Econ. J. of Hokkaido Univ.,
Vol. 31 (2002), pp. 1~26

Who Transmits Monetary Policy to Real Economic Activity? The Case of the U. S. Economy

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This paper attempts to clarify the monetary transmission mechanism in the U. S. by quantifying the main GNP components transmitting monetary policy shocks to real economic activity. Some demand components absorbed by households respond to monetary policy shocks earlier than the components absorbed by firms and real output itself. This observation contradicts the prediction of monetized Real Business Cycle models. On the other hand, the IS-LM model cannot satisfactorily explain the quick response of non-durable consumption. The analysis suggests that institutional constraints on households' expenditures generate the statistically significant but small real effects of monetary policy shocks. (*JEL* E 52)

1. Introduction

An empirical regularity in macroeconomics is that there is often a period with higher nominal interest rates preceding recession, and a surge in monetary aggregates preceding a boom. Not a small number of economists consider these correlations as manifestations of monetary policy. With U. S. macro data, this paper attempts to identify the principal GNP components that transmit the shocks in monetary policy to aggregate real economic activity. In doing this, I pursue two goals. The first goal is to add knowledge about the monetary transmission mechanism. The second and more ambitious goal is to evaluate the two competing frameworks in empirical macroeconomics, the IS-LM model and the "liquidity effect models," in the light of U. S. macro data.

In explaining economic fluctuations, the Keynesians emphasize market failures and consequently the role of demand constraints. Among the various models of Keynesians, the IS-LM model still can represent their basic features.[1] In the textbook IS-LM model, demand components that are sensitive to cost of capital transmit the disturbances in the money market to the goods market. Business investment is often employed as a typical example of such

1 See Mankiw (1990) for a rationale to use the IS-LM model in applied study. For a criticism, see King (1993).

components. Coupled with some sluggishness in price level, a decrease in money supply drives up real interest rates, and then drives down the demand for investment. A decrease in investment leads to a decrease in real output. There are, however, few previous efforts to statistically examine the role of various demand components in the monetary transmission mechanism.[2] As Friedman (1995) emphasizes in his survey, the transmission mechanism of monetary policy is a big remaining question.

Among academic macroeconomists, the IS-LM framework has been out of fashion. Real Business Cycle (RBC) theory, which is built on intertemporal general equilibrium models, has taken over the main role in research. The advocates of RBC theory assume competitive markets, and emphasize the role of the supply side in economic fluctuations. In the evolution of the Real Business Cycle school, money and financial intermediaries are integrated into the framework through cash-in-advance constraints or a transactions demand for money. A shortcoming of these *monetized* RBC model has been that they have difficulties to generate the observed short-term correlation between nominal disturbances in the money market and real economic activity. With the presumptions of competitive markets, a dichotomy generally obtains between nominal and real variables.[3] There have been two strains of researchers challenging this problem.

One strain of researchers keeps the belief that monetary policy is neutral to real economic activity, by focusing on the causality from real activity to money. King and Plosser (1984) represent this strain. By modeling financial services as an input of final production, King and Plosser construct a monetized RBC model in which demand for money responds to real shocks earlier than the final output. In their model, the shocks in money supply are uncorrelated with real activity. The vector autoregressions (VAR) literature, however, has accumulated empirical evidence that the innovations in the presumed "monetary policy variables" have considerable predictive power for the variations in future real output (See Sims [1992] and its references). These findings lend a hand for the survival of the IS-LM framework in applied studies.

The other strain of theorists has accepted the real effects of monetary disturbances, and has tried to construct a new class of intertemporal general equilibrium models that generates the real effects. Their basic strategy is to impose a particular set of rigidities on the models. Among these new versions,

2 Bernanke and Gertler (1995) appear to be an important exception. In section 5, our method and results are compared to those in the extant studies.

3 A well-known exception is the case of a persistent increase in money supply, which can drive down real output through the anticipated inflation-tax effect.

the ones that most frequently appear in the current literature are referred to as *liquidity effect models*. The rigidity assumed there is an information lag between agents about new money injected by the central bank (Christiano [1991], Lucas[1990], etc). Fuerst (1992), for example, models that firms can obtain information about new money and gain access to it within a period, while households cannot. With this rigidity, households cannot adjust their savings to monetary policy shocks within a period. In the case of contractionary policy shocks, interest rates rise to induce firms to give up some funds in a period. With less cash, firms reduce production and their demand for goods: investment. In other words, real output declines without a preceding decrease in any demand components. Later we will carefully examine the implications of various liquidity effect models, and their consistency with U. S. macro data.

This paper proceeds as follows. Section 2 discusses the empirical methodology, structural VAR, and the data. Section 3 measures the overall real effects of monetary policy shocks. I have obtained two principal findings. First, the real effects of monetary policy shocks are not large. Monetary policy shocks explain at most 16% of the forecast error variance in real output. Second, the real effects are not temporary, but last about four to five years. Section 4 tries to find the principal demand components transmitting monetary policy shocks to real activity. Some demand components absorbed by households respond to monetary policy shocks earlier than the real output. In contrast, the responses of GNP components absorbed by firms are almost parallel to the response of real output. Section 5 compares these findings with the theoretical predictions of the IS-LM and the liquidity effect models. Both frameworks have some diffculties in explaining our observations. Section 6 concludes the paper. The findings in the paper suggest that liquidity constraints on households provide a key to resolving the statistically significant but small real effects of monetary policy shocks.

2. Method and Data

2.1 Method

To start, we must measure the overall real effects of monetary policy in the U. S. economy. Here a common problem in empirical studies stands squarely in front of us: identification. Monetary policy consists of two parts. In most countries, there is a monetary-policy *rule* built in the economy. In the U. S. , the Federal Reserve Board (Fed) accommodates various changes in the economy based on its policy rules, in other words, its reaction function. When the U. S. economy is in an excess boom, for example, the Fed almost automatically tightens its policy stance to prevent inflation. This part of the monetary policy is endogenous in the economy. The Fed can also implement discretional

monetary policy which does not follow its reaction function. This part of the monetary policy is exogenous to the economy.

The developments in the economy after a Fed's policy change also consist of two parts: the agents' *ex ante* adjustment to the anticipated changes in monetary policy, and their *ex post* adjustment to the unexpected changes in monetary policy. In order to obtain the pure policy effects, only the latter should be measured.

As was noted above, many empirical studies circumvent this identification problem by employing the VAR innovations in a single "monetary policy variable." But the monetary policy variables, such as monetary aggregates and short-term interest rates, are observed only at the intersections of demand and supply of money. Recall that King and Plosser (1984) object the real effects of monetary policy by emphasizing the movement in money demand. Therefore monetary policy shocks must be separated from money demand shocks. All in all, we must decompose the innovations in monetary policy variables into the orthogonalized shocks of money supply and money demand.

Specifically, this study estimates the structural VARs *a la* Bernanke (1986) and Sims (1986). Their method decomposes the innovations of a non-restricted VAR into the orthogonal shocks by imposing restrictions *only* on the contemporaneous correlations among the variables. The main advantage of structural VARs is that identification can be attained with least restrictions.

The structural VARs in the paper maximize the following log-likelihood function.

$$T \log |A_0| - \frac{T}{2} \mathrm{trace}(A_0' * A_0 * \hat{\Omega}), \tag{1}$$

$$A_0 * u_t = \eta_t,$$

$$E(\eta_t \eta_t') = I_n$$

where T is the number of observations, n is the number of variables, A_0 is a $n * n$ coeffcient matrix, $\hat{\Omega}$ is the variance-covariance matrix of the residuals u_t from a non-restricted (that is, a reduced-form) VAR, and η_t is a vector of standardized structural shocks which are orthogonal to each other. Identification is attained by imposing an appropriate set of restrictions on the contemporaneous relationships among u_t. Putting sufficient zero elements in the A_0 matrix yields such a restriction. Since $\hat{\Omega}$ is a symmetric matrix, we can estimate $n(n+1)/2$ free parameters in A_0.[4] It is the A_0 matrix that represents the model to be examined. Giannini (1992) and Sims and Zha (1995b) provide a detailed explanation of this class of structural VARs.

