in the estimated coefficient of money in the class of low-inflation countries. Another way of phrasing this interpretation is as follows. Most of the inter-country differences in money growth reflect different experiences in velocity. As a result, the observed cross-country differences in money growth do not reflect systematic differences in monetary policies, but the "noise" coming from differences in velocity. It follows that the observed differences in money growth will not well explain differences in inflation across countries; for a similar interpretation, see Gerlach (2002).

2. In the class of high-inflation countries, money growth has a more than proportional effect on inflation, without affecting output growth to any large extent. Thus, the quantity theory identity ($m + v = p + y$) suggests money growth and velocity growth to be positively correlated. This phenomenon can easily be interpreted by hyperinflationary dynamics, i.e., an increase in the growth rate of the money stock leads to an acceleration of velocity which, in turn, reinforces the hyperinfla-

tionary dynamics. This phenomenon has been well documented in studies of hyperinflation; see e.g. Cagan (1956). This also suggests that the positive correlation between money growth and velocity (the error term) leads to an upward bias in the estimated coefficient of money growth in the class of high-inflation countries.

The results above suggest that theoretical models which specify velocity as a function of the interest rate (and thus inflation) are a better representation of long-run empirical relations than models considering velocity to be fixed, such as cash-in-advance models and the early generation of search models.

IV. *Panel Data Evidence: Less than the Long Run*

Next, we consider panel data models to further explore the relation between money supply growth and the inflation rate. The use of panel data implies that we now focus on the relation between money growth and inflation over shorter horizons (typically a year). We should not expect high-frequency observations of the type used here to reveal the long-run relationship between money growth and inflation as predicted by the QTM. However, these panel data are interesting for two reasons. First, they allow us to test whether there are subsamples of countries (e.g. those of high-inflation countries) for which the QTM prediction could occur even with highfrequency data. Second, we use these yearly observations as a first step towards gradual aggregation of the observations over longer time spans.

Here, the use of panel data also introduces the necessity of checking for the existence of unit roots in the annual data. Applying unit root tests, we found that some of the time series are stationary, while others are not. This means that our panel is heterogeneous, which appears even within crosssections. Unfortunately, in such a situation, we could not apply standard procedures of handling non-stationarity of panel models, since they are designed to be used with homogeneous panels.

We proceed as follows. First, we specify and estimate a fixed-effect model using yearly observations of all countries in the sample. Second, we examine the same models with different time aggregation and dummy variables.

The fixed-effect model is specified as follows:

$$p_{it} = \beta_{0i} + \beta_1 m_{it} + \xi_{it}, \qquad (6)$$

where the subscript i refers to countries and the subscript t to time (years), β_1 is common for all countries and each country gets its own constant β_{0i}. The latter represent time-invariant, country-characteristic factors, which influence the inflation rate. These country-specific factors include the long-term growth rates of output and trend changes in velocity.

We applied this model to both the M1 and M2 definitions of money. Due to data availability, the second panel is slightly smaller than the first. The yearly data are the same as those used to compute the average rates, analysed in detail in preceding sections. The model was estimated using GLS, assuming the presence of cross-section heteroscedasticity. Table 7 reports the results of the estimations. We find significant but small effects of money growth on inflation. The coefficient of M1 growth is 0.096, while the coefficient of M2 growth is 0.2. As argued earlier, the small size of the coefficients should not come as a surprise, since the QTM is a theory about the long-run effects of money.

Figures 5 and 6 show the fixed effects (vertical axis) and relate these to the average money growth rates of each country (horizontal axis). The relation appears to be highly non-linear. That is why we also show the relation on a logarithmic scale in the right-hand panel.

We find a strong correlation between the average money growth rates and the fixed effects (the correlation coefficients are 0.69 and 0.67 for M1 and M2 samples, respectively). The non-linear nature of this relation implies that as the average growth rates of money increase, the fixed effects (countryspecific effects) tend to increase more than proportionately. Our favoured interpretation, which is also in line with our earlier conclusion, runs as follows: when money growth becomes very high, the dynamics of hyperinflation is set in motion, thereby producing strong increases in the velocity of money. This tends to increase inflation more than proportionately; see the classical paper by Cagan (1956).

