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IDENTIFYING THE OUTPUT EFFECTS OF MONETARY POLICY

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ABSTRACT

What are the relative effects of anticipated vs. unanticipated monetary policy? I examine the effect of this identifying assumption on VAR estimates of the output response to money, assuming that anticipated monetary policy can have some effect on output results in much shorter and smaller output response estimates—estimates closer to the predictions of most monetary models.

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1 Introduction

What are the real effects of monetary policy?

A huge recent literature has returned to this classic empirical question, trying to measure the dynamic path of real (and nominal) variables following a monetary shock.[1] By thinking carefully about what variables to include in a vector autoregression and how to identify money supply shocks (or, as a critic might put it, by extensive fishing), this literature has at last produced impulse-response functions that capture common priors about the qualitative effects of monetary shocks.

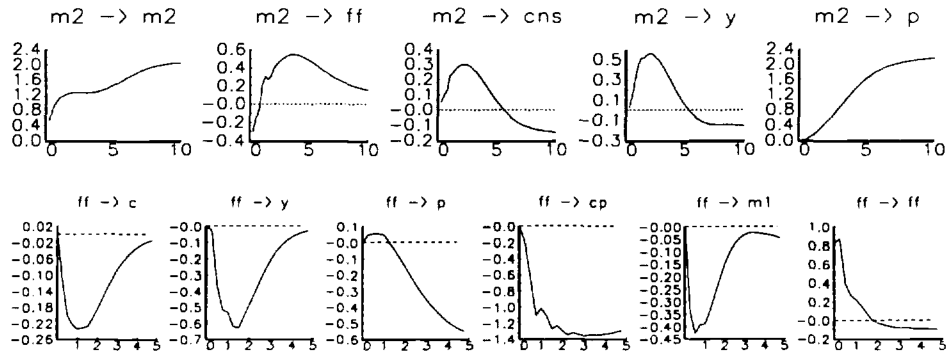

Figure 1: Responses to monetary shocks in two VARs. Horizontal axis in years, variables are 100*logs except ff in percent. Top panel: response to M2 shocks in M2, federal funds (ff), ND+S consumption (c), GDP (y), GDP deflator (p) VAR. Estimated in error correction form: log differences (except ff) on 4 lags and lagged c-y and lagged m2-p-y, quarterly 1959-1993 and orthogonalized in the given order. Bottom panel: response to ff shocks in c, y, p, cp (commodity price index), m1, ff VAR, estimated in log levels with 4 lags.

Figure 1 presents two examples, taken from Cochrane (1994a) which surveys this literature. The top row presents responses to M2 shocks. An M2 shock leads to a protracted rise in M2. Federal funds respond with an initial decline—a liquidity effect—and then a protracted rise—an inflation effect. Consumption and output rise temporarily, and prices rise. The long-run output effect is much less than one standard error from zero. In the

[1]See among many others Bernanke and Blinder (1988), Christiano and Eichenbaum (1991), Christiano, Eichenbaum and Evans (1994), Eichenbaum and Evans (1992a), Gordon and Leeper (1993), Sims (1992) and Strongin (1992) in the VAR tradition, and Romer and Romer (1994) for an estimate based on reading the FOMC minutes to identify money supply shocks.

bottom row, federal funds rate innovations are used to identify money supply shocks. In response to a surprise increase in federal funds, consumption and output decline temporarily, prices decline, and m1 declines. The federal funds shock is persistent, lasting about 2 years.

Although the signs of these responses are comforting, they are puzzlingly protracted. Output peaks two *years* after a monetary shock, and takes five years to die out. And these specifications were picked in part to minimize the length of output responses. By contrast, most monetary theories predict very short output responses. Furthermore, the output responses build up over time. Most monetary models with any dynamics have an immediate response followed by geometric decay, rather than this pronounced hump-shape. (See, for example, Christiano and Eichenbaum 1992.) Finally, the output responses are surprisingly large, given the size of typical open market operations.

However, we make an implicit identifying assumption when interpreting impulse-response functions in this way: *only unexpected money matters.* If we assume that expected changes in money can affect output, then the impulse response function confounds the effect of money on output with the effect of a monetary shock on future money. The continued expansion of money that is expected to occur following a shock can, *when it happens,* cause the prolonged expansion of output, via a short and small structural response.

In the body of this paper, I make the above observation concrete and quantitative. I specify two models by which anticipated money can affect output, I use them to infer structural output effects from the VARs, and I plot the responses to several monetary experiments. The anticipated money models infer output effects that are much shorter and smaller than the impulse-response function. Quantitatively, this theoretical identifying assumption is more important to the response function one recovers than the variable selection and orthogonalization issues on which so much of the VAR literature focuses.

Which identifying assumption is correct? The data (at least from one policy regime) cannot distinguish the anticipated from unanticipated money story. This is Sargent's (1976) "Observational equivalence." However, one can judge the plausibility of the results. The short and small output responses that one recovers on assuming some anticipated money effect are attractive, since they accord well with monetary theory; if only unanticipated money can affect output, we need a theory for the long distributed lag. In addition, the output response builds after a monetary shock in the same way that the monetary variable builds after the shock. Figure 2 dramatizes this point by plotting the M2 and output responses together. If only unanticipated money matters, the similarity of these two responses is pure coincidence, as the output response would be the same for any money response. In an anticipated money story, the output response has its shape *because* the monetary response has that shape. Thus, the responses suggest (but of course cannot prove) that there is at least some role for anticipated, systematic monetary policy.

