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Pedro Teles and Harald Uhlig

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Pedro Teles, Banco de Portugal, Universidade Catolica Portuguesa and CEPR
Harald Uhlig, University of Chicago, Bundesbank, CentER, NBER and CEPR

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Centre for Economic Policy Research
53–56 Gt Sutton St, London EC1V 0DG, UK
Tel: (44 20) 7183 8801, Fax: (44 20) 7183 8820
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

Is Quantity Theory Still Alive?*

This paper investigates whether the quantity theory of money is still alive. We argue that it is, but that the slippage is not negligible. For countries with low inflation, the relationship between average inflation and the growth rate of money is tenuous at best. A correction for variation in output growth and the opportunity cost of money, using theory implied elasticities, helps explain the slippage. For the period since 1990, inflation targeting at low rates of inflation makes it harder to establish the long run relationship between monetary growth and inflation.

JEL Classification: E31, E40, E41 and E52
Keywords: inflation, money demand, quantity theory of money

Pedro Teles
Departamento de Estudos Economicos
Banco de Portugal
R, Francisco Ribeiro, n. 2
P-1150 Lisboa
PORTUGAL

Email: pteles@fcee.ucp.pt

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Harald Uhlig
Department of Economics
University of Chicago
1126 East 59th Street
Chicago, IL 60637
USA

Email: huhlig@uchicago.edu

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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 and re-investigates the relationship between monetary growth and inflation. To do so, we provide a series of graphs. For countries of moderate inflation, it turns out that the relationship is tenuous at best or even nonexistent. We investigate whether this relationship can be improved upon by taking into account the growth rate of real GDP, as quantity theory would suggest one should: however, it turns out not to help much. Additional mileage can be obtained by including a yield effect. On theoretical grounds, 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 recently 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 for a selected set of countries, for which bond yield data was available, we demonstrate that the fit indeed markedly improves. It can furthermore be improved upon, if the relationship suggested by Lucas is modified to take into account the different elasticities following Miller and Orr (1966). Nonetheless, the slippage is still considerable and of the order of plus or minus two percent in the average long run inflation rate for several countries. We finally obtain a practically perfect relationship, if we use T-bill rates rather than long-term government bond yields, and estimate rather than pick the coefficients on real GDP growth and on the yield.

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). Among newer cross-country studies on inflation, Assenmacher-Wesche and Gerlach (2006) find a unit relationship between money growth and inflation across several countries, and Kwon, McFarlane and Robinson (2006) emphasize the importance of public debt in triggering inflation.

Traditionally estimated money demand equations have been under quite some debate in the 90s, as this 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). We therefore split our analysis into two parts. In the first part, we use data until the early 90s. In the second part, we include data up to 2005. 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 the relationship between average inflation and the growth rate of money. But variation across countries in average growth of money is still hard to explain. Possibly higher dispersion in regulation or financial inovation may account for part of it.

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 vexing issue of subsample instability, interpreting it as a change in monetary policy rules around 1990.

We conclude that quantity theory is still alive and provides a guide to long-term monetary policy, but that one should be cautious in over-interpreting its conclusion.

In particular, one may wonder how to make use of these relationships for e.g. the conduct of monetary policy. For example, Woodford (2006) has recently argued, that 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. While his paper builds on a "New Keynesian" framework, his logical point appears to be more general. More importantly for us and as Woodford also points out, his analysis is not inconsistent with the quantity theory investigated here. Moreover, while there may be no need to track money growth for achieving low inflation, once low inflation has sustainably been achieved in the short- and medium term, the practical question for any central bank must be, how to achieve this in the first place. Understanding the relationships between money growth and inflation may well be key for that (see also the analysis in Fischer et al, 2006).

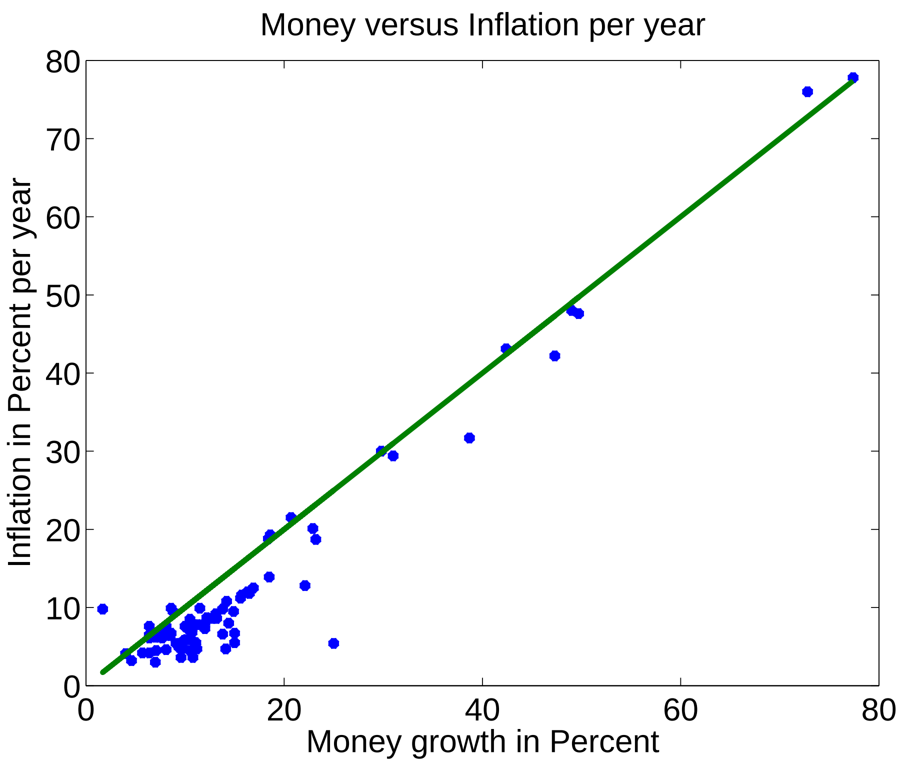

Figure 1: *This figure, which just restates figures drawn in Barro (1993, 2007), McCandless and Weber (1995) or Lucas (1996) shows the relationship between monetary growth rates and inflation in a sample of 79 countries. The data is from Barro (1993). Also drawn is the 45 degree line: it seems, that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

