# Changes in Monetary Policy Effectiveness: Evidence from Large Macroeconometric Models

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Since the mid-1970s, large institutional, regulatory, and technological changes in financial markets and intermediaries have significantly altered the nature and extent of monetary policy's influence on the real economy. Several recent studies have reported on these effects.[1] The common theme in these studies is that the ways in which monetary policy is transmitted to housing, business investment, trade, and perhaps consumption have changed substantially in the last fifteen years. There is less agreement, however, on whether the economy overall has become more or less sensitive to monetary policy.

Several researchers have identified small changes, both increases and decreases, in the size of aggregate demand responses to monetary policy. This finding is not surprising since these studies typically show offsetting effects in different sectors. For example, housing investment is probably less sensitive to monetary policy because of the removal of interest rate ceilings and the subsequent decline in disintermediation, but business investment may be more sensitive because of increased corporate leverage.

[1]For a summary of recent studies, see Paul Bennett, "The Influence of Financial Changes on Interest Rates and Monetary Policy: A Review of Recent Evidence," Federal Reserve Bank of New York *Quarterly Review*, Summer 1990. In addition, see Barry Bosworth, "Institutional Change and the Efficacy of Monetary Policy," *Brookings Papers on Economic Activity*, 1 1989, pp 77-110; Benjamin Friedman, "Changing Effects of Monetary Policy on Real Economic Activity," *Monetary Policy Issues in the 1990s*, Federal Reserve Bank of Kansas City, 1989, and Eileen Mauskopf, "The Transmission Channels of Monetary Policy. How Have They Changed?" *Federal Reserve Bulletin*, December 1990 See Patricia Mosser, "Large Model Comparisons of Monetary Policy Sensitivity," Federal Reserve Bank of New York, Research Paper no 9207, April 1992, for a more complete reference list

This article evaluates changes in the aggregate effectiveness of monetary policy and changes in transmission mechanisms by examining how traditional large-scale macroeconometric models have changed in the last ten to fifteen years. Because these large-scale models are designed to measure the important structural interrelationships among economic variables and across different sectors of the economy, they give a fairly complete accounting of the complex transmission mechanisms of monetary policy. For example, they measure the effects of policy changes as conveyed through money markets to other financial markets and intermediaries, and finally to spending by households and businesses. Thus, large models can be used to analyze the impact of policy changes on many sectors of the economy simultaneously.

Using large-scale models to evaluate the impact of policy changes does have some drawbacks. In particular, it is possible that changes over time in policy sensitivity as measured by these models reflect improvements in the model builders' knowledge of how the economy works and not changes in the actual economy. In addition, how these models measure policy sensitivity depends on the particular monetary policies used over the period the models were estimated. For example, if investment responds only to large changes in interest rates, a model estimated over a period of stable interest rates will understate the impact of a sharp change in monetary policy. Consequently, large models' evaluation of the impact of new policies may be inaccurate. Nonetheless, because these large models do summarize many of the important statistical relationships between macroeconomic variables, and because they are regularly reevaluated, changes over time in the link between policy and the real economy should be reflected in changes in their structures.

The article explores changes in policy linkages in two ways. First, it reports monetary policy experiments ("black-box" experiments) that use both past and present versions of several large macroeconometric models to measure the responses of real GNP, inflation, and financial variables to changes in monetary policy. Second, the article looks at changes in model structure over time. Since large-scale models were respecified and reestimated several times during the institutional and regulatory changes of the last decade and a half, examining their evolution can give insights into some of the ways in which monetary policy's influence on the economy has changed. In large models, these evolutionary changes include restructuring of links between financial variables and the real economy in some sectors, changes in the estimated interest rate and wealth sensitivities in other sectors, and changes in estimation procedures.

The article is organized as follows. The first section discusses different ways of measuring sensitivity to monetary policy and the strengths and weaknesses of the large-model approach. The second section documents how monetary policy's overall influence on the real economy has changed in the past decade, as measured by current and past dynamic money multipliers for several different models. The next section uses the Data Resources Inc. (DRI) Model to illustrate some examples of structural changes in these large models since the early 1980s.[2] The discussion focuses on what, if any, implications these changes have had for this model's estimate of the sensitivity of final demand to monetary policy, particularly interest rate sensitivity. Finally, simulation exercises, again using DRI, examine the outcomes of identical policy shocks across different historical versions of the model.

### Measuring changes in policy effectiveness using large-scale models

Changes in output sensitivity to monetary policy can be measured in different ways. Reduced form estimation is one possible approach. For example, a 1989 study uses vector autoregressions to summarize the dynamic relationship between interest rates and real output. It concludes that real GNP is slightly less sensitive to federal funds rate changes now than a decade ago.[3] Unfortunately, this approach cannot address policy changes directly since not all interest rate fluctuations are policy induced, nor are interest rates necessarily the only way policy changes are transmitted to the real economy.

An alternative strategy is to use large models. Most large-scale macroeconometric models contain a number of transmission channels from monetary policy to the real economy. The most direct linkage is through interest rates. In most models, monetary policy shocks are implemented by changes in bank reserve positions (open market operations), which affect the supply of bank reserves and the federal funds rate. In turn, changes in interbank lending rates feed through to other short-term interest rates and eventually to long-term interest rates as well. Both short- and long-term interest rates directly affect the models' predictions of several components of final demand, particularly investment.

In addition to incorporating interest rate channels, many large models allow for monetary policy to directly affect bank lending policy. Bank lending in turn may have a direct impact on household and business spending (independent of the interest rate changes), particularly if credit rationing is common. Changes in household and business wealth, which help to determine consumption and investment in some models, are another policy channel. Finally, most models now allow for policy-induced changes in international interest rate spreads to cause actual or incipient capital flows that affect exchange rates and, ultimately, the trade balance.

One example of the large model approach is a recent Federal Reserve Board study that measured changes in policy effectiveness by testing for changes in parameter values before and after 1980 in final demand equations from the Federal Reserve Board/MPS model.[4] The main conclusion of that study was that except for the housing and trade sectors, the regulatory and institutional changes of the 1980s had little or no impact on the policy sensitivity of final demand. Unlike the reduced-form approach, the MPS model study measured changes in a broad range of transmission mechanisms: short-term and long-term interest rates, wealth effects, and the exchange rate. The tests focused largely on single equation estimates, however, with little or no dynamic feedback effects from goods markets to financial markets and with no inflation or price level effects. In addition, the same equation structure with the same

[2]The study focuses on the DRI model, both because of its accessibility as a commercial model and because of the detail available on the 1980-81 version, the time period of most interest in this study. Joyce Yanchar, Mark Lasky, and David Wyss of DRI provided helpful information on the structure and estimation of the current DRI model as well as the historical tracking simulation used in the exercises below.

[3]See George Kahn, "The Changing Interest Sensitivity of the U.S. Economy," Federal Reserve Bank of Kansas City *Economic Review*, November 1989.

[4]See Mauskopf, "The Transmission Channels."

explanatory variables was imposed on regressions estimated both before and after 1980.

Like the Board study, this article adopts a large-model strategy for assessing changes in policy sensitivity. It differs from the earlier study, however, in that it evaluates changes in policy sensitivity by comparing the current structures of large models (including MPS) and their dynamic simulation multipliers with those used before the institutional changes of the last ten to fifteen years. This procedure has several advantages. First, by using dynamic simulations, it allows for full feedback and multiplier effects between financial variables, real output, and inflation. Second, these comparisons do not impose current model or economic structure on history, since presumably model builders would not have chosen the same specification in the 1970s (that is, the same explanatory variables, lag lengths, and so forth) as they are using today. Such "endogenous" specification changes in the last decade cannot be captured by reestimating current equations, but are available by comparing old and new equation structures and by comparing current model simulations to historical ones. Finally, using a large macroeconometric model with a detailed financial sector means that monetary policy effects can be measured relative to more than one policy lever: for example, did a 100 basis point decrease in the federal funds rate or a 2 percent increase in bank reserves have the same impact on output in models of the mid- to late 1970s as it has in current versions of these models?

Despite these advantages, large-scale macro models have disadvantages in evaluating policy experiments. One problem, known as the Lucas critique, focuses on the expectational effects of changes in policy.[5] Changes in monetary policy affect the real economy both directly, through interest rates and the like, and indirectly, by changing people's expectations of the future state of the economy. Most large-scale macroeconometric models, however, do not completely capture the expectational effects of a policy change. Thus they may not accurately reflect the outcome of policy experiments such as a cut in the federal funds rate or higher money growth.

In practice, this problem appears to be important for large changes in monetary policy regimes but less important in evaluating the effects of relatively small policy changes within a particular policy regime such as interest rate targeting or reserves targeting.[6] Thus large regime changes may cause traditional macroeconometric models to produce inaccurate predictions and may eventually lead model builders to restructure and reestimate their large models. In fact, it seems likely that the large shifts in both monetary policy procedures and in financial structures and institutions that took place at the end of the 1970s represent just such a large regime change, one for which the Lucas critique *should* matter and for which the specifications and parameters of macroeconometric models *should* have changed. If this is the case, a comparison of identical (small) policy experiments done with different historical versions of these models will be useful in determining whether the overall response of the economy to shocks has changed as well.