We choose to focus on the fixed-effects model for a number of reasons. In a situation where a panel is constructed of time series representing single countries or large companies or industries ("one of a kind") and we want to make predictions for one cross-section or a group of them, it is usually advisable to use a fixed-effects model. Since, in such a situation, the observations cannot be assumed to be randomly drawn from a certain underlying (common) distribution, determining the individual characteristics of cross-sections is important in interpreting the results of the estimation.

Table 7. *Estimation of fixed effects*

		M1		
Variable	Coefficient	Std. error	t-Statistic	p-Value
m1	0.0961	0.0073	13.2381	0.0000
Adjusted R-squared	0.3033		Durbin–Watson statistic	1.0627
		M2		
Variable	Coefficient	Std. error	t-Statistic	p-Value
m2	0.2005	0.0039	51.1270	0.0000
Adjusted R-squared	0.6392		Durbin–Watson statistic	1.2290

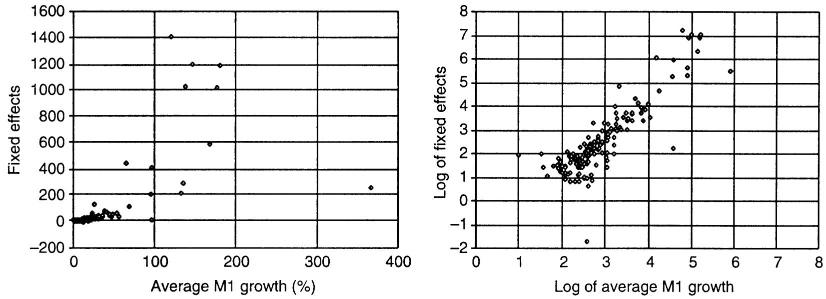

Fig. 5. Fixed effects and money growth (M1). Left panel—prime data; right panel—logs

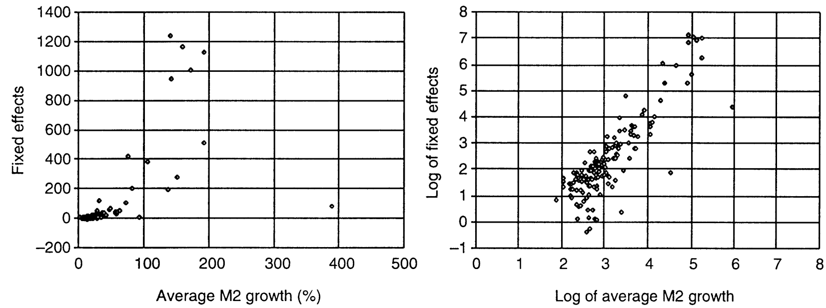

Fig. 6. Fixed effects and money growth (M2). Left panel—prime data; right panel—logs

A clear sign of the situation where a fixed-effects model should be preferred is correlation between fixed effects and the regressor. If there is correlation, the random effects estimator is inconsistent, since it ignores this correlation. Therefore, after observing high correlation between fixed effects and money growth, we limit the analysis to the estimation of the fixedeffects model; see Verbeek (2000).

Note that the Hausman test which can be used to select a random-effects model over a fixed-effects model is not informative in our case. We only estimate one parameter (we have one regressor), which implies that we have to use critical values from a χ^2 distribution with only one degree of freedom. Therefore, our test statistic is very likely to fall in the confidence interval and make us accept the null hypothesis of no difference between randomand fixed-effects models. As a result, we rely solely on the strong correlation between money growth and fixed effects as the argument in favour of the fixed-effects model.