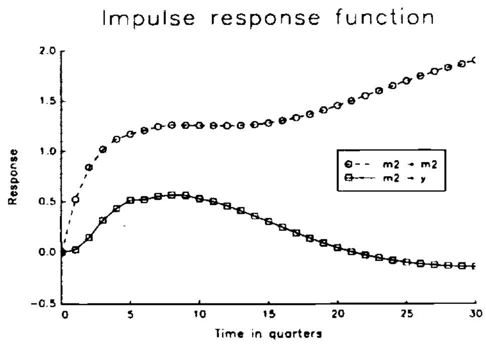

Figure 2: M2 and output responses from M2 VAR, plotted on same scale.

This anticipated-unanticipated identifying assumption is unrelated to the identification of a monetary shock by variable choice and covariance matrix orthogonalization, on which most of the recent literature focuses. An incautious reader of this literature can get the impression that impulse response functions measure the economy's structural response to monetary policy, if only one correctly identifies exogenous money supply shocks. This presumption is false. Also, I focus on money and output, but the same point is true of other responses to shocks. For example, every monetary view predicts that anticipated money should affect prices, so it is a mystery why we ever try to interpret the price impulse response function.

Expected money?

Should an empiricist even consider the possibility that anticipated monetary can have real effects? Lucas (1972, 1973) says no. In that model, only *unexpected* monetary policy shocks can have real effects.

Lucas' view is attractive, since it can explain the fact that monetary policy sometimes seems to have large output effects but at other times seems to have small or no effects. The monetary contraction of 1979 and subsequent recession is often seen as a classic example of a large effect. The debate over the great depression seems now to be over *how* monetary policy caused the depression rather than *whether* it did so. But in the ends of hyperinflations (Sargent 1986) and currency revaluations, money growth or its stock can change by factors of thousands, literally overnight, with no real effect at all. The difficulties that central banks have faced in fine tuning output or exchange rates may be more prosaic examples.

Lucas' reconciliation of these different regimes has a dramatic implication: *systematic* monetary policies—policies taken predictably by central banks to offset recessions—have no real effects, a point made forcefully by Sargent and Wallace (1975).

However, Lucas' view has not been universally accepted. For example, Romer and Romer (1994) claim that *systematic* monetary policy ended postwar recessions. The argument against currency unions and fixed exchange rates is that they prevent national governments from pursuing systematic monetary policy to offset country-specific real shocks. The literature that evaluates nominal GNP targeting (Feldstein and Stock 1994, Hall and Mankiw 1994 are recent examples) is predicated on the idea that better systematic policies can reduce the variance of output.

Monetary theorists have also constructed models in which anticipated monetary shocks can have real effects. Overlapping contract models (Taylor 1979), sticky price models (Rotemberg 1982, 1994), limited participation models (such as Grossman and Weiss' 1983 model in which few agents are at the bank at any one time) are examples. Lucas' (1972) model can generate effects of anticipated money if money is not injected by proportional transfer. In Lucas and Stokey's (1983) cash in advance model only *anticipated* monetary policy has real, inflation-tax, effects. Cash-in-advance models with adjustment costs (Fuerst 1992, Christiano and Eichenbaum 1992, 1995) produce more traditional real effects of anticipated and unanticipated money.

For all these reasons, it seems that an empiricist should at least consider the possibility that anticipated monetary changes can have real effects.

2 Structural models

I specify two structural models for the relation between output and money, and I show how to infer the parameters of each model from the VAR impulse-response function.

The first model allows expected and unexpected money to affect output. It is

$$y_t = a^*(L)\left[\lambda m_t + (1-\lambda)(m_t - E_{t-1}m_t)\right] + b^*(L)\,\delta_t.$$

Asterisks on $a^*(L)$ and $b^*(L)$ denote structural lag polynomials. λ is a prespecified parameter which varies between 0 and 1. $b^*(L)\,\delta_t$ captures non-monetary output disturbances. As $\lambda \to 0$ this model specifies that only unanticipated money matters. As $\lambda \to 1$ there is no difference between anticipated and unanticipated money, output is just generated from a lag of money.

The second model is derived from a standard sticky-price model (Rotemberg 1982, 1994), in which prices respond slowly to expected future money. It is

$$y_t = a^*(L)\left[m_t - \frac{1-\alpha}{1-\alpha L}E_{t-1}\left(\frac{1-\alpha\beta}{1-\alpha\beta L^{-1}}m_t\right)\right] + b^*(L)\,\delta_t.$$

β is a discount factor, slightly less than 1, and α between 0 and 1 measures the costs of price adjustment. As the price-stickiness parameter $\alpha \to 0$, this model also reduces to the unexpected money model ($\lambda = 0$), and as $\alpha \to 1$ it reduces to the mechanistic model ($\lambda = 1$). It gives a model in between these two extremes that is more complicated but somewhat more grounded in economic theory than the first model.

"Structural" means that I assume these relations between money and output are invariant to the policy regime; once we have estimated the parameters $a^*(L)$, we can calculate the response of output to arbitrary monetary experiments. Lucas (1976) argued that a good source—but not the only source—of policy-invariant relations are relations carefully grounded in economic theory. Both of the above models have some grounding in economic theory, but the dynamics $a^*(L)$ are ad-hoc. The conclusion calls for better models that are useful for this purpose.