**Changes over time in policy multipliers of large-scale models**

Ideally one would measure the change in the overall sensitivity of the real economy to monetary policy by introducing identical monetary policy shocks to current and past versions of macroeconometric models. Unfortunately, because of data revisions and changes in software and hardware, macroeconometric models of the mid- and late 1970s are difficult (if not impossible) to simulate. However, policy multipliers summarizing the impact of policy on real output are available in print for several models.

One broad-ranging comparison of policy multipliers reports GNP/reserves multipliers for the mid-1970s versions of several models.[7] Recently, policy multipliers have been recalculated for newer versions of the models.[8] These recent-vintage models date from the late 1980s and 1990, and hereafter will be referred to as the "1990" models. Since this article is concerned with historical comparisons, it considers only models used in both sources: the Bureau of Economic Analysis Model (BEA); the Data Resources Inc. Model (DRI), the Federal Reserve Board/MPS Model, and the Wharton Econometric Forecasting Associates Model (WEFA).

[5]See Robert Lucas, "Econometric Policy Evaluation: A Critique," *Carnegie-Rochester Conference Series on Public Policy*, 1976, pp. 19-42. A counterargument can be found in Christopher Sims, "Policy Analysis with Econometric Models," *Brookings Papers on Economic Activity*, 1 1982, pp. 101-52.

[6]The phrase "small policy changes" refers to changes in policy variables that are of the same size and duration as actual policy changes during the model estimation period. Policy regimes may be thought of as large institutional changes in financial markets or in monetary policy procedures. See Christopher Sims, "Are Forecasting Models Usable for Policy Analysis?" Federal Reserve Bank of Minneapolis *Quarterly Review*, Winter 1986.

*Footnote 6 continued*

[7]See Gary Fromm and Lawrence R. Klein, "The NBER/NSF Model Comparison Seminar: An Analysis of Results," chap. 18 in Lawrence R. Klein and E. Burmeister, eds., *Econometric Model Performance* (Philadelphia: University of Pennsylvania Press, 1976).

[8]F. Gerald Adams and Lawrence R. Klein, "Performance of Quarterly Econometric Models of the United States: A New Round of Model Comparisons," chap. 2 in Lawrence R. Klein, ed., *Comparative Performance of U.S. Econometric Models* (New York: Oxford University Press, 1991). This chapter also contains brief descriptions of the 1990 versions of the models used in this article.

Table 1 summarizes the policy multipliers for the mid-1970s versions of the four models listed above Baselines were historical tracking simulations starting in 1961, 1962, or 1965. Historical tracking simulations are model solutions over the estimation sample period in which residual add-factors are adjusted to force the model to replicate historical data exactly. For each model, the monetary policy shock was an increase of $0.5 billion or 2.6 percent in nonborrowed reserves.[9]

The top half of Table 1 presents GNP/reserves multipliers: the percent change in real (1958 dollars) GNP (from the baseline) as a proportion of the percent change in reserves. Multipliers for all the models, except MPS, peak at two or three years The MPS model has positive (and growing) long-run money effects, WEFA has a positive but declining multiplier in the long run, BEA is neutral, and DRI gives a lower real output path in the long run.

The bottom half of Table 1 gives similar calculations for price level/reserves multipliers Except for WEFA (which shows a decline in prices in the short run), the models have price level effects that are positive but generally quite small, with prices rising significantly only after several years Long-run price level multipliers are well below 1 for all the models.

Table 2 gives policy multipliers for the 1990 versions of the same models. Although these multipliers are also reported in elasticities, comparisons with Table 1 results are complicated because the 1990 multipliers are stated in terms of M1 rather than reserves Here, simulations begin in the first quarter of 1975, with a gradual adjustment to a 3 percent higher path for M1. Specifically, M1 was raised 0.1 percent in the first quarter of the simulation, 0.7 percent in the second, 1 9 percent in the third, 2 8 percent in the fourth, and 3 0 percent in the fifth and all subsequent quarters.

As in the earlier exercise, the GNP multipliers for most models (WEFA is the exception) peak after three years. The size of the 1990 multipliers, however, is at least twice that of the mid-1970s multipliers As in Table 1,

[9]The ratio of nonborrowed reserves to M1 was approximately 0 13 between 1962 and 1965 If this average ratio is assumed to hold for changes in reserves as well as levels, then the increase in nonborrowed reserves translates to an approximate $4 0 billion increase in M1

Table 1
### Reserves Multipliers for 1975-Vintage Macroeconometric Models

| Quarters after Shock | BEA | DRI | MPS | WEFA |
|---|---|---|---|---|
| | **Real GNP** | | | |
| 1 | 0 0 | 0 011 | 0 011 | 0 043 |
| 2 | 0 0 | 0 018 | 0 035 | 0 080 |
| 4 | 0 007 | 0 155 | 0 113 | 0 143 |
| 8 | 0 014 | 0 293 | 0 284 | 0 219 |
| 12 | 0 023 | 0 220 | 0 410 | 0 268 |
| 40 | 0 0 | −0 149 | 0 501† | 0 081 |
| | **Implicit Deflator** | | | |
| 1 | 0 0 | 0 0 | 0 004 | −0 003 |
| 2 | 0 0 | 0 004 | 0 004 | −0 006 |
| 4 | 0 0 | 0 008 | 0 014 | −0 013 |
| 8 | 0 003 | 0 018 | 0 101 | −0 012 |
| 12 | 0 003 | 0 047 | 0 166 | −0 012 |
| 40 | 0 052 | 0 160 | 0 623† | 0.033 |

Notes Reserves multipliers were calculated as the percent deviation in real GNP or the deflator, divided by percent deviation in nonborrowed reserves Multipliers were converted from dollar-level changes—ΔGNP/Δ (nonborrowed reserves) and Δ(GNP in 1958 dollars)/Δ (nonborrowed reserves)—reported in Fromm and Klein, "The NBER/NSF Model Comparison," p 405 The increase in nonborrowed reserves was $0 5 billion or approximately 3 percent To calculate multipliers in percentages, historical values of real and nominal GNP, available in 1975 (the year the simulations were run), were used as base values Implicit deflator multipliers (base year 1958) were calculated as the difference between nominal and real GNP percent deviations

Historical tracking simulations were used as base cases, and monetary shocks were introduced in the first quarter of 1961 for DRI, 1965 for WEFA, and 1962 for all others

†Figures for the MPS model are twenty-four quarters after the shock.

Table 2
### Money Multipliers for 1990-Vintage Macroeconometric Models

| Quarters after Shock | BEA | DRI | MPS | WEFA |
|---|---|---|---|---|
| | **Real GNP** | | | |
| 1 | 0 07 | −0 14 | 0 14 | 0 50 |
| 2 | 0 08 | 0 0 | 0 16 | 0 44 |
| 4 | 0 11 | 0 17 | 0 29 | 0 27 |
| 8 | 0 18 | 0 84 | 0 77 | 0 36 |
| 12 | 0 19 | 1 28 | 1 00 | 0 39 |
| 40 | −0 34 | −0 95 | 0 21 | 0 41 |
| | **Implicit Deflator** | | | |
| 1 | 0 0 | 0 0 | 0 0 | 0 14 |
| 2 | 0 0 | −0 03 | 0 0 | −0 04 |
| 4 | 0 0 | −0 03 | 0 02 | 0 01 |
| 8 | 0 05 | 0 09 | 0 22 | 0 12 |
| 12 | 0 10 | 0 43 | 0 74 | 0 20 |
| 40 | 0 52 | 2 46 | 0 52 | 0 57 |

Notes M1 multipliers are calculated as the percent deviation in real GNP or the deflator, divided by the percent deviation in M1 M1 was increased by 0 14 percent in the first quarter of the simulations, 0 73 percent in the second, 1 88 percent in the third, 2 8 percent in the fourth, and 3 0 percent in the fifth and all subsequent quarters All simulations used historical tracking simulations as baselines, and policy shocks were introduced in the first quarter of 1975 the DRI and MPS models have the largest real output increases after eight to twelve quarters.

Similarly, while the price level multipliers are near zero for the first year (as in the earlier study), after two to three years they are five to ten times as large as those reported in Table 1. This difference certainly reflects the more volatile U.S. inflation experience since the mid-1970s and the significant changes made in modeling output and inflation linkages in response to this experience.

Taken at face value, Tables 1 and 2 make a striking case that both the real economy and inflation have become much more sensitive to monetary policy in the last fifteen years, at least as measured by these models. In comparison with the very small changes in policy sensitivity measured by previous studies, however, the large jump in multipliers from Table 1 to Table 2 seems extreme, and perhaps it should be viewed with some skepticism.

