Oesterreichische Nationalbank

Working Paper 46

Exchange Rates, Prices and Money
A Long Run Perspective

Paul De Grauwe and Marianna Grimaldi

Statement of Purpose

The Working Paper series of the Oesterreichische Nationalbank is designed to disseminate and to provide a platform for discussion of either work of the staff of the OeNB economists or outside contributors on topics which are of special interest to the OeNB. To ensure the high quality of their content, the contributions are subjected to an international refereeing process. The opinions are strictly those of the authors and do in no way commit the OeNB.

Imprint: Responsibility according to Austrian media law: Wolfdietrich Grau, Secretariat of the Board of Executive Directors, Oesterreichische Nationalbank
Published and printed by Oesterreichische Nationalbank, Wien.
The Working Papers are also available on our website:
http://www.oenb.co.at/workpaper/pubwork.htm

Editorial

On April 19 – 20, 2001 the Oesterreichische Nationalbank sponsored a Workshop organized by Richard Clarida (Columbia University), Helmut Frisch (TU Wien) and Eduard Hochreiter (OeNB) on „Exchange Rate and Monetary Policy Issues". It took place at the Institute for Advanced Studies, Vienna. A number of papers presented at this workshop is being made available to a broader audience in the Working Paper series of the Bank. This volume contains the second of these papers, while the first one was issued as OeNB Working Paper 44. The paper by Paul de Grauwe and Marianna Grimaldi (p. 5ff.) is followed by a discussion by Hans Genberg (p. 49ff.).

May 31, 2001.

1. Introduction[*]

According to the *purchasing power parity theory* (PPP) exchange rates move in the same proportion to prices in the long run, ceteris paribus. According to *the quantity theory of money* (QTM) prices move in the same proportion to money in the long run, ceteris paribus. Combining these two theories one can derive the proposition that money, exchange rates and prices should all move proportionally in the long run.

These propositions are well-known since the early writings of classical economists[1]. In this paper we want to test these propositions. One may ask the question why we want to analyse these propositions that have been studied so often in the past. We see two reasons for this. First, these PPP and QTM propositions have often been analysed separately. We test these propositions jointly. Second, the inflationary regimes can affect these propositions. In particular, high and low inflation countries may experience different transmission processes of money to prices and to exchange rates. Therefore we analyse if the PPP and QTM propositions hold differently for low inflation and high inflation countries.

2. The theory

There is a long tradition in the economic theory that explains the long run behaviour of the rate of inflation and the rate of depreciation (appreciation) of the currency. This tradition is based on the Quantity Theory of Money (QTM) and the Purchasing Power Parity (PPP) Theory. These two theories can be presented by the following equations.

We start from the well-known identity of the QTM for two countries

$$p = m + v - y \qquad (1)$$

$$p^* = m^* + v^* - y^* \qquad (2)$$

---

[*] The authors are affiliated with the University of Leuven and CEPR. Paper prepared for the Workshop on “Exchange Rate and Monetary Policy Issues”, Vienna, April 19-20, 2001. The authors are grateful to Michael Artis, Giuseppe Bertola, Richard Clarida, Hans Genberg, Massimiliano Marcellino and the participants of a seminar at the European University Institute in Florence for comments on a previous draft.

[1] see Niehans (1976) for a discussion.

where p is the percent change in the domestic price level, m is the percent change in money supply, v is the percent change in velocity, y is the growth rate of output. The variables with * relate to the foreign country.

The QTM transforms this identity into a theory by formulating the following propositions about the relations between these variables[2]:

1. in the long run money is *neutral*, i.e. changes in money do not affect output changes when a sufficiently long period of time is allowed for.
2. in the long run changes in money and prices are *proportional,* i.e. an increase in the money stock by x% leads to an equal increase of x% in the price level.

We now introduce PPP in the following way:

$$e = p - p^* + k \qquad (3)$$

e is the nominal rate of depreciation of the domestic relative to the foreign currency, k is the real depreciation of the domestic currency.

The PPP theory implies that there is a *proportionality* between the rate of depreciation of the domestic currency and the rate of change in domestic prices.

We now substitute (1) and (2) into (3). This yields

$$e = (m - m^*) + (v - v^*) - (y - y^*) + k \qquad (4)$$

Equation (4) allows us to combine QTM and PPP. It implies that there is a proportional relation between the changes in money, the exchange rate and the price level[3]. This paper aims to test the validity of these proportionality propositions.

The QTM and PPP theory make additional predictions concerning the long run effect of the output changes. From the equations 1, 2 and 4 it follows that

- a higher rate of domestic output growth (for a given foreign growth rate) leads to lower inflation, given the money growth;

[2] These propositions can be derived formally in the context of a large class of modern macroeconomic models (see Walsh(1998), Blanchard & Fischer(1996) and Clarida, Gali, Gertler(1999).
[3] These propositions can be derived from modern open economy macromodels (see Obstfeld & Rogoff(1996).

- a higher rate of domestic output growth (for a given foreign growth rate)leads to an appreciation of the domestic currency, given the money growth.

This theory assumes that the previous propositions hold for all countries irrespective of the institutional differences between them. There are many sources of institutional differences between countries. One important source concerns the difference in the inflationary regime that countries experience. Some countries have experienced high inflation, other countries low inflation. These different experiences affect institutions. We want to test if these differences affect the validity of the QTM and PPP theories.

3. QTM and PPP : empirical tests

In this section we present the empirical tests of the propositions derived in the previous section.

3.1 The data

The dataset is from *IFS*-IMF. We computed average yearly rates of growth of money (M1 and M2), of the consumer price index, of exchange rates and of output over the period 1970-99. We also computed the average yearly growth of income velocity over the same period. This velocity estimate was also obtained from IFS. However, it is collected independently from the previous data on output, inflation and money, so as to avoid that velocity is just a variable derived from the identities (1) and (2).
We selected the countries that have data for at least 20 years. This rule reduces the total number of countries from 172 to approximately 100. The exchange rates are expressed relative to the US dollar. As a result, money growth, output growth and inflation are expressed as differences relative to the corresponding US values.

3.2 Tests of the proportionality propositions

In this section we test both the proportionality between the exchange rate and money growth, and between inflation and money growth. In order to do so we specify the following relations:

$$e_i = b_1 + b_2 m_i + b_3 y_i + b_4 v_i + \nu_i \qquad (5)$$

$$p_i = a_1 + a_2 m_i + a_3 y_i + a_4 v_i + \omega_i \qquad (6)$$

where e_i is the rate of depreciation of currency i against the US dollar; p_i m_i y_i and v_i are the differences in the rates of growth of prices (CPI), money, output (GDP) and velocity between country i and the US, ν_i and ω_i are the error terms. All the variables are yearly averages over the period 1970-99. Therefore the data refer to averages of almost 30 years. Such a period can be considered as representing the long run.

We only have data of velocity of M2. Therefore we will estimate (5) and (6) using M2. We will, however, also present the results of estimating these equations without velocity. This will allow us to use M1 also.

A test of proportionality consists in checking whether the estimated coefficients of money (b_2 and a_2) are equal to one.

An econometric issue that arises with the specification (5) and (6) is the potential for collinearity between the regressors. We will analyse this issue in more detail later when we test for neutrality of money (which is a test of independence between money, output and velocity). Here it will suffice to compute the correlation coefficients between these regressors. These are shown table 1. We observe that these correlation coefficients are relatively low, thereby limiting the risk of collinearity.

Table 1 : Correlation matrix

	M2	**GDP**	**VELM2**
M2	1.000000	-0.294541	0.235851
GDP	-0.294541	1.000000	-0.210572
VELM2	0.235851	-0.210572	1.000000

The results of estimating equations (5) and (6) with OLS are presented in the following table (Table 1). The explanatory power of the equations is remarkably high, considering that the data are cross-section. Close to 98% of the inter-country differences in inflation is explained by just three variables, money growth, output growth and velocity growth. The coefficients of money (M2) are highly significant and very close to 1. This suggests that there is a strong link between exchange rate changes and money growth, and between inflation and money growth in a sample of countries over a thirty year period.

In Table 2 we show the t-statistics for the null hypothesis that these coefficients are equal to one (as predicted by the theory). In the case of equation (5) we maintain the null, in the case of equation (6) we reject the null hypothesis. It should be mentioned, however, that even if we reject strict proportionality, we remain very close to proportionality.

Table 1: OLS regression results of equations (5) and (6) using M2

Variable	Coefficient	t-Statistic
Equation 5		
Constant	-0.009 (0.007)	-1.324
Money (M2)	0.985 (0.019)	51.58
GDP	-1.334 (0.307)	-4.339
Velocity	1.238 (0.306)	4.036
Adjusted R-squared	0.979	
Equation 6		
Constant	-0.0184 (0.006)	-2.73
Money (M2)	1.068 (0.017)	61.40
GDP	-1.588 (0.280)	-5.66
Velocity	1.029 (0.279)	3.68
Adjusted R-squared	0.985	

Note: standard errors in parenthesis

Table 2 : t-statistics for the null hypothesis M2 coefficient equal to one

Equation 5	-0.798
Equation 6	2.00

From table 1 we also find that the coefficients of GDP are significantly different from zero and have the expected negative sign, i.e. higher output growth leads to an appreciation of the currency and to a lower inflation, for any given level of money growth. Similarly, the coefficients of velocity are significant and have the expected positive sign, i.e. an increase in velocity leads to a depreciation of the currency and to an increase in inflation. Thus, on the whole the QTM and the PPP theory seem to hold very well in a sample of about 100 countries over a thirty year period.

The next step in the analysis consists in detecting what the quantitative importance is of the different regressors in explaining inter-country differences in inflation over this thirty year period. In a first step we drop velocity from the regression. This will also allow us to present regression results using M1 (in addition to M2). The results are shown in table 3. We find that the omission of velocity has no perceptible effects on the explanatory power of the equation. The R2 are practically unaffected, and the coefficients of money and output are barely changed. In particular the coefficients of money are very close to 1. We also note that the results of estimating the equations with M1 leads to very similar results.

Table 3: OLS regression results of equations (5) and (6)

	M1		M2	
Variable	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Equation 5				
Constant	-0.026	-5.78	-0.019	-3.13
	(0.004)		(0.006)	
Money	1.069	79.32	0.977	59.05
	(0.013)		(0.016)	
GDP	-0.963	-5.36	-1.488	-6.23
	(0.18)		(0.239)	
Adjusted R-squared	0.986		Adjusted R-squared	0.978
Equation 6				
Constant	-0.039	-9.03	-0.032	-5.26
	(0.004)		(0.006)	
Money	1.172	79.21	1.076	56.99
	(0.015)		(0.019)	
GDP	-0.726	-3.77	-1.357	-5.14
	(0.192)		(0.264)	
Adjusted R-squared	0.988		Adjusted R-squared	0.978

Note: standard errors in parenthesis

The next step in the analysis consisted in the estimation of the previous equations without the output growth. By comparing the results with the previous ones we can evaluate the additional explanatory power of output growth in explaining inflation differentials across countries. Table 4 shows the results of the estimations when output growth is omitted.

Table 4: OLS regression results of PPP and QTM single equations without output growth

	M1		M2	
Variable	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Equation 5				
Constant	-0.033 (0.005)	-6.66	-0.028 (0.007)	-3.926
Money	1.082 (0.015)	73.71	0.996 (0.019)	51.402
Adjusted R-squared	0.98		Adjusted R-squared	0.97
Equation 6				
Constant	-0.044 (0.004)	-9.78	-0.041 (0.007)	-6.025
Money	1.19 (0.015)	78.49	1.103 (0.021)	52.95
Adjusted R-squared	0.985		Adjusted R-squared	0.97

Note: standard errors in parenthesis

The results of table 4 are very similar to the previous ones. The coefficients on M1 and M2 are almost identical and the explanatory power of the regressions is practically the same. More than 98 % of inflation differentials across countries and of exchange rate changes are explained by money growth differentials. This suggests that in the long run, inflation and exchange rate changes are dominated by money growth. Although output growth (like velocity) has a significant effect on inflation and on exchange rate changes, it is not quantitatively important in explaining cross-country differences in inflation and exchange rate changes.

In the previous estimations, PPP was estimated indirectly. It is worthwhile to estimate PPP directly. In order to do so we specify the following equation:

$$e_i = c_1 + c_2 p_i + z_i \qquad (7)$$

where p_i represents the average yearly inflation rate of country i during the sample period, and z_i is the error term. Since the exchange rate changes and the inflation rates are endogenous variables, equation (7) is affected by simultaneity. Therefore we used a 2SLS procedure and we used the money growth as instrument for inflation. The results are presented in the Table 5.

Table 5: 2SLS regression results of "pure" PPP equation

Variable	Coefficient	t-Statistic
C	0.006 (0.004)	1.713
CPI	0.93 (0.011)	82.86
Equation: EXR = C_1 + C_2*CPI Observations: 89		
Adjusted R-squared	0.987	

Note: standard errors in parenthesis

The results of Table 5 are in line with the previous ones, i.e.; there is an (almost) proportional relation between inflation and exchange rate changes. This confirms that in the long run, i.e. almost 30 years, PPP holds and therefore the links between exchange rate changes and inflation rates are strong. Moreover, these results are in line with the time series studies on PPP that affirms that over long periods of time exchange rates converge to their PPP value (see Cheung and Lai 2000, Frankel 1986, Kim 1990, Abuaf and Jorion 1990, Ardeni and Lubian 1991, Glen 1992). Nonetheless some doubts exist (Engel 2000).

The regression analysis of PPP was also performed with OLS. The OLS sample is larger than the 2SLS sample because we do not need an instrument variable that has fewer observations than the inflation data. The following Table 6 shows the results. The results are pretty much similar to the previous one using a 2SLS procedure.

Table 6 : OLS regression results of PPP

Variable	Coefficient	t-Statistic
C	0.008 (0.003)	2.455
CPI	0.923 (0.011)	87.550
Adjusted R-squared	0.985	

Note: standard errors in parenthesis

3.3 Neutrality of money

According to QTM, money is neutral in the long run. In this section we test this proposition. In order to do so, we estimate the following equation:

$$y_i = d_1 + d_2 m_i + \varepsilon_i \qquad (8)$$

$$v_I = d_3 + d_4 m_i + \eta_i \qquad (9)$$

where y_i is the average yearly output growth of country i during the sample period, v_i is the average yearly growth in velocity, m_i represents the average yearly money growth and ε_I and η_i are the error terms. Table 8 shows the results of estimating equations (8) and (9) with OLS.

Table 8: OLS regression results of money neutrality

	Equation 8		*Equation 9*[4]	
Variable	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Constant	0.006 (0.002)	2.36	-0.013 (0.002)	-5.40
Money	0.016 (0.008)	-2.057	0.014 (0.007)	2.00
Adjusted R-squared	0.038		Adjusted R-squared	0.041

Note: standard errors in parenthesis

In both regressions we find that the explanatory power of money is very low, i.e. less than 5% of inter country differences in output growth and velocity growth is explained by money growth. In addition the coefficients of money growth, although

[4] The data on velocity growth are computed with only M2 data.

significant, are very close to zero. Thus this suggests that money is very close to be neutral.

It should be noted that the sign of the coefficient of money in the output equation is negative which is the opposite of what is expected from the traditional theory. This says that an increase in money growth stimulates economic activity, at least in the short run. The results obtained here suggest the opposite relation, i.e. that an increase in money growth leads to a (small) long-term decline in output growth. This result is in line, however, with the results shown by the economic growth literature[5] indicating that an increase in inflation leads to a decline in output growth.

4 QTM, PPP and the level of inflation : empirical tests

From the results of the previous section one is tempted to celebrate the victory of the quantity theory and the purchasing power parity. Both theories do exceedingly well in explaining why long term differences in inflation occur and why currencies depreciate in the long run. Inflation and exchange rate changes appear to be purely monetary phenomena, at least if one takes a sufficiently long time perspective. Things turn out to be a little more complicated than that, however. It is too early to uncork the champagne bottles as this section will show.

