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# Commentary

## Lawrence J. Christiano

The Pagan and Robertson article presents a useful review of the evidence on the empirical status of the liquidity effect proposition—that an exogenous increase in the money supply drives the rate of interest down. It discusses how the consensus in the empirical literature has shifted from an initial one of skepticism to what Pagan and Robertson call "the new view": that the liquidity effect proposition has substantial empirical support. In my comment, I offer an alternative perspective on the evolution of the empirical literature, one which focuses on the dynamic correlations between three monetary aggregates and the federal funds rate.

A valuable contribution of the Pagan and Robertson article is to document evidence to suggest that the liquidity effect may have gotten smaller in the years since 1982. This is an important observation which deserves more attention to determine exactly what it means. It may simply be a statistical artifact, reflecting the relatively small amount of information in the post-1982 data. Assessing this is complicated by the fact, documented further below, that most of the evidence of a change reflects sub-sample variation in the estimated variance-covariance matrix of vector autoregression (VAR) residuals. As Pagan and Robertson note, these residuals appear to be characterized by autoregressive conditional heteroskedasticity (ARCH) effects and, under these circumstances, it may be difficult to identify a true change in an unconditional variance-covariance matrix. But, assuming that the change in the variance-covariance matrix of VAR residuals is in fact real, then this raises further interesting questions of interpretation: Has the liquidity effect in fact gotten smaller, or is the evidence of a reduction an artifact of an error in the specification of monetary policy? The calculations that produce evidence of a change in the liquidity effect assume there has been no change in monetary policy. Most commentators on Fed policy think that there was a shift in policy in late 1982.

### WHAT IS THE "LIQUIDITY EFFECT" AND WHY CARE ABOUT IT?

I begin my discussion by defining what I mean by a liquidity effect, which I take to be a property of an economic model. An economic model possesses a liquidity effect if it has the following characteristic: An exogenous, persistent, upward shock in the growth rate of the monetary base, engineered by the central bank and not associated with any current or prospective adjustment in distortionary taxes, drives the nominal rate of interest down for a significant period of time.

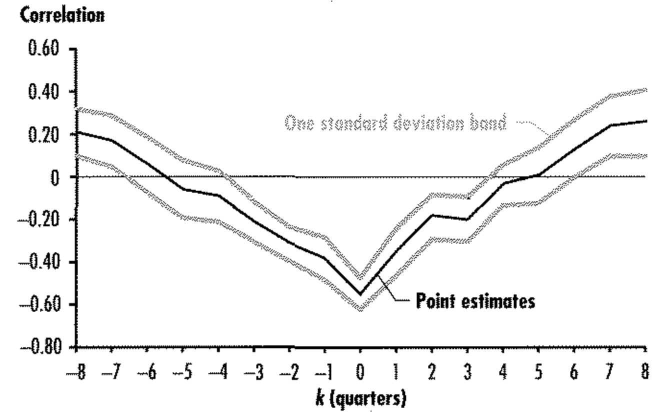
This definition of the liquidity effect can be distinguished from the traditional, partial-equilibrium liquidity effect in the literature. That refers to the fall in the interest rate that is required by a downward-sloped money demand schedule when the money supply increases and there is no change in the price level and level of income. Many existing general-equilibrium models that do not possess a liquidity effect in the sense that I define it do display a partial-equilibrium liquidity effect.

The basic question addressed in the Pagan and Robertson article, and in the empirical liquidity effect literature, is: What do the data say about the relative plausibility of the following two types of models: models with a liquidity effect and models with the implication that an exogenous increase in the monetary base drives the nominal rate of interest up?

The reason why this question is interesting is that the answer one selects has important implications for the construction of quantitative macroeconomic models with money. This is discussed further in Christiano (1991) and Christiano and Eichenbaum (1995).