One reason for caution in interpreting Tables 1 and 2 is that the policy experiments in the two cases are not strictly comparable. The 1976 study reports the response of GNP to changes in reserves, while the later study focuses on the response of GNP to shifts in M1. If there were a simple, stable relationship between reserves and M1, this difference would not pose problems in comparing the medium-term and long-term multipliers. (Note, however, that even with a stable M1/reserves relationship, the slower response of M1 to policy changes might cause a problem in comparing the short-term multipliers.) Unfortunately, the institutional and regulatory changes of the last fifteen years suggest that the M1/reserves relationship has not been stable.

The link between reserves and M1 has been affected by, among other things, reserve requirements that changed substantially over the periods when these simulations were conducted. Reserve requirements have generally fallen, and consequently the M1/reserves multiplier has risen. Even after one adjusts for reserve requirement changes, the M1/reserves ratio shows a steady rise over the last thirty years: from 11 in 1962, to about 13½ in 1975, to more than 17 in 1991.[10]

Comparing reserves changes to M1 changes over time is further complicated by the instability and changing interest sensitivity of M1 demand.[11] The removal of deposit rate ceilings increased the interest sensitivity of M1 in the 1980s. Furthermore, the phasing out of reserve requirements on nontransaction M2 deposits has made bank reserves almost entirely a function of the deposits portion of M1. Thus, as checkable deposits have become more interest sensitive, so have reserves. Finally, as a practical matter, analysis is complicated by several changes in the definition of M1 since the earlier study was done.

Although the cumulative effect of these changes makes it difficult to compare the multipliers in Tables 1 and 2 precisely, the greater interest sensitivity of M1 demand suggests that GNP should have become *less*, rather than more, sensitive to changes in the money stock in recent years. If the demand functions for reserves and M1 are more interest sensitive in the later period, then a reserves injection will lower short-term rates less in the later models than in the earlier ones. In turn, if real output responds to monetary policy largely through interest rates, then smaller rather than larger output multipliers would result. Obviously, then, greater money demand elasticity cannot account for the results in Tables 1 and 2 and in fact works in the opposite direction.[12]

This finding only reinforces the surprising conclusions from Table 2: the very large change in the size of the multipliers indicates that monetary policy in recent-vintage macro models has much larger effects on the economy than in earlier models. Several explanations for this result are possible. The differences between earlier and later versions of the models could reflect changes in the structure of the actual economy and its linkages to monetary policy. These could include changes in sensitivity of final demand to interest rates, financial wealth, and other policy-influenced variables in the last decade, as well as changes in financial markets and institutions that have altered the channels of monetary policy to the real economy. The shifts in money demand documented above are one example.

However, the increases in the model multipliers from Table 1 to Table 2 are so large, particularly in comparison with other findings, that they must certainly also reflect improvements in model building in the last fifteen years. Some of these innovations include major changes in the modeling of inflation, particularly the Phillips curve, and in the specification of aggregate supply. In addition, nearly all the models incorporate more extensive links between the real economy and the financial sector in their recent vintages. For example, previously exogenous sectors such as exchange rates

[10]This rise is due, in part, to a positive long-term trend in the ratio of currency to checkable deposits.

[11]For example, see John P. Judd and John L. Scadding, "The Search for a Stable Money Demand Function: A Survey of the Post-1973 Literature," *Journal of Economic Literature*, vol. 20 (1982), pp. 991-1023, and Robert Hetzel and Yash Mehra, "The Behavior of Monetary Demand in the 1980s," *Journal of Money, Credit, and Banking*, vol. 21 (November 1989).

[12]Across-model comparisons of M2 or interest rate changes would probably be preferable, given the problems with M1. Unfortunately, M2 multipliers for these large models are not available in print, and simulations comparing interest rate changes are available only for the 1990 versions of the models.

and foreign trade, or state and local government purchases, are now often modeled with direct and indirect interest rate effects. Finally, improved estimation techniques and statistical tests, including some innovations in time-series econometrics, may have contributed to the changes in the simulation multipliers.

How much of the measured increase in sensitivity in these large models is due to structural changes in the actual economy's response to policy, however, and how much is due to new modeling procedures or improved estimation is unclear. For example, it is likely that the changes in exchange rate sensitivity measured by the models stem from a mixture of both factors. In the late 1970s, actual exchange rates certainly responded to monetary policy, but for modeling purposes they were treated as exogenous because model builders did not have enough data on the post-1973 flexible exchange rate system to measure the effects. At the same time, actual exchange rates have probably become more interest rate sensitive in the last decade as capital markets have become more internationally integrated.

In practice it is not possible to differentiate completely between model changes that reflect "true" changes in the economy and those that result from model builders' better understanding of how the economy works. Nevertheless, the results in Tables 1 and 2, although extreme, do suggest that large macroeconometric models estimate a larger influence of policy on the real economy and the price level today than fifteen years ago. Because these results are quite different from the findings of other authors, it is useful to look more closely at the structure of these large models, particularly the linkages from monetary policy to the real economy, and to examine how these linkages have changed in the last decade. Doing so may help clarify whether the larger money multipliers in Table 2 reflect changes in the actual economy or just in model builders' measures of it.

### A structural comparison: 1981 and 1990 versions of the DRI model

Although comparing all of the structural changes in all of the macro models in Tables 1 and 2 would be difficult, if not impossible, an idea of the direction and size of structural changes in macro modeling may be inferred from comparing the current 1990 version of the DRI model with the 1981 version, described in detail by Eckstein in *The DRI Model of the U.S. Economy*.[13] The 1981 DRI model was, for the most part, estimated using data before the upheavals in monetary policy and financial structure in the 1980s. Thus, if structural model specifications have changed substantially in the last ten years, comparing final demand equations and financial sector equations across the two vintages should yield some information on how monetary policy channels have changed.

For the final demand equations, structural changes generally come from three sources: changes in the estimated sensitivity of final demand to interest rates, either short-term or long-term; changes in the response of final demand to financial wealth and/or credit constraints; and changes in estimated coefficients due to changes in the modeling of dynamic relationships. In addition, changes in the ways both exchange rates and the term structure of interest rates are modeled have affected policy transmission as well.

Table 3 compares 1981 and 1990 DRI equations for final demand components that depend directly on financial variables and thus are sensitive to monetary policy. Consumption, investment, and trade are modeled in some detail by DRI, but the basics of the equations for individual components are similar. Thus only single component equations for consumer durables (furniture), housing (single family starts), business investment (equipment), inventory investment (manufacturing), and exports (capital goods except autos) are highlighted.

In the equation for consumer expenditures on furniture and household equipment, income and interest rate elasticities have changed very little from 1981 to 1990, but the effects of consumer sentiment and net worth show clear changes. While the direct interest rate sensitivity fell slightly in the 1990 model, indirect interest rate effects may have been larger because the elasticity of consumer sentiment nearly tripled. Historically, this survey has been very sensitive to interest rate changes, and short-term interest rates are important explanatory variables in the DRI model specification of sentiment. The large expansion of consumer installment debt during the 1980s and the accompanying vulnerability of highly leveraged debtors to interest rate changes may help to explain why indirect interest rate effects conveyed through consumer sentiment have increased.

At the same time, household net worth appears to have a substantially smaller effect on furniture purchases in 1990 than in 1981. This decrease in the wealth elasticity may also reflect how the increased use of consumer credit lines has "disconnected" durables purchases from household financial wealth. Thus, while the sentiment effect indicates that monetary policy may have a larger impact on consumer durables today than ten years ago, the insensitivity to financial wealth suggests the opposite. Model simulations in the next section should help clarify which of these effects is more important.

Table 3 also compares equations for business invest-

[13]Otto Eckstein, *The DRI Model of the U.S Economy* (New York: McGraw-Hill, 1983)

ment in producers' durable equipment. In 1981, DRI estimated a single equation for equipment. By 1990, rapidly expanding computer and office equipment investment, combined with huge relative price changes, led DRI to model equipment investment in three component equations: office equipment, autos, and all other investment. The 1981 equation was a stock adjustment model that defined the desired stock level in terms of the inverse of the real rental price of capital (the cost of capital divided by the price of investment goods) and real output. The equation also included a debt service variable designed to capture capital market imperfections associated with liquidity constraints and credit rationing. In contrast, the 1990 equation for nonauto/nonoffice equipment has no stock adjustment mechanism or credit rationing effects, and investment depends only on very long lags in output and the rental price.

In the face of such large specification changes, direct measurement of changes in monetary policy effects is virtually impossible. Nevertheless, the changes in specification are important in and of themselves. The exclusion of the debt-to-cash-flow measure in the later version of the model suggests that financial market deregulation and innovation made this tightness measure less important as an independent transmission channel. Financial market changes such as the introduction of junk bonds, the increased use of loan commitments, and the growth of the commercial paper market have increased access to credit markets, making firms' plans—and probably their cash flows as well—more sensitive to market interest rates. Thus monetary policy effects on investment may now be adequately captured purely by the rental price. This change does not necessarily mean that the impact of policy changes is smaller, just that interest rates (through the rental price) are now the most important channel to investment.

