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Abstract

Using U.S. and euro area data, this paper presents a significant and proportional relationship between money growth and subsequent inflation when accounting for equilibrium velocity movements due to inflation regimes changes. These movements, driven by money demand adjustments to low-frequency Fisherian interest rate variations, are derived from consistent U.S. and euro area money demand specifications – after contradictory coexisting results are explained. Not accounting for equilibrium velocity and interest rate movements biases cross-country and time series dynamic money growth / inflation estimated relationships, and leads to the non-proportional, non-significant, and reverse causality results found in studies that include the post-1980 period. (JEL E52, E58, E41, E31)

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In the 1980s and 1990s, the consensus about the existence of a useful link between money and inflation and/or a stable money demand relationship broke down. For example, Friedman and Kuttner (1992) wrote: "[i]ncluding data from the 1980's sharply weakens the postwar time-series evidence indicating significant relationships between money (however defined) and nominal income or between money and either real income or prices separately. Focusing on data from 1970 onward destroys this evidence altogether", and further: "...before the 1980's, there was widespread agreement that fluctuations in money did contain at least potentially useful information about future income and price movements. In the 1980's, however, the empirical basis underlying that agreement disappeared." Other examples include DeLong (2000), who stated that "...the velocity of money turned unstable in the 1980s, but not in any manner simply correlated with the rate of money growth", and Mankiw (1997), who wrote: "[t]he deep recession that the United States experienced in 1982 is partly attributable to a large, unexpected, and still mostly unexplained decline in velocity".

Even though studies using data from the euro area have been relatively more supportive of monetary aggregates[1], the reported relationships between money and inflation as well as the estimated money demand specifications vary substantially from one study to another. Moreover, De Grauwe and Polan (2001) argue that "[t]he relationship between inflation and money growth for low inflation countries (on average less than 10% per annum over the last 30 years) is weak", i.e. below proportionality and non-significant; the latter study has been used, for example, to criticize the ECB

[1] See, for example, Assenmacher-Wesche and Gerlach (2005), Benati (2005a, b), Brand, Gerdesmeier and Roffia (2002) and references therein, Bruggeman, Donati and Warne (2003), Bruggeman et al. (2005), Gerlach (2003, 2004), Gerlach and Svensson (2003), Kugler and Kaufmann (2005), Neumann (2003), Neumann and Greiber (2004) and references therein, Nicoletti Altimari (2001), and von Hagen (2004).

monetary policy strategy[2].

I will develop here my arguments using U.S. and euro area data, respectively from the 1950s and 1970s, and compare the findings to the existing literature. The analysis presented in this paper establishes that there exists a significant and proportional relationship between money growth and subsequent inflation even during low inflation episodes, like e.g. in the U.S. and the euro area in the 1980s and 1990s. The analysis generalizes to other countries and allows for cross-country comparisons.

The paper argues that the reported weak relationship between money growth and inflation in low inflation economies, in the forms of a non-significant or non-proportional influence of money growth on inflation, in cross-country or time series studies, is due to not accounting for movements in equilibrium velocity due to Fisherian movements in interest rates. This is why issues appear when including data from the 1980s and 1990s, a period characterized by disinflation in most industrialized countries. As Nelson (2003) reports, Friedman (1985) notes that "[a] break in the trend of velocity [...] has been observed whenever and wherever accelerating inflation has been succeeded by disinflation". Nelson, in his review of empirical evidence on money and inflation, argues that falls in interest rates due to the Fisher effect can justify the negative correlation between money growth and velocity growth that puzzle De Grauwe and Polan and weaken cross-country money growth / inflation relationships. Those changes in equilibrium velocity are central to the analysis presented below.

The paper establishes that, when movements in equilibrium velocity due to money demand adjustments to different inflation regimes are accounted for, there is a significant and proportional relationship between money growth and subsequent inflation,

[2] See Begg et al. (2002) and Svensson (2002), referenced in Nelson (2003).

even with data starting only in the 1970s or 1980s. The relationship between money growth and inflation is examined through different angles, i.e. with long run averages, spectral analysis and a vector autoregression framework, and results are robust to different specifications and periods considered. I find proportionality between the two variables, a substantial and significant fraction of inflation forecast error variance explained by money growth "shocks", and that money growth Granger-causes inflation.

In contrast, not accounting for equilibrium changes in velocity and interest rates leads to the non-proportional and non-significant influence of money growth on inflation, and even reverse causality, that the literature including the post-1980 period has reported for time series as well as cross-country studies of low inflation economies.

The basic idea is that, for example, when inflation persistently decreases, as it did in the past 25 years in most industrialized countries, money grows faster than prices as interest rates and the opportunity cost of money persistently decrease, which induces people to hold additional money balances. Comparing money growth with inflation without accounting for that change in equilibrium velocity thus leads to a weakened link between money growth and future inflation. Increasing money balances resulting from declining interest rates due to the Fisher effect is a transitory level effect that can last several years and which is not associated with higher subsequent inflation; this thus biases empirical results on the relationship between money growth and inflation. In other words, as interest rates decline as the result of disinflation, inflation decreases by more than what money could explain if we do not account for interest rates equilibrium movements. This is what has led many observers to conclude that the link between money and inflation is weak in low inflation countries, as many industrialized countries experienced disinflation in the past two decades. The same argument (but in the opposite direction) applies in inflationary episodes, like e.g. in the 1970s in the U.S. Moreover, when samples with accelerating inflation as well as disinflation are considered, the dynamic relationship between money growth and inflation is also affected and the result of a less than proportional effect of money growth on inflation emerges, as Fisherian interest rate movements generate a negative correlation between low-frequency money growth and velocity growth. Thus, not accounting for changes in equilibrium velocity and interest rates results in biased coefficients in estimations of the influence of money growth and other variables on inflation. Moreover, the corresponding results are dependent of the sample considered, as the underlying trend and fluctuations in velocity growth differ across samples.

To account for changes in equilibrium velocity, I adjust monetary aggregates by money demand responses to low-frequency opportunity cost movements, driven by changes in inflationary environments, using long run money demand elasticity estimates[3]. Money growth rates are thus purged from these transitional but protracted cost-driven level effects on money balances. The argument does not rely on short-term money demand econometric stability but uses long-term elasticity estimates to account for equilibrium Fisherian changes in interest rates. Given that the literature has provided with various apparently inconsistent results on money demand relationships, i.e. cases of instability or different estimates, particularly with respect to income elasticity, section I reviews some results and explains why these apparently contradicting findings have coexisted in the literature since the 1980s disinflation pe-

[3]Both sets of variables, market interest rates and opportunity costs, the latter being computed as market rates minus own deposit rates of monetary aggregates, are dominated by Fisherian low-frequency movements in the datasets considered. I use the true opportunity cost where available. Further discussions on opportunity costs are provided below.

riod. I present consistent results for both U.S. and euro area long run money demand estimates, which are then used in section II to account for changes in equilibrium velocity.

The analysis shows that when monetary assets are chosen so as to correspond to the transaction concept of Baumol-Tobin, i.e. assets yielding transaction or monetary services, and when the effects of disinflation on money demand are appropriately accounted for, money demand estimation results in a unitary aggregate income elasticity and a similar interest rate elasticity with both U.S. and euro area data. A unitary income elasticity corresponds to the prediction of the Baumol theory if we assume that "it is the *number* of cash flows to be managed that doubles whenever real GDP doubles, not their average size" (Lucas, 2000).

Different U.S. estimates emerge depending on whether substitutes to checking accounts, also yielding transaction services, are accounted for, and how the particularly eventful period of the 1970s is treated. As those substitutes were introduced in the early 1980s with financial deregulation, at a time characterized by disinflation and a corresponding drop in interest rates, not accounting for these additional accounts creates the appearance of a weak money demand relative to the drop in opportunity cost. This, together with preceding financial market events in the 1970s which induced a major structural change in aggregate money demand, made it difficult to interpret the changing behavior of M1 when interest rates and inflation were declining, and explain why recent income elasticity estimates of narrow monetary aggregates have been relatively low. U.S. studies were thus mostly affected by issues of definitions and events interpretations.

Euro area money demand studies have also resulted in various estimated money demand specifications. I argue that the key factor to account for, which has been neglected in some studies, is that the opportunity cost of holding money balances has gone down dramatically during the past twenty-five years. Not accounting for this fact leads to money demand misspecifications, as the level of money balances has shifted up as a result of this development. Given that income has been increasing as well, not accounting for the drop in opportunity cost as a cause of the real money level increase leads to an overestimation of income elasticity.

Moreover, given that the commonly used euro area data samples begin in the early 1980s and are thus dominated by the disinflation period, both combinations of higher income elasticity / lower interest rate elasticity and lower income elasticity / higher interest rate elasticity can coexist econometrically, depending on the exact sample period or estimation method, as income and money were trending upward while interest rates were trending downward, with all relatively smooth trends. The argument is similar to that of Lucas (1988), but in the opposite direction, i.e. in a disinflationary rather than an inflationary environment. Lucas showed that, as all three series of money, interest rate and income were increasing during the 1970s inflationary episode in the U.S., money demand estimations over the 1958-85 period can result in unitary income elasticity, confirming the pre-war specification of Meltzer (1963), or in both lower income and interest elasticities. When the sample is extended and include "stationary periods", a unitary income elasticity emerges.

Given that some episodes have to be assessed using cross-sectional evidence and other periods lead to an observational equivalence or imprecise results in terms of money demand estimates, I impose the elasticity estimates uncovered by the analysis of section I, similar for both U.S. and euro area data, to account for equilibrium velocity movements in section II. This guarantees that these latter movements are appropriately accounted for and improves the estimates efficiency. Readers interested only in the paper findings regarding the estimated influence of money growth on inflation can skip section I and go directly to section II. Section III concludes.

I. Disinflation and money demand estimates

A. Nonlinearity, deregulation and financial innovations - U.S. data

The first blow to the consensus that considered money a useful indicator for monetary policy came in the early 1980s. At that time, the velocity of $M1$, the monetary aggregate officially considered by the Federal Reserve Board, started to exhibit fluctuations, as can be seen from Figure 1, after having grown smoothly for the prior three decades[4].

Given the change in behavior of $M1$ velocity, it was argued that the demand for $M1$ had become unstable. DeLong (2000), by referring to a figure plotting the velocity of $M1$ against a pre-1980 trend line over the period 1960-2000, writes: "[t]he sharp swings in the velocity of money in the 1980s, as shown in Figure 1, led not to a renewed commitment to stable inflation and money growth to eliminate such swings, but instead to a distrust by central bankers of monetary aggregates as indicators." What was considered as a change in behavior of the velocity of $M1$ in the 1980s coincided with financial deregulation, with the introduction of new accounts providing

[4] $M1$ consists of cash, demand and checking deposits. The opportunity cost is the 3-month Treasury bill rate minus the weighted average of interest rates paid on the different monetary assets. U.S. data were downloaded from the Federal Reserve Bank of St. Louis FRED (internet) database, and are released by the Federal Reserve Board, the Bureau of Economic Analysis and the Bureau of Labor Statistics. Monetary series prior to 1959 are from Rasche (1987, 1990). Interest rates paid on the various monetary assets were provided to me by Ruth Judson and Robert Rasche. All series except interest rates are seasonally adjusted.

transactions services, and with the disinflation. Instead of recognizing the transaction properties of those newly introduced accounts, the change in the behavior of M1 was attributed to the fact that the distinction between what was traditionally considered as transactions and savings balances became difficult to draw, as checking accounts began to earn interest. Referring to graphs which compare the evolution of the velocity of $M1$ with its pre-1980 trend, economists sharing this view seem to have expected transaction balances not to react to their opportunity cost, and their velocity to keep increasing smoothly[5]. It is often suggested that an explanation for the upward trend in $M1$ velocity during the post-war period is that technical progress in credit cards and other advances would have allowed individuals to economize on money balances, justifying an income elasticity below unity.