**Figure 1**

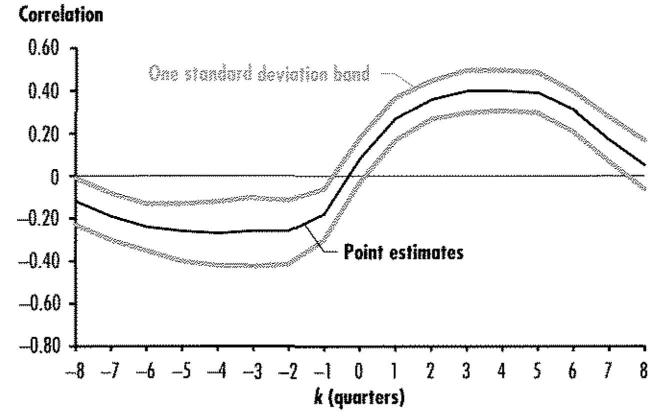
**Correlation Between the Fed Funds Rate(*t*) and NBR(*t*-*k*)**



Notes: Data are quarterly and cover the period 1959:1-1991:4. Money data have been logged, and both series have been HP-filtered prior to doing the computations.

**Figure 2**

**Correlation Between the Fed Funds Rate(*t*) and the Monetary Base(*t*-*k*)**



Notes: See notes to Figure 1.

## EVOLUTION OF VIEWS ON THE EMPIRICAL STATUS OF THE LIQUIDITY EFFECT

Historically, economists have taken the plausibility of the liquidity effect for granted. This is reflected in standard intermediate macroeconomics textbooks, which feature models exhibiting liquidity effects. However, when researchers initially attempted to quantify the liquidity effect using data, they came away quite skeptical as to its plausibility. (Examples include King, 1983; Melvin, 1983; and Mishkin, 1983). This had an impact on the development of monetary business cycle models. For example, Barro (1987, p. 521) and Robert King (1991) cite these findings as evidence in support of the first wave of monetized real business cycle models. These models have the implication that an exogenous increase in money growth, if persistent, leads to a *rise* in the nominal rate of interest. Now the consensus has returned to the traditional position in favor of liquidity effects. This in turn has sparked efforts to identify frictions which allow monetary models to display a liquidity effect.

A case can be made that this evolution in thinking reflects early analysts' tendency to focus exclusively on broader monetary aggregates and their tendency to ignore the sources of endogeneity in money. To gain insight into the role played by these considerations, consider the results reported in Figures 1-3, taken from Christiano and Eichenbaum (1992). They display the cross-correlation between different monetary aggregates and the federal funds rate (black line), together with plus-and-minus one standard-deviation confidence bands (blue line). The monetary aggregates examined include nonborrowed reserves (NBR), the monetary base (M0) and M1. Both the interest rate and the monetary aggregates have been logged and Hodrick-Prescott filtered prior to the computations.[1] The data display three key features: (1) The broad monetary aggregates covary *positively* with current and future values of the interest rate; (2) *negatively* with past values of the interest rate; and (3) NBR covaries *negatively* with current and future values of the interest rate.

In view of the first feature, it is perhaps not surprising that analysts who assumed the endogenous component of money is small and focused on broader monetary aggregates, arrived at the view that the evidence does not support an important liquidity effect. Early research which recognized the potential role of endogeneity took the view that the Fed conducts monetary policy by targeting the nominal interest rate. (See, for example, Bernanke and Blinder, 1992; and Sims, 1986.) Under this view, exogenous innovations in

[1] The nonborrowed reserves data were obtained from Steve Strongin. The other data were taken from CITIBASE. The federal funds rate, monetary base and M1 have mnemonics FFYF, FMBASE and FM1, respectively. The results reported in Figures 1-3 are robust to alternative detrending procedures and sample periods. See Christiano and Eichenbaum (1992) for details.

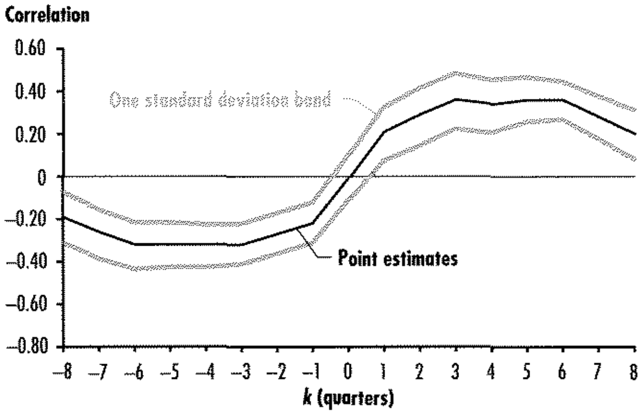
base growth engineered by the central bank are associated with innovations in the interest rate. Feature two of the data helps explain why these analysts favor the liquidity effect view that an upward revision in the Fed's interest rate target is implemented by engineering a *reduction* in the money supply. Finally, beginning with Thornton (1988), researchers have recently begun working with NBR. In light of feature three, it is perhaps not surprising that they have tended to conclude that the evidence favors the liquidity effect view.