In the remainder of this section, I develop and motivate these models, and I show how exactly to identify the parameters $a^*(L)$ from the impulse response function.

2.1 Anticipated-unanticipated model

Model

First, suppose that only unanticipated money affects output. The standard model is a variant of Lucas (1973),

$$y_t = \theta\left(m_t - E_{t-1}m_t\right). \tag{1}$$

In Lucas (1973) even this representation is not structural or policy invariant. (That is the point of Lucas' paper.) The parameter θ depends on the relative variance of aggregate and idiosyncratic price shocks. However, regime changes that do not alter this ratio will leave θ unchanged, so we can at least evaluate a limited set of regime changes.

This simple model does not allow for serially correlated output. Therefore, empirical specifications allow lagged effects of monetary shocks. (See Sargent 1987 p. 444 for a critical review of such extensions to the Lucas model.) In addition, we should allow for serially correlated non-monetary output disturbances. Thus, I specify the structural model

$$y_t = a^*(L)\left[m_t - E_{t-1}m_t\right] + b^*(L)\,\delta_t.$$

I assume that the non-monetary shocks δ_t are orthogonal to monetary shocks ϵ_{mt}.

There are many reasons to complain about this model. I include it because of its historical interest, and because it is *a* model that justifies interpretation of the impulse-response function.

Second, suppose there is no distinction between anticipated and unanticipated money, so our structural view is

$$y_t = a^*(L)\,m_t + b^*(L)\,\delta_t.$$

Typically one hopes or imposes that $a^*(1) = 0$, so that the level of money has no long-run effect on output.

Again, one may complain about the lack of micro-foundations for this model. However, it is a model with a great historical tradition in empirical work, from the St. Lois Fed regressions (Anderson and Jordan 1968) and its many antecedents to the dynamic multipliers calculated by Romer and Romer (1994). Most importantly, this model is implicit in any discussion that does not explicitly distinguish effects of anticipated vs. unanticipated monetary policy. Since that is almost all policy discussions, even among academics, it seems worth interpreting the data with this view.

Finally, we want a model that assumes that anticipated money can have some effect, though unanticipated money might have stronger effects. As a way to model different effects of anticipated and unanticipated money,[2] I assume a value for λ in

$$y_t = a^*(L)\left[\lambda m_t + (1-\lambda)(m_t - E_{t-1}m_t)\right] + b^*(L)\,\delta_t. \tag{2}$$

Identification

I denote the joint moving average representation of output and money, as one might recover from a VAR, as follows.

$$\begin{bmatrix} m_t \\ y_t \end{bmatrix} = \begin{bmatrix} c_{mm}(L) & c_{my}(L) \\ c_{ym}(L) & c_{yy}(L) \end{bmatrix} \begin{bmatrix} \epsilon_{mt} \\ \epsilon_{yt} \end{bmatrix}; \quad E\left(\begin{bmatrix} \epsilon_{mt} \\ \epsilon_{yt} \end{bmatrix} \begin{bmatrix} \epsilon_{mt} & \epsilon_{yt} \end{bmatrix}\right) = I.$$

Every identification formula below goes through unchanged in larger VARs. I drop constants and possible time trends, so that y and m typically represent the detrended log of output and a monetary aggregate. I focus on the output response to monetary policy, so I do not question variable selection, specification, shock variable choice, orthogonalization, and sampling error questions that (rightly) pervade the VAR literature.

In order to identify $a^*(L)$, substitute the moving average representations for y_t and m_t into equation (2), resulting in

$$c_{ym}(L) = a^*(L)\left[\lambda c_{mm}(L) + (1-\lambda)\,c_{mm}(0)\right]. \tag{3}$$

[2] Many other schemes are possible. One might try to allow separate dynamic effects of anticipated and unanticipated money,

$$y_t = a_a^*(L)\,m_t + a_u^*(L)(m_t - E_{t-1}m_t) + b^*(L)\,\delta_t.$$

Alas, a_a^* and a_u^* are not separately identified. (See Cochrane 1994b for a proof in this specific case; this is the point of Sargent 1976 more generally.) The model in the text adds to this specification an ad-hoc assumption that shape of a_a^* and a_u^* are the same, so that so that $a_a^*(L) = \lambda/(1-\lambda)\,a_u^*(L)$ and one parameter choice λ identifies the two polynomials,

Motivated by information lags, we might allow only k period expectations affect output,

$$y_t = a^*(L)\left[m_t - E_{t-k}m_t\right] + b^*(L)\,\delta_t.$$

then, after plugging in the moving average representation for money, we obtain

$$a^*(L) = \left[1 + c_{mm,1}L + \ldots + c_{mm,k-1}L^{k-1}\right]^{-1} c_{ym}(L).$$

As $k \to \infty$, we recover the anticipated money case, as $k = 1$, we recover the unanticipated money case. This assumption led to k period oscillations in $a^*(L)$, so I do not present the results.