In this section we study whether the QTM and PPP propositions hold equally tightly for countries experiencing different inflation regimes. A first look at the data for different sub-samples of countries experiencing different inflation regimes during the sample period seems to suggest that the relation between inflation and money is not stable. We show the evidence in appendix 1. In figure A1 we present the average rates of depreciation against the average growth rate of money for low inflation countries (less than 5% inflation per year) and we then add observations of higher inflation countries, until we obtain the full sample. It is striking to find that there is relatively little relation to be found in the sub-sample of low inflation countries, and that the fit improves as we add high inflation (HI) countries to the sample. The same

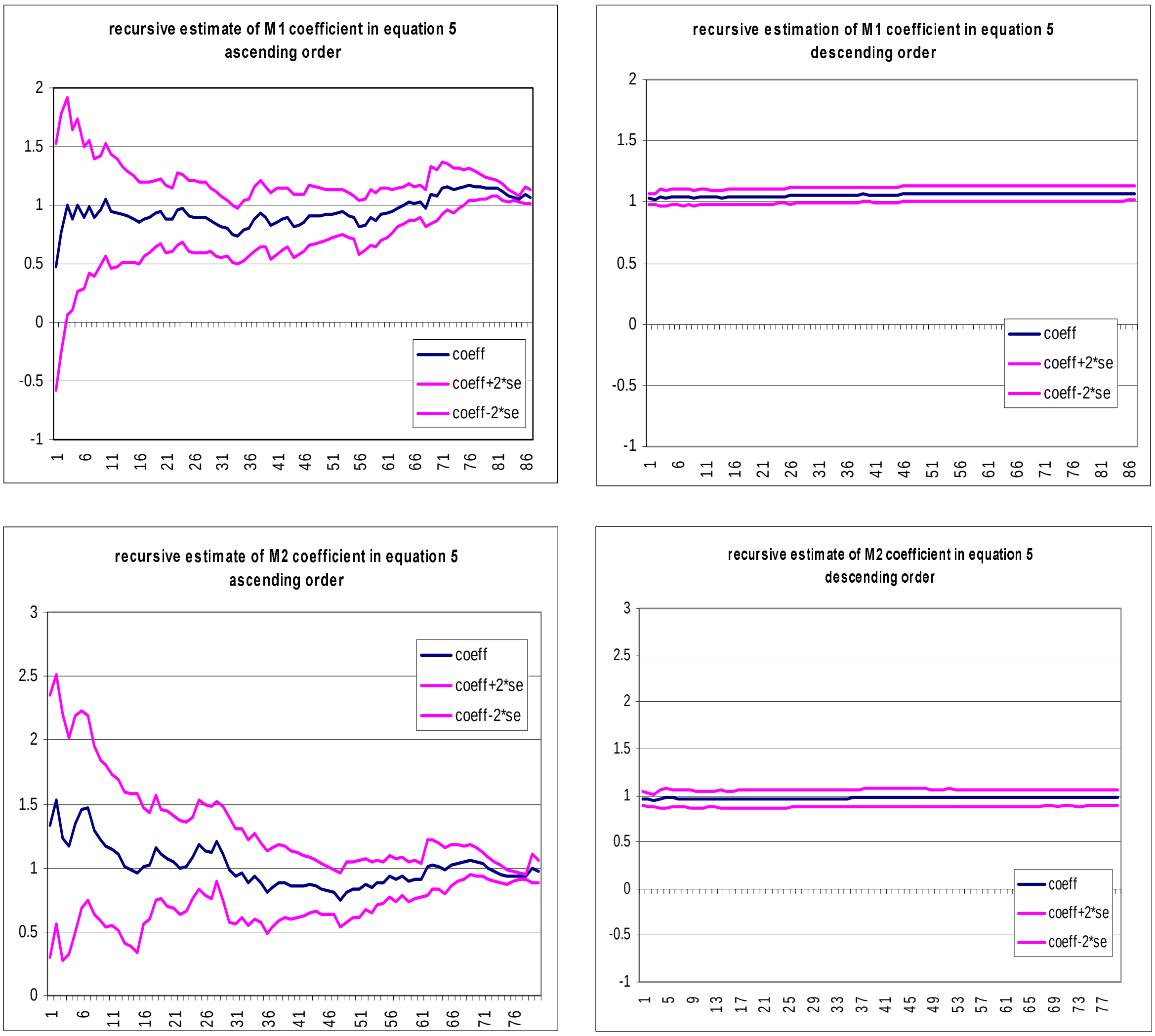
[5] See Barro 1995 (inflation and growth). This effect was shown to exist only when high inflation countries are added to the sample. We return to this theme in the next section.

phenomenon is observed when we plot the average yearly rates of inflation against the average yearly rates of money growth (figure A2).

4.1 Proportionality tests for low inflation (LI) and high inflation (HI) countries

In order to test for systematic differences in the validity of the PPP and QTM propositions, we analysed the stability of the M1 and M2 coefficients as a function of the level of inflation in equations 5 and 6. We started with the recursive estimation of equation 5 (exchange rate money equation). The following picture (Figure 1) shows the recursive estimate of the M1 and M2 coefficients. The data are ordered in ascending and descending order of inflation. Because such systematic ordering produces heteroskedasticity we used the White corrected standard error OLS.

Figure 1



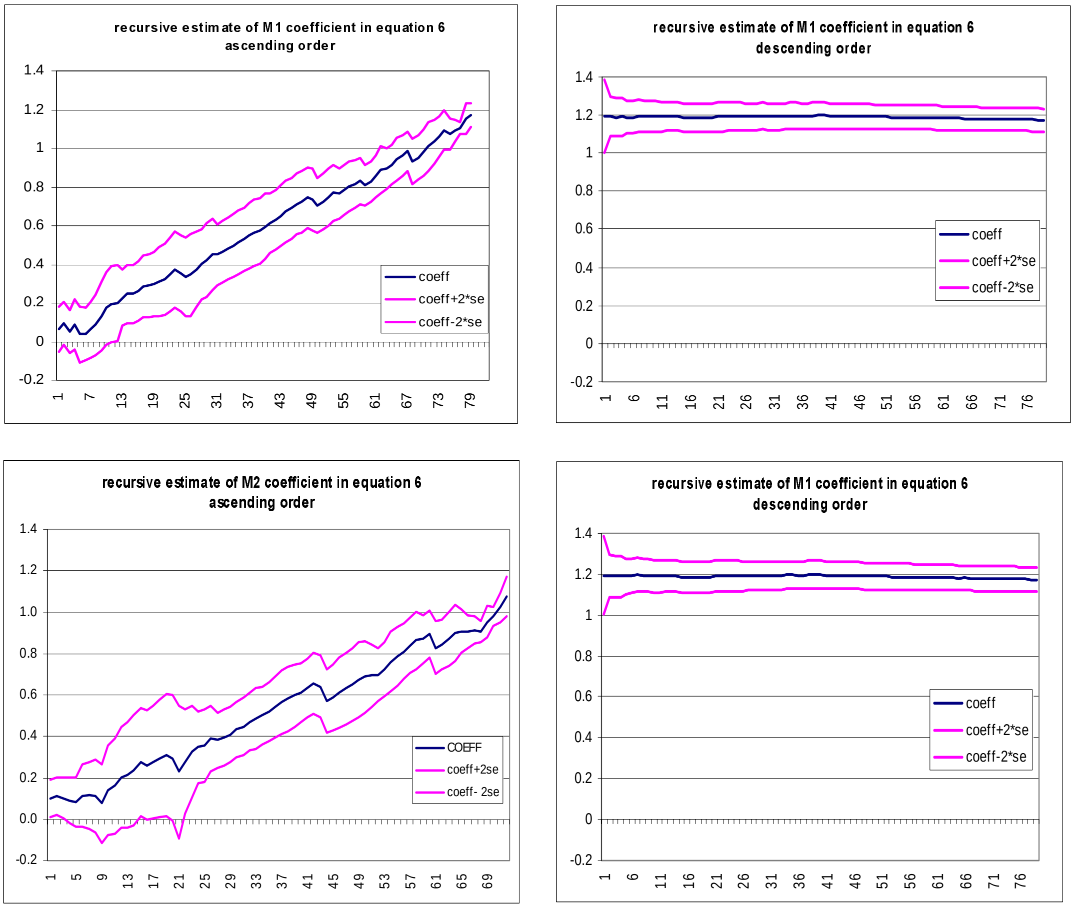
The recursive estimation in ascending order shows a low precision for the M1 and M2 coefficient for the low inflation countries. As HI countries are added the precision increases and the coefficient has a value of (almost) one. Since the low precision for the low inflation countries might be due at least partly to the fact that we observe few countries, we performed the recursive estimation organising the data in descending order of inflation. We observe that the precision of the estimate for HI countries is very high even if few countries are observed. This suggests that for HI countries the relation between exchange rate and money (M1 and M2) is much tighter than for the LI countries. This also suggests that the tight relation that we found for the whole sample is largely due to the HI countries.

The analysis of the recursive estimate of the money coefficients in equation 6 (quantity theory equation) leads to somewhat different conclusions (see figure 2).

For the LI countries we reject the null hypothesis of proportionality. The coefficients of M1 and M2 are not significantly different from zero and significantly different from one. Adding HI countries to the sample leads to an increasing coefficient that then becomes close to one when the highest HI countries are added to the sample.

The contrast with the results of the recursive estimate based on the descending order of inflation is striking. When performing the recursive estimation in descending order, we find that the coefficient of money growth starts immediately at one and does not change by adding LI countries to the sample. This confirms that the (close to) proportional relation between inflation and money growth found in the whole sample is exclusively due to the HI countries. For LI-countries there does not appear to be such a proportionality between inflation and money growth.

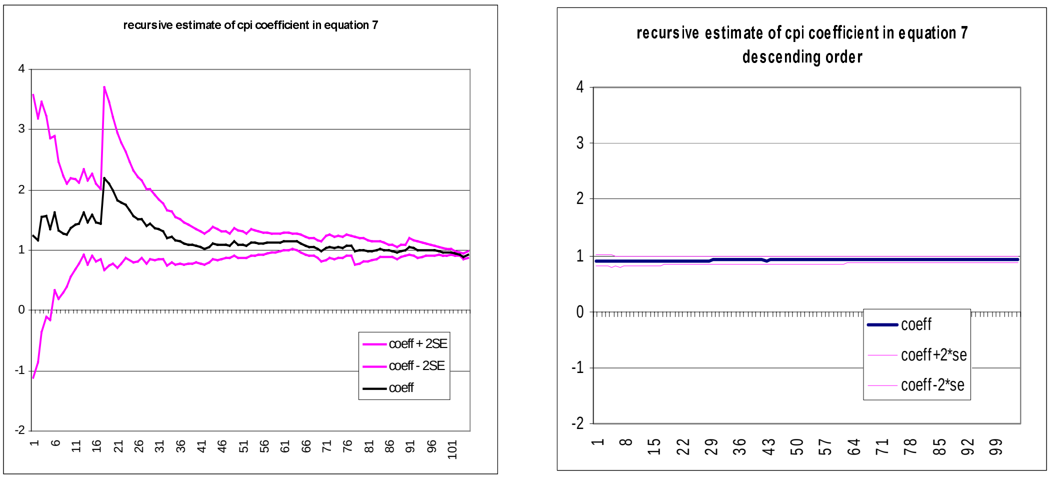
Figure 2



4.2 PPP in different inflationary regimes

Similar questions arise with respect to PPP. Does this relation hold as tightly for all countries independent of their inflation regimes? In order to answer this question, we performed a similar recursive analysis on the PPP relationship (equation 7). The results are shown in the following Figure 3 and are qualitatively very similar to the results of the recursive analysis of the exchange rate - money equation (equation 4). We observe that the precision of the inflation coefficient for the LI countries is low. For the twenty lowest inflation countries we cannot reject that the coefficient is equal to zero. This sub-sample includes most of the industrialised countries. In contrast, the precision for the HI countries is very high, as shown by the right-hand graph of Figure 3 (descending order). We conclude that PPP holds very tightly for the HI countries, while for the LI countries we do not find such a result[6]. Again, the precision of the estimate that we have for the whole sample seems to be due to almost exclusively to the HI countries.

Figure 3

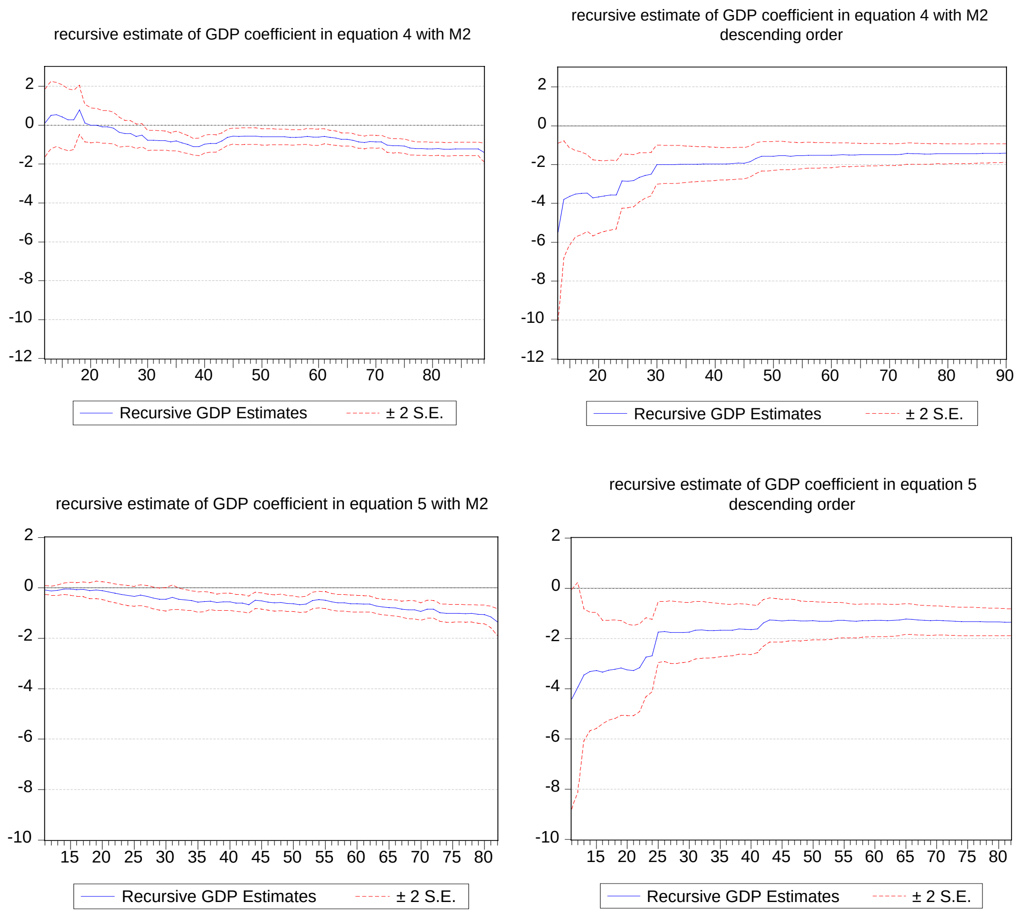


4.3 Exchange rate changes, inflation and output growth in LI and HI countries

The analysis of the effect of output growth on inflation and exchange rate changes in the whole sample shows that, given the money growth, an increase in output leads to an appreciation of the currency and to a decline in inflation. We tested if these results hold in sub-samples defined according the inflationary regimes by performing similar recursive estimates as in the previous sections. The results are shown in the following Figure 4. As the results for M1 and M2 are similar we only show the results when the money supply is defined as M2. In Appendix 2 we show the results for M1

[6] This result contrasts with the results obtained by Frankel and Rose(1996) who concluded from a panel data analysis that PPP holds relatively well . The reason for this contrasting result is that Frankel and

Figure 4



The recursive analysis shows that the effect of output growth on exchange rates changes and on inflation is not significant for LI countries. It becomes significant when we add HI countries in the sample. This suggests that the negative coefficient that we found for the sample as whole stems from the effect output growth has in HI countries.

An interpretation of this phenomenon might be the following: HI countries have a credibility problem. This problem is made worse when output growth is weak, i.e. for given money growth weak output growth reinforces inflation. As a result, inflationary expectations are worsened which in turn increases the rate of depreciation of the currency and inflation. Conversely, when output growth increases, this improves

---

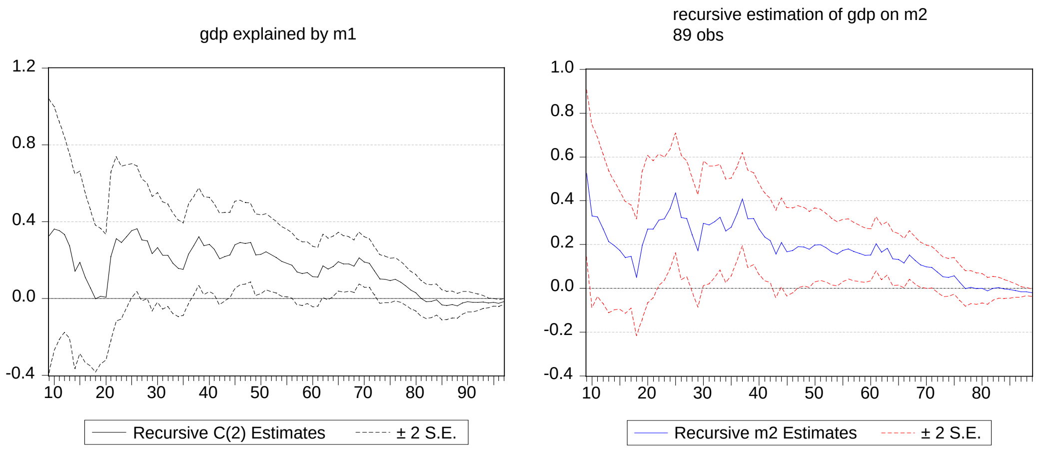
Rose did not isolate the low inflation countries in their sample (except for a dummy for inflation less than 10% which is a pretty high rate of inflation).

credibility. This leads to lower inflationary expectations and, therefore, to lower inflation and to an appreciation of the currency.

4.4 Neutrality of money in LI and HI countries

In the analysis of the whole sample we found that an increase in money growth reduces output growth. In this section we analyse if this effect is stable under different inflationary regimes. Figure 5 shows the results of the recursive estimation for both M1 and M2 of the coefficient of money in the equation explaining output growth (equation (8)).