The 1990 equations for housing starts are also simpler than their 1981 counterparts. Housing specifications are now stock adjustment equations in which affordability measures and consumer sentiment determine the desired stock. In contrast, the 1981 equation included a rationing variable for mortgages (the real value of new commitments) and the ratio of houses sold to those offered, a variable that measured short-term building supply constraints. The introduction of variable rate mortgages and removal of interest rate ceilings allowed these disintermediation variables to be dropped. Although the effect of these changes on the long-run sensitivity of housing to policy is unclear (the simulations below will address this issue), the removal of credit constraints suggests that the short-run policy impact on housing has become smaller.

Current DRI specifications for manufacturing inventory investment equations incorporate interest rate effects (and thus monetary policy linkages) that were completely absent in 1981. The 1981 equations were traditional stock adjustment specifications that assigned no role to real interest rates. In contrast, the 1990 equations model the inventory-to-expected-sales ratio directly as a function of unexpected sales and real

Table 3

**DRI Final Demand Equations, 1981 versus 1990**

| | | |
|---|---|---|
| **Consumer Expenditure—Furniture and Household Equipment (Logs)** | | |
| | 1981 | 1990 |
| Income elasticity† | 0.914 | 1.006 (4) |
| Interest rate | −0.011 (2) | −0.010 |
| Consumer sentiment | 0.06 (2) | 0.187 (4) |
| Net worth elasticity | 0.393 | 0.084 |
| **Producers' Durable Equipment (Levels)** | | |
| | 1981 (Total) | 1990 (Nonauto, Noncomputer) |
| Δ(output/real rental price) | 0.006 (5) | 0.144 (14) |
| Debt/cash flow | −11.87 (6) | N.A. |
| **Single Family Housing Starts** | | |
| | 1981 (Levels) | 1990 (Starts/Stock) |
| Sold/offer ratio | 0.143 | N.A. |
| Sales price/cost | 0.005 | N.A. |
| Housing stock | −30.61 | N.A. |
| New mortgage commitments | 0.011 (5) | N.A. |
| Electricity prices | −0.144 | N.A. |
| Consumer sentiment | N.A. | 0.355 |
| Affordability | N.A. | −3.45 |
| **Manufacturing Inventory Investment** | | |
| | 1981 (Levels) | 1990 (Inventory/Sales Ratio) |
| Real rate | N.A. | −0.0003 |
| Labor costs | N.A. | −0.1071 |
| Sales surprise | N.A. | −0.162 (2) |
| Expected sales | N.A. | 1.0 (implicit) |
| Sales | −0.048 | N.A. |
| Lagged sales | 0.079 | N.A. |
| **Exports of Capital Goods Excluding Autos (Logs)** | | |
| | 1981 | 1990 (Excluding Computers) |
| Foreign demand | 1.232 (4) | 1.222 (13) |
| Relative price | −0.836 (6) | −1.389 (11) |

Notes: Numbers in parentheses are length of lags in specifications. DRI commonly uses polynomial distributed lags to increase the number of degrees of freedom in estimation.

†Long-run permanent income elasticities.

factor costs, including unit labor costs and real interest rates. This change may be due to more sophisticated inventory management techniques, to a threshold effect of higher levels of real rates, or to econometric issues such as the larger variation in real rates in the 1980s.

The trade sector of the 1990 DRI model is more sensitive to monetary policy than its 1981 counterpart largely because the dollar exchange rate is now endogenous, whereas it was completely exogenous in the 1981 model. In the current formulation, spreads between U.S. and world real interest rates directly affect the exchange rate and thus the relative prices of exports and imports. For example, a 100 basis point increase in the spread between U.S. and foreign real long-term rates will raise the dollar by 6 percent over six quarters, an effect that was nonexistent in the earlier model. In addition, estimated relative price elasticities are slightly larger in the 1990 model (Table 3). The combination of a policy-sensitive exchange rate and greater sensitivity of trade to relative price changes suggests that DRI's trade sector should be more sensitive to monetary policy shocks in 1990. Because of the amount of export and import detail in the DRI model, the aggregate importance of these changes for policy sensitivity can best be seen in simulations in the next section.

Substantial changes have also been made to the financial sector of the DRI model, particularly the modeling of interest rates. Short-term interest rate equations in the earlier model had a high degree of simultaneity, each equation depending on rates of close substitutes as well as on bank reserves. In addition, the 1981 model used a segmented markets rather than a term structure approach to determining equilibrium long-term rates. As a result, long rates responded only indirectly to short rates but directly to supply and demand conditions in individual asset markets. In contrast, the 1990 model has a more recursive structure for short rates, and long rates are tied to short rates through term structure equations. The cumulative effect of these changes is that in the 1990 model, short rates are somewhat less sensitive to reserves changes, but long rates are more sensitive.

The switch from a segmented markets structure to term structure specification is unique to the DRI model. Nearly all other large macro models, including those examined earlier in this article, used a term structure approach to modeling long-term interest rates in both the late 1970s and the 1990 versions. Still, estimates using the most recent MPS model also show that long rates during the 1980s were more responsive to short rates than they had previously been.[14]

[14]See Mauskopf, "The Transmission Channels "

The changes in interest rate modeling are an important component in the way DRI has changed links from monetary policy to real investment over time. In the later model (with long rates modeled using the term structure), monetary policy affects investment through the rental price. By contrast, in the earlier model (with segmented markets for long-term rates), monetary policy affected investment through both the cost of capital and cash flow.

In summary, inventories and trade equations appear to be more directly sensitive to interest rates in the 1990 DRI model than they were ten years earlier. The overall effects of monetary policy on consumption and particularly investment are less clear because of changes in the modeling of interest rate linkages and changes in financial markets and financial intermediaries. Monetary policy simulations are needed to disentangle these different effects.

**Monetary policy simulations using the DRI model**

This section examines how the responses of final demand components to monetary policy shocks in the DRI model have changed over the last decade. In particular, the simulations reported below are designed to measure only the effect of the specification changes of the last decade. To this end, simulations of 1981-vintage and 1990-vintage models using identical policy shocks and spanning identical time periods are compared. The use of identical time periods ensures that initial conditions such as wealth and debt levels do not affect the results. Changes due solely to initial conditions are analyzed in the appendix by simulating the current DRI model over different periods.

Eckstein reports results from a 1981 DRI model simulation in which monetary policy was tightened by a cut in nonborrowed reserves starting in the second quarter of 1975. A summary of his findings is reported in Table 4 as the "1981 simulation." An identical reserves shock experiment using the 1990 DRI model was performed and is reported in Table 4 as the "1990a simulation." Since both of these exercises were conducted from historical bases starting in 1975, comparing them should provide the most direct evidence of model changes over the last decade.[15]

Table 4 shows that the short-run (less than one year) and the long-run (sixteen quarters) responses of real GNP to a cut in reserves are different in the two models. However, the intermediate (eight quarters) effect of tight money on output is very similar—approximately a 4 percent decline in real GNP—in both cases. Policy

[15]Of course, simulating a 1990-vintage model from 1975 to 1979 will not give an accurate picture of how monetary policy influenced the economy in 1975 But the point of these exercises is to compare current policy effects with past ones

shocks have a smaller immediate impact in the 1990 model, largely because of smaller initial declines in investment and in state and local government purchases Beyond four quarters, the models give approximately the same output change, but after four years, real output is 0.5 percent stronger using the 1990 model.