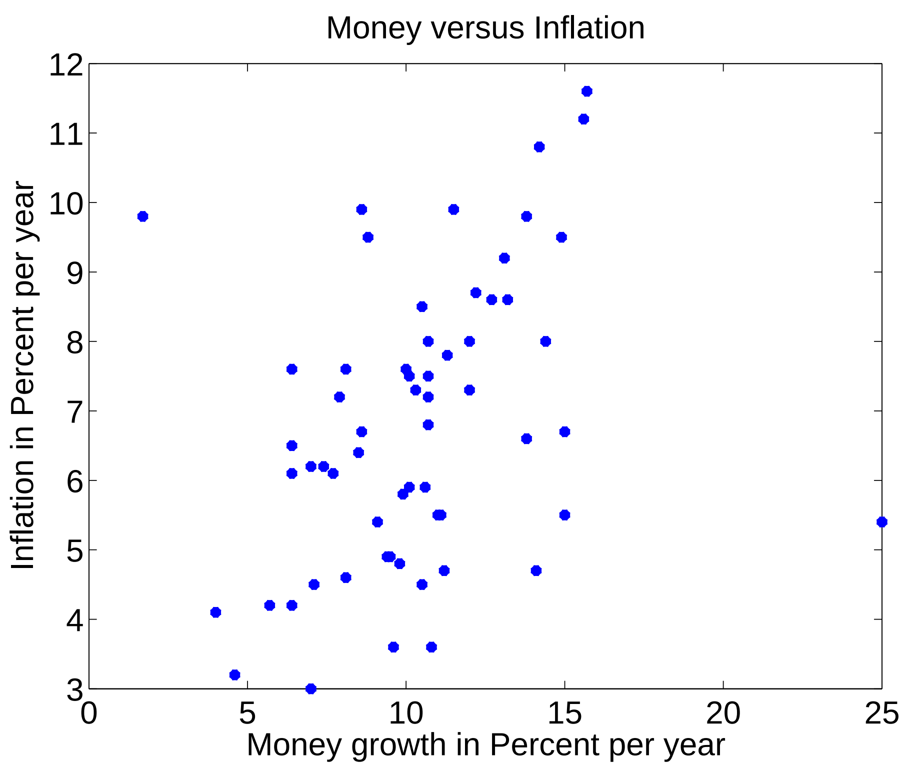

Figure 2: *This figure is the same as figure 1, but restricting attention to only those countries, whose inflation rate was below 12 percent. Instead of a tight relationship between monetary growth and inflation, one can just see a cloud.*

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: 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

A tricky issue to deal with is technical progress in both production of final goods as well as production of transaction services. 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 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 a function of required labor input per requested transaction services, given real money balances,

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

where $l(\cdot,\cdot)$ is a function of real consumption c_t and real money $m_t = M_t/P_t$. Equating labor productivity to wages, a generic maximization of a consumer would read

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

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 long run growth.

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, $c_t = y_t$, 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

$$0 = (1-b)\dot{m}_j + \dot{i}_j - a\dot{y}_j - \dot{A}_{p,j} + a\dot{A}_{s,j} \tag{7}$$

where we have disentangled A_t again into its two components. There is some debate in the literature as to whether nominal interest rates can truly be stationary and whether therefore $\dot{i}_j$ should converge to zero, as T gets very large. While (7) is correct as a statement of the relationship between the changes or growth rates of variables, given a particular sample, 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.

Along the balanced growth path, $\dot{i}_j = 0$. Equation (7) and (8) now implies

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

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*

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

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

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

For our exercise, however, the growth rates are "in sample" and not long run. Indeed and in sample, there may have been a permanent level-shift in the transaction technology parameter. 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,

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

where we assume 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

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

which we shall estimate with ordinary least squares, where

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

Equivalently,

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

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 all three structural parameters a, b, ψ are identified per (16) and perhaps proceed to a full nonlinear estimation of a, b, ψ, or one can directly measure the fit of that equation for given specifications of the transaction technology. In particular, we note that

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

for the Baumol-Tobin specification and

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

for the Miller-Orr specification.

As a final note and as a consequence of Theorem 1, note that the Baumol-Tobin specification without the productivity growth considerations would have implied

$$\dot{P}_j = \dot{M}_j - \frac{1}{2}\dot{y}_j + \frac{1}{2}\dot{i}_j + \psi + \epsilon_j \tag{21}$$

i.e., involve a coefficient of 0.5 on the growth rate of output rather than 1. 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 be inconsistent with (21), it actually is consistent with equation (19), thereby resolving this apparent paradox.

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 important consequences for calculating the welfare costs of inflation (see also Correia and Teles (1997), Chen and Imrohoroglu (1997), Dutta and Kapur (1996), Mulligan and Sala-i-Martin (1992, 1997)). We follow Lucas (2000), because the fit of the log-log specification seems to be better, and as it furthermore is implied by our theoretical derivation above.

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. A detailed table with the data sources is available from the authors upon request. We excluded the transition countries (i.e. Poland, the Slovak Republic, the Czech Republic and Hungary). We excluded Finland because of some apparent data coding problem in the price data. Finally, as above, we concentrated on countries with an average inflation rate of no more than 12 percent over any specific sample. We used short rates as well as M1 for all countries, but also tried out M2 (which often seemed to work best) as well as M3. We also tried long rates. The results were generally rather similar.

