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ABSTRACT

Is Quantity Theory Still Alive?*

This paper investigates whether the quantity theory of money is still alive. We demonstrate three insights. First, for countries with low inflation, the raw relationship between average inflation and the growth rate of money is tenuous at best. Second, the fit markedly improves, when correcting for variation in output growth and the opportunity cost of money, using elasticities implied by theories of Baumol-Tobin and Miller-Orr. Finally, the sample after 1990 shows considerably less inflation variability, worsening the fit of a one-for-one relationship between money growth and inflation, and generates a fairly low elasticity of money demand.

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1 Introduction

One of the most established folk wisdoms in monetary economics is a relationship, which, in its practical version for monetary policy might be stated as follows: long run inflation is related one-for-one with long-run monetary growth. This "quantity theory" relationship seems firmly established at least since Friedman (1956) and Lucas (1980).

This paper takes a cross-section of countries from 1970 to 2005, see appendix A, and re-investigates the relationship between monetary growth and inflation. We demonstrate three insights. First, for countries with low inflation, the raw relationship between average inflation and the growth rate of money is tenuous at best. Second, the fit markedly improves, when correcting for variation in output growth and the opportunity cost of money, using elasticities implied by theories of Baumol-Tobin and Miller-Orr. Finally, the sample after 1990 shows considerably less inflation variability, worsening the fit of a one-for-one relationship between money growth and inflation, and generates a fairly low elasticity of money demand.

To demonstrate these insights, we provide a series of graphs and tables. For countries with moderate inflation, we show that the raw relationship between money growth and inflation is tenuous at best or even nonexistent. Quantity theory suggest to take into account the growth rate of real GDP. Additionally, monetary theory has pointed out the dependence of velocity on yields. The correction for GDP growth alone turns out not to help. However, the correction for a yield effect has a remarkable impact. Indeed, one would expect a rise in nominal yields to increase the opportunity costs of holding money, and thus to lead to reductions in the real quantity of money per real unit of output: ceteris paribus, this should then lead to additional inflation. Lucas (2000) has documented a rather tight fit of the ratio of the real quantity of money to real output vis-a-vis the yield on government bonds, which furthermore is close to a relationship predicted by theories on the transaction demand for money, see Baumol (1952), Tobin (1956), Miller and Orr (1966). Taking into account the relationship suggested by Lucas, we demonstrate that the fit indeed markedly improves. A similarly good fit is obtained, when using the elasticity values suggested by Miller and Orr (1966). We finally estimate the relationship and find just a small improvement over the theoretical specifications.

The estimation of money demand equations has been under quite some debate in the 90s. It has been a testing decade for these equations, see in particular the debate in e.g. Ball (2001), Carlson et al (2000), Coenen and Vega (2001), and Teles and

Zhou (2005), Ireland (2009), Sargent and Surico (2011), Lucas and Nicolini (2013). We therefore split our data into two parts. For the first part, we use data from 1970 to 1990, whereas we use data from 1990 to 2005 for the second part. The breaking point in 1990 is chosen to reflect changes in monetary regimes and regulation, but is perhaps somewhat arbitrary. Teles and Zhou (2005) and Lucas and Nicolini (2013), consider 1980 as the data break for the US, focusing on the effects on monetary aggregates of banking deregulation introduced after 1980.[1] Those changes together with the financial innovation in the 1990s associated with the development of electronic payments suggest that M1 might not be the most appropriate monetary aggregate to use in the second part of the sample. Another justification for a data break, more in line with the work of Sargent and Surico (2011), is the generalized use of some form of inflation targeting around a low target. A natural data break there is 1990, which dates the explicit use of inflation targeting by different countries around the world (New Zealand first introduced it in 1991) and the convergence to low inflation in most developed countries.

We show that the relationship between money growth and inflation has become much looser during this second part of the sample. Generalized inflation targeting at low inflation rates makes it harder to establish a one-for-one relationship between average inflation and the growth rate of money, as also argued by Sargent and Surico (2011) using US time series data. But variation across countries in average growth of money is still hard to explain. Possibly higher dispersion in regulation or financial innovation may account for part of it.

We also document, using the cross section of countries, the reduction in the interest elasticity of the money demand for the more recent data that has been observed in the time series for different countries, as in e.g. Ireland (2009). This also means that the apparent coincidence between the estimated relationship and the theory-implied elasticities for the whole sample is somewhat illusory, as the overall sample estimated elasticity happens to be an average of a high elasticity for the first part of the sample and a low elasticity for the second part of the sample.

Investigating international cross-sections of countries to analyze the evidence on the quantity theory of money has obviously been done before, notably by Candless and Weber (1995), restated in Lucas (1996), and Duck (1993). We build up on this literature. More recent literature such as Assenmacher-Wesche and Gerlach (2006),

[1] The Depository Institutions Deregulation and Monetary Control Act of 1980.and the Garn–St Germain Depository Institutions Act of 1982.

using information on the interest rate, and Benati (2009) find a long run unit relationship between money growth and inflation for several countries, but do not exploit the cross section evidence as we do.

The outline of the paper is as follows. We largely proceed by showing pictures. Section 2 provides a basic perspective on the cross-country data. Section 3 provides a model and a more sophisticated analysis, introducing technological progress in production and the transactions technology, and allowing for additional "corrective" terms. Section 4 examines the issue of subsample instability. The data is described in section A. An online appendix and a .zip file provide further graphs and tables, as well as the data used and the programs for calculating all results.

We conclude that quantity theory is still alive. Whether it should be used as a guide to long-term monetary policy is more debatable, and it is certainly beyond the scope of this paper. As argued by Woodford (2008), there is no independent role for tracking the growth rate of money, if a central bank is already willing and able to stabilize inflation rates at short and medium-term horizons, without making an explicit use of monetary aggregates. The practice of central banks seems to be reassuring, that it is possible to keep inflation low using, as it appears to be the case, some form of interest rate feedback rule. However, theory is more sceptical about that capacity, pointing out that local determinacy does not imply uniqueness (see e. g. Benhabib, Schmitt-Grohe and Uribe, 2001). The tracking of money supply could be a means of avoiding some of that multiplicity (see Atkeson, Chari and Kehoe, 2010, as well as the analysis in Fischer et al, 2006).

2 The World

Teachers of intermediate macroeconomics may have consulted Barro (1993 or 2007) in order to teach students the relationship between monetary growth rates and inflation. His figure 7.1 in the 1993 edition shows a large sample of countries, and plots this relationship, having calculated the growth rates of money and prices from, typically, the fifties to 1990. The figure is reproduced here as figure 1: one apparently gets a nice fit to the 45 degree line.

