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COMMODITY PRICES, OVERSHOOTING, MONEY SURPRISES, AND FED CREDIBILITY

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ABSTRACT

The general price level does not provide a sensitive indicator of whether monetary policy is tight or loose, because most prices are sticky. Interest rates are free to move, but they are an ambiguous indicator of monetary policy: one does not know whether changes in the interest rate are due to changes in the expected inflation rate or the real interest rate. Commodity prices provide the ideal sensitive indicator.

This paper has two distinct aims. First, a theoretical model of "overshooting" in commodity markets is presented. A known change in the money supply is shown to cause an instantaneous change in commodity prices that is greater than the proportionate change that describes long-run equilibrium. Second, we take the occasion of the Fed's Friday money supply announcements to test the theory. We find that an unexpectedly large money announcement causes significant negative reactions in prices of six commodities. This supports at once the sticky-price or overshooting view, and the notion that the market has confidence in the Fed's commitment to correct any deviations from its money growth targets.

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1. Introduction

Strict monetarist theory holds that excessive money growth, or the expectation of future money growth, shows up immediately in rapid inflation of goods prices. However, it is widely agreed that for most goods, prices are in fact sticky in the short run, and reflect money growth only in the long run. If one seeks a sensitive market measure of the perceived looseness or tightness of monetary policy, one must look elsewhere than at the general price level.

Interest rates, being determined in quickly adjusting financial markets, are free to respond immediately to expectations regarding monetary policy. For example, every Friday at 4:10 p.m. Eastern Standard Time the Federal Reserve Board announces the money stock for the week ending nine days previously. If the announced money supply is greater than what the market had been expecting, interest rates generally jump in the same direction. Clearly they are responding to revisions of the expected future money supply path. But they are an ambiguous indicator of expectations. On the one hand, an announced increase in the money supply may be received by the market as a sign that the Fed has increased its target money growth rate. The higher expected money growth rate would then imply a higher expected inflation rate, and the rise in interest rates would be explained as an inflation premium. On the other hand, the market may have confidence in the Fed's commitment to stick to its money growth target and may interpret the money supply change as an unintended fluctuation originating in money demand or in the banking system. The market would then expect the Fed to contract the money supply in the near future to get back to the target path. The rise in nominal interest rates would be explained as an

increase in real interest rates, without any necessary change in expected inflation.

Arthur Okun (1975), among others, drew a distinction between manufactured goods (and other "customer goods" and services) and basic commodities (or "auction goods"). The former are the ones with sticky prices: they are differentiated products traded in imperfectly competitive markets where there is no instantaneous arbitrage to insure perfect price flexibility. But the latter do have flexible prices: they are homogeneous products traded in competitive markets where arbitrage does insure instantaneous price adjustment. Commodities are more like assets in this respect. Since their prices are free to adjust from day to day, and even from minute to minute, they offer a potential measure of the market's perception of current monetary policy. And, unlike interest rates, they are an unambiguous indication of the direction in which monetary expectations are revised, as we will see.

While the literature on commodity prices is extensive, the macroeconomic side of the subject has been relatively neglected. Okun himself recognized that commodity prices would be sensitive indicators of inflationary expectations. It is not just that commodity prices are free to adjust and others are not. Commodities tend to be more easily stored and resold, so that they take on the speculative quality of assets as well. An expectation of future inflation will raise demand for commodity stocks, and thus drive up the price today. Indeed the sensitivity of commodity prices, particularly precious metals, to expected money growth is a familiar phenomenon to market participants and the financial press. (See for example the editorial in the Wall Street Journal of January 21, 1983, which points to rising gold prices as the first indicator that the Fed is anew losing its

grip on the money supply.)[1] The dampening effect that high real interest rates have on commodity prices is also recognized, though less often. In the short-term financial markets, high interest rates are thought of as reducing commodity prices because they make bonds more attractive to investors and commodity contracts less attractive. In the longer-term context of the fundamental supply and demand for the commodity, high interest rates are thought of as reducing the demand for commodities and therefore the prices because, along with storage costs, they constitute the cost of carrying inventories over into the next period.