2.2 The Data

To precisely estimate the effects of monetary policy shocks, the VARs must include all the important variables that the Fed has utilized to determine its policy stance. Our basic data set consists of the quarterly time series of an unemployment rate (UN, male ages 25-54), real GNP (Y), GNP deflator (P), commodity price index (CP), total reserve (TR), and the Federal fund rate (FF). Data for UN, Y, P, and TR are seasonally adjusted. Data for UN, CP, TR, and FF correspond to the first month in each quarter. Detailed descriptions of the data are gathered in Appendix.

The goods market in the empirical model is described by real output (Y), price level (P) and unemployment (UN). There is no rebuttal to arguing that these three variables are the principal policy targets of the Fed.

Commodity price (CP) is a well-known indicator of potential inflationary pressure. The minutes of the Federal Open Market Committee (FOMC) have recorded a lot of discussions over the movement of CP.

Total reserves (TR) and Federal fund rate (FF) are the indicators of the Federal fund market. Since the 1960s, the Federal fund market has been the principal short-term fund market in which the Fed can most closely intervene. The levels of TR and FF are simultaneously determined at the intersection of reserve supply by the Fed through open market operations and the reserve demand by private financial intermediates. The task to be accomplished is to purify the money supply shocks from the movement in TR and FF.[5]

The data set is available from the first quarter of 1959 to the last quarter of 1994. We here have to note a caveat provided by the previous studies. The reaction function of the Fed may significantly differ over the period (Brunner [1994], Stigum [1990], Strongin [1995], etc). Therefore we must balance the trade-off between the degree of freedom in the estimation and the possible changes in the Fed's response function over the sample period. Although various conclusions have been provided in the existing studies, the consensus is that it is in the period of "monetarist experiment (hereafter ME)" from the fourth quarter of 1979 to the fourth quarter of 1982 that the policy implementation of the Fed is most different from the other periods. Thus, in the following,

4 There are no analytical criteria for the identifiable restrictions on A_0. Therefore, a perturbation test has been implemented on all the estimates. In each test, I added small random numbers to the estimates, and re-maximized (1). If the re-estimated values were different from the original estimates, the local identification would be subject to serious doubt.

5 Bernanke and Blinder (1992) argue that, within a month, the Fed has supplied bank reserves extremely elastically at its target Federal fund rate (FF), and therefore FF itself is a good indicator of monetary policy stances. Gordon and Leeper (1994), however, find an upward-sloping supply curve of total reserves (TR) in monthly data. Since we use quarterly data to exploit the information in the GNP components, it is further decent to presume a sloping supply curve of TR.

it seems prudent to run the VARs both with and without the ME period.

3. Real Effects of Monetary Policy Shocks

The structural VARs specified in (1) require two-step estimation. First, I estimate a reduced-form VAR to obtain white-noise like innovations u_t. Then I maximize (1) by imposing various sets of restrictions on A_0. All the reduced-form VARs include constant terms and four lags of each variable.

Table 1 shows our basic identification restrictions in the A_0 matrix, the VAR6EX model, and its estimated coefficients.

The standard errors are shown in the parentheses under the coefficients.[6] This empirical model includes all the variables of the basic data set: unemployment rate (UN), real GNP (Y), GNP deflator (P), commodity price index (CP), total reserve (TR), and the Federal fund rate (FF). All but UN and FF enter as logarithms, while UN and FF enter as percentages. The VAR6EX model is estimated without the monetarist experiment (ME) period. Although the estimates with and without the ME period are usually similar, those without it are generally less vulnerable to different initial values in maximization. Thus, hereafter, only the estimates without the ME period are shown. I will report the estimates which show significant differences with and without the ME period.

Table 1: VAR6EX Model

500.62 (31.92)	0	0	0	0	0	UN
179.95 (46.57)	164.67 (10.50)	0	0	0	0	Y
56.28 (48.10)	- 18.29 (14.89)	344.59 (21.97)	0	0	0	P
72.39 (48.46)	- 8.07 (15.05)	- 128.87 (32.21)	99.29 (14.29)	- 9.94 (6.60)	36.43 (38.72)	CP
0	18.74 (14.26)	- 20.44 (33.20)	0	72.58 (5.11)	16.09 (30.08)	TR (MD)
0	0	0	- 57.35 (20.61)	- 8.14 (13.49)	171.47 (13.21)	FF (MS)

6 The standard errors are calculated from the analytical Hessian evaluated at the maximum.

3.1 Empirical Assumptions

The VAR6EX model in Table 1 contains the identification scheme common to our various estimates. The identification scheme consists of three blocks, and is similar to that of Gordon and Leeper (1994). The first three rows summarize the goods market, the forth row deals with the indicator of inflationary pressure, and the last two rows model the reserve market. The assumptions for identification are as follows.

In the goods market, within a quarter, neither the real economic activity (UN and Y) nor the general price level (P) responds to the shocks in the inflationary indicator and the reserve market. Among the goods-market variables, I adopt recursive orderings. The plausibility of these assumptions will be reported in the course of discussion.

In terms of the inflationary-pressure indicator (CP : commodity price index), following Sims and Zha (1995a), I model it responding to all the shocks in the economy without a lag. This is the most important difference from Gordon and Leeper (1994), who assume that the indicators of inflationary pressure respond to the shocks in the money market with a lag. The assumption here is more plausible, because most commodity prices in the CP index are formed in the *daily competitive* markets. The usage of quarterly data in this study makes this specification yet more sensible.

Finally, the assumptions to identify the supply and demand of bank reserves are imposed on the last block. The essence is an information lag between the private financial intermediaries and the Fed. The fifth row specifies the total-reserve demand (MD) of the private financial intermediaries that contemporaneously, that is within a quarter, respond to the innovations in real GNP (Y), GNP deflator (P), and the money supply (MS). This is similar to the traditional money-demand function that increases in response to an increase in Y and P, and decreases in response to an increase in the Federal fund (FF) rate. Although I expect the same signs in the estimates, note that our assumptions are imposed only on the *contemporaneous* innovations, and not so restrictive as in the traditional money-demand functions.

Contrary to the private sector, the Fed cannot detect the contemporaneous shocks in the economy because of the period necessary to collect and construct economic data. Thus, the Fed has carefully sought and observed indicators of inflationary pressure, which are formed in daily competitive markets. The sixth row models the *contemporaneous* reaction function of the Fed (MS : money-supply function). It can accommodate the current innovations in the commodity price index (CP) and total-reserve demand (MD), but cannot accommodate the current innovations in the goods-market variables. We expect that the Fed negatively responds to the contemporaneous shocks in CP and

MD to prevent inflation.

3.2 Estimates

All the estimated coeffcients of the VAR6EX model, except for that of real GNP (Y) in the total-reserve demand (MD), have the expected signs. Figure 1 shows the impulse responses of the economy to a one-standard-deviation increase in the orthogonalized money-supply shock, that is, a contractionary monetary-policy shock. The 95% error bands are attached.[7]

These responses are consistent with the intuition about the effects of monetary tightening. Real output (Y) begins to decline within four quarters after the shock, and hits the bottom about two years later. The bottom corresponds to a level that is about 36 basis points (0.36%) lower than its base line. Y does not recover to its base line even five years after the shock. Further, the error bands show that the negative relationship between the spike in the Federal fund (FF) rate in the early stages and the decrease in real output (Y) in the later stages is statistically the most significant among the impulse responses. We do have identified the significant real effects of monetary policy shocks in the U. S. economy.