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 . Figure 5 also 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). While the countries loosely scatter around the 45-degree line in figure 5), the correction with the yield actually worsens rather than improves the fit, per essentially shifting the data points upwards. Equation (19) implies, that this shift ought to be interpreted as a general improvement of the transaction technology, i.e. a positive value for ψ. This is certainly plausible. 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. 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 3. One can see that a low elasticity on interest rates is required to fit the data, if one does not allow for technological progress in the transactions technology, but that the elasticity goes up considerably, if one allows for it. If $\gamma = 1$ is imposed, progress in the transaction technology is always estimated to be positive, but turns non-significantly negative for 1990-2005, if γ is not restricted.

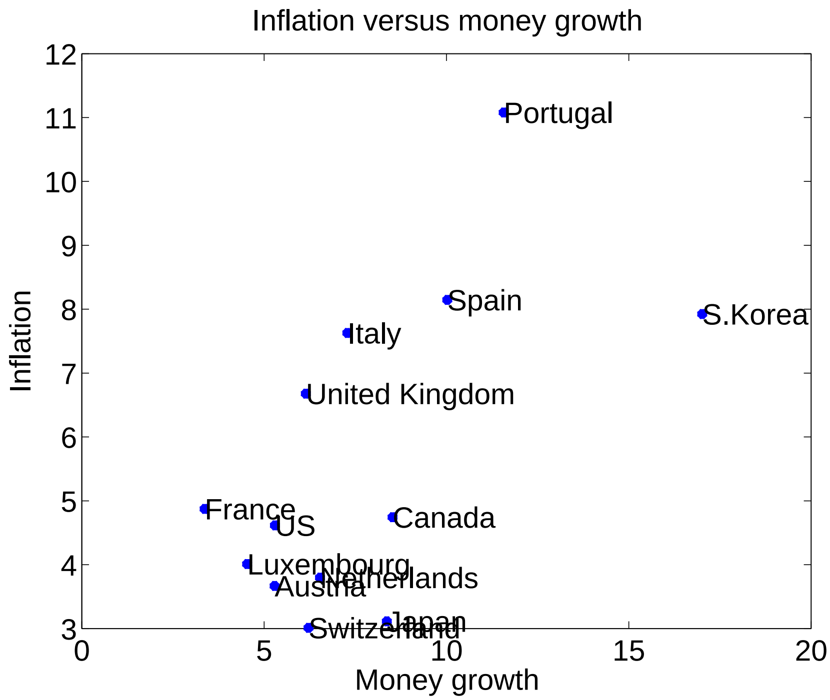

Figure 3: *Money versus inflation, 1970-2005.*

Period	Baumol-Tobin, w/o yield	Baumol-Tobin, yield-corr.	Miller-Orr	esti-mated
1970-2005	61	135	93	57
1970-1990	85	62	67	43
1990-2005	115	275	160	99

Table 1: Variance of residual in percent of variance of de-meaned inflation minus money.

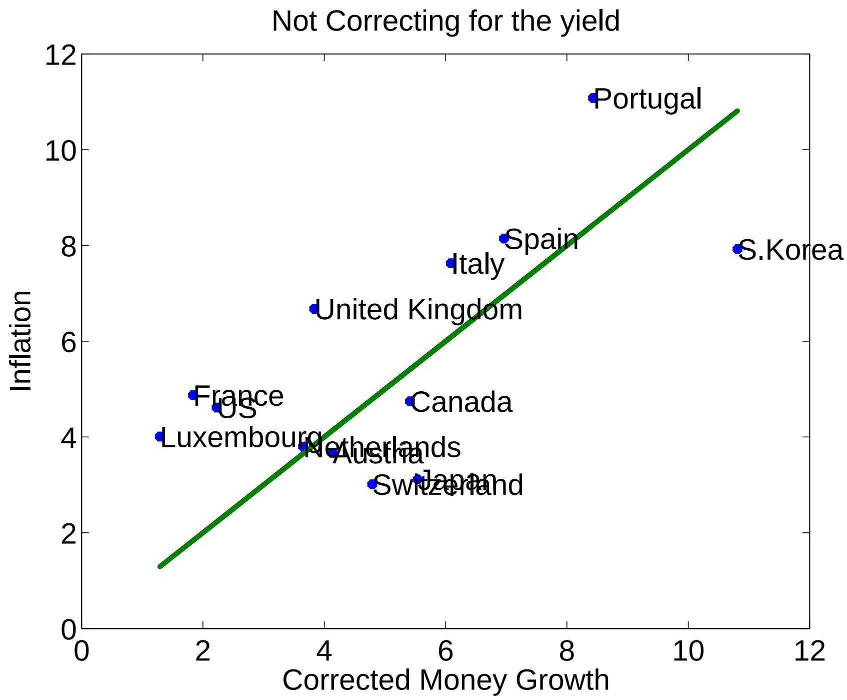

Figure 4: *Corrected monetary growth rate here is monetary growth minus real GDP growth. Inflation is plotted vis-a-vis corrected monetary growth rate. The points scatter loosely around the 45-degree line.*

Period	no const.		with const.		
	α	γ	α	γ	ψ
(Benchmark:	1/3..1/2	1	1/3..1/2	1	0)
1970-2005	0.18	0.66	0.59	1.43	4.30
	(0.21)	(0.33)	(0.19)	(0.33)	(1.19)
1970-1990	0.74	0.57	0.63	0.89	1.20
	(0.25)	(0.19)	(0.26)	(0.19)	(1.21)
1990-2005	0.17	0.69	0.09	0.41	-1.65
	(0.11)	(0.38)	(0.19)	(0.38)	(3.18)

Table 2: Regression results. Second line: standard deviations.