While the correlations I just described go a long way toward explaining why different researchers reached different conclusions about the empirical status of liquidity effects, they do not tell the whole story. That is because the liquidity effect pertains to the sign of the correlation between the components of interest rates and money that reflect *exogenous* disturbances to monetary policy. Raw correlations, by contrast, reflect the joint movements of interest rates and money arising due to the effects of all shocks, not just exogenous monetary policy shocks. To see why this distinction probably matters, consider the correlation between logged and detrended gross domestic product and NBR in Figure 4.[2] The fact that the contemporaneous correlation is significantly negative may reflect a policy of "leaning against the wind" at the Fed. If so, then the raw correlation between interest rates and NBR reflects in part the response of both variables to whatever shocks are driving GDP. Such shocks could in principle produce a positive or negative correlation between money and interest rates, independent of whether the liquidity effect is operative.

Coleman, Gilles and Labadie (1995), CGL, present a couple of hypothetical examples that illustrate very nicely how this could happen. The examples underscore the importance of isolating the exogenous monetary policy component of a monetary indicator variable. They are also useful for illustrating the kind of steps researchers take in practice to build confidence that the shocks they have isolated are indeed monetary policy shocks and not something else. In one of CGL's examples, the economy is driven by a single shock, one that is non-monetary in origin. CGL assume that the shock drives up the equilibrium nominal rate of interest, and that this produces an accommodation at the Federal Reserve's discount window. The Federal Open Market Committee (FOMC) is assumed to partially offset the impact of this on total bank reserves by undertaking contractionary open market operations which have the effect of reducing nonborrowed reserves. In an economy like this, there would be a negative correlation between the rate of interest and NBR, even

Figure 3

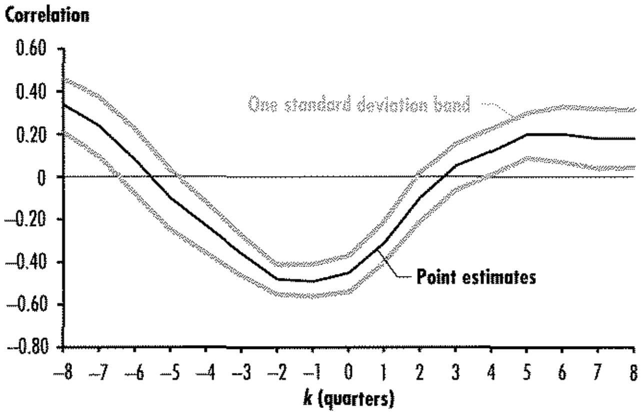
**Correlation Between the Fed Funds Rate(*t*) and M1(*t*-*k*)**



Notes: See notes to Figure 1.

Figure 4

**Correlation Between GDP(*t*) and NBR(*t*-*k*)**



Notes: Data are quarterly and cover the period 1959: 1-1991:4. Both variables were logged and HP-filtered prior to the compuutations.

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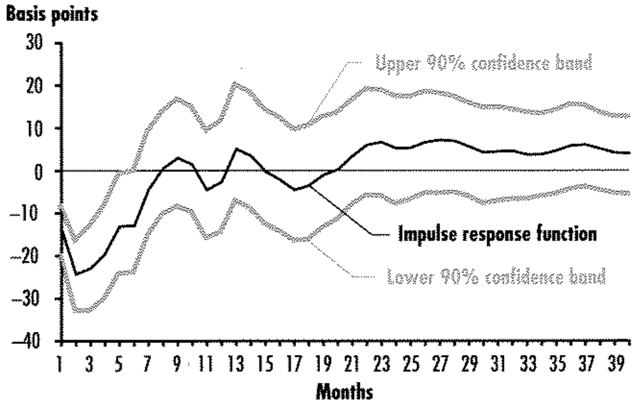
[2] The gross domestic product data are taken from CITIBASE.

