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Money and Interest Rates (p. 2)

Cyril Monnet
Warren E. Weber

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Some Monetary Facts (p. 14)

George T. McCandless Jr.
Warren E. Weber

Federal Reserve Bank of Minneapolis

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Money and Interest Rates

Cyril Monnet*
Economist
Directorate General Research
European Central Bank

Warren E. Weber*
Senior Research Officer
Research Department
Federal Reserve Bank of Minneapolis

Central banks routinely state monetary policies in terms of interest rates. For example, in October 2001, the European Central Bank stated that it had not changed interest rates recently because it considered current rates “consistent with the maintenance of price stability over the medium term” (ECB 2001, p. 5). In May 2001, Brazil’s central bank “increased interest rates” because it was “worried about mounting inflationary pressure,” according to the *New York Times* (Rich 2001). And in the first half of 2000, the U.S. Federal Open Market Committee increased the federal funds rate target three times in order to head off “inflationary imbalances” (FR Board 2000).

Despite this common practice, central banks do not control interest rates directly. They can target interest rates, but they can only attempt to hit those targets by adjusting other instruments they do control, such as the supply of bank reserves. Changes in these instruments directly affect a country’s stock of money, and financial market reactions to money supply changes are what actually change the level of interest rates. Clearly, in order to hit interest rate targets, central banks must have a reliable view about the relationship between money supply changes and interest rate changes.

Economic theory offers two seemingly contradictory views of this relationship. One view, which follows from the interaction of money demand and supply, is that money and interest rates are negatively related: increasing interest rates, for example, requires a decrease in the stock of mon-

ey. According to this view, money demand is a decreasing function of the nominal interest rate because the interest rate is the opportunity cost of holding cash (liquidity). So a decrease in the supply of money must cause interest rates to increase in order to keep the money market in equilibrium. We call this the *liquidity effect view*.¹

Another view, which follows from the Fisher equation, is that money and interest rates are positively related: increasing interest rates requires an increase in the rate of money growth. The Fisher equation states that the nominal interest rate equals the real interest rate plus the expected rate of inflation (Fisher 1896).² If monetary policy does not

*The authors thank Russ Cooper, Urban Jermann, and Art Rolnick for helpful discussions of earlier versions of this article.

¹The term *liquidity effect* as now used in the literature refers to the effect of unexpected changes in money growth rather than the effect of changes in the money stock. Nonetheless, since the origin of this idea is the interaction of money demand and supply, we use the term as a convenient label for the idea that money and interest rates are negatively related.

²The reasoning behind the Fisher equation is straightforward. Lenders (and borrowers) care about the number of units of goods they will get (or have to pay) for each unit of goods they lend (or borrow) today; this number is the *real* interest rate. However, loan contracts are written in terms of the number of dollars, not the goods, that the lenders (and borrowers) will receive (or pay) in the future; this number is the *nominal* interest rate. If the price of goods could never change over time, then real and nominal interest rates would be the same. But the price of goods can change. How much the price of goods is expected to change between the time a loan is made and the time it is repaid is the *expected rate of inflation*. Since loan contracts take account of the expected inflation rate, adding that rate to the real interest rate converts rates of return in terms of goods to equivalent rates of return in terms of dollars.

affect the real interest rate (and errors in inflation expectations are ignored), then the Fisher equation implies that higher nominal interest rates are associated with higher rates of inflation. Since in the long run, high inflation rates are associated with high money growth rates, the Fisher equation suggests that an increase in interest rates requires an increase in the money growth rate. We call this the *Fisher equation view*.

These two views provide seemingly conflicting answers to the question of how a central bank should translate its interest rate targets into actual changes in the money supply. One view implies that interest rates move in the opposite direction as the money supply; the other, that they move in the same direction.

This study presents empirical evidence as well as a simple model to explore this apparent conflict. The empirical evidence supports both views of the relationship between changes in money and changes in interest rates. The model shows that the two views are not, in fact, contradictory. Which view applies at any particular point in time depends on when the central bank's change in money is to occur and how long the public expects it to last. According to the model, the nominal interest rate at any point in time is determined by current and expected future money growth rates. A surprise increase in the current rate of money growth, for example, causes the nominal interest rate to fall if the public expects the surprise increase to be temporary, that is, if their expectations for future money growth rates are not increased as a result. However, if a surprise increase in current money growth is interpreted by the public as permanent, then the nominal interest rate will rise. A surprise increase only in expected future money growth rates will also raise the nominal interest rate.

Our study has three parts. In the first part, we consider the empirical evidence for the two views. We start by considering cross-country correlations between average money growth rates and average nominal interest rates for about 40 countries, both developed and developing. Using long-run averages, we find strong, positive correlations between these variables. The correlations remain positive when the time period over which the averages are taken is as short as one year. We also briefly examine the U.S. experience since 1960, and that is consistent with the long-run cross-country evidence. We see all of this evidence as support for the Fisher equation view.