The next step in the analysis consists of testing for different effects of money growth on inflation, depending on the level of inflation. For this purpose, we created six dummies for increasing levels of inflation (D1: 0 to 10%, D2: 10% to 20%, . . . , D6: more than 50%). Then, we multiplied these dummies by m to obtain a slope coefficient (coefficient of *m*) for each group of inflation. The panel-data model was re-estimated including these dummies. The results are shown in Table 8. All slope coefficients are significant for both *m1* and *m2*. As predicted, they are higher for countries with higher average inflation rates. The differences are quite substantial. Countries with low inflation (less than 10% per year) exhibit very low coefficients of money growth. Only high-inflation countries have coefficients which come close to that predicted by the QTM. Thus, in high-inflation countries, we cannot reject the QTM prediction on a yearly basis, i.e., when inflation is very high, the prediction that inflation and money growth are proportional holds even in high-frequency observations. This result suggests that the speed at which inflation adjusts to increases in the growth rate of money is not constant. It increases with the level of inflation. In high-inflation regimes, prices adjust quickly to monetary shocks. This is consistent with historical evidence about the speed of adjustment of prices in hyperinflationary regimes; see Bresciani-Turroni (1937).

The final step in our analysis of the panel data is to apply different levels of time aggregation. We start with a panel constructed with non-overlapping, two-year averages of money growth and inflation. We then turn to averages over three years or more, and finish with a panel of six-year averages. By analysing these panels, we want to see how the influence of money growth on inflation changes as we pass through increasing levels of time aggregation.

We estimate the following model:

$$p_{it\tau} = \delta_{0\tau} + \delta_{1\tau} m_{it\tau} + \zeta_{it\tau}, \tag{7}$$

where i denotes the country, t the time period, τ is the length of the period over which averages are computed ($\tau = 1, \ldots, 6$), *Dj* denotes the dummy variable, and j is the number of the inflation group ($j = 1, \ldots, 6$).

This model allows us to study how the level of time aggregation affects the coefficients of money growth. The QTM predicts that with increasing time aggregation, the effect of money growth on inflation increases. Similarly, the model allows us to study how the level of inflation affects the coefficients of money growth for different levels of time aggregation. Here, we concentrate on the coefficients of *m1* and *m2*, which are shown in Table 9. (Full and detailed results are available on request). The results lend themselves to the following interpretation. First, the coefficients of money growth increase with the level of inflation, for all levels of time aggregation.

Table 8. *Estimation of panels with a distinction between inflation groups (fixed-effect models)*

Variable	Coefficient	p-Value $\beta = 0$	Variable	Coefficient	p-Value $\beta = 0$
*m1*D1*	0.0604	0.0000	*m2*D1*	0.1663	0.0000
*m1*D2*	0.0605	0.0010	*m2*D2*	0.1446	0.0000
*m1*D3*	0.5880	0.0000	*m2*D3*	0.6794	0.0000
*m1*D4*	1.2343	0.0000	*m2*D4*	0.8346	0.0000
*m1*D5*	1.0738	0.0000	*m2*D5*	0.6890	0.0000
*m1*D6*	1.1470	0.0000	*m2*D6*	1.2248	0.0000
Benchmark	0.0961		Benchmark	0.2005	

Note: The sizes of the different subsamples are: D1—83; D2—35; D3—12; D4—9; D5—7; D6—20.

Second, time aggregation increases the value of the coefficients of *m1* and *m2* for low-inflation countries. When moving from one-yearly averages to three-yearly averages, we see that the coefficients of low-inflation countries (*D1*) increase to approximately 0.5. Further time aggregation reduces this coefficient, however.

Table 9. *Estimated coefficients of m1 and m2 for different levels of inflation (D1 ... D6) and different levels of time aggregation (1, ... , 6 years)*

	1 year	2 years	3 years	4 years	5 years	6 years
M1						
D1	0.0465	0.2486	0.5322	0.2004	0.2555	−0.3061
D2	0.1574	0.3684	0.5747	0.3440	0.3685	0.0007*
D3	0.5159	0.7576	0.7377	0.8163	0.9060	0.5807
D4	0.9162	1.0300	1.0739	1.0583	1.0128	0.8550
D5	1.0592	1.0728	1.0603	1.0707	1.0228	0.9662
D6	1.1105	1.3864	1.3130	1.1136	1.0463	0.8265
M2						
D1	0.1641	0.3883	0.4276	0.2608	0.3174	0.0906*
D2	0.2032	0.3545	0.4067	0.3367	0.3760	0.2198
D3	0.4601	0.6920	0.7156	0.6161	0.6715	0.5730
D4	0.7051	0.8183	0.9595	0.8692	0.9416	0.7937
D5	0.9821	0.9126	1.1264	0.9446	0.9960	1.0382
D6	1.1001	1.1797	0.9623	0.9903	1.0348	0.8241

*Not significant at the 5% level.

