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# The Disposition of Failed Japanese Bank Assets: Lessons from the U.S. Savings and Loan Crisis\*

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This paper reviews the Japanese experience with “put guarantees” recently offered in the sale of several failed banks. These guarantees, meant to address information asymmetry problems, are shown to create moral hazard problems of their own. In particular, the guarantees make acquiring banks reluctant to accept first-best renegotiations with problem borrowers. These issues also arose in the U.S. savings and loan crisis. Regulators in that crisis turned to an alternative guarantee mechanism known as “loss-sharing arrangements” with apparently positive results. I introduce a formal debt model to examine the conditions determining the relative merits of these guarantees. The results show that both forms of guarantees reduce expected regulator revenues and that the impact of economic downturns on the relative desirability of the two guarantees is ambiguous.

## 1. Introduction

The Japanese government closed the failed Long-Term Credit Bank (LTCB) and Nippon Credit Bank (NCB) in 1998. These failures occurred during a turbulent period in Japan, and there was a strong desire to dispose of the assets of these banks quickly to avoid the possibility of further regulatory losses. In both cases the Financial Reconstruction Commission (FRC) invited bidders for these banks under the condition that sale was to take place too quickly for standard due diligence investigations concerning the underlying value of the failed banks’ assets.

LTCB was sold to an American investment group, Ripplewood Holdings. Because of the inability to conduct due diligence investigations, Ripplewood demanded that the Japanese government include put guarantees on the assets of the failed bank, allowing the purchaser to return the assets to the government for liquidation if their value fell sufficiently low. Such guarantees had been used in the United States in the savings and loan (S&L) crisis in the late 1980s and early 1990s (Rosengren and Simons 1992, 1994).<sup>1</sup>

Japanese regulators quickly discovered that these guarantees influenced the acquiring bank’s management of the failed bank’s loans. In particular, the acquiring banks demonstrated a reluctance to grant major concessions to avoid the liquidation of problem loans. This reluctance appears to have been motivated at least in part by the compensation from the put guarantees under liquidation.

In this paper, I review the circumstances surrounding the sale of LTCB and NCB and the subsequent behavior of their acquirers. I then review the U.S. experience with put guarantee sales in the S&L crisis. I argue that the difficulties experienced by the Japanese with the acquirers of LTCB and NCB matched those of the United States 10 years earlier. During this crisis, the Federal Deposit Insurance Corporation (FDIC) and the Resolution Trust Corporation (RTC) offered put guarantees similar to those offered by the Japanese regulatory agencies in the LTCB and NCB transactions.

The U.S. regulatory agencies also noted difficulties with put guarantee transactions. First, acquiring banks responded to the guarantees by what was referred to as “cherry-picking,” retaining only assets with market values that exceeded their book values and returning the rest to the

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1. In the absence of any guarantees, it would be expected that information asymmetry problems, discussed in more detail below, would deteri-

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orate the terms of sale. Indeed, the preponderance of empirical evidence suggests that the bids in these transactions are low, in the sense that winning bidders in failed bank auctions experience positive abnormal returns (James and Wier 1987, Balbirer, et al. 1992, Gupta, et al. 1993). However, Gupta, et al. (1997) and Stover (1997) fail to find statistically significant abnormal returns for acquiring banks.

FDIC. Second, the acquiring banks appeared not to put the usual level of effort into monitoring and administering loans covered by the put guarantees (Bean, et al. 1998).

Put guarantees were abandoned in 1991; afterward, the FDIC implemented loss-sharing arrangements in selected purchase and assumption (P&A) transactions. Under these arrangements, the FDIC agreed to absorb a portion of the losses on covered assets, typically 80 percent, and the acquiring bank was responsible for the remaining losses. These arrangements were implemented in 16 agreements involving 24 failed banks between 1991 and 1993. As loss-sharing arrangements typically were involved in the failures of larger banks, these agreements involved 40 percent of the total failed bank assets resolved over this period (Gallagher and Armstrong 1998).

As I demonstrate below, it appears that the U.S. experience with loss-sharing arrangements was positive. In particular, loss-sharing arrangements appeared to reduce the regulatory burden of the resolution of bank failures in the S&L crisis, even after adjusting for bank size. It appears likely that the Japanese government also could benefit from implementing loss-sharing arrangements in resolving its bank failures.

To evaluate the advantages of loss-sharing arrangements over put guarantees and the conditions that influence their relative advantages, I introduce a model of the disposition of failed bank assets. The model is a simplification of that in Spiegel (2001). There is a regulatory agency who auctions off the assets of a failed bank to a set of competitive potential acquiring banks. The regulator is assumed to lack credibility in his designation of asset quality and instead extends either put guarantees or loss-sharing arrangements to insure the representative acquiring bank against loss.<sup>2</sup>

As in Hart and Moore (1998), it is assumed that the acquiring bank can profitably renegotiate with a problem debtor, while the regulatory authority cannot. This implies that there are assets which are more valuable inside the banking system than they would be to a nonbank such as the regulatory authority. Under this assumption, liquidating certain assets prior to sale is likely to be costly. Evidence in favor of this assumption is provided by James (1991), who argues that even after controlling for asset quality, the value of assets is higher in the banking system than under the receivership of the regulatory authority. This loss of value is also known in regulatory circles, and is commonly referred to as the “liquidation differential” (Carns and

Nejezchleb 1992). This condition implies that the exercise of a put guarantee in this environment is costly because it takes these assets out of the banking sector and thereby reduces their value.

In this simple model where the extension of such guarantees fails to influence regulator credibility and all agents are risk-neutral, the results demonstrate that both put guarantees and loss-sharing arrangements reduce the expected revenues to the regulatory authority. In the case of the put guarantees, the loss is directly attributable to the dead-weight loss associated with the probability-weighted retirement of assets for liquidation that would be more valuable under renegotiation in the banking sector. In the case of the loss-sharing arrangement, the loss stems from the higher administrative costs associated with maintaining this arrangement.<sup>3</sup>

I also examine how changes in underlying economic conditions may influence the relative desirability of put guarantees and loss-sharing arrangements. Below, I derive an expression for the difference in administrative costs that leaves the regulatory authority indifferent between offering the put guarantee and the loss-sharing arrangement. I then conduct comparative static exercises on this difference with respect to parameters that are likely to change as economic conditions worsen.

One might expect that the loss-sharing arrangement would become more attractive as economic conditions worsen. The reasoning would be that as conditions worsen, the losses associated with unnecessary liquidation would increase, making the put guarantees relatively more costly to the regulator. Below I demonstrate that this is the case. However, it also is likely that the share of loans that should be liquidated would increase in an economic downturn. This effect favors put guarantees over the loss-sharing arrangements. Below, I demonstrate that this is also the case, leaving an ambiguous net impact of economic downturns on the relative desirability of loss-sharing arrangements to put guarantees.

The remainder of this paper is divided into five sections. Section 2 reviews Japan’s experience with the disposition of the assets of LTCB and NCB. Section 3 reviews the United States’ historical experiences during the S&L crisis, including its experiences with put guarantees and its eventual turn to loss-sharing arrangements. Section 4 introduces a formal model of the determinants of the relative desirability of put guarantees and loss-sharing arrange-

2. Spiegel (2001) allows regulator credibility to vary with an exogenous penalty function that measures the reputation cost of designating assets improperly. Under this more general model, designations by the regulator may or may not be credible. Moreover, the credibility of the regulator can be influenced by the extension of put guarantees and loss-sharing arrangements.

3. In a richer model where the credibility of the regulator is in question, such as Spiegel (2001), either of these guarantees can potentially increase expected regulatory authority revenues if the extension of such guarantees moves the regulator from lacking credibility to enjoying credibility.

ments in the disposition of failed bank assets. Section 5 concludes.

## 2. The Disposition of Assets Held by Long-Term Credit Bank and Nippon Credit Bank

### 2.1. Long-Term Credit Bank

LTCB was declared insolvent and closed in 1998. According to common practice, the FRC evaluated the assets to determine their suitability for sale to an acquiring bank. Loans were given five grades: 1–Normal, 2–Needs attention, 3–In danger of bankruptcy, 4–Effectively bankrupt, and 5–Bankrupt. (See Table 1 for details.) Loans in category 1 were automatically classified as suitable for sale, while loans in categories 3, 4, and 5 were automatically classified as not suitable for sale. Those loans were absorbed by the Deposit Insurance Corporation (DIC) for liquidation.

The marginal loans from the viewpoint of assessing suitability for sale were then those in category 2. Loans in category 2 were considered unsuitable for sale if the borrower's capital account was negative (i.e., its assets fell short of its liabilities) or if its carried-forward earnings were negative. However, there was a provision that the latter criterion could be waived if the borrower had an acceptable plan for financial recovery within two years.

LTCB's total assets in book value at the time of sale equaled ¥24.6 trillion. Of these, ¥19.4 trillion initially were classified as suitable and included in the sale. The initial

government outlays in assisting the resolution of LTCB amounted to ¥6.4 trillion (see Table 2).<sup>4</sup>

It has since become clear that the government overstated the share of suitable assets on LTCB's balance sheet. Recently released minutes of 1998 FRC meetings reveal that the FRC deviated from the formal criteria described above in assessing assets. For example, officials considered potential support from main banks or the local government in assessing a loan's risk of failure, although such considerations were not in the formal rules. Moreover, much of the anticipated support did not materialize.

There were a number of potential acquiring banks bidding for the rights to LTCB. These included a foreign group, headed by the Ripplewood Holdings Corporation of the United States. This group was formally referred to in the proceedings as the United States Investment Group (USIG).

The USIG bid was higher than those of the domestic groups, but the group demanded that the government back LTCB's assets with a put guarantee. As such guarantees were commonly extended in the sale of failed bank assets in the United States, USIG claimed that it would be "common sense" to include such guarantees in the transaction. At that time, however, there was no formal mandate for the FRC to include such provisions in the sale of failed Japanese bank assets. However, ex ante estimates suggested that the regulatory losses from selling the bank to USIG with the put guarantees would be significantly less than those that would be incurred by selling to the highest-bidding Japanese group with the required write-offs.

TABLE 1  
BORROWER CLASSIFICATION GUIDELINES  
FOR THE JAPANESE GOVERNMENT

1. Normal	Strong results and no particular problems with its financial position.
2. Needs attention	Problems with lending conditions and fulfillment, has poor results or is unstable, has problems with its financial position, or otherwise requires special attention and management.
3. In danger of bankruptcy	Not bankrupt now, but is facing business difficulties and has failed to make adequate progress on its business improvement plan, etc., so that there is a large possibility it will fall into bankruptcy in the future.
4. Effectively bankrupt	Not yet legally and formally bankrupt, but is in serious business difficulties from which it is considered impossible to rebuild.
5. Bankrupt	Legally and formally bankrupt.

Source: Deposit Insurance Corporation.

TABLE 2  
INITIAL RESOLUTION COSTS OF LTCB AND NCB FAILURES<sup>a</sup>  
(¥ BILLIONS)

	LTCB	NCB
Initial Grants <sup>b</sup>	3,235	3,141
Compensation for Losses after Failure <sup>c</sup>	355	95
Asset Purchases by the DIC	305	319
Equity Purchases by the DIC	2,276	650
Underwriting of Preferred Stock	240	260
Total Initial Outlays	6,411	4,465

<sup>a</sup>Figures represent initial outlays. Actual resolution costs will be mitigated by recoveries on purchased assets and equities.

<sup>b</sup>Refers to government contributions at the time of the bank failure.

<sup>c</sup>Refers to government contributions while the bank was under public management.

Source: Financial Reconstruction Commission.

4. Actual losses would fall below this figure. Losses would be mitigated by returns on purchased assets and equity as well as the lack of losses in preferred stock underwriting.



Consequently, the FRC decided to sell to USIG, inclusive of the put guarantees. It stressed the minimization of the “public burden” as its motivation for choosing USIG.

The put guarantee allowed the “new LTCB,” as it was originally known, to cancel a portion of the sale if an individual loan was found to be defective and if its book value fell 20 percent or more. A loan was considered defective if the “basis for judgment” used in classifying the asset as suitable for sale turned out to have initially been mistaken or to have subsequently become untrue.

The details of the put guarantee offered to the new LTCB were as follows: Loans whose sale were canceled were returned to the DIC. The DIC was required to reimburse the new LTCB the value of the loan minus its initial loan loss reserves (also minus any repayments that had taken place). The provision lasts for three years, expiring in March 2003. The guarantee was limited to loans exceeding ¥100 million. However, all assets exceeding this value were fully covered. The guarantee required the new LTCB to inform the DIC of its claims on a quarterly basis. Finally, the guarantee provided some protection to the DIC against systemic losses: Losses that could be attributed to a “major event,” such as a deep recession, were not to be covered fully by the DIC. Instead, the parties were to negotiate in good faith over the extent to which a loan becoming defective was attributable to this major event.

There were three major channels through which a loan could be classified as defective: first, if its borrowing firm was more than 30 percent below the target of its financial recovery plan; second, if strong financial support from the borrowing firm’s parent company, anticipated in classifying a loan as appropriate, did not materialize; third, if the borrower was more than three months delinquent, if the borrower went bankrupt, or if the borrower requested a renegotiation of his credit terms. The bulk of reclassifications was done under the first channel.

The criterion of a 20 percent loss in book value was calculated as follows: The initial value of a loan was equal to its book value minus its loan loss reserves. For example, suppose that a loan carried initial loan loss reserves equal to 10 percent of its book value and collateral equal to 70 percent of its book value. Because of its loan loss reserves, its initial value would be calculated as 90 percent of book value, including 70 percent collateral and 20 percent own risk.

Now suppose that the debtor went bankrupt. In that case, the loan’s own-risk value would be reduced to zero and the loan’s present value would be reduced to its collateral value, or 70 percent of book value. The decrease in loan value,  $\Phi$ , then would be calculated as the percentage change in initial value

$$\Phi = \frac{\text{initial value} - \text{present value}}{\text{initial value}}.$$

In this example, the decrease ratio would satisfy

$$\begin{aligned}\Phi &= \frac{0.90 - 0.70}{0.90} \\ &= 0.22.\end{aligned}$$

As 22 percent exceeds 20 percent, the loan in this example would be a candidate for sale cancellation if the acquirer could demonstrate that the loan was defective.

In June 2000, the new LTCB was launched as Shinsei Bank. Almost since its inception, Shinsei Bank has been a controversial figure in Japanese financial markets. The company has been actively introducing Western business practices, including Western management techniques and the promotion of women employees in management positions. The most controversial aspect of Shinsei’s behavior is its relative unwillingness to roll over loans of problem debtors. The contract Shinsei signed with the Japanese government was interpreted widely as suggesting that the bank would be expected to pursue standard Japanese banking practices. In particular, the contract agreed that Shinsei would “respond to funds demand, including rollover and seasonal funds, for three years.” However, the contract also contained a loophole which stated that Shinsei Bank could deny rollovers if there were reasonable expectations of losses.

In what was widely considered a departure from standard Japanese banking practices, Shinsei has been aggressive in demanding restructuring plans from problem debtors and has indicated that it would not shy away from collateral seizure in the event of default. By September 2001, it was revealed that ¥558 billion in loans had been returned by Shinsei to the DIC, at an initial outlay to the government of ¥312 billion (*Nihon Keizai Shimbun* 2001).<sup>5</sup>

Two of Shinsei’s most controversial decisions were its denial of the request for debt forgiveness by Sogo Department store and its takeover of the failed consumer credit company, Life Co. Sogo’s plan to avoid liquidation in July 2000 included \$5.96 billion in debt forgiveness by 72 banks, including Sogo’s main bank, Industrial Bank of Japan (IBJ). In addition, IBJ agreed to provide Sogo with \$272 million in new lending. Shinsei Bank disapproved of the debt forgiveness plan and instead requested that the DIC take over its assets. The DIC eventually agreed to repurchase Sogo’s debts at 80 cents on the dollar (Stover 2000).

5. This outlay represents the DIC’s purchase price. The ultimate cost of the guarantee will be reduced by the recovery on the repurchased loans.

Shinsei had been Life Co.'s main bank, and would have been expected to provide it with financial assistance under standard Japanese practices. However, Shinsei refused to provide additional assistance to Life, to the disappointment of other creditors who had extended funds to the firm. Many speculated that Shinsei's desire to take over Life was motivated by the potential positive impact the takeover might have on Shinsei's credit card business (*Nikkei Weekly* 2000).

The put guarantees included in LTCB's takeover contract clearly played a role in Shinsei's unwillingness to roll over the debt of existing problem debtors such as Life Co. Shinsei announced that it would return all ¥120 billion of Life Co.'s debt to the DIC, rather than reschedule it. However, the DIC refused Shinsei's request to repurchase the bad loans owed by Life Co., and the loans remained on Shinsei's books. The DIC defended its decision on the basis that Life had been servicing more than 50 percent of its debts, a figure far higher than that paid by other failed firms whose assets were covered, such as Sogo.

## 2.2. Nippon Credit Bank

The terms of the sale of Nippon Credit Bank (NCB) were similar to those of LTCB. In November 1999, the FRC received initial proposals from a number of competing groups. The FRC held nine meetings over the next three months, after which two groups, Softbank Group, a Japanese group, and the group known as the U.S. Investment Fund were invited to give second bids.<sup>6</sup> These finalists were instructed to give more details about their proposals for NCB's recovery plan. They also were informed that all of their initial bids were insufficient. Because of the precedent set by the LTCB sale, it was assumed by all parties throughout the process that the ultimate deal would include a put guarantee.

In February 2000, the FRC chose Softbank Group as the priority party for negotiation. The transaction was delayed by controversy over the put guarantee in the agreement, partly because of the adverse experiences the government had with the LTCB transaction. Nevertheless, the put guarantee remained intact.

Time constraints limited Softbank's ability to perform due diligence inquiries. The FRC placed a premium on completing the sale of NCB as quickly as possible after completing its assessment of NCB's assets to prevent the deterioration of its assets and to minimize the taxpayer burden. Because of the short due diligence period, Softbank

was effectively limited to conducting interviews concerning asset quality.

Relative to the LTCB decision described above, the decision criteria used in choosing Softbank appears to have given less weight to the consideration of mitigating taxpayer burden. The FRC gave five reasons for choosing Softbank: (1) the Group had a strong small-business customer base and ties with regional financial institutions; (2) the Group would actively support new financing techniques for venture companies; (3) the Group would use new technologies, including Internet transactions; (4) the acquiring Group was led by financially strong companies; and (5) the terms of the purchase satisfied the basic concept of "minimizing public burden."

NCB was sold to Softbank on September 1, 2000, for ¥101 billion. At the time of sale, NCB had assets totaling ¥11.4 trillion in book value. The FRC designated ¥6.6 trillion of these assets as suitable for sale to Softbank. Initial outlays of government assistance for the resolution of NCB amounted to over ¥3.8 trillion (see Table 2).

The bank was renamed Aozora Bank in January 2001. After the fact, it was revealed that over a fourth of the assets designated as suitable for sale by the FRC were actually problem loans. Again, the FRC revealed that its designation was based on "other factors," such as potential main bank support, which were outside the formal terms of its initial memorandum of understanding. While the FRC appears to have followed the letter of its memorandum of understanding with Softbank in its designation of assets, it is clear that the regulatory agency used some of the discretion allowed in the memorandum to improperly designate asset performance. In particular, the FRC factored in non-standard considerations, such as potential support for problem borrowers from other lenders. It also exhibited a reluctance to liquidate loans from firms in sensitive industries (*Shukan Bunshun* 2000a, b).

As a result, Aozora found itself immediately facing bad loan problems. Roughly 32 percent of its loans were to the troubled real estate sector, while an additional 6 percent were to construction firms. It was generally agreed that NCB's balance sheet was weaker than that of Shinsei at the time of its launch. The bank's first president, Tadayo Honma, committed suicide on September 20, 2000, reportedly in part because of NCB's formidable bad loan difficulties.

In general, Aozora Bank has not appeared to be as aggressive as Shinsei in refusing to roll over problem loans and in returning assets to the DIC. Nevertheless, by September 2001, Aozora Bank had returned ¥42.8 billion in loans to the DIC at a cost to the government of ¥23.9 billion (*Nihon Keizai Shimbun* 2001).

6. Softbank Group included Orix Corporation and Tokyo Marine and Fire Insurance Company.

### 2.3. Summary

The Japanese experiences with the sale of LTCB and NCB reveal both the motivation for guarantees and the problems the extension of those guarantees create: because of its reluctance to foreclose on problem borrowers, the FRC systematically overstated the quality of assets it sold to acquiring banks (*Shukan Bunshun* 2000a, b). This resulted in an asymmetric information problem between the seller and its potential buyers, which was addressed through the extension of a put guarantee. However, the put guarantee created problems of its own. In particular, it gave the acquiring banks the incentive to deviate from what was commonly considered standard banking practices to maximize the benefits of the guarantees that had been extended.

### 3. The Disposition of Assets during the U.S. Savings and Loan Crisis

As discussed above, the Ripplewood Group that won the bid for LTCB demanded the inclusion of put guarantees in its sale because such guarantees had been commonly used in the disposition of failed bank assets in Western transactions. In this section, I review the U.S. experience with such guarantees during its financial crisis in the 1980s and early 1990s.

Between 1980 and 1994, 1,617 banks with \$302.6 billion in assets were closed or received assistance from the FDIC. At the same time, 1,295 S&Ls, carrying \$621 billion in assets were closed by the Federal Savings and Loan Insurance Corporation (FSLIC) or RTC, or received assistance from the FSLIC. These accounted for roughly one out of every six federally insured financial institutions and 20.5 percent of these institutions' assets. During the height of the crisis period, 1988–1992, an average of one bank or S&L was closed every day (Bean, et al. 1998).

The method of asset disposition used by the FDIC changed over time. In the 1970s and early 1980s, the FDIC typically was more concerned about the health of the newly created bank than about the sale of the assets of the failed bank. It typically only included cash and cash equivalents in P&A transactions.<sup>7</sup> Under these transactions, due diligence was not required. Indeed, due diligence often was avoided to maintain secrecy about impending bank closures to avoid instigating runs (Bean, et al. 1998). However, as the number of failures grew in the 1980s, limiting sales to cash and cash equivalents quickly left the FDIC with unmanageable levels of asset holdings. In response, the FDIC began using put guarantees to facili-

tate the sale of all assets of a failed bank to a healthy acquiring bank. Under these agreements, the acquiring bank was allowed to return any assets it did not desire to the FDIC for reimbursement for a limited period of time after acquisition.

The RTC was established in 1989, immediately assuming responsibility for 262 banks in conservatorship with assets of \$115 billion. Because of the large numbers of bank failures during its operation, as well as chronic funding difficulties, the emphasis in the RTC was on quick disposal of assets. These initially were done in standard P&A transactions, but the RTC quickly began selling the assets of failed banks separately from their deposit franchises. Of the 747 failed institutions resolved by the RTC, 497 institutions were handled through P&A transactions. These institutions represented 73 percent of the value of the failed institution assets handled by the RTC.

The RTC also used put guarantees during its first year. However, it quickly became clear that an undesirably large portion of assets was being returned. Over half of the \$40 billion in assets that were sold by the RTC subject to put options were returned to the regulatory authority. It also was clear that the acquiring banks were “cherry-picking,” choosing only assets with market values above book values and returning other assets. Moreover, there was some perception that acquiring banks tended to neglect assets during the period in which they were covered by the put option, implying that the guarantee led to moral hazard in the form of suboptimal monitoring activity. The put option structure was discontinued in 1991.

In 1991, the FDIC turned to loss-sharing transactions to sell the problem assets of large bank failures at superior terms. These arrangements were offered on failed banks' commercial loans and commercial real estate loans, but not on family mortgage and consumer loans.

The typical terms of the loss-sharing arrangement were that purchasers had a set period of time, typically three to five years, to return assets to the FDIC in return for 80 percent of net charge-offs plus reimbursable expenses. There was a “shared recovery period,” during which the acquiring bank paid the FDIC 80 percent of any recoveries on loss-share assets previously experiencing a loss. This period ran concurrently with the loss-sharing period and lasted one to three years beyond the expiration of the loss-sharing period. The remaining 20 percent of losses were assumed by the acquiring bank.

The agreement also guarded acquiring banks against large downside losses. At the time of sale, the FDIC projected a “transition amount” of ultimate losses the acquired assets should face. Losses exceeding this transition amount were covered at a 95 percent rate by the FDIC.

7. Cash equivalents included widely quoted assets, such as the bank's securities holdings, and were transacted at quoted prices.



TABLE 3  
FDIC LOSS-SHARING TRANSACTIONS, 1991–1993  
(\$ MILLIONS)

Transaction Date	Failed Bank	Total Assets	Resolution Costs	% of Total Assets
09/19/91	Southeast Bank, N.A. <sup>a</sup>	\$10,478	\$ 0	0.00
10/10/91	New Dartmouth Bank	2,268	571	25.19
10/10/91	First New Hampshire	2,109	319	15.14
11/14/91	Connecticut Savings Bank	1,047	207	19.77
08/21/92	Attleboro Pawtucket Savings Bank	595	32	5.41
10/02/92	First Constitution Bank	1,580	127	8.01
10/02/92	The Howard Savings Bank	3,258	87	2.67
12/04/92	Heritage Bank for Savings	1,272	21	1.70
12/11/92	Eastland Savings Bank <sup>b</sup>	545	17	3.30
12/11/92	Meritor Savings Bank	3,579	0	0.00
02/13/93	First City, TX-Austin, N.A.	347	0	0.00
02/13/93	First City, TX-Dallas	1,325	0	0.00
02/13/93	First City, TX-Houston, N.A.	3,576	0	0.00
04/23/93	Missouri Bridge Bank, N.A.	1,911	356	18.62
06/04/93	First National Bank of Vermont	225	34	14.97
08/12/93	CrossLand Savings, FSB	7,269	740	10.18
Total		\$41,384	\$2,511	6.07

<sup>a</sup>Represents loss-sharing agreements for two banks: Southeast Bank, N.A., and Southeast Bank of West Florida.

<sup>b</sup>Represents loss-sharing agreements for two banks: Eastland Savings Bank and Eastland Bank.

Source: FDIC (1998).

There were a number of perceived benefits of the loss-sharing arrangement relative to the put guarantee framework. First, the arrangement facilitated the fast sale of as many assets as possible to the acquiring bank. In particular, like the put guarantee, the loss-sharing arrangement mitigated the information difficulties that arose from the need to dispose of assets quickly. The assets under the loss-sharing arrangement also were sold too quickly for the acquiring banks to conduct standard due diligence inspections.

Second, it was perceived that the loss-sharing arrangement resulted in nonperforming assets being managed in a way that aligned the interests of the FDIC and the acquiring bank, as each held a partial equity stake in the underlying assets. Since banks did not need to liquidate their claims on borrowers to activate their guarantees from the FDIC, the guarantees did not encourage the early liquidation of loans. To the extent that bank loans could be more profitable under a renegotiated settlement, the equity stake held by the acquiring bank in the outstanding loan gave the bank an incentive to undertake such renegotiation. This reduced the need for the FDIC to oversee the acquiring bank.

The FDIC entered into 16 loss-sharing agreements to resolve 24 bank failures between 1991 and 1993 (see Table 3). These included many of the largest bank failures of the period, as loss-sharing arrangements were offered only if the pool of eligible assets exceeded \$100 million.

However, as most large failures were covered, the arrangements were offered on a substantial share of disposed assets: while only 10 percent of banks that failed over this period had loss-sharing agreements, these agreements covered 40 percent of total failed bank assets.

The FDIC generally characterizes the loss-sharing experience as successful, and the method still is used today in the resolution of large failed bank assets.<sup>8</sup> Loss-sharing arrangements are perceived to satisfy the criterion of minimizing the taxpayer burden in the resolution of failed bank assets. For example, there were 175 P&A transactions in 1991 and 1992 involving \$62.1 billion worth of bank assets. These failures were resolved at a cost of \$6.5 billion, or 10.4 percent of asset value. In contrast, the 24 loss-sharing banks had assets worth \$41.4 billion and were resolved at a cost of \$2.5 billion, or 6.1 percent of asset value (Gallagher and Armstrong 1998).

As loss-sharing arrangements were limited to the largest bank failures, it is likely that some of the discrepancy in costs can be explained by economies of scale in the resolution of failed bank assets. As shown in Table 4, the average resolution cost as a percentage of failed assets with or without the use of loss-sharing arrangements is greater for

8. For example, a loss-sharing arrangement was used in the resolution of Mutual Federal Savings Bank of Atlanta in 2000.

TABLE 4  
FDIC'S RESOLUTION COSTS AS PERCENTAGE OF ASSETS  
1991–1992

	Average Cost of Resolution (%)	Median Cost of Resolution (%)
Failed Banks with Total Assets over \$500 million		
With Loss-Sharing	5.38	7.77
Without Loss-Sharing	8.66	12.21
Failed Banks with Total Assets under \$500 million		
With Loss-Sharing	9.55	6.06
Without Loss-Sharing	15.82	17.10

Source: FDIC (1998).

failed banks with less than \$500 million in assets. Nevertheless, Table 4 also clearly demonstrates that loss-sharing arrangements were associated with reduced resolution costs for banks with both more and less than \$500 million in assets.

The limited number of loss-sharing arrangements suggests that there must be disadvantages to the resolution method as well. First, it is well-documented that these arrangements are administratively costly to implement, particularly for small bank failures (Gallagher and Armstrong 1998). Second, there is also a perception that some potential acquiring banks do not want to be involved in loss-sharing arrangements. There is a fear that these banks will refrain from bidding on failures that contain such arrangements and reduce the proceeds from their asset sales.

Nevertheless, the successful experience of U.S. banks during the S&L crisis, as well as the continued use of loss-sharing arrangements today, suggests that they are perceived in practice to be a desirable form of asset disposition, particularly for larger bank failures. In the following section, I introduce a model of asset disposition and formally investigate the conditions under which a loss-sharing arrangement may dominate a put guarantee as a resolution method.

#### 4. A Simple Model of the Disposition of Failed Bank Assets

##### 4.1. Setup

In this section, I introduce a simple model that examines the conditions determining the outcomes of failed bank asset sales in the presence of put guarantees and loss-sharing arrangements. The setup closely follows Spiegel (2001), with the simplification here that the regulatory au-

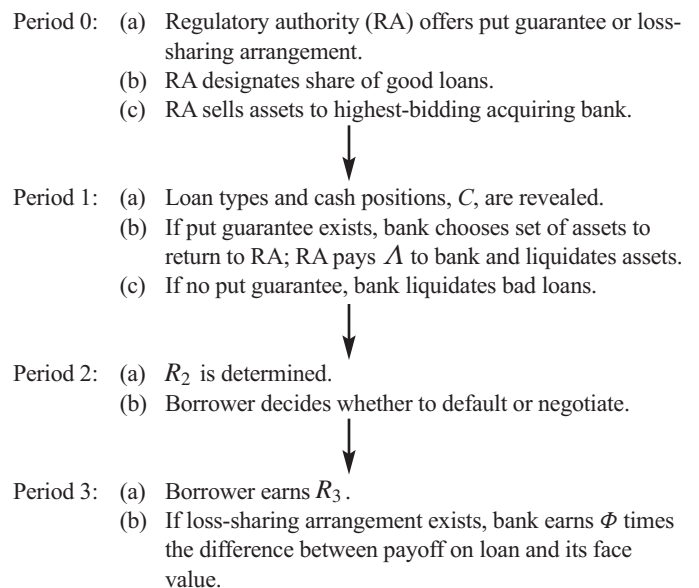
thority always lacks credibility, as discussed below. There are three players: the regulatory authority who is selling the assets of the failed bank, the representative acquiring bank, and the representative borrower. All agents are assumed to be risk-neutral and to discount at the market rate (which is set to 0 for simplicity).

The structural form of the model is shown in Figure 1. There are four periods, 0, 1, 2, and 3. Agents are assumed to be interested only in maximizing period 3 wealth. In period 0, the regulatory authority is endowed with the assets of a failed bank that is assumed to be small relative to the banking sector. These assets are all debt contracts calling for a fixed contractual payment from the borrower to its creditor equal to  $\bar{D}$  in period 2.

The borrowers underlying these assets are assumed to have cash positions,  $C$ , that are unobservable to either the regulatory authority or the acquiring bank. These cash positions are assumed to be protected from seizure by creditors. However, as shown below, they can influence loan payoffs under renegotiation.  $C$  is assumed to be distributed on the interval  $(0, \infty)$  with density function  $f(\cdot)$  and cumulative distribution  $F(\cdot)$ .

There are two types of loans in the population from which the bank's assets are drawn: A share  $1 - \pi$  ( $0 < \pi < 1$ ) of the assets constitutes "good" loans, while the remaining  $\pi$  share of the assets constitutes "bad" loans. Good loans and bad loans are identical ex ante, and the analysis is conducted in terms of representative good and bad loans. For simplicity, I normalize the

FIGURE 1  
EXTENSIVE FORM OF THE MODEL



asset size of the bank to 1, so that it is expected to have  $(1 - \pi)$  good loans and  $\pi$  bad loans.

Good loans and bad loans are assumed to differ in their investment opportunities. In particular, good loans are assumed to behave similarly to the Hart and Moore (1998) (HM) model. Renegotiation on a good loan is profitable ex post because the value of ongoing investments left in place exceeds their value under liquidation. In contrast, bad loans face a return on reinvestment which is below the market rate. This implies that liquidation is a first-best outcome for bad loans.

The sale of the failed bank assets also takes place in period 0. The regulatory authority designates a share of the failed bank's assets as good loans, which then are auctioned off. Competitive bidding is assumed to ensure that assets designated as good loans are sold to the acquiring bank at its reservation price.<sup>9</sup> Loans designated as bad are immediately liquidated. The acquiring bank is assumed to face a fixed cost  $b$  of administering an asset.

In the spirit of a rapid asset sale, the potential acquiring banks are not allowed to conduct due diligence examinations of the failed bank's assets prior to acquisition. This is modeled as the acquiring bank's lack of knowledge about the share of good and bad loans in the failed bank's asset portfolio. This leads to an asymmetric information problem between the regulatory authority and the potential acquiring bank because the regulatory authority lacks credibility concerning its designation of loans as good or bad. Below, I confirm that when the regulatory authority lacks credibility, its optimal response is to designate all of the loans as "good" and offer them for sale. The acquiring bank's optimal response is then to assume that the probability that a loan actually is good matches to the population probability, or  $1 - \pi$ .

To mitigate the asymmetric information difficulties, the regulatory authority can offer either a "put-guarantee" or a "loss-sharing arrangement." These are offered in period 0 and are discussed in more detail below.

In period 1, the acquiring bank learns each asset's true type as well as its cash position. At that point, the acquiring bank can exercise its put guarantee if one has been extended.

Loans have divisible underlying assets that last two periods, and are worthless in period 3. These assets yield uncertain returns  $R_2$  in period 2 and  $R_3$  or 0 in period 3, depending on the loan's type. Good loans are assumed to have investments that yield constant returns  $R_3$  in period 3

( $R_3 > 0$ ), while bad loans earn return 0 in period 3.  $R_2$  also is assumed to be normally distributed, with density function  $h(\cdot)$  and cumulative distribution  $H(\cdot)$ . These funds also are assumed to be under the control of the borrower and not subject to seizure by the bank. In addition, any funds retained by good loan borrowers at the end of period 2 can be reinvested in the project at rate of return  $s$ , where  $s$  is a constant that satisfies

$$(1) \quad 1 < s < \frac{R_3}{L},$$

where  $L$  represents the liquidation value of the asset, which is assumed to be a constant.<sup>10</sup> The above condition implies that the going-concern value of the project exceeds its liquidation value, so that liquidation is costly.

As stated above, the loans call for a fixed contractual payment from the borrower to his creditor equal to  $\bar{D}$  in period 2. The borrower has assets equal to  $C + R_2$  which are not exposed to seizure. It follows that the borrower is solvent if and only if

$$(2) \quad C + R_2 + L \geq \bar{D}.$$

If the borrower is solvent, he can either make the payment  $\bar{D}$  or choose to default. If the borrower is insolvent, he defaults with certainty.

If the borrower services his debt obligations or reaches a renegotiation agreement with his creditor, he remains in operation with his remaining investment in place. All period 3 investment proceeds must go to the borrower, as his creditor no longer has any bargaining power in period 3.

If the solvency condition holds with inequality, the entire project need not be liquidated to service the borrower's outstanding debt obligations in full. Assumption (1) implies that the borrower would always prefer to draw down his cash position fully before beginning to liquidate his project.

If the borrower defaults on his loan obligation, the acquiring bank has the option of liquidating his investment. In the event of default and no renegotiation, the project is completely liquidated. In this case, the bank gets  $L$ , the liquidation value of the asset, while the borrower gets  $C + R_2$ . In practice, bad loans will be completely liquidated.

However, for good loans, both sides can do better through renegotiation since the rate of return on even rein-

9. James and Wier (1987) find a significant relationship between the number of bidders in a failed bank auction and the abnormal returns to the winning bidder after the auction, suggesting that in practice competition among acquiring banks may not be perfect.