Thus, the conventional view is to consider the swings in the velocity of $M1$ in the 1980s, and the fact that the velocity stopped its smooth ascension, as a puzzle, and as an argument that monetary aggregates should not be considered anymore as indicators for monetary policy. However, if we have in mind a model where people trade off real resources with monetary assets, in order to carry out transactions, the puzzle is rather the smooth behavior of the velocity of $M1$ during the 1970s, i.e. in particular the fact that velocity did not drop with the falls in nominal interest rates in 1970 and 1974, and the fact that velocity increased faster than interest rates over the 1950s, 60s and 70s. Moreover, instead of being surprised by the decline in velocity at the beginning of the 1980s, we would wonder why the velocity did not decrease more sharply at that time, with the initial fall in nominal interest rates.

[5] For example, Mankiw (1997) wrote: "[f]or reasons that are still not fully understood, the velocity of money (nominal GDP divided by M1) fell in the early 1980s substantially below its previous upward trend. This fall contributed to a reduction in aggregate demand, which in turn led to the 1982 recession, one of the deepest in recent history", and further: "[t]he experience of the early 1980s shows that the Fed cannot rely on the velocity of money remaining stable".

Indeed, if we compare the evolution of $M1$ with its opportunity cost, as shown in Figure 1, we notice that $M1$ velocity did not decline by the amount justified by the strong decrease in opportunity cost in 1982 due to Volcker's disinflation. This apparent puzzle actually reflects the fact that, with financial deregulation and innovations, new types of accounts providing monetary services, thus substitutes to $M1$, were introduced. Those accounts generally yield rates close to checking accounts, below the 3-month T-bill rate, and are checkable. When those new accounts are included, as is the case in Figure 2, in an aggregate called M^{US} hereafter for comparisons with euro area data, then a clear drop in velocity occurs with the disinflation, i.e. a strong increase in money demand as interest rates dropped[6].

The swings in $M1$ velocity represented thus well the effect of disinflation and fluctuations in its opportunity cost. The apparent instability of $M1$ velocity since the late 1990s reflects a particular financial innovation, sweep programs[7], which induced substitutions internalized in M^{US}. The reason why the sensitivity of $M1$ and M^{US} to interest rate fluctuations has increased since the late 1970s and velocity shifted upwards in the 1970s can be explained by an increase in financial market participation that took place mostly in the 1970s, as documented in Reynard (2004). Note that M^{US} seems to have grown faster than what would have been expected from the evo-

[6] M^{US} corresponds to $M2$ minus small time deposits, or $M2$ Minus in the FRED database. It includes $M1$ plus savings accounts, money market deposit accounts, and retail money market funds. These assets correspond to what the Surveys of Consumer Finances group as "Transaction Accounts" (see Kennickell et al., 2000). For a study of monetary assets in the context of Divisia or Currency-Equivalent indexes, see Rotemberg et al. (1995). Analysis of this and broader aggregates can be found in Carlson, Hoffman, Keen and Rasche (2000), Carlson and Keen (1996), Motley (1988), Poole (1991), and Reynard (2004). Compared to the aggregate MZM, M^{US} does not include institutional money market funds as the latter assets are related to portfolio rather than transaction considerations and exhibit instability from the mid-1990s on (see discussion on broad aggregates below).

[7] Sweep programs allow banks to temporarily transfer funds between money market accounts and other checkable accounts, in an optimal timing, so as to reduce the amount of required reserves. See Anderson (1997a, b).

lution of its opportunity cost towards the end of the sample; however, this apparent instability does not appear when the logarithms of those variables are considered, i.e. in a log-log money demand specification, as can be seen from Figure 3.

Money demand estimations of M^{US} appear in Table 1[8]. We thus obtain a unitary income elasticity, and an increase in interest rate elasticity from -.065 before the velocity shift, to -.128 after the shift. In order to account for the increase in financial market participation, in section II M^{US} will be adjusted for the 1970s velocity shift[9].

The behavior of money in the 1980s, when correctly measured, was thus affected by the disinflation in the way we expect money to react to a change in its opportunity cost, i.e. with a strong increase in money balances reflecting the sharp fall in interest rates. But given the particular events that took place during the 1970s, i.e. the increase in financial market participation, the change in behavior of $M1$ was not correctly interpreted. People considered the smooth increase in the 1970s as normal and a large literature developed around modeling dynamic short-term money demand adjustments, where in fact those fluctuations were due to instability episodes.

When changes in financial market participation and substitutes of monetary assets included in $M1$ are not taken into account, the effects of the disinflation period are not correctly assessed and this explains why different income elasticity estimates have emerged from econometric studies. Studies based on narrower aggregates not including checking accounts substitutes, like e.g. Ball (2001), find income elasticity

[8] DOLS regressions use one lead and lag of the first differences and an AR(2) process for the error. Samples choice according to Reynard (2004).

[9] To account for the increase in financial market participation, an estimated trend will be added to M^{US} from 1970 to 1976. Moreover, when money will be adjusted by its interest rate elasticity to account for equilibrium velocity movements, both the pre- and post- velocity shift interest elasticity estimates will be used, together with an estimated trend on the elasticity between 1970 and 1976. Results in section II are not significantly affected if instead the trend covers the 1965-1976 period and/or if a single interest rate elasticity is used over the whole sample.

estimates below unity, whereas studies based on broader aggregates, e.g. Carlson, Hoffman, Keen and Rasche (2000) and Reynard (2004), find a higher and usually unitary income elasticity. This is due to the fact that when substitutes from checkable deposits and the increase in financial market participation are not taken into account, money does not appear to have increased as much as the decline in opportunity cost would have implied during the early 1980s disinflation, and the velocity of $M1$ appears to have increased faster than interest rates in the 1960s and 70s. As a result, the pre-1980 increase in velocity is not attributed to the increase in interest rate but to economies of scale, thus the estimated income elasticity is below unity.

Additional assets, like certificates of deposits or institutional money market mutual funds, have been used in broader U.S. monetary aggregates studies, and similar assets with maturity over 3 months and up to many years are included in broader monetary aggregates in general. However, I do not consider them as monetary assets, as their link to the transaction concept is less clear, and both of them are closely related to portfolio considerations. Although it is difficult to know exactly where to draw the line, there are several issues in considering such assets. First, if we consider assets like time deposits with longer maturities, it would be natural then to include other assets, like e.g. bonds, with similar maturities. Not including those additional assets is likely to generate money demand instability due to portfolio considerations linked with financial market events, similar to what happened in the early 1990s in the U.S.[10]; at that time, the switch from certificates of deposits to bonds and stocks mutual funds caused instability in $M2$. Also, institutional money market funds grew abnormally fast from the mid-1990s on. Second, given their looser link with transactions, broader

[10] Several explanations for that event have been provided. See e.g. Carlson, Hoffman, Keen and Rasche (2000), and Collins and Edwards (1994).

monetary aggregates are less likely to exhibit a stable relationship with GDP, i.e. a stable income elasticity. Different studies with broader aggregates, for example in the euro area, result in different values for income elasticity, usually significantly above unity, with no theory to restrict it, and those estimates are usually very sensitive to the sample period. And third, as assets included in those aggregates yield rates equal to or above the 3-month market rate, those aggregates are sometimes positively correlated with the 3-month rate, thus making their policy stance interpretation difficult.

The analysis in section II, assessing the effects of money growth on inflation, will thus use money demand estimates from M^{US}, which includes assets usually yielding an interest rate close to the one paid on checkable accounts and below the 3-month risk-free rate, thus providing transaction or monetary services: households and firms accept a lower yield, reflecting banks' resources to provide transaction services, in order to have assets available to buy goods and services. Moreover, the apparent instability and stability phases of M^{US} can be explained in terms of extensive/intensive margins of money demand, as shown in Reynard (2004): an upward velocity shift occurred in the 1970s as a larger fraction of U.S. households started to hold non-monetary assets as part of their financial portfolio, and money demand remained stable in the 1980s and 1990s as financial market participation remained constant as a fraction of U.S. households.

B. Disinflation, term structure and short samples - euro area data

Money demand studies using euro area data have also resulted in various outcomes regarding money demand specifications, particularly with respect to the income elasticity. Some euro area studies have found a unitary income elasticity, e.g. von Hagen

(2004), whereas other studies find an income elasticity significantly greater than unity, e.g. Neumann and Greiber (2004) and references therein, Brand, Gerdesmeier and Roffia (2002) and references therein, Bruggeman, Donati and Warne (2003), and Gerlach and Svensson (2003), who find a unitary income elasticity but with a positive trend in money balances, which, as argued below, amounts to finding a higher income elasticity over the period considered. I will illustrate my arguments with both $M2$, the counterpart of M^{US} in the euro area, hereafter referred to as M^{2EA}, and $M3$, hereafter M^{3EA}, the aggregate usually used in euro area studies. While my analysis applies to both M^{2EA} and M^{3EA}, my preference for M^{2EA} over M^{3EA} is based on the discussion above[11].

The choice of opportunity cost - Studies which find an income elasticity significantly higher than unity usually use the spread between long- and short-term interest rates (i.e. 10-year and 3-month, respectively) as the opportunity cost of money balances. An important feature of that spread is that it does not exhibit a downward trend over the past 25 years, as shown in Figure 4. A major conceptual issue in using that spread as the opportunity cost is that the 3-month rate, supposed to reflect the own rate, is in fact the alternative rate of large parts of M^{2EA} and M^{3EA}. In contrast, own rates of monetary assets are lower than 3-month market rates, as those assets provide transaction services, and are relatively sticky.

[11] M^{2EA} includes currency, overnight deposits, deposits with an agreed maturity up to 2 years, and deposits redeemable at a period of notice up to 3 months. Thus M^{2EA} includes some time deposits with maturity over 3 months, but does not include debt securities, included in M^{3EA}. Note also that M^{2EA} does not include money market funds, contrary to M^{US}. However, including or not these latter assets is not crutial empirically; issues arise mainly when assets with yields close to checking or transaction accounts are not included, and/or if significant amounts of assets with yields above a (policy-controlled) 3-month interest rate are included, for the reasons mentioned in the discussion above. Euro area data are from the euro Area Wide Model (AWM; see Fagan, Henry, and Mestre, 2005), Bruggeman, Donati, and Warne (2003), and the ECB internet site, and were provided to me by Alistair Dieppe, Paola Donati, Björn Fischer, Adriana Lojschova and Rolf Strauch. All series except interest rates are seasonally adjusted.

However, Figure 5, which displays the (log) velocity[12] of M^{2EA} together with the (log) 3-month interest rate, suggests that the velocity of money has been affected by the disinflation over the 1980s and 1990s. It is clear from Figure 5 that the strong (about 25 percent) decrease in velocity of the 1980s and 1990s was associated with the major disinflation that occurred during that same period in the euro area. A similar picture is obtained when velocity is plotted against the long-term interest rate, and available opportunity cost measures for M^{3EA} also show a downward trend similar to market rates, as retail rates are relatively sticky and did not decrease to the same extent as financial market rates did[13].