The $b^*(L)$ and responses to other shocks are irrelevant; $a^*(L)$ is identified from the output and money responses alone. I match powers of L in equation (3) to find the $\{a_j^*\}$ from $\{c_{ym,j}\}$ and $\{c_{mm,j}\}$. Expanding and matching powers of L, we obtain

$$a_0^* = \frac{c_{ym,0}}{c_{mm,0}}; \quad a_j^* = \frac{c_{ym,,j} - \lambda \sum_{k=0}^{j-1} a_k^* c_{mm,,j-k}}{c_{mm,0}} \; j > 0.$$

In the special case that only unanticipated money matters, $\lambda = 0$, equation (3) simplifies to

$$a^*(L) = c_{ym}(L) / c_{mm}(0). \tag{4}$$

In this case, we recover the structural coefficients $a^*(L)$ from the impulse-response function.

If there is no distinction between anticipated and unanticipated money, $\lambda = 1$, equation (3) simplifies to

$$a^*(L) = c_{ym}(L) / c_{mm}(L). \tag{5}$$

This expression is the dynamic response of output to a unit impulse to *money*, m_t rather than to the money *innovation*, ϵ_{mt}.[3] With this identification, the regression coefficients of y on m are invariant to policy, not the impulse-response function.

The Lucas model also makes predictions about prices. In its textbook form, it is derived from a relation between output and price surprises

$$y_t = \frac{\theta}{1-\theta} [p_t - E_{t-1} p_t]$$

together with

$$m_t = y_t + p_t.$$

I do not use the measured price responses in the calculations that follow. My focus is on the effect of an identifying assumption on the money to output relation. For this focus, I don't want to impose price restrictions on the VARs, or further generalize the models

[3]Inverting the matrix of lag polynomials in the moving average representation, the first line of the autoregressive representation of the VAR given above is

$$d(L)^{-1} c_{mm}(L) y_t = d(L)^{-1} c_{ym}(L) m_t + \epsilon_{yt}$$

where

$$d(L) = c_{yy}(L) c_{mm}(L) - c_{ym}(L) c_{my}(L)$$

Since the $d(L)$ term is the same on both sides, the path of y_t following a unit blip in m_t is given by $c_{ym}(L) / c_{mm}(L)$.

so there aren't any price restrictions. Also, results that include prices are sensitive to the choice of index. (For example, see the difference between the commodity price and GDP deflator responses in Figure 1.) I don't want price measurement issues to interfere with the interpretation of the money-output relation. Finally, the Lucas (1972) model is not the only unanticipated-money model; for example the Lucas and Woodford (1994) model in which firms set their supply curve in advance also generates output effects based only on unanticipated money shocks, but with different price predictions. However, for the purpose of evaluating a given model and its descriptions of alternative policies, one would want to look at all important variables including prices, and impose and test any restrictions.

2.2 Sticky price model

Model

A mechanistic relation between money and output, $y_t = a(L)\,m_t$ is not considered a serious model by monetary theorists, despite its continued popularity in policy discussions (i.e., the absence of a distinction between expected and unexpected policy actions) and empirical work. Instead, models in which prices are fixed in advance by nominal contracts or other frictions are a common and tractable alternative that features anticipated money effects. One must of course specify what prices are set *to* in advance.

I consider an explicit sticky price model. The model is a slight modification of Rotemberg (1982, 1994). Its specification and central predictions are typical of many sticky price and nominal contract models.

Rotemberg posits a detailed and rigorous microeconomic structure. However, the results of his loglinearized first order conditions are the same as those of a representative price-setter who maximizes an objective function with a price adjustment cost term,

$$\max_{\{p_t\}} -\frac{1}{2}E\sum_t \beta^t \left[(1-\alpha)(1-\alpha\beta)(p_t - m_t)^2 + \alpha(p_t - p_{t-1})^2\right]. \qquad (6)$$

α is a parameter between 0 and 1 that measures the costs of price adjustment. Scaling the first term by $1-\alpha\beta$ simplifies the following expressions; the ratio of level costs to price change costs is all that matters, and that ratio goes from 0 to ∞ as α goes from 0 to 1. I modify Rotemberg's model slightly by requiring p_t to be set as a function of time

$t-1$ information. In this way, the limit $\alpha \to 0$ leads to the unexpected money model rather than just $p_t = m_t$ and $y_t =$ constant.

The first order condition is

$$\left(1+\alpha^2\beta\right) p_t - \alpha p_{t-1} - \alpha\beta E_{t-1} p_{t+1} = (1-\alpha)(1-\alpha\beta) E_{t-1} m_t$$

Factoring the lag polynomial and solving for prices, we obtain

$$p_t = \alpha p_{t-1} + (1-\alpha)(1-\alpha\beta) E_{t-1} \sum_{j=0}^{\infty} (\alpha\beta)^j m_{t+j} \tag{7}$$

To model the relation between output and money, I add money demand $m_t = p_t + y_t$, leading to

$$y_t = m_t - p_t = \left[m_t - \frac{1-\alpha}{1-\alpha L} E_{t-1} \frac{1-\alpha\beta}{1-\alpha\beta L^{-1}} m_t \right]$$

This simple structure captures effects common to most sticky price and overlapping contract models. Prices can rise and hence output can decline in response to *expected future* monetary increases. Prices adapt slowly to monetary shocks. The model imposes long-run neutrality: $y = 0$ for any constant level of m.