Table 4

**Monetary Policy Tightening: Comparison of 1981 and 1990 DRI Model Simulations**

Percent Deviation from Base Case

| | Quarters after Shock | | | | |
|---|---|---|---|---|---|
| | 1 | 4 | 8 | 12 | 16 |
| **1981 simulation** | | | | | |
| Nonborrowed reserves | −5 8 | −5 8 | −5 8 | −5 5 | −5 0 |
| Federal funds rate | 3 46 | 4 64 | 3 64 | 2 75 | 2 35 |
| AAA corporate rate | 0 28 | 0 01 | −0 54 | −0 70 | −0 61 |
| Real GNP | −0 9 | −3 1 | −4 2 | −3 2 | −2 0 |
| Consumption | −0 7 | −2 3 | −3 2 | −2 3 | −1 5 |
| Residential construction | −3 7 | −16 4 | −20 6 | −14 7 | −8 6 |
| Business fixed investment | −1 0 | −4 1 | −6 6 | −5 7 | −3 5 |
| State and local purchases | −1 1 | −2 0 | −2 5 | −2 6 | −2 4 |
| Net exports† | N A | N A | 0 3 | N A | N A |
| **1990a simulation** | | | | | |
| Nonborrowed reserves | −5 8 | −5 8 | −5 8 | −5 5 | −5 0 |
| Federal funds rate | 3 04 | 3 57 | 1 44 | −0 06 | −0 76 |
| AAA corporate rate | 1 14 | 2 31 | 1 52 | 0 46 | −0 20 |
| Real GNP | −0 1 | −2 7 | −4 3 | −3 0 | −1 5 |
| Consumption | −0 6 | −1 4 | −2 4 | −1 8 | −1 0 |
| Residential construction | −2 6 | −23 4 | −18 7 | −3 2 | 4 2 |
| Business fixed investment | 0 0 | −3 6 | −11 8 | −12 8 | −8 0 |
| State and local purchases | 0 0 | −0 1 | −0 7 | −1 3 | −1 3 |
| Net exports† | 0 0 | 0 3 | 0 3 | −0 1 | −0 2 |
| **1990b simulation** | | | | | |
| Nonborrowed reserves | −6 6 | −6 4 | −8 9 | −11 1 | −13 6 |
| Federal funds rate | 3 46 | 4 64 | 3 64 | 2 75 | 2 36 |
| AAA corporate rate | 1 30 | 2 70 | 2 81 | 2 38 | 2 14 |
| Real GNP | −0 1 | −2 6 | −5 5 | −5 9 | −5 8 |
| Consumption | −0 7 | −1 3 | −3 0 | −3 4 | −3 2 |
| Residential construction | −3 0 | −22 8 | −28 4 | −19 7 | −14 1 |
| Business fixed investment | 0 0 | −3 4 | −13 2 | −19 1 | −18 6 |
| State and local purchases | 0 0 | −0 1 | −0 8 | −1 7 | −2 2 |
| Net exports† | 0 0 | 0 3 | 0 5 | 0 0 | −0 2 |

Notes The 1981 simulation results are reproduced from Otto Eckstein, *The DRI Model*, p 88 The baseline simulation used for 1990a and 1990b is a historical tracking simulation for the 1990 DRI model starting in the second quarter of 1975 Simulations 1981 and 1990a impose a permanent decrease in nonborrowed reserves starting the second quarter of 1975 In the 1990b simulation, the federal funds rate path is matched to that in the 1981 simulation by adjusting nonborrowed reserves appropriately Federal funds and AAA corporate interest rates are reported as percentage point deviations from baseline

†Differences for net exports are reported as a percentage of real GNP The figure from the 1981 simulation was rebased from 1972 to 1982 dollars to adjust for the large change in the relative valuation of imports between 1972 and 1982

Part of the reason for the later downturn and quicker upturn in the 1990 model is evident in the response of equilibrium short-term interest rates, particularly on federal funds, to changes in the nonborrowed reserves In both experiments, nonborrowed reserves were decreased by 5.8 percent.[16] In the later model, the federal funds rate rose by at most 357 basis points, while in the earlier case, rates peaked more than 100 basis points higher. In the 1981 model exercise, the federal funds rate was still nearly 250 basis points above the base after four years, whereas in the 1990 model, short-term interest rates had already returned to baseline levels

There are several explanations for the difference in short-term rate responses. It may be due in part to revisions in monetary aggregates, including reserves, since the 1981 simulations were run If this is the case, a 6 percent cut in reserves may be a milder policy contraction in the current model than in the 1981 model and thus result in smaller interest rate changes. Probably more important is the fact that DRI model structure reflects changes in money demand sensitivity to interest rates and changes in reserve requirements As noted earlier, the cumulative effect of such changes is that the demand for M1 and reserves is more interest sensitive today than ten years ago Thus, all other things equal, a decrease in the supply of reserves by the Fed will raise the federal funds rate less today than in 1981

In light of the substantially different interest rate responses across the two models, an additional "tight money" simulation is reported in Table 4. In "simulation 1990b," the path of the federal funds rate is matched to that reported in the 1981 simulations, and nonborrowed reserves are adjusted appropriately to achieve that path. Because reserves are more interest sensitive in the 1990 model, a sustained tight money policy—defined by the level of the nominal federal funds rate—involves a much more drastic cut in reserves in the 1990 model than in the 1981 model. After four years, the reduction in nonborrowed reserves necessary to keep the funds rate at levels consistent with the 1981 experiment is two and a half times larger in the 1990 model.

Not surprisingly, targeting the federal funds rate rather than reserves gives a very different output path in

[16]The decrease in nonborrowed reserves reported in Eckstein was $2 0 billion in all quarters This corresponded to reductions of 5 8 percent in 1975 and 1976, approximately 5 5 percent in 1977, and 5 0 percent in 1978 Because of data revisions and changes in coverage, a 5 8 percent cut in nonborrowed reserves in 1975 corresponds to only a $1 5 billion decrease in the current data series

the 1990 model. For the first year, the downturn in real GNP under interest rate targeting (1990b) is similar to that under reserves targeting (1990a). But after four years, the higher rates push real GNP down nearly 6 percent, while GNP drops only 1.5 percent under reserves targeting.

In comparison with the 1981 simulation, the 1990b simulation (like 1990a) produces a somewhat milder downturn in real output in the short run. This observation is consistent with findings from other studies that the lag between a change in monetary policy and its impact on the real economy has lengthened. After two years, however, output declines in the 1990b simulation are substantially larger than those in the 1981 exercise, despite the identical paths for the federal funds rate. This finding suggests that real final demand is, in the longer term, more sensitive to nominal short-term interest rates in the 1990 model.

Whether policy changes are measured by reserves or interest rates, simulations show that the composition of final demand responses to policy is very different in the two model vintages. As expected, residential structures are, in the very short run, down more sharply in the 1981 simulation than in the 1990 simulations. Thereafter, housing falls farther in the 1990 simulations, but with a quicker and stronger recovery when reserves are targeted. Increased sensitivity of housing to short rates due to adjustable rate mortgages appears to explain the steeper downturn in the 1990 model, and the sharp recovery in the 1990a simulation stems from a quicker turnaround in short rates. When monetary policy is standardized on short-term interest rates, the 1990 model gives a downturn in housing that is both deeper and longer (after the first quarter) than that found in the 1981 model, in part because term structure relationships hold up long-term rates.

Even with a milder path for interest rates (1990a), the drop in business fixed investment is later, and substantially larger and longer, than in the 1981 model. The longer policy lag is attributable to the removal of debt service and credit constraint variables, while the larger long-term response is due to a much stronger reaction of long-term interest rates, and thus of the cost of capital, to short rates in the 1990 model. The increase in long-term rates is larger and the downturn in business fixed investment is even deeper when short-term rates are matched to the 1981 simulation path.

The closer term structure links between long and short rates seen in the 1990 simulations may be related to lower inflation risks in the late 1980s (which would make long rates more predictable from short rates). Nevertheless, the change in the DRI specification, and thus in the policy response, seems to be extreme in comparison with the other macroeconometric models discussed above. Roughly speaking, the 1990 DRI model substitutes a monetary transmission mechanism that operates through the term structure of interest rates for the credit/cash constraint mechanism that

Table 5

**Monetary Policy Tightening with Exogenous Exchange Rate: Comparison of 1981 and 1990 DRI Simulations**

Percent Deviation from Base Case

| | Quarters after Shock | | | | |
|---|---|---|---|---|---|
| | 1 | 4 | 8 | 12 | 16 |
| **1981 simulation** | | | | | |
| Nonborrowed reserves | −5.8 | −5.8 | −5.8 | −5.5 | −5.0 |
| Federal funds rate | 3.46 | 4.64 | 3.64 | 2.75 | 2.35 |
| AAA corporate rate | 0.28 | 0.01 | −0.54 | −0.70 | −0.61 |
| Real GNP | −0.9 | −3.1 | −4.2 | −3.2 | −2.0 |
| Consumption | −0.7 | −2.3 | −3.2 | −2.3 | −1.5 |
| Residential construction | −3.7 | −16.4 | −20.6 | −14.7 | −8.6 |
| Business fixed investment | −1.0 | −4.1 | −6.6 | −5.7 | −3.5 |
| State and local purchases | −1.1 | −2.0 | −2.5 | −2.6 | −2.4 |
| Net exports† | N.A. | N.A. | 0.3 | N.A. | N.A. |
| **1990a simulation** | | | | | |
| Nonborrowed reserves | −5.8 | −5.8 | −5.8 | −5.5 | −5.0 |
| Federal funds rate | 3.04 | 3.62 | 1.64 | 0.37 | 0.01 |
| AAA corporate rate | 1.15 | 2.23 | 1.60 | 0.60 | 0.06 |
| Real GNP | −0.1 | −2.6 | −3.8 | −2.1 | −0.5 |
| Consumption | 0.0 | −1.4 | −2.5 | −1.8 | −0.9 |
| Residential construction | −2.6 | −23.6 | −19.1 | −3.7 | 2.5 |
| Business fixed investment | 0.0 | −3.6 | −11.6 | −12.2 | −7.3 |
| State and local purchases | 0.0 | −0.1 | −0.7 | −1.2 | −1.1 |
| Net exports† | 0.0 | 0.6 | 1.2 | 0.9 | −0.4 |
| **1990b simulation** | | | | | |
| Nonborrowed reserves | −6.5 | −6.8 | −8.2 | −9.8 | −11.8 |
| Federal funds rate | 3.46 | 4.64 | 3.64 | 2.75 | 2.36 |
| AAA corporate rate | 1.30 | 2.56 | 3.64 | 2.75 | 1.97 |
| Real GNP | −0.1 | −2.3 | −5.1 | −4.9 | −3.7 |
| Consumption | 0.0 | −1.2 | −3.1 | −3.5 | −3.0 |
| Residential construction | −3.0 | −20.7 | −30.0 | −21.1 | −12.6 |
| Business fixed investment | 0.0 | −3.2 | −12.5 | −18.4 | −17.4 |
| State and local purchases | 0.0 | −0.1 | −0.8 | −1.6 | −2.0 |
| Net exports† | 0.0 | 0.5 | 1.5 | 1.9 | 1.7 |