What is missing from the literature, so far as we know, is a complete model of monetary policy and the determination of commodity prices that recognizes both the positive effect of an expected long-run rate of money growth and inflation, and the negative effect of currently tight liquidity and high real interest rates. We wish in particular to analyze the over-shooting phenomenon that is familiar from models of the foreign exchange market.[2] Consider a sudden known one percent drop in the money supply that is expected to be permanent. In the long run we would expect all prices, manufactured goods as well as commodities, to fall by one percent, in the absence of new disturbances. But in the short run manufacture prices are fixed. Thus the reduction in the nominal money supply is a reduction in the real money supply. To equilibrate money demand, interest rates of course rise. But we have an arbitrage condition that must hold in the commodity markets: since commodities are storable, the rate of return on Treasury bills can be no greater than the expected rate of increase of commodity prices, plus storage costs. This means that the spot price of commodities must fall today, and must fall by more than the one percent that it is expected to fall in the long run. In other words, commodities

prices must overshoot their long-run value. Only then can there be a rational market anticipation of future capital gain that is sufficient to offset the higher interest rate. The overshooting phenomenon can be thought of as a macroeconomic example of the Le Chatelier principle: because one variable in the system (manufactured goods prices) is not free to adjust, the other variables in the system (commodity prices) must jump correspondingly farther in order to compensate.

Consider now a sudden increase in the expected long-run rate of money growth, with no change in the current actual money supply. Of course the rate of increase of all prices, manufactured goods as well as commodities, will in the long run be equal to the new rate of money growth, in the absence of new disturbances. (We are taking secular growth in real income and in velocity as exogenous, and for simplicity equal to zero.) In the long run the inflation rate will be built into a high nominal interest rate.[3] But in the short run the nominal interest rate does not rise fully to reflect the higher inflation rate. The real interest rate falls. Now recall the arbitrage condition that precludes a difference between the interest rate and the expected rate of increase of commodity prices plus storage costs. At the moment of the increase in the expected rate of money growth, commodity prices must jump up above their long-run equilibrium path. Only then can there be a rational market anticipation of future depreciation (relative to the long-run inflation rate in the economy) that is sufficient to offset the lower (real) interest rate. Thus we have overshooting of equilibrium in this case as well.

In Section 2 we develop the model of determination of commodity prices that formalizes this notion of overshooting in response to changes in the expected level or growth rate of the money supply. However, the over-

shooting theory is only the first stage of this paper. In Section 3 we go on to examine empirically how futures prices for six commodities (gold, silver, sugar, cocoa, cattle and feeders) respond to the Fed's weekly money supply announcements. We find significant negative reactions to money surprises between the close of the market on Friday and the open on Monday. Clearly the market responds to positive money surprises by anticipating a future monetary contraction and an increase in the real interest rate, which causes commodity prices to fall immediately. These empirical findings can be used for two distinct purposes. First they can be thought of as a clean test of the sticky-price or overshooting theory, one with remarkably favorable results. Second, they can be thought of as a test of the credibility of the Fed to stick to its money growth targets. The results are evidence that the Fed did have high credibility with the market during the 1980-82 period.

2. The Overshooting Model of Commodity Prices[4]

We define two prices, the price of commodities, p_c in log form, and the price of manufactures, p_m in log form. Commodities are storable and thus subject to the arbitrage condition that their expected rate of change $\dot{p}_c^e$ minus storage costs sc, is equal to the short-term nominal interest rate i:

$$i = \dot{p}_c^e - sc \quad . \tag{1}$$

(We assume that the risk premium is either equal to zero or is subsumed in the storage costs, which are assumed constant.) It will turn out that the level of p_c is determined by equation (1) together with the rest of the model and the assumption that expectations are rational. Any readers who are not thrilled by the algebra of saddle-path equilibria are invited to skip to equation (15).

