

*Preliminary draft*

**Exchange Rates, Prices and Money.**

**A Long Run Perspective**

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## 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<sup>1</sup>. 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

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

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

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<sup>1</sup> 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<sup>2</sup>:

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:

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

$e$  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

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

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<sup>3</sup>. 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;

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<sup>2</sup> 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).

<sup>3</sup> 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:

$$e_i = b_1 + b_2m_i + b_3y_i + v_i \quad (5)$$

$$p_i = a_1 + a_2m_i + a_3y_i + \omega_i \quad (6)$$

where  $e_i$  is the rate of depreciation of currency  $i$  against the US dollar;  $p_i$   $m_i$   $y_i$  are the differences in the rates of growth of prices (CPI), money, and output (GDP) between country  $i$  and the US,  $v_i$  and  $\omega_i$  are the error terms. Note that velocity is now in the error term. We do not include velocity to avoid estimating an identity. 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.

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 among the regressors and between the regressors and the error term (which includes velocity). 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 and velocity growth. These are shown table 1. We observe that these correlation coefficients are relatively low, thereby limiting the risk of collinearity and correlation between regressors and the error term.

**Table 1: Correlation matrix**

	<b>M2</b>	<b>GDP</b>	<b>VELM2</b>
<b>M2</b>	1.000000	-0.294541	0.235851
<b>GDP</b>	-0.294541	1.000000	-0.210572
<b>VELM2</b>	0.235851	-0.210572	1.000000

The results of estimating equations (5) and (6) with OLS are presented in the following table (Table 2). 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 two variables, money growth and output growth. The coefficients of money (M1 and 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 3 we show the t-statistics for the null hypothesis that these coefficients are equal to one (as predicted by the theory). In three out of four cases we reject the null hypothesis of a coefficient equal to one. It should be mentioned, however, that even if we reject strict proportionality, we remain very close to it.

**Table 2: OLS regression results of equations (5) and (6)**

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

**Table 3 : t-statistics for the null hypothesis M1 and M2 coefficient equal to one**

	<b>M1</b>		<b>M2</b>	
<b>Variable</b>	<b>Coefficient</b>	<b>t-Statistic</b>	<b>Coefficient</b>	<b>t-Statistic</b>
<b>Money</b> (equation 5)	1.089 (0.015)	5.804	0.998 (0.019)	-0.105
<b>Money</b> (equation 6)	1.173 (0.015)	11.900	1.076 (0.018)	4.22

Note: standard errors in parenthesis

From table 2 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. 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 output growth in explaining inter-country differences in inflation over this thirty year period. This is done by estimating 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. We find that the omission of output growth has no perceptible effects on the explanatory power of the equation. The  $R^2$  are practically unaffected, and the coefficients of money are barely changed. In particular the coefficients of money are very close to 1.

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

Variable	M1		M2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
<i>Equation 5</i>				
<b>Constant</b>	-0.033 (0.005)	-6.66	-0.028 (0.007)	-3.926
<b>Money</b>	1.082 (0.015)	73.71	0.996 (0.019)	51.402
Adjusted R-squared	0.98		Adjusted R-squared 0.97	
<i>Equation 6</i>				
<b>Constant</b>	-0.044 (0.004)	-9.78	-0.041 (0.007)	-6.025
<b>Money</b>	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

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

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

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:

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

$$v_i = d_3 + d_4 m_i + \eta_i \quad (9)$$

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 (M2) and  $\varepsilon_i$  and  $\eta_i$  are the error terms. Table 8 shows the results of estimating equations (8) and (9) with OLS<sup>4</sup>.

<sup>4</sup> As mentioned earlier, we have only independent estimates of velocity using M2. Therefore we only report results with M2.

**Table 8: OLS regression results of money neutrality**

	<i>Equation 8</i>		<i>Equation 9</i>	
<b>Variable</b>	<b>Coefficient</b>	<b>t-Statistic</b>	<b>Coefficient</b>	<b>t-Statistic</b>
<b>Constant</b>	0.006 (0.002)	2.36	-0.013 (0.002)	-5.40
<b>Money(M2)</b>	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 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<sup>5</sup> 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.

<sup>5</sup> 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.

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 where 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 phenomenon is observed when we plot the average yearly rates of inflation against the average yearly rates of money growth (figure 2 Appendix 1).

#### **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 in equations 5 and 6. We use a recursive estimation procedure where we ordered the data first by increasing rate of money growth and second by decreasing rate of money growth<sup>6</sup>. The results are shown in figure 1 for M1. The results for M2 are shown in appendix (appendix 2) and they are very similar.

The recursive analysis in ascending order of money growth reveals that for low inflation countries the precision of the estimate is so low that we cannot exclude a coefficient equal to zero. At the same time we cannot reject that it is equal to one either. As we add the HI countries, however, the coefficient of money grows closer to one and it reaches one when we add the very high inflation countries.

Figure 1 also shows the recursive estimate of the money coefficient when we order the observations in descending order of money growth. Strikingly we find that the estimates of the money coefficient of the HI countries dominate and adding the LI countries does not change the result. We also obtain a very high precision, which

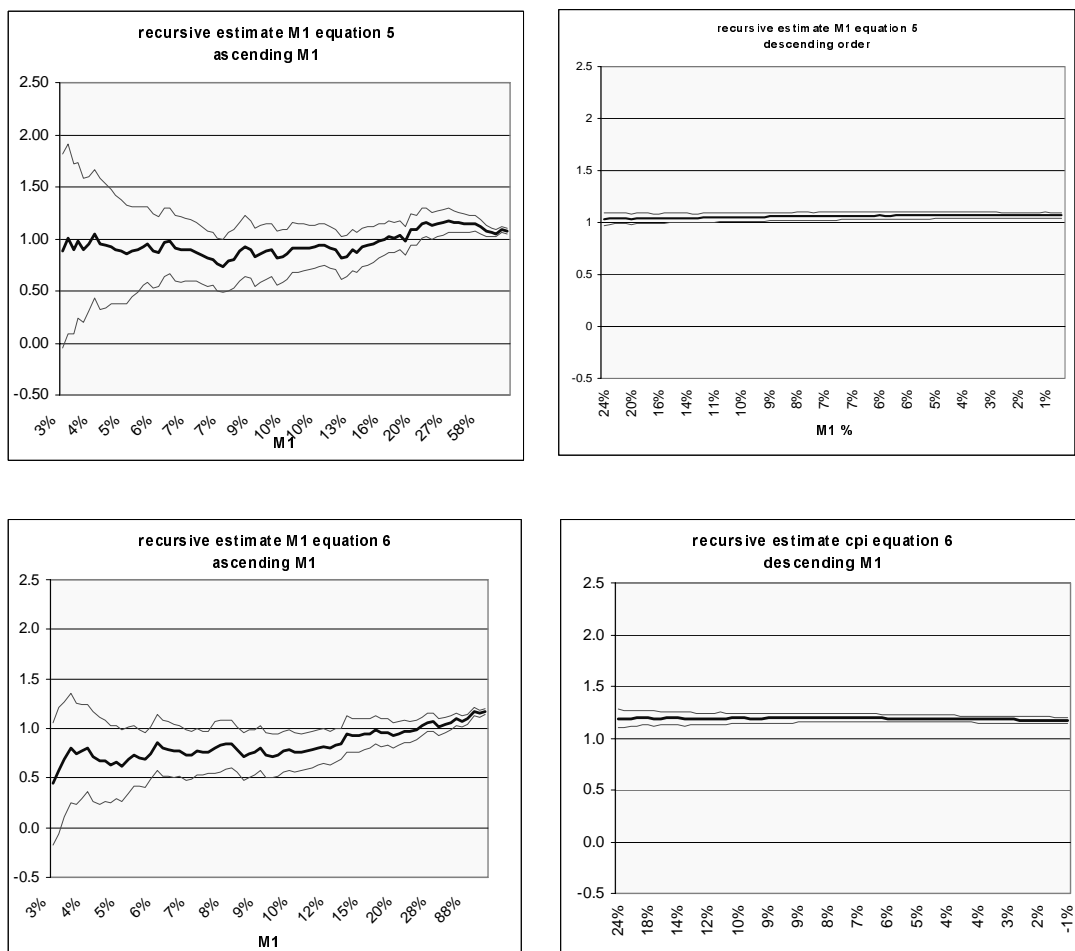
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<sup>6</sup>The data must be ordered according to the independent variables to avoid a bias. This bias will occur if the data are ordered by the dependent variable, e.g. inflation. In that case the independent variable is correlated with the error term.

contrasts with the results when the observations are ordered in ascending order of inflation.