Figure 5



The analysis shows that the effect of money on output growth is negative for the whole sample but these results come from adding to the sample the very high inflation countries. Without these few hyperinflationary countries the coefficient of money is positive even though not significant. Therefore one can conclude that for most of the sample money seems to be neutral. The negative sign we obtained for the sample as a whole is exclusively due to the last few countries in the sample with extremely high inflation. This result confirms results obtained in the economic growth literature. There it is found that inflation reduces economic growth, but that this negative effect of inflation is only observed if inflation increases sufficiently (Barro(1995)).

It should be pointed out that there is a potential simultaneity bias when we estimate the money coefficient in equation (8). The bias is due to a possible inverse causality, i.e. output may affect money. This causality stems from the fact that monetary authorities often accommodate output increases. If this is the case, the bias of the estimated money coefficient is positive. In other words, we may be overestimating the coefficient of money in equation (8). If such a bias exists, our conclusion that money is neutral would be reinforced.

5. QTM, PPP and the level of inflation : additional empirical tests

The recursive estimates of the previous section implicitly give a high weight to the extreme countries of the sample, i.e. the very low inflation and the very high inflation countries. In this section we apply the rolling regression techniques, which give the same weight to all the countries in the sample. The starting point is to estimate our equations for the first n countries, i.e. the sample of this first regression goes from 1 to n. For the second regression we have a sample that goes from 2 to n+1 . We continue this process until the last regression has the sample going from N-n to N , where N is the total sample size. We have set n=20.

Moreover, as in the previous section we applied the White correction to the estimates in order to avoid the serial correlation caused by the ascending order of the data. The results of these rolling estimates of the coefficient of money in equation 5 are presented in figure 6, while the results for equation 6 are presented in figure 7

Figure 6

Rolling Estimate of money coefficient in equation 5

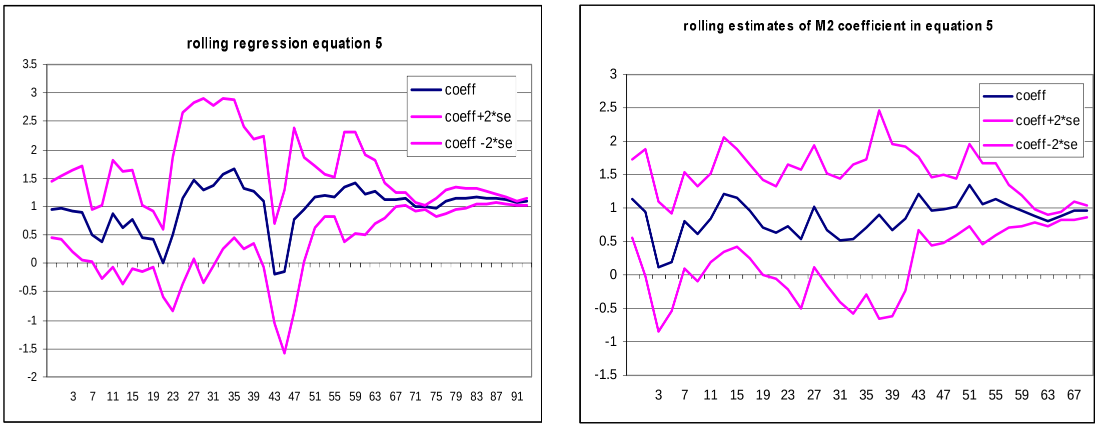
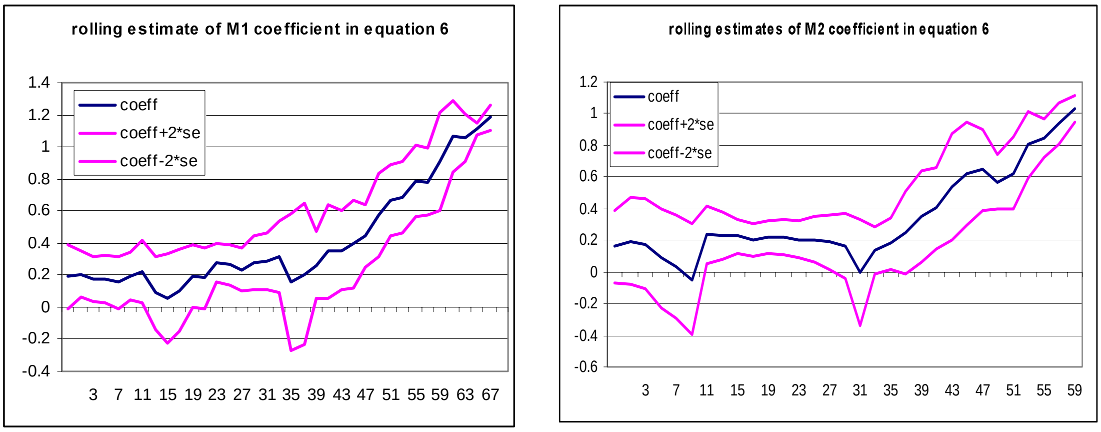


Figure 7

Rolling Estimate of money coefficient in equation 6



For both LI and HI countries we obtain very similar results as in the recursive estimates of the previous section. Thus the coefficients of money of the HI countries in both equations are very close to one. For the LI countries the same pattern as in the previous section appears, i.e. a lower precision of the estimate in equation 5 (exchange rate equation) and a coefficient not significantly different from zero in equation 6 (QTM equation). Moreover, it appears that the countries in the intermediate range follow the same pattern as the low inflation countries. We also observe that the coefficients of money in equation (5) are unstable, converging to 1 for the very high inflation countries.

In order to check the difference in explanatory power of the different regressors, we omitted each regressor consequently. We performed this exercise for different sub-samples of countries: low inflation, intermediate and high inflation countries. The results are presented in table 9. The results can be interpreted as follows. For the high inflation countries the omission of velocity and GDP does not reduce the explanatory power of the regression in any significant way. Money is the only variable that matters. This is not the case for the other group of countries. For the low inflation countries both GDP and money have about the same low explanatory power. Moreover in this sub-sample velocity does not seem to have any role in explaining inflation. Finally for the intermediate inflation countries velocity seems to have the greatest (even though low) explanatory power, while money and GDP have no importance in explaining inflation.

All this suggests that for low and intermediate inflation countries the explanatory power of money, output and velocity is unstable and crucially depends on the countries included in the sample. When inflation increases sufficiently, however, money becomes the only variable that matters in explaining inflation.

Table 9: OLS regression results QTM equation with omitted variables for LI and HI countries

Low inflation countries (lowest 20 inflation countries)								
	1		2		3		4	
Variable	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic
Constant	-0.007 (0.005)	-1.395	-0.001 (0.005)	-0.276	-0.008 (0.004)	-1.724	-0.003 (0.005)	-0.652
Money	0.295 (0.177)	1.666			0.273 (0.152)	1.791	0.096 (0.106)	0.905
GDP	-0.427 (0.243)	-1.756	-0.059 (0.164)	-0.362	-0.408 (0.23)	-1.771		
Money Velocity Growth	0.081 (0.315)	0.257	-0.082 (0.217)	-0.381			0.009 (0.295)	0.032
Adjusted R-squared	0.0192		-0.098		0.067		-0.061	

High inflation countries (highest 20 inflation countries)								
	1		2		3		4	
Variable	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic
Constant	-0.021 (0.022)	-0.947	0.427 (0.084)	5.05	-0.045 (0.020)	-2.249	-0.018 (0.026)	-0.719
Money	1.059 (0.052)	20.12			1.077 (0.05)	21.315	16.92 (0.06)	0.905
GDP	-2.354 (0.671)	-3.504	-11.705 (7.38)	-1.584	-3.032 (0.79)	-3.822		
Money Velocity Growth	2.32 (1.171)	0.257	7.265 (8.048)	0.902			3.046 (1.275)	2.38
Adjusted R-squared	0.987		-0.329		0.984		0.983	

Intermediate inflation countries (20 inflation countries in the middle of the sample)								
	1		2		3		4	
Variable	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic
Constant	0.049 (0.009)	5.717	0.054 (0.004)	13.481	0.046 (0.009)	5.436	0.047 (0.006)	7.798
Money	0.059 (0.109)	0.544			0.123 (0.094)	1.309	0.089 (0.068)	1.313
GDP	0.088 (0.274)	0.322	0.157 (0.182)	0.862	0.011 (0.285)	0.037		
Money Velocity Growth	-0.191 (0.143)	-1.327	-0.230 (0.108)	-2.129			-0.171 (0.127)	-1.345
Adjusted R-squared	-0.017		0.029		-0.017		0.033	

Note: standard errors in parenthesis

6. Theoretical issues and puzzles

In section 3 we found that for the sample as a whole the PPP and QTM propositions hold remarkably well. In section 4 we found that this success of PPP and QTM is almost exclusively due to the HI countries in the sample. For the LI countries the PPP and QTM propositions do not seem to hold well. These empirical findings raise a number of theoretical issues that we discuss now.

6.1 Puzzle 1: the proportionality propositions are weak in the LI countries.

In low inflation countries the long-term links between *money and prices*, *money and exchange rates*, *prices and exchange rates* are weak. For the low inflation countries we can generally not reject that the coefficients of money in regressions explaining inflation and exchange rate changes over an horizon of 30 years are zero, neither can we reject the hypothesis that exchange rate changes are unrelated to inflation rates (zero coefficients of inflation in PPP-regressions) over the same time horizon. For high inflation countries we systematically reject that these coefficients are zero. When we look at the sample as a whole we do reject that these coefficients are zero, but this is solely due to the high inflation countries in the sample.

6.2 Puzzle 2: PPP seems to hold better than QTM for low inflation countries.

In the equations explaining the exchange rate changes we find coefficients of money growth and of inflation close to 1, albeit not significantly different for 0. At the same time they are not significantly different from 1 either. Thus we cannot really reject the proportionality hypothesis in these equations explaining the exchange rate. The problem with these estimates is their low precision, so that we do not really know with any confidence what the value is of these coefficients for low inflation countries.

The contrast with the quantity theory is great. Here we find that we can reject the proportionality hypothesis for low inflation countries, i.e. we reject the hypothesis that the coefficient of money is 1, and we cannot reject that it is 0.

How can these puzzles be explained? This question is taken up in the next section.

6.3 Possible explanations

We discuss different possible explanations in increasing order of plausibility.

- *Imperfect competition* in conjunction with small costs in changing prices (*menu costs*) creates price rigidities. Thus, since in low inflation countries nominal (inflation) shocks are small, the incentives to change prices are low. As a result, we observe price rigidity. This is much less the case in high inflation countries where nominal shocks are high. In these countries we observe more price flexibility[7].

  The problem with this explanation is that it has a counterpart, i.e. in low inflation countries money should then be non-neutral (it affects output in the long run). We have found that there is no evidence for this proposition for most of the countries in the sample except for the few very high inflation countries.

  This explanation based on imperfect competition and menu costs can be maintained if the pricing rules the firms follow are 'state dependent' (see Blanchard and Fischer(1996), p. 402). In that case, some models predict that money is neutral while prices and money are proportional.

  The problem remains, however, whether price rigidity is a sufficient explanation for the lack of proportionality between money, prices and exchange rates over a *thirty-year period.* The problem can be illustrated graphically (see Figure 8). On the vertical axis we set out the money stock over different periods; on the horizontal axis we have the price levels over the same periods. We assume that the money stock increases at a constant rate each period during a thirty-year period. Prices are sticky. We assume that it takes 10 years for the price level to fully adjust to an increase in the money stock that occurs in any given year. This assumption is based on the empirical evidence about PPP, which finds that the half-life of the adjustment of prices to the PPP long run equilibrium is about 5 years[8]. We represent how the prices adjust over time by the line segments whose slopes increase over time. For example, in the first period money increases from m_0 to m_1 and this leads to a price increase from p_0 to p_{10} that is completed in period 10. In the second period the new price line starts in point A. Its slope is

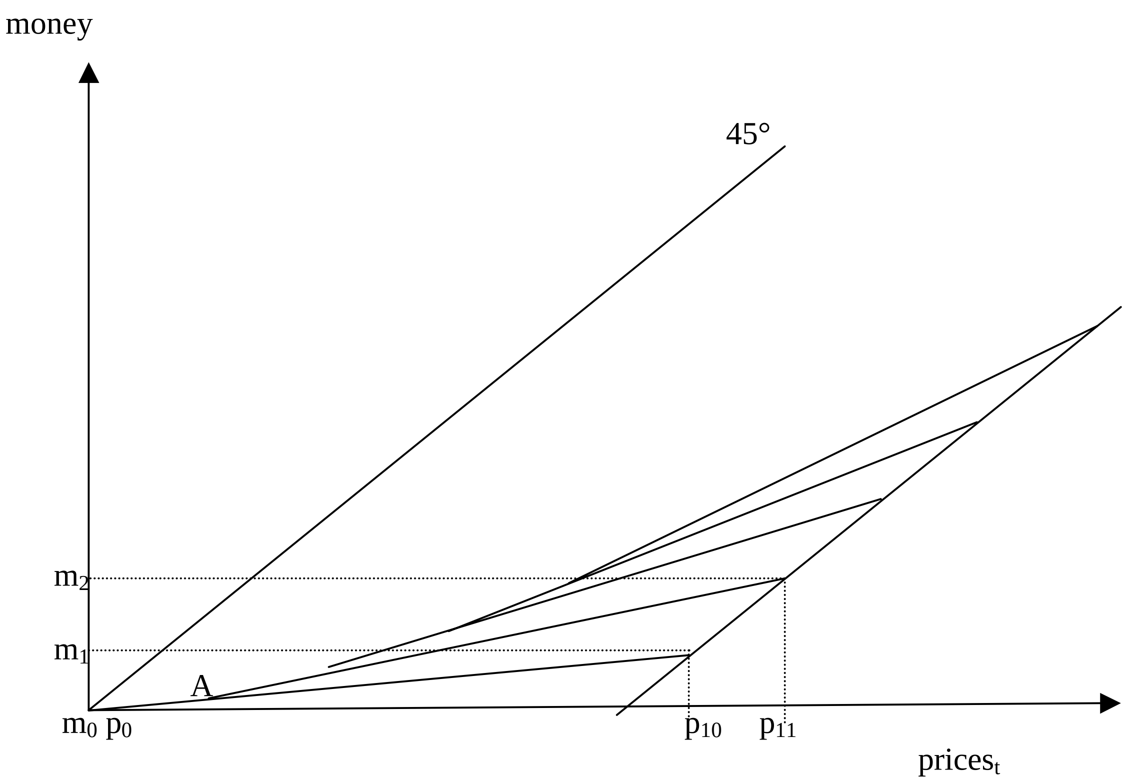
[7] There is a strand of empirical evidence on this issue, for details see Barro (1995)

now influenced by the increases in money of the first and second period, and so on. Asymptotically the slope of these price lines becomes equal to the 45° line. The latter represents the QTM proportionality relation between money and prices. Since we estimate the relation between money and prices over a thirty-year period only, our estimate of the true proportionality line (45%) is biased towards zero. In this concrete example (sample period=30 while the price adjustment lag is 10 years) one can show that we will estimate a coefficient equal to 0.666 [(30-10)/30].

It will be remembered that we could not reject that the coefficient of money in the QTM equation is zero. Price rigidity therefore explains part of this bias, but not fully so.

Figure 8

Money and prices in a model with price rigidities



---

[8] Cheung and Lai (2000)

- The second possible explanation is that we face an econometric problem, which arises from *measurement errors*. The problem can be formulated as follows. We start from the QTM equation (equation 5) that we rewrite as:

$$p_i = a_1 + a_2 m_i^* + a_3 y_i + u_i \qquad (5')$$

where m_i^* is the rate of growth of money stock induced by monetary policy actions. However, the observed money growth, m_i, is also influenced by non-monetary policy shocks, e.g. financial innovations, changes in money definitions, etc. The latter do not affect inflation. Therefore we can write

$$m_i = m_i^* + \varepsilon_i \qquad (10)$$

where ε_i are the shocks in money stock non related to monetary policy.
We substitute (10) in (5') :

$$p_i = a_1 + a_2 m_i + a_3 y_i + (u_i - a_2 \varepsilon_i) \qquad (11)$$

From equation (10) we conclude that m_i and the error term in (11) are negatively correlated. This leads to the conclusion that the m_i coefficient is biased towards zero. This is particularly severe in the low inflation countries because the shocks in money unrelated to the monetary policy (ε_i) tend to be large compared to the shocks in money supply related to monetary policy (m_i^*). Conversely, in the HI countries the policy-induced shocks in money supply tend to dominate the other ones. As a result, the bias should be smaller in HI countries than in LI countries.

In order to resolve this problem an appropriate instrumental variable for the money supply has to be found. We leave it to future research to investigate this.

It should be pointed out, however, that this explanation does not do well in explaining the exchange rate money relation. As will be remembered, the estimates of the money coefficients in that equation did not seem to be biased downward. We found coefficients to be close to 1, albeit with large standard errors. If there is a bias because of errors in measurement of money in the quantity theory equation, the same bias should exist in the equation relating the exchange rate to the money stock. Since we do not find this bias, the explanation based on measurement errors in money is not fully satisfactory.