However, that picture turns out to be misleading and mainly driven by high inflation countries. Concentrating on the subset of countries, whose inflation rate was below 12 percent, the points no longer assemble nicely around a line, but rather produce a rather randomly looking scatter plot, see figure 2. The question is thus:

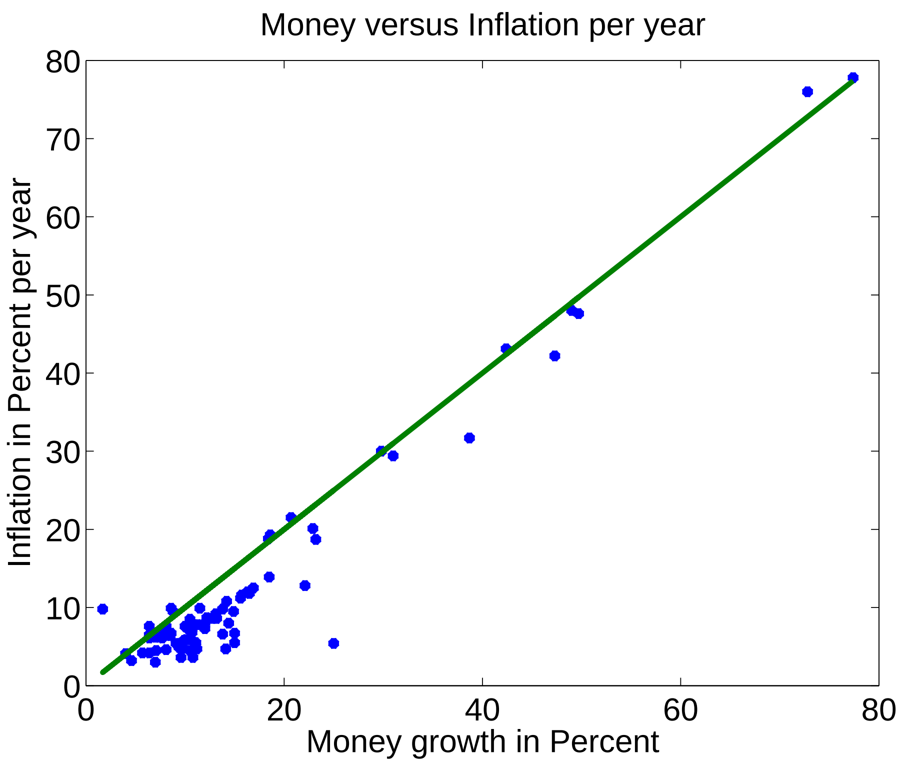

Figure 1: *This figure, which just restates figures drawn in Barro (1993, 2007), McCandless and Weber (1995) or Lucas (1996) shows the relationship between monetary growth rates and inflation in a sample of 79 countries. The data is from Barro (1993). Also drawn is the 45 degree line: it seems, that indeed long-term monetary growth is synonymous with long-term inflation.*

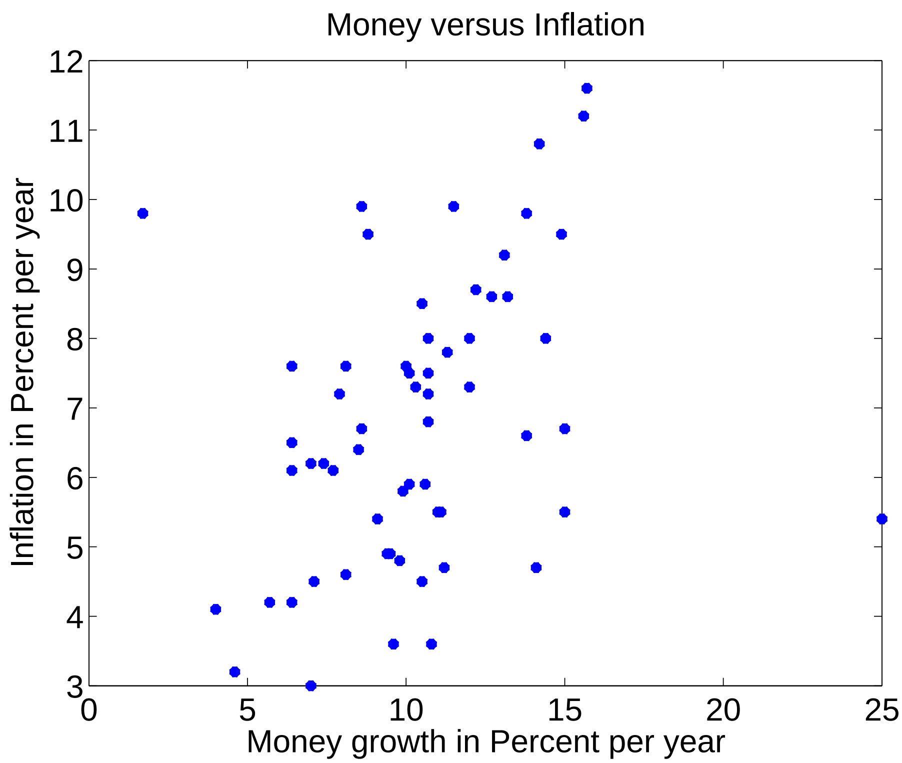

Figure 2: *This figure is the same as figure 1, but restricting attention to only those countries, whose inflation rate was below 12 percent. Instead of a tight relationship between monetary growth and inflation, one can just see a cloud.*

is the relationship between monetary growth and inflation too loose to be of any relevance for low inflation countries?

These pictures should be considered disturbing by anybody who believes in a tight relationship between monetary growth and inflation and bases monetary policy advice on such a belief. Additional issues may be of relevance at low rates of inflation, however. In particular, GDP growth, changes in interest rates, technological progress in transaction technologies as well as production may make a difference. Some theory is needed to sort out the issues.

3 Money demand and technological progress

In deriving an equilibrium money demand relationship, a tricky issue to deal with is technical progress in both production of final goods as well as production of transaction services. We consider a very simple monetary model similar to the one in Lucas (2000) with labor only, a transactions technology, and exogenous technical progress in both production and transactions. Suppose, that each unit of labor produces $A_{p,t}$ units of the final good in goods production and that $A_{s,t}$ measures progress in the transactions technology. We assume the (representative) agent needs transaction services proportional to real consumption c_t, which are produced with labor time on transaction services s_t and real money balances $m_t = M_t/P_t$,

$$c_t = A_{s,t} f(s_t, m_t)$$

Under mild conditions, this can be rewritten as

$$s_t = l(A_{s,t}^{-1} c_t, m_t). \tag{1}$$

Equating labor productivity to wages, a generic maximization of a consumer would read

$$\max_{c_t, h_t, B_t, M_t} \sum_{t=0}^{\infty} U(c_t, h_t)$$

$$\begin{aligned} P_t c_t + M_{t+1} + B_{t+1} &\leq M_t + (1 + i_t) B_t + P_t A_{p,t}(1 - h_t - s_t) - T_t,\ t \geq 0 \\ M_0 + B_0 &\leq W_0 \\ s_t &= l(A_{s,t}^{-1} c_t, \frac{M_t}{P_t}),\ t \geq 0 \end{aligned}$$

together with a no-Ponzi games condition, where B_t are nominal bonds, collecting a nominal interest rate i_t, and h_t is leisure with total time endowment of unity, and where we assume that preferences $U(c_t, h_t)$ are consistent with balanced growth. T_t are lump sum taxes.