However, a potential problem arises due to the possibility of reverse causality between money and exchange rate, and between money and inflation. A group of countries pegged the exchange rate during the sample period. These countries, regularly experienced devaluations or revaluations. As a result, for these countries the causality will be reversed. That is, in equation 5 the money stock adjusts to the change in exchange rate. A similar reverse causality then occurs in equation 6, i.e. the devaluations (and revaluations) affect the domestic inflation rate, which in turn influences the money stock. Note that a reverse equation 6 can also be interpreted as a money demand equation.

**Figure 1**



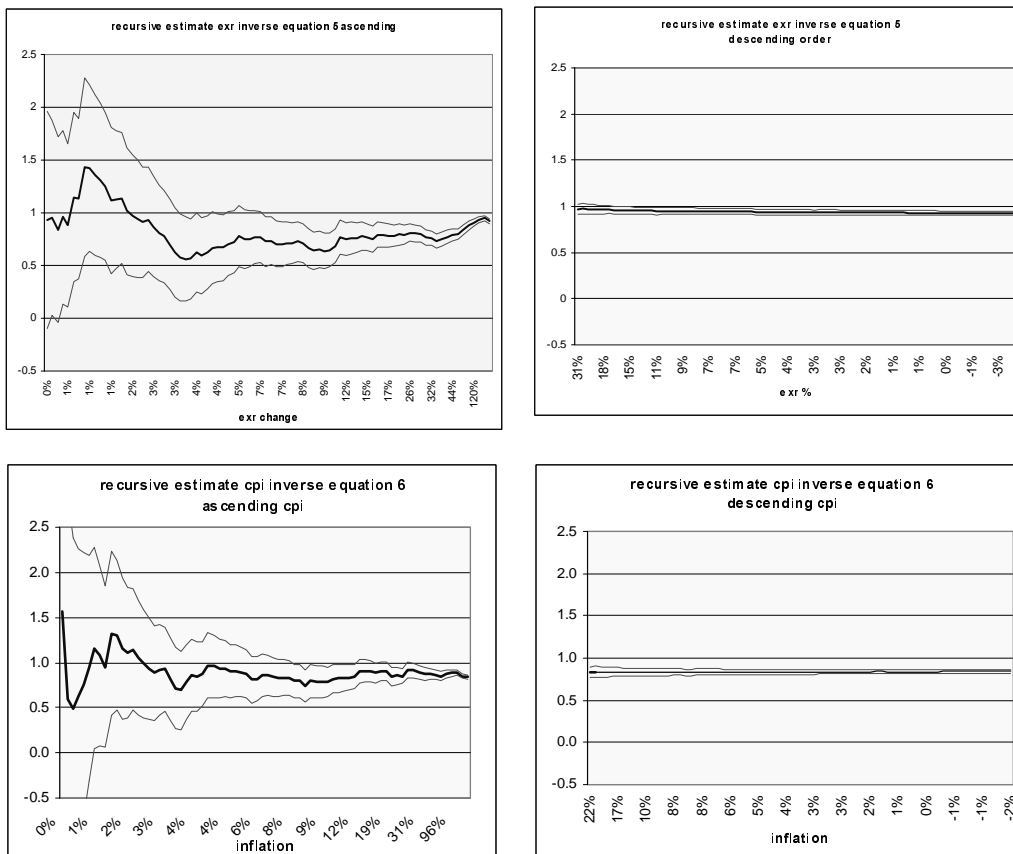
In order to test the importance of this reverse causality effect we estimate both equations 5 and 6 in reverse order, i.e.:

$$m_i = b_1' + b_2'e_i + b_3'y_i + v_i' \quad (5')$$

$$m_i = a_1' + a_2'p_i + a_3'y_i + \omega_i' \quad (6')$$

The regression results are shown in appendix (appendix 3) and the recursive estimate of the coefficient of the exchange rate in equation 5' ( $b_2'$ ) and of the coefficient of inflation in equation 6' ( $a_2'$ ) are shown in figure 2.

**Figure 2**



As in the previous recursive estimates we cannot reject proportionality for the low inflation countries. However, the precision of the estimates is again so low that we cannot exclude that the coefficients are zero either. Note that the recursive estimates in descending order of money growth exhibit the same features as in figure 1, i.e. the

high inflation countries' estimates dominate the results. Adding low inflation countries to the sample does not add information.

When we compare the inverse regression results for the sample as a whole (see Table A3 in appendix 3) with those obtained in the original specification of equations (5) and (6) (Table 2) we find that they are very much comparable. Thus, however we estimate these equations for the whole sample, we find strong evidence of proportionality. The recursive estimates suggest, however, that this is almost exclusively due to the high inflation countries in the sample.

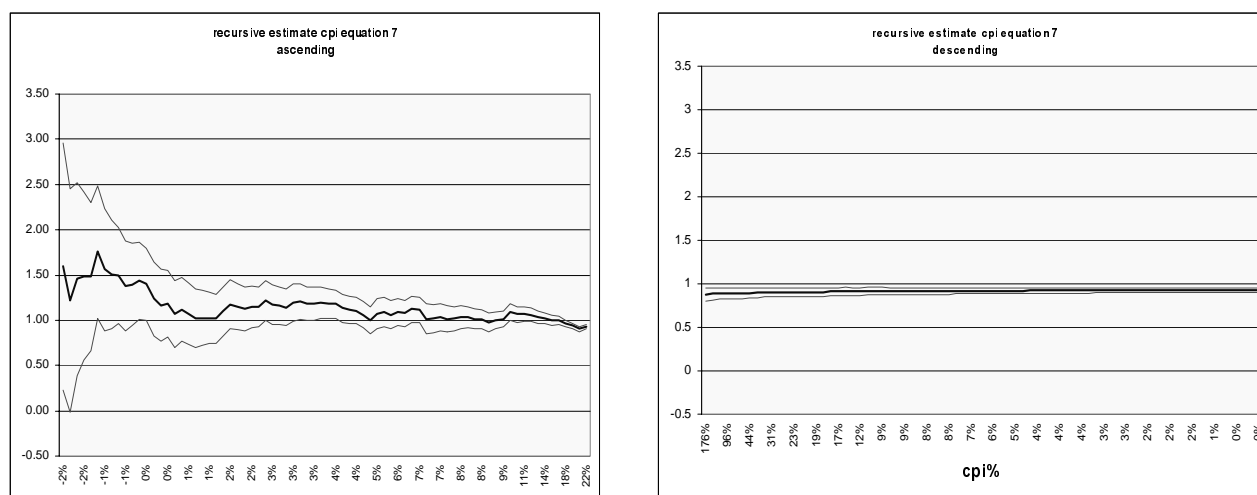
#### **4.2 PPP in different inflationary regimes**

Does the PPP 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. They are qualitatively very similar to the results of the recursive analysis of the exchange rate-money equation (equation 5). We observe that the precision of the inflation coefficient for the low inflation/low money growth (LILM) countries is low. For the twenty lowest LILM 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 high inflation/high money growth (HIHM) 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 HIHM countries, while for the LILM countries we do not find such a result<sup>7</sup>. Again, the precision of the estimate that we have for the whole sample seems to be due almost exclusively to the HIHM countries.