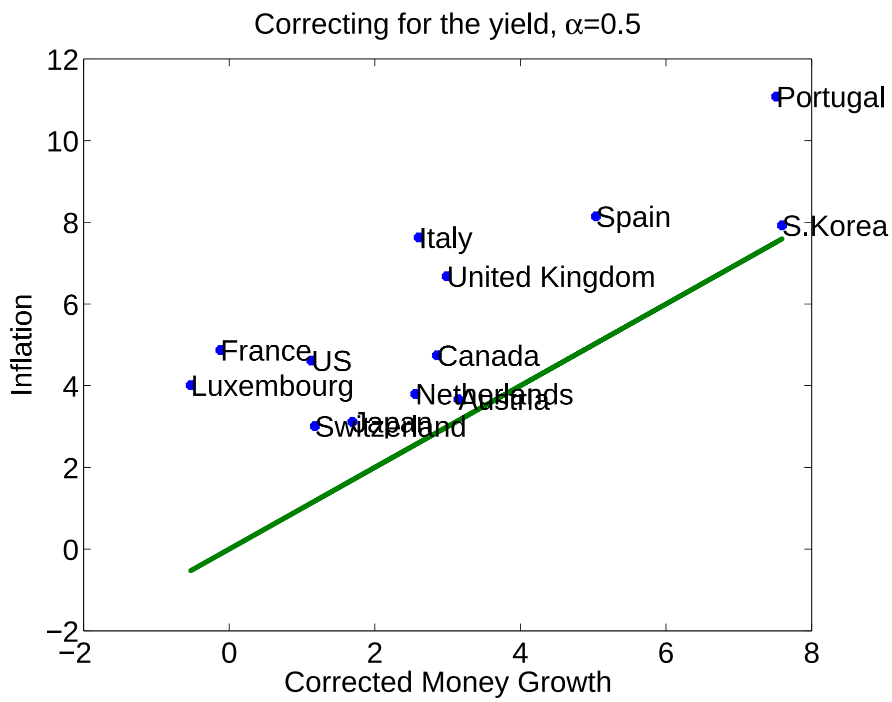

Figure 5: *Corrected monetary growth rate here is monetary growth minus real GDP growth plus the differences in log-government bond yields, divided by two, following 19 as well as the suggestion of Lucas (2000). The correction with the yield actually worsens rather than improves the fit to the 45-degree line, per essentially shifting the data points upwards. Equation (19) implies, that this shift ought to be interpreted as a general* worsening *of the transaction technology, i.e. a negative value for ψ.*

	no const.	with const.	
Period	α	α	ψ
(Benchmark:	1/3..1/2	1/3..1/2	0)
1970-2005	0.01	0.61	3.22
	(0.12)	(0.19)	(0.88)
1970-1990	0.68	0.60	1.51
	(0.25)	(0.24)	(0.60)
1990-2005	0.11	0.16	0.67
	(0.07)	(0.17)	(1.84)

Table 3: Regression results, imposing $\gamma = 1$. Second line: standard deviations.

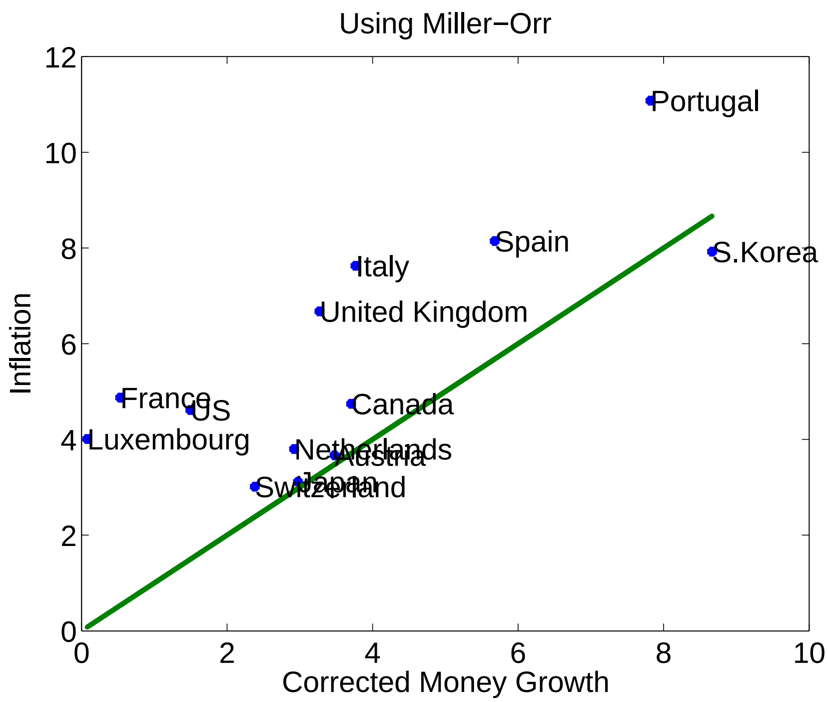

Figure 6: *Corrected monetary growth rate here is monetary growth minus real GDP growth plus the differences in log-government bond yields, divided by three, capturing the transactions technology model due to Miller and Orr (1966). The fit around the 45 degree line is improved compared to the Baumol-Tobin specification, since a lower interest elasticity provides a better fit, in the absence of mean technological progress in the transactions technology.*