Thus the 1980s and 1990s were characterized by falling inflation and interest rates, through the Fisher effect, and real money balances reacted to that evolution by increasing strongly. Studies that consider the long/short interest rate spread as the opportunity cost are thus likely to overlook the effect of disinflation and find a higher income elasticity, as the increase in money balances is attributed to increasing income, given that the spread is not trending downwards. If, however, a trend is included in those money demand specifications, as in Gerlach and Svensson (2003) for example, the effect of disinflation, i.e. the fact that money increased by more than prices on average over the sample, appears in the trend instead of the income elasticity.

The cointegrating money demand relation, estimated by dynamic least squares

[12] The HICP is used for the price level. Using the GDP deflator instead does not affect the analysis, but the fit with M^{2EA} deteriorates, particularly in the 1970s, whereas the fit with M^{3EA} improves in that earlier period; over the 1975-2003 period, M^{3EA} income and interest elasticities are 1.01 and $-.13$, respectively.

[13] Opportunity cost measures are particularly difficult to compute for the euro area, and an opportunity cost for M^{2EA} can currently not be computed for the whole sample. However, the opportunity cost of M^{3EA} computed by Bruggeman, Donati and Warne (2003) over the 1980-2001 sample trends downwards, similarly to the short- and long-term rates. The reason why those authors find an income elasticity higher than unity and an imprecise estimate of the interest rate elasticity might come from the particular sample used, as explained below.

(Stock and Watson, 1993) with M^{2EA} over the 1975-2003 period, is as follows[14]:

$$\ln\left(\frac{M_t^{2EA}}{P_t}\right) = \underset{(0.71)}{-10.87} + \underset{(0.05)}{1.04} \cdot \ln(y_t) - \underset{(0.03)}{0.13} \cdot \ln(il_t), \tag{1}$$

where P is HICP (Harmonized Index of Consumer Prices), y is real GDP, and il is the 10-year government bond rate[15]. An interesting finding is that the money demand function, using a comparable monetary aggregate, is very similar to the U.S. money demand: as in the U.S. case, income elasticity is not significantly different from unity, and the point estimate of interest rate elasticity is the same as the one obtained with U.S. data for the post-velocity shift period starting in 1977.

Disinflation sample - An additional fact, also linked to the disinflation, is responsible for generating different outcomes for the income elasticity, given that most euro area studies on money demand use data from 1980 only. During a disinflation, as was the case in the 1980s and 1990s, interest rates decrease. Given that, at the same time, output keeps increasing, different combinations of interest and income elasticities can emerge from money demand estimations, i.e. a lower income elasticity and a higher interest elasticity or vice versa, depending on the exact sample period and estimation method, i.e. how the dynamics are modeled. This is similar, although in the opposite direction, to the argument of Lucas (1988), who provided an explanation for the various estimates of income elasticity in the U.S. during the period including

[14] Quarterly data. Regressions use two leads and lags of the first differences and an AR(2) process for the error. Standard errors in parentheses.

[15] I report here results with the long-term rate to ease comparison with the existing euro area literature. Similar results are obtained when the short (3-month) rate is used instead of the long rate, with an interest rate elasticity of .08. When income elasticity is constrained to unity, interest elasticity is .14 and .1 for long and short rates, respectively.

the inflation of the 1970s.

Equation (2) shows M^{2EA} demand results for the 1980-2003 period, i.e. the period usually considered in euro area money demand studies.

$$\ln\left(\frac{M_t^{2EA}}{P_t}\right) = \underset{(1.10)}{-12.57} + \underset{(0.07)}{1.15} \cdot \ln(y_t) - \underset{(0.03)}{0.09} \cdot \ln(il_t)\,. \tag{2}$$

The income elasticity is higher, significantly higher than unity, and the interest rate elasticity is lower than in equation (1), when the information preceding the disinflation period is not taken into account. However, when income elasticity is restricted to unity, we recover the same higher interest rate elasticity of 0.14 over both periods, i.e. 1975-2003 and 1980-2003. This thus explains why different money demand estimates coexist in euro area studies, as given data limitation the sample period is usually limited to the disinflation period, when the opportunity cost of money was trending downwards and income was trending upwards.

Results for M^{3EA} over the 1980-2003 period are as follows:

$$\ln\left(\frac{M_t^{3EA}}{P_t}\right) = \underset{(1.32)}{-19.38} + \underset{(0.09)}{1.63} \cdot \ln(y_t) - \underset{(0.04)}{0.00} \cdot \ln(il_t)\,. \tag{3}$$

Unlike von Hagen (2004), despite using the same sample, the estimated income elasticity here is much higher than unity. This reflects the previous argument, i.e. different estimation results can emerge from a sample limited to the disinflation period. Indeed, when income elasticity is restricted to unity, a long-term interest rate semi-elasticity[16] of 0.029 is obtained, close to what was estimated by von Hagen (0.034).

II. Reconsidering the effects of money growth on inflation

This section presents different types of evidence in favor of a strong and proportional relationship between money growth and subsequent inflation. Section A explains the bias in cross-country as well as time series dynamic estimates of the money growth / inflation relationship when equilibrium velocity movements due to inflation regimes changes are not accounted for. Section B proposes a way of accounting for these equilibrium movements. Section C presents proportionality results for medium to long run averages and low-frequency spectral analysis. Section D presents time series dynamic evidence of the influence of money growth on subsequent inflation and nominal income growth, with forecast error variance decompositions and Granger-causality tests based on a VAR framework. The dramatic qualitative and quantitative effects of the equilibrium velocity adjustment are presented for both long run and dynamic analysis. Finally, section E relates the findings to existing studies.

A. Inflation regimes, equilibrium velocity and econometric bias

As mentioned in the introduction, many economists have questioned the usefulness of money in predicting subsequent price or nominal income movements in the 1980s and 1990s. Consider Figure 6, which displays the (log) level of M^{US} together with the after-1985 trend (6 percent per year) in nominal output. After 1985, the opportunity

[16] Von Hagen uses the semi-log specification, so I report here the semi-elasticity. Using the $M3$ opportunity cost (3-month minus own rates) from Bruggeman, Donati and Warne (2003), yields an interest rate elasticity of .09 when income elasticity is restricted to unity.

cost of U.S. money balances has been stationary (see Figure 2), real output has grown at an average of 3 percent, and inflation has been relatively stable at around 3 percent as well, with a temporary increase around 1990 and a temporary drop in the late 1990s. Figure 6 displays a clear relationship between nominal income growth and money growth during that period, in sharp contrast with the claims cited above. Moreover, the two inflation fluctuations of the early and late 1990s followed, with a lag, deviations of money from its trend[17]. The following analysis explains the econometric misspecification that lead economists, like e.g. Friedman and Kuttner (FK), to claim that including the post-1980 period destroys evidence of a link between money and nominal income, and provides an appropriate specification that can be implemented in empirical studies of inflation dynamics.

Money growth / inflation discrepancies and inflation regimes changes - The main issue is that money growth increased significantly with the disinflation of the early 1980s, as a result of the Fisherian decrease in interest rates and opportunity cost, without a corresponding subsequent increase in inflation or nominal income, which thus biases the estimated effect of money growth on inflation. That strong increase in money level can clearly be seen on Figure 6, around 1983. Even reverse causality can appear in estimation results, given that this strong increase in money holdings was preceded by high inflation. More generally, this issue arises whenever there is a major inflation regime change.

Figure 7 displays the Hodrick-Prescott (HP) filtered series of U.S. money growth, inflation, and the opportunity cost of money. Money growth is adjusted by potential output growth, which does not affect fluctuations but only the level and thus, given

[17] Note that the latest increase in M^{US} reflects a strong fall in opportunity cost, as interest rates reached historially low levels (see Figure 3).

the unitary income elasticity, makes it directly comparable to inflation. The variables are filtered to purge from short run phenomena and uncover long run comovements. The filtered opportunity cost removes short-term influences, like liquidity or business cycle effects, and picks up only inflation trends, as can be seen from Figure 7.

Note that the opportunity cost is computed as the difference between the 3-month market interest rate and the weighted average of rates offered on the different deposits included in M^{US}. So we would expect commercial banks to adapt deposit rates to market rates with inflation regime changes and thus to obtain a stationary opportunity cost without low-frequency Fisherian movements. However, in addition to the facts that deposits rates are usually sticky[18] and that some accounts are not remunerated, the facts that interest payments were prohibited on checking accounts and ceilings were imposed on rates served on savings accounts before the 1980s, and that in addition interest rates were introduced on checking accounts in the early 1980s, contributed to the low-frequency Fisherian opportunity cost movements. Note that low-frequency opportunity cost movements can also come from real factors; however, in the datasets considered in this paper, they are dominated by Fisherian movements.

We clearly see from Figure 7 that the major discrepancies between money growth and inflation - notwithstanding sample extremities HP related movements - occurred when changes in inflationary environments (accelerating inflation or disinflation) and the corresponding low-frequency Fisherian movements in interest rates and opportunity cost occurred, i.e. in the late 1960s (initial inflation increase), late 1970s (inflation burst) and early 1980s (disinflation).

To understand how these discrepancies affect econometric estimates, and how the problem can be appropriately dealt with, note that by definition, given that money

[18] See e.g. Moore, Porter and Small (1990).

growth has been adjusted for real output growth, velocity growth is the difference between inflation and money growth, and the velocity level is mirrored by the opportunity cost level. Velocity low-frequency movements, which I call equilibrium movements, thus occur with changes in inflation regimes, due to money balances adjustment to changes in inflationary environments and opportunity cost, and are associated with low-frequency discrepancies in the money growth / inflation relationship, as these monetary movements are without consequences for future inflation. Moreover, velocity growth is clearly negatively correlated with money growth, with the negative comovements occurring when interest rates move as a result of changes in inflationary environments: velocity grew strongly in the late 1960s and late 1970s, as interest rates increased and money growth decreased, and velocity decreased in the early 1980s, as interest rates decreased and money growth increased. In the other periods, except at both sample extremities, velocity was stable and inflation was approximately equal to money growth (adjusted by output growth).

Effects on econometric estimates - These negative comovements affect econometric estimates in the following way. Let ν be equilibrium velocity growth. Then, if we estimate equation (5) instead of equation (4), we obtain the OLS estimate in (6).

$$\pi_t = \beta + \beta_1 \mu_t + \beta_2 \nu_t + \epsilon_t \tag{4}$$

$$\pi_t = \gamma + \gamma_1 \mu_t + u_t \tag{5}$$

$$\gamma_1^{OLS} = \beta_1 + \beta_2 \frac{Cov(\mu_t, \nu_t)}{Var(\mu_t)} \tag{6}$$

As it is clear from the discussion above and Figure 7, as well as from the averages presented in the next section, money growth is negatively correlated with velocity growth driven by low-frequency (equilibrium) Fisherian interest rate changes. Thus, if systematic changes in velocity are not accounted for by controlling for interest rate equilibrium movements, regressing inflation on money growth leads to a coefficient on money growth below unity (and often non-significant). This applies to cross-section as well as time series dynamic estimations of the influence of money growth on inflation.