But we also find empirical evidence consistent with the liquidity effect view. We summarize the results of studies

that have considered how a surprise change in the money supply—a so-called monetary policy shock—affects interest rates. Although somewhat mixed, the empirical evidence on balance does support the liquidity effect conclusion that the money–interest rate relationship is negative. A surprise decrease in the money supply, for example, will lead to increases in interest rates.

In the second part of the study, we turn to economic theory and present a simple model that incorporates both views of the money–interest rate relationship. The model allows money supply changes within a period to be accompanied by nominal interest rate changes in the opposite direction, which is consistent with the liquidity effect view. The model also allows the long-run average nominal interest rate to move positively, percentage point for percentage point, with the long-run average rate of money supply growth, which is consistent with the Fisher equation view. The model shows that how changes in the money supply affect interest rates depends both on what happens to the money stock today and on what is expected to happen to it in the future. If the money stock is unexpectedly changed today, but future money growth rates are expected to remain unchanged, then interest rates move in the opposite direction. But if the money stock is unexpectedly changed today and future money growth rates are expected to move in the same direction, then interest rates move in that direction too.

Finally, in the third part of the study, we shift from one type of monetary policy to another. Up to this point, we have assumed that the monetary policy is stated in terms of the money supply. However, again, because most central banks today state their policies in terms of interest rates, we examine the question of whether money and interest rates have the same relationship when central banks formulate monetary policy in terms of an interest rate rule rather than a money supply rule. We show that they do. We do that by incorporating into our model a version of the so-called Taylor rule, which approximates the way that many central banks currently appear to set monetary policy (Taylor 1993). Under this rule, the central bank has an inflation target, and it raises nominal interest rates when inflation is above target and lowers them when it is below target. We find that under such a policy rule, money growth and interest rates move in opposite directions as long as the inflation target remains unchanged. However, in order to lower that target, a central bank must lower both money growth and nominal interest rates.

Table 1
The Samples

Developing and Developed Countries With IMF Data Covering at Least 14 Years of Money Growth and of an Interest Rate Series

Country		Time Period Covered	
		Short-Term Money Market Rates	Long-Term Government Bond Yields
Type	Name		
Developed	Australia	1970-95	1960-98
	Austria	1967-97	1965-97
	Belgium	1960-97	1960-97
	Canada	1975-98	1960-98
	Denmark	1972-98	1960-98
	Finland	1978-97	—
	France	1960-97	1960-97
	Germany	1960-98	1960-98
	Ireland	1971-96	1960-96
	Italy	1969-97	1960-97
	Japan	1960-98	1960-98
	Netherlands	1960-97	1960-97
	New Zealand	1983-97	1960-97
	Norway	1972-98	1960-98
	Portugal	1978-97	1960-97
	South Africa	1960-98	1960-98
	Spain	1974-97	1979-97
	Switzerland	1969-98	1960-98
	United States	1960-98	1960-98
	Developing	Fiji	1982-98
Honduras		—	1983-98
India		1960-97	—
Indonesia		1974-98	—
Jamaica		—	1962-97
Korea		1977-98	1974-98
Kuwait		1979-98	—
Malawi		—	1981-97
Malaysia		1968-98	—
Mauritius		1978-98	—
Netherlands Antilles		—	1983-98
Nepal		—	1981-97
Pakistan		1960-98	1960-97
Singapore		1972-98	—
Solomon Islands		—	1981-98
Sri Lanka		1978-98	—
Thailand		1977-98	1976-98
Trinidad and Tobago		—	1967-92
Tunisia		1981-98	—
Venezuela		—	1984-98
Western Samoa	—	1979-98	
Zimbabwe	1975-98	1968-92	

Empirical Evidence

We start our study by examining the empirical evidence relevant to the relationship between money and interest rates. We begin with cross-country and U.S. evidence that turns out to support the Fisher equation view. Then we present a brief review of evidence that supports, to some extent, the liquidity effect view.

The Fisher Equation View: A Positive Relationship
Evidence that supports the Fisher equation view of the relationship between money and interest rates comes primarily from correlations between these two variables within a cross section of countries.

To examine these data, we start by computing the correlation between long-run averages of the two variables. We use the long-run averages because the quantity theory relationship between money growth and inflation, which is an essential part of the link between money growth and interest rates, appears empirically to hold in the long run, but not the short run (Lucas 1980). That is, the correlation between money growth and inflation is strong and positive over long horizons, but much weaker over short horizons.³ Thus, we expect that the correlation between money growth and nominal interest rates will be much stronger in long-run data than in short-run data.

And that is what we find. Correlations over long periods are strong and positive. Correlations over short periods are weaker, but still positive. We use data for a cross section of countries rather than for just one country in order to get a reasonable number of data points on which to base the correlations between the long-run averages.