Unlike the commodities, the level of manufacture prices is fixed by its own past history. It can adjust in response to excess demand only gradually over time, in accordance with an expectations-augmented Phillips curve:

$$\dot{p}_m = \pi(d - \bar{y}_m) + \mu \tag{2}$$

where d is the log of demand for manufactures, $\bar{y}_m$ is the log of potential output in that sector, and μ is a term representing the expected secular rate of inflation. Here we can think of μ as the expected rate of money growth.[5] Excess demand is in turn defined to be an increasing function of the price of commodities relative to manufactures, and a decreasing function of the real interest rate:[6]

$$d - \bar{y}_m = \delta(p_c - p_m) - \sigma(i - \mu - \bar{r}) \quad . \tag{3}$$

We can think of $\bar{r}$ as any constant term. But our definition of long-run equilibrium will be zero excess demand $(\bar{d} = \bar{y}_m)$. So in long-run equilibrium

the relative price of the two commodities $(p_c - p_m)$ settles down to a given value $(\bar{p}_c - \bar{p}_m)$, for convenience normalized at zero in log form, and the real interest rate $(i - \mu)$ settles down to the given constant value $\bar{r}$.

We substitute (3) in (2).

$$\dot{p}_m = \pi[\delta(p_c - p_m) - \sigma(i - \mu - \bar{r})] + \mu \quad . \tag{4}$$

The last sector of our model is the money market. We assume a simple money demand equation:

$$m - p = \phi y - \lambda i \quad , \tag{5}$$

where m is the log of the nominal money supply, p is the log of the overall price level, y is the log of total output, ϕ is the elasticity of money demand with respect to output, and λ is the semi-elasticity of money demand with respect to the interest rate. The overall price level is an average of manufacture prices, with weight α, and commodity prices, with weight $(1 - \alpha)$:

$$p = \alpha p_m + (1 - \alpha)p_c \tag{6}$$

Substituting in (5),

$$m - \alpha p_m - (1 - \alpha)p_c = \phi y - \lambda i \quad . \tag{7}$$

We now consider the long-run equilibrium version of the money demand equation:

$$\begin{aligned} \bar{m} - \alpha\bar{p}_m - (1 - \alpha)\bar{p}_c &= \phi\bar{y} - \lambda\bar{i} \quad , \\ &= \phi\bar{y} - \lambda(\bar{r} + \mu) \quad , \end{aligned} \tag{8}$$

where we have used our result that the long-run real interest rate $\bar{i} - \mu$ is $\bar{r}$.

We take the difference of the two equations (7) and (8)

$$\alpha(p_m - \bar{p}_m) + (1 - \alpha)(p_c - \bar{p}_c) = \lambda(i - \mu - \bar{r}) \quad , \tag{9}$$

where we have assumed that there are no expected changes in the money supply ($m = \bar{m}$) other than the expected rate of constant growth, and we have for simplicity here taken output to be fixed at the level of potential output:[7] $y = \bar{y}$.

Now we bring the different components of our model together. We combine equations (1) and (9):

$$\dot{p}_c^e = \frac{\alpha}{\lambda}(p_m - \bar{p}_m) + \frac{(1-\alpha)}{\lambda}(p_c - \bar{p}_c) + \mu + \bar{r} + sc \quad . \tag{10}$$

We also combine equations (4) and (9) (and use the normalization $\bar{p}_c - \bar{p}_m = 0$):

$$\dot{p}_m = \pi[\delta((p_c - \bar{p}_c) - (p_m - \bar{p}_m)) - \sigma/\lambda(\alpha(p_m - \bar{p}_m) + (1-\alpha)(p_c - \bar{p}_c))] + \mu$$

$$= -\pi[\delta + \sigma\alpha/\lambda](p_m - \bar{p}_m) + \pi[\delta - \sigma(1-\alpha)/\lambda](p_c - \bar{p}_c) + \mu \quad . \tag{11}$$

We close the model by assuming that expectations are formed rationally: $\dot{p}_c = \dot{p}_c^e$. Equations (10) and (11) can be represented in matrix form:

$$\begin{bmatrix} \dot{p}_m \\ \dot{p}_c \end{bmatrix} = \begin{bmatrix} -\pi(\delta + \sigma\alpha/\lambda) & \pi(\delta - \sigma(1-\alpha)/\lambda) \\ \alpha/\lambda & (1-\alpha)/\lambda \end{bmatrix} \begin{bmatrix} (p_m - \bar{p}_m) \\ (p_c - \bar{p}_c) \end{bmatrix} + \begin{bmatrix} \mu \\ \mu + \bar{r} + sc \end{bmatrix} \tag{12}$$