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<sup>7</sup> 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 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).

**Figure 3**



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

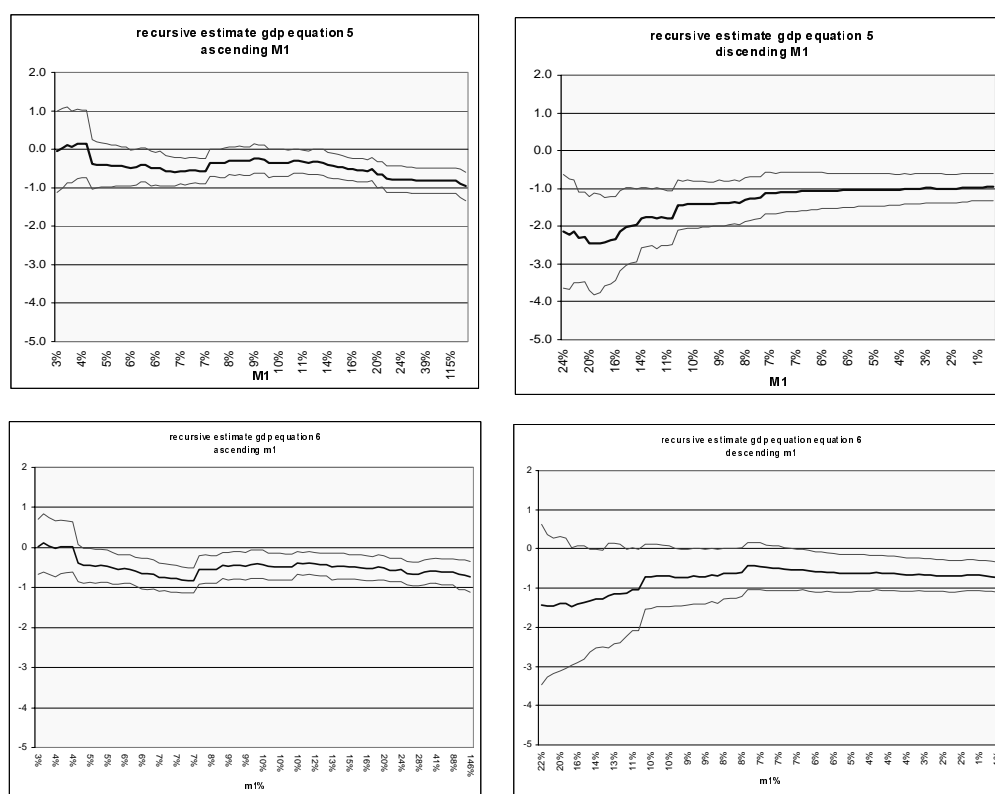
The analysis of the effect of output growth on inflation and exchange rate changes in the whole sample shows that, given the money growth, an increase in output leads to an appreciation of the currency and to a decline in inflation. We tested if these results hold in sub-samples defined according the inflationary regimes by performing similar recursive estimates as in the previous sections<sup>8</sup>. 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 M1.

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

**Figure 4**



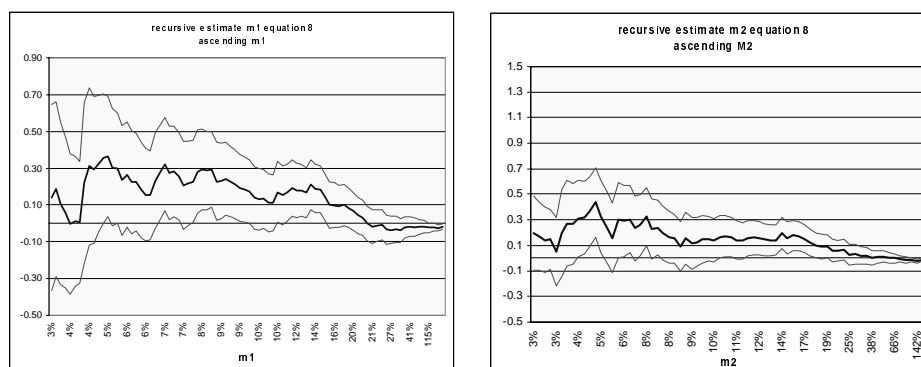
#### 4.4 Neutrality of money in LI and HI countries

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

<sup>8</sup> We returned to the ordering of the data by the rate of inflation. The box ordering method produces very similar results here.

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.

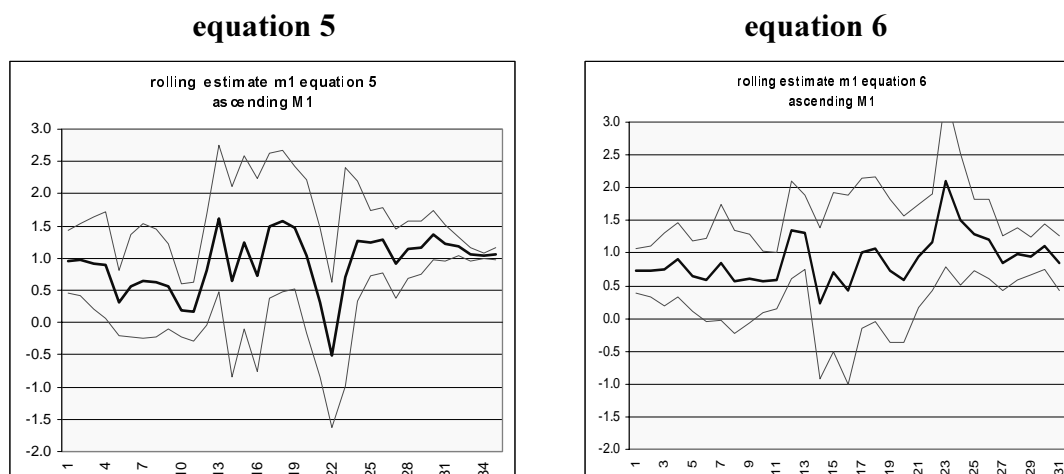
## 5. QTM, PPP and the level of inflation: additional empirical tests

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 using the box method, 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 equations 5 and 6 are presented in figure 6.

**Figure 6**

Rolling Estimate of money coefficient (M1)



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. Moreover, it appears that the countries in the intermediate range the precision of the estimate is even lower. We observe that the coefficients of money in both equations 5 and 6 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 consecutively. We performed this exercise for different subsamples 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 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 intermediate inflation countries both GDP and money have about the same low explanatory power. For the low inflation countries money has more explanatory power than GDP, but this explanatory power is low. Experimenting with other subsamples among the low and intermediate inflation countries reveals that for these countries the explanatory power of money and output 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**

<b>Low inflation countries (lowest 21 inflation countries)</b>						
	<b>1</b>		<b>2</b>		<b>3</b>	
Variable	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic
<b>Constant</b>	-0.013 (0.004)	-2.795	-0.004 (0.004)	-0.966	-0.010 (0.004)	-2.445
<b>Money</b>	0.722 (0.168)	4.269			0.638 (0.204)	3.131
<b>GDP</b>	-0.383 (0.247)	-1.506	-0.219 (0.194)	-1.126		
Adjusted R-squared	0.313		-0.033		0.287	
<b>High inflation countries (highest 21 inflation countries)</b>						
	<b>1</b>		<b>2</b>		<b>3</b>	
Variable	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic
<b>Constant</b>	-0.053 (0.019)	-2.873	0.405 (0.068)	5.970	-0.05 (0.018)	-3.177
<b>Money</b>	1.182 (0.040)	29.232			1.213 (0.042)	28.362
<b>GDP</b>	-1.326 (0.478)	-2.773	-14.552 (6.842)	-2.127		
Adjusted R-squared	0.987		-0.301		0.985	
<b>Intermediate inflation countries (21 inflation countries in the middle of the sample)</b>						
	<b>1</b>		<b>2</b>		<b>3</b>	
Variable	Coeff.	t-Statistic	Coeff.	t-Statistic	Coeff.	t-Statistic
<b>Constant</b>	-0.025 (0.047)	-0.539	0.044 (0.006)	7.899	-0.026 (0.050)	-0.511
<b>Money</b>	0.933 (0.635)	1.468			0.899 (0.700)	1.328
<b>GDP</b>	-0.413 (0.396)	-1.045	-0.388 (0.381)	-1.019		
Adjusted R-squared	0.172		0.069		0.093	

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.