The data we use cover the period from 1961 to 1998 and are from the DRI-WEFA version of the International Monetary Fund's publication *International Financial Statistics* (IMF, various dates). For money growth rates, we use the series *money* (line 34 in the IMF tables), which is essentially a measure of the U.S. M1 definition of the money supply. For nominal interest rates, we use two series: *money market rates* (line 60b), which is the rates on "short-term lending between financial institutions," and *government bond yields* (line 61), which is the "yields to maturity of government bonds or other bonds that would indicate longer term rates." By using both series, we are able to check that the results are not sensitive to the maturity of the nominal interest rate chosen.

³The relationship between money growth and inflation has been extensively studied by examining cross-country correlations. (See, for example, McCandless and Weber 1995, reprinted elsewhere in this issue.) However, the money growth-nominal interest rate relationship has not.

For our computations, we use only countries that have data covering at least 14 years on money growth and on one or both interest rates. (See Table 1.) For the money market rate series, we found 43 countries (20 developed and 23 developing) that satisfy these criteria. Because of some data problems, however, we are able to use only 32 of these countries (19 developed and 13 developing) as our short-term interest rate sample.⁴

For the government bond yield series, we found 31 countries (18 developed and 13 developing) that satisfy the criteria. However, because one country, Venezuela, has had both money growth and nominal interest rates considerably higher than the other countries with this series (both slightly over 28 percent), we report results for the long-run interest rate sample both with and without data for Venezuela.

As can be seen in Table 1, there is considerable overlap between the developed countries in the two samples; the 18 countries with government bond yield data also have money market rate data. (The country with only money market rate data is Finland.) However, there is less overlap between the developing countries in the two samples; only Korea, Pakistan, Thailand, and Zimbabwe appear in both.

□ Long-Run Correlations

First we examine the relationships between the average rate of money growth and the average of the annual interest rates over the period from 1961 to 1998. The individual country observations with money market rates and government bond yields (with Venezuela omitted) as the interest rate measures are shown in Charts 1 and 2, respectively.⁵ The observations for developed and developing countries are distinguished in the charts. The calculated correlations are reported at the top of Table 2.

We find that the long-run correlations between those two variables are all positive and strong—all 0.62 or high-

⁴We eliminated Iceland, Maldives, and Morocco from the money market rate sample because although these countries' interest rate data span at least 14 years, several of their individual yearly observations are missing. We also eliminated seven African countries that are members of the French franc zone. Because of the monetary arrangements among these countries and between these countries and France, their nominal interest rates are unrelated to variations in their individual country money supplies. Instead, their nominal interest rates are almost identical and almost perfectly correlated with each other and strongly positively correlated with French interest rates. (All correlations between the French money market rate and interest rates for these countries are 0.90 or above.) Obviously, including these countries in our money market rate sample would bias downward the correlations we obtain. Finally, we eliminated Mexico, Argentina, and Brazil because we do not want the correlation results determined almost exclusively by countries with extremely high rates of inflation and nominal interest rates.

⁵Chart 2 appears to have only 17 developed country observations plotted because the observations for Denmark and Ireland are virtually identical.

Charts 1–2

A Strong, Positive Relationship Across Countries in the Long Run

Money Growth Rates vs. Short- and Long-Term Interest Rates in Developed and Developing Countries, * 1961–98 Averages

● Developed Countries ■ Developing Countries

Chart 1 Money Growth vs. Money Market Rates

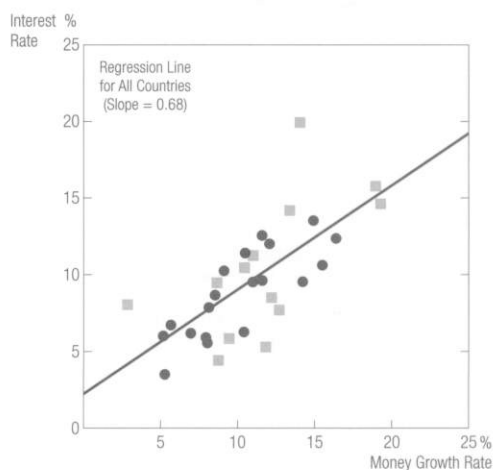
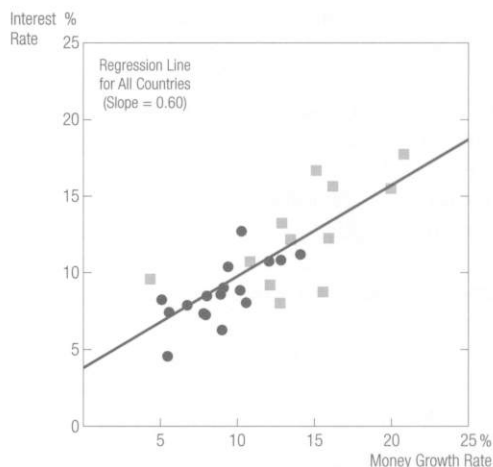


Chart 2 Money Growth vs. Government Bond Yields**



*For an identification of the countries in the two samples, see Table 1.