The characteristic roots for (12) are the solutions $-\theta_1$ and $-\theta_2$ to

$$[-\pi(\delta + \sigma\alpha/\lambda) + \theta][(1-\alpha)/\lambda + \theta] - (\alpha/\lambda)\pi(\delta - \sigma(1-\alpha)/\lambda) = 0$$

$$-\theta = [-(1-\alpha)/2\lambda + \pi(\delta + \sigma\alpha/\lambda)/2] \pm \sqrt{[-(1-\alpha)/2\lambda + \pi(\delta+\sigma\alpha/\lambda)/2]^2 + \delta\pi/\lambda} \tag{13}$$

The solutions for the expected future paths of the two prices in level form, as τ goes from 0 to ∞ , are:

$$p_m(\tau) - \bar{p}_m(\tau) = \exp(-\theta\tau)[p_m(0) - \bar{p}_m(0)]$$

$$\text{and} \quad p_c(\tau) - \bar{p}_c(\tau) = \exp(-\theta\tau)[p_c(0) - \bar{p}_c(0)] \quad , \tag{14}$$

where $-\theta$ is the negative root from (13).

(We have thrown out the positive root to insure stability.) In rate-of-change form the equations are:[8]

$$\dot{p}_m = -\theta\,(p_m - \bar{p}_m) + \mu$$

$$\dot{p}_c = -\theta\,(p_c - \bar{p}_c) + \mu + \bar{r} + sc \quad . \tag{15}$$

Notice that in the special case in which manufacture prices are perfectly flexible (π, their responsiveness to excess demand, is infinite), θ is infinite, and the entire system adjusts to its long-run equilibrium instantaneously.

Most of the preceding was simply to establish that the rationally expected rate of change of commodities prices takes the simple regressive form of (15). Combining with the arbitrage condition (1):

$$p_c = \bar{p}_c - \frac{1}{\theta}\,(i - \mu - \bar{r}) \quad . \tag{16}$$

Notice that an increase in the real interest rate $i - \mu$ above its long-run equilibrium level $\bar{r}$ causes commodity prices p_c to fall below their long-run equilibrium path $\bar{p}_c$. It is necessary that commodities be currently "undervalued" so that there will be an expected future rate of increase in the price sufficient to offset the high real interest rate. Notice further that the higher is the speed of adjustment θ, the less will p_c react. It is a <u>slow</u> speed of adjustment in manufactured goods markets (π, to which θ is directly related that causes overshooting in the commodity markets.

What determines the long-run equilibrium path $\bar{p}_c$? In the long run, relative prices are determined exogenously, so

$$\bar{p}_c = \bar{p}_m = \bar{p} = \bar{m} - \phi\bar{y} + \lambda(\bar{r} + \mu) \quad , \tag{17}$$

where we have used the long-run money demand equation (8). Substituting into (16),

$$p_c = \bar{m} - \phi\bar{y} + \lambda(\bar{r} + \mu) - \frac{1}{\theta}(i - \mu - \bar{r}) \quad . \tag{18}$$

We see that, aside from the effect of the real interest rate, an increase in the expected long-run rate of money growth increases the current $\bar{p}_c$ and therefore the current p_c. We thus have what we wanted, a model of commodity prices that shows both the negative effect of the real interest rate and the positive effect of the expected long-run money growth rate. We will call it the "overshooting model" to distinguish it from the special case in which all prices are perfectly flexible and so the system is always at its long-run equilibrium.

3. The Market Reaction to Weekly Money Announcements

The positive reaction of short-term interest rates to surprises in the Fed's weekly money announcements is by now well-documented.[9] Several papers have looked at the reactions in other markets: Engel and Frankel (1982) and Cornell (1982b) for foreign exchange, Pearce and Roley (1982) for equities, and Hardouvelis (1982) for both. The motivation has often been similar to ours here. If the explanation for the increase in the interest rate is an increase in expected inflation, then the price of foreign exchange or equities, like the price of commodities, should in theory move in the same direction. If the explanation for the increase in the interest rate is an increase in the real interest rate, then the price of foreign exchange or equities, like the price of commodities, should move in the other direction. In each market, expected inflation raises the long-run equilibrium price. And in each market the real

interest rate reduces the current spot price relative to the long-run equilibrium price.[10] But, to our knowledge, no one has previously looked at the reactions of commodity prices to the money announcements.