The response of the unemployment rate (UN) is much smaller than that of real GNP (Y), only about 9 basis points.[8] The price level (P) stays at the base-line level more than a year, then steadily declines. Although the error bands of P have a wide range, the inclusion of commodity price index (CP) resolves the "price puzzle", a significant positive response of price level to monetary tightening, which is often found in the VAR literature (see Sims [1992] and its references).[9] The total reserve (TR) negatively responds to the tightening. The error bands of TR, however, have a fairly wide range. A one-

Table 2: Forecast Variance Decomposition of Output (%)

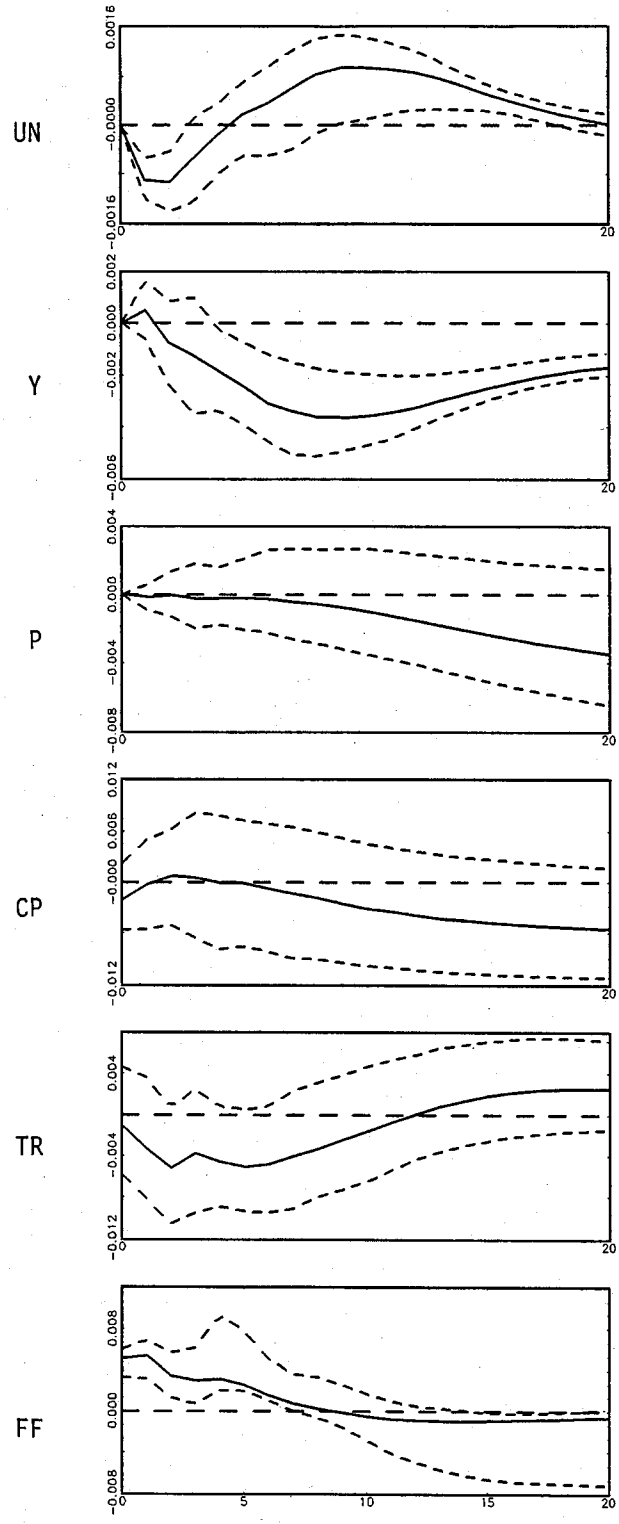
k-quarters	VAR6EX	VAR6
4	1.4	0.9
8	8.3	6.3
12	12.0	10.7
16	15.2	13.2
20	16.5	14.0

VAR6 estimates with the ME period.

7 These error bands are constructed from a Bayesian method developed by Sims and Zha (1995b). Each band is calculated from 16,000 or 20,000 sample draws. The standard errors of these Monte Carlo experiments are available from the author on request.

8 A problem is the small but statistically significant dip of UN in the initial stages. The conversion of UN from monthly to quarterly data may have caused this dip.

Figure 1


UN
0.0016
-0.0000
-0.0016
0
20
Y
0.002
0.000
-0.002
-0.006
0
20
P
0.004
0.000
-0.004
-0.008
0
20
CP
0.012
0.006
-0.000
-0.012
0
20
TR
0.004
-0.004
-0.012
0
20
FF
0.008
0.000
-0.008
0
5
10
15
20

unit increase in monetary policy tightening thrusts up the Federal fund (FF) rate by about 50 basis points. Around two years after the tightening, FF already returns to its base line.[10]

Although the effect of monetary policy shocks on real output (Y) is statistically significant, it is not as large as proposed by Gordon and Leeper (1994), Romer and Romer (1994), and Strongin (1995), etc. Table 2 summarizes the forecast variance decomposition of real output (Y) due to a one-standard increase in contractionary monetary-policy shock. Monetary policy shocks account for at most 16.5% of the fluctuations in real output at a long horizon, increasing from almost nothing at a short horizon. The small real effect of monetary policy shocks is becoming a common result in the structural VAR literature which explicitly considers the daily-market feature of commodity prices (Sims and Zha [1995a], and Kim [1995]).[11]

The findings of this section can be summarized as follows. I) Monetary policy shocks have the statistically significant real effect on the U. S. economy. II) The real effect of monetary policy shocks is not large. It explains at most 16.5% of the forecast error variance in real output.[12] III) There seems to be a propagation mechanism, which amplifies the real effect of monetary policy shocks over time.

4. Various Components

Then how do monetary policy shocks affect the real economy? This section scrutinizes the monetary transmission mechanism by including GNP components into the structural VARs. To focus on *who* transmits the effects of monetary policy shocks, it is convenient to classify the GNP components into three groups. The firms purchase fixed business investment and inventories. The households spend on consumption and residential investment. The other components are absorbed by the government sector or foreign countries.

In the basic specification with GNP components, each component is added individually between UN and Y of the VAR6EX model, that is, at the second

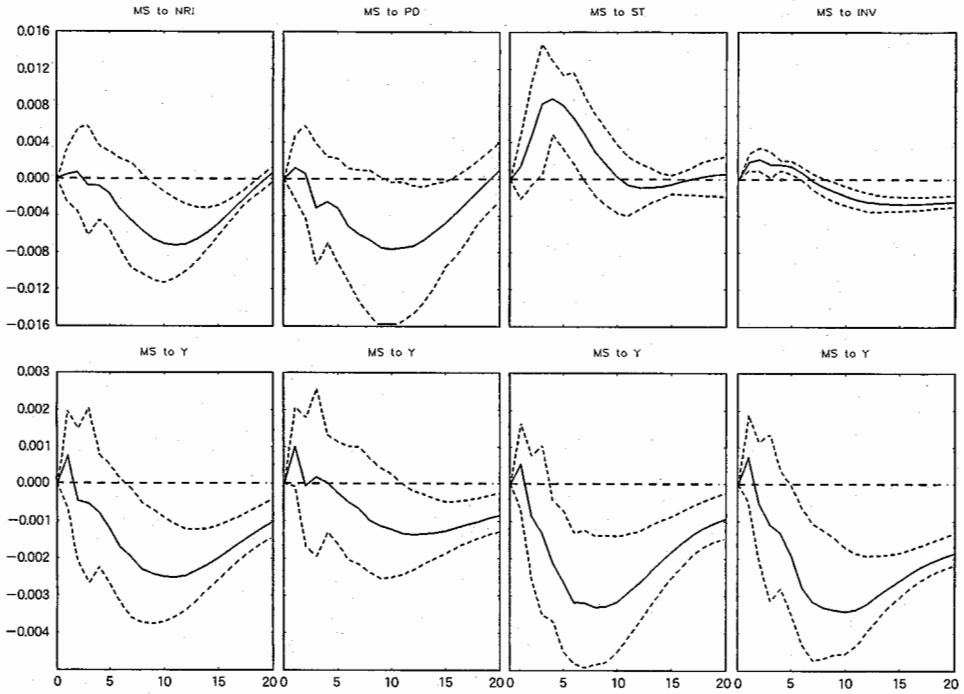
9 I have also examined the long-term interest rate (R10) and the difference between the long-term and the short-term interest rate (R10 - FF) as indicators of inflationary pressure. Both of them have been known as forecasting indicator of real economic activity (Gordon and Leeper [1994], Stock and Watson [1989]). However, neither R10 nor (R10 - FF) solves the "price puzzle" when their daily-competitive-market feature is explicitly modeled.