We assume that the function l is of the form

$$l(c,m) = \eta c^a m^b \tag{2}$$

for some η, a and b, where we assume that $b < 0$ and $\eta > 0$.

When $a = 1$ and $b = -1$, the form for the transactions technology can be justified by assuming, inspired by Baumol (1952) and Tobin (1956), that the consumer spends cash holdings intended for the purchase of the good at a constant rate c_t per unit of time. $\frac{c_t}{m_t}$ is the number of times cash balances for transactions of the good are exhausted and must be restored, the number of trips to the bank. This time cost is a constant η. The Miller-Orr (1966) specification amounts to $l(c,m) = \eta\left(\frac{c}{m}\right)^2$, i.e. $a = 2$ and $b = -2$.

The first order conditions imply

$$-A_{p,t} l_m(A_{s,t}^{-1} c_t, m_t) = i_t \tag{3}$$

or

$$A_t c_t^a m_t^{b-1} = i_t$$

where

$$A_t = -\eta b A_{p,t} A_{s,t}^{-a} > 0$$

In logs, and equating consumption to output, $c_t = y_t = A_{p,t}(1 - h_t - s_t)$, we get

$$\log\left(\frac{m_t^{1-b}}{y_t^a}\right) = \log A_t - \log i_t \tag{4}$$

Taking the first difference between two consecutive years, (4) implies

$$0 = (1-b)\Delta \log m_t + \Delta \log i_t - a\Delta \log y_t - \Delta \log A_t \tag{5}$$

To make contact with the data, we wish to examine a panel of countries $j = 1, \ldots, J$ and a period $t = 0, \ldots, T$. Summing from some initial year 0 to some terminal year T, and dividing by the length of time T, one gets a relationship between the growth rates over that time period. For a country j and a variable $x_{j,t}$, generally denote this sample growth rate with

$$\dot{x}_j = \frac{\log x_{j,T} - \log x_{0,T}}{T} \tag{6}$$

Equation (5) can then be rewritten as

$$\dot{m}_j = -\frac{1}{1-b}\dot{i}_j + \frac{a}{1-b}\dot{y}_j + \frac{1}{1-b}\dot{A}_{p,j} - \frac{a}{1-b}\dot{A}_{s,j} \tag{7}$$

where we have disentangled A_t again into its two components. While, given a particular sample, equation (7) is correct as a statement of the relationship between the changes or growth rates of variables, stationarity of i_t may induce that term to be quantitatively small. Whether this is so is an empirical issue, and one answered by our figures: it turns out that this term can make quite a difference indeed.

The link between production and labor productivity is useful for providing further insight. If production labor stays constant, then

$$\dot{c}_j = \dot{y}_j = \dot{A}_{p,j} \tag{8}$$

Note that $A_{p,t}$ essentially reflects the opportunity cost for time to be used in the transaction technology versus the production technology, and equals the real spot wage $w_{p,t}$. More generally (and beyond the model at hand), it is the equality between the growth of that opportunity cost or the real spot wage and the growth rate of output that is needed. We are considering off-balanced-growth equilibria, however: note e.g. the potential change in nominal interest rates. Therefore, the theory would typically not imply constancy of labor in production or equality of growth rates between wages and output. Empirically, there surely is always some discrepancy between these two growth rates, and it is due to a variety of factors. The long-run shift between production labor and transaction time surely is a rather minor driving force here, though. Therefore, for the purpose of the exercise at hand, we feel comfortable employing (8) for the empirical application, even off the balanced growth path.

Balanced growth Along a balanced growth path the nominal interest rate would be constant, $\dot{i}_j = 0$. Equation (7) and (8) would imply

$$(1-b)\dot{m}_j = (1+a)\dot{y}_j - a\dot{A}_{s,j}. \tag{9}$$

On the other hand, (1) and (2) together with the balanced growth condition $s_t \equiv s$ implies

$$b\dot{m}_j = a\dot{A}_{s,j} - a\dot{y}_j \tag{10}$$

These two equations together now imply the following result:

Theorem 1 *To be consistent with balanced growth, the rate of technological progress in the transaction technology must satisfy*

$$\dot{A}_s = \frac{a+b}{a}\dot{A}_p \tag{11}$$

In particular, in the case of $a + b = 0$ (e.g. Baumol-Tobin, Miller-Orr),

$$\dot{A}_s = 0 \tag{12}$$

In other words, and for the Baumol-Tobin as well as the Miller-Orr specification, the theory above implies that there cannot be technological progress in the transactions technology in the long run along the balanced growth path. Also note, that as consequence of (11), we have

$$\dot{m} = \dot{y}. \tag{13}$$

Off the balanced growth path For our exercise, the growth rates are "in sample" and not long run. Indeed, in the sample, there may have been a permanent level-shift in the transaction technology parameter that may differ across countries, which would be incompatible with balanced growth under the Baumol-Tobin or Miller-Orr specifications. We still assume that $\dot{y}_j = \dot{A}_{p,j}$, but do not impose that $\dot{i}_j = 0$ and $\dot{A}_{s,j} = \frac{a+b}{a}\dot{A}_{p,j}$, which would be needed for balanced growth.

It may be hard to measure $A_{s,t}$ directly. For example, one could consider to follow the detailed analysis in Attanasio, Guiso and Jappelli (2002). Instead, we shall proceed by assuming that the cross-country level shift can be captured by a random fixed effect,

$$\frac{a}{1-b}\dot{A}_{s,j} = \epsilon_j, \tag{14}$$

where we assume, and this is a strong assumption, that ϵ_j is independent of $\dot{y}_j$ and $\dot{i}_j$. With this assumption as well as with (8), we finally obtain the empirical specification

$$\dot{m}_j = \gamma\dot{y}_j - \alpha\dot{i}_j - \epsilon_j, \tag{15}$$

which we shall estimate with ordinary least squares, where

$$\gamma = \frac{1+a}{1-b}, \; \alpha = \frac{1}{1-b}. \tag{16}$$

Equivalently,

$$\dot{M}_j - \dot{P}_j = \frac{1+a}{1-b}\dot{y}_j - \frac{1}{1-b}\dot{i}_j - \epsilon_j. \tag{17}$$

Note that $\dot{P}_j$ is essentially the in-sample inflation rate,

$$\pi_j = \frac{1}{T}\sum_{t=1}^{T}\frac{P_t - P_{t-1}}{P_{t-1}} \tag{18}$$

of country j: we therefore call $\dot{P}_j$ "inflation" in our figures.