**This sample excludes Venezuela.

Source of basic data: IMF, various dates, lines 34, 60b, 61

er. Further, the correlations for all countries and for developing countries are quite similar regardless of which interest rate series is used. The correlation for developed countries is stronger when the shorter-term interest rates

(money market rates) are used than when the longer-term rates (government bond yields) are. Overall, however, the results in the charts and Table 2 indicate that in the long run, at least, countries that have low rates of money growth

Table 2

Measures of the Relationship Between Money and Interest Rates

Correlation Coefficients and Regression Slope Coefficients for Money Growth Rates† and Interest Rates in Developed and Developing Countries in Various Periods Between 1961 and 1998

Type of Measure	Time Period	Type of Country	Coefficient for Interest Rate Sample		
			Short-Term: Money Market Rates	Long-Term: Government Bond Yields With Venezuela	
				Excluded	Included
Correlation Coefficient	Long Run (1961-98)	All	.71	.79	.87
		Developed	.81	.70	.70
		Developing	.62	.66	.84
	Short Run 5-Year Periods (1964-98)	All	.52	.59	.68
		Developed	.52	.50	.50
		Developing	.49	.53	.69
	1-Year Periods (1961-98)	All	.24	.34	.41
		Developed	.22	.26	.26
		Developing	.23	.30	.41
Regression Slope Coefficient	Long Run (1961-98)	All	.68**	.60**	—
		Developed	.68**	.56**	—
		Developing	.66*	.51**	—
	Short Run 5-Year Periods (1964-98)	All	.63**	.44**	—
		Developed	.38**	.35**	—
		Developing	.50**	.44**	—

†Money growth is based on a series comparable to the U.S. M1 definition of the money supply.

*Statistic is significantly greater than zero, but not significantly less than one, at the 0.05 level.

**Statistic is significantly greater than zero and significantly less than one, at the 0.05 level.

Source of basic data: IMF, various dates, lines 34, 60b, 61

tend to have low nominal interest rates and countries with high rates of money growth tend to have high nominal interest rates.

The high correlations between money growth rates and nominal interest rates suggest that the relationship between these two variables is close to linear. The natural question is, what is the slope of this relationship? That is, how much do nominal interest rates increase for each percentage point increase in money growth?

To answer that, we regressed nominal interest rates on money growth for each interest rate sample as a whole and separately for the two subsamples of developed and developing countries. The regression lines based on the entire sample for each interest rate series are also shown in Charts 1 and 2. The points cluster rather tightly around these lines, as the strong correlations indicate. The slope coefficients for the entire two samples and for their subsamples are displayed at the bottom of Table 2. These statistics indicate that nominal interest rates increase about 50–70 basis points for each one percentage point increase in the rate of growth of money. All these coefficients are statistically significantly greater than zero, and most are also significantly less than one, at the 0.05 level.

□ Shorter-Run Correlations

Next we examine the correlations between money growth rates and nominal interest rates over shorter time periods. Again, we do this because studies of the relationship between money growth and inflation have found much weaker correlations in short-run data than in long-run data.

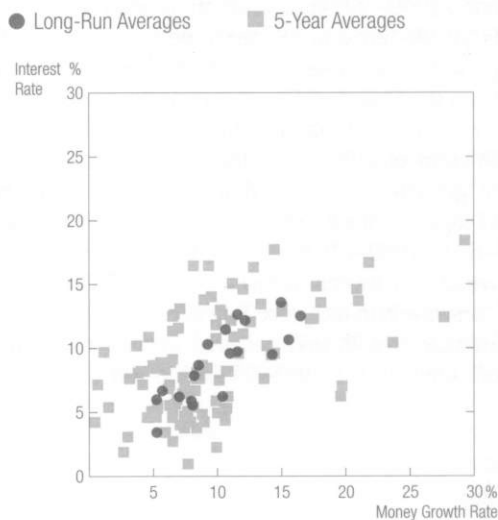
Our first shorter time period for the cross-country correlations of money growth and interest rates is five years. Our observations for these correlations are obtained by computing, for each country in each of the two interest rate samples, money growth rates and average nominal interest rates during nonoverlapping five-year periods beginning in 1964 and ending in 1998. (For some developing countries, we included observations that only cover four-year periods in order to increase the size of the sample.)

The resulting correlations between money growth and nominal interest rates are also reported in Table 2. As is true for other studies, here the correlation between money growth and nominal interest rates is somewhat weaker for the shorter time period. All of the correlations are lower than the corresponding correlations for the entire 1961–98 period. This indicates that the cluster of these observations around a line is less tight than for the longer-run observations. This is illustrated in Chart 3, where for the developed countries in the money market rate sample, we plot both

Chart 3

A Weaker, But Still Positive Relationship in the Shorter Run

Money Growth Rates vs. Money Market Interest Rates in 19 Developed Countries 1961–98 Averages and 5-Year Averages Over 1961–98



Source of basic data: IMF, various dates, lines 34, 60b

the long-run and five-year observations. Still, as Table 2 reports, all the correlations for the shorter-period averages are quite strong—0.49 or higher.⁶

Not only do the correlations weaken as the time horizon is shortened, but the slope of the relationship becomes less steep. This is shown at the bottom of Table 2. With the five-year periods, the slope coefficients for both samples range between 0.35 and 0.63. All of these coefficients are statistically significantly different from both zero and one.