➢ A third explanation that we favour has the following ingredients: p*roductivity shocks* in the goods markets and *transactions costs* in international trade. As stressed in a recent paper by Obstfeld and Rogoff (2000), many puzzles in international macroeconomics can be explained by the existence of transactions costs. In addition, these transactions costs do not have to be terribly large to explain these puzzles.

We use a simple model of aggregate demand and supply. We first analyse the closed economy version of the model. This will allow us to concentrate on the QTM puzzles. We then open up the model to make the link with PPP.

The model is very standard and consists of four basic equations (see Walsh(1998) for more explanation[9].)

Aggregate supply	$y_t = E_{t-1}y_t + a(p_t - E_{t-1}p_t) + (\delta + \varepsilon_t)$	(12)
Aggregate demand	$y_t = E_t y_{t+1} - r_t + u_t$	(13)
Money demand	$m_t - p_t = y_t - \phi\, i_t + v_t$	(14)
Fisher equation	$i_t = r_t + E_t p_{t+1} - p_t = r_t + E_t \pi_{t+1}$	(15)

where y_t represents output, p_t is the prices level, i_t is the nominal interest rate, r_t represents the real interest rate, π_t is the inflation rate , u_t , ε_t and v_t are random disturbances, E is the expectation operator. The subscript t refers to the time. Note that the supply shocks are driven by a random component ε_t and a constant δ. This constant reflects productivity growth which is assumed to occur at a constant rate.

Note that the aggregate demand equation is specified in a way that is consistent with inter-temporal utility optimisation by the consumer (see Walsh(1998), p. 205).

We assume that the monetary authorities set m_t according to the following rule

$$m_t = \mu + m_{t-1} + a_1 u_t + a_2 v_t + a_3 \varepsilon_t \qquad (16)$$

---

9 See Clarida, Gali and Gertler(1999) for a similar model.

where μ is the average growth rate of the money supply. We assume it to consist of two components, i.e. $\mu = \mu' + \delta$, where μ' is the rate of money growth in excess of productivity growth. This excess of money growth determines the long-term inflation. Productivity shocks are assumed to be serially uncorrelated and, therefore, $E_t y_{t+1} = \delta$ [10].

In order to find the equilibrium solution we substitute the Fisher equation into the money demand equation. Then, we obtain aggregate demand by substituting the money demand equation and solving for y. Equating aggregate supply with aggregate demand, we find the equilibrium value of output and price level for given expectations. Finally we solve for rational expectations using the method of undetermined coefficients. This yields the following expression:

$$
\begin{aligned}
p_t &= \frac{\mu(1+\phi)}{\phi} + m_{t-1} + b_1 u_t + b_2 v_t + b_3 \varepsilon_t \\
y_t &= a\left(b_1 u_t + b_2 v_t\right) + b_4 \varepsilon_t
\end{aligned}
\qquad (17)
$$

where

$$b_1 = \left[\frac{1 + a_1(1+\phi)}{(1+a)(1+\phi)}\right]$$

$$b_2 = \left[\frac{a_3(1+\phi) - \phi}{(1+a)(1+\phi)}\right]$$

$$b_3 = \left[\frac{a_2 - 1}{(1+a)}\right]$$

$$b_4 = \left[\frac{a a_2 + 1}{(1+a)}\right]$$

We concentrate on the effects of productivity shocks, ε_t. These shocks have unambiguously positive effects on y, but an ambiguous effect on prices that depends

[10] The equilibrium solution that we are going to derive considers two periods but it can be easily solved forward (see Walsh pag 207)

on a_2, i.e. the policy reaction of the monetary authorities to shocks in productivity. If the monetary authority set $a_2 < 1$ the productivity shocks lower the price level.

Taking the expected value for p in equation 17 and using the monetary policy rule we obtain the average expected inflation rate:

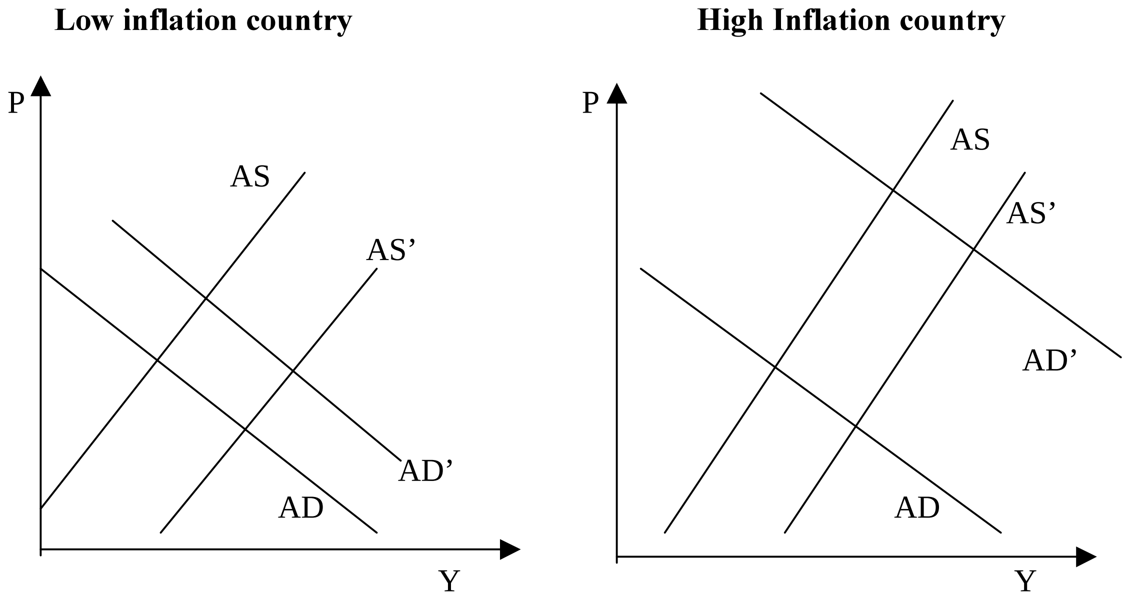
$$E_t \pi_{t+1} = \mu - \delta + (a_1 - b_1)u_t + (a_2 - b_2)v_t + (a_3 - b_3)\varepsilon_t \tag{18}$$

On average, the expected inflation rate is equal to the average money growth minus the permanent component of the productivity growth. The intuition is that agents know that the increases in money that accommodate the permanent increases in productivity will not affect the average rate of inflation. The expected inflation rate is also affected by shocks, in particular, by supply shocks. Since the coefficient of the supply shocks is positive these shocks positively affect the expected inflation rate.

Permanent increases in productivity growth have an opposite effect on inflation and money growth, i.e. they lower the former and increase the latter. This effect is likely to be relatively large for LI countries where the μ' is small. As a result, the observed correlation between inflation and money growth will be small or even negative. For the HI countries μ' is relatively large. Therefore the positive correlation between money growth and inflation will dominate.

We show these results graphically in Figure 7. The AD and AS curves represent the aggregate demand and supply equations. In the low inflation countries the yearly productivity growth which shifts the supply curve downwards is relatively large compared to the positive demand shift induced by money growth. These shifts are shown by the movements from AS to AS' and AD to AD' respectively. As a result the price level may go up or down, and the price level will show little positive correlation with the money stock (assumed to be increasing continuously). Things are very different in the high inflation country, where the money induced demand shocks by far dominate the productivity increases. As a result, we observe a strong correlation between prices and money stock.

Figure 9



We now study the open economy version of the model. The model consists of the same basic equations.

Aggregate supply	$y_t = E_{t-1}y_t + a(p_t – E_{t-1}p_t) +(\delta+ \varepsilon_t)$	(12)
Aggregate demand	$y_t = E_t y_{t+1} – r_t + \gamma\rho_t + u_t$	(13')
Money demand	$m_t - p_t = y_t - \phi i_t + v_t$	(14)
Fisher equation	$i_t = r_t + E_t p_{t+1} - p_t = r_t + E_t\pi_{t+1}$	(15)
Open interest parity	$i_t = i_t^* + E_t s_{t+1} - s_t$	(19)
Real exchange rate	$\rho_t = s_t - p_t + p_t^*$	(20)
Money supply process	$m_t = \mu + m_{t-1} + \alpha_1 u_t + a_2 v_t + a_3 \varepsilon_t$	(21)

We have added the real exchange rate ρ_t into the aggregate demand equation (13'). s_t represents the nominal exchange rate. The * variables represent the foreign variables. There are similar equations (12) to (15) and (21) for the foreign country. We assume that the domestic country is a small country. Therefore, the foreign variables are assumed to be exogenous.

We first solve the model for the real exchange rate. This is done by subtracting the foreign from the domestic supply, and the foreign from the domestic demand. Equalising these differences, we can solve for the real exchange rate:

$$\rho_t = \frac{1}{2\gamma+1}\left[a\left(p_t - E_{t-1}p_t\right) - a\left(p*_t - E_{t-1}p*_t\right) + E_t\rho_{t+1} + (\delta - \delta*) + \left(\varepsilon_t - \varepsilon_t*\right) - \left(u_t - u_t*\right)\right] \tag{22}$$

Solving equation (22) by forward iterations and assuming the no-bubble condition, yields the following expression:

$$\rho_t = \frac{1}{2\gamma}\left((\delta - \delta*) + \left(\varepsilon_t - \varepsilon_t^*\right) + \left(u_t - u_t^*\right)\right) \tag{23}$$

From equation (23) we observe that the real exchange rate will be affected by permanent productivity shocks only if these are different between the countries. In other words, equal productivity shocks in the domestic and foreign country do not affect the equilibrium value of the real exchange rate. When these shocks are identical between countries then the real exchange rate is constant and the nominal exchange rate will change in the same proportion as the price levels.

We now solve the model for p_t , $p*_t$ and s_t , assuming rational expectations. We obtain

$$p_t = (1+\varphi)\mu + m_{t-1} \tag{24}$$

$$p*_t = (1+\varphi)\mu* + m*_{t-1} \tag{25}$$

$$s_t = (1+\varphi)\mu + m_{t-1} - (1+\varphi)\mu* - m*_{t-1} \tag{26}$$

where for the sake of simplicity and because we concentrate on the long run, we have set all the random shocks equal to zero. The model, therefore, predicts proportionality between prices and exchange rates when the shocks are monetary. Note that, as stressed earlier, as long as productivity shocks are equal between countries they do not affect the proportionality between the exchange rate and the price levels (PPP). Whether they are equal or not, these productivity shocks, however, do interfere with the proportionality relations between the domestic price level and the domestic money stock. Thus, among low inflation countries where productivity shocks tend to be of equal magnitude the estimated quantity theory relationship will be biased while no such bias may exist in the PPP-relations. Nevertheless, the precision in the estimates of PPP may be very low. In order to understand this we have to introduce transactions costs.

We introduce transaction costs as follows. We assume that these costs represent a fixed proportion, τ, of the prices of products. These costs then define a transaction band within which PPP arbitrage does not occur because it is not profitable. We apply this idea more formally as follows:

$$\text{If} \quad s_{t+i} - s_t \leq \tau \quad \Rightarrow \quad s_{t+i} = s_t$$

$$s_{t+i} - s_t > \tau \quad \Rightarrow \quad s_{t+i} = (1+\varphi)\mu + m_{t-1+i} - (1+\varphi)\mu^* - m^*_{t-1+i}$$

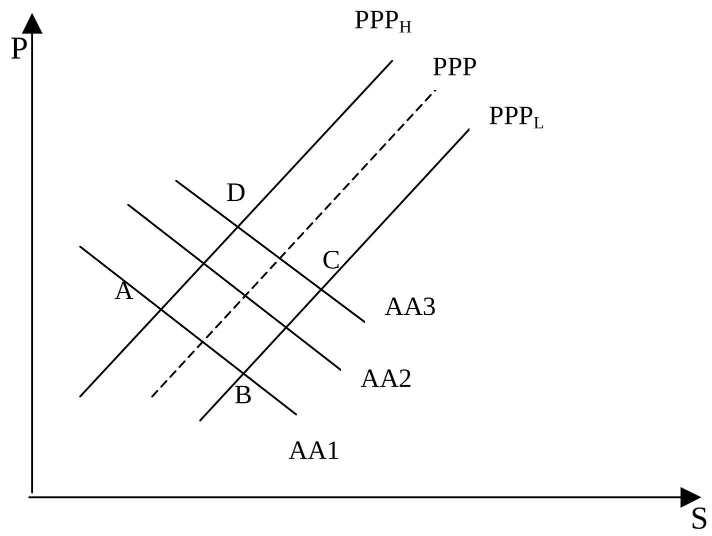
$$\forall i = 1, \ldots T \tag{27}$$

In LI countries the yearly differentials in money growth rate μ -μ^* are very small. As a result, the yearly changes in the equilibrium exchange rate are small, typically much smaller than the transactions band. Thus, the arbitrage forces tending to force the exchange rate towards its PPP-value will be weak or non-existent. Under these conditions it will take many years before arbitrage forces the adjustment of the exchange rate towards its PPP-value. In HI countries, however, the yearly differentials in money growth are large, so that PPP-arbitrage forces the adjustment of the exchange rate along a proportional path with the price level.

We show these results graphically in figure 10. The PPP line shows the proportional relationship between the domestic price level and the exchange rate resulting from monetary shocks. The AA line represents the asset market equilibrium. It combines the interest parity relation and money market equilibrium, and can be derived from equations (14), (15), (19). (See also Krugman and Obstfeld (2000)) .

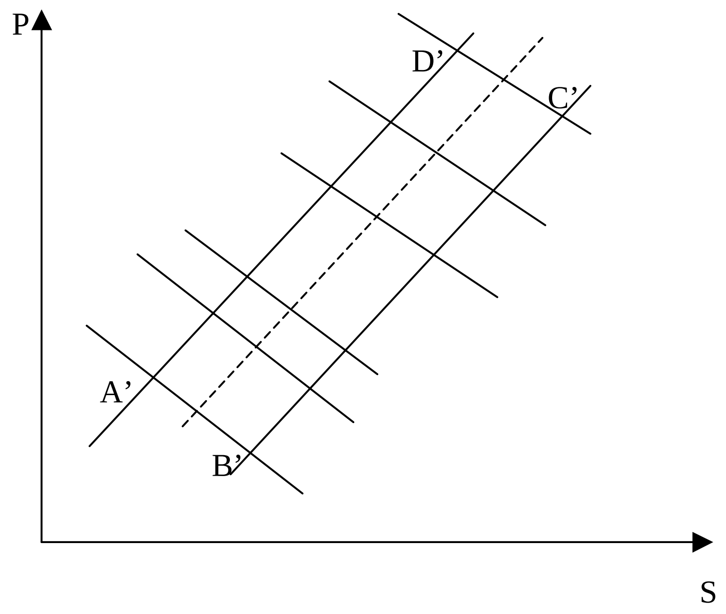
Because of transaction costs, arbitrage will not occur when the price-exchange rate observations are between the band given by the parallel lines PPP_L and PPP_U. Thus, when observations are within that band there is no mechanism driving the price-exchange rates towards the PPP-line. When the domestic money stock increases faster than the foreign money stock (called the US here) the AA line shift upwards. When the domestic money stock growth is lower than in the US the AA line shifts downwards. When we consider the LI countries, the changes in money stock relative to the reference country (the US) will be relatively small. The lines AA1 AA2 AA3 represent different LI countries that have different monetary policies compared to the US. These shifts are small compared to the transaction costs band around the PPP line. The scatter of the observations will be located within the ABCD area. Therefore when we estimate the PPP relation, i.e. the relation between P and S, the precision of this estimate will typically be low.

Figure 10



When we add HI countries to the sample we obtain the next Figure 11. We have added the asset lines of the HI countries that experience relatively large increases in money compared to the US. The observation points now will be located in the stretched area A’B’C’D’. As a result, the PPP relation will be estimated with a much higher precision.

Figure 11



The previous theoretical model allows us to understand why the PPP relation will have a low precision in LI-countries. It is worthwhile to stress that we do not need terribly high transactions costs to explain this low precision. To show this we observe that among the LI countries the inflation differentials have been small during the last 30 years. In Appendix 3 we show these yearly inflation differentials with the US. We observe that for the lowest 20 LI countries the yearly differentials are within a band of approximately 2,5%. However, the price differentials should be considered cumulatively over a period of thirty years. The cumulative differentials compared with the US are presented in Figure 12 in Appendix 3. The transaction costs are assumed to be 20%.[11] We find that out of the lowest inflation countries 11 countries stay in this transaction costs band over the whole period of 30 years. This means that for these countries even over this long period there was no mechanism that drove the prices to their PPP long run equilibrium. For the other low inflation countries this mechanism did exist, but must have taken a long time to operate.