Above, we added ad-hoc dynamics and real shocks to the Lucas model so that it could be used to interpret the impulse-response function from a VAR. The natural analogy is to add ad-hoc dynamics to the sticky price model, giving[4]

$$y_t = a^*(L) \left[m_t - \frac{1-\alpha}{1-\alpha L} E_{t-1} \left(\frac{1-\alpha\beta}{1-\alpha\beta L^{-1}} m_t \right) \right] + b^*(L)\, \delta_t. \tag{8}$$

[4] I investigated an alternative way to enrich the dynamics, adding higher derivatives to the objective function, i.e.

$$-\frac{1}{2} E \sum_t \beta^t \left[(p_t - m_t)^2 + \sum_{k=1}^{\infty} \eta_k (p_t - p_{t-k})^2 \right]$$

The flexibility in $\eta(L)$ allows the model to produce more complex money and output impulse-response functions. However, all impulse-response functions are not possible, so this model still imposes restrictions on $c_{ym}(L)$ and $c_{mm}(L)$ that are not satisfied by the VARs investigated below. One might be able to estimate this model by maximum likelyhood, imposing its restrictions on the data. However, the costs of higher derivatives of price change do not seem much more compelling than the $a^*(L)$ polynomial as a policy-invariant description of technology, so this exercise does not seem worth the effort.

It is tempting to generalize the model (8) by simply allowing general lagged effects of a distributed lead of future money,

$$a^*(L)\, p_t = E_t d^*\left(L^{-1}\right) m_t.$$

This form captures the majority of sticky price or nomial contract models. However, one cannot separately identify a^* and b^*. Furthermore, the point of the sticky price model is that the forward and backward lag polynomials are linked by common "techological" parameters.

We can think of this model as allowing velocity to respond to monetary shocks, i.e. $y_t = a^*(L)(m_t - p_t)$.

Identification

I prespecify α and β. β is a discount factor, which I specify as $\beta = 0.98$. The results are very insensitive to β so long as it is nearer to 1 than to 0. I vary the parameter α from 0 to 1 and track the results, as we examined the sensitivity to the parameter λ above. We have to identify $a^*(L)$ from the impulse-response function.

Plugging the responses to money shocks into (8), we obtain[5]

$$(1-\alpha L)(1-\alpha\beta L^{-1})c_{ym}(L) =$$

$$a^*(L)\left[\alpha(1-L)(1-\beta L^{-1})c_{mm}(L) + (1-\alpha)(1-\alpha\beta)c_{mm}(\alpha\beta)\right] \tag{9}$$

As $\alpha \to 0$, equation (9) recovers the impulse-response function as in the $\lambda = 0$ case, equation (4). As $\alpha \to 1$, we recover the same dynamic multiplier of the $\lambda = 1$ case, equation (5). In the latter case, the firm sets price p to a constant. For $\alpha \in (0,1)$, I solve equation (9) recursively for the $\left\{a_j^*\right\}$ from values for $\{c_{mm,j},\ c_{ym,j}\}$ by matching the coefficients on each power of L.

To calculate the output response to monetary experiments, I first find the price path. I solve equation (7) for prices given a path of money[6] and I then find output from

$$y_t = a^*(L)(m_t - p_t).$$

[5]We obtain directly

$$c_{ym}(L)\epsilon_{mt} = a^*(L)\left[1 - \frac{1-\alpha}{1-\alpha L}E_{t-1}\frac{1-\alpha\beta}{1-\alpha\beta L^{-1}}\right]c_{mm}(L)\epsilon_{mt}.$$

Now,

$$E_{t-1}\frac{1}{1-\alpha\beta L^{-1}}c_{mm}(L)\epsilon_{mt} = \frac{c_{mm}(L) - c_{mm}(\alpha\beta)}{1-\alpha\beta L^{-1}}\epsilon_{mt}.$$

(You can check directly that the $c_{mm}(\alpha\beta)$ terms removes the current and future ϵ_{mt} . See Sargent 1987 p. 304.) Hence,

$$c_{ym}(L) = a^*(L)\left\{c_{mm}(L) - \left(\frac{1-\alpha}{1-\alpha L}\right)\left(\frac{1-\alpha\beta}{1-\alpha\beta L^{-1}}\right)\left[c_{mm}(L) - c_{mm}(\alpha\beta)\right]\right\}$$

Equation (9) follows by multiplying both sides by $(1-\alpha L)(1-\alpha\beta L^{-1})$ and simplifying the coefficient on $c_{mm}(L)$.

[6]I find p_1 from the requirement that prices not explode as $t \to -\infty$, and then find other prices recursively. The solutions are

1) Anticipated step: $t \le 1: \ p_t = \frac{1-\alpha}{1-\alpha^2\beta}(\alpha\beta)^{1-t}; \ t \ge 1: \ p_t = 1 - \left(\frac{1-\alpha\beta}{1-\alpha^2\beta}\right)\alpha^t$.

2) Unanticipated step: $t \le 0: \ p_t = 0; \ t \ge 1: \ p_t = 1 - \alpha^{t-1}$.

This model also makes predictions for prices. As above, I focus on the relationship between money and output, ignoring extra restrictions that come from price data.

3 VAR results

3.1 M2 VAR, anticipated-unanticipated model.

The VAR consists of m2, the federal funds rate (ff), nondurable+services consumption (c), GDP (y), and the GDP deflator (p). I impose two cointegrating vectors, $m2 - p - y$ and $c - y$. I include 4 lags, using postwar quarterly data, and orthogonalize the residuals in the given order. The VAR specifications and data are exactly the same as the corresponding VARs in Cochrane (1994a), which contains an extensive discussion of specification and robustness. Figure 1 plots the responses to the money shock and Figure 2 collects the money and output responses to a money shock.