Lastly, we examine the correlations at a one-year horizon. Table 2 shows that the one-year correlations are still positive, but they are much lower than the five-year correlations for all categories of countries. The very low correlations mean that at a one-year horizon, money growth and nominal interest rates have only a weak, positive relationship.

⁶The less tight clustering of five-year observations in Chart 3 also would be apparent if we were to use government bond yields, even though the correlations with these interest rates are stronger than those with money market rates.

□ *The U.S. Experience*

The data for the United States alone tell the same story as the cross-country data.

In Chart 4 we plot the time series of ten-year average growth rates for the M1 measure of the money supply and for ten-year average yields on six-month U.S. Treasury bills, beginning with the period 1960–69 and ending with the period 1990–99. The points are plotted at five-year intervals, so the ten-year averages are for overlapping ten-year periods. For these U.S. calculations, we use money data from the Board of Governors of the Federal Reserve System and interest rate data from DRI-WEFA.

The chart clearly shows that over the long run, U.S. money growth and nominal interest rates have usually moved together since 1960. In each ten-year period from 1960–69 to 1980–89, the rate of U.S. money growth and the average six-month Treasury bill yield both increased from their levels in the preceding period. And in 1990–99, U.S. money growth and nominal interest rates both decreased. Only in the 1985–94 period did these variables

move in opposite directions; money growth rose in this period while nominal interest rates fell. The correlation between average M1 growth and six-month Treasury bill yields for the observations plotted in Chart 4 is 0.83. (If only the four nonoverlapping intervals are used, the correlation is 0.94.)

We also examine the correlation between money growth and interest rates in the United States at a one-year horizon. These observations are plotted in Chart 5 along with the ten-year averages just discussed. The correlation for the one-year averages is 0.20. Thus, with U.S. data as well as with cross-country data, the correlation between money and interest rates is weaker over the short run than over the long run. Even over the short run, however, the correlation is still positive.

The Liquidity Effect View: A Negative Relationship
The correlations presented above seem to support the Fisher equation view that money growth and interest rates are positively related. Still, other evidence does seem to sup-

Charts 4–5

A Similar Relationship in the United States

Money Growth Rates (M1) and Interest Rates (6-Month U.S. Treasury Bill Rates) in 1960–99

Chart 4 Strong and Positive in the Long Run
(Overlapping 10-Year Averages)

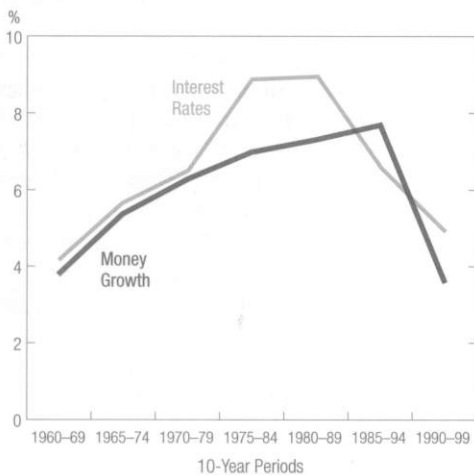
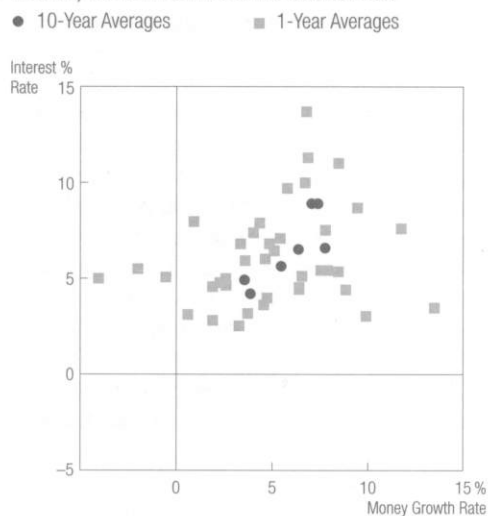


Chart 5 Weaker, But Still Positive in the Shorter Run



Sources of basic data: Federal Reserve Board of Governors, DRI-WEFA

port the opposite, liquidity effect view, that these variables are negatively related.

This evidence comes from studies that take a different approach to the idea of a *liquidity effect*. Since the rational expectations revolution of the 1970s, economic theory has come to recognize that expected and unexpected policy changes can have quite different effects. Thus, rather than define the liquidity effect as involving just changes in the money stock, recent studies make a distinction between the effects of expected and unexpected changes in the money stock—and in other monetary policy variables, as well. What matters for the liquidity effect, the studies assume, is unexpected changes, or *shocks*, to money and other policy variables. Monetary policy shocks are thought to occur for many reasons. For example, the preferences of policymakers can change, or the preliminary data available when policymakers are making their decisions can have measurement errors. (For more on monetary policy shocks, see Christiano, Eichenbaum, and Evans 1999.) According to the updated version of the liquidity effect view of the money–interest rate relationship, positive monetary policy shocks push interest rates down and negative shocks push them up.