10 The spike in FF means that we have also identified the liquidity effect, which are defined as a spike in the short-term interest rates responding to a decrease in exogenous money supply.

11 In fact, the application of the Gordon-Leeper (1994) model to the data set increases the portion of forecast errors in real output due to monetary policy shocks.

12 The small real effects may not mar the *usefulness* of monetary policy. Compared to fiscal and various supply-side policies, monetary policy can be quickly altered. Also note that only the real effects of *unexpected* monetary-policy changes are measured here.

Figure 2



place of the recursive ordering in the block of the goods market. Before proceeding, we need some notes for this specification.

First, adding a different GNP component slightly alters the identified policy shocks across the VARs. I will report when a GNP component largely alters the impulse responses or the results of forecast variance decompositions.[13] Second, this specification implicitly assumes that there are no specific correlations among the GNP components. Every effect from the other components are summarized and transmitted by the aggregate GNP. The first and the second assumptions are necessary to maintain a parsimonious specification. Thirdly, for those who consider recursive ordering as a modeling of specific economic theory, our specification may seem to favor the textbook Keynesian models. In our specification, there is a one-sided contemporaneous effect from a demand factor to real output. To deal with this criticism, I have tried other orderings in the block of the goods market. Lastly, some demand components may respond to monetary policy shocks within a quarter, which the quarterly specification here cannot perceive. I then test the specifications in which each GNP component can contemporaneously respond to the innovations in the Federal fund

13 The forecast variance decomposition attributes the mean squared errors of forecast to each orthogonalized shock. Therefore, to add a variable inevitably lowers the explanatory power of some extant variables in a VAR system.

(FF) rate.

4.1 Firms as a Carrier of Monetary Policy Shocks

4.1.1 Fixed Business Investment

In the investigation period, non-residential fixed business investment (NRI) accounts for 10.5% of the U.S. GNP. The first column of Figure 2 shows the impulse responses of NRI and real GNP (Y) to a one-standard-deviation increase in the contractionary monetary-policy shock. Inclusion of NRI does not cause noteworthy changes to the responses of the variables in the VAR6EX model.

NRI significantly declines after the monetary tightening, and hits the bottom 10 to 12 periods after the shock. Two observations merit to be noted. First, the negative response of NRI is larger than that of real GNP (Y). Second, NRI moves along with Y. Particularly in the phase of declining, the responses of NRI and Y have quite similar shapes. There is neither lag nor lead between the responses of NRI and Y. Unlike the examples in the textbook IS-LM model, the U. S. data does not show a decrease in nonresidential business investment (NRI) prior to a decrease in real output (Y).

The second and third column of Table 3 summarize the variance decompositions of NRI and Y due to exogenous monetary tightening. Monetary policy shocks do not explain much of the forecast error in NRI : at most 5%. The contribution of monetary policy shocks to the Y's fluctuations is reduced to about half in the VAR6EX estimate.

Table 3: Forecast Variance Decomposition: Firms' Component (%)

k-quarters	NRI	Y	PD	Y	ST	Y	INV	Y
4	0.1	0.6	0.7	0.6	3.5	1.7	8.6	1.1
8	1.1	2.6	2.4	0.5	5.3	8.9	5.1	6.2
12	3.5	4.5	4.1	0.7	4.5	11.8	7.7	8.3
16	5.0	6.6	4.4	1.6	4.3	13.0	11.2	12.4
20	5.0	7.3	4.1	2.2	4.2	13.0	14.0	14.3

NRI : Non-residential Fixed Business Investment, Y: Real GNP
PD : Producers' Durable Equipment, ST: Structures
INV : *Level* of Non-farm Business Inventories

The alternative specifications alluded at the beginning of this section, different ordering among the goods-market variables etc., do not alter the basic observations. In sum, non-residential fixed investment (NRI) responds to an exogenous monetary-policy shock in parallel to real output (Y). But the monetary policy shocks explain only a tiny part of the NRI fluctuations.

We can further our scrutiny of non-residential fixed business investment

(NRI) by dividing it into its two components : producers' durable equipment (PD) and structures (ST). In the sample periods, PD has accounted for 61. 7% of NRI. Most of the investment in ST has been the expenditures on non-residential buildings.

Producers' Durable Equipment

The second column of Figure 2 shows the impulse responses of producers' durable-equipment (PD) and real GNP (Y). The impulse response of PD is quite similar to that of the aggregated non-residential business investment (NRI). It is not clear whether the response of PD leads to the response of real output (Y). The response of Y becomes shallower with PD than that in the VAR6EX model and than the estimates with NRI.[14] Columns 4 and 5 of Table 3 summarize the variance decomposition of PD and Y. Similar to the change in impulse responses, the inclusion of producers' durable equipment (PD) drastically reduces the contribution of monetary policy shocks to the forecast error variance in real GNP (Y). These two findings may suggest that the movements of PD and Y are quite similar, and our identification assumptions are too weak to separate them clearly.[15] The other specifications cause little changes.

Structures

The third column of Figure 2 shows the impulse response of structure component (ST) and that of real output (Y) to a contractionary monetary-policy shock. Inclusion of ST does not significantly alter the responses of the other variables. But ST shows a strange response that contradicts our prior expectation about the effects of monetary tightening. The structure component (ST) quickly and *positively* responds to monetary tightening.

The other possible specifications do not resolve this counter-intuitive response of ST. The different orderings among the goods-market variables cause little change. The specification, in which ST can respond to the current innovation in the short-term interest rate (FF), messes up both the impulse responses and the variance decompositions. This result indicates that the contemporaneous response of ST to FF is not a correct specification.

A possible explanation for the exotic response of the structure component (ST) is that ST may be closely related to the government expenditure (GO). As will be confirmed later, GO also positively responds to a contractionary

14 In Figure 2 , 3 and 4 , for ease of reference, I set the same scale for Y axes in each row.

15 Similar timing of the responses of PD and Y seems to support the accelerator models in which business investment is not a transmitter but a propagator of the shocks in Y. As well as the monetary policy shocks, however, the shocks in Y do not explain much of the forecast error variance in PD (at most 6%).

monetary-policy shock. The positive response of GO is, however, *not* counter-intuitive because the government tends to increase its expenditures in recessions. If the construction of non-residential buildings (main component of ST) is closely related to or induced by government expenditures (GO), for example, through a quicker authorization, ST can also have a positive response to monetary tightening.

The findings about the non-residential fixed business investment (NRI) can be summarized as follows. First, there is a significant difference in the two components of NRI: producers' durable equipment (PD) and structures (ST). To treat NRI as a single component is not an appropriate approach in the study of a monetary transmission mechanism. Second, PD largely declines after the monetary tightening. There is, however, no clear lead of PD to the decline of real output (Y).