One can now either proceed to estimate (15), noting that the two structural parameters a and b are identified per (16), or one can directly measure the fit of that equation for given specifications of the transaction technology. In particular, we note that

$$\dot{M}_j - \dot{P}_j = \dot{y}_j - \frac{1}{2}\dot{i}_j - \epsilon_j \tag{19}$$

for the Baumol-Tobin specification and

$$\dot{M}_j - \dot{P}_j = \dot{y}_j - \frac{1}{3}\dot{i}_j - \epsilon_j \tag{20}$$

for the Miller-Orr specification.

As a final note and as a consequence of Theorem 1, note that the Baumol-Tobin specification , with $a = 1$ and $b = -1$, would have implied

$$\dot{M}_j - \dot{P}_j = -\frac{1}{2}\dot{i}_j + \frac{1}{2}\dot{y}_j + \frac{1}{2}\dot{A}_{p,j} - \frac{1}{2}\dot{A}_{s,j} \tag{21}$$

i.e., involve a coefficient of 0.5 on $\dot{y}_j$. This would be in contrast to typical formulations of the quantity theory. In particular, Lucas (2000) proposes to use the relationship

$$\log\left(\frac{M_t}{P_t Y_t^{\gamma}}\right) = \text{const} - \alpha \log i_t \tag{22}$$

with $\gamma = 1$ and $\alpha = 0.5$. While this parameter choice would appear to be inconsistent with (21), it actually is consistent with equation (19), thereby resolving this apparent paradox. It is because $\dot{y}_j = \dot{A}_{p,j}$ under balanced growth that the income elasticity is one rather than one half. The unit elasticity of the money demand to output is a feature of long run growth.

Our specification in (15) like the specification in (22) is "log-log" in contrast to some semi-log specifications, see the discussion in Bailey (1956). This difference in specifications has implications for calculating the welfare costs of inflation (see also Correia and Teles (1999), Dutta and Kapur (1998), Mulligan and Sala-i-Martin (1992, 1998)). We follow Lucas (2000), because the log-log specification is implied by our theoretical derivation above and because the fit of the semi-log is only negligibly better than the log-log. Details are available in the online appendix.

3.1 Data and Results

For our investigation, we have chosen 1970, 1990 and 2005 for all OECD countries, drawing on statistics of the IMF as well as the OECD and other sources. We excluded countries with average inflation above 12 percent, transition countries and countries with missing data. The reason not to include data after 2005 is not to include the zero bound episode in the aftermath of the financial crisis. At zero interest rates, money and bonds are perfect substitutes and the demand for money is not uniquely pinned down. Put differently, if we are to find changes in the relationship between money growth and inflation after 1990, they will not be due to zero bound considerations. We used short rates as well as M1 for all countries. We also experimented with M2 and M3, as well as long rates: the data problems there were generally greater, but preliminary results looked rather similar to the results documented here. More information on the data as well as explanations for the short codes used to denote countries are in appendix A.

Since both the selection of countries as well as the sample differs from those in the previous figures, figure 3 shows a version of figure 2 for this updated data set. Figure 4 "corrects" the money growth rate by subtracting the GDP growth rate. The points scatter loosely below the 45-degree line. Figure 5 removes the yield effect with the coefficient of 0.5 on the interest rate change as suggested by the Baumol-Tobin specification (19), as well as suggested by Lucas (2000). The correction with the yield considerably improves the fit, shifting the data points upwards, that now line up nicely along the 45-degree line. Information about the quality of fit, by calculating the variances of ϵ_i is in table 1, including results for subsamples, see section 4.

Figure 6 contains the result for the Miller-Orr specification, while Figure 7 finally contains the result of estimating (15) per ordinary least squares. The results from this regression are in table 2, including results for subsamples, see section 4. The estimated coefficients are between the Baumol-Tobin and Miller-Orr values. For the whole sample, all three specifications provide essentially the same quality of fit. We have also calculated the regression results, imposing $\gamma = 1$, as is implied by our two benchmark transaction technology specifications: the results are in table 2.