Figure 5

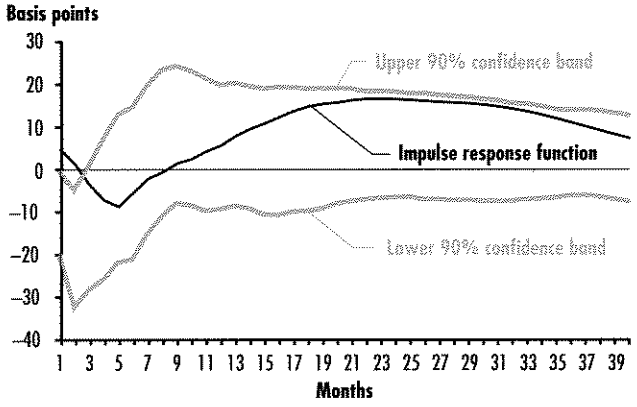
**Interest Rate Response to Orthogonalized NBR Shock**



Notes: Impulse response based on 14-lag, six-variable VAR estimated using monthly data, 1959:1-1991:10.

Figure 6

**Interest Rate Response to Orthogonalized NBR Shock**



Notes: Impulse response function based on six-lag, six-variable VAR estimated for period 1982:12-1991:10. Confidence interval is the one implied by the 14-lag, six-variable VAR fit to whole sample.

though there are no monetary policy shocks at all.

CGL's second example illustrates how an economy with monetary policy shocks, but only an anticipated inflation effect and *no* liquidity effect, could also generate a negative correlation between nonborrowed reserves and the interest rate. Suppose the Fed signals policy shifts in advance of actually implementing them, and that a signal of an imminent increase in the growth of total reserves produces an immediate rise in the interest rate. Suppose the rise in the interest rate results in an accommodation at the discount window, so that to insulate total reserves from this, the Fed must reduce nonborrowed reserves. In a world like this, one would expect a negative correlation between nonborrowed reserves and the interest rate, even though there is no liquidity effect.

It is in an effort to avoid the sort of pitfalls illustrated by the CGL examples that the recent literature has taken great pains to isolate the exogenous component of monetary policy in monetary indicator variables. The assumptions made to do this are called identifying assumptions, and they typically involve incorporating more variables into the analysis. Additional steps are taken to further reduce the likelihood of the kind of problems emphasized in the CGL examples. One strategy for doing so is pursued in Christiano, Eichenbaum and Evans (1994), CEE. To build confidence that their shocks correctly isolate the exogenous shock to policy, CEE analyze the impact of their monetary policy shock measures on many macroeconomic variables. Based on their findings, they conclude that their monetary policy shock measures probably do not suffer significantly from the sort of distortions illustrated in the two CGL examples. For example, it seems unlikely that the CEE policy shock really measures the private economy shock in CGL's first example. That's because CEE find that a negative shock to nonborrowed reserves leads to a rise in unemployment and inventories, and a fall in output, employment, profits, and the broad monetary aggregates. It seems hard to imagine a reasonable model in which a non-monetary shock would have these effects. Finally, CGL's second example seems implausible in light of the CEE finding that a negative shock to NBR leads to a fall in the broader monetary aggregates.

In sum, the basic outlines of the story describing the evolution of thinking about liquidity effects can be understood with reference to simple correlations between various monetary aggregates and the interest rate. The full story is more complicated and involves a broader set of variables. These are used first to isolate a measure of the exogenous component of monetary policy, and then to "test" that the resulting measure does not confound shocks that are non-monetary in origin. This part of the story involves many assumptions. Significantly, researchers using a wide variety of plausible assumptions have reached the conclusion that the data support the liquidity effect view.