4.1.2 Inventory

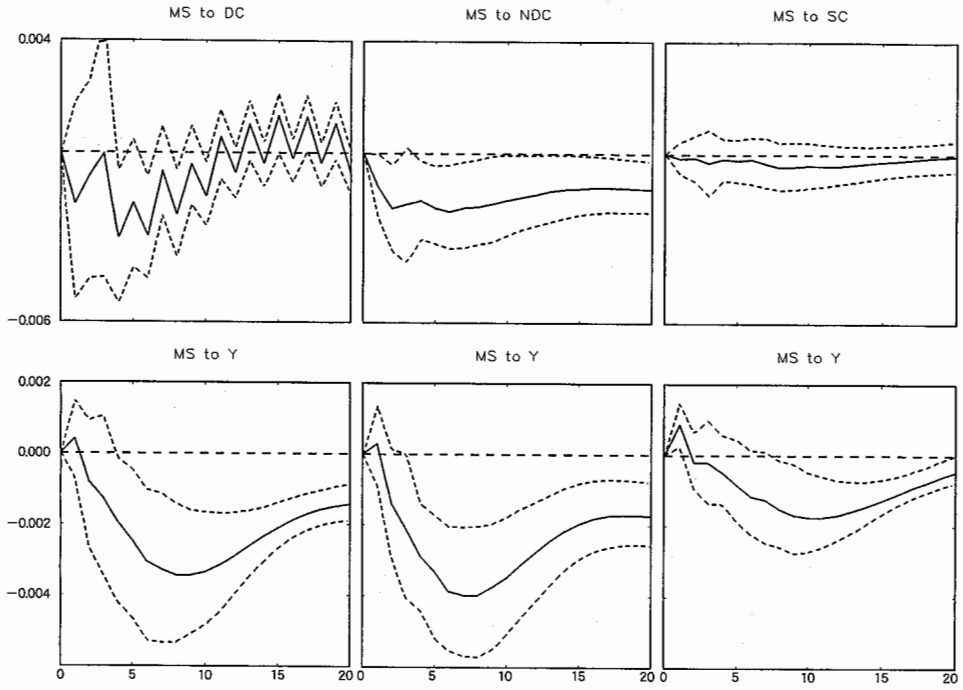
Despite its tiny ratio in the aggregate output, inventory investment has been a primary suspect of economic fluctuations (Blinder and Maccini [1991]). There are two main hypotheses for the role of inventory investment in economic fluctuations.

In the accelerator models, inventory is neither an original cause of fluctuations nor a main transmitter of the shocks in the other sectors to real output, but is a propagation mechanism of the fluctuations in real output. On the other hand, inventories can be a main transmitter of monetary policy shocks, if the optimal inventory level is largely affected by the real interest rate. In the latter hypothesis, we expect a lead in inventory investment to real output (Y) in response to monetary tightening.

Since inventory investment sometimes takes negative values, the logarithm of the *level* of non-farm business inventory (INV) is included into the VARs. The fourth column of Figure 2 collects the impulse response of INV and real output (Y) to monetary tightening. The inclusion of INV does not cause much changes in the responses of the other variables in the VAR6EX model.

In response to monetary tightening, the level of non-farm business inventory (INV) jumps up at the initial stages, which is statistically significant, and then steadily declines. That is, there is inventory *investment* in the initial stages, followed by inventory *dis-investment*. There is no clear lead of the inventory dis-investment to the decline of real output (Y). The inventory dis-investment continues along with the decline of Y, and it stops when Y begins to recover from the bottom. The last two columns of Table 3 report the results of the variance decomposition with INV. Compared to fixed business investment, the inventory *level* is more sensitive to monetary tightening.[16]

Figure 3



The other specifications in the VARs do not largely alter the results. To summarize, the parallel responses of the inventory dis-investment and real output (Y) do not support the hypothesis that the inventory investment is a main transmitter of monetary policy shocks. The statistically significant inventory investment in the initial stages suggests that there are some demand components which respond to monetary policy shocks earlier than real output (Y), and contribute to pile up business inventory.[17]

4.2 Households as a Carrier of Monetary Policy Shocks

4.2.1 Consumption

Consumption has been the largest demand component in the U.S. economy, and accounts for 63.8% of GNP in the investigation period. Consumption consists of the expenditure on three components: durables, non-durables, and services.

16 This may be because INV is a stock (level) variable, while the components of fixed business investment are flow variables.

17 A VAR with gross final sales (SA), that is real output (Y) minus inventory investment, is also examined. The quick drop of SA in response to a contractionary monetary-policy shock supports the interpretation through inventory level (INV) that the inventory investment in the initial stages is unintended. The identification of the structural VAR with SA is, however, subject to doubt. As far as I have examined, the inverse of analytical Hessian at the maximum is not positive definite for the structural VAR with SA.

Durable Consumption

Durable consumption (DC) has been the smallest consumption component, 11.7% of total consumption, in the investigation period. The major components of DC are motor vehicles, furniture, and books. Although it has been a relatively small component, durable consumption (DC) has been one of the main suspects of monetary policy transmitter, since it is likely to be sensitive to cost of capital (Mankiw [1985]).

The first column of Figure 3 shows the impulse responses of durable consumption (DC) and real output (Y) to monetary tightening. Inclusion of DC does not substantially alter the responses of the variables in the VAR6EX model. With fluctuations, DC quickly declines.[18] The fourth quarter after the shock, it hits the bottom: about 30 basis points lower than the baseline level. Both the decline and recovery of DC's response seem to be earlier than the response of Y. The error bands of DC, however, have quite wide range, particularly in the initial stages. The second and third column of Table 4 report the results of variance decomposition. Monetary policy shocks contribute less than 2% of the future variance in durable consumption (DC).

Table 4: Variance Decomposition: Households' Component (%)

k−quarters	DC	Y	NDC	Y	SC	Y	RI	Y
4	0.5	1.3	4.7	3.5	0.3	0.5	2.0	1.2
8	1.7	8.1	5.9	13.4	0.3	1.2	5.0	7.2
12	1.4	9.1	5.0	16.1	3.0	1.8	5.6	7.9
16	1.3	11.8	5.7	17.3	2.4	2.8	5.6	11.1
20	1.1	12.6	6.3	17.4	2.0	3.1	6.2	11.7

DC : Durable Consumption, Y: Real GNP
NDC : Non-durable Consumption, SC: Service Consumption
RI : Residential Investment

I could not obtain convergence in the specification in which DC contemporaneously (within a quarter) responds to the innovations in the short-term interest rate (FF). This observation suggests that, although DC quickly responds to monetary tightening, it does not respond within a quarter. In sum, the response of durable consumption (DC) seems to lead to the decline and recovery of real output (Y). The wide error bands in the initial stages of DC's response and the tiny ratios in the variance decomposition, however, make this lead of DC to Y statistically inconclusive.

18 In the estimate with the monetarist experiment (ME) period, the fluctuation in the impulse response of DC does not appear.

Non-Durable Consumption

Non-durable consumption (NDC) comprises about 36.9% of total consumption expenditure in our investigation period. Its major components are food, clothing and fuels.

It is worth noting that non-durable consumption (NDC) is qualitatively different from the GNP components we have examined above. NDC is not an expenditure on durables whose stock generates service flows. Thus NDC is less likely to be affected by the changes in cost of capital than durable consumption and business investments.