V. Conclusions

The quantity theory of money is based on two propositions. First, in the long run, there is *proportionality* between money growth and inflation, i.e., when money growth increases by *x*% inflation also rises by *x*%. Second, in the long run, there is *neutrality* between money growth on the one hand and output growth and velocity changes on the other.

We subjected these statements to empirical tests using a sample which covers most countries in the world during the last 30 years. Our findings can be summarised as follows. First, when analysing the full sample of countries, we find a strong positive relation between the long-run growth rate of money and inflation. However, this relation is not proportional.

Our second finding is that this strong link between inflation and money growth is almost wholly due to the presence of high-inflation or hyperinflation countries in the sample. The relation between inflation and money growth for low-inflation countries (on average less than 10% per year over 30 years) is weak, if not absent. However, we also find that this lack of proportionality between money growth and inflation is not due to systematic relationship between money growth and output growth. We find that, in low-inflation countries, money growth and output growth are independent in the long run. This finding is consistent with the large number of econometric analyses using time series of single countries. Most of these studies have found money to be neutral in the long run.

A third finding (obtained from a panel-data analysis) indicates that country-specific effects become increasingly important when the rate of inflation increases. We interpret this to mean that velocity accelerates with increasing inflation, thereby leading to inflation rates exceeding the growth rates of the money stock. This also explains why in cross-section regressions, inflation rates increase more than proportionately to money growth in highinflation countries.

Fourth, the panel-data analysis revealed "long run" to be a relative concept, i.e., the time it takes for the long-run effects of monetary expansions to be realised depends on the level of inflation. We found the transmission of money growth into inflation to be established within a year in high-inflation countries.

Finally, we found that in the class of low-inflation countries, money growth and velocity changes are inversely related, while in the class of high-inflation countries the reverse holds, i.e., money growth and velocity growth are positively related. The latter confirms our interpretation of the positive correlation between money growth and fixed effects in our paneldata model.

These results can be given the following interpretation. In the class of low-inflation countries, inflation and output growth seem to be exogenously driven phenomena, mostly unrelated to the growth rate of the money stock. As a result, changes in velocity necessarily lead to opposite changes in the stock of money (given the definition $p + y = m + v$). Put differently, most of the inter-country differences in money growth reflect different experiences in velocity. As a result, the observed cross-country differences in money growth do not reflect systematic differences in monetary policies, but the "noise" coming from velocity differences. It thus follows that the observed differences in money growth have a poor explanatory power with respect to differences in inflation across countries in the class of lowinflation countries.

For high-inflation countries, on the other hand, an increase in the growth of the money stock leads to an increase in both inflation and velocity. The latter reinforces the inflationary dynamics. This is also the reason why, in the class of high-inflation countries, we find a coefficient of money growth typically exceeding 1. This process has been well documented in empirical studies of hyperinflation and it is confirmed by our results; see Cagan (1956).

Our results have some implications for the question regarding the use of the money stock as an intermediate target in monetary policy. As is well known, the European Central Bank continues to assign a prominent role to the growth rate of the money stock in its monetary policy strategy [5]. The ECB bases this strategy on the view that "inflation is always and everywhere a monetary phenomenon" [6]. This may be true for high-inflation countries. Our results, however, indicate that there is no evidence for this statement in relatively low-inflation environments, which happen to be a characteristic of the EMU countries. In these environments, money growth is not a useful signal of inflationary conditions, because it is dominated by "noise" originating from velocity shocks. It also follows that the use of the money stock as a guide for steering policies towards price stability is not likely to be useful for countries with a history of low inflation.

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[5] In May 2003, the ECB announced that it would downplay, but not eliminate, the prominent role it assigns to the evolution of the money stock in its monetary policy strategy.

[6] The monetary policy strategy of the ECB is described in the *Monthly Bulletin* of January 1999. On p. 47, the section describing the role of money in this strategy starts with the statement: "Inflation is ultimately a monetary phenomenon".

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