Notes: The 1981 simulation results are reproduced from Otto Eckstein, *The DRI Model*, p. 88 The baseline simulation used for 1990a and 1990b is a historical tracking simulation for the 1990 DRI model starting in the second quarter of 1975. Simulations 1981 and 1990a impose a permanent decrease in nonborrowed reserves starting the second quarter of 1975. In the 1990b simulation, the federal funds rate path is matched to that in the 1981 simulation by adjusting nonborrowed reserves appropriately. Federal funds and AAA corporate interest rates are reported as percentage point deviations from baseline.

†Differences for net exports are reported as a percentage of real GNP. The figure from the 1981 simulation was rebased from 1972 to 1982 dollars to adjust for the large change in the relative valuation of imports between 1972 and 1982

existed in the 1981 model. In fact, if the path of long-term rates from the earlier simulation is imposed on the 1990 model, the impact of tight policy on business investment and the rest of the economy is substantially smaller than that measured in the 1981 simulation.[17]

A comparison of the trade balance reactions across the models is more complicated, in part because of changes in exchange rate modeling, but also because of income effects. In the 1990 model, tighter monetary policy has a direct negative effect on the trade balance: higher U.S. interest rates lead to capital inflows and a stronger dollar, eventually producing a decline in net exports. In both models, however, tight money also produces lower income, and thus lower U.S. demand for imports. This outcome pushes the trade balance in the opposite (positive) direction for the first two years. Furthermore, the income effect appears to be somewhat larger in the 1990 model.

To convey an idea of the size of the changes in income and exchange rate effects in the later model, Table 5 presents simulations for the 1990 model while keeping the exchange rate exogenous, as it was in 1981. Without the exchange rate mechanism, real net exports have an even larger and more persistent positive effect on real GNP in the 1990 simulation than in the 1981 simulation.[18] A comparison of Tables 4 and 5 reveals that tighter monetary policy, operating through the trade balance in the 1990 model, does have a depressing effect on the economy—an effect missing from the 1981 model.

The other components of real output show less dramatic changes in policy responses. In the short run, consumption is actually less sensitive to policy in the 1990 model than in the 1981 model, particularly when reserves are used to measure policy changes. This finding also holds for the first two years of the interest rate targeting exercise, but thereafter consumer spending declines are much larger, probably because of the stronger consumer sentiment effects. State and local government purchases are somewhat more responsive to rates in the 1981 model, and federal government purchases, by assumption, are identical.

Unfortunately, a comparison of inflation responses to monetary policy is not possible because inflation changes for the 1981 DRI simulation were not recorded. However, if the comparisons of inflation multipliers reported earlier are indicative, inflation responses are probably larger in the 1990 model than in the 1981 model. If tight money prompts a larger decline in inflation in the 1990 model, then this result could partially explain the lower path of short-term nominal interest rates in the 1990 reserves targeting simulation.

Overall, if one defines sensitivity to monetary policy in terms of the responses of real output to nominal short-term rates (that is, the federal funds rate), then the estimated sensitivities embodied in the DRI model are somewhat smaller in the short run, but substantially larger in the longer term, than they were ten years ago. But if policy is measured in terms of changes in high-powered money, then the overall sensitivity—in the one-to three-year horizon—has changed very little.

What is behind the divergence in the two policy measures? One factor, certainly, is the change in the relationship between reserves, money, and short-term interest rates. As noted earlier, the larger interest elasticities in M1 and reserves can explain why a decrease in reserves causes a smaller increase in short-term interest rates in 1990 and, similarly, why a larger increase in reserves is necessary to "hit" the same federal funds rate level.

A second explanation for the divergence between the reserves targeting and interest rate targeting exercises is that the sensitivity of aggregate demand to nominal short-term interest rates in the DRI model appears to have increased in the last ten years. Larger interest rate effects, particularly after several quarters, are consistent with the finding that equilibrium output declines more in the 1990 simulations when policy changes are measured in terms of short-term interest rates.

The short-term interest rate sensitivity of real demand might be greater today than a decade ago for several reasons. Financial deregulation and innovation have increased the number of economic agents directly affected by market interest rate changes and made it much easier for firms and consumers to substitute among different financial assets—both in borrowing and lending. These effects help to explain the stronger term structure relationships and the stronger response of final demand to market interest rates, particularly short-term rates. The tighter links between interest rates and the dollar have probably made net exports more sensitive to interest rates as well.

Although changes in the interest rate sensitivity of both money and final demand are not the only explanations for the results in Table 4, their effects can easily be explained by the textbook Keynesian macroeconomic model, ISLM. Although ISLM is a very simple macro model, the underlying structures of most

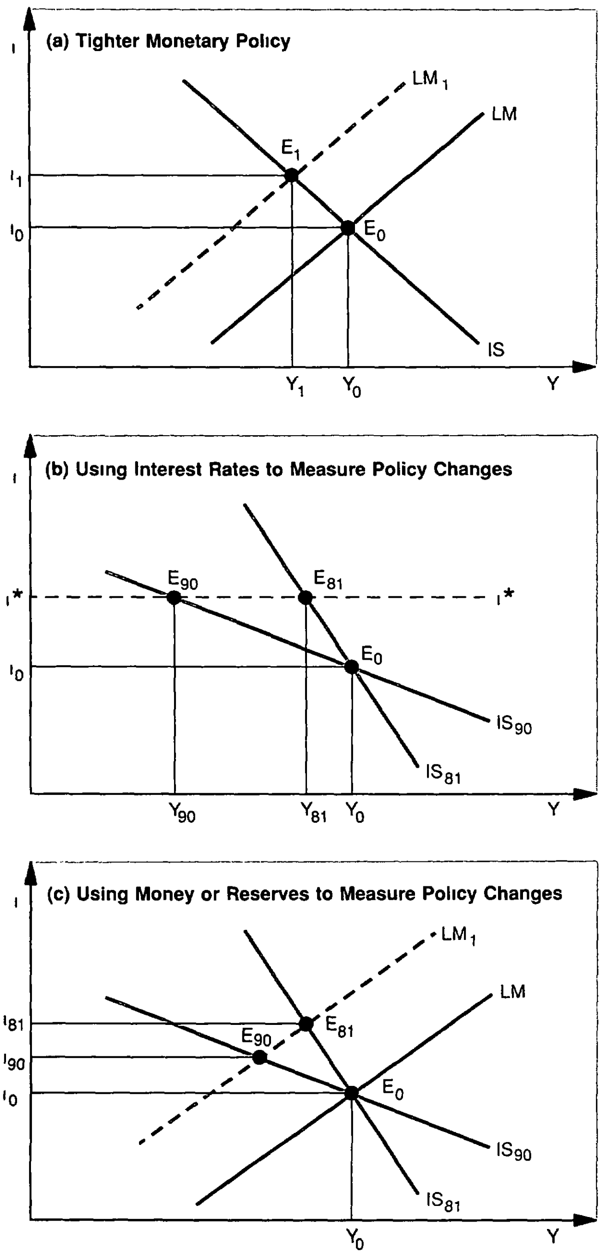
[17]This finding was reached by simulating the 1990 DRI model, targeting first reserves and then the federal funds rate while forcing long-term interest rates to match the paths reported in Eckstein. These model simulations were somewhat unstable, and so are not reported. But output, particularly business investment, was unambiguously higher when the lower long-term rate pattern was used.