When we cumulate yearly differentials over a period of 15 years almost all LI countries stay within the transaction costs band, as showed in figure 13 in Appendix 3. This means that even for the outliers in the group of the LI countries it takes at least

[11] This is a rough estimate. It is worth noting that for the tradable goods the transaction costs are likely to be lower. However, since we are considering the CPI levels this means that we are considering all goods, i.e. also non tradable goods for which the transaction costs are much higher than for tradable goods. (see Obstfeld & Rogoff (2000))

15 years for the PPP dynamics to work. It is therefore no surprise that exchange rates are disconnected from their fundamental value (PPP) even over the very long run among the low inflation countries.

The previous discussion also implies that we are likely to observe relatively large real exchange rate changes among LI countries. We show these cumulative changes for low inflation countries during 1971-99. Figure 14 in Appendix 3 shows the cumulative real exchange rate changes for the countries that experienced average yearly inflation differentials with the US between –2% and +2%. The next figure 15 shows these real exchange rate changes for the industrialised countries in this group of low inflation countries. These figures confirm that the real exchange rate changes can be substantial.

There are two possible explanations for these real exchange rate changes. One is to explain these by changes in real variables, in particular by productivity growth differentials. The problem with this explanation is that we need large productivity growth differentials between countries. This may be appropriate in the case of Japan, but is much less so for the sample of industrialised countries that have experienced similar technological developments.

The other explanation is based on our analysis of transactions costs. The latter are responsible for sustained deviations of the exchange rates of LI countries from their PPP-value. To the extent that the observed real exchange rate changes fall within the transactions costs band, they cannot be associated with long-term divergent developments in productivity or other real variables.

For most industrialised countries the existence of transaction costs can explain a significant amount of observed real exchange rate changes. For these countries transactions costs may have more relevance than different technological developments. There are certainly exceptions (e.g. Japan) and for these countries one may have to combine transactions costs and productivity growth differentials to obtain a good explanation of observed real exchange rate changes.

7. Conclusion

According to PPP, there is a proportional relationship between exchange rate changes and inflation. The QTM envelops two propositions: 1) a *proportionality* proposition that states that there is a proportional relationship between money growth and inflation, 2) a *neutrality* proposition saying that money growth does not affect output growth in the long run. In this paper we combined the PPP theory and the QTM. We tested the validity of these propositions in the long run using a cross-section of approximately 100 countries over a thirty-year period. We found the PPP and QTM propositions to hold quite well for the sample as whole. However, when we distinguished between high and low inflation countries the results are quite different. We reject the QTM proportionality proposition for the LI countries, i.e. in these countries an increase in the growth rate of money stock does not have a long run proportional effect on inflation. We are less sure about PPP for the LI countries because the estimated coefficients are very imprecise. All this contrasts with the results of the HI countries where the proportionality propositions hold very tightly both in the context of the QTM and of PPP.

These results lead to two theoretical puzzles:

1. Why does PPP seem to hold better than QTM for low inflation countries?
2. Why are the proportionality propositions weak in the low inflation countries?

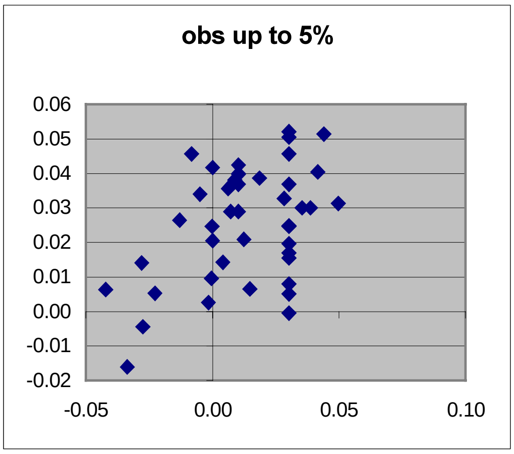
We proposed an explanation based on *transaction costs* and *productivity shocks* to explain both puzzles. The empirical evidence seems to confirm our theoretical analysis, but further research is necessary to find out what the relative importance is of these transactions costs and productivity shocks to explain the long-term movements of exchange rates.

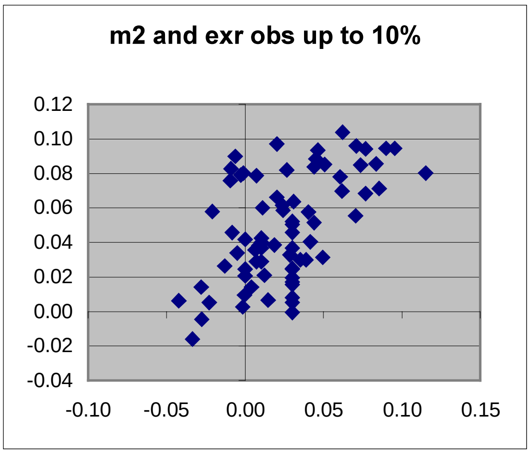
An implication of our findings relates to the movements of exchange rates of major industrial countries. These exchange rates have exhibited relatively long cyclical movements since 25 years. It has been very difficult to associate these movements with movements of underlying fundamentals. Our results put these difficulties in perspective. We found that for low inflation countries the links between exchange rate changes and their most basic fundamentals, i.e. inflation rates and money supply growth rates, are very weak even over a long period of 30 years. The forces that tie down the exchange rates to these fundamentals seem to be quite weak in low inflation countries. It is therefore not really surprising that exchange rates can be observed to “wander away “ from these fundamentals for prolonged periods of time.

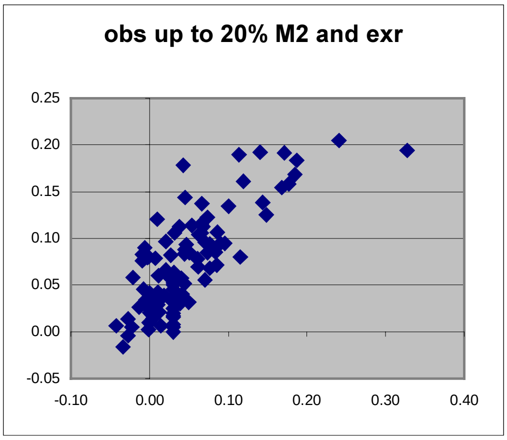
Another implication of our findings concerns the use of the money stock as an intermediate target for monetary policies. Our results suggest that in low inflation countries, the money stock gives poor signals about inflationary pressures even over long periods of time. The money stock is therefore likely to be unhelpful as a guide for controlling inflation in countries experiencing low inflation rates (less than 5 to 10% per year). Since most industrialised countries fall in this category, money supply targeting is unlikely to be of much use in the industrialised world.

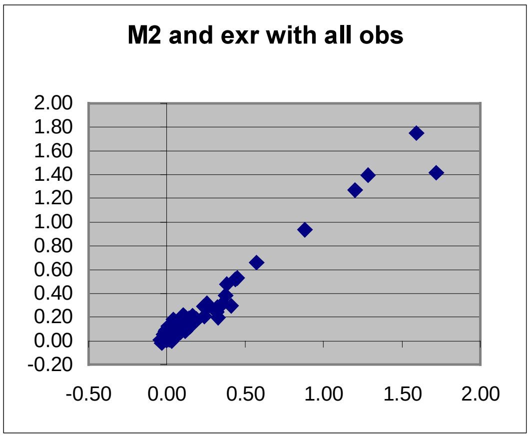
APPENDIX 1

Relationship between exchange rate changes and money (M2) growth for different level of money.

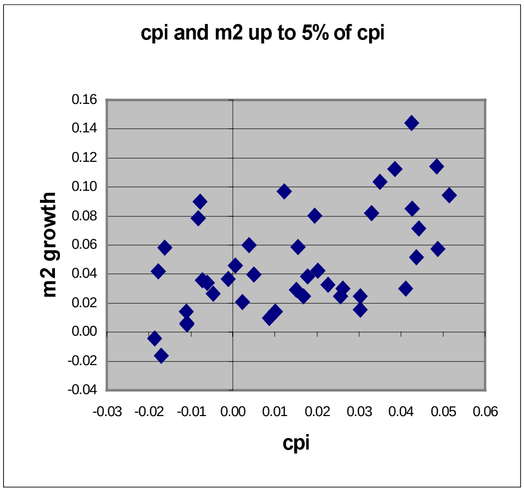


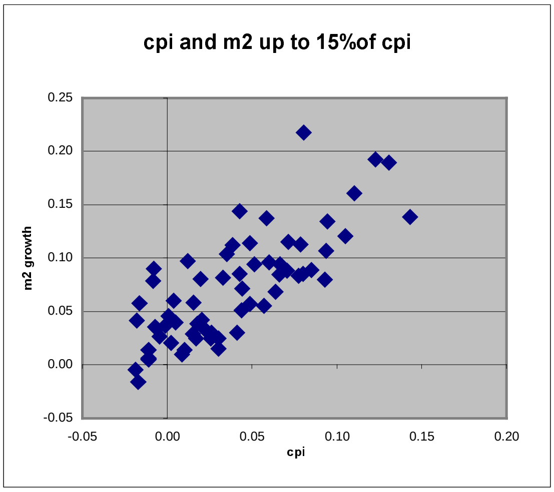


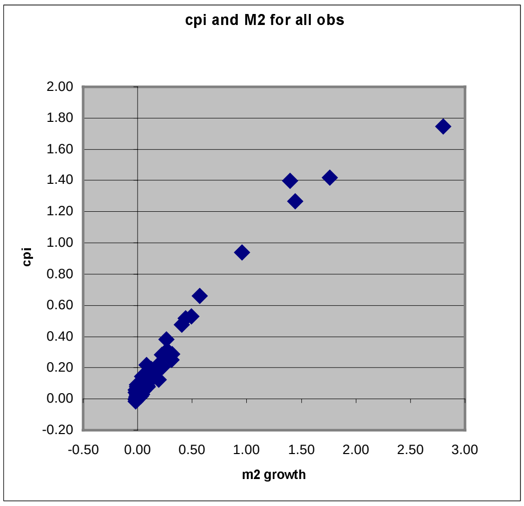




Relationship between inflation and money (M2) growth for different level of inflation

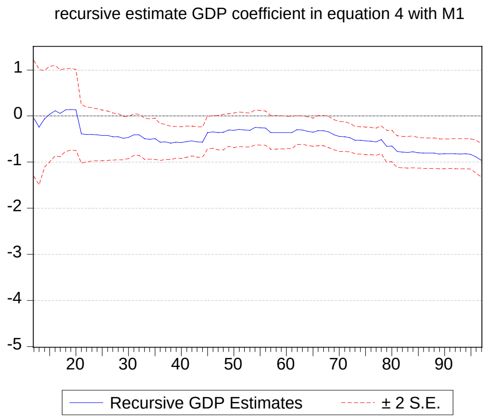


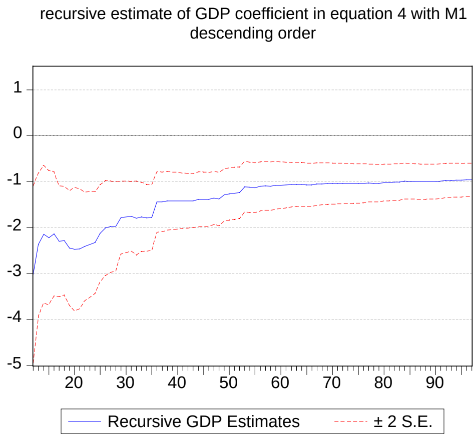




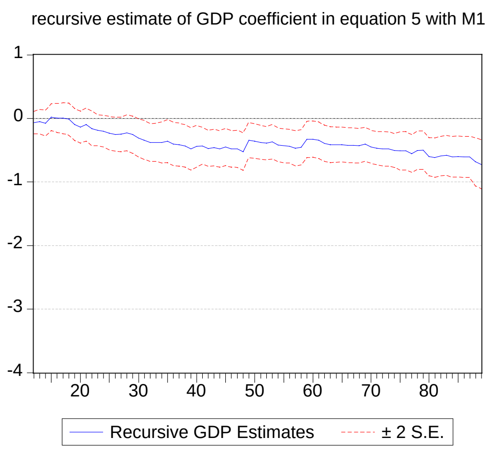
APPENDIX 2

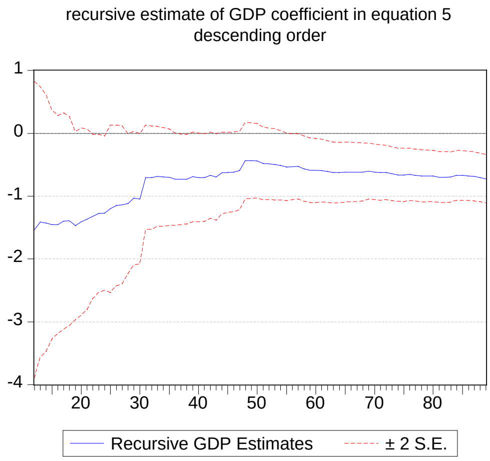
Recursive estimation of GDP coefficient in **equation 5** with M1



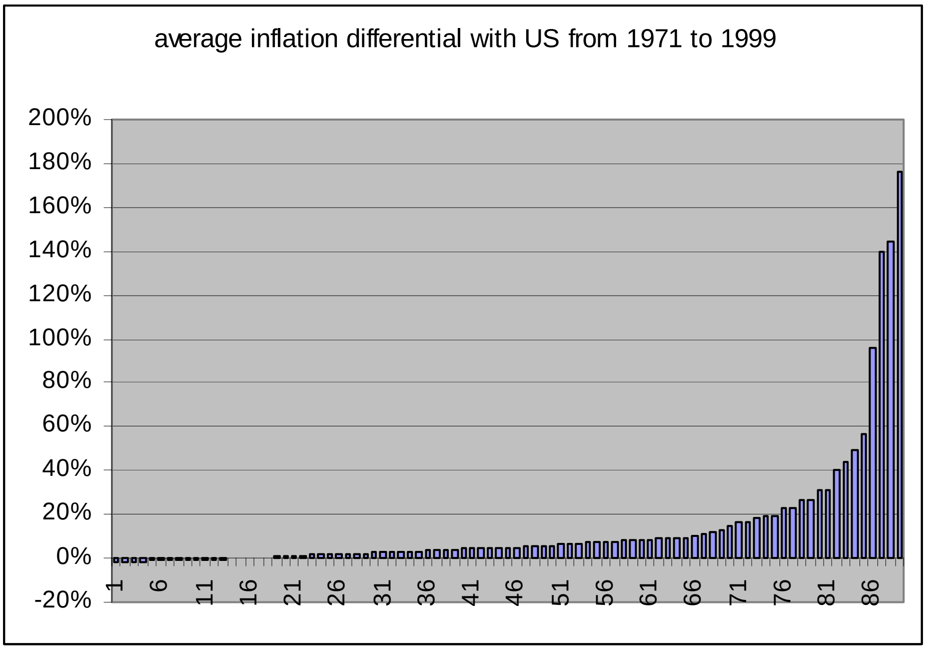


Recursive estimation for the GDP coefficient in QTM equation (**equation 6**) with M1





APPENDIX 3


average inflation differential with US from 1971 to 1999
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
-20%
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86

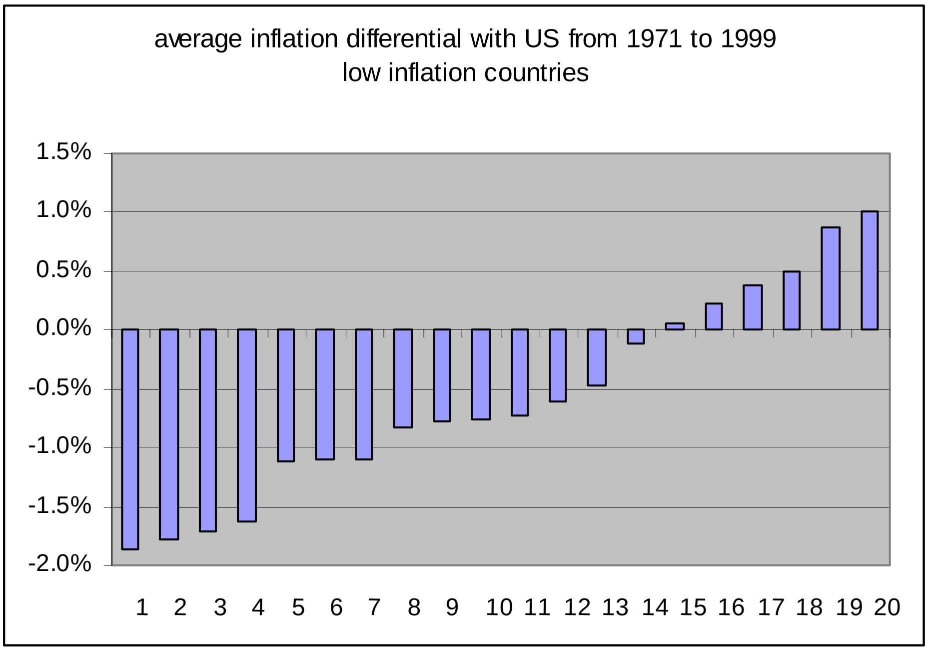

average inflation differential with US from 1971 to 1999
low inflation countries
1.5%
1.0%
0.5%
0.0%
-0.5%
-1.0%
-1.5%
-2.0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Figure 12