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.

How can these empirical findings be explained? We discuss different possible explanations in increasing order of plausibility

### 6.1 Possible explanations: imperfect competition and menu costs

*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<sup>9</sup>.

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.

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<sup>9</sup> There is a strand of empirical evidence on this issue, for details see Barro (1995)

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.

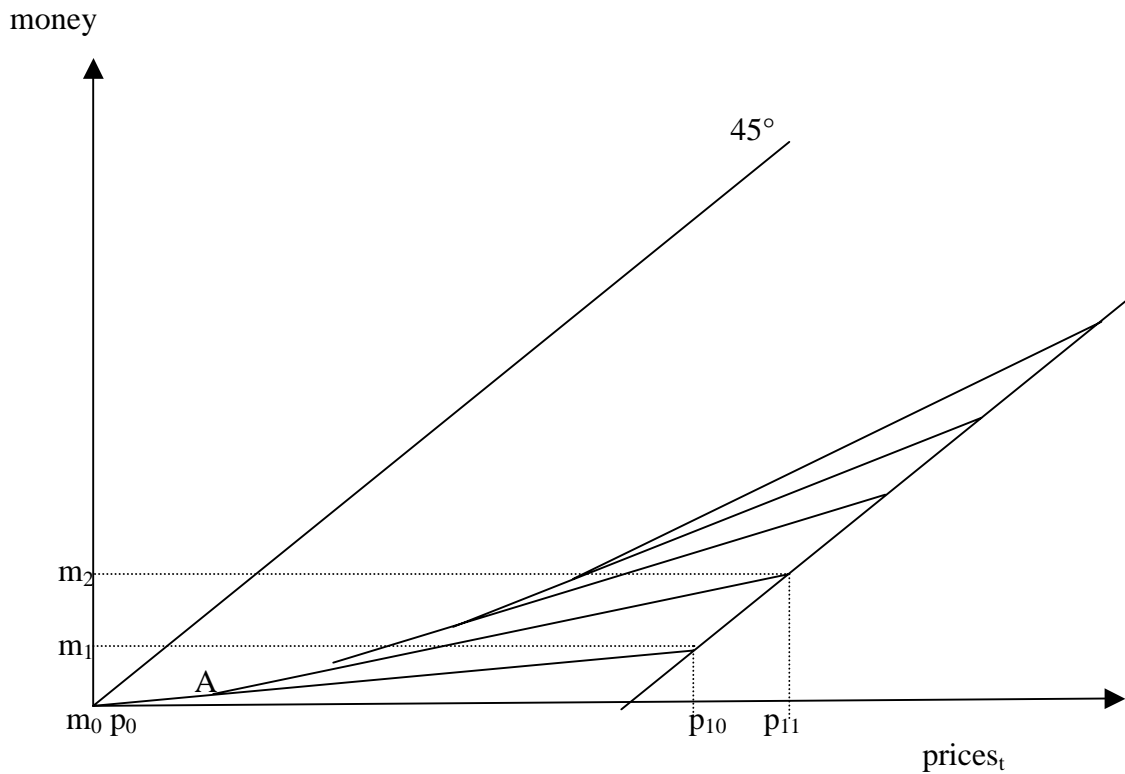
The problem remains, however, whether price rigidity is a sufficient explanation for the lack of proportionality between money, prices and exchange rates over a *thirty-year period*. The problem can be illustrated graphically (see Figure 7). On the vertical axis we set out the money stock over different 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<sup>10</sup>. 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 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.

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<sup>10</sup> Cheung and Lai (2000)

**Figure 7**  
**Money and prices in a model with price rigidities**



### 6.2 Possible explanations: measurement errors

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:

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

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

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

where  $\varepsilon_i$  are the shocks in money stock non related to monetary policy.

We substitute (10) in (5') :

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

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 ( $\varepsilon_i$ ) 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.

### **6.3 Possible explanations: productivity shocks and transactions costs in international trade**

A third explanation that we favour has the following ingredients: *productivity 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 relationship. 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<sup>11</sup>.)

$$\textit{Aggregate supply} \quad y_t = E_{t-1}y_t + a(p_t - E_{t-1}p_t) + (\delta + \varepsilon_t) \quad (12)$$

$$\textit{Aggregate demand} \quad y_t = E_t y_{t+1} - r_t + u_t \quad (13)$$

$$\textit{Money demand} \quad m_t - p_t = y_t - \phi i_t + v_t \quad (14)$$

$$\textit{Fisher equation} \quad i_t = r_t + E_t p_{t+1} - p_t = r_t + E_t \pi_{t+1} \quad (15)$$

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,  $\pi_t$  is the inflation rate,  $u_t$ ,  $\varepsilon_t$  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  $\varepsilon_t$  and a constant  $\delta$ . 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

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

where  $\mu$  is the average growth rate of the money supply. We assume it to consist of two components, i.e.  $\mu = \mu' + \delta$ , where  $\mu'$  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,  $E_t y_{t+1} = \delta$ <sup>12</sup>.

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:

<sup>11</sup> See Clarida, Gali and Gertler(1999) for a similar model.

<sup>12</sup> The equilibrium solution that we are going to derive considers two periods but it can be easily solved forward ( see Walsh pag 207)

$$p_t = \frac{\mu(1+\phi)}{\phi} + m_{t-1} + b_1 u_t + b_2 v_t + b_3 \varepsilon_t \quad (17)$$

$$y_t = a(b_1 u_t + b_2 v_t) + b_4 \varepsilon_t$$

where

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

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

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

$$b_4 = \left[ \frac{aa_2 + 1}{(1+a)} \right]$$

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

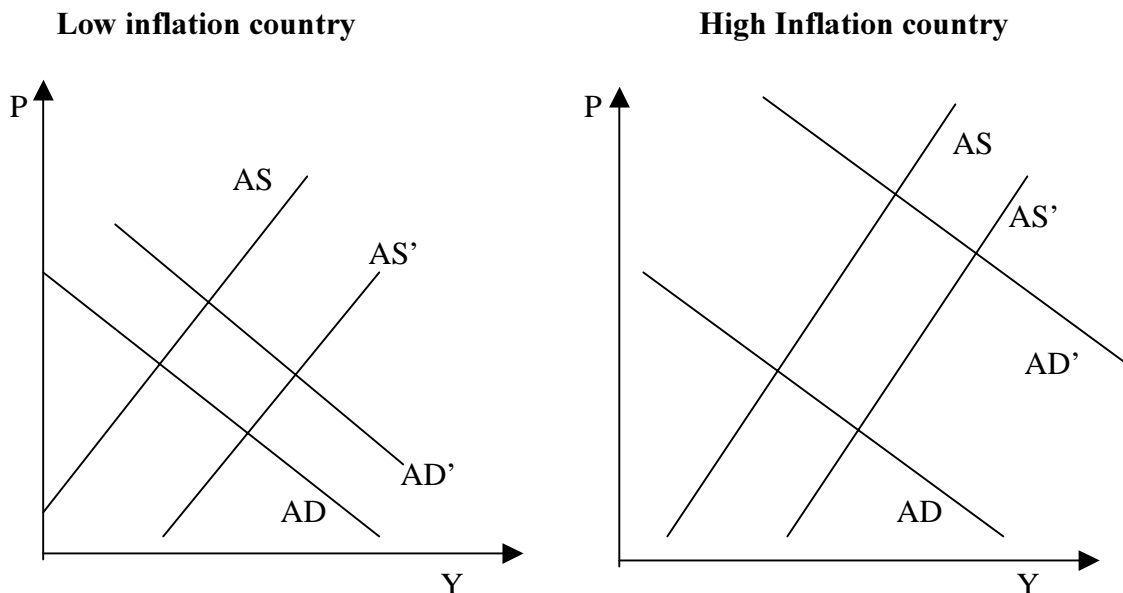
$$E_t \pi_{t+1} = \mu - \delta + (a_1 - b_1) \mu_t + (a_2 - b_2) v_t + (a_3 - b_3) \varepsilon_t \quad (18)$$