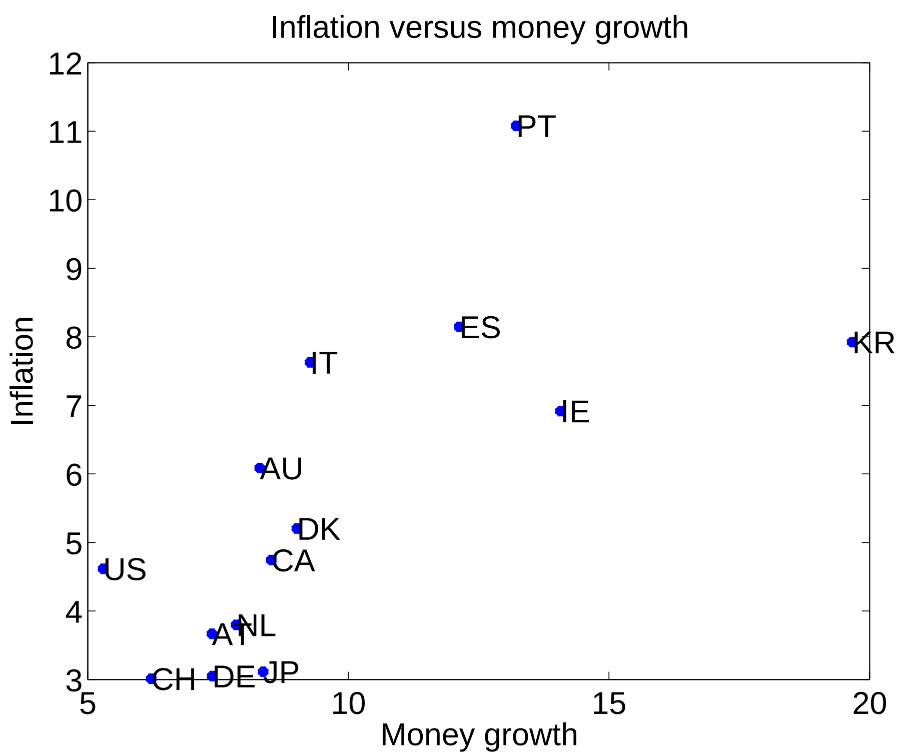

Figure 3: *Money versus inflation, 1970-2005.*

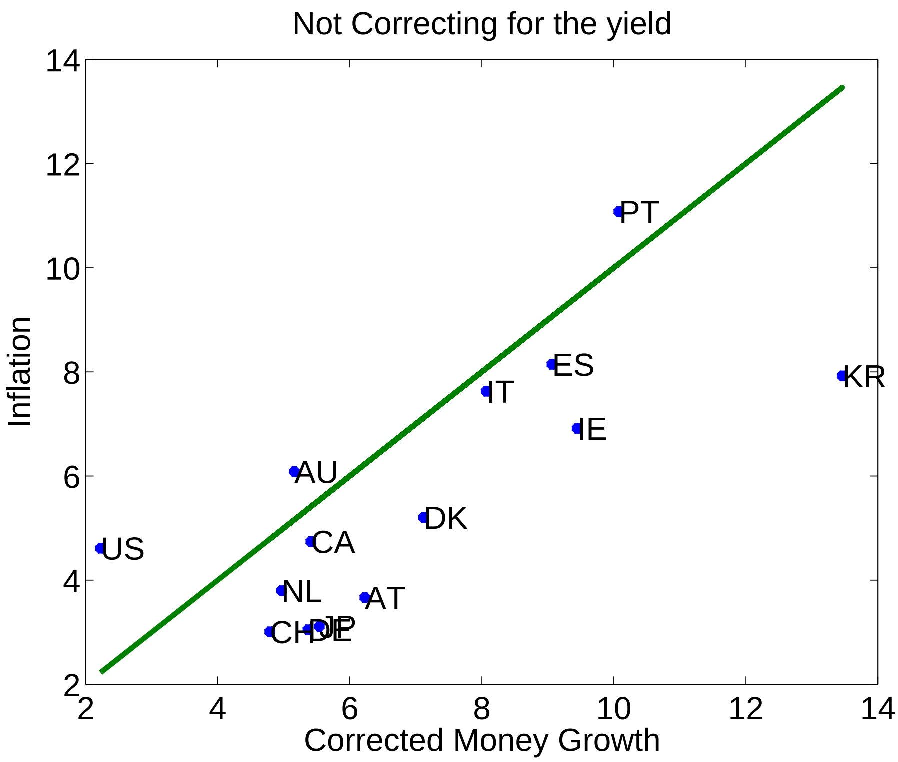

Figure 4: *Corrected monetary growth rate here is monetary growth minus real GDP growth. Inflation is plotted vis-a-vis corrected monetary growth rate. The points scatter loosely around, but mostly below the 45-degree line.*

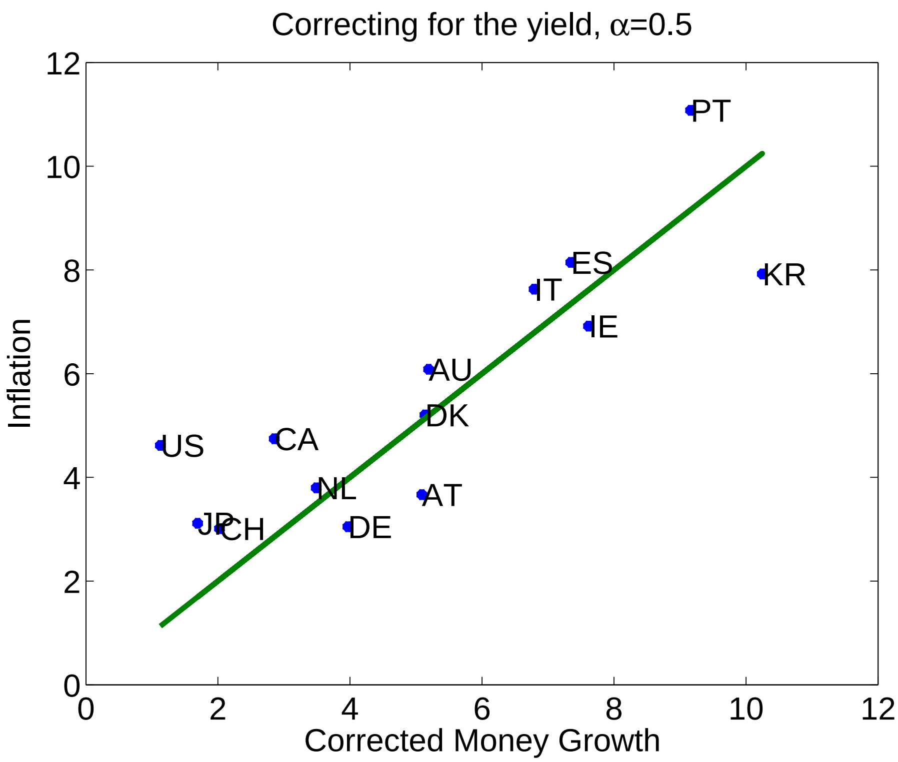

Figure 5: *Baumol-Tobin: corrected monetary growth rate here is monetary growth minus real GDP growth plus the differences in log-government bond yields, divided by two, following 19 as well as the suggestion of Lucas (2000). The correction with the yield improves the fit to the 45-degree line.*

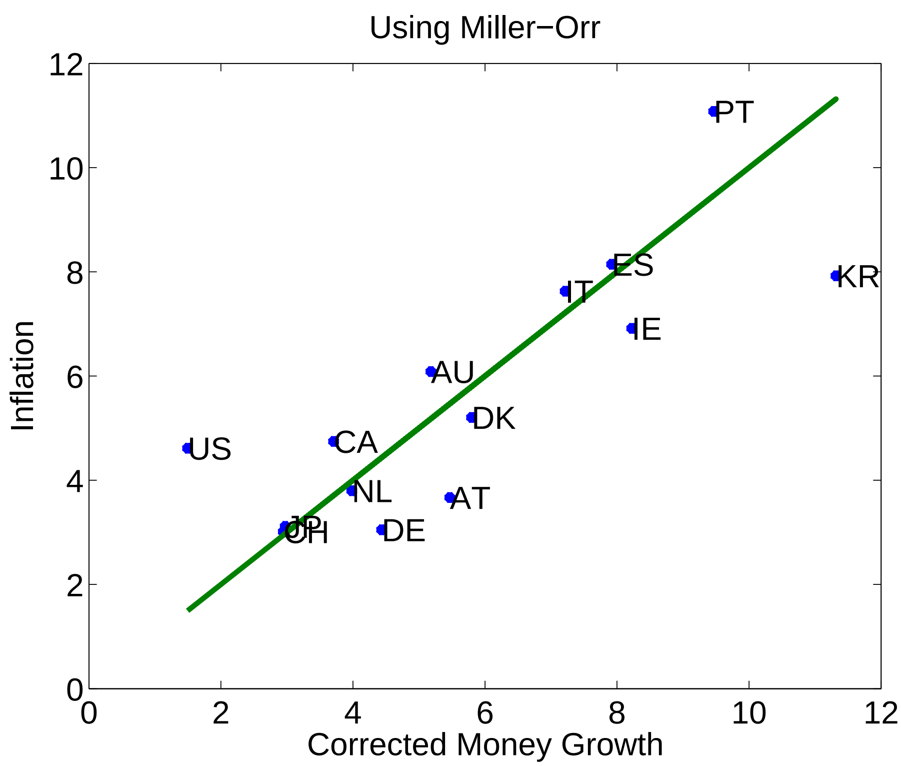

Figure 6: *Corrected monetary growth rate here is monetary growth minus real GDP growth plus the differences in log-government bond yields, divided by three, capturing the transactions technology model due to Miller and Orr (1966). The fit around the 45 degree line is similar to the Baumol-Tobin specification.*