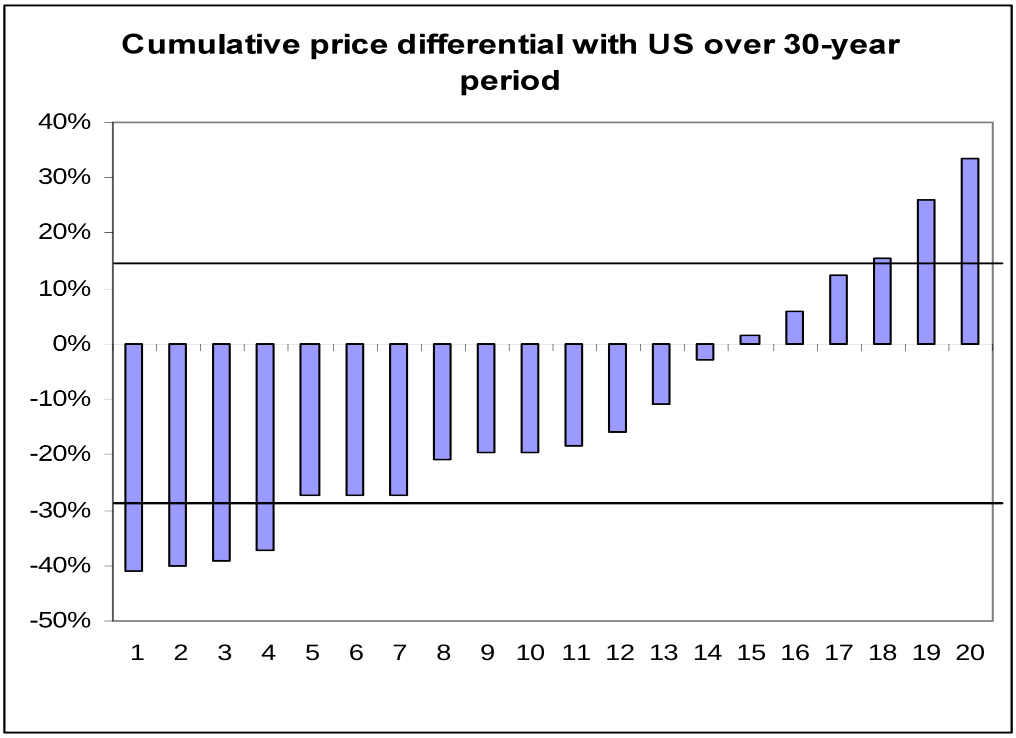


Figure 13

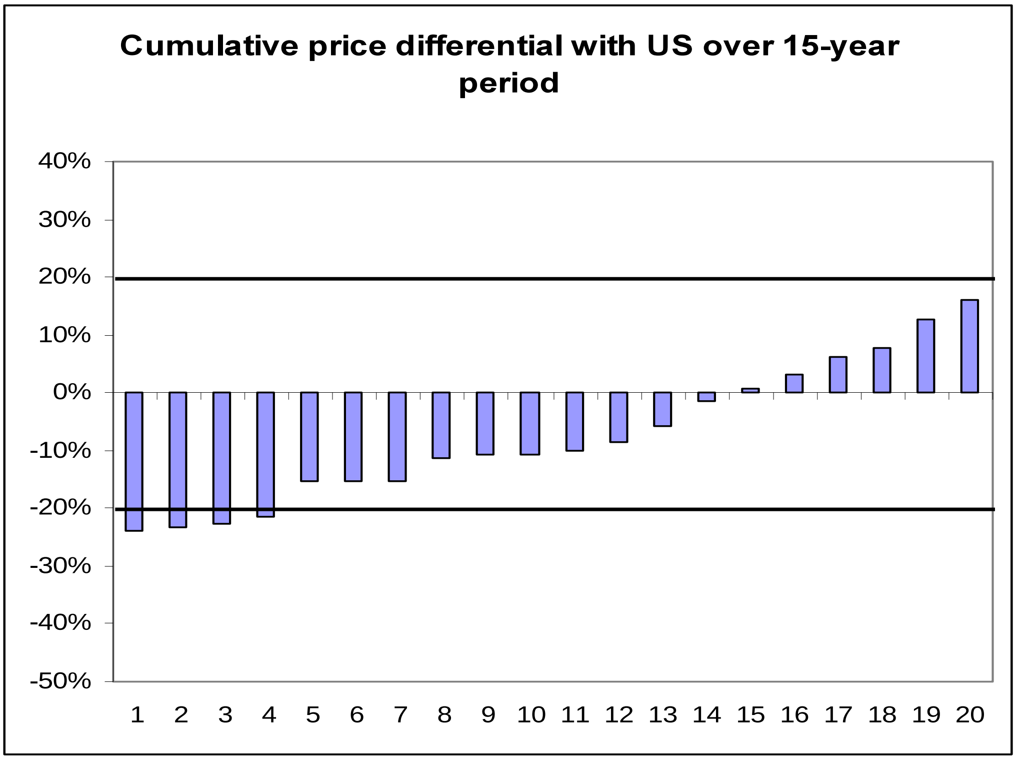


Figure 14

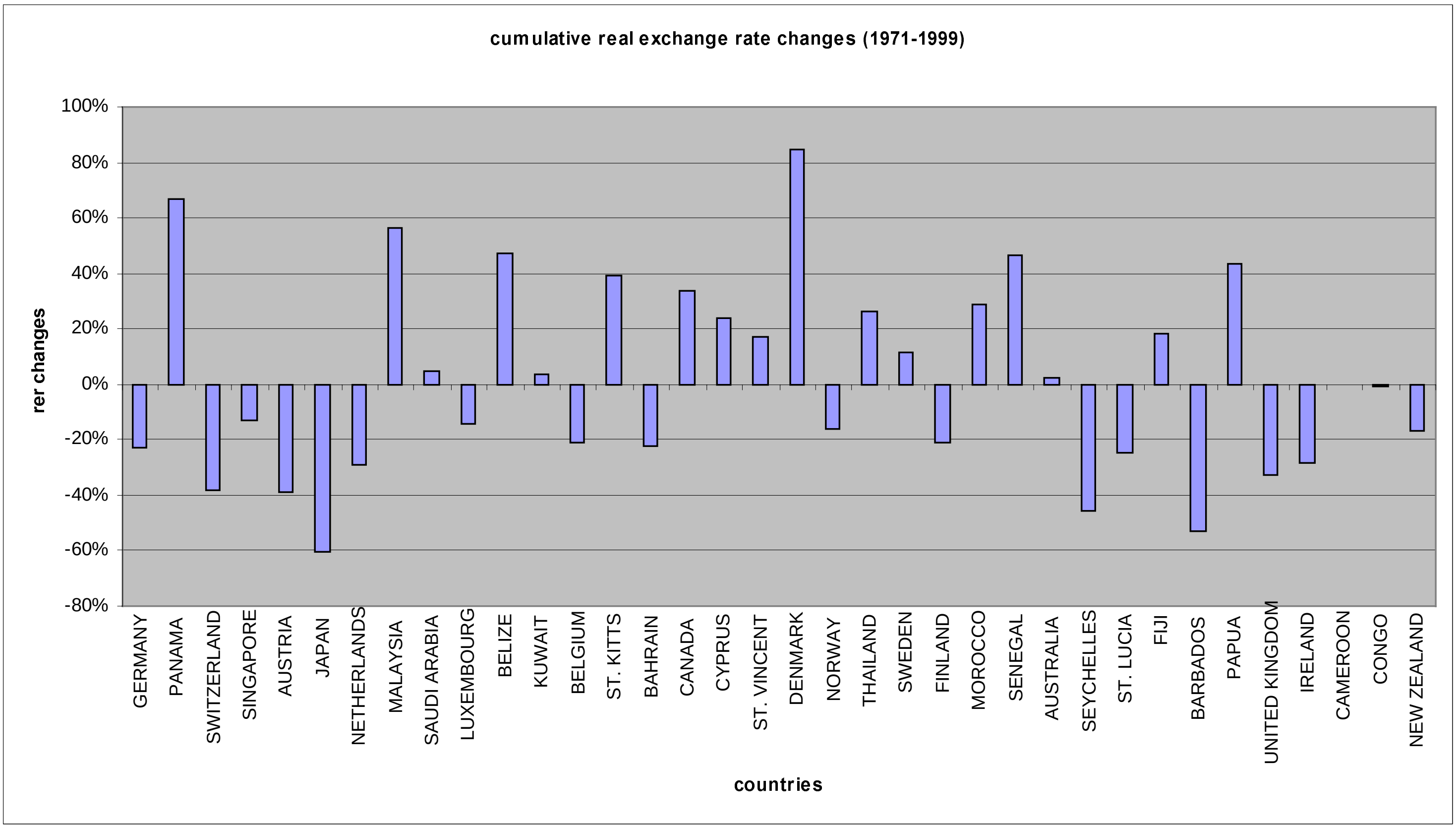
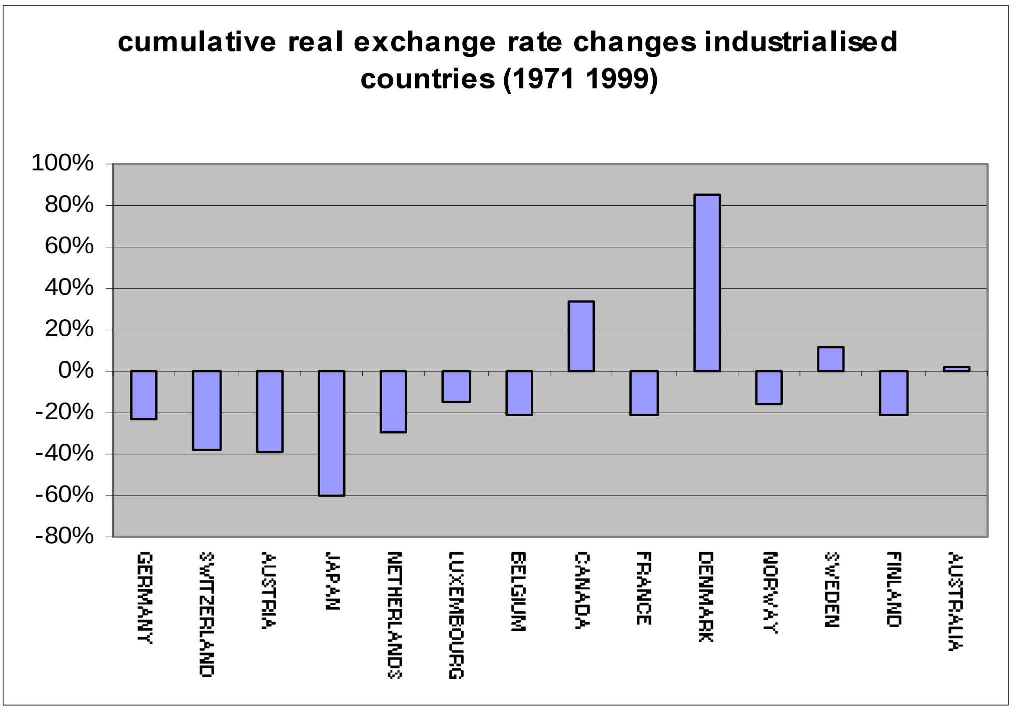
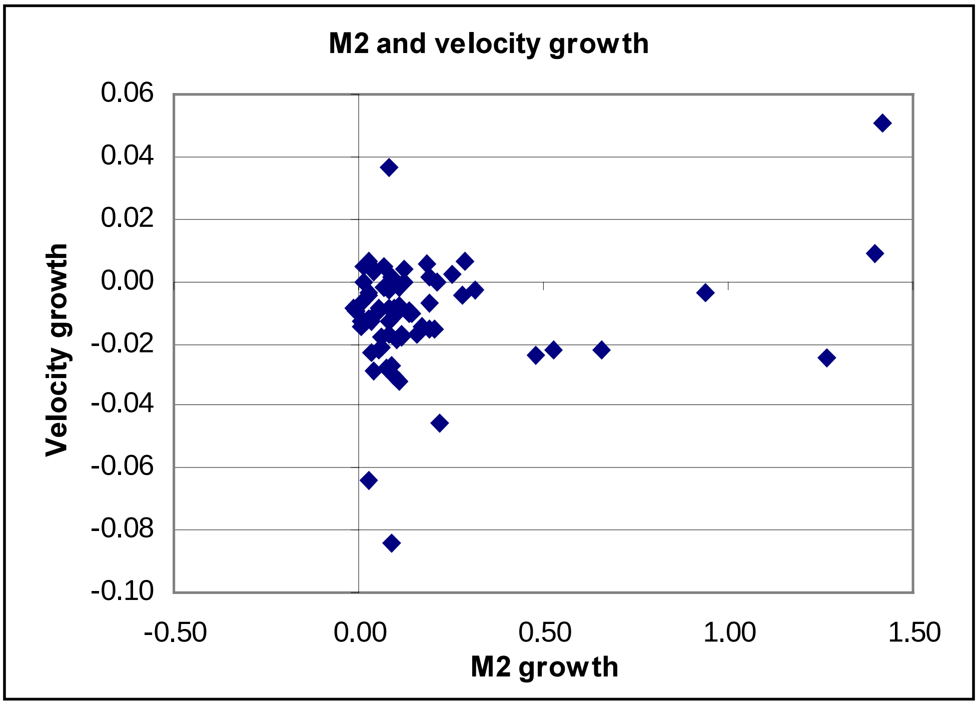


Figure 15



APPENDIX 4

Velocity and money growth in 1970-1999



REFERENCES

Abuaf N. and Jorion P., " Purchasing power parity in the long run*", Journal of Finance,* 45 (1990)

Ardeni P and Lubian D., " Is there a trend reversion in the purchasing power parity?", *European Economic Review* 35, (1991)

Barro R., " Inflation and economic growth", *NBER working paper* 5326 (1995)

Blanchard O. and Fischer S., " *Lectures on Macroeconomics*", MIT press , (1996)

Cheung Y. and Lai K., "On the purchasing power parity puzzle", *Journal of International Economics*, 52 (2000)

Clarida, R., Gali, J. and Gertler, M., "The Science of Monetary Policy: A New Keynesian Perpective", *Journal of Economic Perspectives*, 37, 1661-707, (1999)

De Grauwe P. and Polan M., " Is inflation always and everywhere a monetary phenomenon?" mimeo University of Leuven, (2000)

Engel C., " Long run PPP may not hold after all", *Journal of International Economics,* 57 (2000)

Engel C. and Rogers J. " Relative price volatility: what role does the border play?" *International Finance Discussion Papers* 623 (1998)

Frankel J. " International capital mobility and crowding out in the US economy: imperfect integration of financial markets or goods markets. In: Hafer, RW 5ed) , *How open is the US economy*, Lexington Books, Lexington.

Frankel J. and Rose A. “ A panel project on purchasing power parity: mean reversion within countries and between countries.” *Journal of International Economics* 40 (1996)

Frenkel J.” The collapse of purchasing power parity during the 1970s” *European Economic Review* 7 (1981).

Kim Y. “ Purchasing power parity in the long run: a cointegration approach” *Journal of Money, Credit and Banking* 22 (1990).

Glen J. “ Real exchange rates in the short, medium and long run. “ *Journal of International Economics* 33 (1992)

Niehans, J., “*The Theory of Money*”, Johns Hopkins University Press, (1978)

Nordhaus W; :” New data and concepts for understanding productivity” *NBER working paper* 8097 (2001)

Nordhaus W; :”Alternative methods for measuring productivity growth” *NBER working paper* 8095, (2001)

Obstfeld M. and Rogoff K, “ The six major puzzles in international macroeconomics: is there a common cause?” *NBER working paper* 7777 (2000)

Rogoff, K., “The Purchasing Power Parity Puzzle”, *Journal of Economic Literature*, vol XXXIV, no. 2, June (2000)

Romer D. ,“ Advanced Macroeconomics”, McGraw-Hill, (1996)

Walsh C. ,“ Monetary theory and policy” , MIT press, (1998)

Discussion

Hans Genberg

Graduate Institute of International Studies, Geneva

In their paper “Exchange Rates, Prices and Money: Long Run Perspective” Paul De Grauwe andMarianna Grimaldi revisit empirically two pillars of monetary analysis, the quantity theory of money (QTM) and the purchasing power parity (PPP) hypothesis. Their goal is to investigate the proportionality hypothesis between money, prices and exchange rates implied by these theories. Instead of taking the usual approach of looking at time series data the authors use a pure cross-country data set covering over 100 countries over a 30-year period.

The main empirical results can be summarized in three points:

1. Proportionality between money and the exchange rate is strong for high-inflation countries and weak for low-inflation countries.

2. PPP works better than QTM for low inflation countries, although neither is really good. Furthermore, strict proportionality between inflation and money growth as implied by QTM is soundly rejected in low inflation countries.

3. The influence of real gdp growth on inflation and the exchange rate is not perceptible in low inflation countries, but it is in those with high inflation.

De Grauwe and Grimaldi offer some interesting explanations for their results based both on theoretical extensions of the QTM and PPP theories and on potential empirical problems with their approach. In terms of theory, they argue that strict PPP may fail to hold due to transportation costs, and they show how their results are consistent with this view. I will return to this explanation later in these comments after providing some additional empirical evidence consistent with it.