10. If  $L$  were allowed to be uncertain, HM show that the assumption that its realization is nonverifiable would be necessary to prove that a debt contract is optimal. Since loss-sharing agreements require that losses be verifiable, that assumption cannot be used here. Therefore, I take  $L$  as a constant.

vested funds by the good borrower exceeds the market rate of interest. As in HM, I assume that with probability  $\alpha$  the bank would get to make a take-it-or-leave-it offer to the borrower, while with probability  $(1 - \alpha)$  the borrower would get to make a take-it-or-leave-it offer to the bank. Moreover, I assume that the outcome of the renegotiation process is that the borrower makes an offer prior to the beginning of the bargaining process equal to the expected value of the payoffs to the creditor, which is always accepted. This payment is then made in period 2.

In period 3, the borrower earns the full proceeds of his remaining investment in place. If the regulatory authority has extended a loss-sharing arrangement guarantee, the acquiring bank is partially compensated for its asset losses in period 3.

The expectation of the acquiring bank concerning its period 2 earnings will influence the value it places on the loans of the failed bank both initially and in period 1 subsequent to the realization of  $C$ . The details of the renegotiation process are shown in the appendix. The expected payoff from a good loan subsequent to the realization of  $C$  is shown to be equal to  $G(C) - b$ , where  $G(C)$  satisfies

$$(3) \quad G(C) = \overline{D} \int_{R_2^*}^{\infty} h(R_2) dR_2 + \int_{-\infty}^{R_2^*} D(C, R_2) h(R_2) dR_2,$$

where  $R_2^*$  represents the realization of  $R_2$  at which equation (2) is just binding and  $D(C, R_2)$  represents the payment by the borrower after renegotiation. As shown in the appendix,  $D(C, R_2)$  satisfies

$$(4) \quad D(C, R_2) = (1 - \alpha)L + \alpha \left[ + \min \left\{ - \left( \frac{C + R_2 - R_3}{s} \right), \left( 1 - \left( \frac{C + R_2}{R_3} \right) \right) L \right\} \right],$$

which represents the probability-weighted payoffs when the borrower and the bank are allowed to make take-it-or-leave-it offers respectively. I also demonstrate in the appendix that  $G'(C) > 0$  and  $G''(C) < 0$ .

As it is clear that  $D(C, R_2) > L$  when  $R_3 > 0$ , the acquiring bank would always choose renegotiation with borrowers of good loans.

In contrast, since the return on investments in period 3 is 0 for bad loans, borrowers always default on bad loans subsequent to the realization of  $R_2$ , and the asset is then liquidated. The returns to the acquiring bank of a bad loan then satisfy  $L - b$ .

#### 4.2. Model with No Guarantees

To provide a benchmark to evaluate the proceeds of sales under the different guarantees considered in the paper, I first evaluate the proceeds that the sale of the failed bank would generate without any guarantees. Let  $\Pi$  represent the payoff to the regulatory authority when no guarantees are extended. As discussed above, since the regulatory authority lacks credibility, it attempts to sell all of the assets and the representative acquiring bank assumes that the share of unsuitable assets is equal to that in the population, or  $\pi$ . The acquiring bank is therefore only willing to bid  $\pi(L - b)$  for these assets.  $\Pi$  therefore satisfies

$$(5) \quad \Pi = \pi L + (1 - \pi)G - b,$$

where  $G$  represents the expected return on good loans in period 0.  $G$  satisfies

$$G = \int_0^{\infty} G(C) f(C) dC.$$

#### 4.3. Model with a Put Guarantee

I next consider the extension of a put guarantee. I assume that the acquiring bank can return its loan for a fixed payoff equal to  $\Lambda$  in period 1, where  $\Lambda > L$ , the loan's liquidation value. Since  $\Lambda > L$ , the acquiring bank will obviously choose to exercise its put option for all bad loans.

However, it is possible that it also may choose to exercise the put options for some good loans. Recall that in period 1 the acquiring bank also learns the cash position of each borrower,  $C$ . A low realization of  $C$  has adverse implications for expected loan payoffs. This raises the possibility that the acquiring bank may wish to return a good loan with a sufficiently low realization of  $C$ . Since  $D(C, R_2) > L$ , the exercising of the put option on good loans would result in a deadweight loss, because good loans are more valuable within the banking sector under renegotiation than under liquidation.

To make the problem nontrivial, I assume that the put guarantee is sufficiently valuable that the acquiring bank would prefer to exercise it under some states of the world. Since the minimum level of cash holdings,  $C$ , is 0, the required assumption is that the put guarantee  $\Lambda$  is sufficiently large that the acquiring bank would choose, if it could, to return the asset upon discovering that the borrower's cash position was 0 but not as large as  $\overline{D}$ , the asset's contractual rate of return.

It is straightforward that the acquiring bank will choose to return a loan when its expected payoff falls short of the put guarantee, i.e., when



$$(6) \quad \Lambda \geq G(C)^{11}$$

The assumption that the put guarantee is sufficiently large that it would be exercised in some, but not all, states for good borrowers is then

$$(7) \quad \bar{D} > \Lambda > G(0),$$

which I adopt.

Define  $C^*$  as the borrower cash position under the put guarantee for which condition (6) is just binding. I demonstrate in the appendix that  $C^*$  exists and is a unique function of  $\Lambda$ , the size of the put guarantee. It follows that loans will be returned if  $C < C^*$  and retained if  $C \geq C^*$ .

Let  $V^P$  represent the acquiring bank's valuation of a good asset under the put guarantee.  $V^P$  satisfies

$$(8) \quad V^P = \Lambda F(C^*) + \int_{C^*}^{\infty} G(C) f(C) dC - b.$$

Let  $\Pi^P$  represent the payoff to the regulatory authority when a put guarantee of magnitude  $\Lambda$  is offered. As above, since the regulatory authority lacks credibility, all assets are offered for sale and the acquiring bank places the population probability  $1 - \pi$  that loans are good.  $\Pi^P$  satisfies

$$(9) \quad \Pi^P = [\pi(\Lambda - b) + (1 - \pi)V^P] - (\Lambda - L)[\pi + (1 - \pi)F(C^*)].$$

The first bracketed term represents the proceeds from the sale of the assets of the failed bank. It is equal to the probability-weighted payoffs of bad and good loans, respectively, in the presence of the put guarantee. The latter term reflects the expected cost to the regulatory authority of servicing the put guarantee. Simplifying and substituting for  $V^P$ ,  $\Pi^P$  satisfies

$$(10) \quad \Pi^P = \pi L + (1 - \pi) \left[ LF(C^*) + \int_{C^*}^{\infty} G(C) f(C) dC \right] - b.$$

I next turn to the question of the implications of the put guarantee on the expected net proceeds to the regulatory authority from the sale of the failed bank. By equations (5) and (10) the loss to a regulatory authority from introducing a put option guarantee satisfies

$$(11) \quad \Pi^P - \Pi = - (1 - \pi) \left[ \int_0^{C^*} G(C) f(C) dC - LF(C^*) \right] < 0.$$

The above expression is negative because the extension of the put option has no impact on the assets that are sold by the regulatory authority. Both in the presence of the put option and in its absence the regulatory authority offers all of the assets of the failed bank for sale. The net loss is then the sum of the probability-weighted expected losses from the acquiring bank returning good loans which have had an adverse cash position realization.

#### 4.4. Model with a Loss-Sharing Arrangement

I next consider the extension of a loss-sharing arrangement. I assume that the purchaser of the asset is guaranteed a reimbursement of  $\phi$  times the magnitude by which the loan payoff falls short of its face value  $\bar{D}$ , where  $\phi \in (0, 1)$ . Let  $b'$  represent the acquiring bank's administrative costs of maintaining the loss-sharing arrangement. In keeping with the literature, I assume that  $b' > b$ , i.e., that the maintenance of the loss-sharing arrangement raises the acquiring bank's administrative costs.

Let  $V_b^l$  represent the expected return to the acquiring bank of a bad loan inclusive of the loss-sharing arrangement. Unlike the put guarantee case, under the loss-sharing case the acquiring bank does not return assets to the regulatory authority. Bad loans are liquidated by the bank itself, and hence yield revenues of  $L - b'$  to the acquiring institution.  $V_b^l$  therefore satisfies

$$(12) \quad V_b^l = L - b' + \phi(\bar{D} - L),$$

where  $\phi(\bar{D} - L)$  is the payoff on bad loans under the loss-sharing arrangement.

Let  $V_g^l$  represent the expected return to the acquiring bank of good loans inclusive of the loss-sharing arrangement. Moreover, let  $\bar{R}_2(C)$  represent the realization of  $R_2$  at which the borrower is indifferent between paying the debt service in full and defaulting.  $\bar{R}_2(C)$  satisfies

$$(13) \quad D[C, \bar{R}_2(C)] = \bar{D}.$$

$V_g^l$  then satisfies

$$(14) \quad V_g^l = G - b' + \phi \int_0^{\infty} \left[ \int_{-\infty}^{\bar{R}_2(C)} [D - \bar{D}(C, R_2)] h(R_2) dR_2 \right] f(C) dC,$$

where the final term represents the expected payoff from the regulatory authority under the loss-sharing arrangement.

11. Note that I am implicitly assuming here that the fixed cost of administering the loan is paid whether or not the loan is returned. This is for analytical simplicity and drives none of the results.



Let  $\Pi^l$  represent the expected payoff to the regulatory authority under a loss-sharing arrangement. As above, the regulatory authority lacks credibility so that all loans are sold and the acquiring bank believes that the share of unsuitable assets is equal to that in the population, or  $\pi$ .  $\Pi^l$  satisfies

$$(15) \quad \Pi^l = \pi L + (1 - \pi) G - b'.$$

I next turn to the implications of the introduction of the loss-sharing arrangement for the expected revenues of the regulatory authority. By equations (5) and (15), the gains from offering the loss-sharing arrangement,  $\Pi^l - \Pi$ , satisfy

$$(16) \quad \Pi^l - \Pi = b - b' \leq 0.$$

Again, the term is negative because the loss-sharing arrangement fails to alter the behavior of the regulatory authority. The only change from offering a loss-sharing arrangement is then the increase in administrative costs to the acquiring bank.<sup>12</sup>

#### 4.5. Comparison of Put Guarantees and Loss-Sharing Arrangements

I next turn to comparing the payoffs from offering the loss-sharing arrangement to those obtained under the put guarantee. By equations (15), (8), and (10), the net gain from offering a loss-sharing arrangement relative to offering a put guarantee,  $\Pi^l - \Pi^p$ , satisfies

$$(17) \quad \Pi^l - \Pi^p = (b - b') + (1 - \pi) \left[ \int_0^{C^*} (G(C) - L) f(C) dC \right].$$

There are two components to the difference in revenues between the loss-sharing arrangement and the put guarantee. The first term is negative, reflecting the additional administrative costs under the loss-sharing arrangement. The second term is positive, reflecting the fact that suitable assets are never liquidated under the loss-sharing arrangement as they are under the put guarantee. The relative merits of the two policies are then dependent on the relative size of these two components.

12. As in the put guarantee case, Spiegel (2001) also demonstrates that the extension of a loss-sharing guarantee can increase the expected revenues of the regulatory authority if it moves the regulatory authority from the no credibility regime to the credibility regime.

Finally, I turn to some comparative static exercises to examine how changes in economic conditions can affect the relative desirability of the put guarantee and the loss-sharing arrangement. Define  $b'^*$  as the administrative cost of the loss-sharing program that leaves regulatory revenue exactly equivalent to the put option guarantee under credibility. By equation (17),  $b'^*$  satisfies

$$(18) \quad b'^* = b + (1 - \pi) \int_0^{C^*} (G(C) - L) f(C) dC.$$

Changes that increase the relative desirability of the loss-sharing arrangement can then be interpreted as changes that increase  $b'^*$ . Differentiating  $b'^*$  with respect to  $L$  yields

$$(19) \quad \frac{db'^*}{dL} = (1 - \pi) \left[ \frac{dC^*}{dL} (G(C^*) - L) f(C^*) + \int_0^{C^*} \left( \frac{dG}{dL} - 1 \right) f(C) dC \right].$$

By equations (2), (3), and (4)  $dC^*/dL$  satisfies

$$(20) \quad \frac{dC^*}{dL} = - \frac{(\bar{D} - D) h(R_2^*) + \int_{-\infty}^{R_2^*} \frac{\partial D}{\partial L} h(R_2) dR_2}{(\bar{D} - D) h(R_2^*) + \int_{-\infty}^{R_2^*} \frac{\partial D}{\partial C} h(R_2) dR_2} < 0.$$

It follows that a sufficient, but not necessary, condition for  $db'^*/dL < 0$  is then

$$(21) \quad (\bar{D} - D) h(R_2^*) + \int_{-\infty}^{R_2^*} \frac{\partial D}{\partial L} h(R_2) dR_2 < 1.$$

Since  $\partial D / \partial L \leq 1$  by equation (4), the above condition is relatively weak, suggesting only that the sensitivity of the value of the asset under intermediation to the liquidation value cannot exceed 1. Under this condition, an increase in the liquidation value of the asset increases the relative desirability of liquidation.

If this condition is satisfied, a decrease in  $L$ , the liquidation value of the asset, raises  $b'^*$ , the loss-sharing administrative cost that leaves the regulatory authority indifferent between the put guarantee and loss-sharing arrangements under credibility. In other words, a decrease in  $L$ , which may be expected to accompany a deterioration in economic conditions, would raise the relative desirability of the loss-sharing arrangement over the put guarantee.

On the other hand, it also is likely that a deterioration in economic conditions would increase  $\pi$ , the share of bad loans in the failed bank's portfolio. Differentiating  $b^*$  with respect to  $\pi$  yields

$$(22) \quad \frac{db^*}{d\pi} = - (1 - \pi) \int_0^{C^*} (G(C) - L) f(C) dC < 0.$$

An increase in  $\pi$  reduces  $b^*$  because it lowers the share of good loans. When there is a smaller share of good loans in the economy, the losses from the put guarantee associated with the return of good loans are reduced.

It is therefore difficult to make a general statement about the marginal impact of a decline in economic conditions on the relative desirability of put guarantees and loss-sharing arrangements because these two effects go in opposite directions. A deterioration in economic conditions should reduce the liquidation value of assets. This would raise the relative desirability of the loss-sharing arrangement because it would raise the cost of liquidation of good loans under the put guarantee. However, one would expect that a deterioration in general conditions also would reduce the overall share of good loans. This effect acts to reduce the relative desirability of the loss-sharing arrangement because it directly mitigates the severity of the problem associated with the liquidation of loans that are more valuable within the banking system.

## 5. Conclusion

This paper examined the circumstances surrounding the sale of two failed Japanese banks, LTCB and NCB, and the historical lessons provided by the U.S. experience during the S&L crisis. In both cases, problems were created by the provision of put guarantees. These guarantees, introduced to address information asymmetry difficulties created by the need for quick asset sales, created moral hazard difficulties of their own. In particular, both in the Japanese and in the United States' cases, acquiring banks were seen to be reluctant to work with problem borrowers when they possessed the alternative of exercising the put guarantee. It was argued that the U.S. experience with loss-sharing arrangements suggests that these arrangements provide a relevant alternative mechanism for addressing the information asymmetries caused by the need for quick sales of failed bank assets.

I then introduced a formal model of both put guarantees and loss-sharing arrangements. The overall superiority of either form of guarantee was shown to depend on the relative magnitude of the losses associated with loans being inappropriately liquidated from the banking sector under the put guarantee and the higher administrative costs experienced under the loss-sharing arrangement. In addition, the impact of deteriorating economic conditions on the relative superiority of put guarantees and loss-sharing arrangements was shown to be ambiguous.

## Appendix

### A.1. Renegotiation

As in HM, I assume that with probability  $\alpha$  the bank would get to make a take-it-or-leave-it offer to the borrower, while with probability  $(1 - \alpha)$  the borrower would get to make a take-it-or-leave-it offer to the bank. Moreover, I assume that the borrower makes an offer prior to the start of renegotiations equal to the expected value of the payoffs to the creditor.

The borrower's take-it-or-leave-it offer is equal to  $L$ , the amount the bank could obtain by liquidating the entire firm. The bank's take-it-or-leave-it offer requires payment sufficient to reduce the payoff to the borrower to its status quo value of  $C + R_2$ .

There are two possibilities for the bank's payoff depending on the wealth of the borrower in period 2. First, suppose that the borrower is relatively wealthy. In particular, suppose that  $C + R_2 \geq R_3$ . In this case, the bank will demand a cash payment from the borrower equal to

$$C + R_2 - \left( \frac{C + R_2 - R_3}{s} \right).$$

Second, suppose that the borrower is poor, i.e., that  $C + R_2 < R_3$ . In this case, some amount of liquidation will be required to reduce the borrower's period 3 payoff to  $C + R_2$ . In particular, the bank will demand all of the borrower's cash,  $C + R_2$ , plus the proceeds from a partial liquidation of the asset. The bank will demand that the borrower liquidate a share of the assets equal to  $1 - (C + R_2)/R_3$ . The payoff to the bank in this case satisfies

$$C + R_2 + \left( 1 - \left( \frac{C + R_2}{R_3} \right) \right) L.$$

The payoff when the bank gets to make the take-it-or-leave-it offer then satisfies

$$C + R_2 + \min \left\{ - \left( \frac{C + R_2 - R_3}{s} \right), \left( 1 - \left( \frac{C + R_2}{R_3} \right) \right) L \right\}.$$

The payoff to the creditor under renegotiation then satisfies equation (4),

$$D(C, R_2) = (1 - \alpha) L + \alpha \left[ C + R_2 + \min \left\{ - \left( \frac{C + R_2 - R_3}{s} \right), \left( 1 - \left( \frac{C + R_2}{R_3} \right) \right) L \right\} \right].$$

Defaults occur if and only if  $\bar{D} \geq D(C, R_2)$ . It follows that the payoff will be exactly like a debt contract. If the bank does not liquidate the loan in period 1, it receives  $\bar{D}$  in period 2 if the borrower is solvent and  $D$  if the borrower is insolvent. The expected payoff to a loan to a good borrower then satisfies equation (3), where  $R_2^*$  represents the realization of  $R_2$  for which equation (2) holds with equality.

To evaluate the model, it is useful to consider how realizations of the borrower's cash position,  $C$ , influence the expected payoff to the acquiring bank. It is easy to show that  $G$  is increasing and concave in  $C$ . Differentiating equation (4) with respect to  $C$  yields

$$\frac{\partial G}{\partial C} = \int_{-\infty}^{R_2^*} \frac{\partial D}{\partial C} h(R_2) dR_2 > 0$$

over the values of  $C$  for which  $\partial D / \partial C$  is defined. This includes all values of  $C$  except  $C = R_3 - R_2$ . At this value of  $C$  the payoff when the bank makes the take-it-or-leave-it offer is kinked. When  $C > R_3 - R_2$ ,

$$\frac{\partial D}{\partial C} = \alpha \left( 1 - \frac{1}{s} \right) > 0,$$

and when  $C < R_3 - R_2$

$$\frac{\partial D}{\partial C} = \alpha \left( 1 - \frac{L}{R_3} \right) > 0.$$

The second derivative satisfies

$$\frac{\partial^2 G}{\partial C^2} = - \frac{\partial D}{\partial C} h(R_2^*) < 0.$$

### A.2. Existence and Uniqueness of $C^*$

Since cash holdings cannot be negative, existence follows directly from assumption (7) and the result in the appendix that  $G(C)$  is strictly increasing in  $C$ . Suppose that  $C = 0$ . By assumption (7), the acquiring bank would choose to return the asset to the regulatory authority at  $C = 0$ . Now consider the payoffs as  $C$  approaches infinity. By equation (2), as  $C \rightarrow \infty$  the probability of default goes to zero. It follows that  $G(C) \rightarrow D$  as  $C \rightarrow \infty$ . Since  $D > A$  by assumption, it follows that the acquiring bank would not return the asset if  $C$  approached infinity. It follows that a unique value of  $C^*$  exists. Moreover,  $C^*$  is the value of  $C$  under which the constraint in equation (6) is just binding.

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# Real-Time Estimation of Trend Output and the Illusion of Interest Rate Smoothing\*

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Empirical estimates of the Federal Reserve's policy rule typically find that the regression coefficient on the lagged federal funds rate is around 0.8 and strongly significant. One economic interpretation of this result is that the Fed intentionally "smoothes" interest rates, i.e., policymakers move gradually over time to bring the current level of the funds rate in line with a desired level that is determined by consideration of recent economic data. This paper develops a small forward-looking macroeconomic model where in each period, the Federal Reserve constructs a current, or "real-time," estimate of trend output by running a regression on past output data. Using the model as a data-generating mechanism, I show that efforts to identify the Fed's policy rule using final data (as opposed to real-time data) can create the illusion of interest rate smoothing behavior when, in fact, none exists. In particular, I show that the lagged federal funds rate can enter spuriously in final-data policy rule regressions because it helps pick up the Fed's serially correlated real-time measurement errors which are not taken into account by the standard estimation procedure. In model simulations, I find that this misspecification problem can explain as much as one-half of the apparent degree of "inertia" or "partial adjustment" in the U.S. federal funds rate.

## 1. Introduction

The Federal Reserve conducts monetary policy primarily through open market operations that influence the overnight interest rate on borrowed reserves among U.S. banks. The overnight interest rate is known as the federal funds rate. The target level for the federal funds rate is set by the Federal Open Market Committee (FOMC), which meets eight times per year. In deciding the appropriate level of the funds rate, members of the FOMC carefully consider the most recent economic data and the implications for the economy going forward.

Given the way in which monetary policy is actually conducted, it is often useful to think about Federal Reserve behavior in terms of a "reaction function" or a "policy rule" that describes how the federal funds rate responds to key macroeconomic variables. An example of such a rule is the one suggested by Taylor (1993). According to the Taylor rule, the appropriate level of the funds rate is determined by a particular weighted combination of the deviation of inflation from a long-run target inflation rate and the "output gap," i.e., the difference between real output and a measure of trend (or potential) output. Interestingly, the

path of the U.S. federal funds rate largely appears to conform to the recommendations of the Taylor rule starting in the mid- to late 1980s and extending into the 1990s. This observation has led to a large number of empirical studies that attempt to estimate the Fed's policy rule directly from U.S. data.

Motivated by the form of the Taylor rule, empirical studies of the Fed's policy rule typically regress the federal funds rate on a set of explanatory variables that includes the inflation rate (or a forecast of future inflation) and a measure of real economic activity such as the output gap. Many of these studies also include the lagged value of the federal funds rate as an additional explanatory variable. This feature turns out to greatly improve the empirical fit of the estimated rule. Using quarterly U.S. data, the regression coefficient on the lagged federal funds rate is generally found to be around 0.8 and strongly significant.<sup>1</sup> One economic interpretation of this result is that the Fed intentionally "smoothes" interest rates, i.e., policymakers move gradually over several quarters to bring the current level of the funds rate in line with a desired level that is determined by consideration of recent economic data. Under this view, the magnitude of the regression coefficient on the lagged

\*For helpful comments, I thank Richard Dennis, John Judd, Yash Mehra, Athanasios Orphanides, Stephen Perez, and Glenn Rudebusch.

1. See, for example, Amato and Laubach (1999), Clarida, et al. (2000), and Rudebusch (2002).

funds rate governs the degree of “inertia” or “partial adjustment” in Fed policy decisions.<sup>2</sup>

Given the apparent degree of interest rate smoothing in quarterly U.S. data, a large amount of research has been devoted to understanding why the Federal Reserve might wish to engage in such behavior.<sup>3</sup> Sack and Weiland (2000) review this research and identify three main arguments that could help explain the apparent gradual response of Fed policymakers to quarterly changes in inflation and the output gap. These are (1) forward-looking expectations, (2) uncertainty about economic data that are subject to revision, and (3) uncertainty about the structure of the economy and the transmission mechanism for monetary policy.

In an economy with forward-looking agents, policymakers can influence current economic activity by affecting agents’ expectations about *future* policy actions. If agents are convinced that an initial change in the federal funds rate will be followed by additional changes in the same direction (as policymakers gradually adjust the funds rate toward the desired level), then the initial policy move will have a larger impact on agents’ decisions. This feature of the economy allows policymakers to achieve their stabilization objectives without having to resort to large, abrupt policy moves, which may be viewed as undesirable because they increase interest rate volatility.<sup>4</sup> Consideration of uncertainty also favors gradual adjustment because policymakers tend to be cautious. Aggressive policy actions are generally resisted because they can lead to severe unintended consequences if the beliefs that motivated such actions later prove to be unfounded.

Without disputing the potential benefits of interest rate smoothing laid out in the above arguments, this paper shows that efforts to identify the Fed’s policy rule using regressions based on final (or ex post revised) data can create the illusion of interest rate smoothing behavior when, in fact, none exists. In particular, I show that the lagged federal funds rate can enter spuriously in final-data policy rule regressions because it helps pick up the Fed’s serially correlated real-time measurement errors which are not taken into account by the standard estimation procedure.

2. The concept of interest rate smoothing is often linked to the idea that Fed policymakers adjust the funds rate in a series of small steps and reverse course only at infrequent intervals. Rudebusch (2002) notes that while this concept of interest rate smoothing applies to federal funds rate movements over the course of several weeks or months, it does not necessarily imply a large regression coefficient on the lagged funds rate at quarterly frequency.

3. The central banks of other countries also appear to exhibit interest rate smoothing behavior. For some details, see Lowe and Ellis (1997) and Srouf (2001).

4. For a formal theoretical argument along these lines, see Woodford (1999).

The framework for my analysis is a small forward-looking macroeconomic model where in each period the Federal Reserve constructs a current, or “real-time,” estimate of the level of potential output by running a regression on past output data. The Fed’s perceived output gap (the difference between actual output and the Fed’s real-time estimate of potential output) is used as an input to the monetary policy rule, while the true output gap influences aggregate demand and inflation.

As in Lansing (2000), I allow for the possibility that true potential output may undergo abrupt shifts in level and/or slope which are unknown to Fed policymakers until some years later. In the model, true potential output is calibrated to match a segmented linear trend fit to U.S. data on real GDP. I allow for two abrupt trend shifts: the first captures the well-documented productivity slowdown of the early 1970s while the second captures the postulated arrival of the so-called “new economy” in the mid-1990s, which is thought by some to be characterized by faster trend productivity growth.<sup>5</sup> Initially, Fed policymakers interpret these trend shifts to be cyclical shocks but their regression algorithm allows them to discover the truth gradually as the economy evolves by assigning more weight to the recent data.

Using the model as a data-generating mechanism, I produce artificial data on interest rates, inflation, and real output for the case where Fed policymakers employ a Taylor-type rule with no interest rate smoothing whatsoever. I then take the perspective of an econometrician who uses these data to estimate the Fed’s policy rule. I consider two possible misspecifications of the econometrician’s regression equation. First, the econometrician uses a final-data potential output series instead of the Fed’s real-time potential output estimates. To keep things simple, I endow the econometrician with full knowledge of the true potential output series defined by the segmented linear trend. Hence, the econometrician’s final-data potential output series coincides exactly with the true series (but differs from the Fed’s real-time estimates). Second, the econometrician may adopt the wrong functional form for the policy rule, i.e., one that differs from the Taylor-type rule that Fed policymakers are actually using in the model. Specifically, I consider the case where the econometrician includes an additional lag of the output gap in the regression equation. The additional lag would be appropriate if the econometri-

5. Oliner and Sichel (2000) present evidence of a pickup in measured U.S. productivity growth after 1995 that appears to be linked to spending on information technology. Gordon (2000) argues that a proper analysis of the productivity data does not support the views of the new economy enthusiasts.

cian believed that Fed policymakers were responding to the deviation of nominal income growth from a long-run target growth rate.

Over the course of 1,000 model simulations, I find that the econometrician almost always obtains a positive and strongly significant regression coefficient on the lagged federal funds rate, even though the Fed in the model is not engaging in any interest rate smoothing. The average point estimate of the spurious regression coefficient is around 0.3 or 0.4, depending on the econometrician's sample period and rule specification. The intuition for this result is straightforward. Since the Fed's algorithm for estimating potential output assigns more weight to recent data, the end-of-sample estimate can undergo substantial changes as new observations arrive—even without a trend shift in the underlying economy. The algorithm gives rise to serially correlated real-time measurement errors that influence the period-by-period setting of the federal funds rate. By ignoring these errors, the econometrician's final-data regression equation is subject to a missing variable problem. The inclusion of the lagged funds rate helps compensate for the problem by acting as a proxy for the missing error terms.

The simulations show that failure to account properly for the Fed's real-time perceptions about potential output can explain as much as one-half of the apparent degree of inertia in the U.S. federal funds rate. This finding complements recent work by Rudebusch (2002), who uses evidence from the term structure of U.S. interest rates to reject the hypothesis of a large degree of monetary policy inertia. Under the assumption that longer-term interest rates are governed by agents' rational expectations of future short-term rates, Rudebusch shows that a coefficient of 0.8 on the lagged federal funds rate is not consistent with U.S. term structure data. A smaller coefficient on the lagged funds rate of, say, 0.4 cannot be rejected, however. Rudebusch draws on a variety of qualitative evidence from historical episodes to argue that "quarterly interest rate smoothing is a very modest phenomenon in practice."

Finally it should be noted that some recent empirical studies have made serious efforts to take into account the Fed's real-time information set when estimating policy rules directly from U.S. data. Examples include the studies by Orphanides (2001), Perez (2001), and Mehra (2001) who employ reconstructed historical data that is intended to capture the information available to Fed policymakers at the time policy decisions actually were made. Orphanides (2001) and Perez (2001) continue to find a large and statistically significant coefficient on the lagged federal funds rate even when policy rules are regressed on the reconstructed real-time data, while Mehra (2001) does not. In particular, Mehra (2001) shows that the lagged funds rate actually may be picking up the Fed's real-time response to

a "smoothed" inflation rate which is defined by a four-quarter moving average of the quarterly inflation rate.

A drawback of the reconstruction approach is that we cannot know for sure what method was being used by Fed policymakers to estimate potential output in real time. Indeed, each of the three studies mentioned above adopts a different method for defining the Fed's real-time estimate of potential output.<sup>6</sup> Another drawback of the reconstruction approach is that we cannot know the exact form of the policy rule that was being used by Fed policymakers during a given period of history. The simulation-based approach adopted here avoids these drawbacks by conducting a controlled scientific experiment where we have full knowledge of all factors that govern the real-time decisions of Fed policymakers.

The remainder of the paper is organized as follows. Section 2 describes the model that is used to generate the artificial data. Section 3 describes the simulation procedure. Section 4 presents the results of the simulations. Section 5 concludes.

## 2. The Model

In this paper, the economic model serves as a data-generating mechanism for the policy rule regressions that are the main focus of the analysis. I use a small forward-looking macroeconomic model adapted from Lansing (2000). The details are contained in Box 1. The model consists of: (1) an aggregate demand equation that links real economic activity to the level of the real interest rate, (2) an equation that describes how true potential output evolves over time, (3) a short-run Phillips curve that links inflation to the level of real economic activity, (4) a term structure equation that links the behavior of short- and long-term interest rates, and (5) a monetary policy rule that describes how the federal funds rate responds to inflation and real economic activity. The model is quite tractable and has the advantage of being able to reproduce the dynamic correlations among U.S. inflation, short-term nominal interest rates, and deviations of real GDP from trend. Lansing (2000) shows that the model also can replicate some of the key low-frequency movements in U.S. inflation over the past several decades.

6. Orphanides (2001) assumes that real-time potential output is defined by the Federal Reserve staff's  $Q^*$  series which is constructed as a segmented linear trend linked to Okun's law. Perez (2001) assumes that real-time potential output is defined by the Hodrick-Prescott (1997) filter. Mehra (2001) assumes that real-time potential output is defined by a log-linear trend fitted to observations of past output.

## Box 1

## DETAILS OF THE MODEL

The equations that describe the model are as follows:

*Aggregate Demand Equation*

$$(1) \quad y_t - \bar{y}_t = a_1 (y_{t-1} - \bar{y}_{t-1}) + a_2 (y_{t-2} - \bar{y}_{t-2}) + a_r (r_{t-1} - \bar{r}) + v_t, \quad v_t \sim N(0, \sigma_v^2),$$

where  $y_t$  is the logarithm of real output (GDP),  $\bar{y}_t$  is the logarithm of true potential output,  $r_{t-1}$  is the lagged value of the ex ante long-term real interest rate, and  $v_t$  is a shock to aggregate demand that may arise, for example, due to changes in government purchases. The true output gap is given by  $y_t - \bar{y}_t$ . In steady state, the output gap is 0 which implies that  $\bar{r}$  is the steady-state real interest rate.

*True Potential Output*

$$(2) \quad \bar{y}_t = \begin{cases} c_0 + \mu_0 \cdot t & \text{for } t_0 \leq t \leq t_1, \\ c_1 + \mu_1 \cdot t & \text{for } t_1 < t \leq t_2, \\ c_2 + \mu_2 \cdot t & \text{for } t > t_2, \end{cases}$$

where  $c_i$  and  $\mu_i$  for  $i = 0, 1, 2$  represent the intercept and slope terms for a segmented linear trend with breakpoints at  $t_1$  and  $t_2$ .

*Short-run Phillips Curve*

$$(3) \quad \pi_t = \frac{1}{2}(\pi_{t-1} + E_{t-1}\pi_t) + \gamma (y_{t-1} - \bar{y}_{t-1}) + z_t, \quad z_t \sim N(0, \sigma_z^2),$$

where  $\pi_t$  is the fully observable inflation rate defined as the log difference of the price level (the GDP price index),  $E_{t-1}$  is the expectation operator conditional on information available at time  $t - 1$ , and  $z_t$  is a cost-push shock. The steady-state version of equation (3) implies that there is no steady-state trade-off between inflation and real output.

*Term Structure Equation*

$$(4) \quad r_{t-1} = \frac{1}{2} E_{t-1} \sum_{i=0}^1 (i_{t-1+i} - \pi_{t+i}) = \frac{1}{2} (i_{t-1} - E_{t-1}\pi_t + E_{t-1}i_t - E_{t-1}\pi_{t+1}),$$

where  $i_t$  is the one-period nominal interest rate (the federal funds rate). Equation (4) summarizes the expectations theory of the term structure for an economy where the “long-term” interest rate corresponds to a two-period Treasury security

(the six-month T-Bill). Private-sector agents use their knowledge of the Fed’s policy rule to compute the expectation  $E_{t-1}i_t$ . In steady state, equation (4) implies the Fisher relationship:  $\bar{i} = \bar{r} + \bar{\pi}$ .

*Federal Reserve Policy Rule*

$$(5) \quad i_t^* = \bar{r} + \bar{\pi} + g_\pi (\pi_{t-1} - \bar{\pi}) + g_y [y_{t-1} - \bar{x}_{t-1} - \phi (y_{t-2} - \bar{x}_{t-2})],$$

$$(6) \quad i_t = \rho i_{t-1} + (1 - \rho) i_t^*,$$

where  $\bar{\pi}$  is the Fed’s long-run inflation target which determines the steady-state inflation rate. The symbol  $\bar{x}_t$  represents the Fed’s real-time estimate of  $\bar{y}_t$ . This estimate is constructed by applying a regression algorithm to the historical sequence of real output data  $\{y_s\}_{s=t_0}^{s=t}$  which is fully observable. The symbol  $i_t^*$  represents the desired (or target) level of the federal funds rate. The parameter  $0 \leq \rho \leq 1$  governs the degree of inertia (or partial adjustment) in the funds rate.

Equations (5) and (6) capture most of the rule specifications that have been studied in the recent monetary policy literature. A simple version of the original Taylor (1993) rule can be represented by  $\rho = 0$ ,  $g_\pi = 1.5$ ,  $g_y = 0.5$ , and  $\phi = 0$ .<sup>a</sup> Taylor (1999) considers a modified version of this rule which is characterized by a stronger response to the output gap, i.e.,  $g_y = 1.0$  rather than  $g_y = 0.5$ .<sup>b</sup> In the appendix, I show that a nominal income growth rule can be obtained by setting  $g_\pi = g_y$  with  $\phi = 1$ .

When  $g_\pi > 1$ , the desired funds rate  $i_t^*$  moves more than one-for-one with inflation. This feature is generally viewed as desirable because it tends to stabilize inflation; any increase in the inflation rate brings about a larger increase in the desired nominal funds rate which will eventually lead to a higher *real* interest rate. A higher real rate restrains aggregate demand and thereby helps to push inflation back down.<sup>c</sup>

<sup>a</sup>The original Taylor (1993) rule assumes that the funds rate responds to the average inflation rate over the past four quarters, whereas equations (5) and (6) imply that the funds rate responds to the inflation rate in the most recent quarter only.

<sup>b</sup>Lansing and Trehan (2001) consider the issue of whether either version of the Taylor rule can be reconciled with optimal discretionary monetary policy.

<sup>c</sup>For additional details, see Taylor (1999) and Clarida, et al. (2000).