Indeed, cross-country studies of the money growth / inflation relationship, e.g. De Grauwe and Polan (2001) and Gerlach (1995), have found a non-proportional link between these variables. Gerlach argues that one potential cause of non-proportionality comes from the omitted variable reasoning discussed above. While De Grauwe and Polan argue that this negative correlation is difficult to interpret for low inflation countries in the sense that this cannot reflect a short run liquidity effect, and interpret it as exogenous (technological and institutional) velocity changes unrelated to growth rates of the money stock but to which money growth adjusts, Nelson (2003) argues that the negative correlation due to the Fisher effect, "could easily leave an imprint on long runs of annual data", which is confirmed by Figure 7 and in the next section.

The following analysis will show that not accounting for these low-frequency equilibrium velocity movements indeed generally leads to a non-significant, or at least non-proportional influence of money growth on inflation or nominal income. Moreover, the extent of the bias depends on the period considered. Consider, for example, Figure 8, which shows the low-frequency movements of euro area variables, i.e. $M2$ growth, inflation and the 10-year interest rate. Most euro area studies use a sample beginning in the early 1980s, which is dominated by the disinflation period. During that time, inflation decreased faster and by more than money growth did, given that the Fisherian decrease in interest rates made money holdings more attractive. Consequently, econometric estimates can lead to an above proportional influence of money growth on inflation, as is the case for example with the OLS estimates presented below. But in general, i.e. over longer sample periods, not accounting for changes in equilibrium velocity weakens the estimated relationship between money growth and subsequent inflation, and results in a less than proportional link. When changes in interest rates are not accounted for, a proportional link would thus only occur by accident, due to a particular sample choice. However, as shown below, accounting for equilibrium velocity movements leads to a clear proportional relationship between money growth and subsequent inflation.

B. Accounting for equilibrium velocity movements

In order to account for equilibrium velocity movements, the opportunity cost of money holdings is (HP) filtered, and then money growth is adjusted by real potential output growth and by the change in the filtered opportunity cost. The filtered opportunity cost represents equilibrium opportunity cost and thus determines equilibrium velocity via the estimated long run money demand relationship discussed in section I. The resulting series, $\widetilde{\mu}^X$, called net money growth, can thus be written as

$$\widetilde{\mu}_t^X = \Delta m_t^X - \Delta y_t^p + \varepsilon_i \Delta i_t^{HP}, \tag{7}$$

where all variables are expressed in logarithm, $\Delta x_t = x_t - x_{t-4}$, m^X is a monetary aggregate, y^p is real potential output, i^{HP} is the HP filtered opportunity cost of money holdings, and ε_i is the absolute value of the interest rate elasticity estimated in section I[19]. Time units are quarters. The upper-script X represents the different aggregates and countries considered, e.g. $\widetilde{\mu}^{2EA}$ represents the net growth rate of $M2$ (2) in the euro area (EA), and $\widetilde{\mu}^{US}$ represents net U.S. money growth.

In equation (7), money growth is corrected by real potential output growth to account for the fact that variations in money growth and potential real output growth offset each others with respect to inflation developments. Note however that whether money growth is adjusted by real potential output growth or not does not affect significantly the quantitative results. I correct by potential instead of actual real output as this allows me, in a first stage, to use this measure to assess the total effect of money growth on inflation rather than only the marginal effect of money given output evolution. Moreover, correcting money growth by actual output would cause μ^X to increase as output decreases after a contractionary policy for example, thus distorting the information of monetary aggregates and potentially resulting in an estimated reverse causality between money growth and inflation, as inflation usually responds to money with longer lags than output does.

Thus, in equation (7), money growth is adjusted by the change in equilibrium velocity; e.g. if interest rates decrease as a result of disinflation, the third term on the right-hand side ($\varepsilon_i \Delta i_t^{HP}$) will be negative, thus money growth will be adjusted downwards as part of the increase in actual money balances (Δm_t^X) reflects an adjustment of money demand to lower interest rates (Fisher effect) and should thus have no impact on future inflation developments.

In the empirical analysis below, I consider two additional adjusted money growth

[19] Note that ε_i is a cointegrating vector estimate and is thus superconsistent.

rates, i.e.

$$\widehat{\mu}_t^X = \Delta m_t^X + \varepsilon_i \Delta i_t^{HP}, \tag{8}$$

$$\mu_t^X = \Delta m_t^X - \Delta y_t^p. \tag{9}$$

$\widehat{\mu}^X$ is used instead of $\widetilde{\mu}^X$ when real or nominal output is included in the VAR. Using $\widetilde{\mu}^X$ or $\widehat{\mu}^X$, i.e. accounting for equilibrium velocity movements, will lead to a significant and proportional relationship between money growth and subsequent inflation. In contrast, the relationship will vanish when these equilibrium movements are not accounted for, i.e. when μ^X or Δm^X are used. μ^X is used when output is not included as a separate variable in the VAR, to contrast with $\widetilde{\mu}^X$ and show that the main source of discrepancy comes from low-frequency interest rate movements (rather than real potential output growth); however, results are not significantly affected if Δm^X is used instead of μ^X.

C. Long run averages, low frequency and proportionality

For euro area data, Neumann (2003), for example, presents sub-periods averages of inflation, money growth and real output growth, in his Table 1. A subtle feature of those numbers is that, for every of the three sub-samples considered, money in excess of real output growth grows faster than inflation, by about 1 percentage point per year on average, although this fact is not emphasized in his paper. For example, over the 1990s (1991-2002), μ^{3EA} averaged at 3.85 percent per year, but inflation averaged at 2.49 percent. However, when adjusted by changes in equilibrium velocity, i.e. using equation (7) above, money growth is close to inflation, i.e. $\widetilde{\mu}^{3EA}$ averaged at 2.32

percent per year. Not accounting for the effect of disinflation thus resulted in about 1.4 percent per year of money growth that does not reflect on inflation. Similarly, when the whole disinflation period (1980-2003) is considered, μ^{3EA} averaged at 5.15 percent per year, whereas $\widetilde{\mu}^{3EA}$ and inflation both averaged at 4.15 percent per year. Thus, over the 1980s and 1990s disinflation, money grew in excess of real output growth by over 25 percentage points more than prices did. Estimates that do not account for the effects of changes in equilibrium velocity will thus find a weaker link between money and inflation, in the short as well as the long run.

Results are similar with U.S. data. Over the disinflation period (1982-1990), μ^{US} averaged at 6.3 percent per year, while $\widetilde{\mu}^{US}$ and inflation averaged at 4.5 percent per year and 4.1 percent per year, respectively. Thus, during the disinflation period in the U.S., the discrepancy was about 2 percentage points per year. During the 1990s however, when the opportunity cost of money was stationary, all measures coincide, i.e. μ^{US}, $\widetilde{\mu}^{US}$ as well as inflation all averaged at 3 percent per year.

Thus, comparing across these economies or over different periods, there is a clear proportional relationship between inflation and money growth when changes in equilibrium velocity are accounted for, i.e. there is a one-to-one relationship between $\widetilde{\mu}^{X}$ and inflation even for low inflation economies like the U.S. and the euro area.

The low-frequency consequences of equilibrium velocity movements can best be seen by considering cross-spectral analysis[20]. Figures 9 and 10 display plots of the gain for the cross-spectrum of U.S. money growth and inflation (with 90 percent

[20] I am thankful to Luca Benati for presenting the consequences of my analysis in the frequency-domain when discussing my paper. Benati showed, with partial cross-spectral methods, that the gain at frequency zero increases to .87 with euro area data and .75 with U.S. data, both not significantly different from unity, when including the opportunity cost. Here I directly impose long run money demand estimates when computing net money growth; not doing so can generate results with potentially inconsistent implied money demand relationships.

bootstrapped confidence intervals), without and with equilibrium velocity adjustment, respectively, and Figures 11 and 12 display the same information for euro area data. The gain represents the frequency-domain equivalent of the sum of coefficients on money growth in a time-domain inflation equation. We clearly see a proportional relationship at frequency zero when equilibrium velocity is accounted for, and a below proportionality relationship when these equilibrium movements are not taken into account. The coherence, not displayed here, is unity at frequency zero for both U.S. and euro area data, with and without velocity adjustment.

D. Money growth and inflation dynamics reconsidered

We now turn to empirical estimates of the dynamic relationship between money growth and inflation. The focus here is on the usefulness of money growth in predicting future inflation, as developed in FK for example, i.e. we will look at whether money growth contains information on future inflation or nominal income growth beyond what is already contained in movements of these variables. The discussion will thus not address causality in a structural sense; for the purpose of this paper, it is best looking at money as a "quantity-side" measure of monetary conditions induced by monetary policy, following Nelson's (2003) terminology.

Illustration of the bias with OLS estimates - As an illustration of the discussion in section II.A, consider a regression of annual inflation, π_t, on current and prior years' net money growth for the euro area (1977-2003, time units are quarters). This yields

$$\begin{aligned}\pi_t \;=\; & \underset{(0.40)}{-0.32} + \underset{(0.10)}{0.20} \cdot \widetilde{\mu}_t^{2EA} + \underset{(0.09)}{0.32} \cdot \widetilde{\mu}_{t-4}^{2EA} + \underset{(0.09)}{0.20} \cdot \widetilde{\mu}_{t-8}^{2EA} + \underset{(0.12)}{0.25} \cdot \widetilde{\mu}_{t-12}^{2EA} + \epsilon_t, \quad (10)\end{aligned}$$

$R^2 = 0.86$, with a coefficients sum of 0.97 on net money growth[21]. This equation thus displays a proportional link between net money growth and inflation, although it does not say anything about "causality" issues, which will be addressed below with a VAR analysis.

However, if instead money growth is not adjusted by changes in equilibrium velocity, we obtain the following results:

$$\pi_t = \underset{(0.57)}{-1.91} + \underset{(0.12)}{0.41} \cdot \mu_t^{2EA} + \underset{(0.09)}{0.51} \cdot \mu_{t-4}^{2EA} + \underset{(0.15)}{0.32} \cdot \mu_{t-8}^{2EA} + \epsilon_t, \tag{11}$$

$R^2 = 0.79$, with a coefficients sum of 1.24 on money growth. A coefficient higher than unity on money growth means that, during the disinflation period, inflation decreased by more than money growth did, if we do not account for interest rates equilibrium movements. This is exactly what we would expect, as falling interest rates lowered the opportunity cost of money, which induced an additional increase in the level of money balances. Furthermore, the regression constant is negative and significant, further indicating a decline in inflation apparently independent from money growth, which in fact represents the decrease in velocity. In general, whether the bias is reflected in the constant, in the money growth coefficients or in other variables considered, depends on the relative variances of money growth and velocity and on the covariance between these variables. This affects dynamic relationships between the variables considered.

The bias discussed in the previous paragraph can be called the disinflation bias.

[21] In this and the following OLS regressions, I include only annual lags significant at the 5% level. Newey-West standard errors in parentheses.

However, in general, when samples include periods of accelerating inflation as well as disinflation, empirical estimates will display a below rather than above proportional relationship between money growth and inflation, due to the omitted variable bias and the negative correlation between money growth and velocity growth discussed in section II.A. Indeed, an OLS regression similar to equation (11) but with U.S. data, over the 1953-2004 sample, yields a coefficients sum of 0.63, i.e. well below unity. Again, when equilibrium velocity movements are accounted for, as in equation (10), we recover a coefficients sum of 1.00, i.e we find proportionality with U.S. data as well.