There is a huge empirical literature on how monetary policy shocks affect a wide range of economic variables. Since this literature is well-reviewed in the recent articles by Bernanke and Mihov (1998) and by Christiano, Eichenbaum, and Evans (1999), we will here only briefly discuss the major findings that relate to the liquidity effect view of how monetary policy shocks affect interest rates.

The bulk of the evidence for this view comes from studies using vector autoregression (VAR) models and post–World War II data for the United States. In these studies, monetary policy shocks are that part of the policy variable that cannot be explained given the information set available at the time. The liquidity effect is found in these studies when the monetary policy variable experiencing the shock is assumed to be M2, nonborrowed reserves, or the federal funds rate. However, when M0 or M1 is the monetary policy variable, the liquidity effect is found to be not statistically significantly different from zero. There is also some evidence that the liquidity effect is weaker after 1980 than before. Nonetheless, on balance, the empirical evidence from VAR models seems to support the existence of a liquidity effect qualitatively, at least in the short run, although researchers do not agree on how large it is quantitatively.

Other evidence comes from Cooley and Hansen (1995), who use a different methodology. They find a negative

correlation between M1 growth and both ten-year U.S. Treasury bond yields and one-month U.S. Treasury bill yields in quarterly data over the period from the first quarter of 1954 through the second quarter of 1991. The data used in this study have been detrended using the Hodrick-Prescott (H-P) filter. Since the H-P trend can be thought of as the anticipated part of the data, the detrended M1 series can be interpreted as the monetary policy shock. Under this interpretation, the negative correlation between money and interest rates is evidence of a liquidity effect.

A Simple Model

Now we present a simple model that is consistent with both views of the relationship between money and interest rates. From this model, we learn that how changes in the money stock affect interest rates depends not only on what is happening to money today, but also on what is expected to happen to money in the future. According to the model, if the money stock is changed today, but future money growth rates are not expected to change, then interest rates move in the opposite direction as the money stock, which is the liquidity effect view. But if the money stock is changed today and future money growth rates are expected to move in the same direction, then interest rates move in that direction too, which is the Fisher equation view.

Our model is that recently formulated by Alvarez, Lucas, and Weber (2001). It uses the cash-in-advance structure used by Lucas and Stokey (1987) first and by many studies since and a segmented market structure adapted from the work of Occhino (2000) and Alvarez, Atkeson, and Kehoe (forthcoming).

The model's economy is an exchange economy; it has no production. All agents in the economy have identical preferences, and each receives an identical endowment y of goods at the beginning of each period. Goods are assumed to be perishable; that is, they disappear at the end of the period if not consumed before then. Agents are assumed to be unable to (or to dislike to) consume their own endowments. Hence, they must shop for goods from other agents.

However, in this economy, goods are assumed to be very hard to transport, so agents cannot carry their own goods around to barter with other agents. This assumption provides a role in this economy for *fiat money*, intrinsically worthless pieces of paper. Think of each agent as a household actually consisting of two people: a seller and a shopper. In each period, the seller stays home to sell the household's goods to other agents for money. The shopper uses the receipts from the previous period's goods sales to buy

goods from other agents. Shoppers spend all their money in each period. Also, assume that shoppers can use a random fraction v_t (which can be interpreted as approximately the log of the velocity of money) of their current period sales receipts for their current period purchases. (Note that velocity in the model is $(1-v_t)^{-1}$.) This introduces uncertainty into the model in the form of velocity shocks.

Although households have identical preferences and endowments, they do not necessarily have the same trading opportunities. Specifically, a fraction $1 - \lambda$ of households, called *nontraders*, can only exchange in the market for goods. Nontraders face a budget constraint of the form

$$(1) \quad P_t c_t^N = v_t P_t y + (1-v_{t-1})P_{t-1}y$$

where c denotes consumption, P denotes the price level, the subscript denotes the time period, and the superscript the agent type ($N = \text{nontrader}$; $T = \text{trader}$). This budget constraint states that the nominal expenditures on consumption in the current period must equal the fraction of receipts from selling the endowment that can be spent in the current period plus the unspent fraction of receipts from selling the endowment in the previous period.