Private-sector agents in the model are completely informed at all times regarding the level of true potential output. This can be justified in one of two ways: (1) the private sector consists of a large number of identical firms, each of which knows its own productive capacity, or (2) the process of aggregating over the distribution of firms yields an economy-wide description that is observationally equivalent to (1). Private-sector agents have rational expectations; they know the form of the monetary policy rule and the Fed's estimate of potential output which is used as an input to the rule.

True potential output in the model is trend stationary but subject to infrequent shifts in level and/or slope. Perron (1989) shows that standard statistical tests cannot reject the hypothesis of a unit root in U.S. real output data when the true data-generating mechanism is one of stationary fluctuations around a deterministic trend with infrequent shifts. More recently, Dolmas, et al. (1999) argue that U.S. labor productivity is more accurately modeled as a deterministic trend with a sudden change in level and slope around 1973, rather than as a unit root process. For simplicity, the model abstracts from any direct theoretical link between the slope of true potential output (which measures the economy's trend growth rate) and the value of the steady-state real interest rate. Even without assumption, however, a sudden unanticipated change in the *level* of potential output would have no theoretical implications for the value of the steady-state real rate.

Following the framework of Clarida, et al. (2000), I use the symbol  $i_t^*$  to represent the desired (or target) level of the federal funds rate that is determined by policymakers' consideration of economic fundamentals. The relevant fundamentals include: (1) the level of the steady-state real interest rate, (2) the deviation of recent inflation from the Fed's long-run target rate, and (3) the gap between recent output and the Fed's real-time estimate of potential output. The model's policy rule specification allows for the possibility that the Fed does not immediately adjust the funds rate to the desired rate but instead engages in "interest rate smoothing" whereby the current federal funds rate  $i_t$  is moved in the direction of the desired rate  $i_t^*$  over time. The parameter  $\rho$  is used here to represent the degree of inertia (or partial adjustment) in the funds rate. Each period the Fed moves the actual funds rate by an amount equal to the fraction  $(1 - \rho)$  of the distance between the desired rate and the actual rate.<sup>7</sup> When  $\rho = 0$ , the adjustment process is immediate; the Fed sets the actual rate equal to the desired rate each period.

7. This can be seen by subtracting  $i_{t-1}$  from both sides of equation (6) to yield  $i_t - i_{t-1} = (1 - \rho)(i_t^* - i_{t-1})$ .

Fed policymakers in the model cannot directly observe true potential output or the shocks hitting the economy. The hidden nature of the shocks is crucial because it prevents policymakers from using any knowledge they may have about the structure of the economy to back-solve for true potential output. The assumption of asymmetric information between the private sector and the Fed is consistent with some recent papers that investigate the performance of alternative policy rules in environments where the output gap that appears in the rule is subject to exogenous stochastic shocks. These shocks are interpreted as "noise" or "measurement error."<sup>8</sup> Unlike these exercises, however, the measurement error in this model is wholly endogenous—it depends on the structure of the economy, the form of the policy rule, and the regression algorithm used by the Fed to construct the real-time potential output series.

The policy rule specification implies that the Fed reacts only to lagged variables and not to contemporaneous variables. This feature addresses the point made by McCallum (1999) that policy rules should be "operational," i.e., rules should reflect the fact that policy decisions often must be made before economic data for the current quarter become available. Finally, as in most quantitative studies of monetary policy rules, the model abstracts from the zero lower bound on nominal interest rates.

## 2.1. Real-Time Estimate of Potential Output

Fed policymakers in the model construct a current, or "real-time," estimate of potential output by running a regression on the historical sequence of real output data. The regression algorithm can be viewed as part of the Fed's policy rule. In choosing an algorithm, I assume that policymakers wish to guard against the possibility that potential output may undergo trend shifts.<sup>9</sup> This feature is achieved through the use of an algorithm that assigns more weight to recent data in constructing the end-of-sample estimate. The result is a flexible trend that can adapt to shifts in true potential output. The Fed's real-time potential output series is updated each period so that policymakers continually revise their view of the past as new observations arrive.

The particular regression algorithm used here is known as the Hodrick-Prescott (HP) filter.<sup>10</sup> The HP filter minimizes the sum of squared differences between trend and

8. See, for example, Orphanides, et al. (2000).

9. See Parry (2000) for some evidence that real-world policymakers guard against the possibility of trend shifts.

10. For details, see Hodrick and Prescott (1997).



the actual series, subject to a penalty term that constrains the size of the second differences.<sup>11</sup> Use of this algorithm introduces an additional parameter into the model, namely, the weight  $\lambda$  assigned to the penalty term. The value of  $\lambda$  controls the smoothness of the resulting trend. When  $\lambda = 0$ , the HP filter returns the original series with no smoothing whatsoever. As  $\lambda \rightarrow \infty$ , the HP filter returns an ordinary least squares (OLS) trend for interior points of a finite sample, but there can be significant distortions from OLS near the sample endpoints. When  $\lambda = 1,600$ , the HP filter applied to a quarterly series approximates a band-pass filter that extracts components of the data that are typically associated with business cycles or high-frequency noise, i.e., components with fluctuations between 2 and 32 quarters. Again, however, there may be significant distortions from the ideal band-pass filter near the sample endpoints.<sup>12</sup>

St-Amant and van Norden (1997) show that when  $\lambda = 1,600$ , the HP filter assigns a weight of 20 percent to observations at the end of the sample, whereas observations at the center of the sample receive no more than a 6 percent weight. Real-time estimates of potential output constructed using the HP filter may therefore undergo substantial changes as new observations arrive—even without a trend shift in the underlying economy or revisions to published data.<sup>13</sup> Orphanides and van Norden (1999) show that this problem arises with other real-time methods of trend estimation as well, but with varying degrees of severity. Unfortunately, the problem cannot be avoided because the future trajectory of the economy (which cannot be known in advance) turns out to provide valuable information about the current level of potential output.

In describing the HP filter, Kydland and Prescott (1990, p. 9) claim that the “implied trend path for the logarithm of real GNP is close to one that students of business cycles and growth would draw through a time plot of this series.” One might argue that Fed policymakers could obtain a more accurate estimate of potential output by taking into account observations of other variables, such as inflation, or by solving an optimal signal extraction problem. I choose not to pursue these options here because their application hinges on the strong assumption that Fed poli-

cymakers possess detailed knowledge about key structural features of the economy such as the slope of the short-run Phillips curve or the distributions governing unobservable shocks. Given that simple univariate algorithms such as the HP filter are commonly used to define potential output in monetary policy research (see, for example, Taylor 1999), the idea that Fed policymakers would adopt similar techniques does not seem unreasonable.

## 2.2. Policy Rule Misspecification

An econometrician who uses final data to estimate the Fed’s policy rule is implicitly assuming that the final-data version of potential output is equal to the Fed’s real-time version of potential output. In the model, this assumption is false. The Fed’s regression algorithm gives rise to real-time measurement errors that influence the period-by-period setting of the federal funds rate. By ignoring these errors, the econometrician’s final-data estimation procedure is subject to a missing variable problem (for details, see Box 2). The Fed’s real-time measurement errors turn out to be highly serially correlated in the quantitative simulations. In such an environment, the econometrician’s estimate of the inertia parameter  $\rho$  will be biased upward relative to the true value because the lagged funds rate serves as a proxy for the missing error terms. This is an example of a well-known econometric problem originally analyzed by Griliches (1961, 1967). In particular, Griliches shows that the OLS estimate of a partial adjustment coefficient (such as  $\rho$ ) will be biased upward relative to its true value if the econometrician ignores the presence of positive serial correlation in the error term.<sup>14</sup> Exploiting this idea, Rudebusch (2002) demonstrates that a noninertial policy rule with serially correlated errors can be nearly observationally equivalent to an inertial policy rule with serially uncorrelated errors. Orphanides (2001) demonstrates analytically how a misspecification of the Fed’s policy rule can lead to the appearance of a larger inertia parameter.

## 3. Simulation Procedure

The parameter values used in the quantitative simulations are described in Box 3. I consider two possibilities for the exogenous time series that defines true potential output in

11. Qualitatively similar results would be obtained with other regression algorithms that assign more weight to recent data, such as moving-window least squares or discounted least squares. For details, see Lansing (2000).

12. For details, see Baxter and King (1999) and Christiano and Fitzgerald (1999).

13. For quantitative demonstrations of this property, see de Brouwer (1998), Orphanides and van Norden (1999), and Christiano and Fitzgerald (1999).

14. Goodfriend (1985) shows how this econometric problem can lead to a spurious finding of partial adjustment in estimated money demand equations when the variables that govern demand (interest rates and transactions) are subject to serially correlated measurement error.

## Box 2

## REDUCED-FORM VERSION OF THE MODEL

Following the procedure outlined in Lansing (2000), the reduced-form version of the aggregate demand equation can be written as follows:

$$(7) \quad y_t - \bar{y}_t = \left[ \frac{a_1 + a_r [(1 - \rho) g_y / 2 - 2\gamma]}{1 + \gamma a_r} \frac{a_2 - a_r (1 - \rho) g_y \phi / 2}{1 + \gamma a_r} \frac{a_r [(1 - \rho) g_\pi / 2 - 1]}{1 + \gamma a_r} \frac{a_r (1 + \rho) / 2}{1 + \gamma a_r} \right] \begin{bmatrix} y_{t-1} - \bar{y}_{t-1} \\ y_{t-2} - \bar{y}_{t-2} \\ \pi_{t-1} - \bar{\pi} \\ i_{t-1} - (\bar{r} + \bar{\pi}) \end{bmatrix} \\ + \left[ 1 \frac{a_r (1 - \rho) g_y / 2}{1 + \gamma a_r} \frac{-a_r (1 - \rho) g_y \phi / 2}{1 + \gamma a_r} \right] \begin{bmatrix} v_t \\ \bar{y}_{t-1} - \bar{x}_{t-1} \\ \bar{y}_{t-2} - \bar{x}_{t-2} \end{bmatrix},$$

where  $\bar{y}_{t-1} - \bar{x}_{t-1}$  represents the Fed's real-time error in measuring potential output in period  $t - 1$ . The last two terms in equation (7) show how the real-time errors are transmitted to the true output gap  $y_t - \bar{y}_t$ .

The reduced-form Phillips curve is given by:

$$(8) \quad \pi_t = \pi_{t-1} + 2\gamma (y_{t-1} - \bar{y}_{t-1}) + z_t,$$

which shows that the Fed's real-time measurement errors affect inflation only indirectly through their influence on the true output gap  $y_t - \bar{y}_t$ .

Combining equations (5) and (6), we can rewrite the Fed's policy rule as

$$(9) \quad i_t = \begin{bmatrix} \rho & (1 - \rho)(\bar{r} + \bar{\pi}) & (1 - \rho)g_\pi & (1 - \rho)g_y & -(1 - \rho)g_y\phi \end{bmatrix} \begin{bmatrix} i_{t-1} \\ 1 \\ \pi_{t-1} - \bar{\pi} \\ y_{t-1} - \bar{y}_{t-1} \\ y_{t-2} - \bar{y}_{t-2} \end{bmatrix} \\ + \begin{bmatrix} (1 - \rho)g_y & -(1 - \rho)g_y\phi \end{bmatrix} \begin{bmatrix} \bar{y}_{t-1} - \bar{x}_{t-1} \\ \bar{y}_{t-2} - \bar{x}_{t-2} \end{bmatrix},$$

where the last two terms show how the Fed's real-time measurement errors influence the setting of the current funds rate  $i_t$ . An econometrician who uses final data to estimate the Fed's policy rule is implicitly imposing the restriction  $\bar{x}_t = \bar{y}_t$  for all  $t$ . This restriction causes the last two terms in equation (9) to drop out, thereby creating a missing variable problem.

The reduced-form version of the model is defined by equations (7), (8), and (9), together with the regression algorithm that defines the Fed's real-time potential output series  $\{\bar{x}_t\}$  from observations of  $\{y_s\}_{s=t_0}^{s=t}$ .

## Box 3

## PARAMETER VALUES FOR QUANTITATIVE SIMULATIONS

Structural Parameters <sup>a</sup>					Standard Deviation of Shocks <sup>b</sup>		Policy Rule Parameters <sup>c</sup>				
$a_1$	$a_2$	$a_r$	$\gamma$	$\bar{r}$	$\sigma_v$	$\sigma_z$	$\rho$	$g_\pi$	$g_y$	$\phi$	$\bar{\pi}$
1.25	-0.35	-0.2	0.04	0.03	0.0045	0.0050	0 <sup>d</sup>	1.5	1.0	0	0.043 <sup>e</sup>

<sup>a</sup>Values are taken from Lansing (2000), who estimates these parameters using quarterly U.S. data for the period 1966:Q1 to 2001:Q2.

<sup>b</sup>Standard deviations of the two shocks are chosen such that the standard deviations of the output gap and inflation in the simulations are close to the corresponding values in U.S. data over the period 1966:Q1 to 2001:Q2.

<sup>c</sup>Values are taken from Lansing (2000) and approximate a modified version of the original Taylor (1993) rule. The modified version (analyzed by Taylor (1999)) involves a stronger response to the output gap.

<sup>d</sup>Value indicates no interest rate smoothing by Fed policymakers in the model.

<sup>e</sup>Value matches the sample mean of U.S. inflation from 1966:Q1 to 2001:Q2. The annualized inflation rate is measured by  $4 \ln (P_t / P_{t-1})$ , where  $P_t$  is the GDP price index in quarter  $t$ .

the model. The first, shown in Figure 1A, is a segmented linear trend fitted to U.S. real GDP data of vintage 2001:Q3.<sup>15</sup> The sample starts at  $t_0 = 1947:Q1$ . I allow for two structural breaks at  $t_1 = 1973:Q4$  and  $t_2 = 1995:Q4$ . The first breakpoint is consistent with research on the dating of the 1970s productivity slowdown. The dating of the second breakpoint is consistent with the analyses of Oliner and Sichel (2000) and Gordon (2000) and is intended to capture the start of the so-called “new economy.” In Figure 1A, the postulated new economy break involves a slope change only; there is no attendant shift in the level of potential output. An unrestricted linear regression over the period 1996:Q1 to 2001:Q2 would imply a downward shift in the level of potential output at 1995:Q4. This outcome seems inconsistent with the mainstream new economy view that I am trying to capture here.<sup>16</sup> The second possibility for the true potential output series, shown in Figure 1B, is a simple linear trend with no breakpoints fitted over the entire sample period, 1947:Q1 to 2001:Q2. This alternative series allows me to gauge the impact of sudden trend shifts on the estimated value of the inertia parameter  $\rho$  in the model simulations.

For each of the two potential output series, I simulate the model 1,000 times with shock realizations drawn randomly from independent normal distributions with the standard deviations shown in Box 3. Each simulation starts from the steady state at  $t_0 = 1947:Q1$  and runs for 218 periods (the number of quarters from 1947:Q1 to 2001:Q2). Fuhrer and Moore (1995) argue that the federal funds rate can be viewed as the primary instrument of monetary policy only since the mid-1960s. Before then, the funds rate traded below the Federal Reserve discount rate. Based on this reasoning, the Fed’s algorithm for constructing the real-time potential output series is placed in service at 1966:Q1. Prior to this date, I set the real-time measure of potential output equal to true potential output. Thus I assume that the U.S. economy was fluctuating around its steady state before the Fed sought to exert control through the federal funds rate in the mid-1960s. Occasionally, a particular sequence of shock realizations will cause the federal funds rate to become negative. Overall, however, I find that this occurs in only about 3 percent of the periods during the simulations.

Each model simulation produces a set of artificial data on interest rates, inflation, and real output. Given the artificial data, I take the perspective of an econometrician who estimates the Fed’s policy rule for two different sam-

ple periods. The first sample period runs from 1966:Q1 to 1979:Q2. The second sample period runs from 1980:Q1 to 2001:Q2. These sample periods are representative of those typically used in the empirical policy rule literature.<sup>17</sup> I consider two possible misspecifications of the econometrician’s regression equation. First, he uses a final-data potential output series in place of the Fed’s real-time potential output series. I assume that the final-data potential output series coincides exactly with the true potential output series.<sup>18</sup> Second, the econometrician may adopt a functional form that differs from the Taylor-type rule that is being used by Fed policymakers.

#### 4. Results: The Illusion of Interest Rate Smoothing

The results of the quantitative simulations are summarized in Tables 1 through 4 and Figures 2 through 7.

Table 1 presents the results of policy rule regressions on model-generated data for the case where the econometrician employs the correct functional form for the regression equation, i.e., a Taylor-type rule. In this case, the only misspecification involves the use of a final-data potential output series in place of the real-time series. The table shows that the estimated inertia parameter  $\hat{\rho}$  is positive and statistically significant in nearly all of the 1,000 trials, even though the Fed is actually using a Taylor-type rule with  $\rho = 0$ .<sup>19</sup> The average magnitude of the spurious regression coefficient is around 0.3 in the first sample period and 0.4 in the second sample period. As noted in Section 2.2, the econometrician’s estimate of the inertia parameter is biased upwards because the lagged funds rate helps compensate for missing variables that influence the period-by-period setting of the funds rate. The missing variables are the Fed’s serially correlated real-time measurement errors. With the inclusion of the lagged funds rate, the empirical fit of the misspecified rule is actually quite good; the average  $\bar{R}^2$  statistic exceeds 90 percent.<sup>20</sup>

17. Empirical policy rule studies typically allow for a break in the monetary policy regime sometime in the late 1970s. For evidence of such a break, see Estrella and Fuhrer (1999).

18. Qualitatively similar results are obtained if the econometrician constructs his own final-data potential output series either by applying the HP filter over the entire sample period 1947:Q1 to 2001:Q2 or by fitting a quadratic trend over the same period.

19. If the  $t$ -statistic associated with a given regression coefficient is above the critical value of 1.96, then the econometrician rejects the null hypothesis that the true value of that coefficient is zero.

20. The  $\bar{R}^2$  statistic gauges the fraction of the variance in the federal funds rate that can be explained by the variables on the right-hand side of the regression equation (with a correction factor applied for the number of regressors).

15. The data are described in Croushore and Stark (1999).

16. Allowing for a downward shift in the level of potential output at 1995:Q4 has a negligible impact on the quantitative results.

FIGURE 1  
U.S. REAL GDP, 1947:Q1 TO 2001:Q2

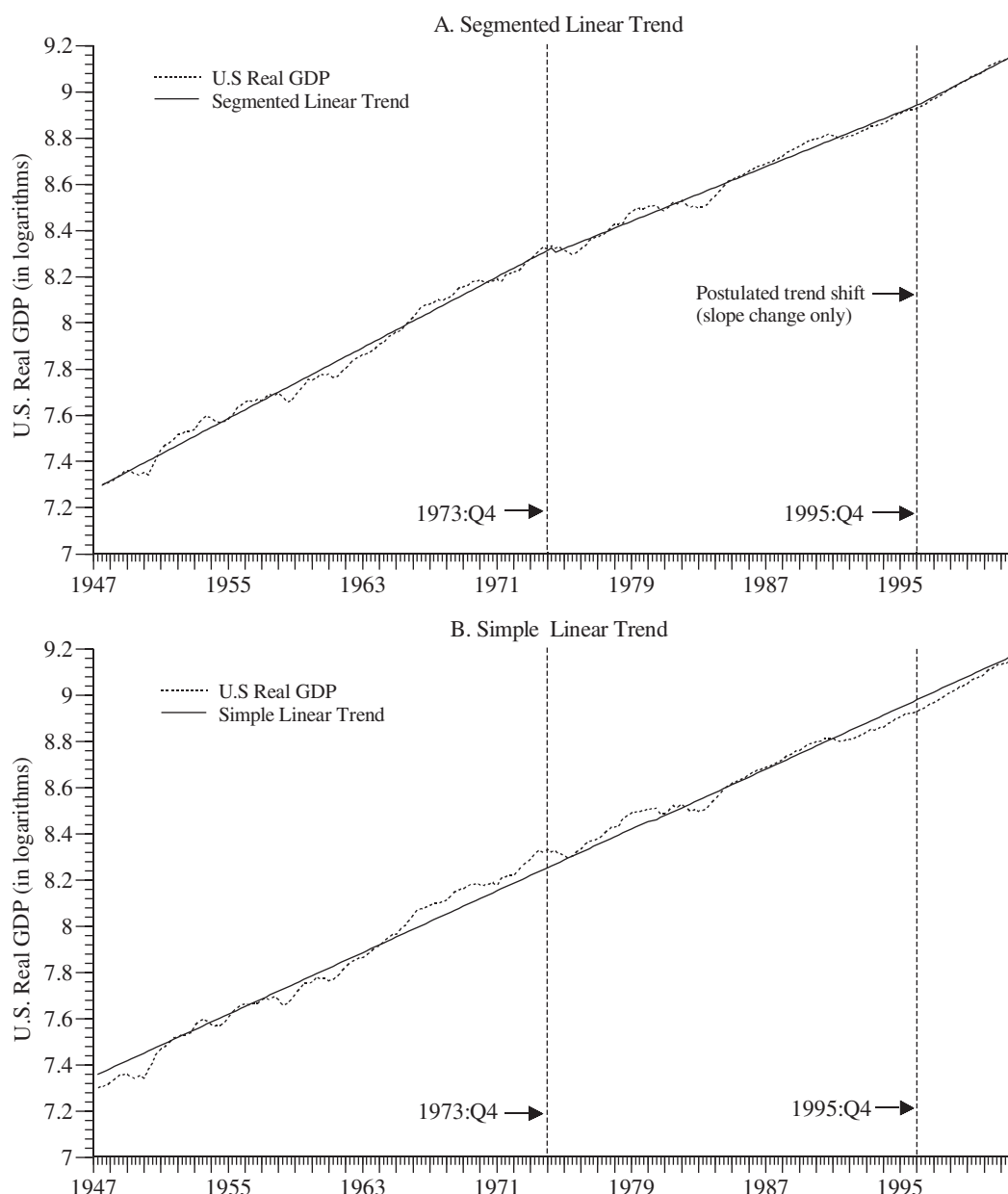


Table 1 also shows that the average point estimate of the inertia parameter does not change much when the model is simulated without trend shifts. This is due to the nature of the regression algorithm (the HP filter) that is used to construct the Fed's real-time estimate of potential output. As discussed further below, the regression algorithm gives rise to serially correlated real-time measurement errors even when there is no fundamental change in the underlying economy.

The average point estimate for the inflation response coefficient  $\hat{g}_\pi$  in Table 1 is around 1.4, only slightly below

the true value of  $g_\pi = 1.5$ . The estimated coefficient is statistically significant in 100 percent of the trials. Hence, the econometrician's use of the final-data potential output series does not lead to significantly incorrect conclusions about the Fed's desired response to inflation during either of the two sample periods. This point relates to the studies by Perez (2001) and Mehra (2001), each of which investigates whether the Fed's desired response to inflation was less aggressive during the 1970s. Both authors note that policy rule regressions based on final data suggest that the desired funds rate moved less than one-for-one with

TABLE 1  
POLICY RULE REGRESSIONS ON MODEL-GENERATED DATA

Actual Taylor-type rule:

$$i_t = 0i_{t-1} + (1 - 0) [0.0085 + 1.5 \pi_{t-1} + 1.0 (y_{t-1} - \bar{x}_{t-1})]$$

Estimated Taylor-type rule:

$$i_t = \hat{\rho}i_{t-1} + (1 - \hat{\rho}) [\hat{g}_0 + \hat{g}_\pi \pi_{t-1} + \hat{g}_y (y_{t-1} - \bar{y}_{t-1})] + \varepsilon_t$$

Model Sample Period	Model with Trend Shifts				Model without Trend Shifts			
	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$
1966:Q1 to 1979:Q2								
Average point estimate	0.34	0.011	1.40	0.22	0.29	0.014	1.37	0.22
Standard deviation of point estimate	0.12	0.008	0.16	0.22	0.12	0.007	0.14	0.20
Average <i>t</i> -statistic	3.81	2.98	18.0	1.99	3.53	4.69	21.5	2.39
% trials with <i>t</i> > 1.96	91.1%	66.3%	100%	46.3%	85.2%	82.5%	100%	31.1%
	Average $\bar{R}^2 = 0.92$ , Average $\sigma_\varepsilon = 0.006$				Average $\bar{R}^2 = 0.94$ , Average $\sigma_\varepsilon = 0.005$			
1980:Q1 to 2001:Q2								
Average point estimate	0.39	0.015	1.37	0.03	0.39	0.014	1.37	0.04
Standard deviation of point estimate	0.09	0.004	0.09	0.13	0.09	0.004	0.09	0.14
Average <i>t</i> -statistic	5.75	6.36	28.5	0.08	5.65	6.06	28.4	0.24
% trials with <i>t</i> > 1.96	99.5%	96.2%	100%	31.5%	99.2%	94.8%	100%	31.1%
	Average $\bar{R}^2 = 0.95$ , Average $\sigma_\varepsilon = 0.006$				Average $\bar{R}^2 = 0.95$ , Average $\sigma_\varepsilon = 0.006$			

Notes: Model statistics are based on 1,000 simulations.  $\sigma_\varepsilon$  is the standard deviation of a serially uncorrelated zero-mean error  $\varepsilon_t$ , added for the purpose of estimation.  $\bar{x}_t$  = Fed's real-time potential output defined by the HP filter with  $\lambda = 1,600$ .  $\bar{y}_t$  = econometrician's final-data potential output defined by a segmented linear trend (Figure 1A) or a simple linear trend (Figure 1B).

inflation (or expected inflation) during the 1970s.<sup>21</sup> Perez (2001) shows that a policy rule estimated using reconstructed historical data yields the opposite conclusion, i.e., the desired funds rate moved *more* than one-for-one with expected inflation during the 1970s.<sup>22</sup> Perez adopts a rule specification where the Fed reacts to real-time forecasts of *future* inflation. The real-time forecasts appear to have systematically underpredicted actual inflation during the 1970s. In contrast, the model-based regressions performed here apply to an economy where the Fed reacts to *lagged* inflation which I assume is observed without error. Also using reconstructed historical data, Mehra (2001) finds that the desired response to inflation during the 1970s was less than one-for-one for a rule where the Fed reacts to the quarterly inflation rate, but not significantly different from one-for-one for a rule where the Fed reacts to a “smoothed” inflation rate defined by a four-quarter moving average of the quarterly inflation rate. Both of these studies demonstrate the general point, also emphasized here, that

empirical estimates of the Fed's policy rule are sensitive to the data vintage and the functional form adopted by the econometrician.

The average point estimate for the output gap response coefficient  $\hat{g}_y$  in Table 1 is substantially below the true value of  $g_y = 1.0$ , particularly during the second sample period. Moreover, the estimated coefficient is statistically significant in less than one-half of the trials. This result shows that quarterly variations in the final-data output gap do not hold much explanatory power for quarterly movements in the model funds rate.

As a benchmark for comparison, Table 2 presents the results of regressing a Taylor-type policy rule on “final” U.S. data of vintage 2001:Q3. For both sample periods, the estimated coefficient  $\hat{\rho}$  on the lagged federal funds rate is around 0.8 and strongly significant. This confirms the statement made earlier that regressions based on final data imply a high degree of policy inertia at quarterly frequency. The table also shows that the estimated values of the other policy rule coefficients,  $\hat{g}_0$ ,  $\hat{g}_\pi$ , and  $\hat{g}_y$ , differ substantially across the two sample periods.<sup>23</sup> Placing an

21. For discussions of this result, see Taylor (1999) and Clarida, et al. (2000).

22. Perez (2001) obtains this result for two different sample periods: the first runs from 1975:Q1 to 1979:Q2 and the second runs from 1969:Q1 to 1976:Q3.

23. The regression coefficient  $\hat{g}_0$  is an estimate of the combined coefficient  $g_0 \equiv \bar{r} + \bar{\pi} (1 - g_\pi)$ . Without additional information, the data cannot separately identify the values of  $\bar{r}$  and  $\bar{\pi}$ .



TABLE 2  
POLICY RULE REGRESSIONS ON FINAL U.S. DATA (VINTAGE 2001:Q3)

Estimated Taylor-type rule:

$$i_t = \hat{\rho}i_{t-1} + (1 - \hat{\rho})[\hat{g}_0 + \hat{g}_\pi \pi_{t-1} + \hat{g}_y(y_{t-1} - \bar{y}_{t-1})] + \varepsilon_t$$

U.S. Sample Period	Regression with Trend Shifts				Regression without Trend Shifts			
	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$
1966:Q1 to 1979:Q2								
U.S. point estimate	0.80	0.033	0.45	1.19	0.70	-0.026	0.66	1.06
U.S. <i>t</i> -statistic	8.82	1.69	1.37	2.45	7.38	-1.36	3.26	3.81
	$\bar{R}^2 = 0.83, \sigma_\varepsilon = 0.009$				$\bar{R}^2 = 0.84, \sigma_\varepsilon = 0.009$			
1980:Q1 to 2001:Q2								
U.S. point estimate	0.77	0.025	1.38	0.24	0.74	0.037	1.17	0.32
U.S. <i>t</i> -statistic	13.0	2.70	6.02	0.98	12.0	3.43	4.92	1.66
	$\bar{R}^2 = 0.91, \sigma_\varepsilon = 0.010$				$\bar{R}^2 = 0.91, \sigma_\varepsilon = 0.010$			

Notes:  $\sigma_\varepsilon$  is the standard deviation of a serially uncorrelated zero-mean error  $\varepsilon_t$  added for the purpose of estimation.  $\bar{y}_t$  = final-data potential output defined by a segmented linear trend (Figure 1A) or a simple linear trend (Figure 1B).

economic interpretation on these results is problematic, however, because policymakers did not see the final data—instead they saw the data that was available at the time policy decisions were made. The real-time data may have presented a very different picture of the economy. Indeed, recent studies by Croushore and Stark (1999), Orphanides (2000, 2001), Perez (2001), and Mehra (2001) make it clear that retrospective analyses based on real-time data often can lead to conclusions that differ from those based on final data.

Figure 2 compares the average trajectory of the Fed's real-time potential output series  $\{\bar{x}_t\}$  with the true potential output series  $\{\bar{y}_t\}$  for the case where the model includes trend shifts. In the periods after the first trend shift at 1973:Q4, the incoming data on real output  $y_t$  (which are fully observable to policymakers) start to plot below the Fed's previously estimated trend because of the unobserved structural break. Fed policymakers interpret the data as evidence of a recession. Following the advice of their policy rule, they lower the federal funds rate in response to the perceived negative output gap. The drop in the funds rate stimulates aggregate demand. Stronger demand, combined with the abrupt reduction in the economy's productive capacity, causes the true output gap to become positive (Figure 3). Later, as more data are received, the Fed adjusts its estimated trend, shrinking the size of the perceived negative output gap.<sup>24</sup>

By the time of the second trend shift at 1995:Q4, the divergence between the true gap and the perceived gap has

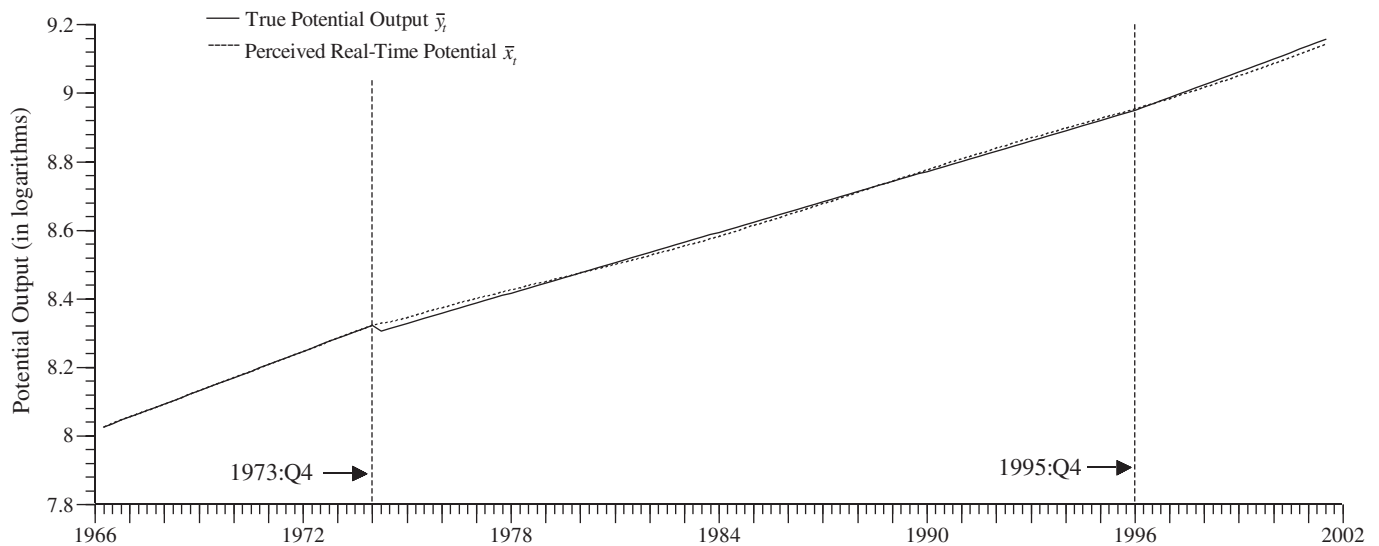
been reduced but not eliminated (Figure 3). In the periods after the second trend shift, the incoming data on  $y_t$  start to plot above the Fed's previously estimated trend because of the unobserved structural break. Fed policymakers interpret the data as evidence of a boom. Following the advice of their policy rule, they raise the federal funds rate in an effort to restrain aggregate demand. This action, combined with expansion in the economy's productive capacity, pushes the true output gap into negative territory while the Fed's perceived gap becomes positive.

The divergence between the perceived real-time gap and the true gap shown in Figure 3 represents the Fed's real-time measurement error. The divergence narrows over time as the Fed's regression algorithm detects the trend shift. Figure 4 plots the trajectory of the real-time error. The real-time errors are highly serially correlated with an autocorrelation coefficient of 0.99. Negative errors tend to be followed by negative errors while positive errors tend to be followed by positive errors. The standard deviation of the real-time errors over the period 1966:Q1 to 2001:Q2 is 2.6 percent (averaged over 1,000 simulations). The statistical properties of the real-time errors are similar to those documented by Orphanides and van Norden (1999) for a variety of real-time methods of trend estimation. This result suggests that the basic nature of the results does not depend on the particular regression algorithm used by Fed policymakers in the model.<sup>25</sup>

24. Further details on the behavior of the output gap, inflation, and the federal funds rate during the model simulations can be found in Lansing (2000).

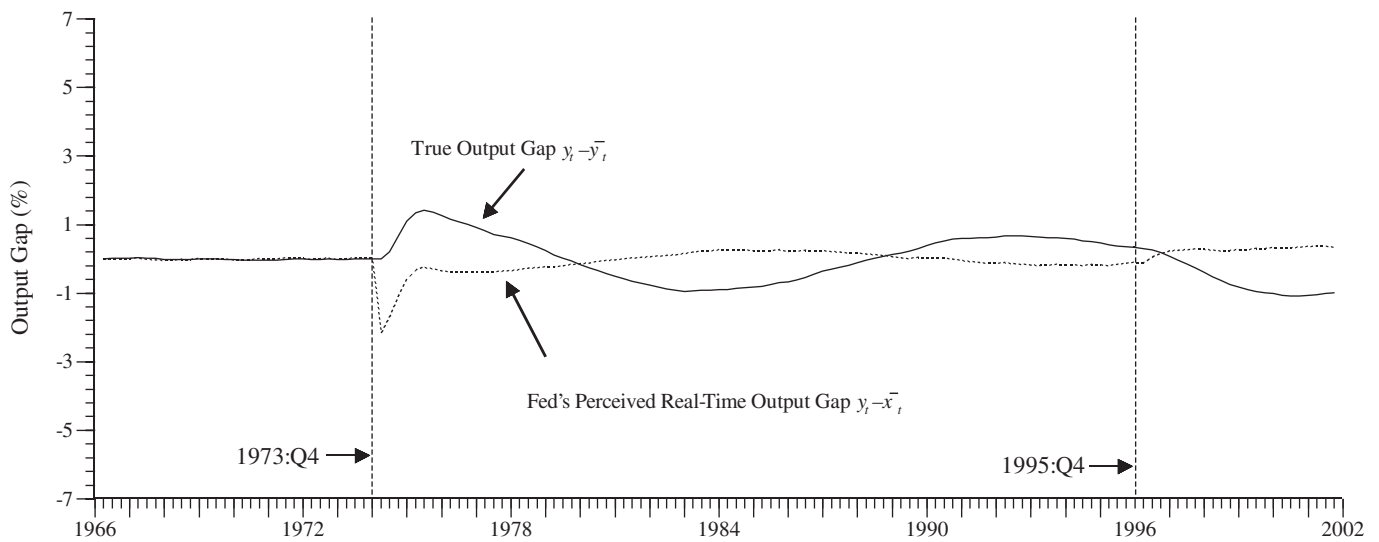
25. The standard deviation of the final-data output gap in the model is 2.37 percent. The standard deviation of the final-data output gap in U.S. data (defined by a segmented linear trend) is 2.24 percent. For additional details, see Lansing (2000).

FIGURE 2  
MODEL POTENTIAL OUTPUT



Note: Average trajectory taken from 1,000 simulations, model with trend shifts.