It is of course the money surprise that should matter, the excess of the announced money supply over what had been expected by the market. If markets are efficient, whatever component of the announcement that was predictable will already have been incorporated into the interest rate and other financial market prices. The market's expectations are determined not only by past money supply figures, but by official pronouncements and many other factors as well. Any attempt to measure expected money growth by, for example, an ARIMA model of the money supply time series, is unlikely to be accurate. Fortunately there exists a convenient measure of market expectations. Money Market Services, Inc., each week surveys sixty individuals who make predictions of what the Friday money announcement will be, and reports the average.[11]

Before we turn to the empirical results, let us backtrack for a moment and examine why the weekly money announcement phenomenon is a good way to test the overshooting theory that we developed in the previous section. One can imagine other ways of testing the theory. For example, we could estimate equation (18), regressing monthly commodity prices against the money supply real income, the short-term interest rate, and some measure of the expected inflation rate. But we could not hope for good results. Commodity prices are determined by weather and a whole host of other real factors that probably overwhelm the monetary factors considered here. Our monetary model was intended to be nothing more than a model of how commodity prices move relative to their real equilibrium. (One could add an exogenous, though changing,

real term $\bar{p}_c - \bar{p}_m$ in equations (17) and (18).) We would have to try to model the other real factors if we were to have any hope of getting statistically significant results. Nor would the high sum of squared residuals be our only problem. Each of the righthand-side variables in equation (18) can be convincingly argued to be endogenous. Thus the regression estimates would be biased and inconsistent.

The weekly money supply announcement phenomenon is a perfect opportunity to test the theory, for two reasons. First, if we look at the change between the close of the market on Friday and the open on Monday, we have grounds for hope that relatively little will happen in between to affect market prices, other than the Fed's money announcement. Of course some relevant news will come out over the weekend. But the other factors will be far less important than they would be in a context of week-to-week or month-to-month changes. Second, there is good reason to believe that the money surprise is predetermined, i.e. that the error term arising from other weekend news will be independent of the money surprise: both the money announcement and the expectations survey are committed to paper before the Friday market close. Thus endogeneity problems vanish.

From our equation (18), the change in commodity prices in response to a money announcement (assuming no change in the actual current money supply on Friday at 4:10) is:

$$\begin{aligned} \Delta p_c &= (\lambda + 1/\theta)\ \Delta\mu - 1/\theta\Delta i \\ &= (\lambda + 1/\theta)\ \Delta\mu - (1/\theta)\ \psi\Delta\varepsilon\ , \end{aligned} \tag{19}$$

where ε is the market estimate of the transitory component of last week's

money supply, which is expected to be removed, and ψ indicates its effect on the interest rate.[12] Thus

$$\Delta p_c = [(\lambda + 1/\theta)\, a - (1/\theta)\psi\, b]\ DME \quad , \tag{20}$$

where DME is the money surprise, "a" is the proportion of it assigned to $\Delta\mu$ and "b" is the proportion of it assigned to $\Delta\varepsilon$. (See Mussa (1975 for a model showing that this form of expectations is rational, for the money supply process we have assumed and for particular values of a and b ; and see Hardouvelis (1982) for an example.)

In Table 1 we show the results of regressing various market prices against the money surprise. The money surprise is defined as the logarithmic change in the money supply announced at 4:10 p.m. on Friday from that announced one week previously, minus the change predicted by the survey. The dependent variable is the logarithmic change in the market price at the Monday opening from the price at the Friday close (times 100, to get the change in percent).[13,14]

We begin with the results for bond and foreign exchange markets, territory that has been covered in earlier papers. The highly significant negative coefficient on the price of 3-month Treasury bills illustrates once again the well-documented fact that the interest rate reacts positively to a money surprise. The negative reaction in the prices of the longer-term bonds is even more significant.[15]

The statistically significant negative coefficient for the dollar price of Swiss francs, and the almost-significant negative coefficient for the dollar price of Canadian dollars, in themselves constitute evidence that the reaction in the nominal interest rate is a reaction in the real interest rate, not in the expected inflation rate.