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  $\mu'$  is small. As a result, the observed correlation between inflation and money growth will be small or even negative. For the HI countries  $\mu'$  is relatively large. Therefore the positive correlation between money growth and inflation will dominate.

We show these results graphically in Figure 8. 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 8**



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

$$\text{Aggregate supply} \quad y_t = E_{t-1}y_t + a(p_t - E_{t-1}p_t) + (\delta + \varepsilon_t) \quad (12)$$

$$\text{Aggregate demand} \quad y_t = E_t y_{t+1} - r_t + \gamma \rho_t + u_t \quad (13')$$

$$\text{Money demand} \quad m_t - p_t = y_t - \phi i_t + v_t \quad (14)$$

$$\text{Fisher equation} \quad i_t = r_t + E_t p_{t+1} - p_t = r_t + E_t \pi_{t+1} \quad (15)$$

$$\text{Open interest parity} \quad i_t = i_t^* + E_t s_{t+1} - s_t \quad (19)$$

$$\text{Real exchange rate} \quad \rho_t = s_t - p_t + p_t^* \quad (20)$$

$$\text{Money supply process} \quad m_t = \mu + m_{t-1} + \alpha_1 u_t + \alpha_2 v_t + \alpha_3 \varepsilon_t \quad (21)$$

We have added the real exchange rate  $\rho_t$  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:

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

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

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

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

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

$$p_t^* = (1 + \varphi)\mu^* + m_{t-1}^* \quad (25)$$

$$s_t = (1 + \varphi)\mu + m_{t-1} - (1 + \varphi)\mu^* - m_{t-1}^* \quad (26)$$

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,  $\tau$ , 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:

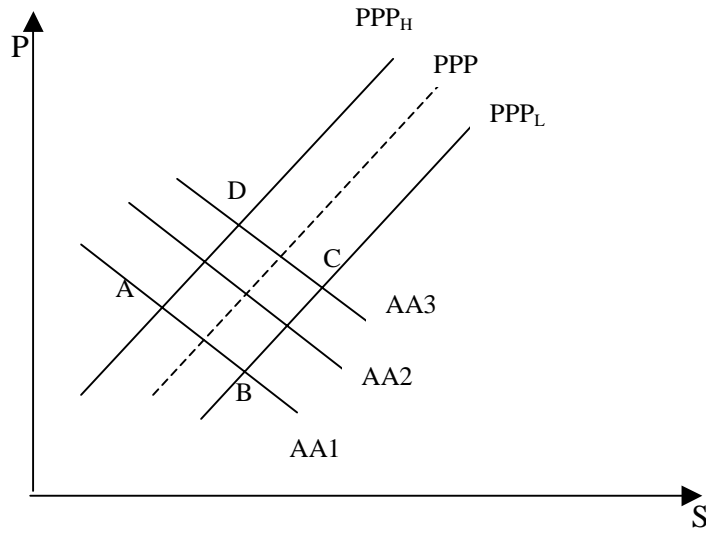
$$\begin{aligned} \text{If } s_{t+i} - s_t \leq \tau & \Rightarrow s_{t+i} = s_t \\ s_{t+i} - s_t > \tau & \Rightarrow s_{t+i} = (1 + \varphi)\mu + m_{t-1+i} - (1 + \varphi)\mu^* - m_{t-1+i}^* \\ & \forall i = 1, \dots, T \end{aligned} \quad (27)$$

In LI countries the yearly differentials in money growth rate  $\mu - \mu^*$  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 9. 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)) .

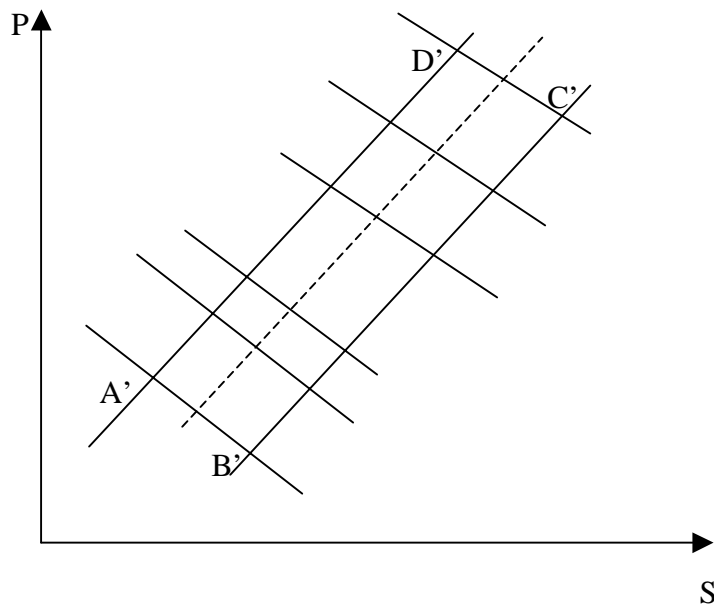
Because of transaction costs, arbitrage will not occur when the price-exchange rate observations are between the band given by the parallel lines  $PPP_L$  and  $PPP_U$ . Thus, when observations are within that band there is no mechanism driving the price-exchange rates towards the PPP-line. When the 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 9**



When we add HI countries to the sample we obtain the next Figure 10. 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 10**



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 4 ( figure 11) 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% (figure 12). 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 13 in Appendix 4. The transaction costs are assumed to be 20%.<sup>13</sup> 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 14 in Appendix 4. This means that even for the outliers in the group of the LI countries it takes at least 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 15 in Appendix 4 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 16 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.

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<sup>13</sup> 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))

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 found that the proportionality propositions for the LI countries are very weak 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 the theoretical puzzle of why the proportionality propositions are weak in the low inflation countries.