FIGURE 3  
MODEL OUTPUT GAP

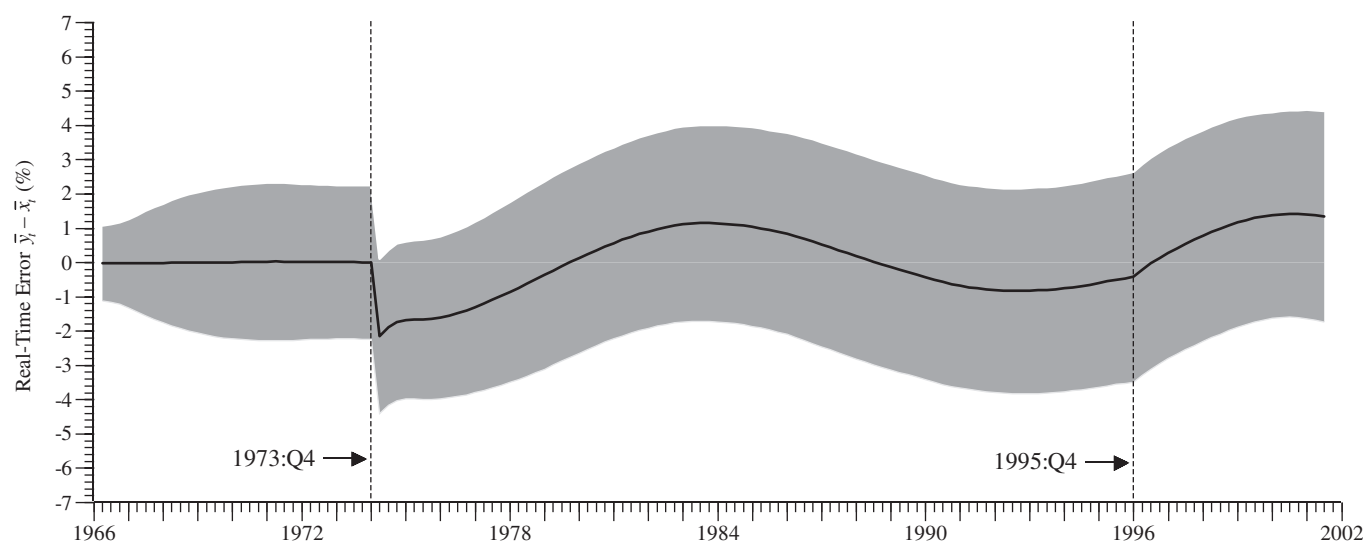


Note: Average trajectory taken from 1,000 simulations, model with trend shifts.

Figure 5 shows that the Fed's regression algorithm exhibits overshooting behavior. Overshooting occurs because the HP filter assigns a relatively high weight to the most recent data. If a sequence of recent data observations happens to fall mostly above or mostly below the Fed's previously estimated trend, then the Fed's real-time estimate of potential output can undergo a substantial revision even when there is no trend shift in the underlying econ-

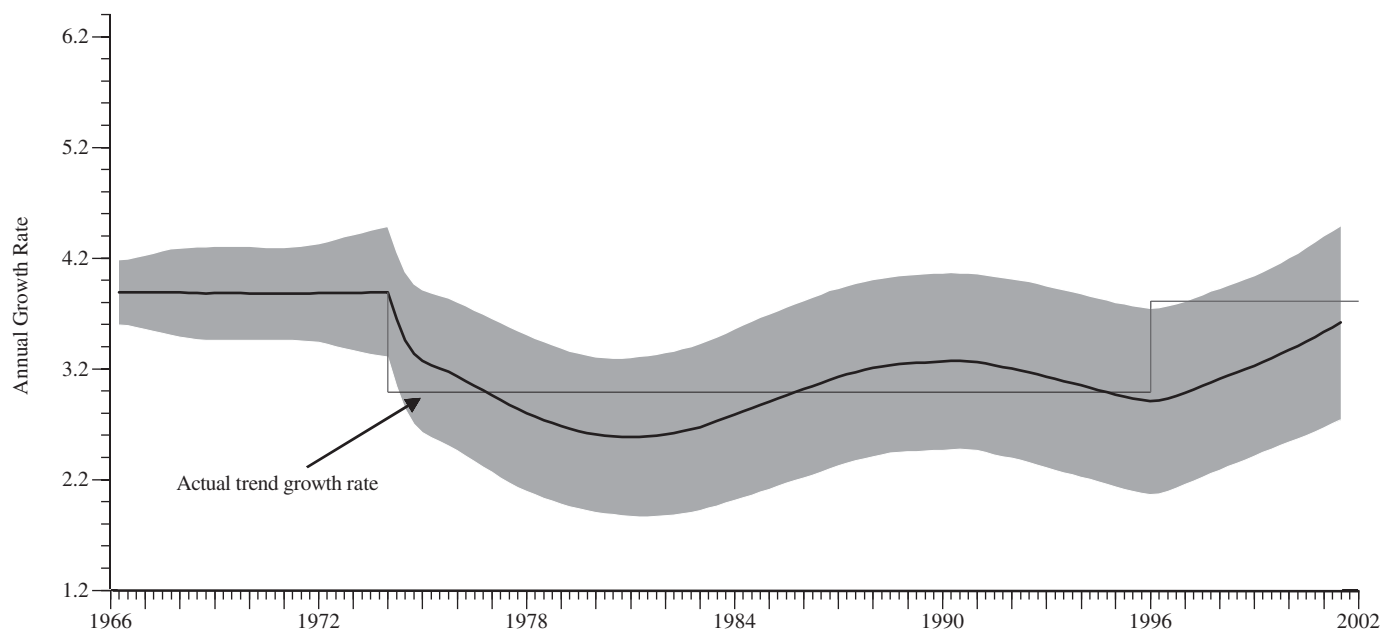
omy. This point is illustrated in Figures 4 and 5 by the fairly wide standard error bands that can be observed around the average trajectories even before the first trend shift takes place at 1973:Q4. The errors induced by the Fed's regression algorithm during normal times are a trade-off for being able to detect a trend shift more quickly when it does occur.

FIGURE 4  
FED'S REAL-TIME MEASUREMENT ERROR



Note: Average trajectory taken from 1,000 simulations, model with trend shifts. Gray band shows  $\pm 1$  standard deviation.

FIGURE 5  
FED'S ESTIMATED GROWTH RATE OF POTENTIAL OUTPUT



Note: Average trajectory taken from 1,000 simulations, model with trend shifts. Gray band shows  $\pm 1$  standard deviation.

TABLE 3  
POLICY RULE REGRESSIONS ON MODEL-GENERATED DATA

Actual Taylor-type rule:

$$i_t = 0i_{t-1} + (1 - 0) \{0.0085 + 1.5\pi_{t-1} + 1.0[(y_{t-1} - \bar{x}_{t-1}) - 0(y_{t-2} - \bar{x}_{t-2})]\}$$

Estimated general rule:

$$i_t = \hat{\rho}i_{t-1} + (1 - \hat{\rho}) \left\{ \hat{g}_0 + \hat{g}_\pi \pi_{t-1} + \hat{g}_y \left[ (y_{t-1} - \bar{y}_{t-1}) - \hat{\phi} (y_{t-2} - \bar{y}_{t-2}) \right] \right\} + \varepsilon_t$$

Model Sample Period	Model with Trend Shifts					Model without Trend Shifts				
	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$	$\hat{\phi}$	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$	$\hat{\phi}$
1966:Q1 to 1979:Q2										
Average point estimate	0.39	0.006	1.51	1.39	0.88	0.33	0.010	1.47	1.31	0.88
Standard deviation of point estimate	0.11	0.008	0.16	0.44	0.16	0.10	0.006	0.12	0.31	0.13
Average <i>t</i> -statistic	5.26	1.88	19.1	4.26	14.5	5.36	3.88	25.9	5.74	18.5
% trials with <i>t</i> > 1.96	98.2%	45.4%	100%	99.6%	99.7%	98.1%	75.7%	100%	100%	100%
	Average $\bar{R}^2 = 0.95$ , Average $\sigma_\varepsilon = 0.005$					Average $\bar{R}^2 = 0.96$ , Average $\sigma_\varepsilon = 0.004$				
1980:Q1 to 2001:Q2										
Average point estimate	0.40	0.010	1.49	1.40	1.00	0.40	0.009	1.48	1.40	0.99
Standard deviation of point estimate	0.07	0.004	0.08	0.29	0.08	0.07	0.003	0.08	0.28	0.08
Average <i>t</i> -statistic	8.04	5.02	34.3	6.39	31.6	7.97	4.74	34.7	6.56	31.7
% trials with <i>t</i> > 1.96	100%	90.1%	100%	100%	100%	100%	87.7%	100%	100%	100%
	Average $\bar{R}^2 = 0.97$ , Average $\sigma_\varepsilon = 0.004$					Average $\bar{R}^2 = 0.98$ , Average $\sigma_\varepsilon = 0.004$				

Notes: Model statistics are based on 1,000 simulations.  $\sigma_\varepsilon$  is the standard deviation of a serially uncorrelated zero-mean error  $\varepsilon_t$  added for the purpose of estimation.  $\bar{x}_t =$  Fed's real-time potential output defined by the HP filter with  $\lambda = 1,600$ .  $\bar{y}_t =$  econometrician's final-data potential output defined by a segmented linear trend (Figure 1A) or a simple linear trend (Figure 1B).

Table 3 presents the results of policy rule regressions on model-generated data for the case where the econometrician adopts the wrong functional form for the Fed's policy rule. The econometrician estimates a general rule that includes the twice-lagged output gap  $(y_{t-2} - \bar{y}_{t-2})$ . As before, the econometrician employs a final-data potential output series in place of the Fed's real-time series. The results are broadly similar to those reported in Table 1. Notice, however, that the average magnitude of the spurious regression coefficient  $\hat{\rho}$  is slightly higher than before. As would be expected, the econometrician's use of the wrong functional form contributes to the upward bias in  $\hat{\rho}$ . This effect is partially offset, however, by the presence of the twice-lagged output gap, which helps to reduce the dependence on the lagged funds rate when fitting the misspecified rule to the data. The twice-lagged gap is strongly significant in nearly all of the trials with an average point estimate of  $\hat{\phi} \approx 1$ . The intuition for the spurious significance of the twice-lagged gap is straightforward. Since the true output gap is highly serially correlated, a point estimate of  $\hat{\phi} \approx 1$  allows successive true output gaps (which contain little explanatory power for  $i_t$ ) to offset one another. Given that the average point estimates imply  $\hat{g}_\pi \approx \hat{g}_y$  and  $\hat{\phi} \approx 1$ , the econometrician may conclude that Fed policymakers are using a smoothed nominal

income growth rule when, in fact, they are using an unsmoothed Taylor-type rule.<sup>26</sup>

Table 4 presents the results of regressing the general policy rule on final U.S. data (vintage 2001:Q3). The estimated coefficient  $\hat{\rho}$  on the lagged funds rate is again in the neighborhood of 0.8. The estimated coefficient  $\hat{\phi}$  on the twice-lagged output gap is statistically significant in both sample periods. In the sample period that runs from 1980:Q1 to 2001:Q2, it is unlikely that one could reject the hypothesis of  $\hat{g}_\pi = \hat{g}_y$  and  $\hat{\phi} = 1$ . Hence, just as in the model-based regressions described above, the time path of the U.S. federal funds rate since 1980 appears to be well approximated by a smoothed nominal income growth rule.<sup>27</sup> Unlike the model, however, we cannot know for sure what policy rule (if any) was being used by Fed policymakers during this sample period.

It is important to recognize that the value of  $\hat{\rho}$  reported in Tables 1 and 3 is an *average* point estimate computed over the course of many simulations. In any given simula-

26. Recall that a nominal income growth rule can be represented as a special case of equation (5) with  $g_\pi = g_y$  and  $\phi = 1$ . See the appendix for details.

27. This result confirms the findings of McCallum and Nelson (1999).

TABLE 4  
POLICY RULE REGRESSIONS ON FINAL U.S. DATA (VINTAGE 2001:Q3)

Estimated general rule:

$$i_t = \hat{\rho}i_{t-1} + (1 - \hat{\rho}) \left\{ \hat{g}_0 + \hat{g}_\pi \pi_{t-1} + \hat{g}_y \left[ (y_{t-1} - \bar{y}_{t-1}) - \hat{\phi} (y_{t-2} - \bar{y}_{t-2}) \right] \right\} + \varepsilon_t$$

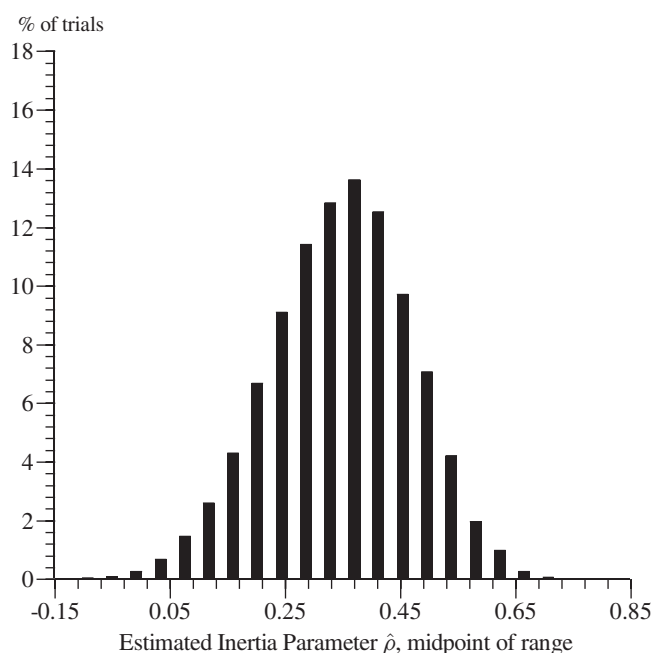
U.S. Sample Period	Regression with Trend Shifts					Regression without Trend Shifts				
	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$	$\hat{\phi}$	$\hat{\rho}$	$\hat{g}_0$	$\hat{g}_\pi$	$\hat{g}_y$	$\hat{\phi}$
1966:Q1 to 1979:Q2										
U.S. point estimate	0.93	0.033	0.40	8.50	0.73	0.80	-0.044	0.79	2.68	0.51
U.S. <i>t</i> -statistic	10.1	0.64	0.45	0.73	6.37	7.61	-1.27	2.60	1.64	3.06
	$\bar{R}^2 = 0.86, \sigma_\varepsilon = 0.008$					$\bar{R}^2 = 0.86, \sigma_\varepsilon = 0.009$				
1980:Q1 to 2001:Q2										
U.S. point estimate	0.76	0.021	1.51	1.63	0.91	0.74	0.030	1.37	1.54	0.85
U.S. <i>t</i> -statistic	13.2	2.33	6.69	2.24	6.76	12.3	2.70	5.41	2.40	6.44
	$\bar{R}^2 = 0.91, \sigma_\varepsilon = 0.010$					$\bar{R}^2 = 0.92, \sigma_\varepsilon = 0.010$				

Notes:  $\sigma_\varepsilon$  is the standard deviation of a serially uncorrelated zero-mean error  $\varepsilon_t$  added for the purpose of estimation.  $\bar{y}_t$  = final-data potential output defined by a segmented linear trend (Figure 1A) or a simple linear trend (Figure 1B).

tion, the estimated coefficient on the lagged funds rate may turn out to be higher or lower than the average value. Figures 6 and 7 show the distribution of point estimates generated by the model for each of the two sample periods.<sup>28</sup> The mean of the distribution is slightly higher in the second sample period because the Fed's regression algorithm has been running longer at that point.<sup>29</sup> This increases the probability that the regression algorithm will generate serially correlated real-time measurement errors. For the sample period that runs from 1966:Q1 to 1979:Q2 (Figure 6), the 95 percent confidence interval for the estimated inertia parameter ranges from a low of 0.09 to a high of 0.57.<sup>30</sup> For the sample period that runs from 1980:Q1 to 2001:Q2 (Figure 7), the 95 percent confidence interval ranges from a low of 0.20 to a high of 0.57. These confidence intervals suggest that the model-generated distributions can be approximated by standard normal distributions with the means and standard deviations shown in Tables 1 and 3.

In contrast to the model simulations, the point estimate for the U.S. inertia parameter reported in Tables 2 and 4

FIGURE 6  
DISTRIBUTION OF POINT ESTIMATES GENERATED  
BY MODEL WITH TREND SHIFTS,  
SIMULATED SAMPLE PERIOD 1966:Q1 TO 1979:Q2



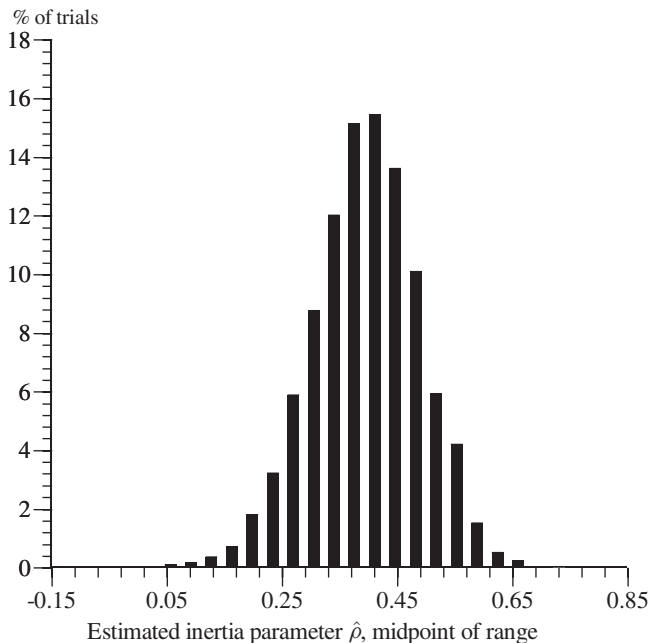
28. In constructing the histograms in Figures 6 and 7, the number of model simulations was increased to 5,000 in order to provide a more accurate picture of the true distribution governing the point estimates.

29. Recall that the Fed's regression algorithm is placed in service at 1966:Q1.

30. In other words, the estimated inertia parameter fell within this interval in 4,750 simulations out of a total of 5,000 simulations  $\left(\frac{4,750}{5,000} = 0.95\right)$ .



FIGURE 7  
DISTRIBUTION OF POINT ESTIMATES GENERATED  
BY MODEL WITH TREND SHIFTS,  
SIMULATED SAMPLE PERIOD 1980:Q1 TO 2001:Q2



represents the outcome of a *single* regression. The point estimate is influenced by the particular sequence of random shocks that hit the U.S. economy during a given period of history. In Table 2, for example, the point estimate for the U.S. inertia parameter is  $\hat{\rho} = 0.77$  when the sample period runs from 1980:Q1 to 2001:Q2 and the regression allows for trend shifts.

By comparing the U.S. point estimate to the distribution of point estimates generated by the model, one may conclude that there is less than a 1 percent chance that the model would produce a point estimate as high as  $\hat{\rho} = 0.77$  during a single simulation. This tells us that the model cannot explain all of the inertia that we observe in the U.S. federal funds rate. Nevertheless, there is a 50 percent chance that the model would produce a point estimate as high as  $\hat{\rho} = 0.39$  during a single simulation and a 25 percent chance that the model would produce a point estimate as high as  $\hat{\rho} = 0.46$ . Hence, the model can easily explain about one-half of the inertia that we observe in the U.S. federal funds rate.

One might argue that it makes sense for the model not to explain all of the U.S. inertia because the model abstracts from real-time errors in observing inflation or real output. Noise or measurement error in these variables may have influenced the setting of the U.S. federal funds rate during

a given sample period. Indeed, Orphanides (2000) presents evidence which suggests that the Fed's real-time measures of inflation (based on a GDP price index) and real output were both too low in the early 1970s. The model also abstracts from any persistent changes in the real interest rate term  $\bar{r}$  which appears in the policy rule equation (5). Rudebusch (2002) notes that a variety of economic influences (e.g., credit crunches, financial crises) can be interpreted as involving a temporary but persistent shift in the real interest rate. A perceived shift in  $\bar{r}$  would induce movements in the funds rate that cannot be explained by observable changes in inflation or the output gap. Finally, the model abstracts from the difficult issue of determining which particular price index policymakers actually use when deciding whether current inflation has deviated from the Fed's long-run target rate. Unlike the model, there are many possible ways to define inflation in the U.S. economy.<sup>31</sup> The above considerations, if incorporated into the model, would contribute to an upward bias in the estimated inertia parameter beyond that which is due solely to the Fed's real-time errors in estimating potential output.

## 5. Conclusion

Empirical estimates of the Fed's policy rule based on quarterly U.S. data typically find that the lagged federal funds rate is a significant explanatory variable. The standard interpretation of this result is that the Fed intentionally "smoothes" interest rates, i.e., policymakers move gradually over time to bring the current level of the funds rate in line with a desired level that is determined by economic fundamentals. This paper employed simulations from a small macroeconomic model to demonstrate that efforts to identify the Fed's policy rule using regressions based on final data can create the illusion of interest rate smoothing behavior when, in fact, none exists. I showed that failure to account properly for policymakers' real-time perceptions about potential output can explain as much as one-half of the apparent degree of inertia in the U.S. federal funds rate. Interestingly, the simulated policy rule regressions suggested that Fed policymakers were using a smoothed nominal income growth rule when actually they were using an unsmoothed Taylor-type rule. Overall, the findings presented here lend support to a growing view within the economics profession that empirical results derived solely from an analysis of final data can provide a distorted picture of the monetary policy process.

31. This point has been emphasized recently by Federal Reserve Chairman Alan Greenspan (2001).

## Appendix

Here I show that a nominal income growth rule can be represented by a special case of equation (5). Imposing  $g_\pi = g_y = \theta > 0$ ,  $\phi = 1$ , and then rearranging yields

$$(A1) \quad i_t^* = \bar{r} + \bar{\pi} + \theta [\pi_{t-1} + y_{t-1} - y_{t-2} - (\bar{x}_{t-1} - \bar{x}_{t-2}) - \bar{\pi}],$$

where all rates are expressed initially on a quarterly basis. Quarterly inflation is given by  $\pi_t = \ln(P_t/P_{t-1})$  for all  $t$ , where  $P_t$  is the GDP price index. We also have  $y_t = \ln Y_t$  for all  $t$ , where  $Y_t$  is quarterly real GDP. Substituting these expressions into equation (A1) and rearranging yields

$$(A2) \quad i_t^* = \bar{r} + \bar{\pi} + \theta [G_{t-1} - (\bar{x}_{t-1} - \bar{x}_{t-2}) - \bar{\pi}],$$

where  $G_{t-1} \equiv \ln(P_{t-1}Y_{t-1}) - \ln(P_{t-2}Y_{t-2})$  is the observed quarterly growth rate of nominal income.

Recall that  $\bar{x}_{t-1}$  and  $\bar{x}_{t-2}$  represent the Fed's estimate of the logarithm of potential output for the periods  $t-1$  and  $t-2$ , respectively. Both of these quantities are computed at  $t-1$ , however, because the Fed runs a regression each period and updates its entire potential output series. Since  $\bar{x}_{t-1}$  and  $\bar{x}_{t-2}$  both lie on the best-fit trend line computed at  $t-1$ , we have  $\hat{\mu}_{t-1} = \bar{x}_{t-1} - \bar{x}_{t-2}$ , where  $\hat{\mu}_{t-1}$  is the Fed's real-time estimate of the quarterly growth rate of potential output. Substituting this expression into equation (A2) yields

$$(A3) \quad i_t^* = \bar{r} + \bar{\pi} + \theta [G_{t-1} - (\hat{\mu}_{t-1} + \bar{\pi})],$$

which shows that the desired federal funds rate  $i_t^*$  will be above its steady-state level  $(\bar{r} + \bar{\pi})$  whenever observed nominal income growth  $G_{t-1}$  exceeds the target growth rate of  $\hat{\mu}_{t-1} + \bar{\pi}$ . Multiplying both sides of equation (A3) by 4 converts all quarterly rates to an annual basis.

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# Banks, Bonds, and the Liquidity Effect\*

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An “easing” of monetary policy can be characterized by an expansion of bank reserves and a persistent decline in the federal funds rate that, with a considerable lag, induces a pickup in employment, output, and prices. This article presents empirical evidence consistent with this depiction of the dynamic response of the economy to monetary policy actions and develops a theoretical model that exhibits similar dynamic properties. The decline in the federal funds rate is referred to as the “liquidity effect” of an expansionary monetary policy. A key feature of this class of theoretical models is the restriction that households do not quickly adjust their liquid asset holdings, in particular their bank deposit position, in response to an unanticipated change in monetary policy. Without this restriction, there would be no liquidity effect, as interest rates would rise rather than fall in response to an easing of monetary policy due to higher anticipated inflation. A bond market that enables households to lend directly to firms is shown to provide a mechanism that induces persistence in the liquidity effect that is otherwise absent from the predictions of the model.

## 1. Introduction

The U.S. experience demonstrates that monetary policy can affect real economic activity, not just inflation. The empirical evidence suggests that the impact of monetary policy on the real economy stems from a liquidity effect, in which Federal Reserve actions can affect short-term interest rates that in turn affect spending and investment decisions by households and businesses.

Exactly what accounts for this liquidity effect, however, is not well understood. The challenge in the theoretical literature has been to develop models that include responses in interest rates (and economic activity) to changes in monetary policy that are consistent with the empirical evidence. In particular, the challenge has been to deal with two puzzles: (1) What causes nominal interest rates to fall, rather

than rise, in response to a policy of monetary easing?<sup>1</sup> (2) What causes the effects of monetary policy on real economic decisions to be so persistent?

This article provides empirical evidence on the liquidity effect in the U.S. and highlights recent theoretical research on one channel through which monetary policy is transmitted to the real economy. In this body of research, banks play a central role because they represent a principal source of short-term financing for current business operations. Even with the changes in banking brought on by financial deregulation, this channel remains relevant to monetary policy. While the volume of commercial and industrial (C&I) loans in U.S. commercial banks relative to GDP experienced a steep decline in the early 1990s as shown in Figure 1, it has since recovered to equal roughly

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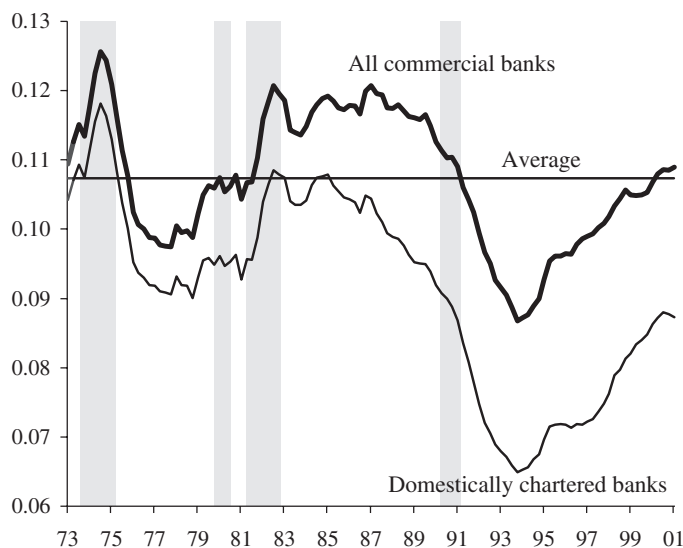
\*We thank Fred Furlong, John Krainer, and Tao Wu for their helpful comments, along with seminar participants at the Federal Reserve Bank of San Francisco, and Chishen Wei for his technical assistance.

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1. An easing of monetary policy in general would be expected eventually to add to inflation (raise the price level). If prices responded and inflation expectations adjusted immediately, a rise in the inflation premium would be expected to increase nominal interest rates.



FIGURE 1  
RATIO OF U.S. COMMERCIAL AND INDUSTRIAL LOANS TO GDP



Source: FAME database.

Notes: "All commercial banks" includes foreign bank affiliates operating in the United States. "Average" refers to the average for all commercial banks.

the long-run average recorded over the 1973:Q1–2001:Q1 period.<sup>2</sup>

A principal focus of this theoretical research on the liquidity effect is the role played by the "precommitment" of bank deposits (and other liquid assets) by households, whereby deposit levels are not quickly adjusted in response to the unexpected injection of reserves into the banking system. This precommitment can be conceptualized (and modeled) as an "information friction" under which households do not take into account this unexpected increase in bank reserves when choosing their deposit positions. A lack of response in bank deposits can cause excess reserves, i.e., reserves that banks hold over and above those required by regulation, to exceed desired levels. Given that reserves are non-interest-bearing assets, banks would like to turn the surplus reserves into loans. To entice borrowers, the bank loan rate may have to fall, thus inducing the "liquidity effect." However, this liquidity effect may vanish as soon as the household adjusts its deposits to reflect the central bank's actions, that is, once the information friction is removed.

2. There has been substantial growth recently in C&I lending by foreign bank affiliates operating in the United States, which accounts for the difference between domestically chartered banks and all commercial banks depicted in Figure 1. For a discussion of this issue, see McCauley and Seth (1992).

One limitation of the models used in much of this literature is the absence of a corporate bond market that can allow households to lend directly to firms. In the absence of this market, all household lending to firms must be intermediated through the banking system, and the only interest-bearing asset available to households is bank deposits. One purpose of this article is to illustrate how the presence of a corporate bond market can increase the magnitude of and induce significant persistence in the liquidity effect that results from a minimalist view of the information friction described above. In effect, as the economy picks up, households respond to their higher income by increasing their savings in the form of bond holdings in order to smooth over time the greater implied future consumption. This greater demand for bonds further lowers market interest rates, thus enhancing the liquidity effect. Given that this increase in bond demand dissipates slowly, it keeps interest rates low over time, thus producing significant persistence in the liquidity effect.

Evidence of the liquidity effect in the U.S. is presented in Section 2. An overview of the theoretical literature related to the liquidity effect is provided in Section 3. In Section 4, we develop a theoretical model that can be used to examine how the information friction and the availability of a corporate bond market to households for saving and to firms for borrowing can offer one solution to the puzzles of the persistent liquidity effect as described above. Conclusions are contained in Section 5.

## 2. Empirical Evidence of a Persistent Liquidity Effect

This section presents evidence on the liquidity effect from empirical results on the relationship between Federal Reserve policy variables and U.S. macroeconomic data. The empirical questions are: How do the macroeconomic variables respond to an unexpected policy change? Is there evidence of a persistent "liquidity effect," as described in the introduction, on which rests a meaningful role for banks to play in the transmission of monetary policy?

The empirical models are taken from Christiano, et al. (1996) and Evans and Marshall (1998) and draw on the work of Christiano (1991) and Sims (1992). They rely on vector autoregressions (VARs) that contain two policy variables and a vector of "information variables" that the Federal Reserve is assumed to monitor in its policy deliberations. The policy variables are the federal funds rate and an empirical measure that is intended to capture the extent to which bank reserves are actively managed by the Federal Reserve through its open market operations. Total reserves comprise "borrowed reserves," i.e., reserves borrowed at the Fed's discount window, and nonborrowed re-



serves. Historically, borrowed reserves have accounted for less than 4 percent of the total and in the past several years have declined to less than 1 percent. It is presumed, as in Chari, et al. (1995) that the Federal Reserve passively administers the discount window to supply reserves on demand, while it actively manages the quantity of nonborrowed reserves in order to attain its monetary policy objectives. Those objectives take the form of inflation and output (or employment) goals. Since monetary policy influences those goal variables with long and variable lags, the Federal Reserve attempts to achieve its goals by setting an intermediate target for one but not both of its policy variables. That is, either it can choose to set the rate of growth of (nonborrowed) reserves and allow the federal funds rate to clear the market for bank reserves in response to fluctuations in demand, or it can choose a federal funds rate and supply reserves through its open market operations in order to ensure that the market clears at that target rate, thus accommodating fluctuations in demand.

In constructing an empirical measure of bank reserves that reflects active monetary policy, the passive supply response of borrowed reserves must be taken into account. In addition, the Federal Reserve has had to accommodate secular changes in reserves demand resulting from an important change in the structure of the federal funds market with the introduction of "sweep accounts" at commercial banks, under which checking account balances in excess of a maximum set by the bank are automatically swept into savings accounts. Sweep arrangements have been widely adopted, especially among large banks. Since their introduction in the mid-1990s, sweep accounts have dramatically reduced the demand for bank reserves.<sup>3</sup>

To account for such changes in total bank reserves that are unrelated to monetary policy, a measure of bank reserves that reflects active monetary policy could be based on the ratio of nonborrowed reserves to total reserves (as, e.g., in Evans and Marshall 1998), where an unexpected increase in this ratio would be associated with an "easing" of monetary policy, and a decline would be associated with a "tightening" of monetary policy. Using unexpected changes in this ratio to identify the policy shocks is consistent with the suggestion of Strongin (1995), who noted that the insensitivity exhibited by the federal funds rate to shocks to total reserves is evidence of an endogenous supply response of borrowed reserves. Therefore, under this construct, a monetary policy shock initially changes only the composition of total reserves between nonborrowed re-

serves and borrowed reserves.<sup>4</sup> This identification of policy shocks from the data also captures the need of the Federal Reserve to adapt to the falling demand for bank reserves as sweep accounts spread nationwide across the banking system.

The information variables that are included in the empirical model are the current and past history of the goal variables, that is, measures of inflation and output (or employment), and an index of sensitive commodity prices. The last of these is intended to capture market expectations of future inflation, and, given that commodity prices are determined in auction markets, it should be informationally efficient.<sup>5</sup>

Quarterly and monthly estimates of the model over the period January 1960 through March 2001 are reported below to indicate the robustness of the results with respect to sampling frequency. The goal variables of GDP and the GDP implicit price deflator (denoted PGDP) that are used in the quarterly model are not available at the monthly frequency; industrial production (IP) and the personal consumption deflator (PCE), respectively, are substituted in the monthly model. The remaining variables include an index of sensitive commodity prices (PCOM) and the two policy variables, taken to be the federal funds rate (RFF) and the ratio of nonborrowed reserves to total reserves (RES).<sup>6</sup> The ordering of the variables in the VAR can affect the results if there is a strong contemporaneous correlation among variables, implying that they carry similar statistical information. When two variables are highly correlated, the variable entered first in the VAR will tend to exhibit greater "explanatory power." In this model, the two policy variables are highly correlated. Therefore, the results are reported for two orderings. The first is: GDP(IP),

4. Strongin argues that total reserves are relatively unresponsive to policy changes in the very short run, and that balance sheet adjustments made by banks to policy shocks occur only with a significant lag. He provides empirical evidence in support of this argument by including total reserves in the VAR described below and demonstrating that the "liquidity effect" identified below is essentially unchanged quantitatively.

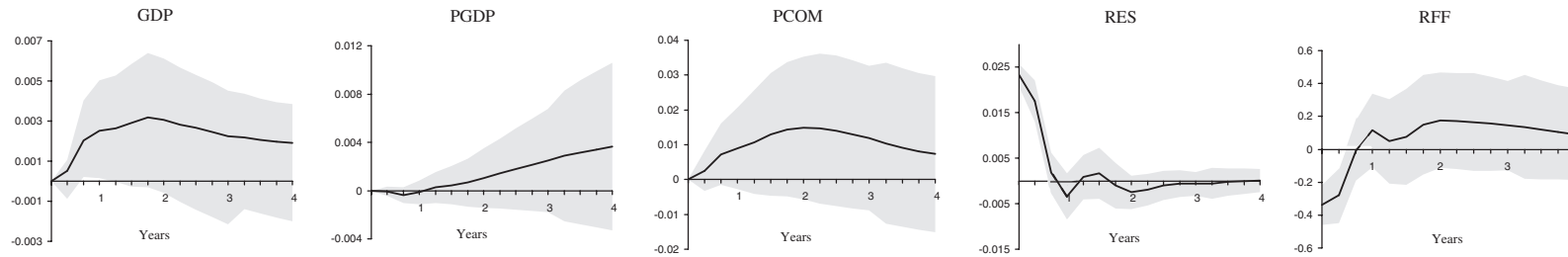
5. Eichenbaum (1992) and Sims (1992) have discussed a so-called "price puzzle" in which goods prices appear to rise in response to a tightening of monetary policy. Sims has suggested that this response could simply reflect the fact that price pressure induced the Federal Reserve to tighten its policy in the first place. Hence, the information of higher future goods price inflation should already be embedded in commodity prices, which the policymakers can easily monitor. As shown by Sims (1992) and others, including this index of commodity prices resolves the price puzzle. See Barth and Ramey (2001) for an alternative explanation of the price puzzle based on a "cost channel" for monetary policy.

6. All data are entered into the VAR in logarithms except for RFF, which is in percent. Four lags are included in the quarterly model and twelve lags in the monthly model.