The left hand panel of Figure 3 presents the lag polynomials $a^*(L)$ that we estimate assuming that various fractions of anticipated and unanticipated money affect output. This is also the output response to a particular monetary experiment, a unit innovation in money or "unanticipated blip."

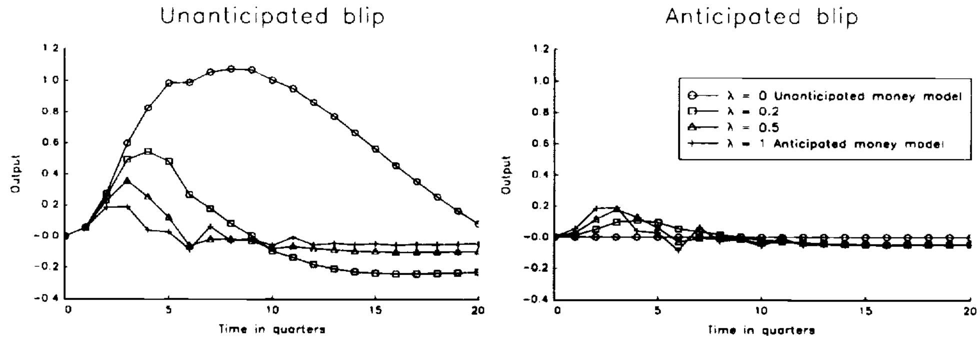

Figure 3: Output effects of two monetary experiments, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from M2 VAR.

The responses are the same across identifying assumptions for the first quarter. But

3) Unanticipated blip: $p_t = 0$.

4) Anticipated blip: $t \leq 1: \; p_t = \frac{(1-\alpha)(1-\alpha\beta)}{1-\alpha^2\beta}(\alpha\beta)^{1-t}; \; t > 1: p_t = \frac{(1-\alpha)(1-\alpha\beta)}{1-\alpha^2\beta}\alpha^t$

then the unanticipated-money response increases dramatically, and decays back to zero very slowly. This response is, of course, the money to output response function plotted in Figure 1 and Figure 2. The response calculated with no anticipated/unanticipated distinction is very small, and reverts to zero after three quarters. If this were the true model, the impulse-response function would give a *very* misleading guide to the effects of this monetary intervention!

Interestingly, one only needs to assume that anticipated money matters slightly in order to identify short-lived effects of this monetary shock. The $\lambda = 0.2$ assumption produces a response pattern much closer to the completely anticipated ($\lambda = 1$) assumption than to the completely unanticipated ($\lambda = 0$) assumption.

Of course, all the models (values of λ) give identical output responses to a money innovation, if followed by further increases in money prescribed by the money $\rightarrow$ money response function. They differ on the question, "What if the Fed shocks money, and then follows a path of future money *different* from the historical pattern?"

An *announced* blip in money is another interesting monetary experiment, since any policy can be decomposed into a sum of expected and unexpected blips. The right hand panel of Figure 3 presents calculations of the response to an announced blip. Now, the anticipated money model response is the largest (least small), and the same as in the left hand panel. As unanticipated money matters more, the response gets smaller.

In every case, one sees much *shorter* and *smaller* responses of output to monetary shocks if one allows anticipated money to even have some affect output. The theoretical identification is quantitatively and economically important; this is not a minor issue of forgotten 1970's methodological debates.

3.2 M2 VAR, sticky price model

Figure 4 presents the lag polynomial $a^*(L)$ inferred from the impulse response function with the sticky price model, via equation (9), for several values of the price stickiness parameter, α. Again, $\alpha = 0$ recovers the impulse-response function, and $\alpha = 1$ recovers the same response as the mechanistic model with $\lambda = 1$. Intermediate values of α give intermediate results.

For a low value of price stickiness α, we need a drawn-out lag polynomial $a^*(L)$ in order to match the VAR impulse-response function. For higher values of α the lag polynomial $a^*(L)$ becomes much smaller and shorter. More of the dynamic relation between money and output can be accounted for by the stickiness in the model, requiring less work from the ad-hoc lags $a^*(L)$. As Rotemberg (1994) argues, this model provides a reasonable account of the data even with no ad-hoc lags, $a^*(L) = 1$, so long as one imposes a high value of price stickiness, above 0.8 or 0.9.

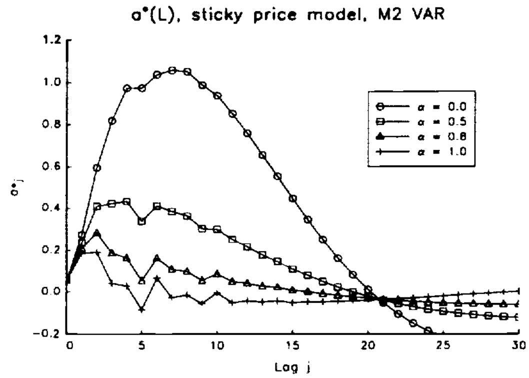

Figure 4: Lag polynomial $a^*(L)$ inferred from $m2$ impulse-response function using sticky price model. α = price stickiness parameter.