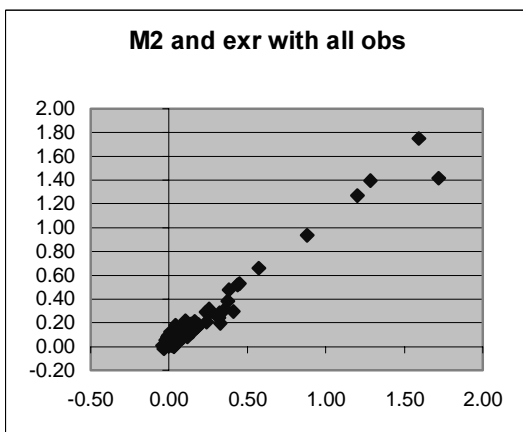
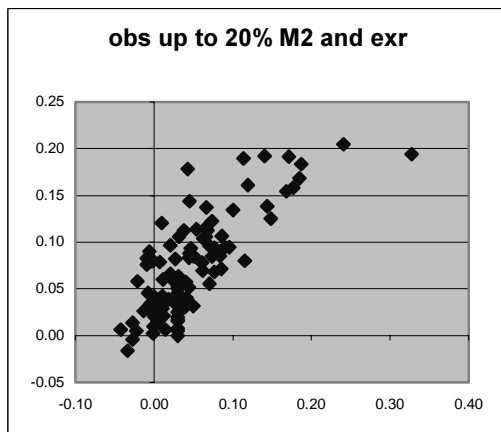
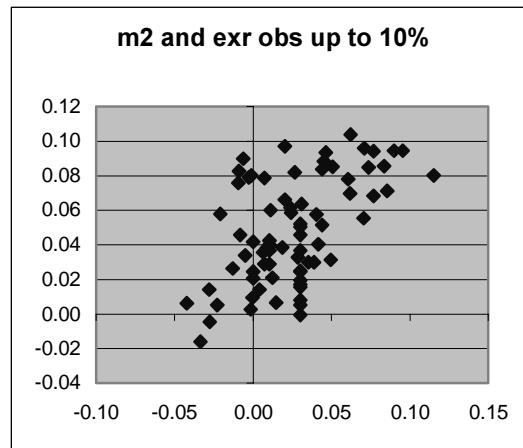
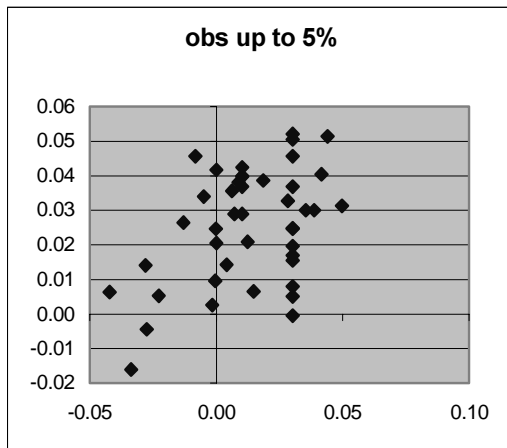
We proposed an explanation based on *transaction costs* and *productivity shocks* to explain it. The empirical evidence seems to confirm our theoretical analysis, but further research is necessary to find out what the relative importance is of these transactions costs and productivity shocks to explain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

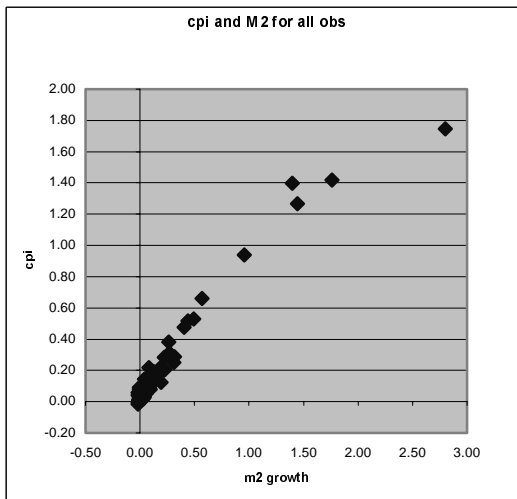
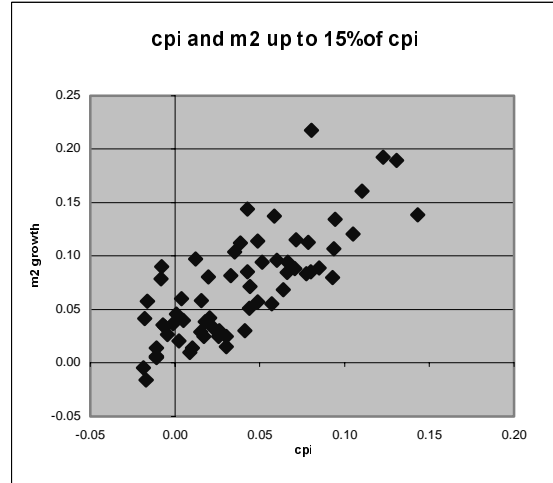
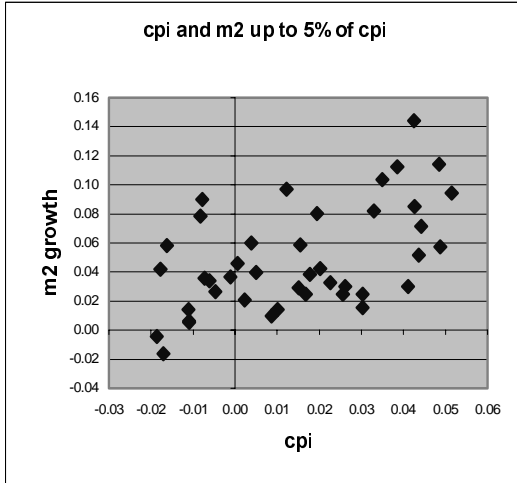
Another implication of our findings concerns the use of the money stock as an intermediate target for monetary policies. Our results suggest that in low inflation countries, the money stock gives poor signals about inflationary pressures even over long periods of time. The money stock is therefore likely 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

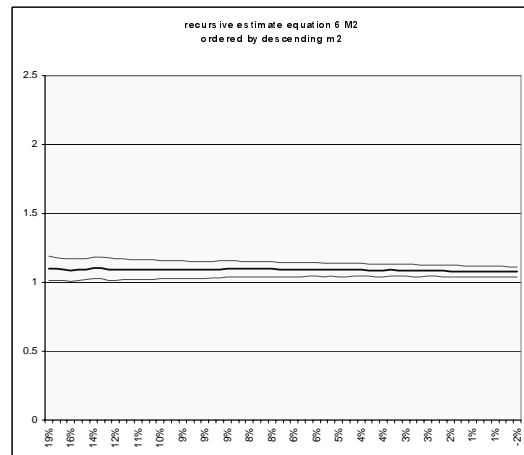
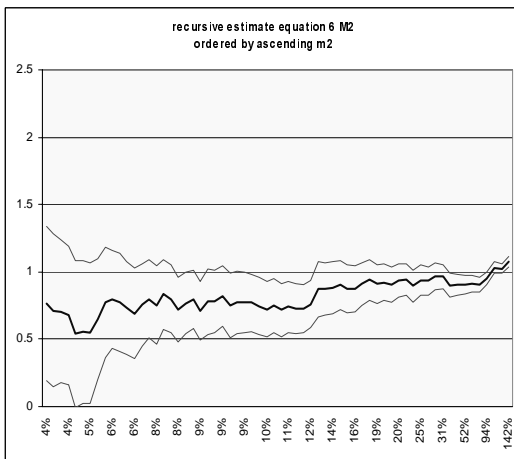
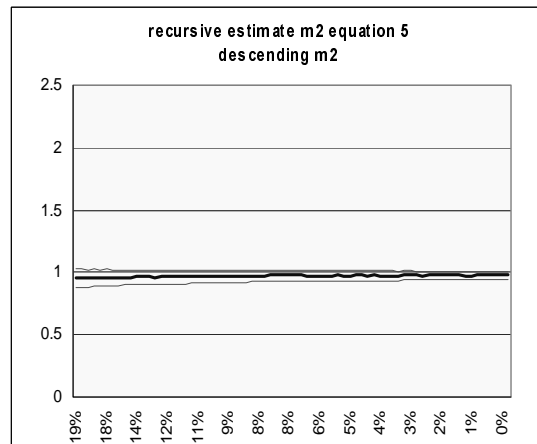
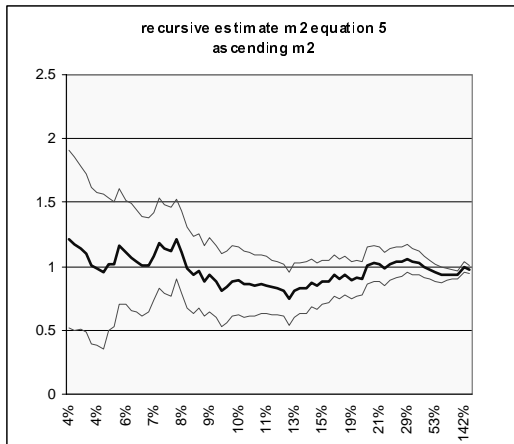
Relationship between exchange rate changes and money ( M2) growth for different level of money.