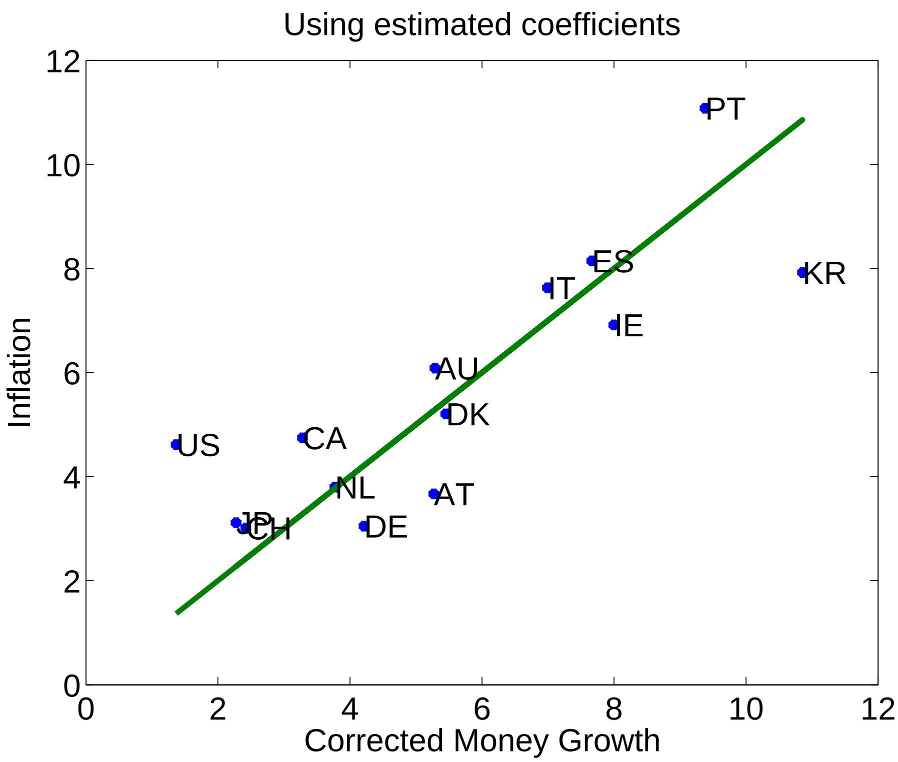

Figure 7: *Corrected monetary growth rate here is monetary growth minus estimated coefficients on real GDP growth as well as on the differences in short-term interest rates (no constant in regression). The fit of the 45 degree line is similar to the theoretical specifications.*

Period	GDP-corrected (w/o yield corr.)	Baumol-Tobin, (yield-corr.)	Miller-Orr	esti-mated
1970-2005	76	35	35	33
1970-1990	53	31	35	28
1990-2005	188	95	62	50

Table 1: Sum-of-squared of residual in percent of variance of real money growth (read: $1-R^2$ in percent. Note: residual may have nonzero mean.). Above 100, the additional variables hurt, rather than explain the variance in real money growth. Regressions does not include a constant.

	γ estim.			$\gamma = 1$	
Period	α	γ	R^2	α	R^2
Benchmark:	1/3..1/2	1		1/3..1/2	
1970-2005	0.44	0.97	0.67	0.42	0.67
	(0.19)	(0.24)		(0.10)	
1970-1990	0.62	1.17	0.72	0.59	0.70
	(0.18)	(0.15)		(0.19)	
1990-2005	0.20	1.62	0.50	0.33	0.38
	(0.08)	(0.28)		(0.05)	

Table 2: Regression results, no constant, without and with imposing $\gamma = 1$. R^2 is calculated as 1 minus (sum-of-squared of residuals divided by variance of real money growth). Since there is no constant as regressor, the residual may have nonzero mean. Second line: standard deviations.

4 Subsamples

4.1 Loss of money demand stability in the 90s...

We now draw attention to the results for the second subsample, for the data after 1990. While the fit for all specifications in the first half of the sample is essentially as good as for the whole sample, the fit becomes worse for the second half of the sample, as table tab:reg shows. The Miller-Orr specification as well as the estimated specification now fit clearly better than the Baumol-Tobin specification.

The figures provide an even more revealing story. Figure 8 shows the results for the Miller-Orr specification for the first part of the sample, and figures 9 and 10 show the results, respectively for Miller-Orr and the estimated coefficients, for the second

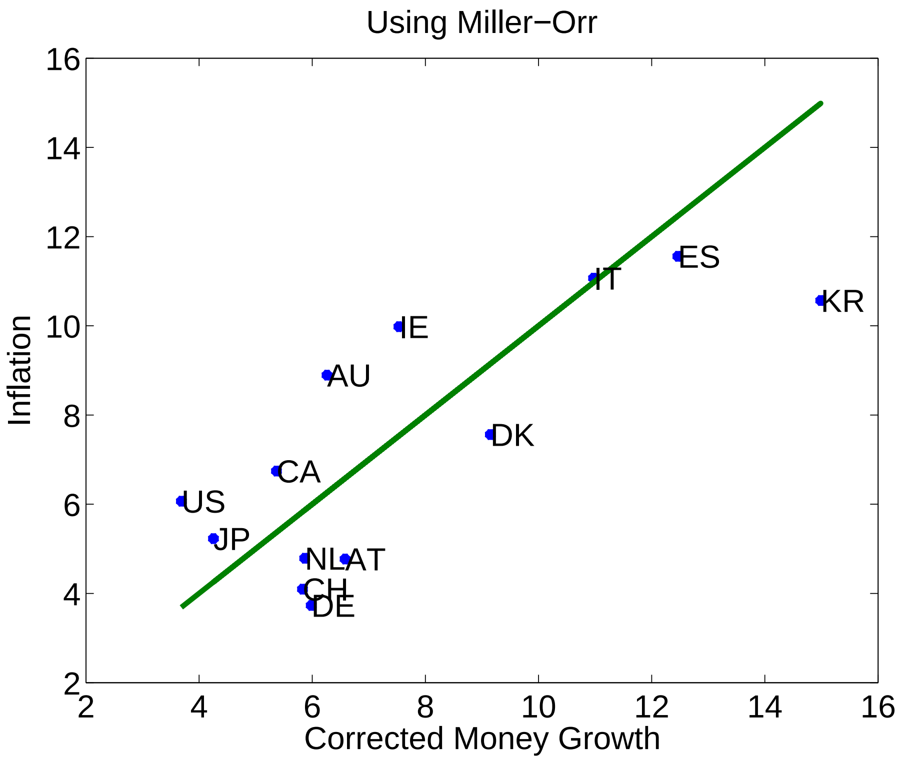

Figure 8: *The relation between inflation and corrected money growth according to the Miller-Orr specification for the first part of the sample, which is 1970-1990. All three money demand specifications (Baumol-Tobin, Miller-Orr, estimated) yield rather similar figures, which in turn are rather similar to the full-sample figure.*

subsample.