However, one must question whether such a high value of the price stickiness parameter is reasonable. $\alpha = 0.8$ implies that the relative costs of price change and price level deviations is $\alpha/[(1-\alpha)(1-\alpha\beta)] = 17$ (see the firm's problem, equation (6)). A 1% quarterly price increase has the same costs as prices 17% away from their proper level. However, Rotemberg (1982, 1994) argues that these relative costs are not so unreasonable, in that the costs of price-level deviations may be low. He posits a model of disaggregated monopolistically competitive firms, in which the costs of having a price level different from the industry average are high, but the industry average can deviate from m_t by a great deal with little cost.

Figure 5 presents the calculated responses to anticipated and unanticipated steps and blips in money for price stickiness $\alpha = 0.8$. The $\alpha = 0$ and $\alpha = 1$ limits are the same as the anticipated $\lambda = 0$ and unanticipated $\lambda = 1$ models investigated above. $\alpha = 0.8$ makes an interesting intermediate case. I include the price paths, since they make clear how the output responses are generated.

Start with the top left corner, an unanticipated blip in money. Prices do not move at all in this case. They cannot move until one period after the blip is known to have happened. But by this time, money has returned to its original level and is expected to remain there. Since $y_t = a^*(L)(m_t - p_t)$, output follows this one-period impulse $m_t - p_t$ with the lag pattern $a^*(L)$. Since the lags $a^*(L)$ are small and short, the model predicts a small and short output response.

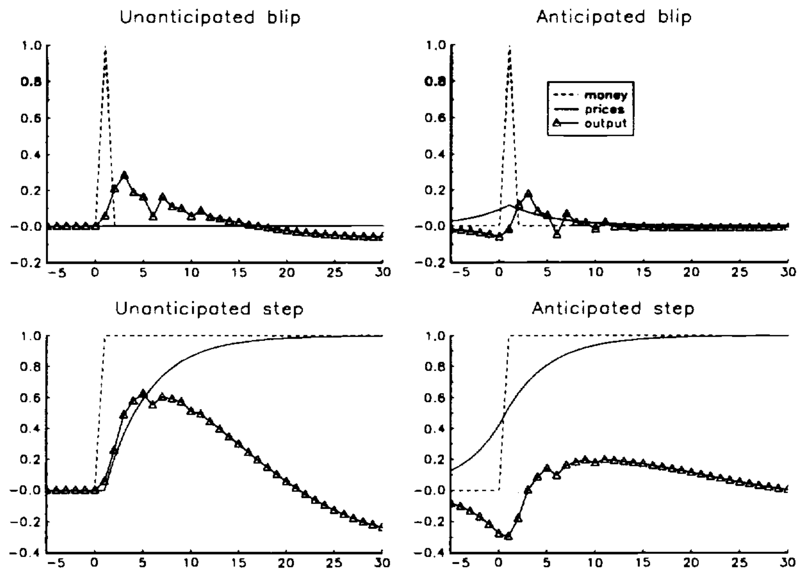

Figure 5: Output and price responses to monetary experiments in sticky price model, using m2 VAR impulse-response function. Stickiness parameter $\alpha = 0.8$.

Notice the counterintuitive result: Assuming *stickier* prices implies *shorter and smaller* effects of monetary policy experiment. The assumption of stickier prices forces us to estimate a much smaller and shorter dynamic relation $a^*(L)$ to remain consistent to the VAR representation of the data.

Next look at the effects of an *an*ticipated money blip in the top right corner. Now prices rise somewhat in advance of the blip, but not much since the blip is expected to last only one period and it is costly to raise prices. Therefore, the output response is similar to, but slightly smaller than the pattern found for the unanticipated blip.

The bottom row, left, presents an unanticipated step in money. After the money innovation, prices slowly increase. The output response looks almost like the impulse-response function. It should, since the unanticipated step is similar to the actual policy regime. The mechanism by which this model reproduces a drawn-out response is quite different from the unanticipated money model however. The difference between m and p

is now strung out over many quarters. $y_t = a^*(L)(m_t - p_t)$ thus gives a drawn out effect of this many-period impulse through the relatively short structural lag $a^*(L)$.

When the money step is anticipated (bottom row, right), prices rise in anticipation of the monetary expansion. The price rise is slow and smooth, since the price stickiness parameter is large. The fact that β is near one makes the price path nearly symmetrical. Output *declines* in advance of the money step, and recovers when the increase in money actually occurs. The major effect of an anticipated step in money is a *depressing* effect on output!

Comparing across columns, it is clear that models with price stickiness cannot be used to justify mechanical relations between output and money that do not distinguish anticipated and unanticipated effects. While a mechanical relation is true for *infinite* stickiness ($\alpha = 1$ and constant prices) even with stickiness $\alpha = 0.8$ or price change costs 17 times the cost of price level errors, one obtains dramatically different predictions for an anticipated vs. unanticipated money step. The reason is simple and general: intertemporally optimizing agents faced with some friction will attempt to adjust *before* an expected change in policy. In fact, the larger the frictions one presents to economic agents, the farther ahead they will start to adjust to the expected change in policy.

3.3 Federal Funds VAR

The monetary VAR literature has recently tried on variables other than monetary aggregates as indicators of a change in monetary policy. Bernanke and Blinder (1988) first used the federal funds rate. Their idea is that the Fed controls the funds rate on a day-to-day basis, accommodating shifts in money demand. A shift in money supply is seen when the Fed changes the federal funds rate.