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



## APPENDIX 2 : Recursive estimate equations 5 and 6 with M2



Appendix 3 : Estimates of equations 5' and 6'

**Table A3: OLS regression results of equations 5' and 6'**

	<b>M1</b>		<b>M2</b>	
<b>Variable</b>	<b>Coefficient</b>	<b>t-Statistic</b>	<b>Coefficient</b>	<b>t-Statistic</b>
<i>Equation 5</i>				
<b>Constant</b>	0.029 (0.004)	7.72	0.024 (0.006)	3.99
<b>Exchange Rate</b>	0.922 (0.028)	33.15	0.999 (0.017)	59.05
<b>GDP</b>	0.646 (0.205)	3.15	1.418 (0.248)	5.73
Adjusted R-squared	0.988		Adjusted R-squared 0.977	
<i>Equation 6</i>				
<b>Constant</b>	0.035 (0.003)	11.21	0.034 (0.005)	6.99
<b>CPI</b>	0.841 (0.021)	40.02	0.907 (0.040)	22.53
<b>GDP</b>	0.558 (0.153)	3.65	1.139 (0.232)	4.91
Adjusted R-squared	0.987		Adjusted R-squared 0.978	

APPENDIX 4

Figure 11

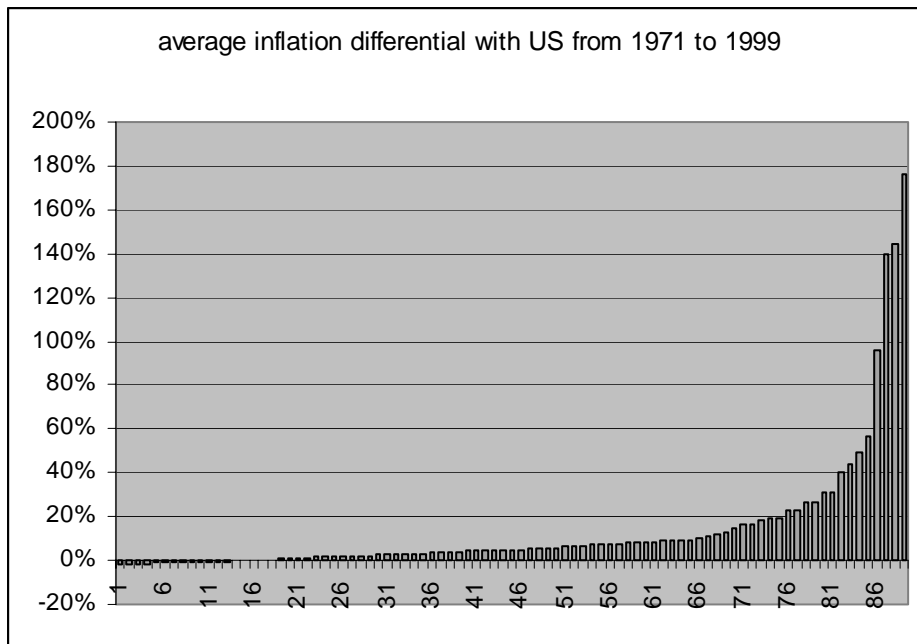


Figure 12

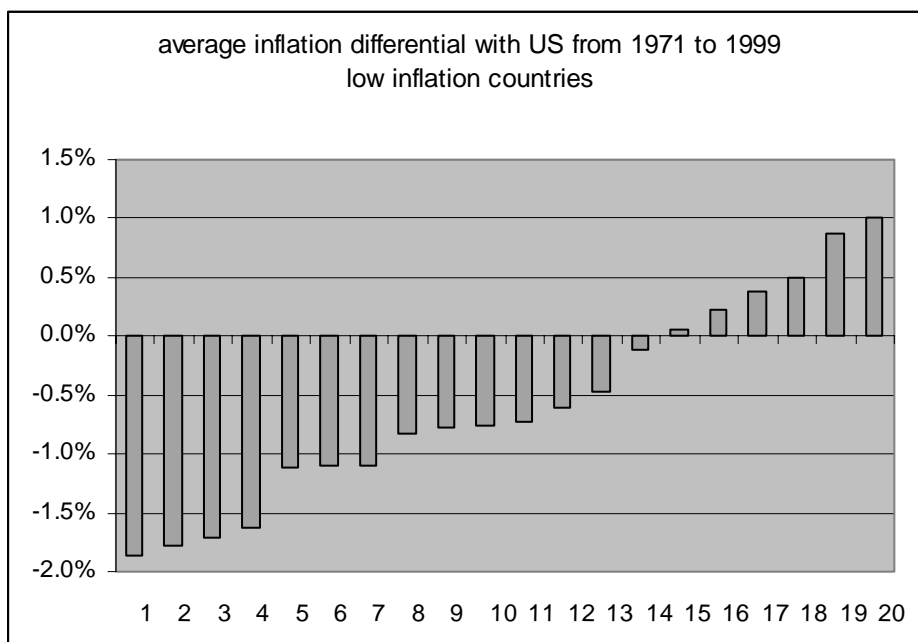


Figure 13

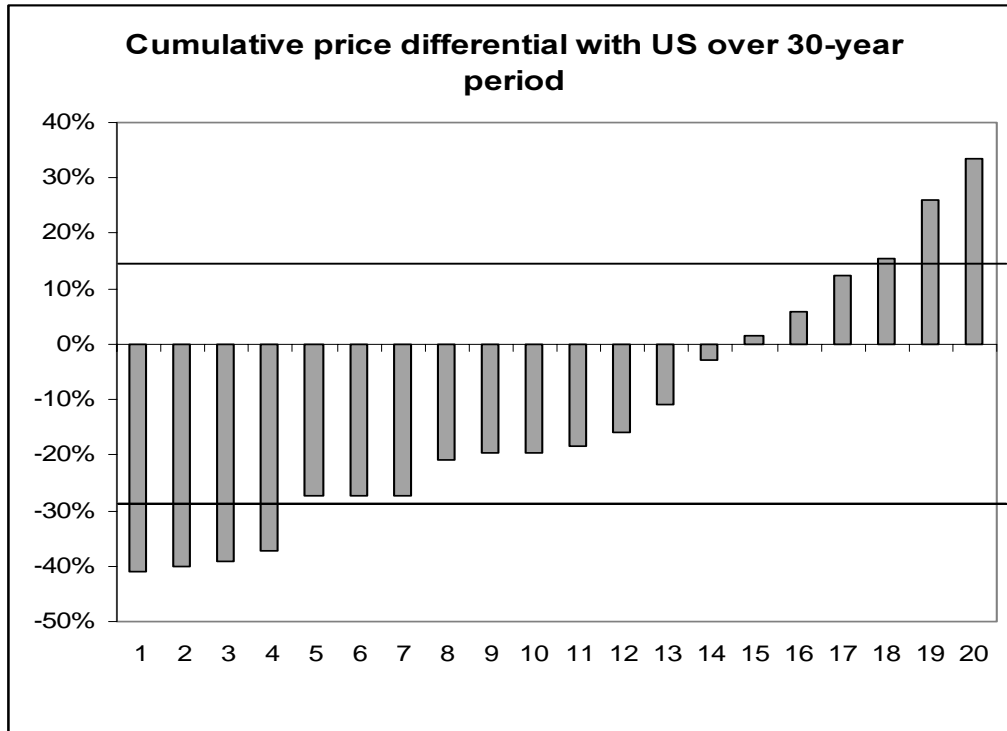
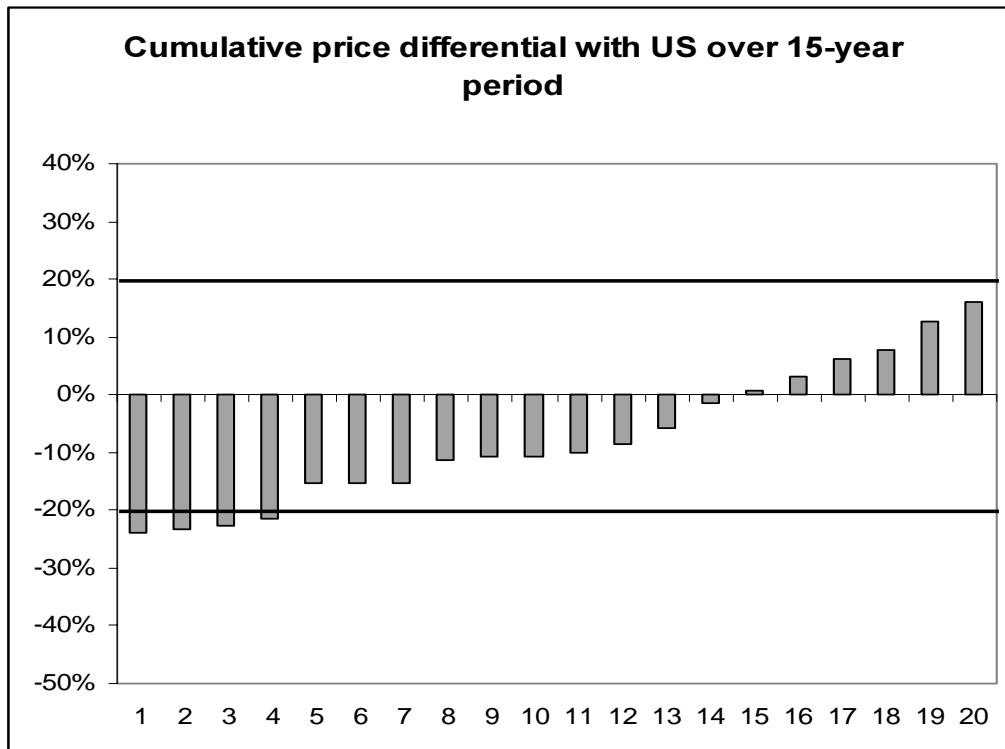


Figure 14



**cumulative real exchange rate changes (1971-1999)**

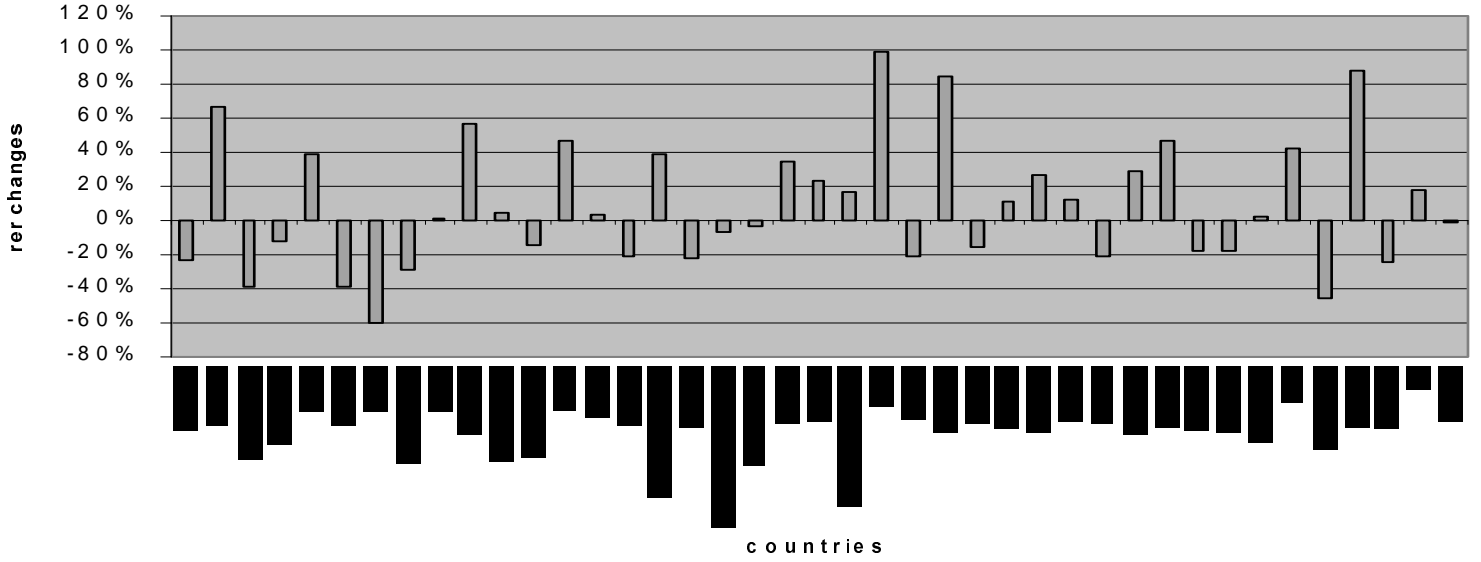
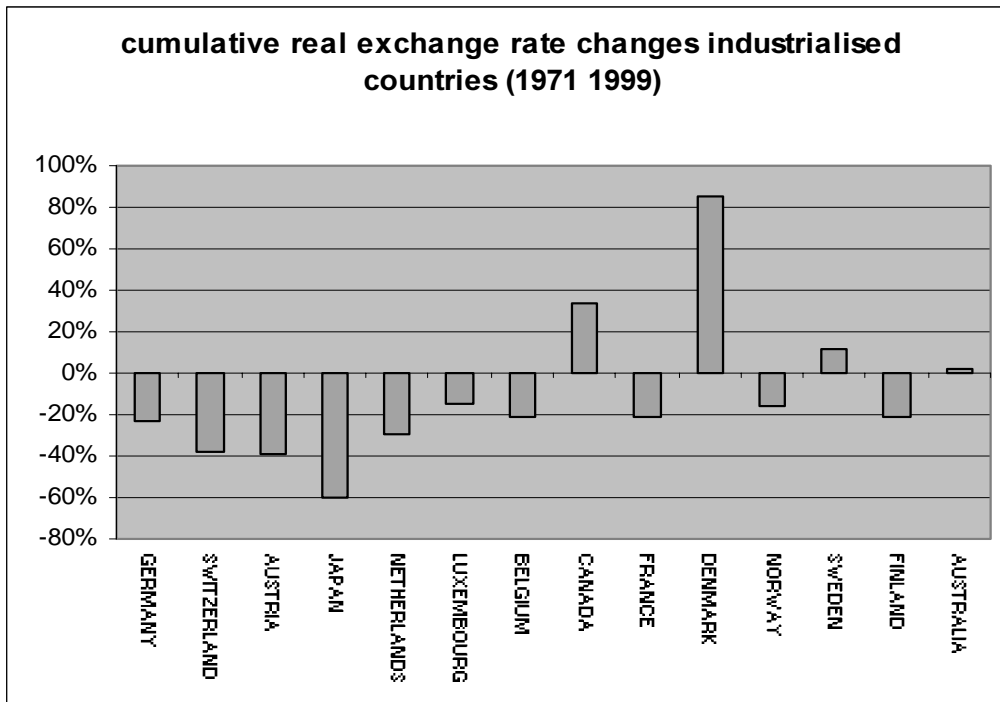


Figure 16



## 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 Perspective”, *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)