In every period, another fraction $0 < \lambda \leq 1$ of households, called *traders*, visit a bond market before going to the goods market. In the bond market, money is exchanged for government bonds, meaning that traders are on the other side of all open market operations engaged in by the monetary authority. As a result, traders absorb all changes in the per capita money supply that occur through open market operations in time period t . If the change in the money supply in period t is $M_t - M_{t-1} = \mu_t M_{t-1}$, then each trader gets $\mu_t M_{t-1} / \lambda$ units of fiat money in the period t bond market (where μ_t is the money supply growth rate). Since this new money is spent in the goods market, the budget constraint of traders is

$$(2) \quad P_t c_t^T = (1-v_{t-1})P_{t-1}y + v_t P_t y + \mu_t M_{t-1} / \lambda.$$

The resource constraint for this economy is that the households' total consumption must equal their total endowment, or

$$(3) \quad \lambda c_t^T + (1-\lambda)c_t^N = y.$$

Substituting equations (1) and (2) into (3) yields

$$(4) \quad P_t y = (1-v_{t-1})P_{t-1}y + v_t P_t y + \mu_t M_{t-1}.$$

Since the total number of units of fiat money carried into period t is

$$(5) \quad M_{t-1} = (1-v_{t-1})P_{t-1}y$$

equation (4) is a version of the quantity theory. Specifically, (4) can be rewritten as the growth rate version of that theory: the rate of inflation in this economy

$$(6) \quad \pi_t = (P_t / P_{t-1}) - 1$$

equals the rate of money supply growth μ_t , plus the rate of velocity growth $v_t - v_{t-1}$, or

$$(7) \quad \pi_t = \mu_t + v_t - v_{t-1}.$$

Solving (1), (2), and (3) reveals that the consumption of traders is

$$(8) \quad c_t^T = y[1 + (\mu_t / \lambda)] / (1 + \mu_t).$$

As long as not all agents are traders, the consumption of traders increases with the rate of growth of the money supply. This is because traders use the money injections to bid up the prices of goods. That activity lowers the real value of the money balances that nontraders brought into the goods market. Thus, traders are able to bid goods away from nontraders in the goods market. When all agents are traders, however, all agents receive the money injections, so that they all enter the goods market with the same quantity of money. Hence, even though prices get bid up, goods are not reallocated. Note that prices will get bid up by the amount that the money supply increases regardless of the fraction of traders in the economy, because the quantity of the endowment is constant.

The determination of nominal interest rates in this economy follows from equilibrium in the bond market and the familiar marginal condition for pricing assets:

$$(9) \quad (1+r_t)^{-1}[U'(c_t^T)/P_t] = (1+\rho)^{-1}E_t[U'(c_{t+1}^T)/P_{t+1}].$$

Assume that bonds issued in period t are promises to one unit of fiat money in period $t + 1$, that r_t is the nominal rate of interest on those bonds in period t , that $E_t(\cdot)$ is an expectation conditional on history in period t and earlier, ρ is the agents' subjective rate of time preference, and U' is marginal utility. Then the left side of (9) is the marginal utility of the goods that agents have to give up in order to

buy a bond in period t . The right side of (9) is the discounted expected marginal utility of the goods that will be received in period $t + 1$. The marginal utilities are evaluated at the consumption of traders, because only traders can participate in the bond market.

If traders have a momentary utility function that displays constant relative risk aversion

$$(10) \quad U(c_t) = c_t^{1-\gamma}/(1-\gamma)$$

where γ is the coefficient of risk aversion, then a useful approximation to (9) is

$$(11) \quad r_t = \hat{\rho} + E_t(\mu_{t+1}) + \phi(E_t\mu_{t+1} - \mu_t) + E_tv_{t+1} - v_t$$

where $\hat{\rho} - \rho > 0$ is a risk correction factor,

$$(12) \quad \phi = \gamma(1-\bar{v})(1-\lambda)/\lambda \geq 0$$

and \bar{v} represents a constant velocity. The equation for the determination of the interest rate (11) is consistent with both views of the relationship between money and interest rates.

To see this, assume, again, that the economy has some nontraders ($\lambda < 1$) and that velocity is constant ($v_t = \bar{v}$). Assume that in the long run, money growth fluctuates randomly around some mean growth rate $\bar{\mu}$,

$$(13) \quad \mu_t = \bar{\mu} + \varepsilon_t$$

where ε_t is a white noise error term that can be interpreted as a transient change in, or *shock* to, the money stock in period t which does not change the expected future rates of money growth. Substituting (13) into (11) yields

$$(14) \quad r_t = \hat{\rho} + \bar{\mu} - \phi\varepsilon_t.$$

Consistent with the liquidity effect view, (14) shows that money growth rate shocks lead to changes in the interest rate in the opposite direction. Consistent with the Fisher equation view, (14) shows that changes in the mean (or long-run) rate of growth of the money supply lead to changes in the nominal interest rate in the same direction.⁷

Different Rule, Same Relationship

Our discussion so far of the relationship between money and interest rates implicitly assumes that the central bank states its monetary policy in terms of money supply

growth. As we have noted, however, today most central banks state their policy in terms of interest rates. Do money and interest rates have the same relationship when central banks use interest rate rules rather than money supply rules? Yes.