[18]In fact, part of the large income effect may reflect the substantial increase in the relative size of the trade sector between 1981 and 1990. The large increase in the import share of GNP means that import income effects will be more important for real output in the 1990 model.

large-scale models derive from it (particularly the money and final demand equations). Consequently, using ISLM to illustrate some of the changes in the large models is not as far-fetched as it might seem

The ISLM model (see diagram) describes combinations of real output (Y) and interest rates (i) that give equilibrium in both the market for money, as embodied in the LM curve, and the market for goods, represented by the IS curve, simultaneously. The IS curve slopes down because increases in interest rates reduce the output of goods, while the LM curve slopes up because higher interest rates require higher output to maintain money market equilibrium. Tighter monetary policy, which decreases the supply of money and raises interest rates (shifting the LM curve up and to the left in panel a), reduces the equilibrium real output level ($Y_0$ to $Y_1$) and raises the equilibrium interest rate ($i_0$ to $i_1$).

**The ISLM Model**




If final demand becomes more interest sensitive, a given increase in interest rates will produce a larger decline in equilibrium output. As a result, the IS curve becomes flatter ($IS_{90}$ in panel b). Thus when tighter monetary policy is measured by interest rate changes (from $i_0$ to $i^*$), a flatter IS curve produces a larger drop in real output ($Y_{90}$ as against $Y_{81}$). This real output result corresponds to the real GNP changes from simulations 1981 and 1990b in Table 4 Similarly, when compared with a steep IS curve, a flat IS curve requires a larger change in the reserves stock to induce a particular change in equilibrium interest rates. Again, this result is consistent with the findings in Table 4

Alternatively, a decrease in the supply of money or reserves, which shifts the LM curve to the left as in panel c, will produce a smaller increase in interest rates when the IS curve is flatter ($i_{90}$ as against $i_{81}$). This is the pattern seen in Table 4 when monetary policy tightness is measured by changes in reserves (simulations 1981 and 1990a) In addition, this effect is reinforced by the increase in interest sensitivity of M1 and reserves demand, suggesting that the LM curve (when defined in terms of M1) has also become flatter in the past decade.[19]

While ISLM analysis can help us to understand some of the changes in monetary policy transmission in the last decade, the model's simple structure cannot address other important changes. These include changes in inflation responses, the term structure of interest rates, and credit rationing.

A change in the inflation response to policy might help explain the smaller short-term interest rate increases in the 1990a simulation If inflation falls more rapidly in response to tight money in 1990, then a smaller jump in short-term rates in 1990 might yield the same real interest rate response as in 1981. If it is real rather than nominal rates that affect final demand, then

[19]In fact, the combination of both a flatter IS curve (more final demand sensitivity to interest rates) and a flatter LM curve (more money demand sensitivity to interest rates) can be used to explain why, when reserves are targeted, changes in equilibrium interest rates are smaller in the 1990 model but changes in real GNP are about the same as in the 1981 model

output responses to monetary policy could be quite similar. Furthermore, matching nominal interest rate paths, as in the 1981 and 1990b simulations, would yield higher real rates in the 1990b simulation and thus lead to larger output declines. Unfortunately, no inflation comparisons are available in the 1981 study, so this hypothesis cannot be checked. The changes reported in Tables 1 and 2 suggest that inflation responses are larger and more rapid in later models, and the DRI specifications of investment, net exports, and consumption do depend on real interest rates. Together these points suggest that larger real interest rate changes in the 1990 model may be one reason for larger output responses.

Tighter links between long-term and short-term interest rates are another change in monetary policy transmission. Large-scale models include a wealth of interest rate detail, with short-term rates closely tied to monetary policy, while long-term rates are modeled (usually) using the term structure. Since final demand components respond to changes in both long and short rates, increased sensitivity of long rates to short rates will change the policy sensitivity of final demand— even if the direct interest elasticities in final demand equations are unchanged.[20]

Finally, one of the most important changes in the monetary policy transmission mechanism has been the weakening of nonprice credit rationing. This development has accompanied the financial deregulation and innovations of the last ten years. Nearly all the studies mentioned above as well as the changes in the DRI equations for investment and housing indicate that the transmission of monetary policy shocks to the real economy through credit constraints has become less important, and in some cases has disappeared entirely, in the last decade. The reduction in credit constraints suggests that monetary policy should have a smaller impact on real output, at least in the very short run. This is precisely what happens in the 1990 simulations in Table 4: real output declines are smaller than those in the 1981 model for the first year of tight money. Thereafter, however, greater sensitivity to nominal interest rates in the 1990 model appears to offset (or more than offset in the 1990b simulation) any reduction of rationing effects.[21]

In summary, policy simulations using DRI's 1990 model show real output, in the medium term, to be substantially more sensitive to monetary policy when nominal short-term rates serve as policy guides but very similar to 1981 model results when reserves are policy targets. A corollary to this conclusion is that movements in nominal short-term rates arising from changes in reserves are smaller and shorter lived than ten years ago. Still, policy lags in the model are longer and output responses to policy are somewhat smaller in the very short run. In addition, the details of final demand sensitivity to policy have changed considerably. Housing (over one year), business investment (from two to four years), and net exports are more sensitive to policy, while consumption is more sensitive to nominal interest rates only in the longer run. Finally, although a simple ISLM model framework incorporating increased interest rate sensitivity of both final demand and bank reserves can account for some of the differences in policy simulations, other factors such as a tighter link between monetary policy and inflation, stronger term structure relationships, and less credit rationing are important as well.

**Conclusions**

This article has explored changes in the sensitivity of the real economy to monetary policy over the last decade in the context of several macroeconometric models. In contrast to the findings of other studies, the bulk of the evidence presented here suggests that the real economy is at least as sensitive to monetary policy today as it was ten to fifteen years ago. In fact, some exercises show that policy has substantially larger effects on output currently. The lags in policy effects, however, are probably longer.

In the most extreme result, money multipliers drawn from published historical simulations are much larger in 1990 than in 1975 for most of the widely used macroeconometric models. The substantial increases in the multipliers suggest major changes in the transmission mechanisms in these large models. Equation specifications from one model (DRI) confirm that innovations in financial regulations and institutions have changed both the transmission mechanisms by which policy affects final demand and the size of policy effects. This finding is particularly clear for the investment and trade sectors.

Finally, the article shows that more detailed estimates of the economy's sensitivity to monetary policy depend crucially on how the policy change is measured:

[20]Similarly, several recent studies (see footnote 1) suggest that the real economy, particularly housing, may be responding more strongly to short-term interest rates in the 1980s but less strongly to long rates. The simulations in Table 4 are consistent with this hypothesis. In the reserves targeting simulation (1990a), short rates rose less while long rates rose more than in the 1981 exercise, but output fell by about the same amount.

[21]In an ISLM framework, credit rationing and disintermediation brought on by tight monetary policy would be reflected in a left shift in the IS curve (in conjunction with the LM curve shift). The decline of credit rationing combined with increased interest rate sensitivity suggests that a flatter IS curve has been substituted for such credit-induced shifts.

*Footnote 21 continued*

through reserves shocks or through interest rate shocks. Simulation exercises comparing the 1981 and 1990 DRI models suggest that tight monetary policy, as measured in reserves growth, has approximately the same effect on output in 1990 as in 1981. Simulations that use interest rates to measure policy tightness require much larger reserves withdrawals and produce much stronger medium- and long-run effects of monetary policy in 1990 than in 1981. These results, interpreted using the simple ISLM model, suggest a flatter IS curve and perhaps a flatter LM curve (defined in terms of M1) currently. The models also highlight other important changes in policy transmission in the last decade, including stronger inflation effects, stronger links between long-term and short-term interest rates, and the removal of credit rationing effects.

**Appendix: The Importance of Initial Conditions**

The simulation results in Tables 4 and 5 measure how changes in the DRI model structure have altered its measurement of monetary policy effectiveness. To isolate the specification changes, the 1981 and 1990 simulations were conducted over identical time periods, but using different DRI model versions (in other words, using different equations). Although this approach captures changes in equation specifications well, it does not necessarily account for all the possible ways that real economy responses to monetary policy within large models have changed.

For example, it is still possible that the economy could respond differently to monetary shocks in 1991 than a decade earlier if initial conditions had changed significantly while the structure of the economy remained unchanged. In the standard ISLM macroeconomic model, initial conditions such as wealth levels, the degree of both private and public debt leverage, regulatory stance, and fiscal and monetary policy structure might affect the link between monetary policy and aggregate output without (drastically) changing the equations that determine the IS and LM curves. Similarly, the underlying core inflation rate and movements in supply-related variables such as relative energy prices are substantially different today than ten years ago. Certainly these factors could influence the dynamic behavior of equilibrium output and prices, and thus alter the impact of monetary policy, without directly changing the structure of consumption functions, investment functions, and so forth.

One way to measure the importance of such initial conditions is to use a single macroeconometric model to conduct simulation experiments before and after the structural changes of the 1980s. Tables A1 and A2 report the results of such an experiment using the 1990 DRI model, with policy shocks introduced in 1979 and 1991.

Simulations in Table A1 involve a 5 percent increase in nonborrowed reserves beginning in the fourth quarter of 1979 (simulation 1979a) and the second quarter of 1991 (1991a). In Table A2, reserves are also augmented, but by an amount sufficient to cut the nominal federal funds rate by 100 basis points (simulations 1979b and 1991b).