Variance decomposition and Granger causality - Estimates from single-equation regressions like equations (10) and (11) might however be biased due to reverse causality and exogenous inflation persistence. The following analysis thus uses VARs, addresses the "causality" issue, and relates the findings to previously established results, particularly to FK.

U.S. data - We first examine the dynamic relationship between U.S. money growth and inflation. Figure 13 displays the impulse-response functions (IR) of a bivariate VAR, estimated over the whole sample (1953-2004), comprising inflation and net money growth (MUSNG stands for $\widetilde{\mu}^{US}$), and Figure 14 displays the forecast error variance decompositions (VD), with 95-percent confidence intervals[22].

Impulse-response functions display a significant influence of net money growth "shocks" on inflation, and net money growth accounts for 60 percent of the inflation forecast error variance after 4 years. Note that "shocks" here do not have struc-

[22] Time units are quarters. The lag length, according to the Akaike info criterion, is 11 quarters. Monte Carlo confidence intervals with 100 draws are displayed. The orthogonalization order is inflation first; results are not significantly affected by the ordering. Also, considering $\widehat{\mu}^{US}$ instead of $\widetilde{\mu}^{US}$, i.e. not correcting money growth by potential output growth, does not affect the results.

tural interpretations. Granger-causality tests indicate both that net money growth Granger-causes inflation (p-value: 0.013) and that inflation Granger-causes net money growth (p-value: 0.001). When sub-samples starting in the early 1970s or early 1980s are considered, estimates are less precise, but the variance decompositions remain similar, with net money growth significantly accounting for 50 to 60 percent of the inflation forecast error variance after 4 years, and the impulse-response functions remain little affected. Additional comparisons of sub-periods and specifications are presented below, in Tables 2-5.

In contrast, when equilibrium changes in velocity are not taken into account, i.e. when not-velocity-adjusted money growth (μ^{US}) is used instead of net money growth ($\widetilde{\mu}^{US}$), the estimated influence of money growth on inflation deteriorates dramatically. Figures 15 and 16 present results of a bivariate VAR similar to the previous one, but with not-velocity-adjusted money growth (MUSYG stands for μ^{US}) instead of net money growth. When equilibrium interest rate changes are not accounted for, the response of inflation to money growth from the impulse-response function is weak and insignificant, and the response of money growth to inflation is significant. Moreover, money growth now only accounts for a non-significant low percentage of the inflation forecast error variance, compared to a significant 60 percent when changes in equilibrium velocity were accounted for. In this case, money growth does not Granger-cause inflation (p-value: 0.135), but inflation Granger-causes money growth (p-value: 0.000).

Euro area data - Equilibrium velocity movements affect euro area data in a similar way. Figure 17 displays the impulse-response functions of a bivariate VAR, estimated over the 1975-2003 period, comprising inflation and net money growth (M2NG stands for $\widetilde{\mu}^{2EA}$), and Figure 18 displays the variance decompositions, with 95% confidence intervals[23].

Granger causality tests indicate that net money growth Granger-causes inflation (p-value: 0.007) but that inflation does not Granger-cause net money growth (p-value: 0.673). Inflation responds significantly to a net money growth shock, but net money growth is not significantly affected by an inflation shock. Net money growth also significantly accounts for 60 percent of the inflation forecast error variance, whereas inflation does not significantly account for net money growth forecast error variance.

However, when equilibrium changes in velocity are not taken into account, i.e. when not-velocity-adjusted money growth (μ^{2EA}) is used instead of net money growth ($\widetilde{\mu}^{2EA}$), the estimated influence of money growth on inflation deteriorates dramatically. Figures 19 and 20 display the impulse responses and the variance decompositions of a bivariate VAR similar to the previous one, but with not-velocity-adjusted money growth (M2GY stands for μ^{2EA}) instead of net money growth. Granger-causality tests in this case indicate that net money growth only barely Granger-causes inflation at the 95-percent level (p-value: 0.049), and this worsens when the disinflation sample (1980-2003) only is considered (p-value: 0.085). In the latter case, the p-value of the null hypothesis that inflation does not Granger-cause money growth even drops to 0.145. Moreover, the response of inflation to money growth from the impulse response functions is insignificant and the response of money growth to inflation becomes significant. In addition, money growth now only accounts for a non-significant low percentage of the inflation forecast error variance, compared to 60

[23] Time units are quarters. The lag length, according to the Akaike info criterion, is 5 quarters. Monte Carlo confidence intervals with 100 draws are displayed. The orthogonalization order is inflation first; results are not significantly affected by the ordering. Also, considering $\widehat{\mu}^{2EA}$ instead of $\widetilde{\mu}^{2EA}$, i.e. not correcting money growth by potential output growth, does not affect the results.

percent when equilibrium velocity changes were accounted for.

Robustness to specifications and samples - Tables 2-5 report variance decompositions and Granger-causality tests for different VAR specifications, with both U.S. and euro area (E.A.) data, and for the U.S. sub-sample starting in the early 1970s to relate the findings to FK's results. Tables 2-3 present results when equilibrium velocity movements are accounted for, and tables 4-5 present results when these equilibrium adjustments are omitted. The left column displays the variables included in the VAR and the orthogonalization order, the second and third columns include U.S. data results with full sample and the sub-period starting in 1970 to relate to FK, respectively, and the last column displays results for the euro area sample. The first VAR considered includes inflation and money growth, the second specification includes nominal income growth (Δyn) and money growth, and the third VAR includes real output growth, inflation and money growth. Money growth is not adjusted by potential output in the second and third specifications, as output is included as a separate variable.

Tables 2 and 4 report inflation (first and third lines) or nominal income growth (second line) forecast error variance, at a 5-year horizon, due to a money growth shock, with 95-percent confidence intervals[24]. Tables 3 and 5 display Granger-causality tests. The first two lines report p-values of the null hypothesis that money growth does not Granger-cause inflation. The values $a/b/c$ in the third line are p-values of the null hypothesis that money growth does not Granger-cause inflation (a), money growth does not Granger-cause real output growth (b), and real output growth does not Granger-cause inflation (c), respectively.

From Table 2, we see that, when equilibrium velocity adjustments are accounted

[24] Monte Carlo simulations with 100 draws.

for, money growth "shocks" significantly account for 40 to 60 percent of the inflation or nominal income growth forecast error variance, for all specifications/samples/economies considered. However, from Table 4, when equilibrium velocity adjustments are not accounted for, those shares drop to only about 20 percent and are non-significant.

Regarding Granger causality, in Table 3, two-variable VARs (first two rows) usually indicate that money growth causes inflation and nominal income at the 95-percent significance level when velocity adjustments are accounted for, except in two cases where p-values are 0.06 and 0.10. However, when velocity adjustments are omitted, in Table 5, p-values substantially increase in all cases, and money growth does not cause inflation anymore. In the three-variable systems (last row), money growth Granger-causes inflation in the euro area when equilibrium adjustments are accounted for, but this is not the case anymore without adjustment. In the U.S. case, when equilibrium velocity adjustments are accounted for, money growth causes inflation via its influence on real output growth, whereas that channel disappears when equilibrium velocity adjustments are not accounted for. Note also that if we use the same samples and specifications as FK, i.e. the 1970:3-1990:4 sample and four lags, but if we account for equilibrium velocity movements, we find that money growth Granger-causes nominal income growth in the two-variable VAR (p-value: 0.046) and that money growth Granger-causes inflation in the three-variable VAR (p-value: 0.00); FK, in contrast, found that M1 and M2 growth Granger-cause nominal income growth only at the $P \leq 0.1$ level, and that none of the monetary aggregates considered Granger-cause inflation, even at the $P \leq 0.1$ level. Note that Batini and Nelson (2001), who looked at the correlation of inflation with money growth in different sub-samples, already pointed out the constant steady-state velocity growth assumption as a weakness of

FK's analysis.

Another interesting result is that when interest rates or interest rate spreads (between interest rates and their equilibria) are included in VARs as well, results are not significantly affected, i.e. money growth adjusted by equilibrium velocity significantly accounts for a large share of inflation forecast error variance, and interest rates account for a small and non-significant share of that variance.

Summarizing the results of this section, variance decompositions and Granger-causality tests indicate a strong relationship between money growth and subsequent movements in inflation and nominal income, when equilibrium velocity movements are accounted for, but the relationship disappears if equilibrium velocity movements are not accounted for. This holds for both U.S. and euro area data, for different specifications and variables ordering, and different sub-periods. Results can differ slightly across samples or specifications, but the general result that not accounting for equilibrium movements in equilibrium velocity dramatically deteriorates the relationship between money growth and subsequent inflation is very robust.

E. Relating the analysis to other studies

The findings of this paper have already been compared above with previous literature results, particularly with FK's results, which are often cited as evidence against the usefulness of monetary aggregates for monetary policy, and which marked the "near-end" of research interest on this topic in the U.S. I contrast here my analysis to a few other recent papers, mostly using euro area data and supportive of monetary aggregates, by presenting the way equilibrium velocity is implicitly treated in those studies.

Several papers, e.g. Neumann (2003), Neumann and Greiber (2004) and Gerlach (2003, 2004), have been looking for a separate low-frequency channel for money in the transmission mechanism, and report a prominent role for monetary aggregates. However, they do not account for interest rates equilibrium fluctuations; in these studies, measures of core money growth (i.e. money growth adjusted by real output growth, μ in my notation, but adjusted by actual instead of potential output, with the potential reverse causality effects discussed in section II.B) are thus higher than inflation on average and over most of the 1980s and 1990s sample period. This latter fact does not appear explicitly in their analysis for different reasons. Neumann explicitly disregards the early 1980s period, when the main disinflation occurred, in its estimation. Neumann and Greiber estimate income elasticity to be 1.5. As discussed in section I.B, this estimate (or in general an estimate biased upwards) can turn out of a model of the 1980s and 1990s or where the opportunity cost is modeled as the long/short interest rate spread. Such an income elasticity compensates for the fact that inflation decreased by more than money growth did over the 1980s and 1990s, but only on average, i.e. output fluctuations do not necessarily always compensate for money responses to opportunity cost changes, and this model specification would probably not fit the data if the sample were extended to include the pre-1980s period. Gerlach, in his graphical analysis, normalizes the data, which removes the relatively higher average growth rate of money but affects the money/inflation relationship if velocity does not follow a deterministic time trend. Velocity is assumed to follow a deterministic time trend in his econometric analysis as well, which, even if it were the case, affects the estimated coefficients depending on how money growth fluctuates and comoves with equilibrium velocity. This fact is recognized by Gerlach (2003), who argues that there should be no presumption of proportionality between core money growth and inflation, from the standard omitted variables reasoning discussed in section II.A. Using the same approach, but with frequency-domain analysis, Assenmacher-Wesche and Gerlach (2005) demean the data, and Bruggeman et al. (2005) consider a sample starting only in the late 1980s, where inflation could be considered as stationary.

Orphanides and Porter (2001) look at the overall effect of money on inflation in a P-star model. They account for a long run trend in U.S. $M2$ velocity from the 1960s till the early 1990s and then adjust that equilibrium velocity upwards to account for the $M2$ instability discussed in section I.A, but do not adjust for equilibrium velocity movements associated with different inflation regimes.