The bulk of the arguments in what follows relates to potential empirical problems with some of the estimated equations in the paper and to some issues of interpretation. My arguments focus on three issues:

- The consequences of possible reversed causality in some of the regressions.

- The interpretation of the different precision in coefficient estimates for high and low inflation countries.

- Whether there is any difference between high and low inflation countries in terms of how closely they conform to the predictions of the PPP and QTM theories.

My overall conclusions will be that long-run money demand with the usual properties is alive and well, and should be retained in economic models, and that PPP theory should allow for transactions costs, i.e. for a band around strict PPP.

Revisiting the empirical results.

1. Reversed causality

Let[12]

p = the rate of inflation
m = the rate of money growth
y = the rate of growth of real income
v = the rate of growth of velocity

Then the quantity theory of money implies

$$m_i + v_i = p_i + y_i$$

where i ranges over the countries in the sample.

Suppose that real income growth is exogenous, and that velocity can be described by a random variable that is uncorrelated with y and has zero mean and astandard deviation σ_y. Suppose further that we are dealing with a country with a floating exchange rate where the central bank sets the growth of the money supply in an autonomous fashion, i.e. independently of movements in inflation and velocity. In this case the regression equation

$$p_i = \beta_0 + \beta_1 m_i + \beta_2 y_i + u_i \qquad (1)$$

is well specified in the sense that OLS estimates of the β coefficients are unbiased and have minimum variance among linear estimators.

Suppose instead we are describing a small economy with a fixed exchange rate that imports inflation (which is therefore exogenous) and where the money supply adjusts endogenously to the demand for money. In this case the appropriately formulated regression equation would have money growth as the dependent variable as in (2).

$$m_i = \gamma_0 + \gamma_1 p_i + \gamma_2 y_i + u_i \qquad (2)$$

Consider now a situation where countries of both types are present in the sample. In this case neither equation is correctly specified for the sample as a whole, and the bias

---

[12] Following the paper, all rates of growth are expressed as averages over the entire sample and as deviations from the corresponding values for the United States. Note that the use of the US as the comparison country is immaterial for any of the substantial empirical results. As noted below, it will influence the interpretation of the results in one instance.

in OLS estimates will depend on the relative number of fixed versus floating exchange rate countries there are in the sample. If, for example, countries that had a similar inflation performance were predominantly fixed exchange rate countries, then equation (2) would be the most appropriate specification for them.

Other sources of bias due to correlation between money growth and the error term in equation (1) can be present. The authors mention the possibility of errors of measurement in money growth. If measured money growth is equal to the 'true' rate plus an error term, then equation (1) will lead to a positive correlation between m and the error term. It is also positive that the Central Bank has systematically adjusted money growth in response to inflation. In this case there is a simultaneity problem present in the estimation.

In order to investigate the empirical relevance of these arguments I estimated the parameters in equation (2) using OLS and data for 82 of the countries the sample described in the paper.[13] Figure 1 shows the point estimate of the coefficient γ_1 attached to the inflation rate. The theoretical value is of course unity. It is interesting to note that the point estimate I obtain with the specification where money growth is the dependent variable is not significantly different from unity for virtually any sample. This is in contrast with the estimate one gets by using the specification (1) where the inflation rate is the dependent variable. In this case, Figure 2, the estimate of β_1 (which also has a theoretical value of one) is statistically different from one for all samples except those that include the countries with the very highest inflation rates.

These results suggest that reversed causality and correlation between money growth and the error term in the inflation regression may be a serious problem especially for low-inflation countries. The reason why the samples dominated by these countries are most affected could be that they contain a large number of countries with a managed exchange rate, and therefore an endogenous money supply, during the sample period.

If we accept the reversed regression, equation (2), as the appropriate one, we are led to conclude that we cannot reject strict proportionality between inflation and money growth. Looking at the estimates of the coefficient γ_2 (see Figure 3), it is not unreasonable to interpret the equation as a money demand equation with a unit coefficient on the price level and an income elasticity of demand for money in the neighborhood of unity. To be sure, the precision of the estimate of γ_1 is low for the smaller samples dominated by low inflation countries. This should not lure us into concluding that the quantity theory of money does not apply as a long-run proposition in low inflation countries, however. This is the issue that I take up next.

[13] I am grateful to Paul De Grauwe for providing me with the data.

Figure 1: Coefficient on inflation in money growth equation

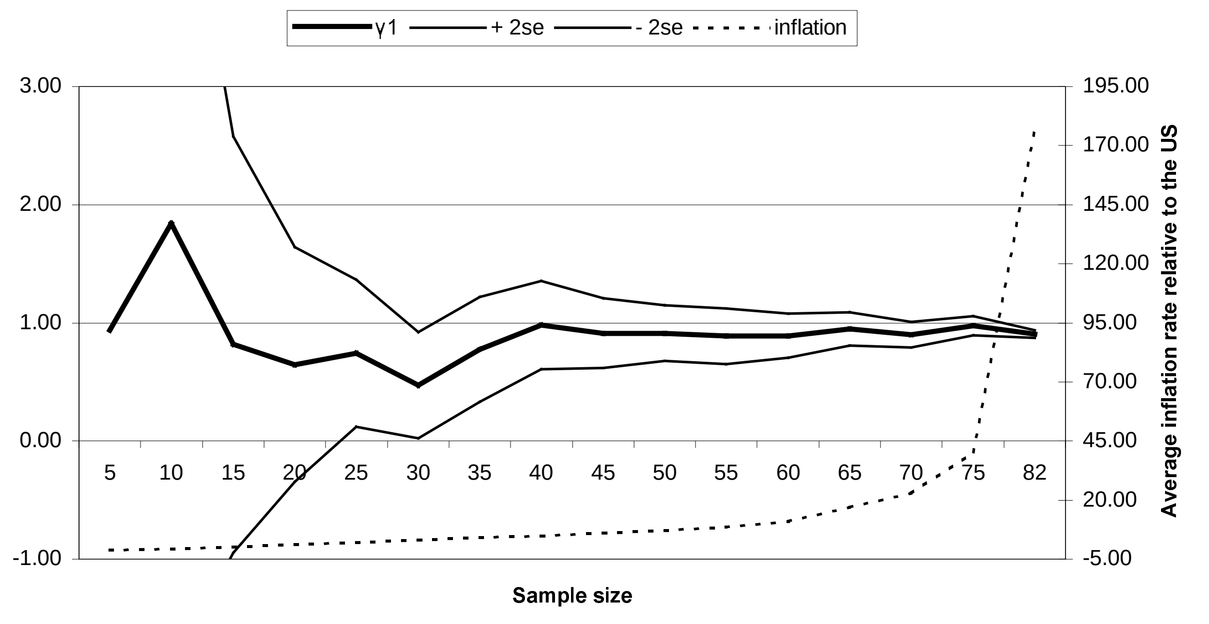
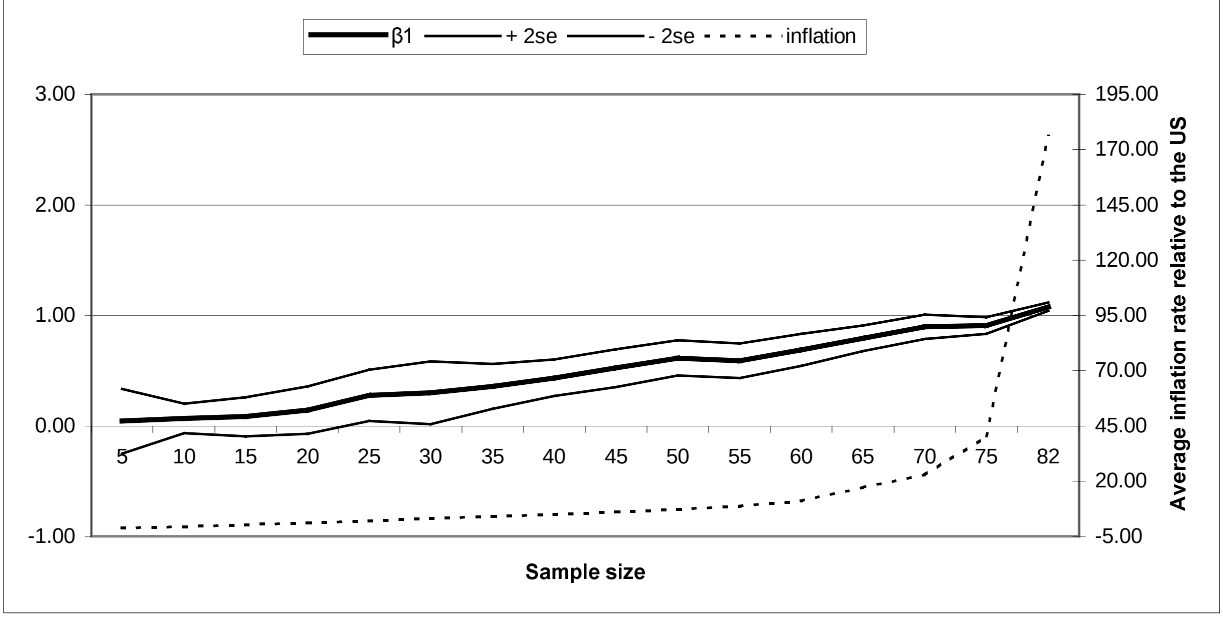
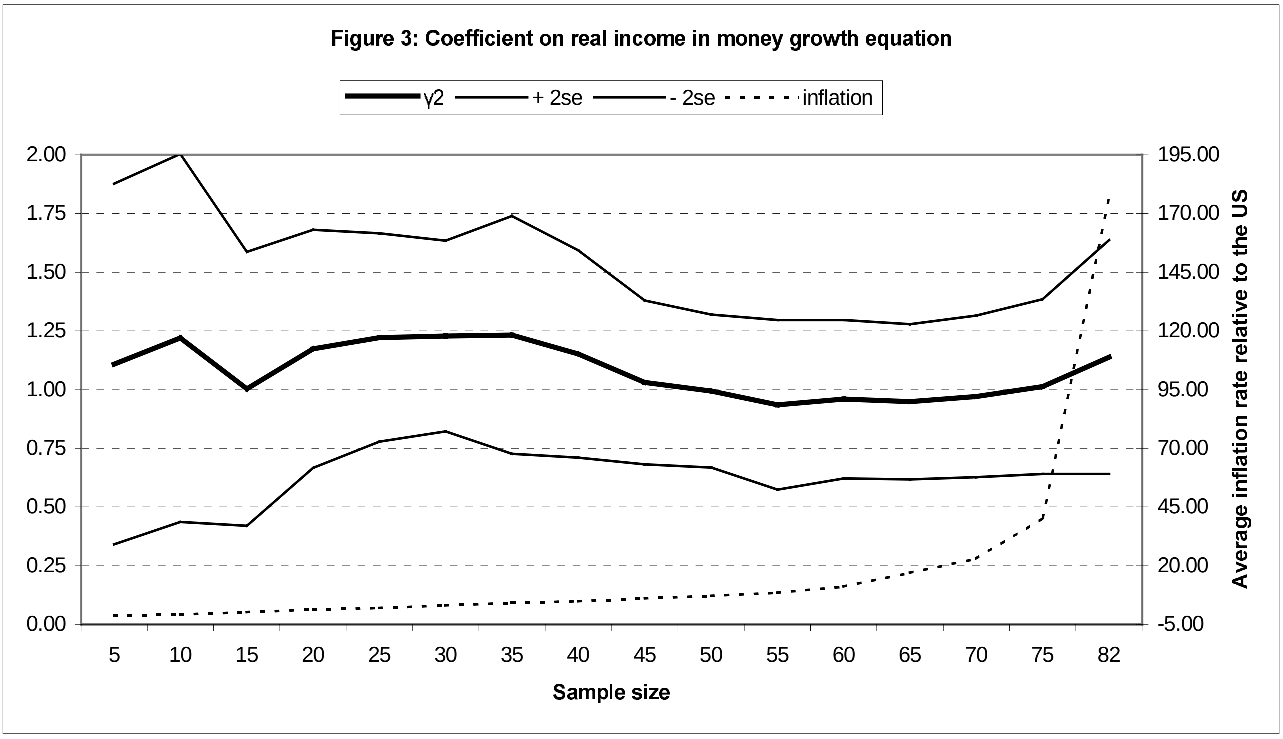


Figure 2: Coefficient on money growth in inflation equation





2. Interpreting the differences in the results for high and low inflation countries.

One of the innovative features of the paper by De Grauwe and Grimaldi stems from defining samples according to the average inflation rate of the included countries. As illustrated in Figures 1-3, the countries are ordered in such a way that increasing the sample size means including countries with successively higher inflation rates relative to the base country (the United States). When we look at the standard-error band in Figure 1 we notice that the coefficient on inflation in the money growth equation is very large for the small samples corresponding to low-inflation countries. De Grauwe and Grimaldi interpret this type of result as indicating that the quantity theory holds less well for low-inflation countries. While this is a possible interpretation, another reason for the result would be that it is the increasing **range** of inflation rates represented in the sample that makes increases the 't-values' of the estimates as the sample size increases. Theoretically that possibility could be explained as follows.

Let two variables, y and x, be related by the simple linear equation

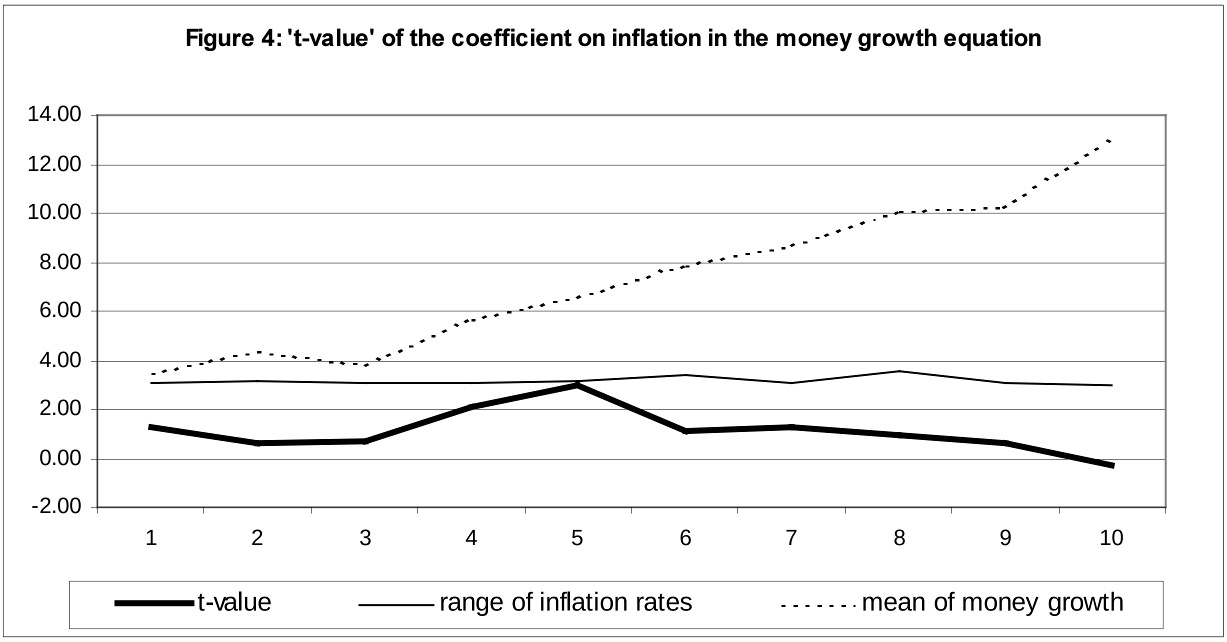
$$y_i = \alpha x_i + u_i$$

where u represents a random error term uncorrelated with x. Suppose we run a regression or y on x. The 't-value' of the estimate of α can be written as

$$t_\alpha = \alpha\ (\Sigma\ (x_i)^2)^{½}/\sigma_u$$

where σ_u is the standard error of u. In other words, for a given value of σ_u, the smaller the range of the values of x in the sample (represented by $\Sigma\ (x_i)^2$), the smaller the 't-value'. This is intuitively reasonable, because as the range of x becomes smaller and smaller, the smaller will be the information in the sample about how y varies with x.

To investigate whether this kind of effect is present in the money-inflation relationship we are concerned with here, I re-estimated equation (2) for samples that were chosen so as to represent an approximately fixed range but with different average inflation rates. The results are presented in Figure 4.



It is quite noticeable that the 't-value' does not increase with the mean rate of money growth in the sample as long as the range of the inflation rates (x-values) remains the same. I tentatively conclude from this that for when differences between countries in money growth rates are small, then the quantity equation (or alternatively the money demand function) will not be a good indicator of differences in inflation rates between them.