We want to stress three points here. The first is that the estimated interest elasticity is considerably lower for the second part of the sample. This result that we obtain in the cross section has been observed in the literature on the stability of the money demand using time series data, as for example in Ireland (2009). Part of the explanation for the low elasticity is the increasing role of money substitutes that are not included in M1, as argued by Teles and Zhou (2005) and, recently also by Lucas and Nicolini (2013).

The second result is the poor fit of a money demand relationship in the second part of the sample. The data shows a high variability of both the inflation-money-growth difference as well as the log-interest-rate regressor in that subsample compared to the full sample.

The third result is that inflation is nearly the same across the countries, despite

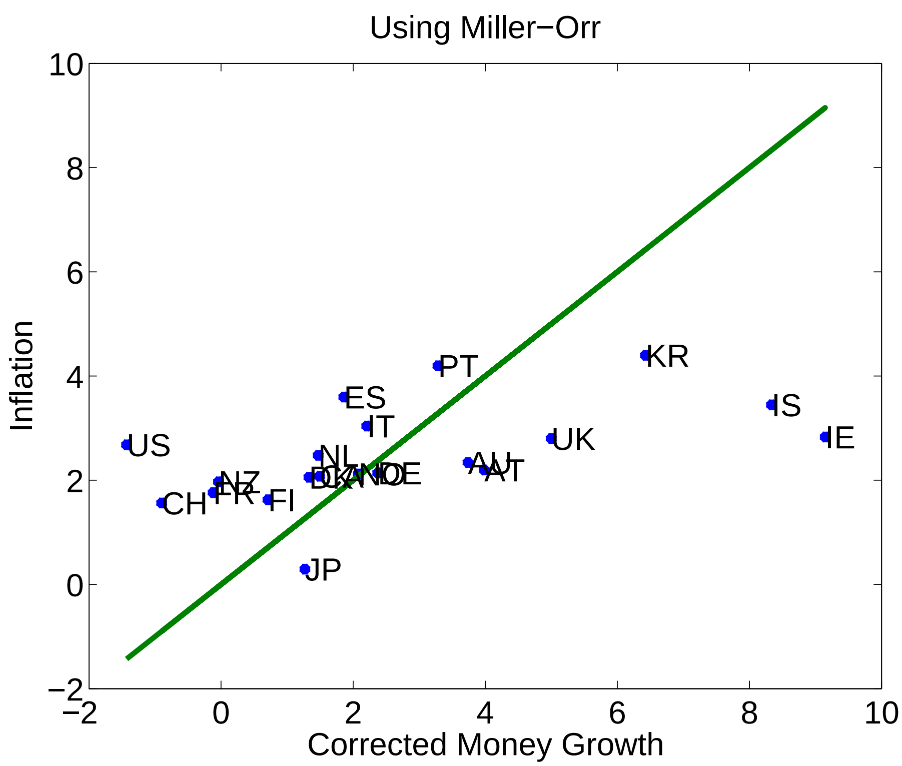

Figure 9: *The relation between inflation and corrected money growth according to the Miller-Orr specification for the second part of the sample, which is 1990-2005. Essentially, the data now form a flat line around what appears to be a common inflation target. The Baumol-Tobin specification yields a similar figure for this episode.*

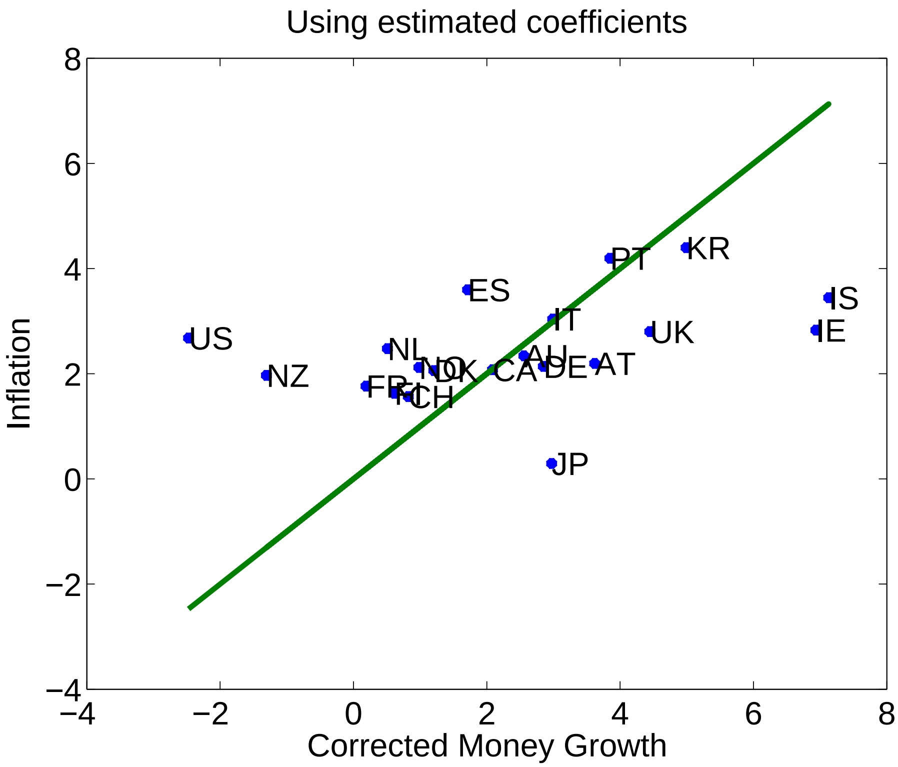

Figure 10: *The relation between inflation and corrected money growth for the second part of the sample, i.e., 1990-2005, using a regression of the difference between inflation and money growth on the change of the log yields as well as GDP growth (no constant in regression). The regression does not alter the insight from the Miller-Orr specification: the data clusters around a flat "inflation-target" line.*

variability in (corrected) money growth rates. Put differently, there is no visible one-to-one relationship between inflation and monetary growth for the second part of the sample. Examining figures 9 and 10 makes this point in a striking way. Our explanation is as follows. Central banks have increasingly focused on achieving a particular target inflation rate. Apparently, they are successful in achieving this goal. Central banks choose a monetary growth rate that offsets shocks to the money-inflation relationship, in order to achieve their common target. There is considerable residual dispersion in money growth, probably due to differing experiences in deregulation and innovation in transactions technologies.