Other studies have looked at the marginal effect of money growth on inflation in cointegrating frameworks. For example, Carlson, Hoffman, Keen and Rasche (2000) find that money demand short-term deviations (cointegrating errors) have marginal predictive power for short-term nominal GDP fluctuations; there, velocity is defined by the cointegrating relationship, and the explanatory power of deviations from velocity evaluated at the current values of the variable considered is assessed. Kugler and Kaufmann (2005) present a cointegrating relationship between money growth and inflation. They have different orders of integration for money and prices (I(2)) than for interest rates (I(1)), thus their estimated long run relationship is not affected by interest rate changes. They however allow for a trend in real money balances, and find evidence for a second regime when inflation and interest rates were increasing in the late 1970s / early 1980s, with decreasing rates in real money growth. The second regime thus corresponds to the period when velocity growth was positive and increasing, before becoming negative and relatively stationary since the mid-1980s.

As argued in section II.A., in general, not accounting for changes in equilibrium velocity and interest rates when assessing the influence of money growth on inflation results in biased coefficients on money growth and on the other variables considered. Moreover, results are dependent of the sample considered: as explained above, the bias in accelerating inflation or disinflation samples are different than periods including both episodes, as the underlying trend and fluctuations in velocity growth differ.

III. Conclusion

Less attention has been paid to monetary aggregates in the past 20 years, as many different money demand specifications or instability results have emerged from econometric studies, and the reported estimated influence of money growth on inflation has usually been non-significant, or at least non-proportional, in time series as well as cross-country studies.

This paper has on the contrary found a significant and proportional relationship between money growth and subsequent inflation, when equilibrium changes in velocity are accounted for. I have shown that not accounting for interest rates equilibrium movements biases the estimated influence of money growth and other variables on inflation, and in particular weakens the estimated influence of money growth on inflation. Furthermore, I have suggested reasons why different money demand relationships have coexisted in the literature, particularly with respect to aggregate income elasticity, which turns out to be unity when the Baumol-Tobin transaction concept is considered.

The current low inflation rates in industrialized countries can thus be explained by much lower money growth rates nowadays - and immediately preceding the current low inflation period - than in the 1970s and 1980s. Relative price shocks like e.g. an increase in international competition, a commonly used argument to explain the current low inflation environment, or an oil price shock, cannot affect growth rates of the general price level without a corresponding change in monetary conditions induced by central banks.

While money demand relationships have been remarkably stable in the past 30 years, the dramatic increase in financial market participation in the U.S. during the 1970s, as documented in Reynard (2004), caused a decline in aggregate money holdings and biased aggregate money demand relationships. Similarly, but in the opposite direction, very low interest rates can generate nonlinearity due to changes in financial market participation, which would induce relatively high growth rates in monetary aggregates not followed by high inflation. Part of the recent relatively high growth rates in monetary aggregates, particularly in the euro area, are likely to be related to that phenomenon. Those facts act as warning signals when interpreting short-term monetary aggregates growth rate fluctuations and call for more research on those nonlinearity issues.

The effects of this paper analysis on various results presented in the literature regarding the influence of monetary aggregates and other variables on inflation and output growth, using cross-country or time series models, are left for future work.

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	1949-1969	1977-2003
Interest Rate Elasticity	-0.065	-0.128
	(0.031)	(0.021)
Income Elasticity	1.001	1.039
	(0.074)	(0.063)

DOLS standard errors in parenthesis.

Table 1. MUS Money Demand Estimates

	U.S. (1953-2004)	U.S. (1970-2004)	E.A. (1975-2003)
$\pi, \widetilde{\mu}$	60 ± 33	61 ± 38	53 ± 39
$\Delta yn, \widehat{\mu}$	40 ± 26	36 ± 26	40 ± 27
$\Delta y, \pi, \widehat{\mu}$	60 ± 32	51 ± 35	43 ± 34

5-year horizon forecast error variance (in percent) of inflation (1st & 3rd row) and nominal income (2nd row) to a money growth shock.
Ranges indicated represent 95-percent confidence intervals.
U.S. lag # (AIK): 11, 10, 10, respectively. E.A. lag # (AIK): 5, 5, 5, respectively.

Table 2. Variance Decomposition - Equilibrium-Velocity Adjusted

	U.S. (1953-2004)	U.S. (1970-2004)	E.A. (1975-2003)
$\pi, \widetilde{\mu}$	0.01	0.10	0.00
$\Delta yn, \widehat{\mu}$	0.01	0.01	0.06
$\Delta y, \pi, \widehat{\mu}$	0.07/0.02/0.01	0.06/0.049/0.00	0.03/0.33/0.37

P-values of Granger-causality tests. Rows 1-2 report p-values of the null hyp. that money growth does not Granger-cause inflation. In row 3, $a/b/c$ are p-values of the null hyp. that money growth does not Granger-cause inflation (a), money growth does not Granger-cause real output growth (b), and real output growth does not Granger-cause inflation (c), respectively. Lags as in Table 2.

Table 3. Granger Causality - Equilibrium-Velocity Adjusted

	U.S. (1953-2004)	U.S. (1970-2004)	E.A. (1975-2003)
π, μ	21 ± 27	17 ± 30	19 ± 36
$\Delta yn, \Delta m$	20 ± 22	18 ± 22	28 ± 32
$\Delta y, \pi, \Delta m$	22 ± 26	15 ± 27	22 ± 29

See notes in Table 2.
U.S. lag # (AIK): 11, 10, 11, respectively. E.A. lag # (AIK): 5, 9, 5, respectively.

Table 4. Variance Decomposition - Not Velocity-Adjusted

	U.S. (1953-2004)	U.S. (1970-2004)	E.A. (1975-2003)
π, μ	0.14	0.37	0.05
$\Delta yn, \Delta m$	0.12	0.07	0.24
$\Delta y, \pi, \Delta m$	0.24/0.43/0.01	0.16/0.35/0.00	0.12/0.26/0.22

See notes in Table 3. Lags as in Table 4.

Table 5. Granger Causality - Not Velocity-Adjusted

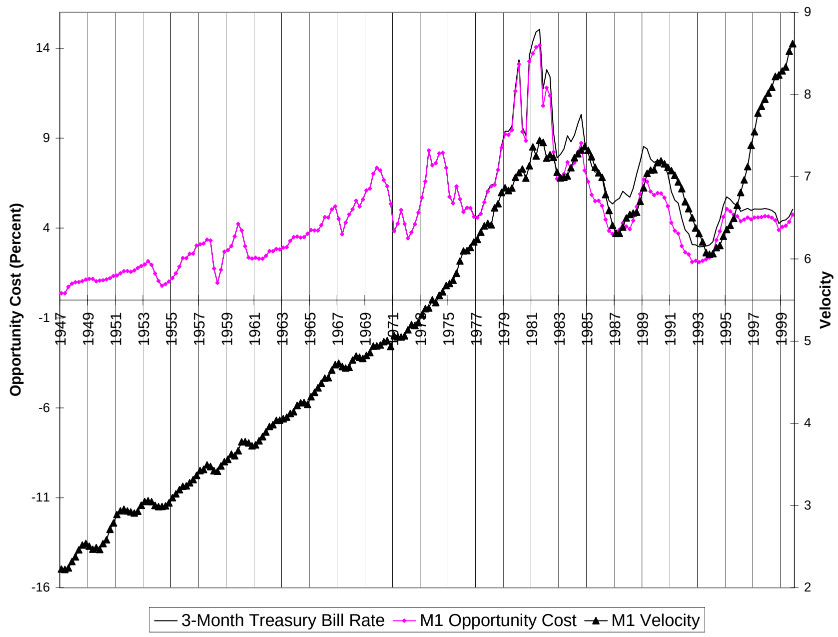

FIG. 1. M1 Velocity in the U.S.

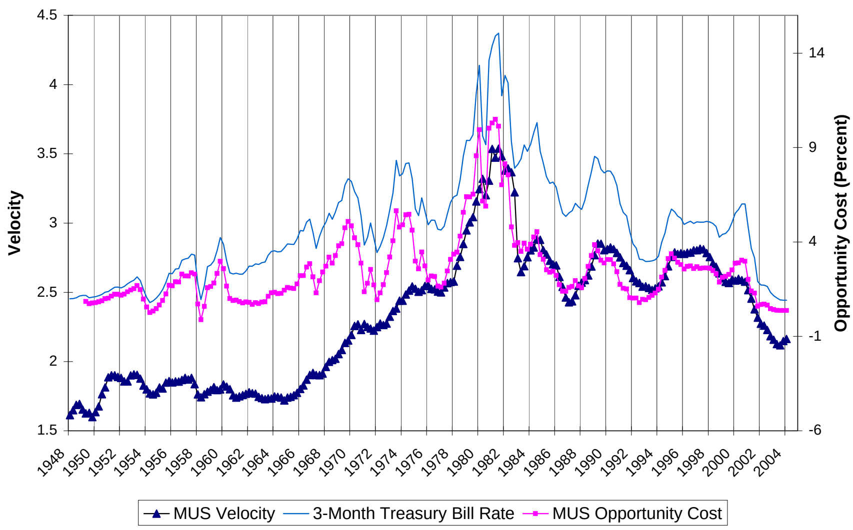

FIG. 2. M^{US} Velocity and Opportunity Cost

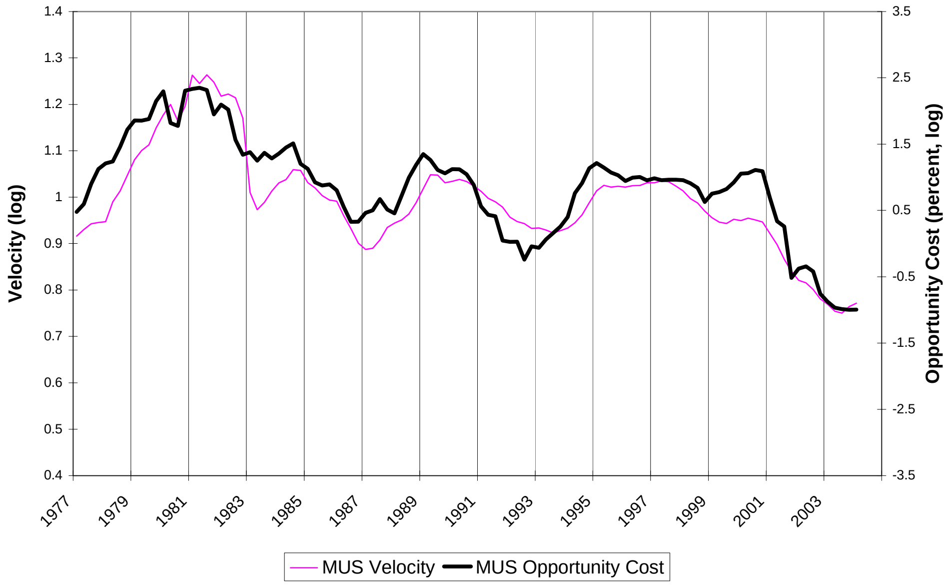

FIG. 3. U.S. Money Demand (log-log)