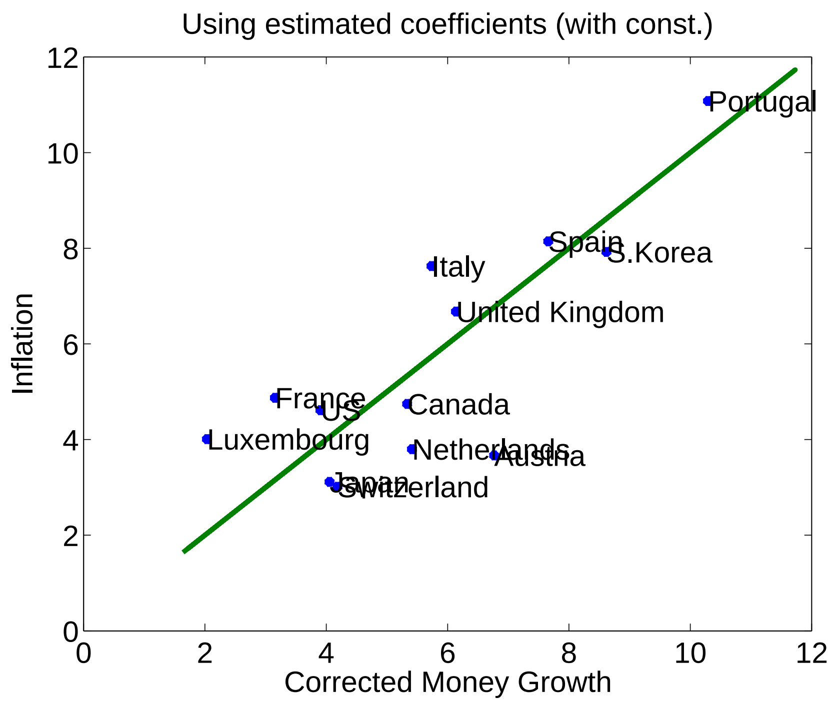

Figure 7: *Corrected monetary growth rate here is monetary growth minus estimated coefficients on real GDP growth as well as on the differences in short-term interest rates and a constant. The fit of the 45 degree line is decent.*

4 Subsamples

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

Figure 8 shows the raw correlation between inflation rates and money growth. While the top panel shows the result for the full sample, the two bottom plots show the results for the period 1970 to 1990 and for the period 1990 to 2005. Interestingly, if anything, the correlation seems to improve, when taking into account the full sample. Figures 9 to 12 provide the various corrections to money growth as outlined above.

To get some idea of the quantitative magnitude in explaining residual inflation, we have also provided table 1, showing the variance of the residual inflation in percent of the variance of the raw difference between inflation and money growth. For this comparison, note that the latter automatically "takes out" the mean, while the correct mean inflation is imposed in the theoretical specifications. This table as well as the figures show, that correcting for the yield works well for the first part of the sample. For the sample from 1990 to 2005, all theoretical specifications actually make matters worse compared to the simple de-meaned money-inflation correlation.

4.2 ... and the seed for an explanation

These results raise an important question. What is going on in the second part of this sample, i.e. since about 1990? The phenomenon that money demand functions seem to have become "less stable" recently, has been emphasized elsewhere, and has led to considerable soul searching at central banks.

We propose the following seed of an explanation. Central banks have increasingly focussed on achieving a particular target inflation rate. Apparently, they are successful in achieving this goal. There is very little dispersion in inflation, so that it is not possible to establish a relationship between inflation and monetary growth. There is considerable dispersion in money growth, probably due to differing experiences in deregulation and inovation in transactions technologies.

Assume that central banks have both perfect knowledge about $\epsilon_{j,t}$ as well choose interest rates and money growth rates as to achieve a particular target $\bar{\pi} = \Delta \log P_t$ for the inflation rate. Equation (17) then implies the solution for the money growth rate the central bank needs to choose, namely

$$\Delta \log M_{j,t} = \bar{\pi} - \alpha \Delta \log(i_{j,t}) + \gamma \Delta \log y_{j,t} + \epsilon_{j,t} \tag{23}$$