Interestingly, the recent work of Sargent and Surico (2011) makes a similar point using the time series evidence for the US, as in Lucas (1988). They also argue that part of difficulty in establishing a relationship between money and prices in the US in the more recent data is due to the policy of inflation targeting. This has reduced the intertemporal variability of inflation, making it harder to find a one-for-one low frequency relationship between money and prices in the US time series.

5 Conclusions

A cross section of long term averages for inflation and money growth plotted one against the other as in e. g. Mc Candless and Weber (1995) has those averages line up nicely along a 45 degree line. In his Nobel lecture Lucas (1996) claims that there is no sharper evidence in monetary economics.[2] But the evidence is by no means as sharp when the sample excludes countres with very high inflation. For countries with moderate inflation, the overwhelming evidence is just not there.

We use a cross section of countries with moderate inflation to reestablish the one-to-one close relationship between long term inflation and money growth. For that we need to take into account the effect of long term movements in nominal interest rates, according to elasticities that match the ones suggested by both theory on transactions technology, as in Baumol (1952), Tobin (1956), Miller-Orr (1966), and estimation using time series data for the US and other countries, as in Lucas (1980, 2000), Ireland (2009), Lucas and Nicolini (2013). Once we take into account

[2]"(...)Central bankers and even some monetary economists talk knowledgeably of using high interest rates to control inflation, but I know of no evidence from even one economy linking these variables in a useful way, let alone evidence as sharp as that displayed in figure 1. The kind of monetary neutrality shown in this figure needs to be a central feature of any monetary or macroeconomic theory that claims empirical seriousness.(...)"

the effect of movements in interest rates according to the Baumol-Tobin or Miller-Orr elasticities for the whole sample, between 1970 and 2005, what appeared to be a random scatter of points is now a 45 degree line through the origin.[3]

The data is split into two subsamples with the data break in 1990. The date is chosen to approximately date the generalized convergence to low inflation, as well as changes in regulation of financial institutions and financial inovation. We find that for this later part of the sample the fit is worse, possibly because of greater dispersion in deregulation and technology adoption, and the interest elasticity is lower. Neither of these results is surprising. What is somewhat surprising is that the interest elasticity in the cross section is so close to the elasticities found by others using the time series for the US, as in e. g. Ireland (2009) or Lucas and Nicolini (2013).

One interesting feature of the data in the later sample is that the variability of inflation is considerably reduced. The points seem to form an horizontal line at low inflation. With low variability of inflation it is not easy to find a one to one relationship between inflation and money growth. This same difficulty was met by Sargent and Surico (2009) in their review of Lucas (1980). They also find that inflation targeting around low inflation, reducing its variability, made it hard to extract from the more recent US data the one-to-one relationship that Lucas (1980) found. Our results here complement their findings, using a cross-country analysis compared to their US time series analysis.

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A Data Description

The countries included in the regressions starts from the list of OECD countries, excluding Chile, Israel, Mexico and Turkey, due to high inflation during relevant parts of the sample. We furthermore excluded Luxembourg (as it is a financial hub in small country) and the transition countries (since there is no useful data for the purpose of the analysis here from 1970 and 1990). For all other countries, we attempted to obtain as much reliable data as possible, dropping Belgium, Greece, and Sweden due to missing data. In the end, 20 countries remain in the sample for at least part of the calculations. Table 3 lists the country codes used and table 4 lists the values of the data, with modest precision. An Excel file containing all the data as well detailed remarks regarding sources and corrections is available as part of an online appendix to the paper. Likewise, the MATLAB programs that perform all the calculations and produce the graphs as part of an online appendix to the paper.

An original version of the data used was collected by Jan Auerbach, an undergraduate RA in Berlin 2006, using EcoWin, a commercial data base, which was available and existence then. The EcoWin data in turn was mostly based on data available from the International Financial Statistics of the IMF, thus providing reasonable comparability across countries. Ding Xuan, an undergraduate RA in Chicago 2012, corrected a few entries, using IMF and World Bank Data. A number of further issues then were dealt with by the authors. Euro zone countries do not have an independent series for M1, but data for their contribution to M1 can be found, often per tradingeconomics.com . For Germany, the M1 as well as the real GDP series was "spliced" across unification, per setting 1990 = 100 for real GDP, and relating 1970 to 1990 in West Germany as well as 2005 to 1990 (real GDP: 1991, set at 102) for all of Germany. Interest rate data and money supply data for 1970 and several individual countries was obtained on a case-by-case basis, typically per data provided by their central banks or the national statistical office. Since the paper at hand focusses on prices, M1, real GDP and short-term interest rates, the data regarding M2, M3 and long-term rates would need further corrections before full use, but appears to be sufficient to provide a "first pass" at the results.

Code	Country
AU	Australia
DK	Denmark
DE	Germany
FI	Finland
FR	France
IE	Ireland
IS	Iceland
IT	Italy
JP	Japan
CA	Canada
KR	S.Korea
NZ	New Zealand
NL	Netherlands
NO	Norway
AT	Austria
PT	Portugal
CH	Switzerland
ES	Spain
UK	United Kingdom
US	US

Table 3: Country Codes

	P			M1			rGDP			r		
	70	90	05	70	90	05	70	90	05	70	90	05
AU	18	106	151	10	45	179	304	554	911	5.4	14.2	5.5
DK	18	81	110	27	244	644	55	77	107	9.0	8.5	2.3
DE	38	80	110	21	100	275	60	100	121	5.4	8.1	2.0
FI	14	78	100	-1	21	50	70	109	150	7.0	8.5	2.3
FR	17	77	100	-1	249	524	91	120	155	8.9	10.2	2.3
IE	10	74	113	12	100	1670	49	100	246	8.1	11.5	2.3
IS	0	73	122	0	33	228	-1	531	834	5.3	21.0	10.3
IT	9	80	127	12	100	298	81	102	123	5.5	12.5	2.3
JP	34	96	100	21	120	399	40	92	107	4.0	3.6	0.3
CA	21	82	112	9	42	185	39	77	116	4.7	9.9	0.8
KR	7	61	118	0	41	305	56	263	493	19.0	7.0	2.0
NZ	9	84	113	-1	11	22	78	80	129	-1.0	13.8	6.5
NL	30	78	113	21	100	326	356	577	976	6.9	9.2	2.5
NO	17	79	109	-1	187	552	75	104	166	4.5	10.5	4.3
AT	31	80	111	27	100	358	208	225	311	5.0	6.5	2.3
PT	2	62	117	4	100	444	42	92	126	4.2	16.9	2.2
CH	36	83	104	33	119	290	266	374	438	4.3	8.3	0.6
ES	7	68	117	5	100	372	253	478	739	8.2	15.0	2.5
UK	11	74	113	-1	178	758	52	81	117	7.9	12.1	4.4
US	23	76	113	21	82	137	377	711	1105	7.6	8.1	3.5

Table 4: Data used. An entry "−1' or "−1.0' indicates missing data, whereas 0 indicates a small number, which was round down to zero in this table, but not in the calculations.