Table 1

Dependent Variable: Percentage change in market price, Open Monday over Close Friday

Independent Variable: Percentage money growth announced in excess of expectations

Sample: December 5, 1980-November 1, 1982 (100 observations)

Market	Constant	Money Growth Surprise	R^2	D-W	SSR
Treasury Bond	.081 (.109)	-1.087* (.215)	.207	1.84	115.98
GNMA	.131 (.087)	-1.001* (.172)	.258	1.92	74.20
Treasury Bill	.087* (.038)	-.428* (.075)	.249	1.81	14.19
Swiss Franc	.084 (.090)	-.520* (.177)	.081	2.17	79.08
Canadian Dollar	-.008 (.024)	-.087 (.046)	.035	1.95	5.42
Gold	-.096 (.186)	-.944* (.366)	.064	2.36	337.09
Silver	-.383 (.225)	-1.005* (.441)	.050	2.37	489.98
Sugar	-.360 (.203)	-.878* (.399)	.047	1.89	400.87
Cocoa	.044 (.150)	-.255 (.295)	.008	1.55	219.40
Cattle	.160 (.110)	-.443* (.215)	.041	2.25	116.87
Feeders	.010 (.077)	-.267 (.151)	.031	2.21	57.57

*Significant at the 95% level (standard errors in parentheses).

Table 2

Stacked Commodity Regressions

Dependent Variable: Percentage change in market price

Independent Variable: Announced money growth in excess of expectations

Sample: December 5, 1980-November 1, 1982 (6 x 100 = 600 observations)

	Constant	Money Growth Surprise	R^2	D-W	SSR
Open Monday over Close Friday	-.128 (.068)	-.632* (.134)	.036	2.11	1659.07
	-.061 (.041)	-.432* (.102)	.029	2.09	599.73
Mid-day Monday over Open Monday	-.166* (.041)	.133 (.080)	.005	1.97	594.84
	-.173* (.041)	.053 (.068)	.001	2.03	600.94
Close Monday over Mid-day Monday	-.163* (.073)	.085 (.144)	.001	1.87	1911.89
	-.090* (.041)	-.001 (.105)	.000	1.88	591.40
Close Monday over Open Monday	-.330* (.080)	.218 (.157)	.003	1.88	2261.84
	-.177* (.041)	.036 (.113)	.000	1.90	594.28
Close Monday over Close Friday	-.458* (.105)	-.414* (.206)	.007	2.04	3897.91
	-.172* (.041)	-.406* (.150)	.012	2.03	590.92

(a) * implies significance at the 95% level (standard errors in parentheses).

(b) The second line of estimates corrects for heteroscedasticity across the six different commodities.

But the new results are those for the six commodities. In each case the reaction is negative, and in every case but cocoa and feeders it is significant. Even gold and silver, which are so widely reputed to be hypersensitive to fears of monetary growth and inflation, clearly move inversely to the money announcement.

The levels of econometric significance in Table 1 are already high by macroeconomic standards. But to get more efficient estimates, we "stacked" the observations for all six commodities in a single regression. In other words, we constrained all reaction coefficients to be the same. This constraint comes out of the theory. A consultation with equation (18) or (19) will recall the fact that an increase in the real interest rate causes overshooting of commodity prices to an extent determined only by θ, the speed of adjustment of the sticky manufacture prices, because that is what drives the whole macroeconomy, not by any characteristic of the individual commodities. And an increase in the expected inflation rate causes an upward shift in equilibrium commodity prices of a magnitude determined by λ, the semi-elasticity of money demand with respect to the interest rate, again not by any characteristics of the individual commodities. Only if a change in the steady-state inflation rate implied a change in the relative price of commodities in long-run equilibrium, i.e. only if money were non-neutral even in the long run, would expected inflation have more effect on some commodity prices than on others.[16] The same is true of effects on foreign exchange prices.

The stacked regression is reported in the first two rows of Table 2. The second row of estimates corrects for heteroscedasticity across the six commodities. Either way, the negative coefficient on the money surprise is

indeed more highly significant than those in the regressions for individual markets.