Comparisons of the "a" simulations show that when reserves are increased by 5 percent permanently, the short-run responses of output are virtually identical. By contrast, the composition of output, particularly investment, differs somewhat. Residential structures rise more sharply in the historical simulation, but these gains are offset by smaller increases in business fixed investment.

Comparison of the federal funds targeting simulations, 1979b and 1991b, also shows similar short-run paths for real output. Again, larger increases in residential investment and smaller increases for nonresidential investment occur in the earlier period. Although the effects are small, the results support the view that initial conditions such as debt leverage ratios increase business investment sensitivity to policy.

Initial conditions appear to have a very small impact on the short-run multipliers, but more significant differences do appear in the longer run. In the 5 percent reserves simulations ("a" simulations), real output is slightly higher in the 1991 simulation after three years, and after ten years remains ½ percent above the baseline. In contrast, the 1979a simulation has GNP just below baseline levels in the long run. The stronger GNP response in the 1991a simulation occurs in spite of relatively higher paths for nominal and *real* interest rates. Notably, both consumption and business fixed investment, sectors where current debt levels are considered to be extraordinarily high, are more responsive to easy monetary policy in the 1991 simulation than in history.

Differences in current and historical responses to interest rate changes induced by reserve changes are shown in Table A2. For the first two years, the increase in nominal reserves necessary to maintain a federal funds rate cut of 100 basis points is about the same in the two simulations. Thereafter, interest rate targeting in the 1991b simulation requires larger and larger injections, until reserves are 50 percent larger after ten years. This extra liquidity translates into substantially higher paths for all components of real output (and for prices) in the long run. In one sense, then, final demand components behave in a way that is more interest rate sensitive in

## Appendix: The Importance of Initial Conditions *(Continued)*

1991 than in 1979 The ex post *real* fed funds rate, measured as fed funds less actual inflation, is down nearly 140 basis points after four years in both simulations. But after ten years the real rate is down nearly 200 basis points in 1991b as compared with 130 basis points in 1979b. This finding explains some of the extra output gain in the 1991 simulation.

These simulations point to the general conclusion that changes in wealth, debt, and other factors affecting the position of aggregate demand and supply in the last decade have changed the short-run impacts of monetary policy very little Long-run responses to persistently loose money, however, are quite different now than in the late 1970s.

Table A1

### Monetary Policy Easing
### The Effects of a 5 Percent Increase in Reserves: A Comparison of Simulations of the 1990 DRI Model

Percent Deviation from Base Case

| | Quarters after Shock | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 4 | 8 | 12 | 16 | 40 |
| **1979a** | | | | | | |
| Nonborrowed reserves | 5 0 | 5 0 | 5 0 | 5 0 | 5 0 | 5 0 |
| Federal funds rate | -2 53 | -2 90 | -1 48 | -0 45 | -0 25 | -0 21 |
| Cost of debt | -0 75 | -1 01 | -0 72 | -0 28 | -0 14 | -0 22 |
| Cost of equity | -0 34 | -1 02 | -0 65 | 0 10 | 0 53 | 0 21 |
| Inflation | 0 0 | 0 3 | 0 8 | 0 8 | 0 8 | 0 0 |
| Price level | 0 0 | 0 1 | 0 7 | 1 6 | 2 4 | 3 8 |
| Real GNP | 0 1 | 2 2 | 3 4 | 2 1 | 0 8 | -0 1 |
| Consumption | 0 0 | 1 1 | 1 9 | 1 2 | 0 4 | -0 5 |
| Residential construction | 1 9 | 23 8 | 27 3 | 6 2 | -4 2 | 0 4 |
| Business fixed investment | 0 0 | 2 6 | 7 9 | 8 9 | 4 0 | 1 6 |
| Net exports | -37 9 | -14 0 | -7 4 | 9 0 | 54 0 | † |
| **1991a** | | | | | | |
| Nonborrowed reserves | 5 0 | 5 0 | 5 0 | 5 0 | 5 0 | 5 0 |
| Federal funds rate | -2 37 | -3 11 | -1 30 | -0 06 | 0 17 | 0 37 |
| Cost of debt | -0 81 | -1 27 | -0 79 | -0 19 | -0 05 | 0 00 |
| Cost of equity | -0 18 | -0 75 | -0 56 | 0 09 | 0 55 | 0 31 |
| Inflation | 0 0 | 0 3 | 0 8 | 0 8 | 0 7 | 0 2 |
| Price level | 0 0 | 0 1 | 0 7 | 1 5 | 2 2 | 4 4 |
| Real GNP | 0 1 | 2 2 | 3 7 | 2 3 | 1 4 | 0 5 |
| Consumption | 0 0 | 1 3 | 1 9 | 1 1 | 0 4 | -0 3 |
| Residential construction | 1 4 | 14 9 | 13 8 | 1 2 | -3 4 | -0 8 |
| Business fixed investment | 0 0 | 3 8 | 10 4 | 7 9 | 3 1 | 2 1 |
| Net exports | -5 5 | -13 6 | -7 2 | 29 6 | 70 6 | 84 7 |

Notes Nominal nonborrowed reserves were increased by 5 0 percent permanently Changes in the federal funds rate and costs of debt and equity are stated in percentage points Corporate costs of debt and equity are after tax The debt cost is the after-tax, new-issue, high-grade corporate bond yield The equity cost is an expected-inflation-adjusted ratio of dividends to stock prices for the Standard & Poor's 500 The change in net exports is expressed as a percentage of the change in real GNP that quarter

†The change in real output was virtually zero

## Appendix: The Importance of Initial Conditions *(Continued)*

Table A2

### Monetary Policy Easing
### The Effects of Lowering the Federal Funds Rate: Comparison of Simulations of the 1990 DRI Model

Percent Deviation from Base Case

| | Quarters after Shock | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 4 | 8 | 12 | 16 | 40 |
| **1979b** | | | | | | |
| Nonborrowed reserves | 1 9 | 1 4 | 2 2 | 3 1 | 3 7 | 6 5 |
| Federal funds rate | −1 00 | −1 00 | −1 00 | −1 00 | −1 00 | −1 00 |
| Cost of debt | −0 30 | −0 34 | −0 39 | −0 38 | −0 38 | −0 54 |
| Cost of equity | −0 14 | −0 34 | −0 38 | −0 35 | −0 08 | 0 23 |
| Inflation | 0 0 | 0 1 | 0 3 | 0 4 | 0 4 | 0 3 |
| Price level | 0 0 | 0 0 | 0 2 | 0 5 | 0 9 | 3 2 |
| Real GNP | 0 0 | 0 7 | 1 2 | 1 3 | 1 2 | 0 8 |
| Consumption | 0 0 | 0 3 | 0 7 | 0 7 | 0 6 | 0 1 |
| Residential construction | 0 8 | 7 2 | 9 8 | 9 9 | 4 5 | 2 8 |
| Business fixed investment | 0 0 | 0 8 | 2 5 | 4 0 | 3 8 | 3 5 |
| Net exports | −33 1 | −13 9 | −21 2 | −3 2 | 1 9 | 23 4 |
| **1991b** | | | | | | |
| Nonborrowed reserves | 2 1 | 1 3 | 2 3 | 3 3 | 4 1 | 9 9 |
| Federal funds rate | −1 00 | −1 00 | −1 00 | −1 00 | −1 00 | −1 00 |
| Cost of debt | −0 34 | −0 41 | −0 46 | −0 47 | −0 49 | −0 59 |
| Cost of equity | −0 08 | −0 25 | −0 28 | −0 23 | −0 13 | 0 40 |
| Inflation | 0 0 | 0 1 | 0 2 | 0 3 | 0 4 | 0 9 |
| Price level | 0 0 | 0 0 | 0 2 | 0 5 | 0 9 | 4 7 |
| Real GNP | 0 0 | 0 7 | 1 3 | 1 5 | 1 7 | 2 7 |
| Consumption | 0 0 | 0 4 | 0 7 | 0 8 | 0 8 | 1 0 |
| Residential construction | 0 6 | 4 6 | 5 8 | 4 8 | 4 2 | 3 7 |
| Business fixed investment | 0 0 | 1 2 | 3 3 | 4 0 | 4 2 | 6 3 |
| Net exports | 0 9 | −14 3 | −6 8 | 7 1 | 15.8 | 30 1 |

Notes Nonborrowed reserves were adjusted by the amount necessary to achieve a 1 percentage point drop in the federal funds rate The federal funds rate and costs of debt and equity are reported as changes in percentage points Corporate costs of debt and equity are after tax The debt cost is the after-tax, new-issue, high-grade corporate bond yield The equity cost is an expected-inflation-adjusted ratio of dividends to stock prices for the Standard & Poor's 500 The change in net exports is expressed as a percentage of the change in real GNP in that quarter