This can be seen by incorporating an interest rate policy rule into our model. A simple interest rate rule that approximates the way in which many central banks currently seem to operate is

$$(15) \quad r_t = \hat{\rho} + \bar{\pi} + \theta(\pi_t - \bar{\pi})$$

with $\theta > 0$. According to this policy, a central bank raises the nominal interest rate above its target of $\hat{\rho} + \bar{\pi}$ whenever current inflation is above the target rate of $\bar{\pi}$ and lowers the nominal interest rate whenever inflation is below that target rate. The policy rule (15) is a simplified version of what is, again, commonly known as the *Taylor rule* (Taylor 1993).

Substituting (7) and (15) into (11) yields a difference equation in $\mu_t - \bar{\pi}$ which can be solved forward under the assumption that $\theta > 1$. In the special case that velocity is independent and identically distributed with mean \bar{v} and variance σ^2 , the solution⁸ is

$$(16) \quad \mu_t - \bar{\pi} = -[(\phi + \theta^2)/(\phi + \theta)^2](v_t - \bar{v}) + [\theta/(\phi + \theta)](v_{t-1} - \bar{v}).$$

Substituting this result into (15) yields

$$(17) \quad r_t = \hat{\rho} + \bar{\pi} + [\theta\phi/(\phi + \theta)^2](2\theta + \phi - 1)(v_t - \bar{v}) - [\theta\phi/(\phi + \theta)](v_{t-1} - \bar{v})$$

and substituting into (17) yields

$$(18) \quad \pi_t - \bar{\pi} = \phi[(2\theta + \phi - 1)/(\phi + \theta)^2](v_t - \bar{v}) - [\phi/(\phi + \theta)](v_{t-1} - \bar{v}).$$

Because of the way that monetary policy has been specified, the only source of uncertainty in the economy is

⁷The model given by (13) and (14) can be correct even though the slope of the regression lines in Charts 1–3 is less than one. When (13) and (14) hold, such a regression has an errors-in-variables problem.

⁸The same general conclusions hold if velocity is assumed to follow a random walk rather than being independent and identically distributed. Then, however, the actual solutions for $\mu_t - \bar{\pi}$ and r_t would be different. For a more complete discussion of these two situations, see Alvarez, Lucas, and Weber 2001.

shocks to velocity. So consider a positive shock to velocity; that is, $v_t - \bar{v} > 0$. Equation (18) shows that this shock causes inflation to be above trend. Following the policy rule (15), the central bank responds by raising the nominal interest rate, as shown by (17), which is achieved by reducing the current rate of money growth, as shown by (16). (Note that in this model, reducing the current rate of money growth means that the money stock in the current period is lower than it otherwise would have been, since the money stock in period $t - 1$ is given.) Thus, under this policy, a central bank fights inflation by doing what is traditionally thought of as monetary tightening—reducing the money supply and raising interest rates.

However, the solutions for $\mu_t - \bar{\pi}$ and r_t also show that a central bank should behave differently if it wants to lower the inflation target rather than respond to deviations of inflation rates from the target. According to the Taylor rule, a lowering of the inflation target requires a central bank to lower nominal interest rates by the same amount as the target is lowered. This is shown by the presence of the $\hat{\rho} + \bar{\pi}$ term in (17). Further, (16) shows that the central bank lowers interest rates by decreasing the current growth rate of the money supply.

Here's the intuition: Suppose that the old inflation target was $\bar{\pi}$, that the new target is $\hat{\pi} < \bar{\pi}$, and that there have never been any shocks to velocity. By reducing the money supply in the current period from what it would otherwise have been, the central bank can lower the price level in the current period and, hence, have $\pi_t = \hat{\pi}$. And since agents know the policy rule, they know about the change in the inflation target. Therefore, they expect lower money growth and lower inflation in the future, which causes the nominal interest rate to immediately decline.

Conclusion

Here we have considered how central banks should translate their interest rate targets into changes in the money supply. Economic theory offers two, apparently conflicting, views about this. One, the liquidity effect view, is that increasing interest rates requires a decrease in the money supply. The other view, the Fisher equation view, is that increasing interest rates requires an increase in the rate of growth of the money supply. We have examined the empirical evidence and found that it is consistent with both views. We have then presented a model that reconciles the two views. In the model, surprise increases in current money growth that leave expected future money growth unchanged lead to lower interest rates. However, increases in

expected future money growth, whether or not they are accompanied by increased current money growth, lead to higher interest rates.

Our analysis also shows why a central bank would move the money supply and interest rates in opposite directions if it were following a monetary policy like the Taylor rule. According to such a rule, the central bank raises interest rates when the rate of inflation is above its target rate. If this deviation of inflation from target were expected to be transitory, as would be true if the deviation were due to a shock to velocity, then the central bank could achieve higher interest rates by temporarily reducing the current money supply (which, equivalently, reduces the current rate of growth of the money supply). This works because there is no reason for people to change their expectations of what money growth will be in the future.

However, if the deviation of inflation from target were expected to be permanent, as might be true if the real interest rate decreased, then money and interest rates would move in the same direction. The central bank would have to lower its interest rate target, and to achieve this, it would have to lower the expected future rate of money growth, as both the quantity theory and the Fisher equation prescribe.

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