The second column of Figure 3 shows the responses of non-durable consumption (NDC) and real output (Y) to a contractionary monetary-policy shock. Inclusion of NDC does not cause substantial changes in the responses of the other variables. The response of NDC is quite interesting. Contrary to my expectation, it declines as quickly and sharply as the durable consumption (DC). Although the response of non-durable consumption (NDC) is shallower (about 20 basis points) than that of durable consumption (DC), the error bands show that the initial negative response of NDC is statistically much more significant than that of DC. The fourth and fifth column of Table 4 report the contribution of monetary policy shocks to the forecast error variance in non-durable consumption (NDC) and real output (Y). Again, contrary to my expectation, NDC is more sensitive to monetary tightening than durable consumption (DC).

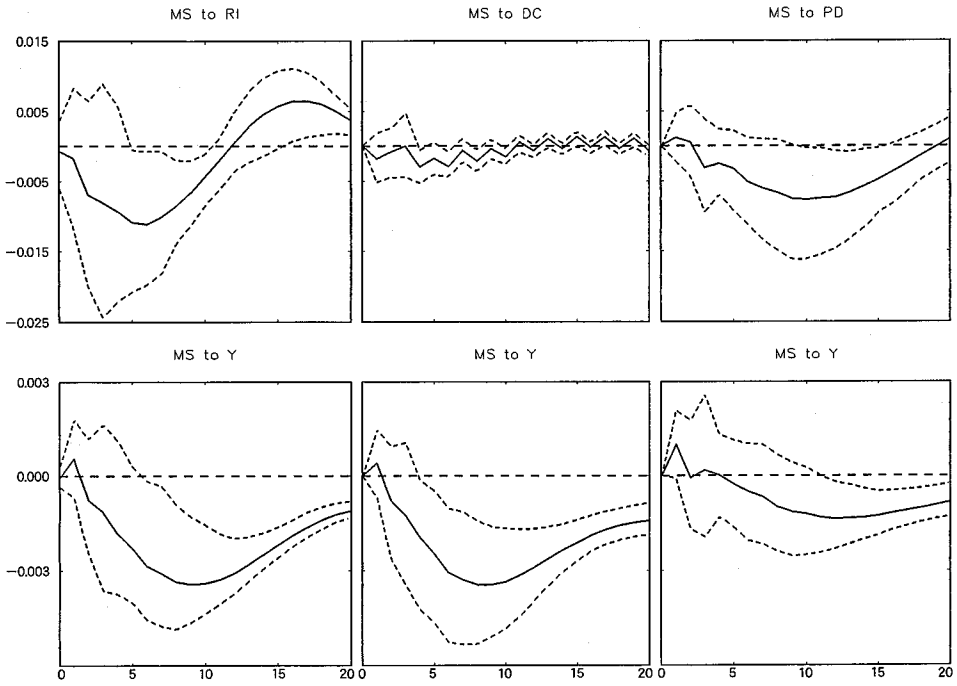
The alternative specifications cause little change. In sum, non-durable consumption (NDC) appears to be an important transmitter of monetary policy shocks.

Service Consumption

Service consumption (SC) has been the largest consumption component that accounts for 51.2% of the total consumption in our investigation period. The major components of SC are rent for housing and medical services, etc.

The last column of Figure 3 shows the impulse responses of service consumption (SC) and real output (Y) to monetary tightening. Inclusion of SC makes the response of Y shallower than in the VAR6EX model. Although SC declines quickly after the shock, its response is very shallow: 5 basis points below the baseline. Furthermore, the error bands of SC show that the negative response of SC is statistically insignificant. Columns 6 and 7 of Table 4 summarize the results of variance decomposition. Monetary policy shocks explain little of the forecast error in service consumption (SC). The contribution of monetary disturbances to the forecast error variance in Y is drastically reduced compared to the results in the VAR6EX model.

Figure 4



Neither the alternative orderings in the goods-market block nor contemporaneous response of SC to short-term interest rate (FF) causes significant changes. In sum, service consumption (SC) does not seem to be an important channel of monetary transmission.[19]

Residential Investment

Residential Investment (RI) accounts for 4.9% of real GNP in our sample period.

In the basic specification in which RI does not respond to the innovations in the short-term interest rate (FF) within a quarter, I could not obtain convergence in the estimation. The first column of Figure 4 shows the impulse responses of residential investment (RI) and real output (Y) in the VAR in which RI is allowed to respond to the current innovations in FF. In this specification, inclusion of RI does not significantly alter the responses of the other variables in the VAR6EX model. Although its error bands have wide range in the initial stages, residential investment (RI) quickly declines in response to

19 Both non-durable consumption (NDC) and service consumption (SC) are the expenditure of households on non-durables. Unlike NDC, however, SC does not appear to be an important channel of monetary transmission. Housing rent is the largest component of SC. Because of the contracts, the rent payment cannot be altered quickly. This institutional factor may dampen the responses of SC to monetary policy shocks.

monetary tightening, and hits the bottom about six quarters after the shock. For ease of reference, I put the impulse responses of durable consumption (DC) and the producer's durable equipment (PD) component of business investment in the second and the third column of Figure 4. The response of RI appears to be deeper than any other components examined above: about 110 basis points below the baseline. More importantly, the response of RI seems to precede the response of real output (Y).

The last two columns of Table 4 show the results of variance decomposition with RI. Monetary policy shock explains a small part of the forecast error in RI : at most 6%. But when we compare the result of RI with the results of the other GNP components, RI appears to be one of the most sensitive components to monetary policy shocks, as well as non-durable consumption (NDC).

In sum, residential investment (RI) appears to be an important transmitter of monetary policy shocks. RI is most likely to respond to a monetary policy shock very quickly: within a quarter. Its negative response is deep, and leads to a decline of real output (Y).

4.3 Other Components

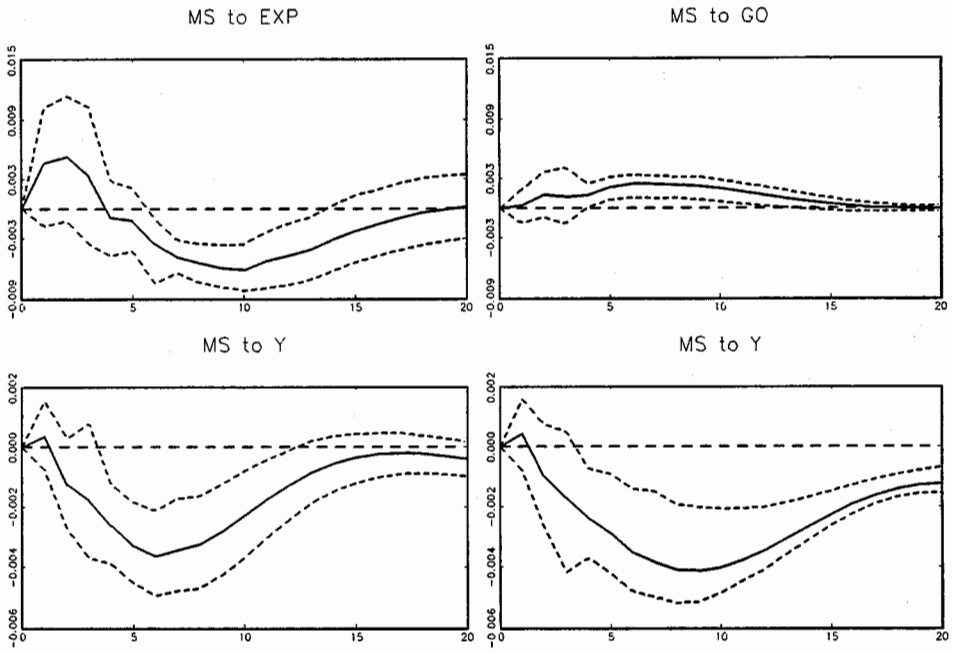
The first column of Figure 5 shows the responses of export (EXP) and real output (Y) to a contractionary monetary-policy shock. The negative response of EXP is deeper than the response of Y, but clearly lags behind it. The diffculty to interpret the results with EXP is that they are likely to be largely altered in the early 1970s, when the U. S. adopted the floating exchange rate system.