The bottom row of Figure 1 plots responses to federal funds shocks. Following Christiano Eichenbaum and Evans (1995) I orthogonalize federal funds last and include a commodity price index in the VAR. Federal funds VARs without this feature produce a "price puzzle"—increases in the federal funds rate produce *increases* in prices. Christiano and Eichenbaum and Evans explain that the Fed contracts on news of future inflation, inducing a spurious correlation between contractionary shocks and subsequent price rises. By including a commodity price index and orthogonalizing federal funds last, they control for the Fed's information. More pragmatically, these choices produce better-looking pictures. Of course, given that prices respond to anticipated money shocks in any model, it is not clear why one should worry about a puzzling price impulse response function in the first place.

Figure 6 presents output responses to federal funds shocks, again imposing that various fractions of anticipated and unanticipated shocks can affect output. We see the usual pattern that responses calculated assuming that anticipated money matters or that the shock is anticipated are much smaller and shorter than the impulse-response function suggests.

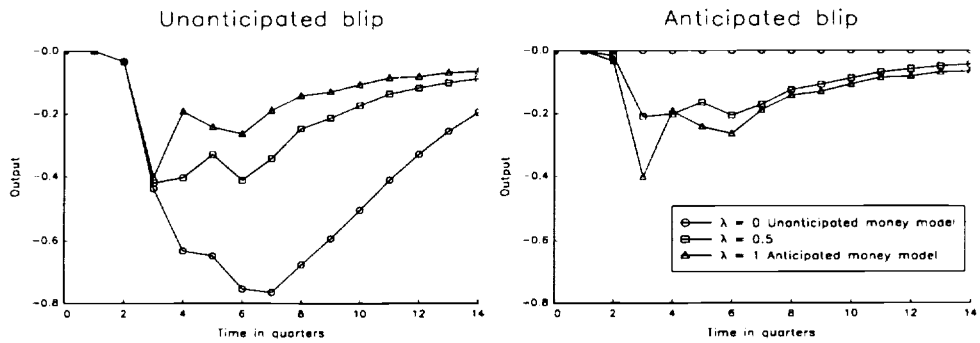

Figure 6: Output effects of two monetary experiments, under various assumptions about the effects of anticipated vs. unanticipated money. Calculated from federal funds VAR.

I do not present calculations for the sticky price model because it is unclear how to apply that model to something other than an actual money aggregate.

Two opinions run through much debate over the Fed's current interest rate policy: 1) A federal funds rate rise now signals output declines in one to two years; and 2) It doesn't matter that the Fed basically preannounces and everyone anticipates federal funds rate rises. At a minimum, Figure 6 shows that these two views are inconsistent, in that opposite theoretical assumptions must be made for the two conclusions.

4 Conclusion

The weakest part of this paper is the theory. Thus, part of its conclusions must be a call for more and better theory.

To estimate structural relations between money and output, and predict the path of output under alternative monetary regimes, one needs to make some theoretical identification. The monetary theory should be based on constructs that are at least plausibly invariant to the policy regime, and its predictions should be consistent with at least the broad brush of experiences with different regimes. If not so profligately parameterized to be exactly identified, as in this paper, it should at least be capable of matching the important features of the data.

The theories I imposed on the data are a long way from this ideal. The basic unanticipated money model does best on consistency across regimes. But the heart of the model for explaining postwar US time series is the long, large, and hump-shaped distributed lag $a^*(L)$. That lag is questionably policy-invariant; distrust of this lag polynomial is exactly my motivation for looking at anticipated money models. The mechanistic model $y_t = a^*(L)\, m_t$ has of course been subject to a generation of derision.

The sticky price model I examine, like most anticipated-money models, is also questionably policy-invariant. Imagine using the Rotemberg (1982 1994) sticky price model, Taylor's (1979) overlapping contract model or a cash in advance model with frictions such as Christiano and Eichenbaum (1992) to understand a hyperinflation. In that regime, contract lengths are optimally chosen to be much shorter, one would doubtless find almost no price stickiness, and the timing conventions and portfolio frictions would disappear. Obviously, the contract length, price stickiness, timing conventions and portfolio frictions are not really fixed features of technology; one might also expect them to change in response to less drastic changes in regime. Hence the "deep" parameters the model needs to specify, and the poor empiricist has to try to estimate, relate to the technology of contracting, or the costs of adopting different timing conventions or portfolio habits. Such models are not yet written, let alone ready to estimate. Furthermore, all these anticipated money models still require some ad-hoc dynamics (something like the $a^*(L)$ used here) to replicate the basic features of postwar US time-series.

While waiting for theory, this paper makes several points.

1) The results are a strong, quantitative reminder of the methodological warning Sargent (1976) gave almost 20 years ago. Estimates of the effects of monetary policy, and calculations such as "how would output have behaved if the Fed followed a different rule?" such as nominal GNP targeting, are almost entirely driven by the *theoretical* assumptions one makes. The data alone do not answer these questions.

2) The results one obtains by imposing different theoretical views on the effects of anticipated money are subtle. I showed here that sticky price models do not justify a view that one can ignore the distinction between anticipated and unanticipated components of monetary policy. All explicit monetary models, including nominal contract models, cash in advance models have this same feature. Also, I showed that the size and persistence of output responses are not necessarily increasing in the degree of price stickiness one assumes.

3) The output responses calculated assuming that anticipated money can affect output are quantitatively much closer to most economists' priors; they are much smaller and shorter than those recovered from the impulse-response function. This fact suggests that anticipated money and systematic monetary policy can in fact affect output.

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