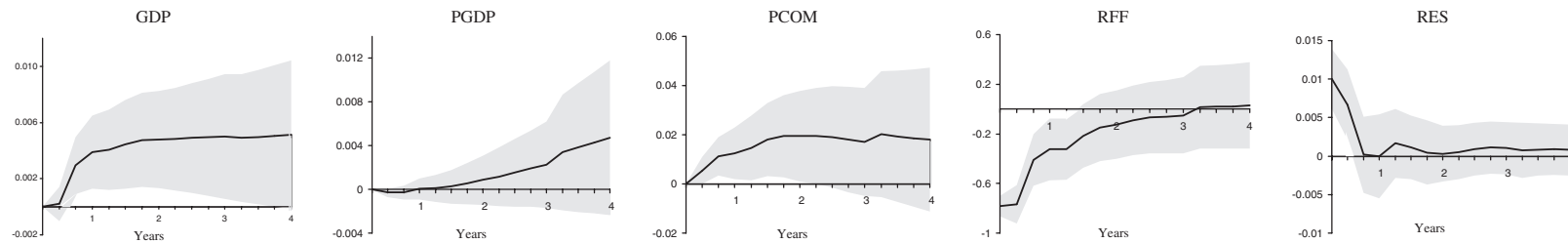
3. With the expanded use of sweeps, total reserves in the banking system fell from a peak of \$6.0 billion in 1994 to approximately \$4.0 billion in 2001.

**FIGURE 2**  
DYNAMIC RESPONSE OF MACROECONOMIC VARIABLES TO ONE STANDARD DEVIATION MONETARY POLICY SHOCKS

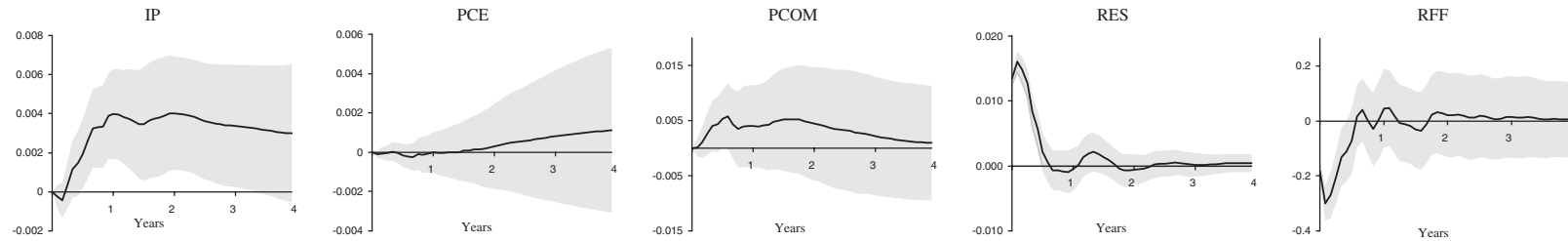
**A. Quarterly Model with Nonborrowed Reserves / Total Reserves as the Policy Variable (RES)**



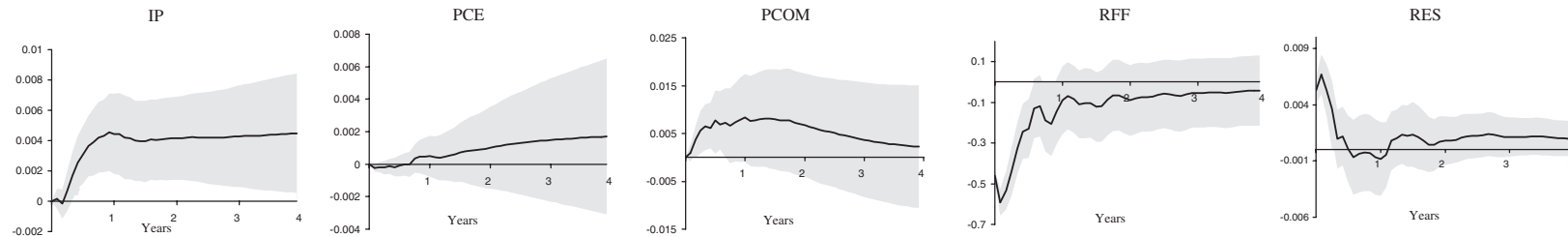
**B. Quarterly Model with the Federal Funds Rate as the Policy Variable (RFF)**



**C. Monthly Model with Nonborrowed Reserves / Total Reserves as the Policy Variable (RES)**



**D. Monthly Model with the Federal Funds Rate as the Policy Variable (RFF)**



Notes: Shocks are one standard deviation positive shocks to reserves (rows A and C) and one standard deviation negative shocks to federal funds rate (rows B and D). Shaded areas show two standard deviation confidence bands.

PGDP(PCE), PCOM, RFF, RES. Qualitatively similar results obtain under the second ordering where RFF and RES are reversed. However, the “liquidity effect,” or the decline in RFF in response to a positive shock to RES, is more pronounced in the latter case.<sup>7</sup>

Figure 2 displays the results of shocking the models with an unexpected “easing” of monetary policy in terms of the dynamic response of each of the five variables in the model. Rows A and B correspond to the quarterly model, where the responses to a one standard deviation *positive* shock to RES (row A) and to a one standard deviation *negative* shock to RFF (a *cut* in the federal funds rate) (row B) are displayed for 16 quarters. Similar responses from the monthly model are displayed in row C for an RES shock and row D for an RFF shock, with responses to these shocks given for the subsequent 48 months. The ordering of the policy variables in the VARs are RES first and RFF second in rows A and C, and vice versa in rows B and D. The first column indicates a positive output (GDP or IP) response to an easing of monetary policy that begins after approximately one quarter. The second column implies a more sluggish adjustment of prices (PGDP and PCE) that sets in after a lag of approximately one year. The third column indicates that commodity prices (PCOM) also rise with the anticipated increase in future inflation. These responses are consistent with the general view that an “easing” of monetary policy due to a cut in the federal funds rate or an expansion of bank reserves stimulates output with a lag and subsequently leads to higher prices.

The last two columns in Figure 2 offer empirical evidence of the “liquidity effect.” As seen in column five of rows A and C, an unexpected expansion of nonborrowed reserves (increase in RES) lowers the federal funds rate (decline in RFF). Using the ordering of RFF preceding RES, similar results are in evidence in rows B and D, where an unexpected cut in the federal funds rate (lower RFF) induces an expansion of bank reserves (rise in RES). These latter results are very robust to sample periods, and they are consistent with theoretical models that emphasize the role played by the banking system in the transmission of monetary policy decisions to the real economy.<sup>8</sup>

### 3. Review of the Literature on the Liquidity Effect

This research hinges to some extent on empirical evidence that is reproduced in Section 2, which suggests that in response to an unexpected increase in (nonborrowed) bank reserves, the federal funds rate declines, followed by an increase in output and employment.<sup>9</sup> With a considerable lag, the federal funds rate then rises back to its original equilibrium level, and the stimulus effect on the economy ceases. However, had this accelerated rate of reserves growth continued, the federal funds rate eventually would have risen above its original equilibrium level. The theoretical rationale for this response is that faster growth in bank reserves ultimately leads to faster growth in the money supply and hence to higher inflation. The markets observe this faster growth rate in bank reserves, expect higher inflation, and factor an inflation premium into nominal interest rates. If this expectation were realized immediately in asset pricing, then interest rates would not fall in response to an “easier” monetary policy, as the data suggest, but instead would rise to their long-run equilibrium level. It is therefore necessary to identify frictions in the economy that preclude this long-run adjustment from taking place quickly. We return to the two puzzles posed in the introduction: What causes nominal interest rates initially to fall rather than to rise in response to an unexpected injection of reserves into the banking system by the Federal Reserve? What causes this effect to be so persistent?

The early theoretical work of Lucas (1990) and Fuerst (1992) identified a possible source of the liquidity effect as a form of market incompleteness in which financial market participants could not fully insure against monetary policy shocks, such that asset portfolios were not immediately adjusted in response to an unanticipated change in monetary policy. Versions of this form of market incompleteness have come to be characterized as “limited participation” in some financial markets by economic agents. As a consequence of this limited participation, an easing of monetary policy corresponds to an unanticipated increase in liquidity in the financial markets, and without a full response on the demand side of those markets, interest rates may have to fall to absorb the additional supply. Fuerst focused on the lack of a demand response on the part of households who would precommit to a liquid asset position that included their holdings of bank deposits. When the central bank injected additional reserves into the banking system, and with no change in bank deposits, the banks would hold

7. Christiano, et al. (1998) attach significance to the ordering of RFF and RES by suggesting that the “instrument” of policy should appear first in the VAR.

8. For an “easing” of monetary policy to have an expansionary effect on the real economy, interest rates that directly affect firm borrowing must also exhibit a “liquidity effect.” Replacing RFF with the 90-day commercial paper rate yields results similar to those displayed in Figure 2.

9. Christiano and Eichenbaum (1999) discuss the identification of “monetary policy shocks” as coincident unanticipated changes in nonborrowed reserves and the federal funds rate that are negatively correlated with each other.

non-interest-earning excess reserves that they would wish to lend out. Given the importance to firms of commercial lending by banks over the business cycle, Fuerst conceived a model under which those excess funds were turned over into working capital loans to firms. In his model, there was no direct lending from households to firms. He illustrated the feasibility of how this slow, liquid asset portfolio adjustment of households to unexpected changes in monetary policy could thus lead to a liquidity effect, or a lowering of market interest rates in response to an easing of monetary policy characterized by an injection of reserves into the banking system.

Using simulations from theoretical models that were calibrated to fit U.S. macroeconomic data, Christiano (1991), Christiano and Eichenbaum (1995), Chari, et al. (1995), Christiano, et al. (1997), Edge (2001), and Einarsson and Marquis (2001a) have examined conditions under which the theoretical possibility of a liquidity effect as described by Fuerst is supported by the data. Christiano (1991) concluded that a precommitment of households to a liquid asset position prior to the reserves shock as in Fuerst was insufficient to induce a dominant liquidity effect, i.e., where the tendency of interest rates to fall in response to the reserves injection is stronger than the tendency of interest rates to rise due to the anticipation of higher future inflation. However, a dominant liquidity effect does result if firms also precommit to their investment decisions prior to the reserves injection. Even then, the liquidity effect does not exhibit the degree of persistence that is evident in the data. One way to obtain this additional persistence is to impose costs on households for adjusting their portfolios quickly, as in Christiano and Eichenbaum (1995) and Chari, et al. (1995).<sup>10</sup>

Much of the theoretical literature on monetary policy does not give banks any significant role in the transmission of monetary policy, but instead relies on an ad hoc formulation of “sticky” or slowly adjusting goods prices. Christiano, et al. (1997) demonstrate that in the absence of incomplete markets as described above, the liquidity effect is incompatible with sticky prices. However, Edge (2001) shows that two features of the model economy that have been used in other macrotheoretic contexts can render a liquidity effect consistent with sticky prices. One feature is the costliness to firms of changing investment decisions, which involve “time to plan” and “time to build” before

putting new capital into place. The second feature is “habit persistence” in household preferences, which characterizes the value that households place on consumption today not in terms of today’s level of consumption, but rather in terms of how today’s consumption compares with the average level of consumption attained in the recent past.

Einarsson and Marquis (2001a, b) add a bond market to the model, which allows firms to have an alternative to banks for their working capital financing needs. They find that in the presence of the bond market, the precommitment by households to their bank deposit position prior to the reserves injection induces a persistent liquidity effect. This persistence requires an overshooting of goods prices from their long-run equilibrium level. They also find that the model predicts a countercyclical role in the degree to which firms rely on bank financing versus alternative sources of financing, and find empirical support for this prediction. The logic of these latter findings and a depiction of models with deposit precommitment are described in a simplified version of the Einarsson and Marquis models in the following section.

#### **4. A Persistent Liquidity Effect:**

##### **A Theoretical Model with Banks and Bonds**

This theoretical model conceives of four major participants in the economy that are each represented by a single decisionmaker: households, firms, banks, and the monetary authority. The model structures time by a sequence of uniform discrete intervals called “periods” over which decisions are made and markets clear. Those periods should be thought of as one quarter in duration. Households own the firms and the banks, and they also hold a portfolio of financial assets that include money, bank deposits, and bonds. Each period, they receive lump sum dividend payments from firms and banks and interest income on bank deposits and bonds. Money and bank deposits are used for transactions in which households purchase consumption goods. Households also provide labor services to firms for which they receive labor income. Firms borrow from households and banks to finance their wage bill and use revenues from sales to finance their capital investment and to retire their debt. Banks take in deposits from households, set aside a sufficient amount of reserves to meet their reserve requirements, and lend out the remainder to firms. The monetary authority supplies bank reserves and currency to the economy. The details of how the important economic decisions of each sector are modeled and how those decisions come together to form a general equilibrium for the economy are described below.

10. Alvarez, et al. (2001) model the market incompleteness described above while abstracting from a financial intermediary and illustrate conditions under which this can lead to a liquidity effect. They simply assume that only a fraction of the households have access to a bond market and the remainder do not. See, also, Alvarez, et al. (2002).



#### 4.1. The Household Sector

The overall objective of the representative household is to maximize the expected present value of a stream of utilities, where each period the household derives positive utility from consumption and from leisure. This objective is expressed mathematically as:

$$(1) \quad \max E \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \quad \beta \in (0, 1),$$

where  $U(C_t, L_t)$  is the period utility function that quantifies the level of utility the household receives in period  $t$  given that its consumption is  $C_t$  and its leisure time is  $L_t$ . The symbol  $\beta$  is the discount factor that establishes how impatient the household is by determining the extent to which it discounts utility that it expects to receive in future periods. A high value of  $\beta$ , i.e., close to 1, implies that the household values future expected consumption highly and hence attaches to it a low rate of discount. The symbol  $E$  is the mathematical expectations operator, which is required since the future is uncertain. The information that the household has available when making its various decisions must be fully specified and is not necessarily the same for all decisions.

The household has three fundamental sets of decisions to make: consumption versus savings, labor versus leisure, and portfolio allocation. In the first, it must decide how much of its wealth to consume today and how much to carry forward. The more that is consumed today, the less that is available for future consumption. Therefore, this decision by the household is intertemporal in nature. Given the amount of savings that the household chooses, it must decide in what form it wishes to carry this wealth forward. In this model, the household must make a portfolio allocation decision among the three financial assets of money, bank deposits, and bonds. Finally, the household must decide how much of its time to devote to labor in order to raise its labor income, at the cost of forgone leisure today.

In making these decisions, the household faces constraints. One is its budget constraint. It cannot allocate more wealth to consumption and savings than it possesses.<sup>11</sup> Mathematically, the budget constraint is given below with “uses” of wealth on the left-hand side and “sources” on the right-hand side.

$$(2) \quad P_t C_t + M_{t+1} + D_{t+1} + B_{t+1} \leq W_t N_t + (1 + r_t^d) D_t + (1 + r_t^b) B_t + M_t + \Pi_t^f + \Pi_t^b.$$

11. There is no borrowing by the representative household, reflecting the fact that collectively households are net suppliers of credit to the economy.

The uses are consumption purchases, or the product of the unit price of output goods,  $P_t$ , times the quantity of consumption goods purchased,  $C_t$ ; and the quantities of money,  $M_{t+1}$ , deposits,  $D_{t+1}$ , and bonds,  $B_{t+1}$ , to carry over to next period, when these decisions are revisited. The sources consist of: labor income, or the wage rate,  $W_t$ , times the amount of labor supplied,  $N_t$ ; the gross return on deposits,  $(1 + r_t^d) D_t$ , where  $D_t$  is the quantity of deposits that the household chose last period, and  $r_t^d$  is the deposit rate; the gross return on corporate bonds,  $(1 + r_t^b) B_t$ , where  $B_t$  is the stock of one-period bonds that the household purchased last period, and  $r_t^b$  is the bond rate; the quantity of money that the household carried over from last period,  $M_t$ ; and the dividend payments that it receives from its ownership in the firms,  $\Pi_t^f$ , and the banks,  $\Pi_t^b$ .

A second constraint that the household faces is in its use of financial assets in conducting transactions. It is assumed that the economy's payment system restricts the household to set aside quantities of liquid assets, i.e., money and deposits, in sufficient amounts to meet its desired level of purchases of consumption goods. Assuming that money and deposits are imperfect substitutes as media of exchange, this constraint is represented mathematically by:

$$(3) \quad P_t C_t \leq G(M_t, D_t).$$

The right-hand side is an increasing function in  $M_t$  and  $D_t$  that characterizes the amount of nominal consumption expenditures that can be supported during the period by the household's liquid asset holdings at the beginning of the period.

Finally, the household is limited in the amount of time that it has available each period, denoted  $T$ , which the sum of its labor supply and leisure cannot exceed.

$$(4) \quad N_t + L_t \leq T.$$

#### 4.2. The Firm Sector

Firms are assumed to maximize the value of their enterprise. This is equivalent to maximizing the expected present value of the current and future dividends that they pay out to shareholders. It is assumed here that dividends are paid out each period and equate to a firm's net cash flows, which has been denoted  $\Pi_t^f$ . Mathematically, this objective can be represented as:

$$(5) \quad \max E \sum_{t=0}^{\infty} \beta^t \beta_t^* \Pi_t^f.$$

Assuming that the firm is acting in the interest of the shareholders, the symbol  $\beta_t^*$  represents the value that the house-



hold places at date  $t$  on receiving a dollar in dividend payments at date  $t$ .<sup>12</sup>

The firm hires labor from households and pays its wage bill by selling bonds to households and by borrowing from the banks. The maturity of these debt instruments is assumed to be one period, reflecting the fact that firms tend to borrow short-term to finance working capital expenses. The total quantity of funds raised by the firm in period  $t$  is denoted by  $Q_{t+1}$ , where the dating convention here indicates the date at which the debt instrument matures. Thus, the financing constraint that applies to this portion of the firm's working capital expenses is given by:

$$(6) \quad W_t N_t \leq Q_{t+1}.$$

The labor that the firm hires is combined with its existing stock of capital, denoted by  $K_t$ , to produce output according to its production technology, which is represented mathematically by the function  $F(\theta_t, K_t, N_t)$ . Supply shocks that affect productivity are embedded in this expression in the random variable,  $\theta_t$ . Consistent with the empirical literature dating back to Robert Solow's seminal work in the 1960s, once a shock to productivity occurs, it is assumed to exhibit a high degree of persistence.<sup>13</sup>

The firm's stock of capital changes in accordance with its gross investment and the rate at which capital depreciates. The stock of capital after investment can therefore be expressed as the undepreciated portion of the beginning-of-period capital stock plus gross investment, denoted by  $I_t$ , or:

$$(7) \quad K_{t+1} = (1 - \delta)K_t + I_t,$$

12. Mathematically,  $\beta_t^* = \beta(U_{C_{t+1}}/P_{t+1})G_{M_{t+1}}$ , where the subscripts on the functions  $U$  and  $G$  represent partial derivatives. The logic of this expression is that the household receives the dividend at the end of the period and cannot spend it immediately, i.e., in period  $t$ . Next period, i.e., in period  $t+1$ , the household can use the dollar to make nominal consumption purchases in the amount given by  $G_{M_{t+1}}$ , which when divided by  $P_{t+1}$  determines the quantity of consumption  $C_{t+1}$  that the household purchases per dollar of dividend received. Each of these consumption units is valued at the marginal utility of consumption  $U_{C_{t+1}}$ , which must be discounted back one period by  $\beta$  to determine its present value at date  $t$ .

13. The standard modeling approach in the literature, e.g., see Kydland and Prescott (1982), is to use the following stochastic process to describe the evolution of total factor productivity:  $\ln \theta_{t+1} = \mu + \rho \ln \theta_t + \epsilon_{t+1}$  where  $\mu > 0$ ,  $\rho \in (0, 1)$  and  $\epsilon_t$  is a zero mean normal random variable with a constant variance. A high value of  $\rho$ , such as 0.99 which is often used for quarterly models, indicates a high degree of persistence. The standard deviation of  $\epsilon_t$  was chosen to be 0.0092, which enabled the volatility in output from the model to roughly match the 1.68 percent standard deviation of output per capita in the quarterly data from 1973:Q1 to 2000:Q1.

where the rate of depreciation per period is given by  $\delta \in (0, 1)$ .

To determine the firm's nominal profits or cash flow for the period, subtract the nominal value of the firm's gross capital investment,  $P_t I_t$ , and its repayment of principal and interest on its maturing debt,  $(1 + r_t^b)Q_t$ , from its nominal sales,  $P_t F(\theta_t, K_t, N_t)$ . This accounting exercise yields:

$$(8) \quad \Pi_t^f = P_t F(\theta_t, K_t, N_t) - P_t I_t - (1 + r_t^b)Q_t.$$

The firm chooses its employment level, which determines the level of output, given its stock of capital and level of productivity, and establishes its borrowings for the current period, given the wage rate. It also must choose its level of investment, which determines the firm's dividend payout, given its level of production and its debt repayment schedule. With an increase in investment today, the funds available for dividends today are reduced, but the production possibilities of next period expand. Therefore, the investment decision is intertemporal in nature and must be made in the face of an uncertain future.

### 4.3. The Banking Sector

The banking sector is assumed to be competitive and the representative bank chooses a sequence of balance sheet positions that maximize the expected present value of net cash flows, which are paid out each period as dividends to its owners, the households. As with the firm, the bank's objective can be expressed mathematically as:

$$(9) \quad \max E \sum_{t=0}^{\infty} \beta^t \beta_t^* \Pi_t^b.$$

The net cash flows of the bank are found by subtracting the principal and interest paid out on deposit accounts,  $(1 + r_t^d)D_t$ , along with the bank's cost of servicing those accounts,  $\xi D_t$ , where  $\xi$  is the marginal cost of servicing deposits, from the principal and interest that it receives on its loans to firms,  $(1 + r_t^b)V_t$ , where  $V_t$  denotes the nominal quantity of working capital loans made to the firm, plus the reserves that the bank is required to maintain,  $Z_t'$ .<sup>14</sup> Performing this accounting exercise:

$$(10) \quad \Pi_t^b = (1 + r_t^b)V_t + Z_t' - (1 + r_t^d)D_t - \xi D_t, \quad \xi \in (0, 1).$$

14. The bank loan rate and the bond rate are identical in equilibrium, since the firm sees the two choices of funding as perfect substitutes. At some cost to the complexity of the model, this can be relaxed as in Einarsson and Marquis (2001a) and Marquis (2001).

In choosing its balance sheet position, the bank must meet its reserve requirements, or:

$$(11) \quad Z_t^r \leq \nu D_t, \quad \nu \in (0, 1),$$

where the reserve requirement ratio, or the fraction of deposits that the bank must hold back in the form of reserves, is denoted by  $\nu$ . It also must satisfy its balance sheet constraint, such that its assets cannot exceed its liabilities, or:

$$(12) \quad Z_t^r + V_t \leq D_t.$$

#### 4.4. The Monetary Authority

The monetary authority chooses to operate in accordance with a rule that governs the evolution of bank reserves. It is assumed that the growth of bank reserves follows a process that has a random component to it. The purpose of this modeling choice is to characterize unanticipated changes in monetary policy by shocks to the growth rate of bank reserves. It is assumed, in accordance with the data, that once a random change in the growth rate of bank reserves occurs, it exhibits a significant degree of persistence. Mathematically, this policy rule can be expressed as:

$$(13) \quad Z_{t+1} = \gamma_t Z_t,$$

where  $Z_t$  denotes the stock of bank reserves determined by the monetary authority, and  $\gamma_t$  represents the gross growth rate of reserves that is subject to persistent random shocks. The central bank supplies money on demand.

#### 4.5. Equilibrium

For this economy to be in equilibrium, households, firms, and the banks must make their respective choices described above such that they attain the objectives of maximizing lifetime utility for households and maximizing the value of the enterprise for firms and banks, while satisfying all of the constraints that the respective decisionmakers face. Those decisions also must produce prices and quantities that clear all of the markets. Notably, the goods market must clear, such that consumption plus investment equals output, or:

$$(14) \quad C_t + I_t = F(\theta_t, K_t, N_t).$$

Also, the total borrowings of the firm must equate to the sum of bonds purchased by the household and the quantity of loans that the firm receives from the bank, or:

$$(15) \quad Q_t = B_t + V_t.$$

Finally, the amount of reserves supplied by the monetary authority is just equal to the quantity of reserves that the bank chooses to hold to meet its required reserves, or

$$(16) \quad Z_t = Z_t^r.$$

#### 4.6. Calibration of the Models

To perform the simulation exercises that will enable the short-run dynamics of the model to be compared with the data, the steady-state version of the model first must be calibrated to the long-run features of the data. For the calibration, the following functional forms were chosen:  $U = \ln C_t + \eta \ln L_t$ ,  $\eta > 0$ ;  $G = g_0 M_t^{g_1} D_t^{1-g_1}$ ,  $g_0 > 0$ ,  $g_1 \in (0, 1)$ ; and  $F = A \theta_t K_t^\alpha N_t^{1-\alpha}$ ,  $A > 0$ ,  $\alpha \in (0, 1)$ . The calibration procedure is a slight modification of Einarsson and Marquis (2001a), where it is described in detail. Ten constraints were needed to identify the ten parameters:  $\beta$ ,  $\eta$ ,  $g_0$ ,  $g_1$ ,  $\alpha$ ,  $\delta$ ,  $A$ ,  $\xi$ ,  $\nu$ , and the mean growth rate of bank reserves,  $\bar{\gamma}$ . These constraints include a quarterly depreciation rate of  $\delta = 0.0212$  and a value for capital's share of income,  $\alpha = 0.314$ ,<sup>15</sup> a currency-deposit ratio of 0.365 (where deposits were defined as other checkable deposits and demand deposit accounts, with the average taken over the 1960–1998 period), a required reserve ratio of  $\nu = 0.1$ , a bond rate of  $r^b = 7.451$  percent (which equated to the 1973–1998 average for the 90-day commercial paper rate), a deposit rate of  $r^d = 4.721$  percent (which is the average of the Federal Reserve Board of Governor's OMS rate for 1973–1999), and an average inflation rate of 3.98 percent (consistent with the 1960–1998 average for the consumer price index). Leisure time was set to 68 percent of the total time allocated each period (based on the diary studies reported by Juster and Stafford 1991). The scale parameter in production was arbitrarily set to  $A = 1$ . Finally, using the *Quarterly Financial Reports for Manufacturing Corporations, 1980*, the ratio of bonds to bank loans,  $B/V = 0.824$  (which is the ratio of commercial paper outstanding plus "other short-term debt" to short-term bank debt). These choices are consistent in the steady state with the remaining unidentified parameter values:  $g_0 = 3.1076$ ,  $g_1 = 0.4995$ ,  $\eta = 1.8621$ ,  $\beta = 0.9914$ , and  $\xi = 0.0050$ .

The purpose of constructing this model is to examine theoretical conditions that are consistent with a persistent liquidity effect. One ingredient in these models is policy

15. To obtain values for  $\delta$  and  $\alpha$ , we use data from 1960 to 1998 and follow the procedure that is outlined in Cooley and Prescott (1995), with two exceptions: government capital is excluded from the capital stock, and the stock of and service flows from consumer durables were obtained from estimates derived by the Federal Reserve Board.

shocks associated with unanticipated changes in the growth rate of bank reserves. This feature of the model requires a characterization of the time series for  $\gamma_t$  in equation (13). One approach is simply to estimate a univariate stochastic process for the growth rate of nonborrowed reserves, where the residuals from that series are taken as the policy shocks. Christiano, et al. (1998) criticize this approach as ignoring the potential feedback into nonborrowed reserves from the monetary authority's reaction to the economy's response to a policy change. One way to capture that feedback is to use the dynamic response of the policy variable in a VAR to a prior policy shock as is depicted, for example, in Figure 2 for RES in row A. This graph maps out the history of changes in the policy variable induced by a one-time unexpected change in the policy variable itself after accounting for the fact that interest rates, output, and prices also are responding to the policy change. Estimates of the two versions of the policy shocks are given below, where they are referred to as the "univariate" and "VAR" models, respectively.<sup>16</sup>

Univariate model of the policy shock:

$$\tilde{\gamma}_t = \bar{\gamma}^U + 0.73\tilde{\gamma}_{t-1} + \tilde{\epsilon}_t, \quad \bar{\gamma}^U > 0, \quad \sigma_{\tilde{\epsilon}} = 0.015.$$

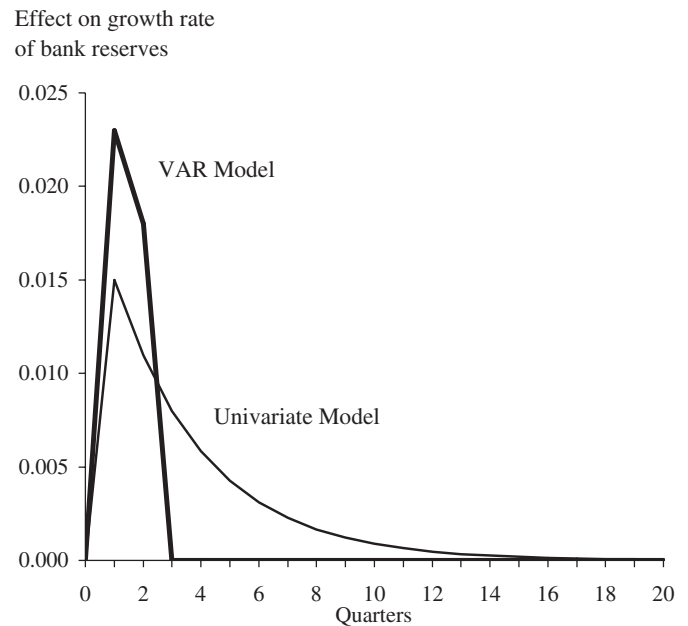
VAR model of the policy shocks:

$$\hat{\gamma}_t = \bar{\gamma}^V + \hat{\epsilon}_t + 0.78\hat{\epsilon}_{t-1}, \quad \bar{\gamma}^V > 0, \quad \sigma_{\hat{\epsilon}} = 0.023.$$

The magnitude and persistence of a policy shock described by these two measures can be compared by examining the evolution of the growth rate of bank reserves in response to positive policy shocks that have an equal probability of occurrence. These (one standard deviation) shocks are displayed in Figure 3. Note that while the patterns of the two shocks are similar, the shock described by the univariate model exhibits a moderately lower value on impact than the shock from the VAR model, but is more persistent.

Three versions of the above model were calibrated and estimated using the univariate model to identify the policy shocks.<sup>17</sup> The first version is referred to as the "No Precommitment Model with a Bond Market." In this model, it is assumed that all decisions described above are made with full contemporaneous information. In this case, the shocks to productivity and to the growth rate of reserves are both observed before any decisions are made. Note that this does not incorporate any incomplete markets or limited participation of the type that is the focus of this literature. To see what effect such market incompleteness

FIGURE 3  
MAGNITUDE AND PERSISTENCE OF  
ONE STANDARD DEVIATION POLICY SHOCKS



has, the second model, labeled "Deposit Precommitment Model with a Bond Market," includes a weak form of the limited participation assumption. It is assumed that households precommit to their deposit position and banks set the deposit rate, that is, that the deposit market clears after observing the productivity shock but prior to observing the monetary policy shock. All other decisions are made with full information, including full knowledge of the Federal Reserve's current monetary policy decisions. Finally, to illustrate the effect of allowing firms a choice between banks and the bond market as a source of funds, a third version of the model, labeled "Deposit Precommitment Model without a Bond Market," is calibrated, and estimated.<sup>18</sup> The same limited participation assumption is maintained as in the "Deposit Precommitment Model with a Bond Market," in that the deposit market is assumed to clear after observing the productivity shock and prior to observing the monetary policy shock.

#### 4.7. Business Cycle Properties of the Models

One gauge of how well a model captures important features of the short-run dynamic behavior of the economy is a comparison of its business cycle properties with actual

16. There is an equivalence between the mean growth rates in the two models such that  $\bar{\gamma}^V = \bar{\gamma}^U / 0.27$ .

17. The stochastic models are estimated using the Parameterized Expectations Algorithm of DenHaan and Marcet (1990).

18. This version of the model required a slight modification to the calibration, i.e., with  $B = 0$ .

data. The cyclical behavior of model economies such as those discussed in this subsection are typically dominated by the nonmonetary shocks to the economy. How the economy responds exclusively to monetary shocks, which is the principal focus of this article, is discussed at length in subsection 4.8.

The first two columns of Table 1 present the volatility (measured as a percent standard deviation) of selected quarterly (detrended) data for the U.S. economy, along with the contemporaneous correlation of those data with output. Among the cyclical features of the data (over the sample period 1973:Q1 to 2000:Q1) that you would like the model economy to replicate are the procyclicality of consumption and investment (i.e., their correlations with output are positive), and the fact that while consumption is less volatile than output, investment is significantly more volatile than output. As the statistics reported in Table 1 indicate, all three versions of the model exhibit this behavior.<sup>19</sup>

The statistics that are of particular interest to this study are those that depict the cyclical behavior of short-term interest rates and bank lending. Referring to Table 1, column 2, the deposit (OMS) rate, the bond (90-day commercial paper) rate, and the bank (prime) lending rate all are procyclical, while the volume of real bank (C&I) loans is very

weakly procyclical. Again, all three models are qualitatively similar, albeit with correlations that are often too high, which could be attributed to some stochastic features of the economy from which the models abstract.

An especially noteworthy statistic reported in the last row of the second column of Table 1 is the negative correlation of the “degree of bank intermediation,” defined as the ratio of C&I loans to GDP, with output. This statistic suggests that even though the working capital requirements of firms are procyclical, the reliance that firms place on bank lending in financing working capital expenditures is countercyclical. As reported in Table 1, all three versions of the model carry this prediction. The theoretical explanation for this feature of the U.S. business cycle is that a major source of funding for bank loans is derived from bank deposits that are linked to consumption. Households’ desire to smooth consumption over the business cycle also smooths the ability of banks to raise deposit funds. When the economy is booming and the demand for bank loans is high, banks have difficulty raising funds in amounts that are sufficient to meet the additional demand. Hence bank lending as a share of GDP falls, as firms find alternative financing sources. The reverse is true during recessions, when firms rely relatively more on banks for working capital finance.

TABLE 1  
SUMMARY OF SECOND MOMENTS

Variable, $x$	U.S. Data 1973:Q1–2000:Q1 <sup>a</sup>		No Precommitment Model with a Bond Market <sup>b</sup>		Deposit Precommitment Model with a Bond Market <sup>b</sup>		Deposit Precommitment Model without a Bond Market <sup>b</sup>	
	$\sigma_x$	$\rho_{xy}$	$\sigma_x$	$\rho_{xy}$	$\sigma_x$	$\rho_{xy}$	$\sigma_x$	$\rho_{xy}$
Output, $y$	1.668	1.000	1.68	1.00	1.73	1.00	1.68	1.00
Consumption, $c$	0.921	0.849	0.68	0.85	1.51	0.56	0.74	0.97
Investment, $I$	6.277	0.943	5.81	0.97	6.65	0.74	5.29	0.99
Deposit rate, $r^d$	0.105	0.168	0.33	0.33	0.18	0.52	0.72	0.97
Bond rate, $r^b$	0.383	0.331	0.36	0.33	0.19	0.53	0.79	0.96
Bank lending rate, $r^v$	0.387	0.174	—	—	—	—	—	—
Real bonds, $b$	—	—	3.43	0.93	3.69	0.85	—	—
Real bank loans, $v'$	3.387	0.077	0.80	0.64	1.68	0.58	0.93	0.92
Degree of bank intermediation, $v'/y$	3.652	−0.372	1.31	−0.81	1.57	−0.49	0.89	−0.92

Notes:  $\sigma_x$  = percent standard deviation.  $\rho_{xy}$  = correlation of  $x$  with output.

<sup>a</sup>Data on the deposit rate and stock and flows of consumer durables were provided by the Federal Reserve Board. All remaining data were extracted from the FAME database. All series were HP filtered. See Einarsson and Marquis (2001a) for details.

<sup>b</sup>Statistics are based on 100 simulations of length 120 periods, with all data HP filtered.

19. The data were detrended using the Hodrick-Prescott filter. The statistics for the U.S. data reported in Tables 1 and 2 are taken from Einarsson and Marquis (2001a). The simulated data reported in Tables 1

and 2 are for 100 simulations of length 120 periods, where the simulated data also were Hodrick-Prescott filtered.



#### 4.8. Dynamic Response of the Model Economies to a Monetary Shock

To examine how monetary policy can affect the macroeconomy, it is of particular interest to know how market interest rates more generally, and not simply the interbank lending rate, react to monetary policy decisions. One implication of a strong liquidity effect resulting from a change in monetary policy is that a policy that eases bank credit by expanding bank reserves should induce a decline in the bond rate. If this effect is strong enough, empirical evidence consistent with this prediction can be found, for example, by estimating the cross-correlation function between the (detrended) growth rate of nonborrowed reserves and the (detrended) 90-day commercial paper rate. As shown in row 1 of Table 2, for the sample period 1973:Q1 to 2000:Q1, there is not only a negative contemporaneous correlation between the growth rate of bank reserves and the bond rate equal to  $-0.25$ , but this negative relationship is stronger at a one-quarter lag of the bond rate, where it peaks (in absolute value) at  $-0.27$ . The interpretation of these results is that, on average over the sample period, an increase in the growth rate of nonborrowed reserves above trend is accompanied by a fall in the bond rate in the current quarter and in the succeeding quarter, suggesting persistence in the interest rate response to the expansion of nonborrowed reserves. Note that these results are simple correlations that make no attempt to account for other macroeconomic conditions that could affect these two variables independently and thereby weaken any estimate of a systematic relationship that may exist between them.