It is of some interest to see what happens Monday after the opening. If the commodity prices were to continue to move in the same direction during the course of trading on Monday, this would constitute evidence of less-than-perfect efficiency in the market and an opportunity for speculative profits. A sharp movement in the opposite direction would constitute evidence of the same.[17] Table 2 shows regressions of the changes during Monday morning and Monday afternoon against the Friday money surprise. The positive coefficients show some movement in the opposite direction, but it is not statistically significant. Nor is the movement enough to undo the significance of the negative reaction computed from the Friday close to mid-day Monday or to the close Monday.

3. Conclusions

Our empirical findings can be used for two distinct purposes: (1) they support the notion that during the 1980-82 period, the market had confidence in the Fed's commitment to stick to its money growth targets, and (2) they support the overshooting model of commodity prices.

If one looked at the reaction of interest rates alone to Fed announcements, one could conceivably doubt the Fed's credibility. When a positive money surprise causes interest rates to rise, it could be interpreted as a sign that the market has revised upwards its expectations of money growth and inflation. But our examination of the reaction of commodity prices refutes this possibility. The movement of commodity prices in the opposite direction

can only mean that the market expects the Fed to tighten the money supply in the near future. In terms of equation (20), b must be large relative to a.

On the other hand, if one looked only at the reaction of commodity prices to Fed announcements, one could conceivably doubt the sticky-price or overshooting model, and cling to a strict monetarist view of the world in which all prices are perfectly flexible. When a positive money surprise causes commodity prices to fall, it would be interpreted as a sign that the market expects the Fed to reduce the money supply in the near future, a change which in a flexible-price world is reflected equally and instantaneously in all prices. But our knowledge of the reaction of interest rates refutes this possibility. The movement of interest rates in the same direction as the money surprise can only mean that the anticipated future decrease in the nominal money supply is a decrease in the real money supply, causing higher real interest rates and the other effects of tightened liquidity.

Footnotes

1. Examples from the academic literature are Bordo (1980), who shows that raw goods prices respond more quickly to monetary growth than do manufactures prices, and Van Duyne (1979), who models the speculative quality of commodities and gives further references.
2. The overshooting model of the exchange rate was developed by Rudiger Dornbusch (1976).
3. Furthermore, the higher interest rate implies a fall in real money demand in the long run. With no jump in the current level of the money supply (as opposed to its growth rate), the long-run equilibrium path of the price level must shift up discretely (in addition to becoming steeper) in order to reduce the equilibrium real money supply. In the exchange rate literature, e.g. Frenkel (1976), this is sometimes called the "magnification effect". See equation (17) below.
4. The model is an application of Dornbusch (1976) with the price of commodities substituted for the price of foreign exchange. We modify the money supply process to allow for disturbances to the rate of growth, in addition to the disturbances to the level that Dornbusch considered. The two degrees of freedom in this money supply process are sufficient to capture the two possible directions of reaction to the weekly money supply announcements that we wish to choose between in Section 3. But we could generalize the money supply process as much as we want, as in Engel and Frankel (1982). The commodity price would then be seen to move to reflect revisions in a presented discounted sum of all expected future money supplies, whatever path they may follow.
5. The model is qualitatively unchanged if we adopt other interpretations of μ such as the rate of change of $\bar{p}_m$ or $\bar{p}$ defined below. See

Obstfeld and Rogoff (1982) or Engel and Frankel (1983).

6. The description of $i - \mu$ as the real interest rate is loose, because i is the short-term interest rate, while μ is the expected long-term inflation rate. However, the model is again qualitatively unchanged if we substitute the expected short-term inflation rate $\dot{p}^e$. See, for example, Obstfeld and Rogoff (1982).

7. The assumption that output is fixed means that the excess demand referred to in equations (1) and (2) must be coming out of inventories. It would be preferable to have manufactured output endogenously determined by demand: $y_m = d$ (and $y = y_m + \bar{y}_c$). Once again, the model is not qualitatively altered by such an extension. See the appendix to Dornbusch (1976).

8. Notice that the secular inflation term in $\dot{p}_c$ exceeds that in $\dot{p}_m$ by $\bar{r} + sc$. This is a general problem with the commodity arbitrage condition (1). There are two possibilities. First, for an agricultural commodity, p_c may gradually increase relative to p_m (monetary considerations aside) during most of the year, as long as some of the previous harvest peak is being stored, and fall discontinuously when the new harvest comes in. (In anticipation, the stocks held would dwindle to zero before the harvest.) Thus there is no long-run trend in $p_c - p_m$. Alternatively, for a nonperishable, nonrenewable commodity such as gold or oil, there may indeed be a long-run trend in $p_c - p_m$, à la Hotelling. We are grateful to Peter Berck and Rudiger Dornbusch for both of these explanations.