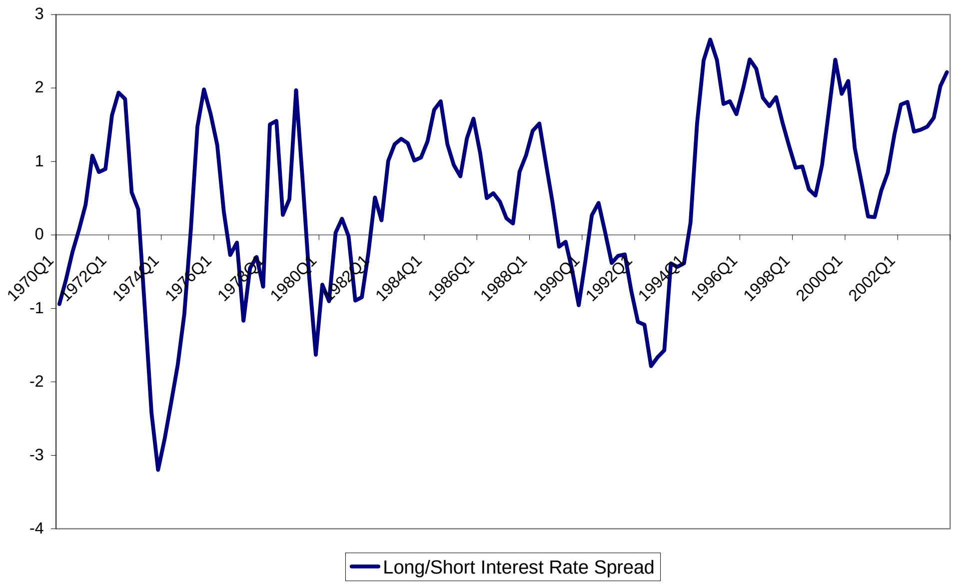

FIG. 4. Long/Short Interest Rate Spread

Fig. 5. Euro Area Money Demand

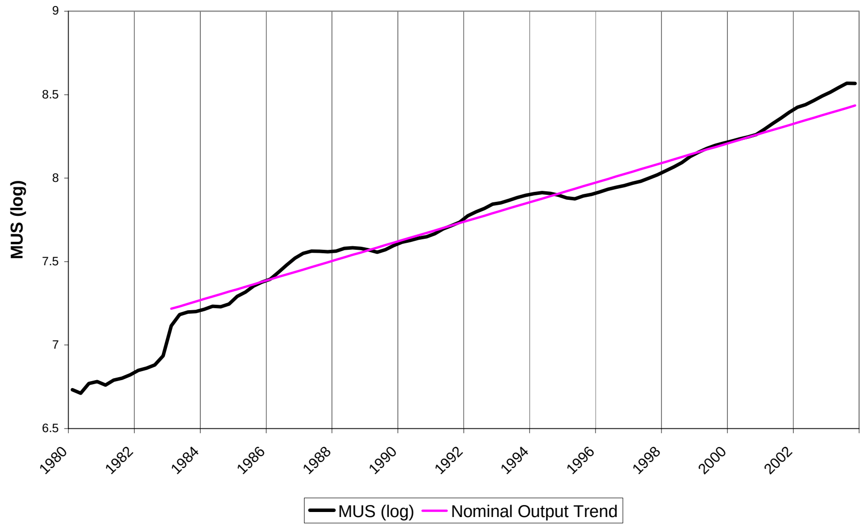

Fig. 6. MUS and Nominal Output Trend

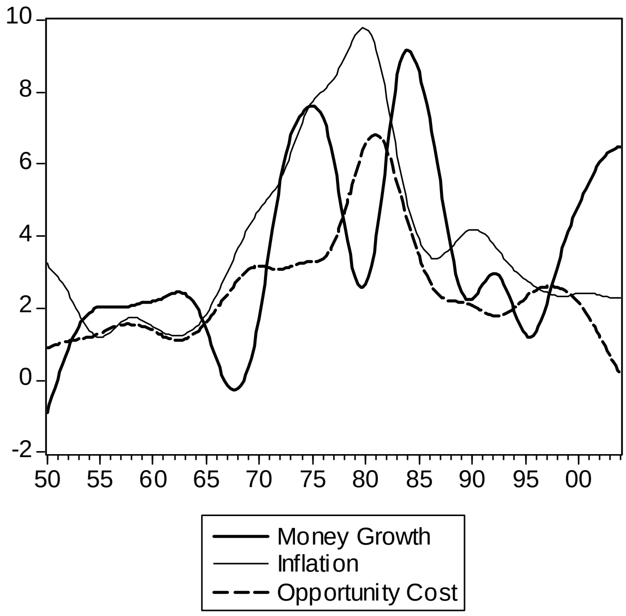

FIG. 7. U.S. money growth, inflation and opportunity cost (HP filtered)

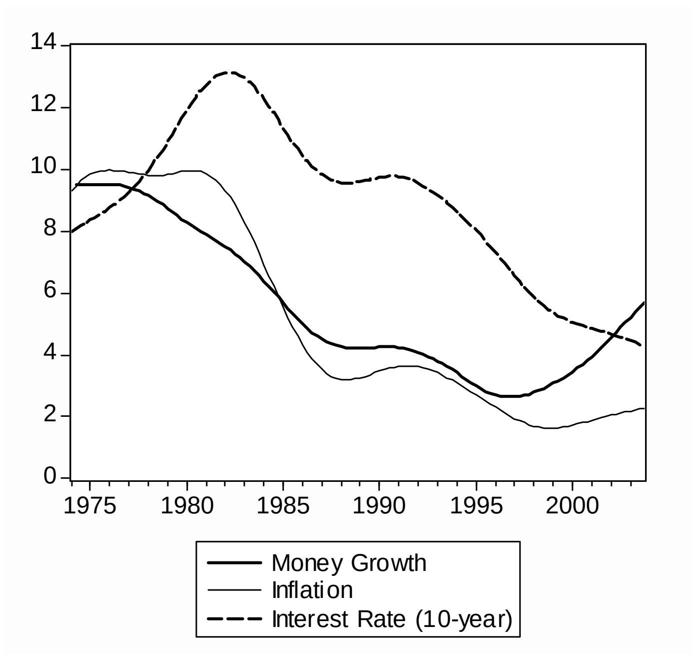

FIG. 8. Euro area money growth, inflation and interest rate (HP filtered)