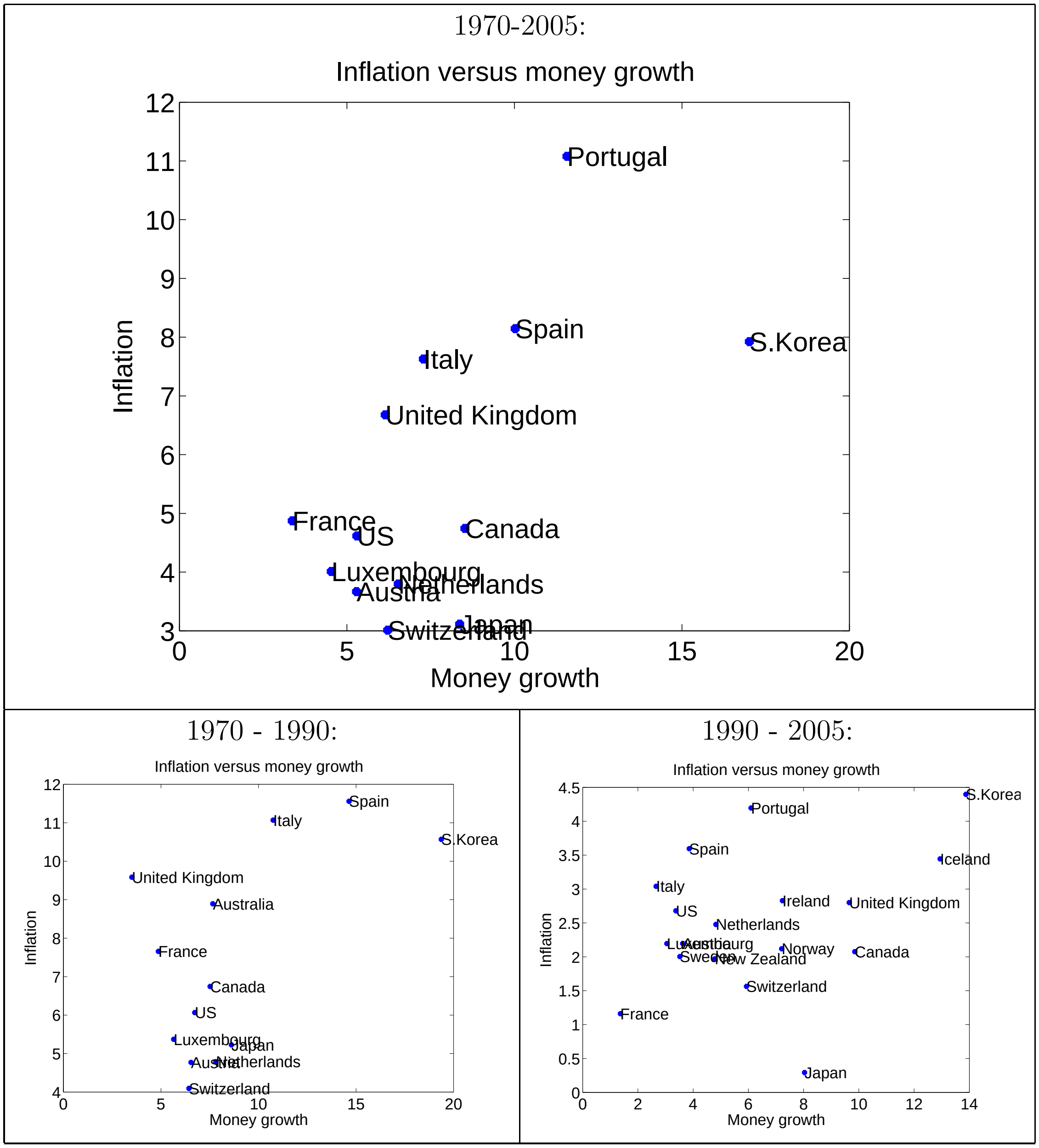

Figure 8: *The raw money-growth versus inflation scatter plots*

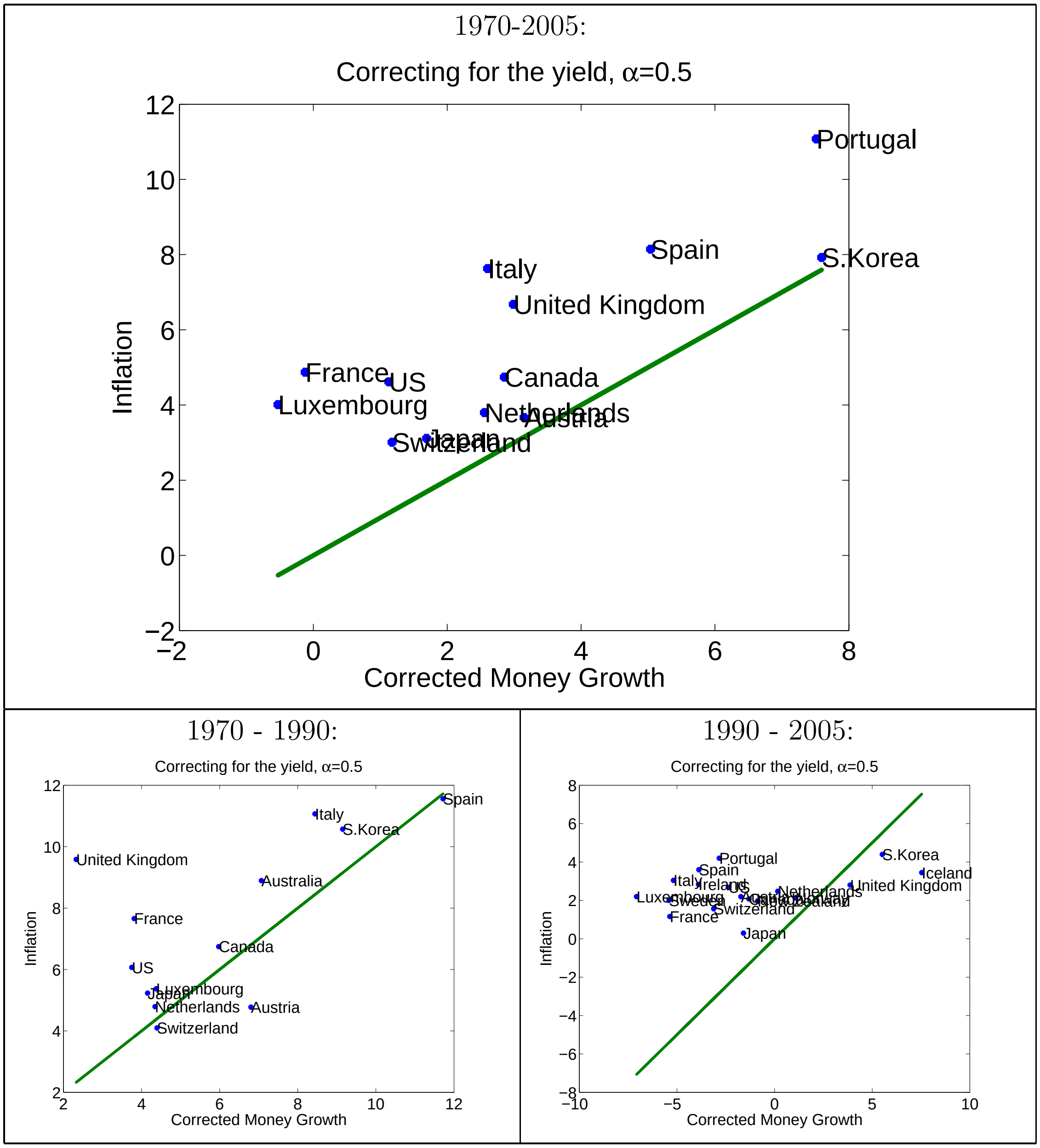

Figure 9: *Money growth corrected for GDP growth, with a coefficient of $\gamma = 1$ and corrected for the yield change.*