9. Grossman (1981), Conrad (1981), Engel and Frankel (1982), Roley (1982), Urich and Wachtel (1981), Urich (1982), Cornell (1982a), and Hardouvelis (1982).

10. The empirical finding in the foreign exchange and equity markets is also the same as this paper's empirical finding from the commodities market: a significant negative reaction to money surprises. This supports (1) the sticky-price or overshooting view, and (2) Fed credibility in the market during the 1980-82 period.

11. The claim that the Money Market Services numbers do in fact represent market expectations, and that these expectations are rational, is supported in Grossman (1981) and in Engel and Frankel (1982), by a demonstration that one cannot use exchange rates or interest rates on the morning of the announcement, or relevant lags, to improve on the survey number as a predictor of what the money announcement will be.

12. In this section we are using i to represent the, say, one-month interest rate. If we were still using it to represent the <u>instantaneously short-term</u> interest rate as in the theory of the preceding section, then the money demand equation (5) would preclude it from jumping when m does not jump. The <u>one-month</u> interest rate can jump even if the instantaneously short-term rate does not, because of an increase in the future instantaneously short-term rates expected during the following month. In Engel and Frankel (1982) it is shown in a discrete-time version of our Section 2 model, that equation (19) holds, with $(1/\theta)\psi \equiv (1 + \lambda\theta)/\theta(1 + \lambda)$.

13. The price is the price of the nearest maturing futures contract. The data on opening (9:00 am Eastern Standard Time) and closing (3:00 pm E.S.T.) prices coincide with those reported in the <u>Wall Street Journal</u>. The data for cattle and feeders are from the Chicago Merchantile Exchange, for cocoa and (world) sugar are from the New York Coffee, Sugar & Cocoa Exchange, for gold and silver are from the New York

Commodity Exchange, for the foreign currencies and Treasury bills are from the International Money Market at the Chicago Merchantile Exchange, and for Treasury bonds and GNMA's are from the Chicago Board of Trade. Some futures contracts are traded during the same month that they mature. Whenever this was the case, we skipped to the next maturing contract. To insure consistency, whenever the month of the nearest maturing contract changed, we made sure that the change did not occur between Friday close to Monday close. The cash markets are distinct from the futures markets. We did not use them because cash price data are not available recorded at precise times before and after the 4:10 money announcements.

14. On a few occasions, the Fed did not announce the money supply until Monday. In that case we used the change in market price in the Tuesday open from the Monday close. When Friday or Monday was a market holiday, we used the preceding market close or next market opening, respectively.

15. While we would expect long-term interest rates to react in the same direction as short-term interest rates, their reaction should be damped. Cornell (1982a) shows that, while the reaction does decline somewhat with the term of maturity, long-term bonds still react far more than one would expect. Hardouvelis (1982) isolates this phenomenon by showing that the forward interest rates (implicit in the term structure) react significantly as far out as ten years. These findings seem to contradict the joint hypothesis of sticky prices (overshooting) and Fed credibility, which all the other empirical evidence supports. Hardouvelis argues that the paradox is explainable by a combination of inflationary expectations and the real interest rate (in equation (20)

above, "a" is large, but "b" is large as well). Or the excess reaction in the long-term interest rates may be due to a risk premium, a factor omitted from these monetary models.

16. One cannot rule out this possibility a priori. (Technically it would be a failure of "superneutrality".) For example, in a model with risk, gold and silver might be considered the only effective hedges against hyperinflation or nuclear war, and so their relative prices might rise permanently in response to an increase in inflationary fears. However Table 1 shows that the tendency of their prices to move in the opposite direction from the money surprise is even stronger than that for the other commodities.

17. The overshooting theory tells us that the commodity prices will come back, but only very gradually over time, as the entire price level of the economy adjusts to excess supply. This counter-movement should not show up in one day of trading. But some market observers feel that prices in fact overshoot by far more than is rational.

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