How well do the theoretical models predict this response? To examine this question, simulations of the three

models were run and the cross-correlations of the theoretical counterparts to nonborrowed reserves growth and the bond rate were estimated. In row 2 of Table 2, the cross-correlations between the (gross) growth rate of nonborrowed reserves,  $\gamma_{t-s}$ , and the bond rate,  $r_t^b$ , that are reported for the No Precommitment Model with a Bond Market are seen to be positive or near zero at all leads and lags. There is no evidence of a liquidity effect. This is confirmed in Figure 4, where the dynamic responses of the bond rate, output, and the price level from the model economy are displayed in row A. Note that the model predicts that an injection of reserves into the banking system induces an immediate *increase* in the bond rate, which then gradually dissipates. These higher interest rates raise the borrowing costs of the firms in the model that reduce employment, and investment slows, with the model economy reaching its nadir in response to the policy shock in about three or four quarters.

These dynamics contrast sharply with the predictions from the Deposit Precommitment Model with a Bond Market. As shown in row 3 of Table 2, the cross-correlations between nonborrowed reserves growth and the bond rate that the model predicts match reasonably well with the actual data in row 1. They suggest the presence of a strong liquidity effect. Given a rise in the growth rate of nonborrowed reserves, the bond rate tends to fall immediately, with a contemporaneous correlation between the two variables of  $-0.29$ . This is followed by an even stronger negative correlation in periods subsequent to the shock, with the peak (absolute) correlation occurring after one quarter, when the correlation is  $-0.47$ , although after two quarters it remains high (in absolute value) at  $-0.33$ . The explanation for these results suggested by the model is that with the deposit market slow to respond to the policy shock, required

TABLE 2  
CROSS-CORRELATIONS OF THE BOND RATE ( $r_t^b$ ) WITH THE GROSS GROWTH RATE OF NONBORROWED RESERVES ( $\gamma_t$ )  
 $Corr(r_t^b, \gamma_{t-s})^a$

Lag, $s$	4	3	2	1	0	-1	-2	-3	-4
U.S. Data (1973:Q1–2000:Q1) 90-day Commercial Paper Rate <sup>b</sup>	-0.11	-0.08	-0.15	-0.27	-0.25	0.03	0.12	0.05	0.06
No Precommitment Model with a Bond Market <sup>c</sup>	0.18	0.31	0.46	0.61	0.74	0.38	0.15	-0.01	-0.11
Deposit Precommitment Model with a Bond Market <sup>c</sup>	-0.12	-0.20	-0.33	-0.47	-0.29	-0.08	0.05	0.12	0.15
Deposit Precommitment Model without a Bond Market <sup>c</sup>	-0.03	0.02	0.09	0.19	0.08	0.05	0.02	0.00	-0.01

<sup>a</sup> $s$  = number of periods that  $\gamma_t$  leads  $r_t^b$ .

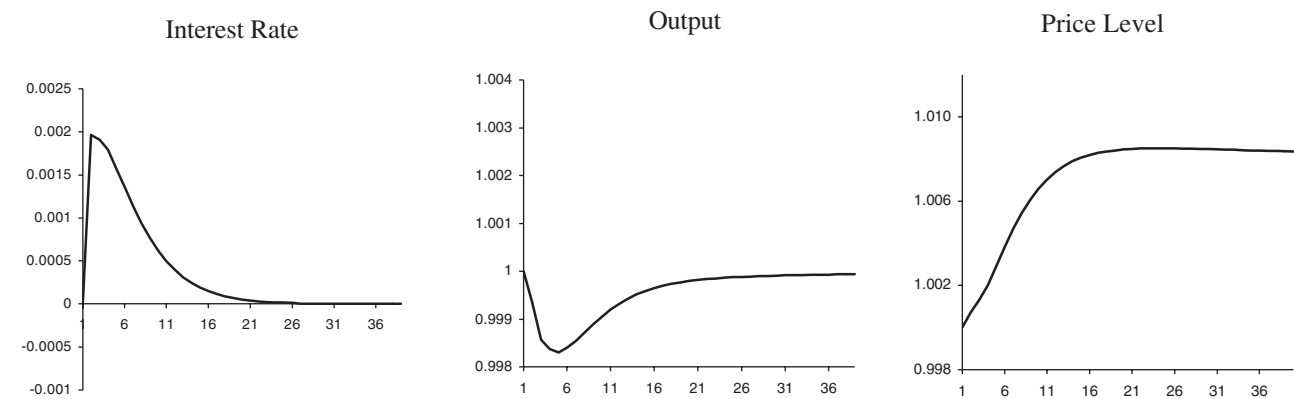
<sup>b</sup>Data on the deposit rate and stock and flows of consumer durables were provided by the Federal Reserve Board. All remaining data were extracted from the FAME database. All series were HP filtered. See Einarsson and Marquis (2001a) for details.

<sup>c</sup>Statistics are based on 100 simulations of length 120 periods, with all data HP filtered.

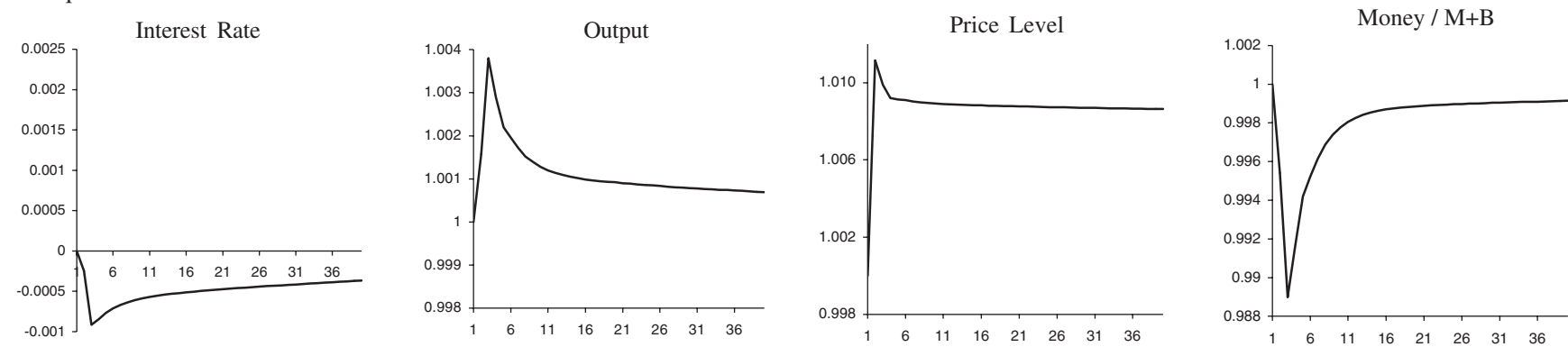


FIGURE 4  
 PREDICTED DYNAMIC RESPONSE OF MACROECONOMIC VARIABLES TO A ONE STANDARD DEVIATION MONETARY POLICY SHOCK

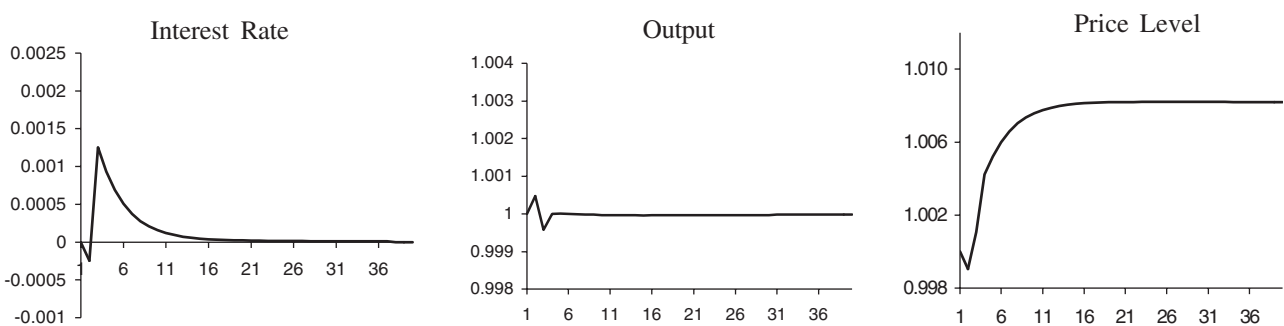
A. No Precommitment Model with a Bond Market



B. Deposit Precommitment Model with a Bond Market



C. Deposit Precommitment Model without a Bond Market



reserves in the banking system are not quickly altered by the injection of reserves and hence the banks find themselves with excess reserves to lend. To entice the firms to borrow, they lower the interest rate. Hence, market interest rates fall. The dynamic response of the economy to this shock is displayed in Figure 4, row B. Note that this model predicts a pronounced and *persistent* liquidity effect, that is, in response to the increase in nonborrowed reserves, the bond rate falls *and* it remains significantly below its long-run level for several quarters thereafter. This decline in the borrowing costs for firms induces them to hire more workers, and this results in a persistent increase in output that peaks in the second quarter after the initial easing of monetary policy.

In Section 2, it was stated that there were really two puzzles associated with the liquidity effect. What produces it? Why is it persistent? The model's answer to the first question is given above. To understand the model's logic that predicts persistence in this response, the results from the Deposit Precommitment Model without a Bond Market can be examined. This model is identical to the Deposit Precommitment Model with a Bond Market with the exception that the firms must borrow only from banks to finance the wage bill. First, note in Table 2 that there is no evidence of a liquidity effect in the cross-correlations of bank reserves growth and the interest rate. The correlations are positive or close to zero at all leads and lags, although much smaller than observed for the No Precommitment Model with a Bond Market. These results imply that the limited participation associated with the early clearing of the deposit market is affecting the relationship between bank reserves and market interest rates, but it does not appear to be very significant. Now turning to row C of Figure 4, a weak liquidity effect is in evidence. In response to an injection of reserves into the banking system, the interest rate does fall. However, the decline is entirely contained within one period, and is reversed in the following quarter. The liquidity effect in this model is not only weak, it also lacks persistence.

The lack of persistence in this version of the model is a direct result of closing down an avenue of savings for the household. After an easing of monetary policy, the economy picks up and household income rises. In each of these models, all of the additional income must be saved in the form of financial assets. However, when there is no bond market available to the household, this additional nominal income must be channeled into liquid asset holdings of money and deposits, which have a relatively high opportunity cost due to their low rates of return. When a bond market is available to the household, as in the Deposit Precommitment Model with a Bond Market, households have a greater incentive to save and, hence, spread out over

several periods the additional consumption possibilities that are implied by the additional wealth. This is evident in the final graph displayed in row B of Figure 4. It shows how the household's financial asset portfolio gives more weight to bonds relative to money and only gradually adjusts to its optimal long-run portfolio. In the interim, the greater demand for bonds keeps the bond rate lower than its long-run equilibrium value, implying a highly persistent liquidity effect associated with the unanticipated reserves injected into the banking system.

One counterfactual prediction of the Deposit Precommitment Model with a Bond Market is the strong price response. As shown in row B, the price level initially overshoots its long-run equilibrium price level, which it then asymptotically approaches from above. One is left to conclude that this model is missing some relevant features that are required to explain the sluggish price dynamics similar to those displayed in Figure 2. This shortcoming is not unique to this model. Currently, no accepted theory explains why prices adjust slowly.

## 5. Conclusion

Despite deregulation and the rapid pace of technological change and financial innovation that have significantly altered the U.S. banking industry, the traditional role that banks play in the economy as an intermediary between households and firms has not significantly diminished. The volume of C&I lending as a fraction of GDP remains near its long-run (post-1973) average, while the bulk of funds that banks raise to finance C&I loans is derived from deposits that households value in part due to the liquidity services that they provide. These features of the banking system are central to a class of theoretical models that attempt to understand one channel through which monetary policy affects the real economy. That channel depicts an "easing" of monetary policy as a cut in the federal funds rate that is supported by an increase in the growth rate of bank reserves through open market operations. These additional bank reserves can stimulate economic activity if they are turned over into loans to businesses that are used to finance working capital expenditures with the attendant expansion of employment and output.

The theoretical literature has identified two puzzles associated with this depiction of how monetary policy affects the real economy. Both relate to the behavior of nominal interest rates in response to a change in monetary policy that is both a central feature of the previously described channel of monetary policy and is evident in the data. The first is that nominal interest rates decline with an unexpected increase in the growth rate of (nonborrowed) bank reserves, which is referred to as the "liquidity effect." This

interest rate response is a puzzle because a faster expansion of bank reserves ultimately leads to faster money growth and higher inflation. This higher inflation eventually *raises* nominal interest rates. Thus, in a frictionless world, if this higher inflation is incorporated into expectations quickly, then nominal interest rates will rise rather than fall with an easing of monetary policy. One theoretical explanation for the empirical finding of a liquidity effect is that deposit markets do not respond quickly to unexpected changes in monetary policy. This can be conceptualized and modeled as an information friction, whereby households and banks do not factor the most recent monetary policy actions that had not been fully anticipated into their decisions on how much wealth households should retain in deposit accounts and what interest rate banks should pay on deposits. In this case, with the level of bank deposits predetermined, the central bank's injection of reserves into the banking system increases the volume of funds available for business lending, and bank lending rates may fall as banks entice firms to borrow more heavily for working capital expenditures, which then expands employment and output.

The second puzzle is the empirical evidence that suggests that the liquidity effect associated with a period of monetary ease persists for several quarters. The theoretical explanation of the liquidity effect that was just described fails to generate any persistent or long-lasting effect on interest rates due to an unexpected increase in the growth rate of bank reserves. Once the new monetary policy action is factored into the pricing of assets, which requires households to take account of the policy when choosing their deposit holdings, and this information is fully reflected in the deposit rate, the "liquidity effect" vanishes. This article presents a theoretical model that illustrates how access by households to a corporate bond market can induce both a larger and a persistent liquidity effect. The logic of the theoretical model is that the increase in household income associated with the increase in economic activity induced by the initial liquidity effect (which is amplified through the lowering of the corporate bond rate) is partially "saved" by households who increase their demand for bonds. This additional savings is extended for several quarters. Therefore, firms expand their supply of bonds and reduce their reliance on banks for working capital finance as interest rates continue to be low and employment and output continue to expand.

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# Foreign Exchange: Macro Puzzles, Micro Tools\*

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This paper reviews recent progress in applying information-theoretic tools to long-standing exchange rate puzzles. I begin by distinguishing the traditional public information approach (e.g., monetary models, including new open economy models) from the newer dispersed information approach. (The latter focuses on how information is aggregated in the trading process.) I then review empirical results from the dispersed information approach and relate them to two key puzzles, the determination puzzle and the excess volatility puzzle. The dispersed information approach has made progress on both.

*To repeat a central fact of life, there is remarkably little evidence that macroeconomic variables have consistent strong effects on floating exchange rates, except during extraordinary circumstances such as hyperinflations. Such negative findings have led the profession to a certain degree of pessimism vis-à-vis exchange-rate research.*

Frankel and Rose (1995, p. 1,709)

## 1. Introduction

Does the foreign exchange market aggregate information? Surely it does: so many of the variables that drive pricing are dispersed throughout the economy (e.g., individuals' risk preferences, firms' productivities, individuals' money demands, individuals' hedging demands, etc.). Indeed, aggregating dispersed information is one of asset markets' central functions.<sup>1</sup> Yet models of exchange rate determination abstract completely from information aggregation. These models (e.g., monetary models, portfolio balance models, new open economy macro models) posit an infor-

mation environment in which all relevant information is publicly known. This approach is sensible if the abstraction misses little, i.e., if dispersed information is rapidly summarized in the public macro variables we rely on to estimate our models. Only recently has this common assumption received any attention.

My thesis is that abstracting from information aggregation when analyzing exchange rates misses quite a lot. The argument rests on two main points. First, empirically the public information approach fares poorly (see, e.g., Meese and Rogoff 1983, Frankel, et al. 1996, and the surveys by Frankel and Rose 1995 and Taylor 1995). Meese (1990) describes the explanatory power of these models (for monthly or quarterly exchange rates) as "essentially zero." More recent models within this approach also fare poorly (Bergin 2001). In sum, there is general agreement that the public information approach is deficient; the open question is why.

My second main point is more positive: recent empirical work on exchange rates using what I call the "dispersed information approach" has enjoyed some success. This work relies on micro models of how, specifically, asset markets accomplish information aggregation. When coupled with the poor performance of public information models, these positive results imply that the above assumption—that dispersed information is rapidly summarized in public information—is dubious.

The remainder of this article focuses on positive results from the dispersed information approach and relates them to fundamental exchange rate puzzles. Section 2 provides an overview of order flow as an information aggregator. Section 3 addresses the determination puzzle—why the explanatory power of concurrent macro variables is so low.

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1. Nobel laureate Friedrich Hayek (1945) provides an early and powerful articulation of this point: "the problem of rational economic order is determined precisely by the fact that knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society is thus a problem of the utilization of knowledge not given to anyone in its totality" (p. 519).



Section 4 addresses the excess volatility puzzle—why floating rates are more volatile than measured fundamentals predict. Section 5 concludes by providing directions for further research.

## 2. Order Flow: An Information Aggregator

### 2.1. Introduction and Definition

When one moves from the public information approach to the dispersed information approach, a variable that plays no role in the former takes center stage: order flow. Order flow is a term from the field of microstructure finance.<sup>2</sup> Understanding it is essential for appreciating how the dispersed information approach departs from the public information approach. Order flow is transaction volume that is *signed* according to whether the transaction is initiated from the buy side (+) or the sell side (−). For example, if you decide to sell a dealer (marketmaker) 10 units (shares, euros, etc.), then transaction volume, which is unsigned, is 10, but order flow is −10.<sup>3</sup> Over time, order flow is measured as the sum of signed buyer-initiated and seller-initiated orders. A negative sum means net selling over the period.

Order flow is a variant of another important term, “excess demand.” It is a variant rather than a synonym for two reasons, the first relating to the excess part and the second relating to the demand part. For the former, note that excess demand equals zero in equilibrium by definition—there are two sides to every transaction. This is not true of order flow: in markets organized like foreign exchange (FX), orders are initiated against a marketmaker, who (if properly compensated) stands ready to absorb imbalances between buyers and sellers. These “uninitiated” trades of the marketmaker drive a wedge between the two concepts, excess demand and order flow.<sup>4</sup> The second reason the con-

cepts differ is that order flow is in fact distinct from demand itself. Order flow measures actual transactions, whereas demand shifts need not induce transactions. For example, the demand shifts that move prices in traditional exchange rate models (e.g., monetary models) are caused by the flow of public information, which moves rates without transactions ever needing to occur.

In dispersed information models, information processing has two stages, the second of which depends on order flow. The first stage is the analysis or observation of dispersed fundamentals by nondealer market participants (mutual funds, hedge funds, individuals with special information, etc.). The second stage is the dealer’s—i.e., the price setter’s—interpretation of the first-stage analysis, which comes from reading the order flow. Dealers set prices on the basis of this reading.

Order flow conveys information about dispersed fundamentals because it contains the trades of those who analyze/observe those fundamentals. It is a transmission mechanism. Naturally, though, these informative trades may be mixed with uninformative trades, making the task of “vote counting” rather complex. In some dispersed information models, the dealer learns nothing about fundamentals that she does not learn from order flow. As a practical matter, this is clearly too strong. The dealer’s dependence on learning only from order flow arises in some models because all of the relevant information is dispersed. When information is publicly known, dealers do not need to learn from order flow. In practice, although some information relevant to FX is publicly known, some is not, so learning from order flow can be important. The empirical models I describe in Section 3 admit both possibilities.

Consider such a “hybrid” model from a graphical perspective. The top panel of Figure 1 illustrates the connection between fundamentals and prices under the public information approach. Under this approach, not only is information about fundamentals publicly known, but so, too, is the mapping from that information to the price. Consequently, price adjustment is direct and immediate. The middle panel shows the dispersed information approach. The focus in that case is on fundamental information that is not publicly known. In those models, information is first transformed into order flow. This order flow becomes a signal to the price setter that the price needs to be adjusted. The bottom panel presents the hybrid view. Here, the model accommodates both possibilities: information that affects prices directly and information that

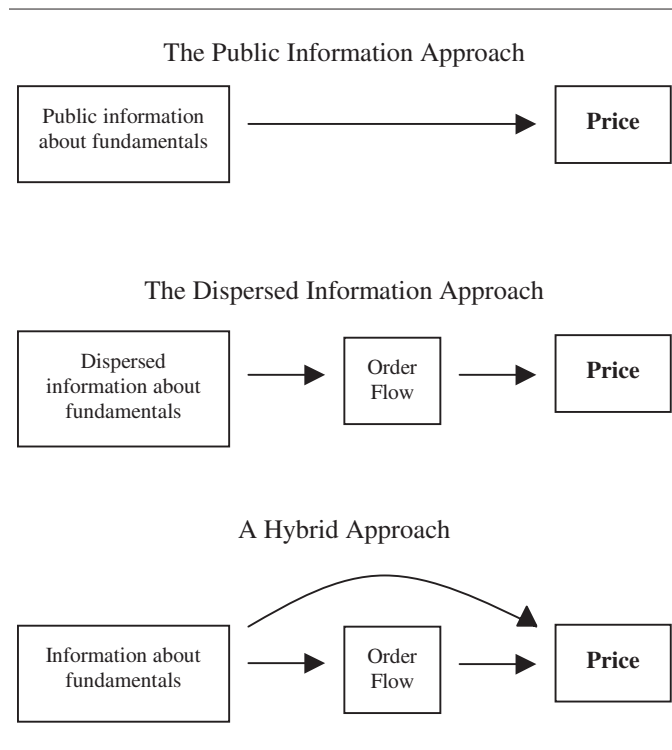
2. Microstructure finance has two main strands: market design and information processing. The dispersed information approach to exchange rates borrows heavily from the second of these strands.

3. Measuring order flow is slightly different when trading takes place via a “limit order book” rather than through dealers. (An example of a limit order is “buy 10 units for me if the market reaches a price of 50.”) Limit orders are collected in an electronic “book,” and the most competitive of those orders define the best available bid and offer prices. When measuring order flow, limit orders are the passive side of any transaction, just as the quoting dealer is always on the passive side when trading involves dealers. When orders arrive that require immediate execution (e.g., an order to “sell 10 units now at the best available price”), these orders—called market orders—generate the signed order flow.

4. In rational expectations (RE) models of trading, order flow is undefined because all transactions in that setting are symmetric. One might conclude from RE models that one could never usefully distinguish the

“sign” of a trade between two willing counterparties. A large empirical literature in microstructure finance suggests otherwise (Lyons 2001).

FIGURE 1  
APPROACHES TO PRICE



affects prices via order flow. With models that allow for both, the data can determine which possibility accounts for more exchange rate variation.

## 2.2. Order Flow and Exchange Rates over Long Horizons

Although empirical work in microstructure finance is generally applied to high frequency events, this does not imply that microstructure tools are irrelevant to lower-frequency, resource relevant phenomena. Indeed, there are ample tools within the micro approach for addressing lower-frequency phenomena. And new tools continue to emerge, thanks in part to a recognition within the broader microstructure literature that resource allocation warrants greater attention.

Regarding long-lived effects, the most important point to recognize is that when order flow conveys information, its effect on prices *should* be long-lived. Indeed, a common assumption in empirical work for distinguishing information from pricing errors is that information's effects on prices are permanent, whereas pricing errors are transitory (French and Roll 1986, Hasbrouck 1991). These long-lived effects are borne out in the data, in equity markets, bond markets, and FX markets. In FX, for example, Evans (1997, 2001), Evans and Lyons (2002), Payne (1999), and

Rime (2000) show that order flow has significant effects on exchange rates that persist. Indeed, statistically these effects appear to be permanent. Among microstructure's long-lived implications, this "information" channel is definitely the most fundamental.

An analogy may be helpful. The dispersed information approach may speak to longer-horizon exchange rates in much the same way that microscopes speak to pathologies with macro impact. In medicine, microscopes provide resolution at the appropriate level—the level at which the phenomenon emerges. This is true irrespective of whether the phenomenon also has macro impact. Resolution at this level is the key to our understanding. Similarly, tools from the dispersed information approach provide resolution at the level where its "phenomenon" emerges—the level where prices are determined. What information do dealers have available to them, and what are the forces that influence their pricing decisions? (Whether we like it or not, it is a stubborn fact that in the major currency markets, *there is no exchange rate other than the prices these people set.*) Answering these questions does indeed help explain exchange rates over longer horizons, as the next section shows.

## 2.3. Applying Microstructure Tools to Exchange Rate Puzzles

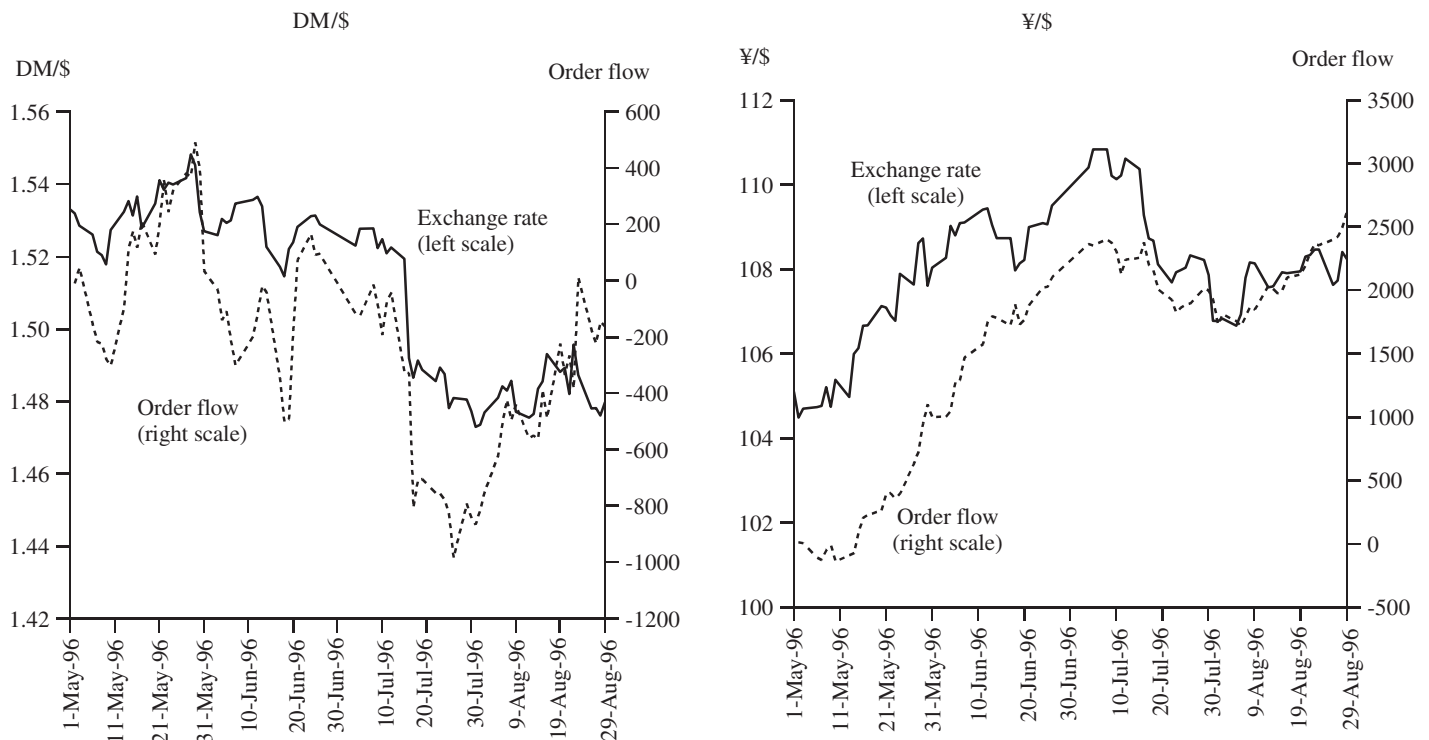
What about the big puzzles in exchange rate economics? Two of the biggest puzzles are:<sup>5</sup>

- (1) **The determination puzzle:** exchange rate movements are virtually unrelated to macroeconomic fundamentals (at least over periods of less than about two years); and
- (2) **The excess volatility puzzle:** exchange rates are excessively volatile relative to our best measures of fundamentals.

5. Within international finance more broadly, there are four main puzzles, the two listed plus the "forward bias" and "home bias" puzzles. (Forward bias refers to conditional bias—potentially due to a risk premium—in forward exchange rates, whereas home bias refers to investors underinvesting internationally.) For applications of the dispersed information approach to these other puzzles, see Lyons (2001).

These four puzzles have analogues in other markets. For equities, papers that address the puzzles include Roll (1988) on determination, Shiller (1981) on excess volatility, Mehra and Prescott (1985) on equity risk premia, and Coval and Moskowitz (1999) on home bias. (The equity market version of the forward bias puzzle—the so-called equity premium puzzle—is a much looser analogue than the others: the large risk premium on equity is rather stable over time and remains positive, whereas the large risk premium in FX changes over time, including frequent changes in sign.) Microstructure tools are just beginning to be applied to those major equity puzzles (see, for example, Easley, et al. 1999).

FIGURE 2  
FOUR MONTHS OF EXCHANGE RATES AND ORDER FLOW, MAY 1 TO AUGUST 31, 1996



Source: Transactions data from Evans (1997).

The dispersed information approach links these puzzles to one another via expectations formation, i.e., how market participants form their expectations of future fundamentals. It makes this link without departing from rational expectations. Rather, the microstructure approach grounds expectations formation more directly in a richer, information-economic setting. The focus is on information *types* (such as public versus dispersed) and *how* information maps into expectations (e.g., whether the aggregation of order flow “votes” is efficient). The issues of information type and mapping to expectations are precisely where tools from microstructure finance provide resolving power.<sup>6</sup>

#### 2.4. A First Look at the Data

Figure 2 provides a convenient summary of order flow’s explanatory power. The solid lines represent the spot rates of the deutsche mark and yen against the dollar over the four-month sample of the Evans (1997) data set. The dashed lines represent cumulative order flow for the respective currencies over the same period. Order flow is the

sum of signed trades (starting from the beginning of the sample) between foreign exchange dealers worldwide.<sup>7</sup> Cumulative order flow and nominal exchange rate levels are strongly positively correlated (prices increase with buying pressure). This result is intriguing. Order flow appears to matter for exchange rate determination, and the effect appears to persist (otherwise the exchange rate’s level would reflect only concurrent or very recent order flow and not *cumulative* order flow). This persistence is an important property, one that I examine more closely below. For order flow to be helpful in resolving big exchange rate puzzles, its effects have to persist over horizons that match those puzzles (monthly, at a minimum).<sup>8</sup>

7. Because the Evans (1997) data set does not include the size of every trade, this measure of order flow is in fact the number of buys minus sells. That is, if a dealer initiates a trade against another dealer’s DM/\$ quote, and that trade is a \$ purchase (sale), then order flow is +1 (–1). These are cumulated across dealers over each 24-hour trading day (weekend trading—which is minimal—is included in Monday).

8. Readers familiar with the concept of cointegration will recognize that it offers a natural means of testing for a long-run relationship. In Section 4, I present evidence that cumulative order flow and the level of the exchange rate are indeed cointegrated, indicating that the relationship between order flow and prices is not limited to high frequencies. I also show in that section why a long-run relationship of this kind is what one should expect.

6. Of course, the dispersed information approach also has its drawbacks, an important one being the lack of publicly available order flow data over long periods.

### 3. The Determination Puzzle

This section and the next examine traditional exchange rate puzzles, showing how tools from microstructure finance are used to address them. They are not intended to put these puzzles to rest: the puzzles wouldn't be traditional if they weren't stubborn. My intent is to provide a sense for how to address macro issues by looking under the "micro lamppost."

As noted, textbook models do a poor job of explaining monthly exchange rate changes. In their survey, Frankel and Rose (1995) summarize as follows:<sup>9</sup>

The Meese and Rogoff analysis at short horizons has never been convincingly overturned or explained. It continues to exert a pessimistic effect on the field of empirical exchange rate modeling in particular and international finance in general...such results indicate that no model based on such standard fundamentals like money supplies, real income, interest rates, inflation rates, and current account balances will ever succeed in explaining or predicting a high percentage of the variation in the exchange rate, at least at short- or medium-term frequencies. (pp. 1,704, 1,708)

This is the determination puzzle. Immense effort has been expended to resolve it.<sup>10</sup>

If determinants are not macro fundamentals like interest rates, money supplies, and trade balances, then what are they? Two alternatives have attracted a lot of attention among macroeconomists. The first is that exchange rate determinants include extraneous variables. These extraneous variables are typically modeled as speculative bubbles. (A bubble is a component of an asset's price that is nonfundamental. A bubble can cause prices to rise so fast that investors are induced to buy, even though the bubble may burst at any time; see, e.g., Meese 1986 and Evans 1986.) On the whole, however, the empirical evidence on bubbles is not supportive; see the survey by Flood and Hodrick (1990). A second alternative to macro fundamentals is irrationality. For example, exchange rates may be determined, in part, from avoidable expectational errors (Dominguez

1986, Frankel and Froot 1987, and Hau 1998). On a priori grounds, many financial economists find this second alternative unappealing. Even if one is sympathetic, however, there is a wide gulf between the presence of irrationality and accounting for exchange rates empirically.<sup>11</sup>

This section addresses the determination puzzle using the dispersed information approach, drawing heavily from work presented in Evans and Lyons (2002). One advantage of this approach is that it directs attention to variables that have escaped the attention of macroeconomists. A telling quote along these lines appears in Meese (1990):

Omitted variables is another possible explanation for the lack of explanatory power in asset market models. However, empirical researchers have shown considerable imagination in their specification searches, so it is not easy to think of variables that have escaped consideration in an exchange rate equation. (p. 130)

Among the variables escaping consideration, order flow may be the most important.

#### 3.1. A Hybrid Model with Both Macro and Micro Determinants

To establish a link between the micro and macro approaches, Figure 1 introduced a "hybrid" model with components from both. The hybrid model in that figure could be written as follows:

$$(1) \quad \Delta P_t = f(i, m, z) + g(X, I, Z) + \varepsilon_t,$$

where the function  $f(i, m, z)$  is the macro component of the model and  $g(X, I, Z)$  is the microstructure component. The driving variables in the function  $f(i, m, z)$  include current and past values of home and foreign nominal interest rates  $i$ , money supply  $m$ , and other macro determinants, denoted here by  $z$ . The driving variables in the function  $g(X, I, Z)$  include order flow  $X$  (signed so as to indicate direction), a measure of dealer net positions (or inventory)  $I$ , and other micro determinants, denoted by  $Z$ . An important take-away from the relevant literatures is that  $f(i, m, z)$  and  $g(X, I, Z)$  depend on more than just current and past values of their determinants—they also depend, crucially, on expectations of the future values of their determinants. This stands to reason: rational markets are forward-looking, so these expectations are important for setting prices today.

9. At longer horizons, e.g., longer than two years, macro models begin to dominate the random walk (e.g., Chinn 1991 and Mark 1995). But exchange rate determination remains a puzzle at horizons shorter than two years (except in cases of hyperinflation, in which case the inflation differential asserts itself as a driving factor, in the spirit of purchasing power parity).

10. The determination puzzle exists in equity markets as well—see Roll (1988). Roll can account for only 20 percent of daily stock returns using traditional equity fundamentals, a result he describes as a "significant challenge to our science."

11. Another alternative to traditional macro modeling is the recent "new open economy macro" approach (e.g., Obstfeld and Rogoff 1995). I do not address this alternative here because, as yet, the approach has not produced empirical exchange rate equations that alter the Meese-Rogoff (1983) conclusions (see Bergin 2001).



Though I have split this stylized hybrid model into two parts, the two parts are not necessarily independent. This will depend on the main micro determinant—order flow  $X$ —and the type of information it conveys. In fact, order flow conveys two main information types: *payoff information* and *discount rate information*. In macro models, information about future payoffs translates to information about future  $(i, m, z)$ . One way order flow can convey information about future  $(i, m, z)$  is by aggregating the information in people's expectations of  $(i, m, z)$ . (Recall that as a measure of expectations, order flow reflects people's willingness to back their beliefs with money; and like actual expectations, this measure evolves rapidly, in contrast to measures derived from macro data.) To fix ideas, write the price of foreign exchange,  $P_t$ , in the standard way as a function of current and expected future macro fundamentals:  $P_t = g(f_t, f_{t+1}^e)$ . In dispersed information models, price setters learn about changes in  $f_{t+1}^e$  by observing order flow. Thus, when order flow conveys payoff information, macro and micro determinants are interdependent: order flow acts as a proximate determinant of prices, but standard macro fundamentals are the underlying determinant.<sup>12</sup>

If order flow  $X$  conveys discount rate information only, then the two sets of determinants  $(i, m, z)$  and  $(X, I, Z)$  can indeed be independent. To understand why, suppose the discount rate information conveyed by order flow  $X$  is about portfolio balance effects (e.g., persistent changes in discount rates, due to changing risk preferences, changing hedging demands, or changing liquidity demands under imperfect substitutability).<sup>13</sup> Now, consider the two monetary macro models (flexible and sticky-price). Portfolio balance effects from order flow  $X$  are unrelated to these models' specifications of  $f(i, m, z)$ . This is because the monetary models assume that different-currency assets are perfect substitutes (i.e., they assume that uncovered interest parity holds: assets differing only in their currency denomination have the same expected return). Thus, effects from imperfect substitutability are necessarily independent of the  $f(i, m, z)$  of these monetary models. In the case of the

macro portfolio balance model, in contrast, portfolio balance effects from order flow  $X$  are quite likely to be related to the determining variables  $(i, m, z)$ . Indeed, in that model, price effects from imperfect substitutability are the focus of  $f(i, m, z)$ .