## A VANISHING LIQUIDITY EFFECT?

Pagan and Robertson report calculations that suggest the liquidity effect may be smaller in the 1980s than before. To see this, first consider Figure 5, which displays the response of the interest rate to an orthogonalized innovation in nonborrowed reserves. The response is based on what Pagan and Robertson call the CP model of Christiano, Eichenbaum and Evans (1994). The underlying six-variable, 14-lag VAR was estimated using the period 1959:01 to 1991:10. The blue lines are 90 percent confidence intervals computed by the bootstrap method outlined in the Pagan and Robertson article.[3] Note the statistically significant negative initial response of the interest rate. A 1 percent rise in nonborrowed reserves drives the funds rate down about 15 basis points (annual rate) in the current month, and 25 basis point in the next month. The Pagan and Robertson observation can be seen by comparing Figure 5 with Figure 6, which displays the interest rate response based on a six-lag, six-variable CP model estimated over the sample 1982:12 to 1991:01.[4] This impulse response function has the implication that a 1 percent rise in nonborrowed reserves leads to a contemporaneous rise of 1 basis point in the funds rate, followed by relatively small reductions of 3, 8 and 13 basis points in the first, second and third months, respectively, after a shock. After that, the point estimates in Figures 5 and 6 are quite similar. The other curves in Figure 6 enable one to test the null hypothesis that the data from the later sample are consistent with the model fit to the whole sample. They define a 90 percent bootstrap confidence interval, constructed using the 14-lag VAR model and its fitted residuals estimated for the entire sample. Note that the first two impulses lie outside this confidence interval, so that the null hypothesis is rejected.[5] This test suggests that the reduction in the liquidity effect in the 1980s is more than what one would expect given that the 1980s constitute a relatively small sample of data.

The primary reason for the shift in the impulse response function appears to lie in a shift in the variance-covariance matrix of the VAR disturbances. One way to see this is to note that the biggest change in going from the full sample to the short sample is in the estimated impact effect of an orthogonalized NBR shock. That object is a direct function of the variance-covariance matrix of the fitted disturbances. (In particular, it is the 5,4 element in the lower triangular Choleski decomposition of the variance-covariance matrix.)

Another way to see this is to consider Figure 7. That reproduces the impulse response functions reported in Figures 5 and 6 for convenience. In addition, Figure 7 reports an impulse response function obtained by combining the lagged coefficients from the 14-lag VAR fit to the period 1959:01-1991:10, with the variance-covariance of the sub-set of its fitted disturbances covering the period 1982:12-1991:10.[6]

Note that the resulting impulse response function resembles the one fit to the post-1982 data in that it implies a small liquidity effect. Thus, in essence the statistical test reported in the previous paragraph (and, presumably, in Pagan and Robertson too) is a rejection of the null hypothesis of constancy of a particular function of the VAR disturbance variance-covariance matrix.

The fact that the smaller liquidity effect in the 1980s reflects instability in the estimated variance-covariance of fitted disturbances raises two questions. First, Pagan and Robertson have emphasized that there is "extensive ARCH in the VAR equations for interest rates and money." But the procedure I used (following Pagan and Robertson) to deduce that there is statistically significant instability in the impulse response functions assumes the disturbances are *iid*. Under these circumstances, one presumes that extensive ARCH in the disturbances would greatly increase the probability of false rejections in tests of the null hypothesis of no change in a variance-covariance matrix. This is because

[3] That is, I used random samples of the fitted VAR disturbances, together with the estimated VAR and actual U.S. data for the required 14 initial conditions to generate 1,000 artificial data sets of 388 observations each, for all six variables in the VAR. In each artificial data set, I fit a 14-lag, six-variable VAR and computed an impulse-response function using the procedure underlying the computations for the point estimates in Figure 5. Let $\alpha_i(k)$ denote the $i^{th}$ month's response of the interest rate to a policy shock, $i = 1,...,36$, on the $k^{th}$ artificial data set, $k = 1, ...,1000$. Then, for each $i$, $\alpha_i(k)$ was ordered from largest to smallest. The 50th and 950th elements are reported as the top and bottom curves in Figure 5.