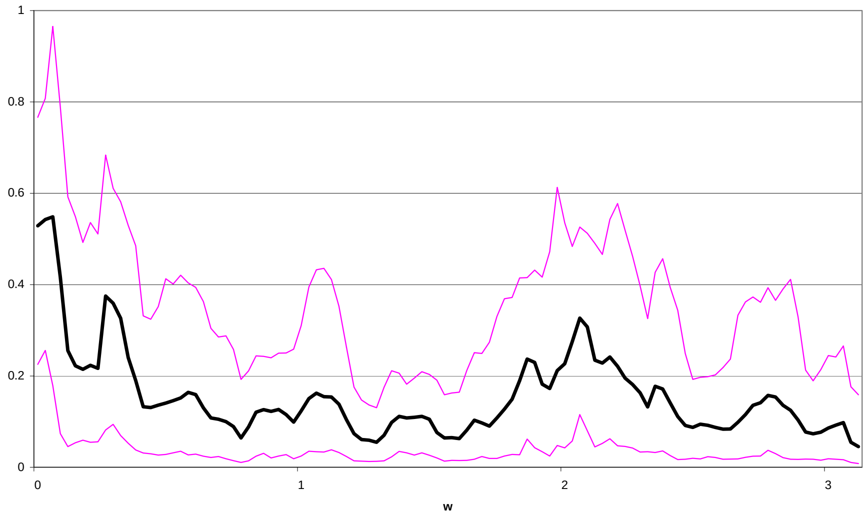

FIG. 9. Gain - U.S. - Not Velocity Adjusted

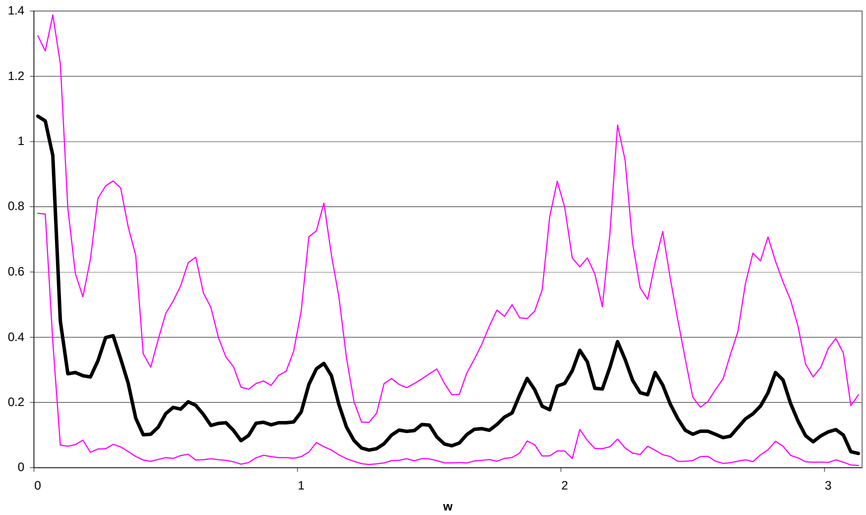

FIG. 10. Gain - U.S. - Velocity Adjusted

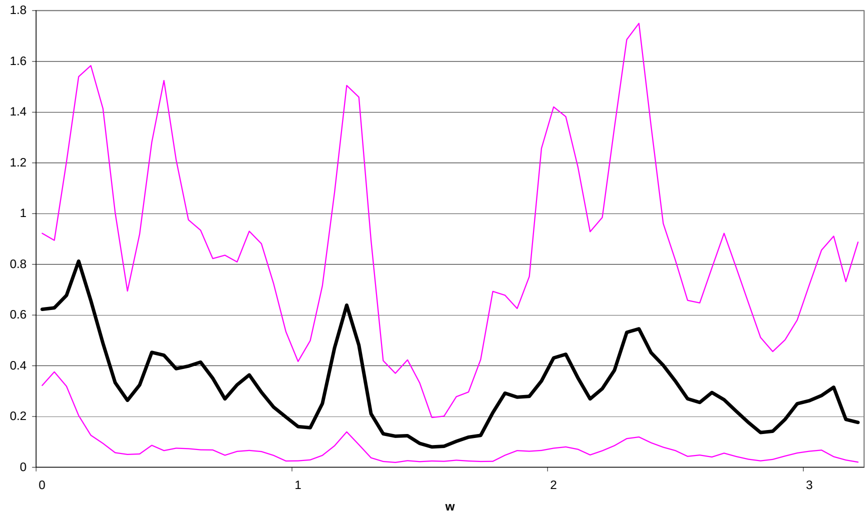

FIG. 11. Gain - Euro Area - Not Velocity Adjusted

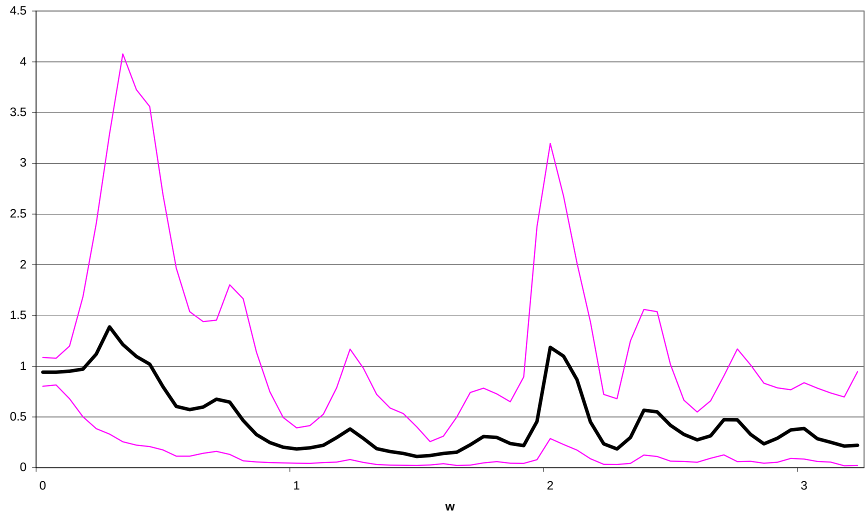

FIG. 12. Gain - Euro Area - Velocity Adjusted

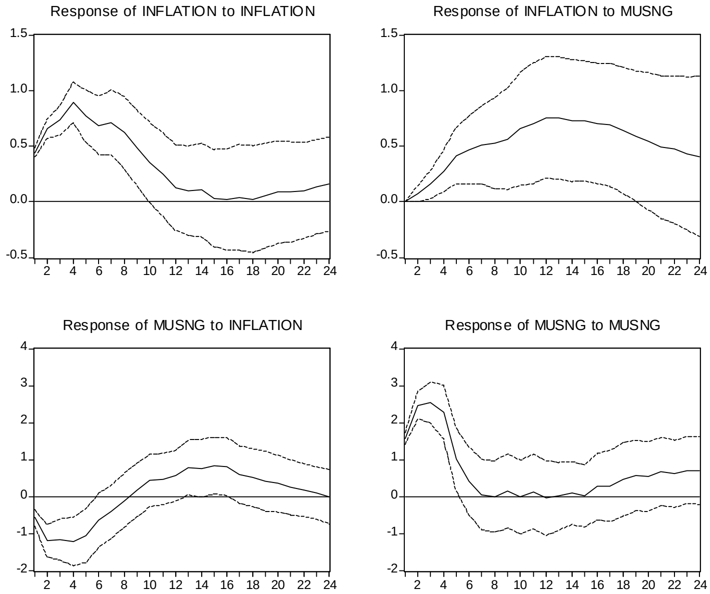

Fig. 13. IR of net money growth and inflation - U.S. (1953-2004)

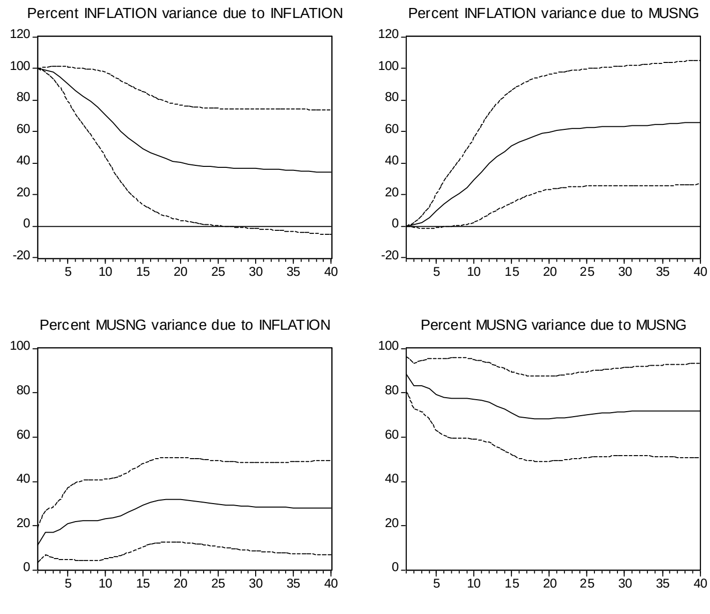

Fig. 14. VD of net money growth and inflation - U.S. (1953-2004)

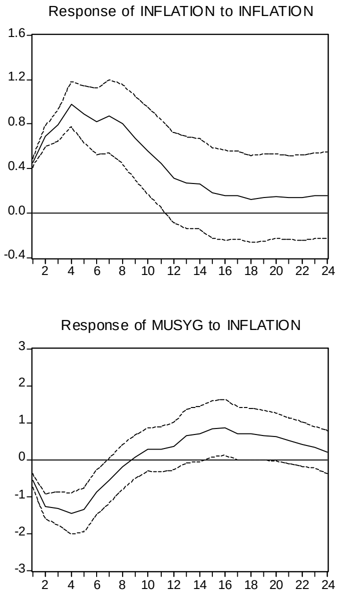

FIG. 15. IR of not-velocity-adjusted money growth and inflation - U.S. (1953-2004)

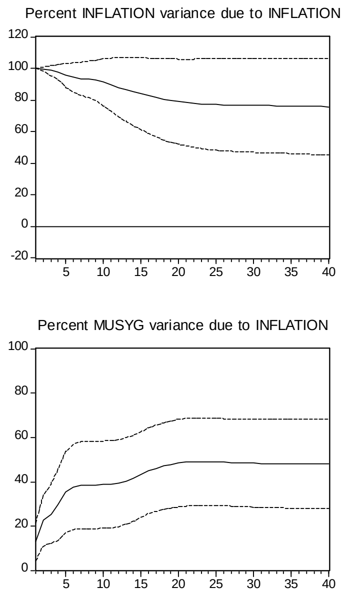

FIG. 16. VD of not-velocity-adjusted money growth and inflation - U.S. (1953-2004)

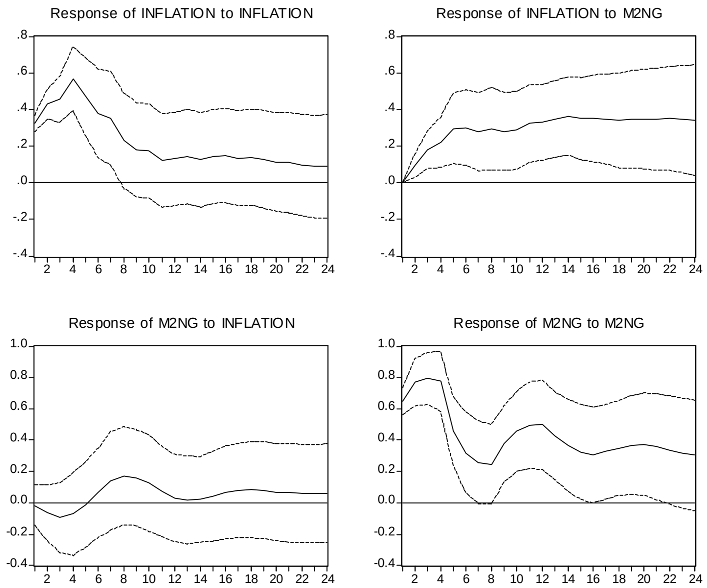

FIG. 17. IR of net money growth and inflation - Euro area (1975-2003)

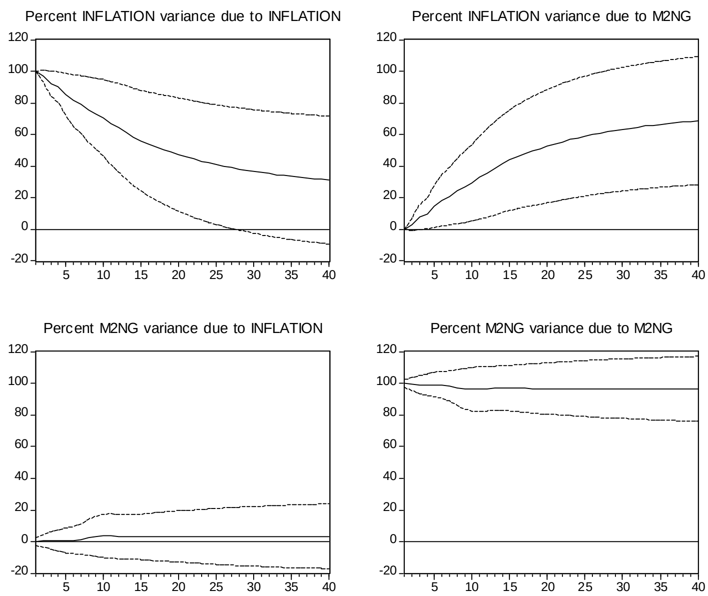

FIG. 18. VD of net money growth and inflation - Euro area (1975-2003)

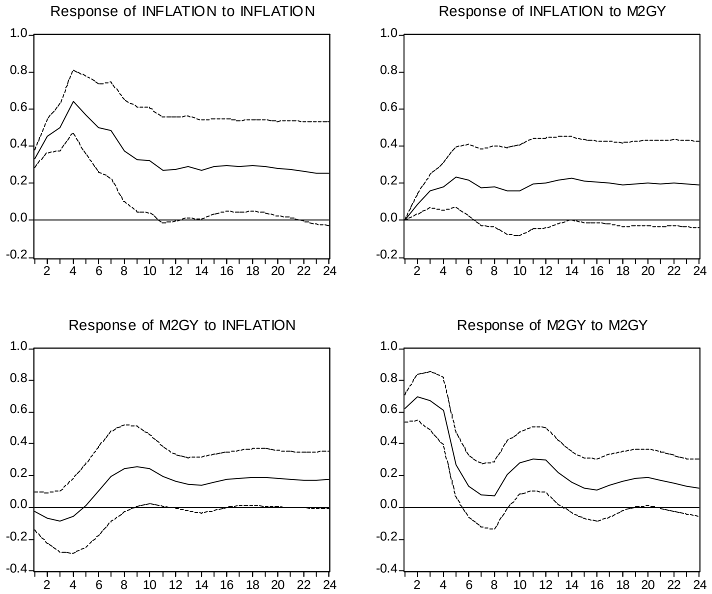

FIG. 19. IR of not-velocity-adjusted money growth and inflation - E.A. (1975-2003)

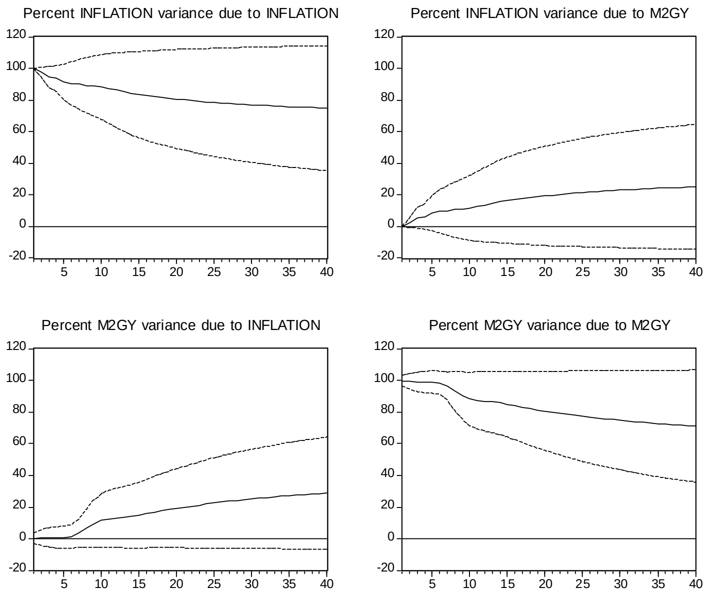

FIG. 20. VD of not-velocity-adjusted money growth and inflation - E.A. (1975-2003)

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