Table 5: Forecast Variance Decomposition with the Other Components (%)

k-quarters	EXP	Y	GO	Y
4	2.9	3.0	0.1	2.2
8	3.5	12.3	1.8	12.2
12	6.1	12.2	1.8	16.7
16	6.6	10.9	1.6	19.8
20	6.0	10.0	1.4	20.2

EXP: Export, Y: Real GNP,
GO: Government Purchases of Goods and Services

Figure 5



The second column of Figure 5 collects the responses of Government Purchases (GO) and real output (Y). Without changing the other responses much, GO *positively* responds to a contractionary monetary-policy shock. As was discussed with the result of structure component (ST), the positive response of GO is not counter-intuitive. To stimulate the economy, the government tends to increase its spending in recessions. The results of variance decomposition analysis are collected in Table 5.

5. Still IS-LM or Liquidity Effect Models?

Our journey looking for the GNP components that transmit monetary policy shocks can be summarized as follows. First of all, for a few quarters after monetary tightening, the inventory level rises. This observation bolsters our suspect for the existence of some demand components transmitting monetary policy shocks to real output (Y). In fact, we have found that some demand components absorbed by households respond to monetary policy shocks *earlier* than real output (Y).

Among the GNP components, the response of residential investment (RI) is the fastest and the deepest (Figure 4). I conclude this, because I cannot obtain reasonable estimates in the specification in which RI does not respond to the current innovations in the short-term interest rate (FF). Contrary to my expectation, non-durable consumption (NDC) also shows a quick decline after

monetary tightening. Although the response of NDC is not so deep, thanks to its large share in the real output, NDC appears to be an important transmitter of monetary-policy shocks. The response of durable consumption (DC) also seems to be earlier than that of real output (Y). But there is a problem to induce a clear conclusion about residential investment (RI) and durable consumption (DC). At the initial stages after the shock, the negative responses of RI and DC are not so statistically significant as that of nondurable consumption (NDC).

In contrast, the responses of the components absorbed by firms do not show clear lead to that of real output (Y).

5.1 Comparison with the Extant Empirical Findings

Bernanke and Gertler (1995) implement a VAR analysis for the purpose similar to ours. They construct monthly GDP data, and use the innovations in the Federal fund (FF) rate regression, which is put last in the recursive ordering, as monetary policy shocks. Our findings with each GNP component are generally consistent with the findings of Bernanke and Gertler (1995). The most important difference is the response of non-residential business investment (NRI). In Bernanke and Gertler (1995), the response of fixed business investment is smaller than those of the components absorbed by households, and even lags behind the response of real GDP.

Another VAR paper considering NRI is Sims (1986) who estimates the structural VARs for the period between 1946 and 1979. He assumes that real output (Y) can instantaneously respond to the innovations in the short-term interest rate. His VARs do not include inflationary-pressure indicators. In Sims (1986), the response of non-residential fixed investment (NRI) slightly lag behind that of Y, as in Bernanke and Gertler (1995).

In our estimates, however, the response of NRI is larger than those of the consumption components (Figure 4), and moves almost along with the response of Y. We also find that the two components of business investment, producers' durable equipment (PD) and structures (ST), have starkly different responses to monetary tightening.[20]

5.2 Comparison with the Theoretical Predictions

Then what kind of macroeconomic models can properly accounts for our findings with the GNP components? As was discussed in the introduction, we currently have two candidates to explain the real effects of monetary policy shocks: the traditional IS-LM model and the evolving liquidity effect models.

20 Bernanke and Gertler (1995) also mention the different responses of PD and ST.

We will, however, find that both of the two candidates cannot explain our findings properly.

The IS-LM Model?

In the textbook IS-LM story, monetary tightening leads to a decrease in real output through raising the cost of capital. In response to monetary tightening, the expenditure on the durable components declines, then unplanned inventory piles up, and finally real output declines in face of tighter demand constraint. This story generally fits our findings with the GNP components. We have found that, in response to monetary tightening, residential investment and (less clearly) durable consumption decline earlier than the real output, and that inventory investment surges at the initial stages.

Two basic complications are left, however. First, the textbook IS-LM model does not explain the different responses between the durables absorbed by households and the durables absorbed by business firms. Why do firms adjust to higher cost of capital *slower* than households? Second and more importantly, the IS-LM model does not explain the reason why the non-durable consumption (NDC) appears to be an important transmitter of monetary policy shocks to real output. As was emphasized above, NDC is not a component directly affected by cost of capital. Lastly, since the traditional IS-LM model is intrinsically static, it cannot explain one of our findings at all : the propagation of real effect from negligible level to about 16% of the forecast error variance in real output. To summarize, the IS-LM model cannot properly explain the fruits of our effort with GNP components.

Liquidity Effect Models?

There are various versions of liquidity effect models. As was discussed in the introduction, the principal assumption common to them is the heterogeneous agents in terms of adjustment to the new money injected by the monetary authority. Since the introduction of this idea by Lucas (1990) and Fuerst (1992), it is often assumed that there is a friction in the households' saving-consumption decision: households cannot quickly adjust their savings after they observe unexpected monetary-policy movements. Then, if the new money injected is smaller than expected, firms have to compete for the unexpectedly small amount of working capital available. Then the firms have to decrease their current expenditure: payment for variable input (labor) and/or fixed business investment. Therefore the ways how the cash-in-advance constraints are imposed on the firms' expenditure largely affect the prediction of the models. For the time being, I follow the case that firms must borrow cash for all the expenses: the wage bill for labor and investment.

In response to monetary tightening, the basic liquidity effect model outlined above is expected to generate a simultaneous decrease in output and business investment. Christiano (1991) and Dow (1995), however, have pointed out that, with plausible parameter values, the calibration of basic liquidity-effect model of Fuerst (1992) does not generate the liquidity effect. This is because, along with unexpected monetary tightening, the demand for money decreases as the demand for investment decreases. If the investment expenditure largely declines in response to monetary tightening, short-term nominal interest rates stagnate or even decline. Depending on the parameter values, declining price level will keep or even raise the real purchasing power (=consumption) of households. These opposite responses in the two demand components, business investment and consumption, offset each other. Then, in the basic liquidity effect model, real output does not fluctuate much in response to monetary tightening.

To deal with this shortcoming, Christiano (1991) and Dow (1995) introduce additional friction in the investment behavior of firms. Their assumptions essentially dampen one of the two activities firms can adjust: production and investment. With the sluggish adjustment of investment, the money demand of firms does not decrease much in response to monetary tightening. Consequently nominal interest rates hikes up. With less cash at hand, firms reduce production, which is the only activity they can still freely adjust.[21]

Unlike in the traditional IS-LM story, real output and demand components respond *simultaneously* in the modified liquidity-effect models of Christiano (1991) and Dow (1995). Thus the modified liquidity-effect models cannot explain the reason why some demand components absorbed by households respond to monetary policy shocks earlier than real output.[22] On the other hand, the modified liquidity-effect models fit to our empirical finding better than the IS-LM story in terms of the response of non-durable consumption (NDC). These models do not have to distinguish the households' expenditure between durables and non-durables.

As well as the textbook IS-LM model, the modified liquidity-effect models cannot explain the propagation of real effects of monetary policy shocks over the period. This is because the optimizing agents can adjust their behavior in

21 This is the case when firms must borrow for wage bills. When firms can pay wages from their profit, Dow (1995) argues that the price rigidity is also necessary to assure a decrease in consumption in response to monetary tightening.