What range of inflation rates is necessary in order for the relationship between money growth and inflation to be sufficiently precise to be useful for policy purposes? To answer this question I proceeded as follows. First I estimated equation (2) with increasing sample sizes chosen such that the range of inflation rates increases in increments of 2 percentage points. I recorded the size of the estimated standard errors as a percentage of the coefficient and used them as if they were applicable in a time series context for a single country. I assumed that inflation and money growth is related as follows

$$p_t = \gamma\, m_t + u_t$$

The coefficient γ could take two values

$\gamma^{high} = 1+\sigma_\gamma$
and
$\gamma^{low} = 1-\sigma_\gamma$

where σ_γ is the standard error of the coefficient estimates mentioned above. I used the high and low values of γ together with the estimate of the standard error of u to form a high and a low estimate for inflation for different horizons assuming that money growth was constant at 2% per year:

$$p^{high} = \gamma^{high} m + \sigma_u$$

$$p^{low} = \gamma^{low} m - \sigma_u$$

The results are shown in Table 1.

Table 1: Inflation estimates using uncertainty estimated from the cross-section

Horizon (years)	γ^{high}	γ^{low}	σ_u	Average annual rate of money growth (% per year)	Average annual inflation rate (% per year) high estimate	Average annual inflation rate (% per year) low estimate
1	4.14	-0.14	2.16	2.00	6.30	-2.30
2	2.94	1.06	1.85	2.00	3.82	0.15
3	2.60	1.40	2.30	2.00	3.31	0.66
4	2.32	1.68	2.29	2.00	2.84	1.14
5	2.26	1.74	2.66	2.00	2.73	1.25
6	2.22	1.78	2.56	2.00	2.59	1.39
7	2.18	1.82	2.58	2.00	2.49	1.50
8	2.17	1.83	2.60	2.00	2.43	1.56
9	2.15	1.85	2.59	2.00	2.38	1.61
10	2.14	1.86	2.55	2.00	2.34	1.65

The last two columns in the table imply that over a one and two year horizon, the quantity equation gives a very wide band of possible inflation rates once the uncertainty of the slope coefficient and the regression equation itself are taken into account. Even at a horizon of three years the range of inflation is relatively large, between 0.66% and 3.31% per year. Beyond that, however, the range narrows considerably, so much so that one could assert that keeping control over the rate of growth of the money supply could maintain inflation in a relatively narrow region around a target rate.

3. Deviations from PPP and QTM in high and low inflation countries.

As I have noted above, the regression equation for the quantity theory fits better when high inflation countries are included in the sample, both in terms of the precision of the coefficient estimates and the overall fit of the regression. De Grauwe and Grimaldi also point out that the same type of result holds for purchasing power parity regressions, the R^2 is generally higher for high inflation countries, and the coefficients are estimated with smaller standard errors. It is tempting to take these results to imply that deviations from QTM and PPP are smaller for high inflation countries. In fact, the opposite is true, as the following calculations indicate.

Let e_i represent the rate of change of the US dollar exchange rate of country i. Then, using the notation already introduced, we can define the deviation from PPP and QTM respectively as

$$dev_i^{PPP} = e_i - p_i - \delta\, y_i$$

$$dev_i^{QTM} = m_i - p_i - \gamma_2\, y_i$$

The terms $\delta\, y_i$ and $\gamma_2\, y_i$ are included in order to allow for an influence of real income on the real exchange rate and velocity (demand for money) respectively. To estimate the deviations from PPP and QTM I first estimated the coefficient δ and γ_2 using OLS. The resulting values are plotted in Figures 5 and 6. Visual inspection indicates that both deviations are generally larger for high inflation countries.[14] For the purchasing power parity relationship this confirms results obtained for hyperinflation countries, and for the quantity theory one can conjecture that very high inflation leads to currency substitution phenomena and changes in velocity and deviation from QTM as defined here.

Concluding remarks.

The paper by De Grauwe and Grimaldi is very useful and innovative in its use of cross-country evidence to test monetary neutrality both in terms of the quantity theory of money and purchasing power parity. The econometric issues that I have highlighted in this note do not detract from their interesting findings and analysis. My results certainly do not contradict the proposition that PPP theory should allow for transactions cost and a band around strict PPP within which exchange rates and prices can move relatively independently of each other. My estimates of the QTM relationship do however lead me to a more favorable outcome than the authors. Although estimates are imprecise when countries with a similar inflation experience are compared, I maintain that they are consistent with the hypothesis that the quantity theory of money is a useful ingredient in a macroeconomic model intended to explain long-run relationships. It follows that controlling the rate of growth of the money can be a useful way to maintain price inflation within bounds. My calculations indicate that for a horizon of three to four years and longer, the rate of money growth is likely to give a relatively good indication of the rate of inflation.

[14] The visual impression can be confirmed by regressing the deviations on the absolute value of the inflation differential.

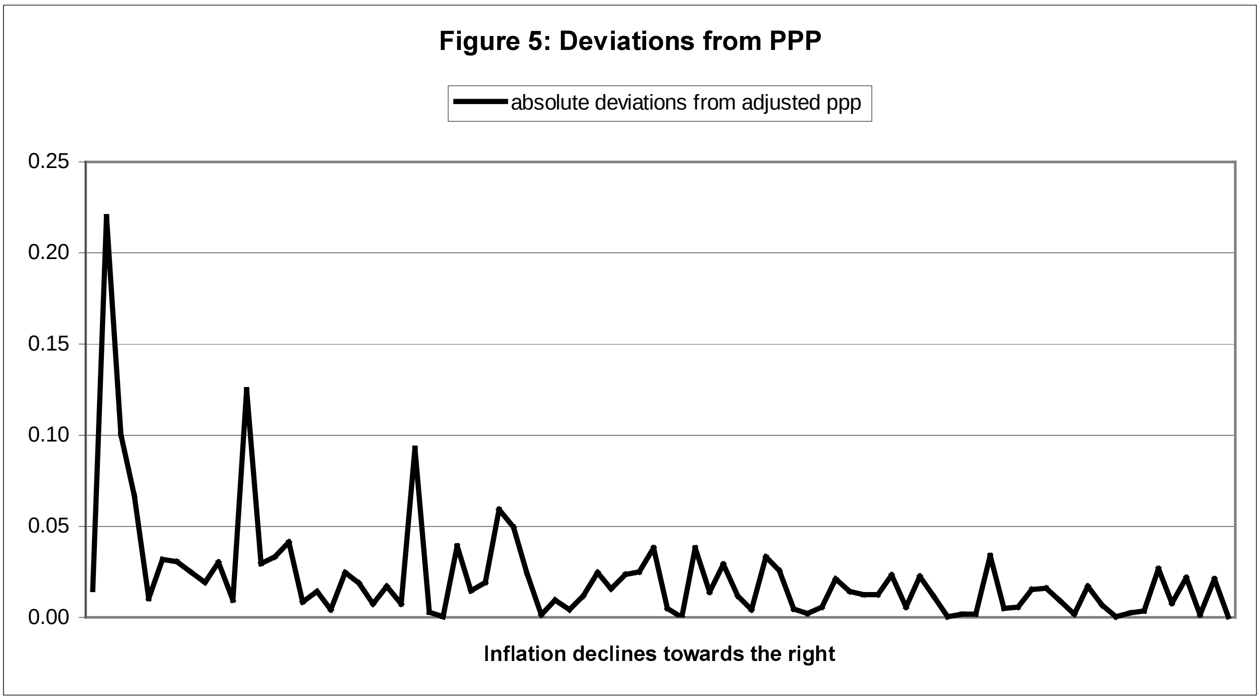


Figure 5: Deviations from PPP
absolute deviations from adjusted ppp
0.25
0.20
0.15
0.10
0.05
0.00
Inflation declines towards the right

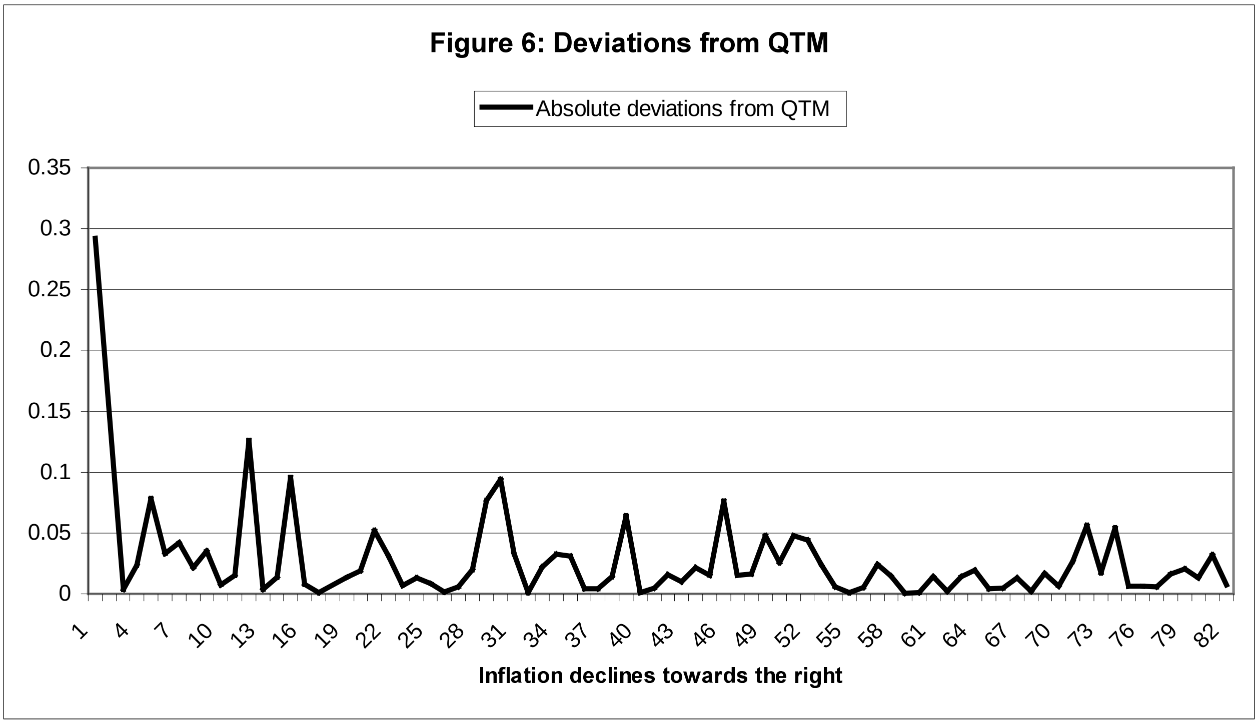


Figure 6: Deviations from QTM
Absolute deviations from QTM
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
Inflation declines towards the right

Index of Working Papers:

August 28, 1990	Pauer Franz	1[1)]	Hat Böhm-Bawerk Recht gehabt? Zum Zusammenhang zwischen Handelsbilanzpassivum und Budgetdefizit in den USA[2)]
March 20, 1991	Backé Peter	2[1)]	Ost- und Mitteleuropa auf dem Weg zur Marktwirtschaft - Anpassungskrise 1990
March 14, 1991	Pauer Franz	3[1)]	Die Wirtschaft Österreichs im Vergleich zu den EG-Staaten - eine makroökonomische Analyse für die 80er Jahre
May 28, 1991	Mauler Kurt	4[1)]	The Soviet Banking Reform
July 16, 1991	Pauer Franz	5[1)]	Die Auswirkungen der Finanzmarkt- und Kapitalverkehrsliberalisierung auf die Wirtschaftsentwicklung und Wirtschaftspolitik in Norwegen, Schweden, Finnland und Großbritannien - mögliche Konsequenzen für Österreich[3)]
August 1, 1991	Backé Peter	6[1)]	Zwei Jahre G-24-Prozess: Bestandsaufnahme und Perspektiven unter besonderer Berücksichtigung makroökonomischer Unterstützungsleistungen[4)]
August 8, 1991	Holzmann Robert	7[1)]	Die Finanzoperationen der öffentlichen Haushalte der Reformländer CSFR, Polen und Ungarn: Eine erste quantitative Analyse
January 27, 1992	Pauer Franz	8[1)]	Erfüllung der Konvergenzkriterien durch die EG-Staaten und die EG-Mitgliedswerber Schweden und Österreich[5)]

1) vergriffen (out of print)
2) In abgeänderter Form erschienen in Berichte und Studien Nr. 4/1990, S 74 ff
3) In abgeänderter Form erschienen in Berichte und Studien Nr. 4/1991, S 44 ff
4) In abgeänderter Form erschienen in Berichte und Studien Nr. 3/1991, S 39 ff
5) In abgeänderter Form erschienen in Berichte und Studien Nr. 1/1992, S 54 ff

October 12, 1992	Hochreiter Eduard (Editor)	9[1)]	Alternative Strategies For Overcoming the Current Output Decline of Economies in Transition
November 10, 1992	Hochreiter Eduard and Winckler Georg	10[1)]	Signaling a Hard Currency Strategy: The Case of Austria
March 12, 1993	Hochreiter Eduard (Editor)	11	The Impact of the Opening-up of the East on the Austrian Economy - A First Quantitative Assessment
June 8, 1993	Anulova Guzel	12	The Scope for Regional Autonomy in Russia
July 14, 1993	Mundell Robert	13	EMU and the International Monetary System: A Transatlantic Perspective
November 29, 1993	Hochreiter Eduard	14	Austria's Role as a Bridgehead Between East and West
March 8, 1994	Hochreiter Eduard (Editor)	15	Prospects for Growth in Eastern Europe
June 8, 1994	Mader Richard	16	A Survey of the Austrian Capital Market
September 1, 1994	Andersen Palle and Dittus Peter	17	Trade and Employment: Can We Afford Better Market Access for Eastern Europe?
November 21, 1994	Rautava Jouko	18[1)]	Interdependence of Politics and Economic Development: Financial Stabilization in Russia
January 30, 1995	Hochreiter Eduard (Editor)	19	Austrian Exchange Rate Policy and European Monetary Integration - Selected Issues
October 3, 1995	Groeneveld Hans	20	Monetary Spill-over Effects in the ERM: The Case of Austria, a Former Shadow Member
December 6, 1995	Frydman Roman et al	21	Investing in Insider-dominated Firms: A Study of Voucher Privatization Funds in Russia

March 5, 1996	Wissels Rutger	22	Recovery in Eastern Europe: Pessimism Confounded ?
June 25, 1996	Pauer Franz	23	Will Asymmetric Shocks Pose a Serious Problem in EMU?
September 19, 1997	Koch Elmar B.	24	Exchange Rates and Monetary Policy in Central Europe - a Survey of Some Issues
April 15, 1998	Weber Axel A.	25	Sources of Currency Crises: An Empirical Analysis
May 28,1998	Brandner Peter, Diebalek Leopold and Schuberth Helene	26	Structural Budget Deficits and Sustainability of Fiscal Positions in the European Union
June 15, 1998	Canzeroni Matthew, Cumby Robert, Diba Behzad and Eudey Gwen	27	Trends in European Productivity: Implications for Real Exchange Rates, Real Interest Rates and Inflation Differentials
June 20, 1998	MacDonald Ronald	28	What Do We Really Know About Real Exchange Rates?
June 30, 1998	Campa José and Wolf Holger	29	Goods Arbitrage and Real Exchange Rate Stationarity
July 3,1998	Papell David H.	30	The Great Appreciation, the Great Depreciation, and the Purchasing Power Parity Hypothesis
July 20,1998	Chinn Menzie David	31	The Usual Suspects? Productivity and Demand Shocks and Asia-Pacific Real Exchange Rates
July 30,1998	Cecchetti Stephen G., Mark Nelson C., Sonora Robert	32	Price Level Convergence Among United States Cities: Lessons for the European Central Bank
September 30,1998	Christine Gartner, Gert Wehinger	33	Core Inflation in Selected European Union Countries

November 5,1998	José Viñals and Juan F. Jimeno	34	The Impact of EMU on European Unemployment
December 11,1998	Helene Schuberth and Gert Wehinger	35	Room for Manoeuvre of Economic Policy in the EU Countries – Are there Costs of Joining EMU?
December 21,1998	Dennis C. Mueller and Burkhard Raunig	36	Heterogeneities within Industries and Structure-Performance Models
May 21, 1999	Alois Geyer and Richard Mader	37	Estimation of the Term Structure of Interest Rates – A Parametric Approach
July 29, 1999	José Viñals and Javier Vallés	38	On the Real Effects of Monetary Policy: A Central Banker´s View
December 20, 1999	John R. Freeman, Jude C. Hays and Helmut Stix	39	Democracy and Markets: The Case of Exchange Rates
March 1, 2000	Eduard Hochreiter and Tadeusz Kowalski	40	Central Banks in European Emerging Market Economies in the 1990s
March 20, 2000	Katrin Wesche	41	Is there a Credit Channel in Austria? The Impact of Monetary Policy on Firms' Investment Decisions
June 20, 2000	Jarko Fidrmuc and Jan Fidrmuc	42	Integration, Disintegration and Trade in Europe: Evolution of Trade Relations During the 1990s
March 06, 2001	Marc Flandreau	43	The Bank, the States, and the Market, A Austro-Hungarian Tale for Euroland, 1867-1914
May 01, 2001	Otmar Issing	44	The Euro Area and the Single Monetary Policy
May 18, 2001	Sylvia Kaufmann	45	Is there an asymmetric effect of monetary policy over time? A Bayesian analysis using Austrian data.

May 31, 2001	Paul De Grauwe and Marianna Grimaldi	46	Exchange Rates, Prices and Money. A Long Run Perspective