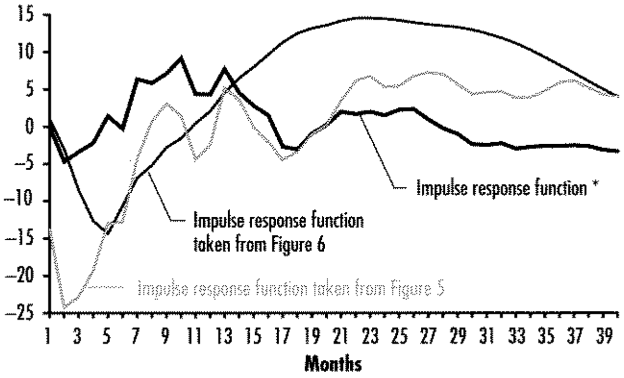
[4] The lags lengths of the two models correspond to the choices made by Pagan and Robertson. A six-lag model for the long sample period does not work well. The Ljung-Box Q-statistic at lag 24 computed on the residuals for the interest rate equation has a value of 43, with a significance level of 1 percent. This convinced me that six lags is too short for this sample. The Q-statistic computed for the six-lag VAR fit to the post-1982 sample did not show any evidence of serial correlation in the residuals.

[5] The bootstrap confidence intervals were computed as follows. Using U.S. data for the required 14 initial conditions, the empirically estimated 14-lag VAR was used to simulate 1,000 artificial data sets of 388 observations each. The residuals for each data set were obtained by random sampling from the fitted residuals. The last 107 observations in each sample were used as the estimation period for fitting a six-lag VAR and computing an impulse response function like the middle

*(continued on following page)*

Figure 7

**Interest Rate Response to Orthogonalized NBR Shock**



* obtained by combining lagged VAR coefficients from VAR fit to whole sample with innovation variance-covariance matrix from post-1982 period.

under ARCH, a sample variance-covariance matrix can display substantial time variation, even though the underlying unconditional variance-covariance matrix is constant. Thus, it remains an open question whether the smaller estimated liquidity effect in the 1980s is simply a statistical artifact.

Second, the apparent instability in the variance-covariance matrix of VAR disturbances suggests it might be fruitful to explore the possibility of policy shifts using the "identified VAR" identification strategy pursued by Bernanke (1986) and Sims (1986). There are two reasons for this: (1) It is widely thought that policy did change across the 1979-82 and 1982-present periods; and (2) the Bernanke-Sims style approach would predict a change in the variance-covariance matrix of residuals under a change in policy. Whether it predicts precisely the instability observed is an open question.[7]

## CONCLUSION

To summarize, the authors draw attention to a reduction in the estimated size of the liquidity effect in the 1980s. This certainly deserves attention. However, the right statistical techniques have not yet been applied to determine whether the apparent change is statistically significant, or just an artifact of the small number of observations. Assuming it is not a statistical artifact, it would be interesting to investigate exactly what it means. Does it reflect specification error due to a change in policy regime? Does it reflect that the liquidity effect actually was smaller in the 1980s, perhaps because agents became more sensitive to news about inflation?

To assess the results in this article, it is important to recall what is at stake here. Views about the presence or absence of a liquidity effect in the data determine what kind of monetary models macroeconomists use to conduct policy analysis. In early monetized real business cycle models, the interest rate money dynamics were dominated by strong anticipated inflation effects. The Pagan-Robertson article presents no evidence to support the notion that there is a strong *rise* in interest rates in response to an expansionary monetary policy shock, as these models require. Instead, all the point estimates indicate a fall in the interest rate in the wake of a positive monetary policy shock. In particular, the Pagan and Robertson article provides no evidence that macroeconomists should abandon models exhibiting liquidity effects and go back to simple monetized real business cycle models.

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(*footnote 5 cont.*)
line in Figure 6. The confidence intervals were computed using the 1,000 impulse response functions with the same method as the one underlying Figure 5.

[6] That is, let $Y_t = A(L)Y_{t-1} + u_t$, where $u_t$ are the fitted VAR disturbances and $A(L)$ denotes the fitted 14-lag matrix polynomial of VAR coefficients. Let $V$ denote the variance-covariance matrix of $u_t$ covering the period 1982:12-1991:10 only. Let $CC' = V$ be the lower triangular Choleski decomposition of V. Then, the numbers in Figure 7 are the coefficients in the 5,4 element of the matrix polynomial $[I - A(L)]^{-1}C$.

[7] Another interesting question is whether such an analysis could be reconciled with dynamic macroeconomic theory.

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