Before describing the hybrid model estimated by Evans and Lyons (2002), let me address some front-end considerations in modeling strategy. First, the determination puzzle concerns exchange rate behavior over months and years, not minutes. Yet most empirical work in microstructure finance is estimated at the transaction frequency. The first order of business is to design a trading model that makes sense at lower frequencies. Several features of the Evans-Lyons model contribute to this (as will be noted specifically below, as the features are presented). Second, because in actual currency markets interdealer order flow is more transparent than customer-dealer order flow, it is more immediately relevant to FX price determination. The hybrid model should reflect this important institutional feature. Third, the model should provide a vehicle for understanding the behavior of interdealer order flow in Figure 2. That figure presents cumulative interdealer flow in the DM/\$ and ¥/\$ markets over the four-month Evans (1997) data set, the same data set used by Evans and Lyons (2002). A puzzling feature is the persistence: there is no obvious evidence of mean reversion in cumulative order flow. How can this be consistent with the fact that individual dealer inventories have a very short half-life (i.e., their positions revert to zero rapidly)? The Evans-Lyons model accounts for this seeming incongruity.

### 3.2. The Evans-Lyons Model

Consider an infinitely lived, pure exchange economy with two assets, one riskless and one with stochastic payoffs representing foreign exchange. The periodic payoff on foreign exchange, denoted  $R_t$ , is composed of a series of increments, so that

$$(2) \quad R_t = \sum_{\tau=1}^t \Delta R_{\tau}.$$

The increments  $\Delta R_t$  are i.i.d.  $\text{Normal}(0, \sigma_R^2)$  and represent the flow of public macroeconomic information—the macro component of the model  $f(i, m, z)$ . For concreteness, one can think of this abstract payoff increment  $\Delta R_t$  as changes in interest rates. Periodic payoffs are realized at the beginning of each day.

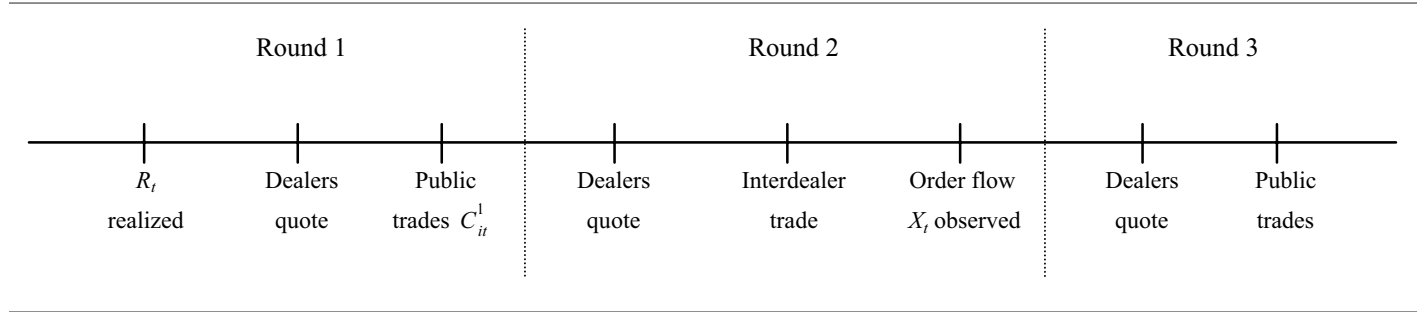
The foreign exchange market is organized as a decentralized dealership market with  $N$  dealers, indexed by  $i$ , and a continuum of nondealer customers (the public), indexed by  $z \in [0, 1]$ . Within each period (day) there are three rounds of trading:

12. If order flow is an informative measure of macro expectations, then it should forecast surprises in important variables (like interest rates). New order flow data sets that cover up to six years of FX trading—such as the data set examined by Fan and Lyons (2001)—provide enough statistical power to test this. The Evans (1997) data set used by Evans and Lyons (2002) is only four months, so they are not able to push in this direction.

13. Lyons (2001) introduces two subcategories of discount rate information: information about inventory effects and information about portfolio balance effects. I do not consider information about inventory effects here because inventory effects are transitory and are therefore unlikely to be relevant for longer-horizon macro puzzles.



FIGURE 3  
DAILY TIMING IN THE EVANS AND LYONS (2002) MODEL



Round 1: dealers trade with the public.

Round 2: dealers trade among themselves to share risk.

Round 3: dealers trade again with the public to share risk more broadly.

The timing within each day is summarized in Figure 3. Dealers and customers all have identical negative exponential utility (constant absolute risk aversion).

Per Figure 3, after observing  $R_t$  each dealer sets a quote for his public customers. These quotes are scalar two-way prices, set simultaneously and independently.<sup>14</sup> Denote this dealer  $i$  quote in Round 1 of day  $t$  as  $P_{it}^1$ . Evans and Lyons show that, in equilibrium, all dealers choose to quote the same price, denoted  $P_t^1$  (implied by no arbitrage). Each dealer then receives a customer-order realization  $C_{it}^1$  that is executed at his quoted price  $P_t^1$ , where  $C_{it}^1 < 0$  denotes a customer sale (dealer  $i$  purchase). Each of these  $N$  customer order realizations is distributed

$$(3) \quad C_{it}^1 \sim \text{Normal}(0, \sigma_C^2),$$

and they are uncorrelated across dealers. Importantly, the  $C_{it}^1$  realizations are not publicly observable. For later discussion of the model's intuition, it is useful to define the aggregate public demand in Round 1 as the sum of the customer orders received by the  $N$  dealers:

$$(4) \quad C_t^1 = \sum_{i=1}^N C_{it}^1.$$

One important choice in specifying the model is the correlation between customer orders  $C_{it}^1$  and the stream of payoff increments  $\Delta R_t$ . This choice determines whether the macro and micro components of the model—the  $f(i, m, z)$  and  $g(X, I, Z)$ —are interdependent. If there is no correlation, it is not possible for order flow to convey payoff information. Because Evans and Lyons (2002) have

only four months of order flow data, they are unable to determine empirically whether order flow conveys payoff information, discount rate information, or both. They choose to model the customer orders  $C_{it}^1$  as distributed independently of the payoff stream  $R_t$ —arguably, a less controversial choice. This means that, in their model, the only kind of information that order flow can convey is discount rate information. And because their model rules out inventory effects at the daily frequency (as we shall see below), the discount rate information in their model corresponds to what macroeconomists call portfolio balance effects.

Round 2 is the interdealer trading round. Each dealer simultaneously and independently quotes a scalar two-way price to other dealers  $P_{it}^2$ . These interdealer quotes are observable and available to all dealers in the market. Evans and Lyons show that, as in Round 1, all dealers choose to quote the same price, denoted  $P_t^2$ . Each dealer then simultaneously and independently trades on other dealers' quotes. (Orders at a given price are split evenly across any dealers quoting that price.) Let  $T_{it}$  denote the interdealer trade initiated by dealer  $i$  in Round 2 of day  $t$  (negative for dealer  $i$  sales).

Importantly, at the close of Round 2 all dealers observe the order flow from interdealer trading that day:

$$(5) \quad X_t = \sum_{i=1}^N T_{it}.$$

This order flow information is important to the model because it conveys the size and sign of the public order flow in Round 1. To understand why, consider the interdealer trading rule derived by Evans and Lyons:

$$(6) \quad T_{it} = \alpha C_{it}^1,$$

where  $\alpha$  is a constant coefficient. Each dealer's trade in Round 2 is proportional to the customer order he receives in Round 1. This implies that when dealers observe the interdealer order flow  $X_t = \sum_i T_{it} = \alpha C_t^1$ , they can infer the aggregate public order flow  $C_t^1$  in Round 1.

14. Introducing a bid-offer spread (or price schedule) in Round 1 to endogenize the number of dealers is a straightforward extension.

In Round 3, dealers share overnight risk with the non-dealer public. This feature is important in distinguishing this model from models focused on intraday trading. Unlike Round 1, the public's trading in Round 3 is nonstochastic. To start the round, each dealer simultaneously and independently quotes a scalar two-way price  $P_t^3$  (also common across dealers). These quotes are observable and available to the public.

A crucial assumption made by Evans and Lyons is that dealers set prices in Round 3 such that the public willingly absorbs all dealer inventory imbalances, so that each dealer ends the day with no net position.<sup>15</sup> As an empirical matter, it is common practice for FX dealers to end each day with no net position, and this squares with the empirical findings (Lyons 1995, Yao 1998). Note too that this assumption rules out inventory effects on prices at the daily frequency (because dealers do not hold overnight positions that require compensation). The Round 3 price that dealers actually quote to induce public absorption of these imbalances depends on the Round 2 interdealer order flow  $X_t$ : this interdealer order flow informs dealers of the size of the total position that the public needs to absorb (as noted,  $X_t = \alpha C_t^1$ ).

More precisely, to determine the Round 3 price, dealers need to know two things: the total position that the public needs to absorb (which they learn from  $X_t$ ), and the public's risk-bearing capacity. Regarding the latter, the public's capacity for bearing foreign exchange risk is assumed less than infinite; i.e., Evans and Lyons assume that foreign- and domestic-currency assets are not perfect substitutes. This is a key assumption: it makes room in the model for portfolio balance effects on prices. Consistent with negative exponential utility, the public's total demand for foreign exchange in Round 3, denoted  $C_t^3$ , is a linear function of its expected return conditional on public information:

$$(7) \quad C_t^3 = \gamma E [\Delta P_{t+1}^3 + R_{t+1} | \Omega_t^3].$$

The positive coefficient  $\gamma$  captures the aggregate risk-bearing capacity of the public: a larger  $\gamma$  means the public is willing to absorb a larger foreign exchange position for a given expected return.  $\Omega_t^3$  is the public information available at the time of trading in Round 3 (which includes all past  $R_t$  and  $X_t$ ).

Evans and Lyons (2002) show that the price at the end of day  $t$  is:

$$(8) \quad P_t = \beta_1 \sum_{\tau=1}^t \Delta R_\tau + \beta_2 \sum_{\tau=1}^t X_\tau.$$

15. This is tantamount to assuming that—when it comes to bearing overnight risk—the dealers' capacity is small relative to the capacity of the whole public.

The change in prices from the end of day  $t-1$  to the end of day  $t$  can therefore be written as:

$$(9) \quad \Delta P_t = \beta_1 \Delta R_t + \beta_2 X_t,$$

where  $\beta_2$  is a positive constant (that depends on  $\gamma$  and  $\alpha$ ).<sup>16</sup> It is not surprising that this price change includes the payoff increment  $\Delta R_t$ : upon realization, the increment  $\Delta R_t$  becomes a known (i.e., risk-free) component of the continuing daily payoff  $R_t$ , and its discounted value is impounded in the price ( $\beta_1$ ).

Let me provide some intuition for the portfolio balance effect—the  $\beta_2 X_t$  term. This term is the required price adjustment that induces reabsorption of the random order flow  $C_t^1$  that occurred at the beginning of the day. The value of the parameter  $\beta_2$  ensures that at the Round 3 price

$$C_t^1 + C_t^3 = 0,$$

i.e., that the dealers have no net overnight position. To understand the link to order flow, recall that the Round 3 price depends on two things: the public's risk-bearing capacity (summarized by  $\gamma$ ) and the total position that the public needs to absorb. As noted, dealers learn about the total position the public needs to absorb from order flow  $X_t$ . This produces the relation between the interdealer order flow and the subsequent price adjustment.

Let's walk through an example. Consider the price at the close of day  $t$ , as described by equation (8). The next day's increment to the daily payoff  $R$ ,  $\Delta R_{t+1}$ , is uncertain, but all previous realizations of the payoff increment  $\Delta R$  are known and are impounded in the price. (Expectations of future realizations do not enter equation (8) due to the simple specification of  $\Delta R_t$  and  $C_t^1$  as independently distributed across time with mean zero.) To understand the portfolio balance term,  $\beta_2 \sum_{\tau=1}^t X_\tau$ , recall that:

$$X_t \equiv \sum_{i=1}^N T_{it} = \alpha C_t^1.$$

Therefore, we can write:

$$\sum_{\tau=1}^t X_\tau \propto \sum_{\tau=1}^t C_\tau^1.$$

The sum of the portfolio shifts  $C_t^1$  represents changes in "effective" asset supply, in the sense that these stochastic shifts out of FX are an increase in the net supply that the remainder of the public must absorb. (I couch this in terms of

16. This model can also be used to generate multiple equilibria. Introducing multiple equilibria obscures the essential portfolio balance logic, however, so I do not pursue this direction here.

supply to connect with traditional portfolio balance intuition.) The total increase in net supply is the sum of past portfolio shifts out of FX,

$$\text{Increase in net supply} = -\sum_{\tau=1}^t C_{\tau}^1.$$

As is standard in portfolio balance models, increases in supply lower prices, and decreases in supply raise prices. This is why a negative cumulative  $X_t$  in equation (8) lowers prices: if cumulative  $X_t$  is negative, this implies that cumulative  $C_t^1$  is also negative, which is an increase in net supply, requiring a decrease in prices to clear the market.  $X_t$  is the variable that conveys this information about the decrease in net supply ( $C_t^1$  is unobservable).  $P_t$  depends on the sum of the  $X_t$  because each additional decrease in supply  $C_t^1$  requires a *persistent* incremental increase in prices.

Before moving on to the Evans-Lyons results, I want to address another of their model's important features. Recall that one of their modeling objectives is to clarify the behavior of order flow in Figure 2. Specifically, cumulative order flow is puzzlingly persistent: there is no obvious evidence of mean reversion in cumulative order flow, yet, empirically, individual dealer inventories have a short half-life. How can these two facts be consistent? The Evans-Lyons model provides an explanation. First, note that dealer inventories in the Evans-Lyons model are short-lived: no dealer carries an inventory longer than one day. At the same time, cumulative interdealer order flow in their model is persistent—in fact, it follows a random walk (i.e., there is no mean reversion whatsoever). Equations (5) and (6) hold the key to this random walk result. Interdealer order flow each day is proportional to the public order flow that occurs at the beginning of that day. Because this public order flow is i.i.d. across dealers and time, cumulative interdealer order flow follows a random walk. In the end, these seemingly incongruous facts are consistent because, ultimately, dealers can only decumulate inventory by trading with the public, so aggregate decumulation is not reflected in interdealer flow.<sup>17</sup>

17. Consider an example. Starting from  $X_t = 0$ , an initial customer sale to a dealer does not move  $X_t$  from zero because  $X_t$  measures interdealer order flow only. After the customer sale (say of one unit), when dealer  $i$  unloads the position by selling to another dealer, dealer  $j$ ,  $X_t$  drops to  $-1$ . A subsequent sale by dealer  $j$  to another dealer, dealer  $k$ , reduces  $X_t$  further to  $-2$ . If a customer happens to buy dealer  $k$ 's position from him, then the process comes to rest with  $X_t$  at  $-2$ . In this simple scenario, order flow measured only from trades between customers and dealers would have reverted to zero: the concluding customer trade offsets the initiating customer trade, putting a stop to the hot potato. The interdealer order flow, however, does not revert to zero.

### 3.3. Evans-Lyons Results

The equation Evans and Lyons actually estimate is the following:

$$(10) \quad \Delta p_t = \beta_0 + \beta_1 \Delta(i_t - i_t^*) + \beta_2 X_t + \eta_t,$$

where  $\Delta p_t$  is the change in the log spot rate (DM/\$ or ¥/\$) from the end of day  $t-1$  to the end of day  $t$ ,  $\Delta(i_t - i_t^*)$  is the change in the overnight interest differential from day  $t-1$  to day  $t$  (\* denotes DM or ¥), and  $X_t$  is the interdealer order flow from the end of day  $t-1$  to the end of day  $t$  (negative denotes net dollar sales).

There are two changes in this equation relative to equation (9). First, the public information payoff  $\Delta R_t$  in equation (9) represents the macro component, or  $f(i, m, z)$ . To estimate the model, Evans and Lyons have to take a stand on what to include in the regression for  $\Delta R_t$ . They choose to include changes in the nominal interest differential; i.e., they define  $\Delta R_t = \Delta(i_t - i_t^*)$ , where  $i_t$  is the nominal dollar interest rate and  $i_t^*$  is the nominal nondollar interest rate (DM or ¥). As a measure of variation in macro fundamentals, the interest differential is obviously incomplete. The reason Evans and Lyons do not specify a full-blown macro model is because other macro variables (e.g., money supply, output, etc.) are not available at the daily frequency. Accordingly, one should not view their model as fully accommodating both the macro and micro approaches. At the same time, if one were to choose a single macro determinant that needs to be included, interest rates would be it: innovations in interest differentials are the main engine of exchange rate variation in macro models (e.g., the sticky-price monetary model).<sup>18</sup> Moreover, using the change in the interest differential rather than the level is consistent with monetary macro models: in monetary models, shocks to prices are driven by unanticipated changes in the differential.<sup>19</sup>

The second difference in equation (10) relative to (9) is the replacement of the change in the price  $\Delta P_t$  with the change in the log price  $\Delta p_t$ . This difference makes their estimation more directly comparable to previous macro specifications, since those specifications use the log change (which is approximately equal to a percentage change). As an empirical matter, using  $\Delta p_t$  is inconsequential: the two

18. Cheung and Chinn (2001) corroborate this empirically: their surveys of foreign exchange traders show that the importance of individual macroeconomic variables shifts over time, but "interest rates always appear to be important."

19. As a diagnostic, though, Evans and Lyons also estimate the model using the level of the differential, à la uncovered interest parity, and find similar results.

different measures for the change in prices produce nearly identical results.

Table 1 presents estimates of the Evans-Lyons model (equation (10)) using daily data for the DM/\$ and ¥/\$ exchange rates. The coefficient  $\beta_2$  on order flow  $X_t$  is correctly signed and significant, with  $t$ -statistics above 5 in both equations. To see that the sign is correct, recall from the model that net purchases of dollars—a positive  $X_t$ —should lead to a higher DM price of dollars. The traditional macro fundamental—the interest differential—is correctly signed, but is only significant in the ¥ equation. (The sign should be positive because, in the sticky-price monetary model, for example, an increase in the dollar interest rate  $i_t$  induces an immediate dollar appreciation—increase in DM/\$.)

The overall fit of the model is striking relative to traditional macro models, with  $R^2$  statistics of 64 percent and 45 percent for the DM and ¥ equations, respectively. Moreover, the explanatory power of these regressions is almost wholly due to order flow  $X_t$ : regressing  $\Delta p_t$  on  $\Delta(i_t - i_t^*)$  alone, plus a constant, produces an  $R^2$  statistic of less than 1 percent in both equations and coefficients on  $\Delta(i_t - i_t^*)$  that are insignificant at the 5 percent level.<sup>20</sup> That the interest differential regains significance once order flow is included, at least in the ¥ equation, is consistent with omitted variable bias in the interest-rates-only specification.

The size of the order flow coefficient is consistent with estimates based on single-dealer data. The coefficient of 2.1 in the DM equation of Table 1 implies that a day with 1,000 more dollar purchases than sales induces an increase in the DM price by 2.1 percent. Given an average trade size in the sample of \$3.9 million, this implies that:<sup>21</sup>

- \$1 billion of net dollar purchases increases the DM price of a dollar by 0.54 percent.

20. There is a vast empirical literature that attempts to increase the explanatory power of interest rates in exchange rate equations (by introducing individual interest rates as separate regressors, by introducing nonlinearities, etc.). Because these efforts have not been successful, it is very unlikely that variations on the interest rate specification could alter the relative importance of order flow.

21. One of the shortcomings of the Evans (1997) data set is that it does not include the size of each trade, so that order flow is measured as the number of buys minus the number of sells. (The data set does include the total volume over the sample, however, so that an average trade size can be calculated.) This shortcoming must be kept in perspective, however: if the Evans-Lyons results were negative, then data concerns would be serious indeed—the negative results could easily be due to noisy data. But their results are quite positive, which noise alone could not produce. Indeed, that there is noise in the data only underscores the apparent strength of the order flow/price relation.

TABLE 1  
OLS ESTIMATES OF THE EVANS-LYONS MODEL  
 $\Delta p_t = \beta_0 + \beta_1 \Delta(i_t - i_t^*) + \beta_2 X_t + \eta_t$

	$\beta_1$	$\beta_2$	$R^2$
DM	0.52 (1.5)	2.10 (10.5)	0.64
¥	2.48 (2.7)	2.90 (6.3)	0.45

Note:  $t$ -statistics are shown in parentheses (constant not reported). In the case of the DM equation, the  $t$ -statistics are corrected for heteroskedasticity; there is no evidence of heteroskedasticity in the ¥ equation, and no evidence of serial correlation in either equation. The dependent variable  $\Delta p_t$  is the change in the log spot exchange rate from 4 p.m. GMT on day  $t-1$  to 4 p.m. GMT on day  $t$  (DM/\$ or ¥/\$). The regressor  $\Delta(i_t - i_t^*)$  is the change in the one-day interest differential from day  $t-1$  to day  $t$  (\* denotes DM or ¥, annual basis). The regressor  $X_t$  is interdealer order flow between 4 p.m. GMT on day  $t-1$  and 4 p.m. GMT on day  $t$  (negative for net dollar sales, in thousands of transactions). The sample spans four months (May 1 to August 31, 1996), which is 89 trading days. (Saturday and Sunday order flow—of which there is little—is included in Monday.)

Equivalently, at a spot rate of 1.5 DM/\$, \$1 billion of net dollar purchases increases the DM price of a dollar by 0.8 pfennig.

Turning now to estimates at the single-dealer level, these show that information asymmetry induces the dealer to increase the price by 1/100th of a pfennig (0.0001 DM) for every incoming buy order of \$10 million (Lyons 1995). That translates to 1 pfennig per \$1 billion, versus the 0.8 pfennig per \$1 billion found by Evans and Lyons. Though linearly extrapolating the single-dealer estimate (based on individual order sizes around \$10 million) to \$1 billion of order flow is certainly not an accurate description of single-dealer price elasticity, with multiple dealers it may be a good description of price elasticity marketwide.

### 3.4. Robustness Checks

To check robustness, Evans and Lyons examine several obvious variations on the model. For example, they include a constant in the regression, even though the model does not call for one; the constant is insignificant for both currencies and has no substantive effect on the other coefficients. Second, in the spirit of uncovered interest parity, they include the level of the interest differential in lieu of its change; the level of the differential is insignificant in both cases. Third, they test for simple forms of nonlinearity, such as adding a squared order flow term, or testing for piece-wise linearity. Though the squared order flow term is insignificant in both equations, and though they find no evidence of piece-wise linearity in the DM equation, they do find some evidence of piece-wise linearity in the ¥ equation (there is a greater sensitivity of the ¥/\$ price to order



flow in the downward direction, though estimates for both directions are positive and significant). Fourth, they test whether the order flow/price relation depends on the gross level of activity. They find that it does: in the DM equation, the order flow coefficient is lowest on days when the number of transactions is at a middling level (i.e., the pattern is U-shaped); in the ¥ equation, they find that the order flow coefficient is lowest on days when the number of transactions are at a low level (i.e., the coefficient increases with activity level). Their model is not rich enough to account for these coefficient variations. Fifth, Evans and Lyons decompose contemporaneous order flow into expected and unexpected components (by projecting order flow on past flow). In their model, all order flow  $X_t$  is unexpected, but this need not be the case in the data. They find, as one would expect, that order flow's explanatory power comes from its unexpected component.

### 3.5. *Isn't This Just Demand Increases Driving Price Increases?*

At first blush, it might appear that the Evans-Lyons results are right out of Economics 101: of course when demand goes up, prices go up. But this misses the most important lesson. A (correct) premise of textbook exchange rate models is that order flow is not necessary to push prices around. Rather, when public information arrives, rational markets adjust prices instantaneously (i.e., excess demand from new information causes prices to adjust without trading—order flow—needing to take place). That order flow explains such a large percentage of price moves underscores the inadequacy of this public information framework. The information the FX market is aggregating is much subtler than textbook models assume. This we learn from our order flow regressions. To summarize, yes, it is demand, but it is demand of a nature very different from the demand in textbook models.

### 3.6. *But What Drives Order Flow?*

An important challenge for the microstructure approach is determining what drives order flow, i.e., the first link in the fundamentals/order flow/price chain (Figure 1). Here are three promising strategies for shedding light on this question. Strategy one is to disaggregate order flow. For example, interdealer order flow can be split into large banks versus small banks or investment banks versus commercial banks. Data sets on customer order flow can be split into nonfinancial corporations, leveraged financial institutions (e.g., hedge funds), and unleveraged financial institutions (e.g., mutual and pension funds). Do all these trade

types have the same price impact? Someone believing that order flow is just undifferentiated demand would predict that they do. In fact, they do not: certain types of orders (e.g., those from financial institutions) convey more information and therefore have more price impact. People who view order flow as undifferentiated demand overlook this level of analysis, i.e., they overlook the fact that order flow is a vehicle for conveying information. Understanding the information intensity of different trade types brings us closer to this market's underlying information structure.

Strategy two for determining what drives order flow focuses on public information intensity. Consider, for example, periods encompassing scheduled macro announcements. Does order flow account for a smaller share of the price variation within these periods? Or is order flow an important driver of prices even at these times, perhaps helping to reconcile differences in people's mapping from public information to price? Work along these lines, too, will shed light on the forces driving order flow.<sup>22</sup>

Strategy three for determining what drives order flow focuses on discriminating payoff information from discount rate information. If order flow conveys payoff information, then it should forecast surprises in important macro variables like interest rates, money supplies, and trade balances. New order flow data sets that cover many years of FX trading—such as those used by Fan and Lyons (2001)—provide enough statistical power to test this. At a broad level, separating these two types of nonpublic information has implications for how we define the concept of “fundamentals.” Order flow that reflects information about payoffs—like expectations of future interest rates—is in keeping with traditional definitions of exchange rate fundamentals. But order flow that reflects changing discount rates may encompass nontraditional exchange rate determinants (e.g., changing risk preferences, or changing hedging demands), calling perhaps for a broader definition.

### 3.7. *Comments on Causality*

Under the Evans-Lyons model's null hypothesis, causality runs strictly from order flow to prices. Accordingly, under the null, their estimation is not subject to simultaneity bias. (Unlike the classic supply-demand identification problem,

22. A direct role for macro announcements in determining order flow warrants exploring as well (see Evans and Lyons 2001). Another possible use of macro announcements is to introduce them directly into an Evans-Lyons-type model. This tack is not likely to be fruitful, however: there is a long literature showing that macro announcements are unable to account for exchange rate first moments (though they do help to account for second moments—see Andersen and Bollerslev 1998 and Andersen, et al. 2001).



Evans and Lyons are not simply regressing prices on quantity; quantity—i.e., volume—and order flow are fundamentally different concepts.) Within microstructure theory more broadly, this direction of causality holds in all the canonical models (i.e., the Kyle (1985) auction model and the Glosten and Milgrom (1985) sequential trade model), despite the fact that prices and order flow are determined simultaneously. In these models, price innovations are a function of order flow innovations, not the other way around. Put differently, order flow is indeed a cause of price changes, but only a proximate cause; the underlying cause is nonpublic information (about payoffs or about discount rates).

Although there is no simultaneity bias under the null hypothesis, alternative hypotheses do exist under which causality is reversed. Let me offer a few thoughts. First, in the FX market there is no momentum in daily returns, so it is difficult to rationalize momentum (i.e., feedback) trading strategies in this context. Second, work by Killeen, et al. (2001) shows that daily FX order flow Granger causes returns, but not vice versa. Finally, even in episodes where one would expect feedback trading, e.g., when institutions are distressed, the evidence is not there. The best example of this is the recent experience of October 1998 in the ¥/\$ market (after the collapse of the hedge fund Long Term Capital Management). The dollar fell from about 130 ¥/\$ to about 118 ¥/\$ *in a single day*. The popular press view of this episode was that hedge funds attempting to stop their already substantial losses felt they had to sell into a falling market, thereby making it fall further. Using data on order flows over that period, I examine this special episode as a case study in Lyons (2001). In the end, the data do not support the popular story that distressed hedge funds were rushing from the dollar en masse that day. On the contrary, they provided liquidity (i.e., they bought the dollar on that day in aggregate). The selling came from other sources.

#### 4. The Excess Volatility Puzzle

This section addresses the second puzzle: the excess volatility puzzle. By excess I mean that exchange rates are much more volatile than our best measures of fundamentals. Though other asset markets share this property (e.g., stock markets; see Shiller 1981), the puzzle in FX markets is in many ways distinctive.<sup>23</sup> Consider, for example, the

fact that most exchange rates are not allowed to float freely but are managed through intervention by central banks. This fact allows one to address the volatility puzzle in ways not possible in other markets. To understand why, note first that exchange rates are generally less volatile when managed. Given this, one can compare regimes with different management intensities to identify why volatility differs, thereby shedding light on volatility's causes. This approach is common in the literature (e.g., Flood and Rose 1995 and Killeen, Lyons, and Moore 2000). The analysis I present here draws primarily on the empirical findings of Killeen, Lyons, and Moore (KLM).

Before reviewing the KLM findings, let me provide more perspective on the “cross-regime” approach to exchange rate volatility.<sup>24</sup> Why is it that similar macro environments produce more volatility when exchange rates float freely? There are two main approaches to this question, one theoretical and one empirical. The theoretical approach was pioneered by Dornbusch (1976) in his sticky-price monetary model. Dornbusch shows that when goods prices are sticky, but the exchange rate is free to jump, then economic shocks have a disproportionately large effect on the exchange rate—so-called overshooting. From the perspective of excess volatility, the sticky-price monetary model generates the kind of “amplification” that might explain why floating rates are more volatile than fundamentals. This theoretical explanation is not borne out empirically, however: the sticky-price model does not fit the data.

The second main approach to why floating rates are more volatile is empirical. A good example is Flood and Rose (1995), who put the cross-regime logic as follows:

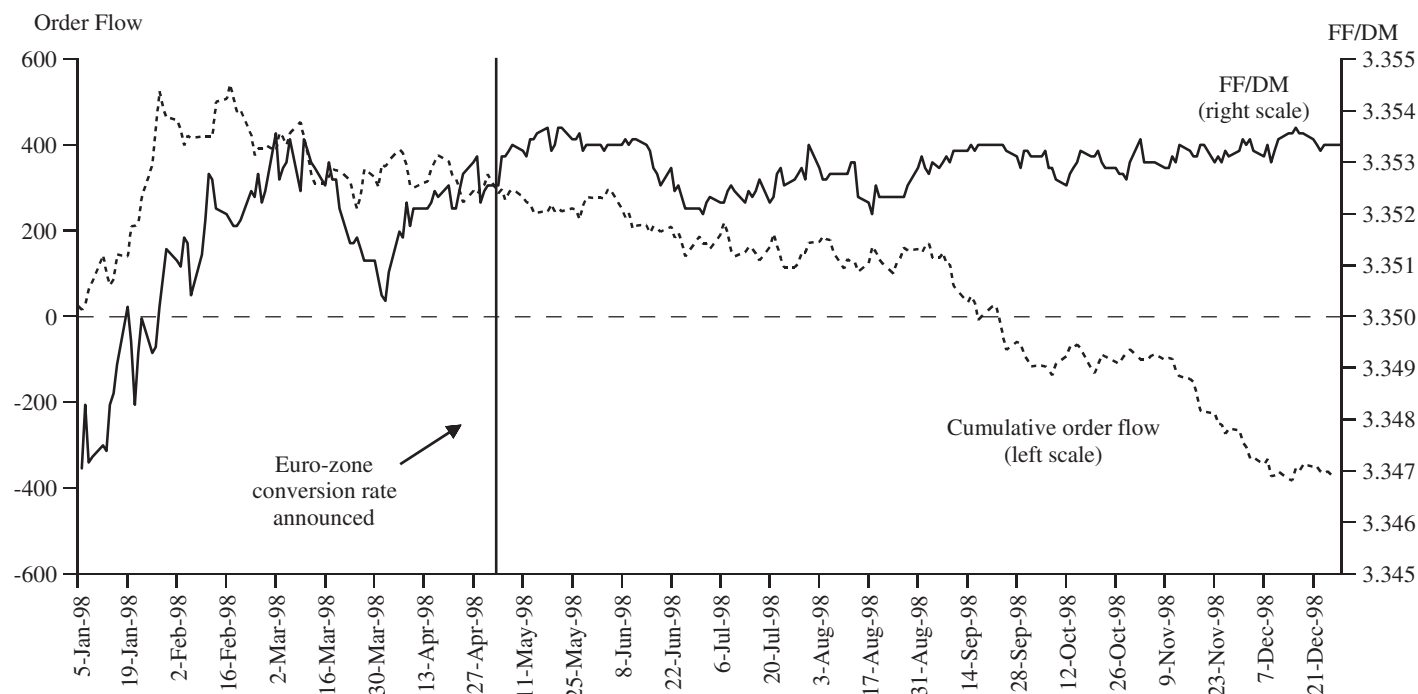
Intuitively, if exchange rate stability arises across regimes without corresponding variation in macroeconomic volatility, then macroeconomic variables will be unable to explain much exchange rate volatility. Thus existing models, such as monetary models, do not pass our test; indeed, this is also true of any potential model that depends on standard macroeconomic variables. We are driven to the conclusion that the most critical determinants of exchange rate volatility are not macroeconomic. (p. 5)

The central idea here starts with the Flood-Rose finding that managing rates does not change the volatility of funda-

23. Contrary to popular belief, in an absolute sense exchange rates are less volatile than stock prices: the annual standard deviation of exchange rate returns is in the 10–12 percent range for major currencies against the dollar, whereas the annual standard deviation of equity market returns is in the 15–20 percent range (and for individual stocks it is still higher).

24. Exchange rate regimes are not limited to floating and fixed. They fall along a spectrum. Ordered in terms of increasing commitment to the exchange rate target, these regimes include: (1) free float, (2) dirty float, (3) target zone, (4) peg—fixed or crawling, (5) currency board, and (6) monetary union. A dirty float involves some limited intervention. A currency board is an institutional commitment to dedicate monetary policy to the exchange rate target.

FIGURE 4  
FF/DM EXCHANGE RATE LEVEL AND CUMULATIVE ORDER FLOW (BUYS MINUS SELLS)



Note: A buy indicates a purchase of DM.

Source: EBS, Datastream.

mentals (fundamentals as described by the public information approach). So, if the volatility reduction from management is not coming from changed behavior of these fundamentals, then it is unlikely these are critical fundamentals. In a sense, then, the Flood-Rose conclusion deepens the puzzle.

KLM take a different tack—they exploit a natural experiment. The experiment is the switch from the European Monetary System (EMS) to European Monetary Union (EMU), which in terms of regimes is a switch from a target zone to a rigidly fixed rate.<sup>25</sup> Starting in January 1999, the euro-country currencies have been rigidly fixed to one another. Before January 1999, however—particularly before May 1998—there was still uncertainty about which countries would participate in the EMU. There was also uncertainty about the timing of interest rate harmonization (which had to occur among the countries adopting the euro).

KLM's analysis of this experiment leads them to the following punch line: exchange rates are more volatile under flexible rates because of order flow. Order flow conveys more information under flexible rates, which increases volatility. Under fixed exchange rates, order flow is prevented from conveying information—as a driver of returns, it is “turned off.” The intuition for why this happens is tied to demand elasticity. Under floating, the elasticity of public demand is (endogenously) low, due to higher volatility and aversion to the risk this higher volatility entails. This makes room for the types of portfolio balance effects that arise in the Evans-Lyons model and allows order flow to convey information about those effects. Under (perfectly credible) fixed rates, the elasticity of public demand is infinite: return volatility shrinks to zero, making the holding of foreign exchange effectively riskless. This eliminates portfolio balance effects and precludes order flow from conveying this type of information. Consequently, order flow as a return driver is shut down.