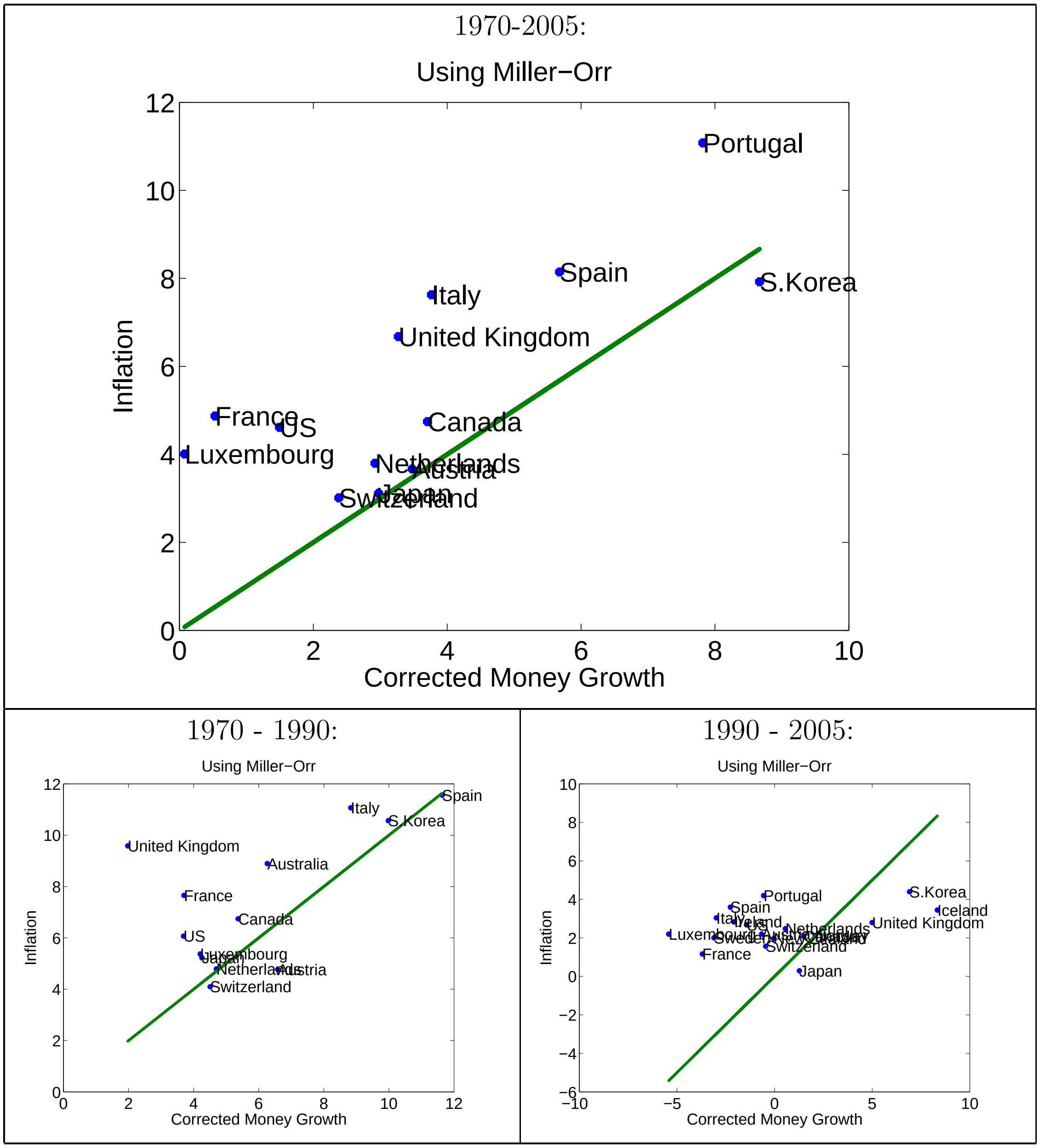

Figure 10: *Money growth corrected according to the Miller-Orr specification*

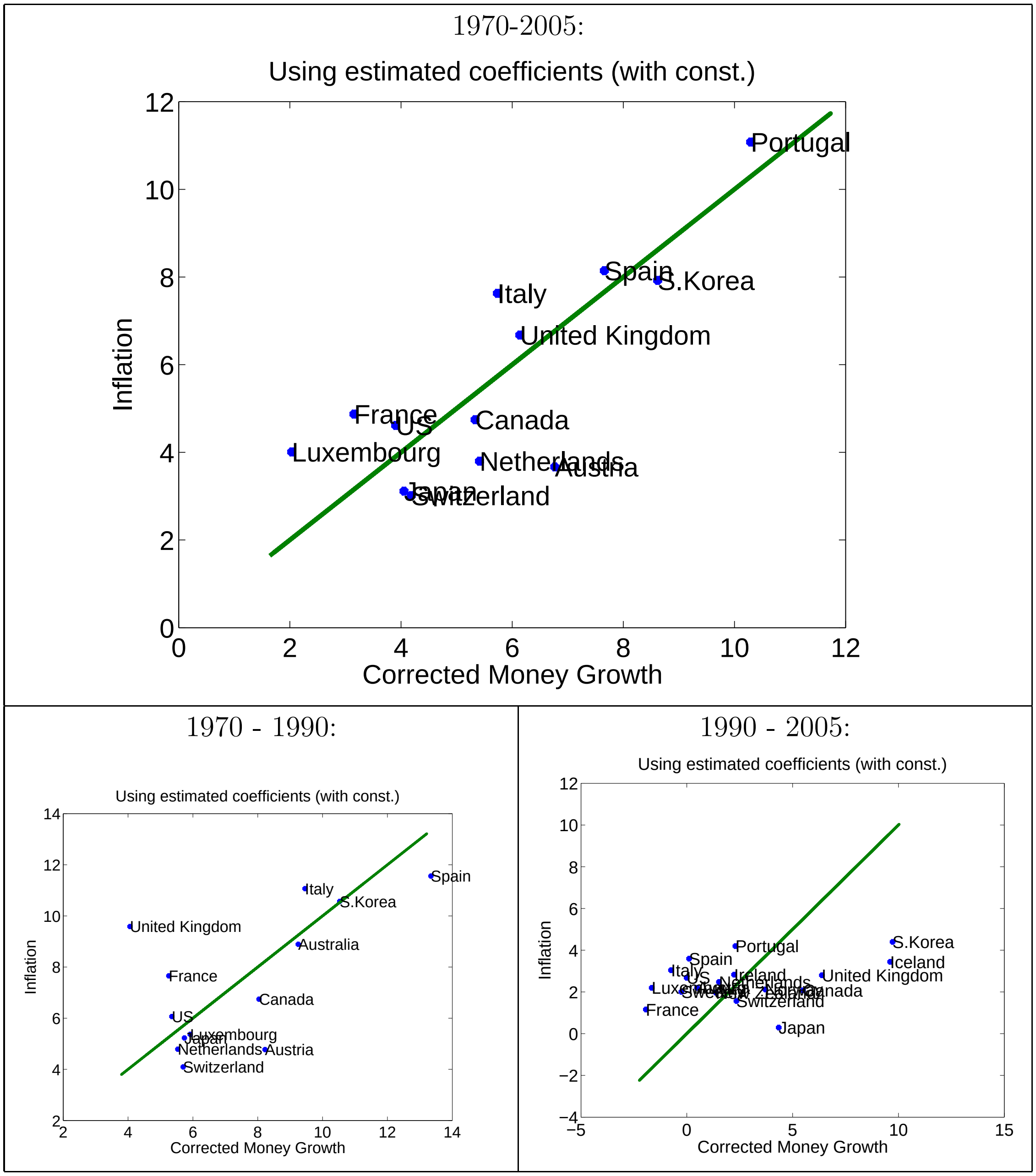

Figure 11: *Money growth corrected, using a regression of the difference between inflation and money growth on the change of the log yields as well as GDP growth (with constant in regression).*

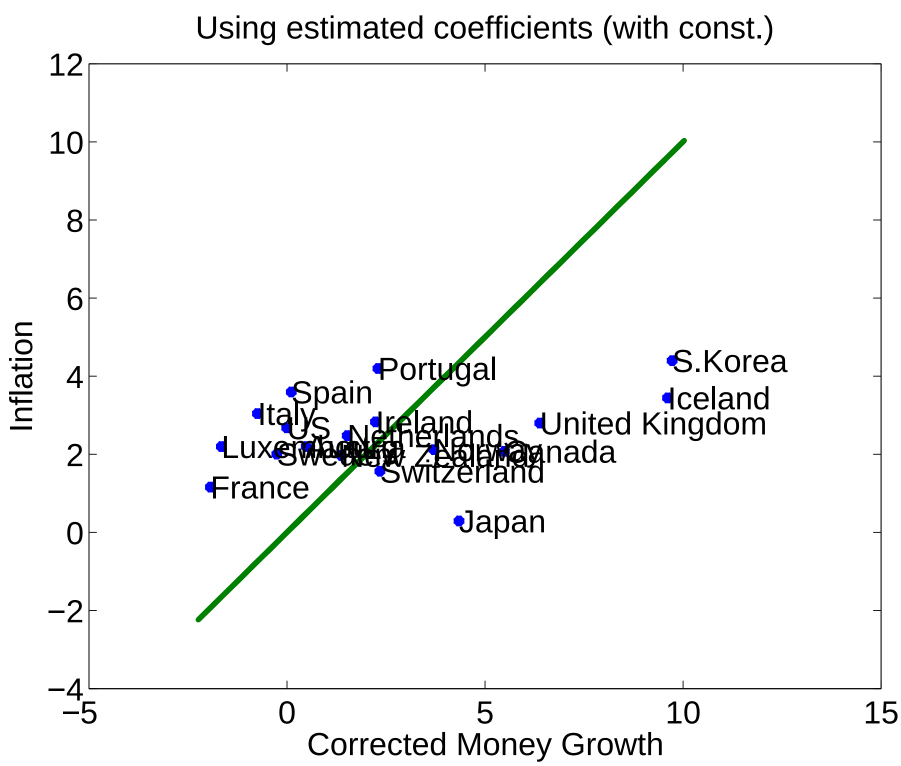

Figure 12: *The relation between inflation and corrected money growth for 1990-2005, using a egression of the difference between inflation and money growth on the change of the log yields as well as GDP growth (with constant in regression).*

or, averaging across time,

$$\dot{M}_j = \bar{\pi} - \alpha \dot{i}_j + \gamma \dot{y}_j + \epsilon_j \tag{24}$$

For low interest rates and stable inflation rates, as we now observe them in many countries, this implies that the central bank must naturally vary the money stock considerably in response to the shocks to the transactions technology. Indeed, these variations have become relatively larger in recent times compared to fluctuations in interest rates and inflation, as central banks have become more successful in stabilizing inflation at a low level.

5 Conclusions

Quantity theory is still alive, but there are some brown spots, which merit serious attention. The slippage between explained long run inflation rates and actual inflation rates can reasonably be as high as six percent, which should be considered dangerously high to base long-term monetary policy upon without taking into account more information.

In particular, for the period since 1990, we argue that success at targeting low inflation, together with greater dispersion in deregulation and technology adoption, make it harder to establish the long run relationship between inflation and monetary growth.

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