22 Christiano and Eichenbaum (1995) construct a modified liquidity-effect model in which consumption responds to monetary policy shocks earlier than business investment. Their key assumptions are that firms must borrow for the payment of wage bills but not for business investment, and that there is some sluggishness in the production process. The model of Christiano and Eichenbaum (1995), however, still does not generate the earlier responses of some demand components absorbed by households than real output.

the next period after an unexpected change in monetary policy.[23]

To summarize, the modified liquidity-effect models with full dynamic optimization cannot explain our empirical findings properly. Their basic diffculty lies in explaining the reason why some components absorbed by households respond to monetary policy shocks earlier than real output.

6. Conclusion

By examining dis-aggregated GNP components, we have found that some demand components absorbed by households respond to monetary policy shocks earlier than real output. Our findings indicate that the monetary transmission mechanism in the U. S. economy is likely to be as follows. In response to a contractionary monetary-policy shock, households reduce their expenditure, which leads to an unintended pileup of business inventory. Faced with a tighter demand constraint, firms reduce their production.

In this transmission mechanism, however, the role of non-residential business investment remains unclear. In response to a contractionary monetary-policy shock, investment on producers' durable equipment (PD) declines larger than real output. But it declines along with real output.

Neither the textbook IS-LM model nor the recent modified liquidity-effect models can explain our findings properly. The observations in the paper suggest that liquidity constraints on the households' expenditure provide a key to clarifying the statistically significant but small real effects of monetary policy shocks. In particular, the quick response of residential investment indicates the importance of liquidity constraints due to institutional factors. In order to resolve the monetary transmission mechanism, in addition to the efforts to improve general equilibrium models, it seems important to evaluate the effects of institutional factors. Empirical work with sub-sample periods, and with international comparisons are also necessary.

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Appendix

Description of the Data Set

All data are from Citibase. The code names are in the brackets.

CP — Producer Price Index : All Commodities. Index for 1982=100 (PW).

DC* — Durable Consumption (GCDQ).

EXP* — U.S. Exports of Goods and Services (GEXQ).

23 Christiano and Eichenbaum (1992) assume sluggish adjustment in households' saving-consumption decision and generate lasting liquidity effect.

FF – Federal Fund rate. Monthly average data (FYFF).

GO* – Purchases by Federal and Local Governments (GGEQ).

INV* – Level of Non-farm Business Inventory (GLNQ).

NDC* – Non-durable Consumption (GCDQ).

NRI* – Non-residential Investment (GINQ).

PD* – Non-residential Investment: Producers' Durable Equipment (GIPDQ).

RI* – Residential Investment (GIRQ).

R10 – U.S. Treasury Constant Maturities: 10 Years (FYGT10).

SA* – Final Sales of Domestic Product (GNSQ).

SC* – Service Consumption (GCSQ).

ST * – Non-residential Investment: Structures. 1987 billion dollars (GISQ).

TR – Total Reserves : Adjusted for reserve requirement changes. Million Dollars (FMRRA).

UN – Unemployment Rate of Males, ages 25 - 54 (LHMU25).

Y* – Real GNP (GNPQ).

The data with supscript (*) are measured by 1987 Billion Dollars.

References

1 Bernanke, Ben S., "Alternative Explanations Money-Income Correlation," *Carnegie-Rochester Conference Series on Public Policy*, 25 (1986): 49-100.

2 ——, and Alan S. Blinder, "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review*, 82 (1992): 901-921.

3 ——, and Mark Gertler, "Inside the Black Box: The Credit Channels of Monetary Policy Transmission," *Journal of Economic Perspective*, 9 (1995): 27-48.

4 Blinder, Alan S., and Louis J. Maccini, "Taking Stock: A Critical Assessment of Recent Research on Inventories," *Journal of Economic Perspective*, 5 (1991): 73-96.

5 Brunner, Allan D., "The Federal Funds Rate and the Implementation of Monetary Policy: Estimating the Federal Reserve's Reaction Function," Board of Governors of the Federal Reserve System, *International Finance Discussion Papers* No. 466, (May 1994).

6 Christiano, Lawrence J., "Modeling the Liquidity Effect of a Monetary Policy Shock," *Quarterly Review of the Federal Reserve Bank of Minneapolis*, (1991): 3-34.

7 ——, and Martin Eichenbaum, "Liquidity Effect, the Monetary Transmission Mechanism, and Monetary Policy," *Federal Reserve Bank of Chicago Economic Perspectives*, XVI (1992): 2-14.

8 ——, and——, "Liquidity Effects, Monetary Policy, and the Business Cycle," *Journal of Money, Credit, and Banking*, 27 (1995): 1113-1136.

9 ——, ——, and Charles Evans, "The Effects of Monetary Policy Shocks: Some Evidence from the Flow of Funds," *Review of Economics and Statistics*, LXXVIII (1996), 16-34.

10 Dow, James P. Jr., "The Demand and Liquidity Effects of Monetary Shocks," *Journal of Monetary Economics*, 36 (1995): 91-115.

11 Friedman, Benjamin M., "Does Monetary Policy Affect Real Economic Activity?: Why Do We still Ask this

Question ? " *NBER Working Paper*, No. 5212, August 1995.

12 Fuerst, Timothy S., "Liquidity, Loanable Funds, and Real Activity," *Journal of Monetary Economics*, 29 (1992): 3-24.

13 Giannini, Carlo, *Topics in Structural VAR Econometrics*, Berlin: Springer-Verlag, 1992.

14 Gordon, David B., and Eric M. Leeper, "The Dynamic Impacts of Monetary Policy : An Exercise in Tentative Identification," *Journal of Political Economy*, 102 (1994): 1228-1247.

15 Kim, Soyoung, "Does Monetary Policy Matter in the G-6 Countries: Using Common Identifying Assumptions about Monetary Policy across Countries," mimeo, Yale University, August 1995.

16 King, Robert G., "Will the New Keynesian Macroeconomics Resurrect the IS-LM Model ? " *Journal of Economic Perspective*, 7 (1993): 67-82.

17 ——, and Charles I. Plosser, "Money, Credit, and Prices in a Real Business Cycle," *American Economic Review*, 74 (1984): 363-380.

18 Lucas, Robert E., Jr., "Liquidity and Interest Rates," *Journal of Economic Theory*, 50 (1990): 237-264.

19 Mankiw, Gregory N., "Consumer Durables and the Real Interest Rate," *Review of Economics and Statistics*, LXVII (1985): 353-362.

20 ——, "A Quick Refresher Course in Macroeconomics," *Journal of Economic Literature*, XXVIII (1990): 1645-1660.

21 Romer, Christina D., and David H. Romer, "What Ends Recessions," *NBER Macroeconomics Annual*, 9 (1994): 13-57.

22 Sims, Christopher A., "Are Forecasting Models Usable for Policy Analysis ? " *Quarterly Review of the Federal Reserve Bank of Minneapolis*, 10 (1986): 2-16.

23 ——, "Interpreting the Macroeconomic Time Series Facts," *European Economic Review*, 36 (1992): 975-1011.

24 ——, and Tao Zha, "Does Monetary Policy Generate Recessions?: Using Less Aggregated Price Data to Identify Monetary Policy," mimeo, Yale University, April 1995a.

25 ——, and ——, "Error Bands for Impulse Responses," mimeo, Yale University, July 1995b.

26 Stigum, Marcia, *The Money Market*, 3rd ed., Burr Ridge, Ill : Richard D. Irwin, Inc., 1990.

27 Stock, James H., and Mark W. Watson, "Interpreting the Evidence on Money-Income Causality," *Journal of Econometrics*, 40 (1989): 161-181.

28 Strongin, Steven, "The Identification of Monetary Policy Disturbances Explaining the Liquidity Puzzle," *Journal of Monetary Economics*, 35 (1995): 463-497.