Figure 4 provides an initial, suggestive illustration of the KLM results. It shows the relationship between the FF/DM exchange rate and cumulative order flow (interdealer order flow from EBS—see Section 4.3.). The vertical line is May 4, 1998, the first trading day after the announcement

25. The transition from EMS to EMU was indisputably a transition toward exchange rate fixity. KLM assume that EMU was perfectly credible after the weekend of May 2–3, 1998—the date the 11 “in” countries were selected and the date the internal conversion rates for the euro-zone were determined. Extending their model to environments of imperfectly credible fixed rates is a natural direction for further research.

of the conversion rates of the euro-participating currencies. The relationship between the two series before May 4 is clearly positive: the correlation is 0.69. After May 4, however, there is a sharp unwinding of long DM positions with no corresponding movement in the exchange rate. In fact, during the second period there is a *negative* correlation of  $-0.35$ . Though total variation in the exchange rate is small, the effect of order flow on the exchange rate appears to have changed from one of clear impact to one of no impact. The model KLM develop provides a more formal framework for addressing this issue (to which I now turn).

#### 4.1. Model Sketch

The specification of trading within each day is identical to that of Evans and Lyons (2002). The key difference here is the presence of two trading regimes: a flexible-rate regime followed by a fixed-rate regime. The shift from flexible to fixed rates is a random event that arrives with constant probability  $p$  at the end of each trading day (after all trading).<sup>26</sup> Once the regime has shifted to fixed rates the central bank commits to setting  $\Delta R_t = 0$  indefinitely.

KLM show that the resulting price level at the end of day  $t$  can be written as:

$$(11) \quad P_t = \begin{cases} \lambda_1 \sum_{\tau=1}^t \Delta R_\tau + \lambda_2 \sum_{\tau=1}^t X_\tau & \text{under flexible rates } (t \leq T) \\ \lambda_1 \sum_{\tau=1}^T \Delta R_\tau + \lambda_2 \sum_{\tau=1}^T X_\tau + \lambda_3 \sum_{\tau=T+1}^t X_\tau & \text{under fixed rates } (t > T), \end{cases}$$

where  $T$  denotes the day on which the regime shifts from flexible to fixed rates. The message of this equation is important: it describes a cointegrating relationship between the level of the exchange rate, cumulative macro fundamentals, and cumulative order flow. (This long-run relationship between cumulative order flow and the level of the exchange rate is not predicted by any traditional exchange rate model.) The cointegrating vector is regime dependent, however.

Under flexible rates, the change in the exchange rate from the end of day  $t-1$  to the end of day  $t$  can be written as:

$$(12) \quad \Delta P_t = \lambda_1 \Delta R_t + \lambda_2 X_t$$

where  $\lambda_1$  and  $\lambda_2$  are positive constants. The portfolio balance effects from order flow enter through  $\lambda_2$ , which depends inversely on  $\gamma$ —the elasticity of public demand with respect to expected return—and also on the variances  $\sigma_R^2$  and  $\sigma_C^2$ .<sup>27</sup>

#### 4.2. Differences across Trading Regimes

Understanding the effects of the different trading regimes—and the changing role of order flow—comes from the effect of the exchange rate regime on equations (11) and (12). Specifically, the parameter  $\gamma$ , which represents the elasticity of public demand, is regime-dependent. This comes from the regime-dependence of the return variance  $\text{Var}[\Delta P_{t+1} + R_{t+1} \mid \Omega_t^3]$  ( $\gamma$  being proportional to the inverse of this variance). The elimination of portfolio balance effects under fixed rates reduces this variance, implying that:

$$(13) \quad \gamma_{\text{flexible}} < \gamma_{\text{fixed}} .$$

Public demand is therefore more elastic in the (credible) fixed-rate regime than in the flexible-rate regime. The implication for the price impact parameters  $\lambda_2$  and  $\lambda_3$  in equation (11)—henceforth  $\lambda_{\text{flexible}}$  and  $\lambda_{\text{fixed}}$ , respectively—is the following:

$$(14) \quad \lambda_{\text{flexible}} > \lambda_{\text{fixed}} .$$

Thus, the exchange rate reacts more to order flow under flexible rates than under fixed rates. For perfectly credible fixed rates (i.e., for which  $\text{Var}[\Delta P_{t+1} + R_{t+1} \mid \Omega_t^3] = 0$ ), we have:

$$(15) \quad \lambda_{\text{fixed}} = 0 .$$

The exchange rate does not respond to order flow in this case. The intuition is clear: under perfect credibility, the variance of exchange rate returns goes to zero because public demand is perfectly elastic, and vice versa.

For intuition, consider  $P_{T+1}$ , the price at the close of the first day of the fixed-rate regime. Foreign exchange is a riskless asset at this point, with return variance equal to zero. A return variance of zero implies that the elasticity of

26. This formulation has two important advantages. First, the effective horizon over which foreign exchange is priced in the flexible-rate regime remains constant. Second, the parameter  $p$  provides a compact means of describing regime shifts as far or near. As an empirical matter, particularly in the context of the EMS-EMU transition, this specification serves as a convenient abstraction from reality.

27. The probability  $p$  of the regime shift adds a parameter to the Evans-Lyons solution that has no qualitative impact on the coefficients of interest here, namely  $\lambda_2$  and  $\lambda_3$ .

the public's speculative demand is infinite, and the price impact parameter  $\lambda_3$  in equation (11) equals zero. This yields a price at the close of trading (Round 3) on day  $T+1$  of:

$$P_{T+1} = \lambda_1 \sum_{t=1}^T \Delta R_t + \lambda_2 \sum_{t=1}^T X_t.$$

The summation over the payoff increment  $\Delta R_t$  does not include an increment for day  $T+1$  because the central bank maintains  $\Delta R_t$  at zero in the fixed regime. Though  $X_{T+1}$  is not equal to zero, this has no effect on prices because  $\lambda_3=0$ , as noted. This logic holds throughout the fixed-rate regime. Under flexible rates, the economics behind the price impact of order flow is the same as that under the Evans-Lyons model, adjusted only by the change in parameter values due to the possibility of regime switch.

### 4.3. The KLM Data Set

The KLM data set includes daily order flow in the FF/DM market for one year, 1998. The data are from EBS, the electronic interdealer broking system. (At that time, EBS accounted for nearly half of interdealer trading in the largest currencies, which translates into about a third of total trading in major currencies; the Evans-Lyons data reflect the other half of interdealer trading—the direct portion.) By KLM's estimate, their sample accounts for about 18 percent of trading in the DM/FF market in 1998. Daily order flow includes all orders passing through the system over 24 hours starting at midnight GMT (weekdays only).

The data set is rich enough to allow measurement of order flow  $X_t$  two ways: number of buys minus number of sells (à la Evans and Lyons 2002) and amount bought minus amount sold (in DM). KLM find that the two measures behave quite similarly: the correlation between the two  $X_t$  measures in the flexible-rate portion of the sample (the first four months) is 0.98. They also find that substituting one measure for the other in their analysis has no substantive effect on their findings.

Let me provide a bit more detail on EBS. As noted, EBS is an electronic broking system for trading spot foreign exchange among dealers. It is limit order driven, screen-based, and ex ante anonymous (ex post, counterparties settle directly with one another). The EBS screen displays the best bid and ask prices together with information on the cash amounts available for trading at these prices. Amounts available at prices other than the best bid and offer are not displayed. Activity fields on this screen track a dealer's own recent trades, including prices and amount, as well as the recent trades executed on EBS systemwide.

There are two ways that dealers can trade currency on EBS. Dealers can either post prices (i.e., submit "limit orders"), which does not ensure execution, or dealers can

"hit" prices (i.e., submit "market orders"), which does ensure execution. To construct a measure of order flow, trades are signed according to the direction of the latter—the initiator of the transaction.

When a dealer submits a limit order, she is displaying to other dealers an intention to buy or sell a given cash amount at a specified price.<sup>28</sup> Bid prices (limit order buys) and offer prices (limit order sells) are submitted with the hope of being executed against the market order of another dealer—the "initiator" of the trade. To be a bit more precise, not all initiating orders arrive in the form of market orders. Sometimes, a dealer will submit a limit order buy that is equal to or higher than the current best offer (or will submit a limit order sell that is equal to or lower than the current best bid). When this happens, the incoming limit order is treated as if it were a market order and is executed against the best opposing limit order immediately. In these cases, the incoming limit order is the initiating side of the trade.

### 4.4. Results

The relationship between cumulative order flow and the exchange rate is illustrated in Figure 4. We saw that the effect of order flow on the exchange rate appears to have changed from one of clear impact to one of no impact. The results that follow address this more formally, based on the KLM model's testable implications.

The analysis proceeds in two stages. First, KLM address whether there is evidence of a cointegrating relationship between order flow and prices, as the model predicts. This first stage also examines the related issues of stationarity and long-run coefficient sizes. The second stage addresses the degree to which order flow is exogenous (as assumed in their model). This stage includes a test for reverse Granger causality, i.e., statistical causality running from the exchange rate to order flow.

#### 4.4.1. Stage 1: Cointegration and Related Issues

Let us begin by repeating equation (11) from the model, which establishes the relationship between the level of the exchange rate  $P_t$ , a variable summarizing public information ( $\Sigma \Delta R_t$ ), and accumulated order flow ( $\Sigma X_t$ ).

28. EBS has a prescreened credit facility whereby dealers can tell which prices correspond to trades that would not violate their counterparty credit limits, thereby eliminating the potential for failed deals because of credit issues.



$$(11) P_t = \begin{cases} \lambda_1 \sum_{\tau=1}^t \Delta R_\tau + \lambda_2 \sum_{\tau=1}^t X_\tau & \text{under flexible rates } (t \leq T) \\ \lambda_1 \sum_{\tau=1}^T \Delta R_\tau + \lambda_2 \sum_{\tau=1}^T X_\tau + \lambda_3 \sum_{\tau=T+1}^t X_\tau & \text{under fixed rates } (t > T). \end{cases}$$

Like Evans and Lyons (2002), KLM use the interest differential as the public information variable (the Paris interbank offer rate minus the Frankfurt interbank offer rate).

The KLM model predicts that before May 4, 1998, all these variables are nonstationary and are cointegrated. After May 4, the model predicts that the exchange rate converges to its conversion rate and should be stationary. During this latter period (May to December), therefore, equation (11) makes sense only if the price impact coefficient,  $\lambda$ , goes to zero (as the model predicts), or if accumulated order flow becomes stationary. Otherwise, the regression is unbalanced, with some stationary variables and some nonstationary variables.

The first step is to test whether the relevant variables are nonstationary. KLM find that in the first four months of 1998, all variables are indeed nonstationary (inference based on Dickey-Fuller tests). In the remaining eight months, the exchange rate is stationary, as expected, but both cumulative order flow and the interest differential remain nonstationary. These results are consistent with a price impact parameter  $\lambda_3$  in the latter period of zero. It is important to determine, however, whether equation (11) actually holds for the January to April period, i.e., whether the variables are cointegrated, as the model predicts.

KLM use the Johansen procedure to test for cointegration (Johansen 1992). The unrestricted vector autoregression (VAR) is assumed to consist of the three variables—the exchange rate, cumulative order flow, and the interest differential—as well as a constant and a trend. After testing various possible lag lengths, KLM find evidence that a lag length of 1 is appropriate.

The cointegration tests show that there is indeed one cointegrating vector. (The null of no cointegrating vectors is rejected in favor of the alternative of at least one cointegrating vector. But the null of one cointegrating vector cannot be rejected in favor of the alternative of at least two.) This implies that a linear combination of the three variables is stationary, as the KLM model predicts.

KLM go one step further and implement the test for cointegration without the interest differential. They find evidence of one cointegrating vector in that case, too, now between the exchange rate and cumulative order flow. The finding of one cointegrating vector in both the bivariate

and trivariate systems suggests that the interest differential enters the trivariate cointegrating vector with a coefficient of zero. When KLM estimate the parameters of the cointegrating vector directly, this is exactly what they find: they cannot reject that the interest differential has a coefficient of zero. By contrast, the coefficient on cumulative order flow is highly significant and correctly signed. (The size of the coefficient implies that a 1 percent increase in cumulative order flow moves the spot rate by about five basis points.)<sup>29</sup> These findings of cointegration and an order flow coefficient that is correctly signed are supportive of their model's emphasis on order flow, even in the long run. At the same time, the lack of explanatory power in the interest differential suggests that this specialization of the payoff increment  $\Delta R_t$  is deficient (in keeping with the negative results of the macro literature more generally).

#### 4.4.2. Exogeneity of Order Flow

An important question facing the dispersed information approach is the degree to which causality can be viewed as running strictly from order flow to the exchange rate, rather than running in both directions. The KLM framework provides a convenient way to address this question. In particular, if a system of variables is cointegrated, then it has an error-correction representation (see Engle and Granger 1987). These error-correction representations provide clues about the direction of causality. Specifically, the error-correction representation allows one to determine whether the burden of adjustment to long-run equilibrium falls on the exchange rate, on cumulative order flow, or both. If adjustment falls at least in part on order flow, then order flow is responding to the rest of the system (i.e., it is not exogenous in the way specified by the Evans-Lyons and KLM models).

The KLM findings suggest that causality is indeed running strictly from order flow to prices and not the other way around. KLM test this by estimating the error-correction term in both the exchange rate and order flow equations. They find that the error-correction term is highly significant in the exchange rate equation, whereas the error-correction term in the order flow equation is insignificant. This implies that adjustment to long-run equilibrium is occurring via the exchange rate. More intuitively, *when a gap opens in the long-run relationship between cumulative order flow and the exchange rate, it is the exchange rate that adjusts to reduce the gap, not*

29. In their sample, the mean value of cumulative order flow is DM1.38 billion.



*cumulative order flow*. In the parlance of the literature, the insignificance of the error-correction term in the order flow equation means that order flow is weakly exogenous. Further, KLM show that there is no evidence of Granger causality running from the exchange rate to order flow (i.e., feedback trading is not taking place). This combination of weak exogeneity and the absence of Granger causality implies that cumulative order flow is strongly exogenous. Finally, the KLM error-correction estimates suggest that about one-third of departures from long-run equilibrium is dissipated each day.

To summarize, the KLM analysis addresses the excess volatility puzzle on two fronts, one theoretical and one empirical. On the theoretical front, they provide a new approach—based on order flow—for why volatility is high when exchange rates float freely. The punch line of their approach is that an important source of volatility is order flow or, more precisely, the information order flow conveys. Under floating, the elasticity of public demand is (endogenously) low, due to higher volatility and aversion to the risk that higher volatility entails. This makes room for the portfolio balance effects that arise in the Evans-Lyons model and allows order flow to convey information about those effects. Under (perfectly credible) fixed rates, the elasticity of public demand is infinite: return volatility shrinks to zero, making the holding of foreign exchange effectively riskless. This eliminates portfolio balance effects and precludes order flow from conveying this type of information. Thus, under fixed rates, order flow as a return driver is shut down.

A nice feature of the KLM approach to excess volatility, relative to other approaches, is that its implications can be brought to the data. There are many fine theoretical papers on excess exchange rate volatility (see, e.g., Hau 1998 and Jeanne and Rose 1999, and references to earlier work contained therein). But, in general, little of the existing theoretical work is easily implemented empirically. The order flow focus of the KLM approach makes it readily implementable. That said, the specific results that KLM offer are only suggestively supportive of their particular story. Much more empirical analysis along these lines remains to be done.

Two of the KLM empirical findings are especially relevant to interpreting work on order flow more generally. First, they find that Granger causality runs from order flow to the exchange rate, but not vice versa. True, Granger causality is not the same as economic causality. Nevertheless, the result does help assuage concern. Second, they find that gaps in the relationship between cumulative order flow and the level of the exchange rate engender an exchange rate response but not an order flow response. This

result, too, helps assuage concern about the direction of causality between these two variables.

One might be tempted to conclude that data for only four months are not enough to produce reliable analysis of cointegration. An important aspect of the KLM results should assuage this concern, however. Recall that KLM find rapid adjustment back to the cointegrating relationship (their error-correction estimates suggest that about one-third of departures from long-run equilibrium is dissipated each day). The half-life of these departures is therefore only about two days. Data for four months are enough to cover about 45 of these half-lives, quite a lot in the context of estimating cointegrating relationships. For comparison, estimates of adjustment back to the cointegrating relationship of purchasing power parity generate half-lives of around 5 years. One would need over 200 years of data to estimate PPP error correction with as many half-lives in the sample.

Note, too, that the KLM model provides a different perspective on exchange rate credibility. In their model, a credible fixed rate is one in which the private sector, not the central bank, willingly absorbs innovations in order flow.<sup>30</sup> The textbook treatment of fixed-rate regimes, in contrast, is centered on the willingness of the central bank to buy and sell domestic currency at a predetermined price; i.e., it is the central bank that absorbs the order flow. If the central bank needs to intervene, the fixed exchange rate regime is already in difficulty because the private sector's demand for order flow is no longer perfectly elastic. It may be useful to revisit analysis of currency crises with this possibility in mind.

Finally, to recap, the KLM model provides a new explanation for the excess volatility puzzle. Shocks to order flow induce volatility under flexible rates because they have portfolio balance effects on price, whereas under fixed rates the same shocks do not have portfolio balance effects. These effects arise in one regime and not the other because the elasticity of speculative demand for foreign exchange is (endogenously) regime-dependent: under flexible rates, low elasticity magnifies portfolio balance effects; under credibly fixed rates, the elasticity of speculative demand is infinite, eliminating portfolio balance effects.

30. This is a theoretical point. Empirically, it appears that there was little intervention by the national central banks or the European Central Bank in the period from May to December, 1998 (these banks are not terribly forthcoming with intervention data over this period).

## 5. Conclusion

I have argued that abstracting from information aggregation when analyzing exchange rates misses quite a lot. The argument commonly offered in support of this abstraction—that dispersed information is rapidly summarized in public macro variables—is untenable. The abstraction would be easier to defend if either (1) both the public and dispersed information approaches performed well empirically or (2) both approaches performed poorly. In reality, the dispersed information approach performs rather well (e.g., Payne 1999 and Evans and Lyons 2002) while the public information approach does not.

How, specifically, can one identify the information that determines order flow? The notion of order flow as an intermediate link between information and prices suggests several strategies for answering this question, all of which are part of ongoing research. Three in particular are outlined here.

One strategy for linking order flow to underlying determinants starts by decomposing order flow. (That it can be decomposed is one of its nice properties.) Fan and Lyons (2001) test whether all parts of the aggregate order flow have the same price impact. They do not: the price impact of FX orders from financial institutions (e.g., mutual funds and hedge funds) is significantly higher than the price impact of orders from nonfinancial corporations. This suggests that order flow is not just undifferentiated demand. Rather, the orders of some participants are more informative than the orders of others. Analyzing order flow's parts gives us clues as to the underlying information structure.

A second strategy for linking order flow to underlying determinants is based on the view that order flow measures individuals' changing expectations. As a measure of expectations, it reflects a willingness to back one's beliefs with money—the backed-by-money expectational votes, if you will. Expectations measured from macro data, on the other hand, are slow-moving and imprecise. If order flow is serving as an expectations proxy, then it should forecast surprises in important macroeconomic variables (like interest rates). New order flow data sets that cover up to six years of FX trading provide enough statistical power to test this. Note too that this line of research offers a possible explanation of the Meese and Rogoff (1983) findings. To understand why, write the price of foreign exchange,  $P_t$ , in the standard way as a function of current and expected future macro fundamentals:  $P_t = g(f_t, f_{t+1}^e)$ . If (big if) the macro variables that order flow is forecasting are largely beyond the one-year horizon, then the empirical link between exchange rates and *current* macro variables  $f_t$  will be loose. That macro empirical results are more positive at horizons beyond one year is consistent with this “anticipation” hypothesis.

A third strategy for determining what drives order flow focuses on public information intensity. Consider, for example, periods encompassing scheduled macro announcements. Does order flow account for a smaller share of price variation within these periods? Or is order flow an important driver of prices even at these times, perhaps helping to reconcile differences in people's mapping from public information to prices? Work along these lines, too, will shed light on the forces driving order flow (see, e.g., Evans and Lyons 2001).

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WP 01-01

### The Federal Reserve Banks' Imputed Cost of Equity Capital

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of Business*

According to the Monetary Control Act of 1980, the Federal Reserve Banks must establish fees for their priced services to recover all operating costs as well as imputed costs of capital and taxes that would be incurred by a profit-making firm. The calculations required to establish these imputed costs are referred to collectively as the Private Sector Adjustment Factor (PSAF). In this paper, we propose a new approach for calculating the cost of equity capital used in the PSAF. The proposed approach is based on a simple average of three methods as applied to a peer group of bank holding companies. The three methods estimate the cost of equity capital from three different perspectives—the historical average of comparable accounting earnings, the discounted value of expected future cashflows, and the equilibrium price of investment risk as per the capital asset pricing model. We show that the proposed approach would have provided stable and sensible estimates of the cost of equity capital for the PSAF from 1981 through 1998.

WP 01-02

### Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia

Glenn D. Rudebusch, *FRB San Francisco*

Forthcoming in *Journal of Monetary Economics*.

[See p. 87 for the abstract of this paper.](#)

WP 01-03

### Forward-looking Behavior and the Optimality of the Taylor Rule

Kevin J. Lansing, *FRB San Francisco*

Bharat Trehan, *FRB San Francisco*

This paper examines the optimal monetary policy under discretion using a small macroeconomic model that allows for varying degrees of forward-looking behavior. We quantify how forward-looking behavior affects the optimal response to inflation and the output gap in the central bank's interest rate rule. Specifically, we isolate the influence of forward-looking behavior in the IS (or aggregate demand) equation, the short-run Phillips curve, and a term structure equation. We show that the data cannot uniquely identify the degree of forward-looking behavior in this class of models. For a baseline parameter calibration, we obtain the usual result that the optimal policy rule calls for a stronger response to inflation and the output gap than is recommended by the well-known Taylor rule. We then consider whether plausible departures from the baseline calibration can deliver the Taylor rule as the optimal monetary policy under discretion. We find that a successful parameter combination must include one or more of the following: (i) a high degree of forward-looking behavior in the IS equation, (ii) a low degree of forward-looking behavior in the term structure equation, or (iii) a large interest rate sensitivity parameter in the IS equation. Notably, these results are obtained without requiring the central bank's loss function to include a term that penalizes interest rate changes. Overall, our quantitative experiments suggest that one cannot rule out the possibility that the Taylor rule is the optimal monetary policy under discretion.



WP 01-04

## Inflation Taxes, Financial Intermediation, and Home Production

Milton H. Marquis, *FRB San Francisco and Florida State University*

This paper examines the incidence and welfare costs of inflation in the presence of financial market frictions and home production. The results suggest that financing constraints on firms' working capital expenditures significantly increase the welfare costs relative to the standard Cooley-Hansen (1989) cash-in-advance framework. These costs are reduced, but remain above those computed by Cooley and Hansen, when a financial intermediary is introduced that engages in asset transformation by creating liquid, interest-bearing deposit accounts and uses the proceeds to finance working capital loans to firms. Explicitly modeling home production activities tends to exacerbate the distortions that inflation induces in employment and market output to a considerable degree, and suggests that the welfare costs of anticipated inflation may be substantially higher than previous estimates. Sensitivity analysis indicates that the magnitude of the market response to inflation and the attendant welfare costs of inflation depend strongly on the elasticity of substitution between capital and labor in home production, and to a much lesser degree on the elasticity of substitution between home and market consumption. When households also must finance their gross investment in home capital by borrowing from the financial intermediary, home production is indirectly taxed by inflation. As a result of this credit friction, resources thus tend to move back into the market, thereby mitigating the adverse effects of inflation on employment and output, while further increasing the welfare losses.

WP 01-05

## Solvency Runs, Sunspot Runs, and International Bailouts

Mark M. Spiegel, *FRB San Francisco*

This paper introduces a model of international lender of last resort (ILLR) activity under asymmetric information. The ILLR is unable to distinguish between runs due to debtor insolvency and those which are the result of pure sunspots. Nevertheless, the ILLR can elicit the underlying state of nature from informed creditors by offering terms consistent with generating a separating equilibrium. Achieving the separating equilibrium requires that the

ILLR lends to the debtor at sufficiently high rates. This adverse selection problem provides an alternative rationale for Bagehot's Principle of last-resort lending at high rates of interest to the moral hazard motivation commonly found in the literature.

WP 01-06

## The Supplemental Security Income Program

Mary C. Daly, *FRB San Francisco*  
Richard V. Burkhauser, *Cornell University*

In this paper we provide the basic information necessary for SSI policymakers to make informed choices about its future. We present a description of SSI, discuss the original rationale for the program, and examine the cultural and political factors that have affected its mission over time. We then summarize the economic issues raised by the existence and structure of the program, review the empirical evidence on the behavioral effects of SSI, and discuss current policy issues and areas of future research.

WP 01-07

## Economic Outcomes of Working-Age People with Disabilities over the Business Cycle: An Examination of the 1980s and 1990s

Richard V. Burkhauser, *Cornell University*  
Mary C. Daly, *FRB San Francisco*  
Andrew J. Houtenville, *Cornell University*  
Nigar Nargis, *Cornell University*

We examine the rate of employment and the household income of the working-age population (aged 25–61) with and without disabilities over the business cycles of the 1980s and 1990s using data from the March Current Population Survey and the National Health Interview Survey. In general, we find that while the employment of working-age men and women with and without disabilities exhibited a procyclical trend during the 1980s business cycle, this was not the case during the 1990s expansion. During the 1990s, the employment of working-age men and women without disabilities continued to be procyclical, but the employment rates of their counterparts with disabilities declined over the entire 1990s business cycle. Although increases in disability transfer income replaced a significant fraction of their lost earnings, the household income of men and women with disabilities fell relative to the rest of the population over the decade.



WP 01-08

## The Policy Preferences of the U.S. Federal Reserve

Richard Dennis, *FRB San Francisco*

This paper uses a small data-consistent model of the United States to identify and estimate the Federal Reserve's policy preferences. We find critical differences between the policy regimes in operation during the Burns-Miller and Volcker-Greenspan periods. Over the Volcker-Greenspan period we estimate the inflation target to be 2.0 percent and find that policymakers were willing to allow the real interest rate to change in order to keep overall changes in the nominal interest rate relatively small. In contrast, for the Burns-Miller period, the inflation target is estimated to be 5.9 percent, and we find that policymakers were much more prepared to tolerate changes in the nominal interest rate than they were changes in the real interest rate. Consequently, over this period policymakers tended to accommodate movements in inflation. We find statistical evidence that a policy regime shift occurred with Volcker's appointment to Federal Reserve chairman.

WP 01-09

## Optimal Policy in Rational-Expectations Models: New Solution Algorithms

Richard Dennis, *FRB San Francisco*

This paper develops algorithms that solve for optimal discretionary and optimal precommitment policies in rational-expectations models. The techniques developed are simpler to apply than existing methods; they do not require identifying and separating predetermined variables from jump variables, and they eliminate many of the mathematical preliminaries that are required to implement existing methods. The techniques developed are applied to examples to assess the benefits of precommitment over discretion.

WP 01-10

## Using Prices to Measure Productivity in a Two-Sector Growth Model

Milton H. Marquis, *FRB San Francisco*Bharat Trehan, *FRB San Francisco*

We construct a two-sector growth model with sector-specific technology shocks where one sector produces intermediate goods while the other produces final goods. Theoretical restrictions from this model are used to compute the time series for sector-specific TFPs based solely on factor prices and the relative price of intermediate goods to final goods over the 1959–2000 period. An aggregate TFP measure based on these series appears quite similar to the multifactor productivity measure constructed by the BLS. We find statistical evidence of structural breaks in the growth rate of our productivity measures in 1973 and 1995. The first of these breaks appears to be due to an economy-wide productivity slowdown, while the second is attributed to a sharp pickup in the growth rate of productivity in the intermediate goods sector. Using only these TFP measures, the model's predictions of output growth rates in the two sectors over the intervals defined by the estimated break dates compare favorably with the actual data on consumer nondurables and services (final goods) and consumer and producer durables (intermediate goods).

WP 01-11

## Impact of Deposit Rate Deregulation in Hong Kong on the Market Value of Commercial Banks

Simon H. Kwan, *FRB San Francisco*

This paper examines the effects of deposit rate deregulation in Hong Kong on the market value of banks. The release of the Consumer Council's Report in 1994 recommending interest rate deregulation is found to produce negative abnormal returns, while the announcement in 1995 terminating the deregulation program led to positive abnormal returns. Furthermore, news about resumption of interest rate deregulation in 1998 and the official announcement in 2000 to abolish the interest rate rules produced negative abnormal returns. The evidence suggests that Hong Kong banks earned rents from deposit rate restrictions and that relaxation of rate ceilings reduced these rents.

WP 01-12

## The Disposition of Failed Bank Assets: Put Guarantees or Loss-Sharing Arrangements?

Mark M. Spiegel, *FRB San Francisco*

To mitigate the regulatory losses associated with bank failures, efforts are usually made to dispose of failed banks' assets quickly. However, this process usually precludes due diligence examination by acquiring banks, leading to problems of asymmetric information concerning asset quality. This paper examines two mechanisms that have been used for dealing with these problems, "put guarantees," under which acquiring banks are allowed to return assets to the regulatory authority for liquidation, and "loss-sharing arrangements," under which the acquiring banks keep all assets under their control to maturity and are then compensated by the regulatory authority for a portion of asset losses. The analysis is conducted in a Hart-Moore framework in which the removal of certain assets from the banking system can reduce their value. Changes in the relative desirability of the two guarantee mechanisms during economic downturns are shown to depend on the credibility of the regulatory authority. When the regulatory authority enjoys credibility, a downturn favors the loss-sharing arrangement, while when the regulatory authority lacks credibility, the impact of a downturn is ambiguous.

WP 01-13

## Does a Currency Union Affect Trade? The Time Series Evidence

Reuven Glick, *FRB San Francisco*

Andrew K. Rose, *Haas School of Business, UC Berkeley*

Forthcoming in *European Economic Review*.

[See p. 83 for the abstract of this paper.](#)

WP 01-14

## Incorporating Equity Market Information into Supervisory Monitoring Models

John Krainer, *FRB San Francisco*

Jose A. Lopez, *FRB San Francisco*

We examine whether equity market variables, such as stock returns and equity-based default probabilities, are useful to bank supervisors for assessing the condition of

bank holding companies. Using an event study framework, we find that equity market variables anticipate supervisory ratings changes by up to four quarters and that the improvements in forecast accuracy arising from conditioning on equity market information are statistically significant. We develop an off-site monitoring model that easily combines supervisory and equity market information, and we find that the model's forecasts also anticipate supervisory ratings changes by several quarters. While the inclusion of equity market variables in the model does not improve forecast accuracy by much relative to simply using supervisory variables, we conclude that equity market information is useful for forecasting supervisory ratings and should be incorporated into supervisory monitoring models.

WP 01-15

## Small Businesses and Computers: Adoption and Performance

Marianne P. Bitler, *RAND and Visiting Scholar,*

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Until recently, little evidence suggested that the computer revolution of recent decades has had much impact on aggregate economic growth. Analysis at the worker level has found evidence that use of computers is associated with higher wages. Although some research questions whether this finding is solely due to unobserved heterogeneity in worker quality, others point to such results as evidence that the wage premia for skilled workers have increased over time. Adoption of new technologies is associated with higher productivity and higher productivity growth. As in the worker literature, firms adopting computers may simply be more productive firms. Using new data from the 1998 Survey of Small Business Finances, I examine the determinants of computer adoption by small privately held firms and analyze whether computer use affects profits, sales, labor productivity, or other measures of firm success. I am able to control for many firm characteristics not available in other data sets. I find that computer adoption is more likely by larger firms, by younger firms, by firms whose markets are national or international, and by limited liability firms. Adoption is also more likely by firms founded or inherited by a current owner and by firms whose primary owners are more educated. Firms with more than 50 percent of their ownership shares held by African Americans or Asians, and in some specifications, firms with more than 50 percent of their shares held by Hispanics are less likely to have adopted computers, echoing results for households in the literature. Evidence

concerning the link between computer use and firm performance is mixed. Current performance as measured by profits or sales is not associated with current computer use in the full sample. In some specifications, use of computers for specific tasks is associated with higher costs. Estimates of the effects of computer use on costs are larger (in absolute value) when the sample is restricted to manufacturing or wholesale trade firms or to larger small businesses. Estimates using the more parsimonious set of control variables widely available in other firm level data show large and positive effects of computer use on firm costs, sales, and profits, suggesting that controlling for managerial, firm, and owner characteristics is important.

#### WP 01-16 Quantifying Embodied Technological Change

Plutarchos Sakellaris, *University of Maryland and  
University of Ioannina*  
Daniel J. Wilson, *FRB San Francisco*

We estimate the rate of embodied technological change directly from plant-level manufacturing data on current output and input choices along with histories on their vintages of equipment investment. Our estimates range between 8 percent and 17 percent for the typical U.S. manufacturing plant during the years 1972–1996. Any number in this range is substantially larger than is conventionally accepted with some important implications. First, the role of investment-specific technological change as an engine of growth is even larger than previously estimated. Second, existing producer durable price indices do not adequately account for quality change. As a result, measured capital stock growth is biased. Third, if accurate, the Hulten and Wykoff (1981) economic depreciation rates may primarily reflect obsolescence.

#### WP 01-17 Is Embodied Technology the Result of Upstream R&D? Industry-Level Evidence

Daniel J. Wilson, *FRB San Francisco*

Forthcoming in *Review of Economic Dynamics*.  
[See p. 89 for the abstract of this paper.](#)

#### WP 01-18 Embodying Embodiment in a Structural Macroeconomic Input-Output Model

Daniel J. Wilson, *FRB San Francisco*

This paper describes an attempt to build a regression-based system of labor productivity equations that incorporate the effects of capital-embodied technological change into IDLIFT, a structural macroeconomic input-output model of the U.S. economy. Builders of regression-based forecasting models have long had difficulty finding labor productivity equations that exhibit the neoclassical or Solowian property that movements in investment should cause accompanying movements in labor productivity. Theory dictates that this causation is driven by the effect of traditional capital deepening as well as technological change embodied in capital. Lack of measurement of the latter has hampered the ability of researchers to properly estimate the productivity-investment relationship. Wilson (2001a), by estimating industry-level embodied technological change, has alleviated this difficulty. In this paper, I utilize those estimates to construct capital stocks that are adjusted for technological change which then are used to estimate neoclassical-type labor productivity equations. It is shown that replacing IDLIFT's former productivity equations, based on changes in output and time trends, with the new equations results in a convergence between the dynamic behavior of the model and that predicted by neoclassical production theory.

#### WP 01-19 Precommitment, the Timeless Perspective, and Policymaking from Behind a Veil of Uncertainty

Richard Dennis, *FRB San Francisco*

Woodford (1999) develops the notion of a “timelessly optimal” precommitment policy. This paper uses a simple business cycle model to illustrate this notion. We show that timelessly optimal policies are not unique and that they are not necessarily better than the time-consistent solution. Further, we describe a method for constructing optimal precommitment rules in an environment where the policymaker does not know the initial state of the economy. This latter solution is useful for characterizing the benefits policymakers extract through exploiting initial conditions.

WP 01-20

## The Employment of Working-Age People with Disabilities in the 1980s and 1990s: What Current Data Can and Cannot Tell Us

Richard V. Burkhauser, *Cornell University*

Mary C. Daly, *FRB San Francisco*

Andrew J. Houtenville, *Cornell University*

Nigar Nargis, *Cornell University*

A new and highly controversial literature argues that the employment of working-age people with disabilities fell dramatically relative to the rest of the working-age population in the 1990s. Some dismiss these results as fundamentally flawed because they come from a self-reported work limitation-based disability population that captures neither the actual population with disabilities nor its employment trends. In this paper, we examine the merits of these criticisms. We first consider some of the difficulties of defining and consistently measuring the population with disabilities. We then discuss how these measurement difficulties potentially bias empirical estimates of the prevalence of disability and of the employment behavior of those with disabilities. Having provided a context for our analysis, we use data from the National Health Interview Survey (NHIS) to compare the prevalence and employment rates across two empirical populations of those with disabilities: one defined by self-reported impairments and one defined by self-reported work limitations. We find that although traditional work limitation-based definitions underestimate the size of the broader population with health impairments, the employment trends in the populations defined by work limitations and impairments are not significantly different from one another over the 1980s and 1990s. We then show that the trends in employment observed for the NHIS population defined by self-reported work limitations are statistically similar to those found in the Current Population Survey (CPS). Based on this analysis, we argue that nationally representative employment-based data sets like the CPS can be used to monitor the employment trends of those with disabilities over the past two decades.



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PB 01-01

### Asian Finance and the Role of Bankruptcy

Thomas F. Cargill, *University Nevada, Reno;*

*Visiting Scholar, FRB San Francisco*

Elliott Parker, *University Nevada, Reno*

The degree to which bankruptcy is permitted to play a role in the allocation of capital is a key distinction between the Asian state-directed financial regime and the Western market-directed version. The paper discusses the two approaches to finance and argues that a major problem with the bank finance model used in many Asian countries is its minimization of bankruptcy risks. A three-sector development model (agriculture, manufacturing, and financial sector) is developed and simulated to compare the outcomes of the two approaches separately and then to evaluate the transition costs of switching from a state- to a market-directed financial regime. The simulation results suggest that the market approach results in a higher long-run growth path because it eliminates inefficient firms through bankruptcy. The results also suggest that switching from a state- to a market-directed model can be very costly to the economy, though the transition costs can be lowered somewhat by a delayed and phased-in liberalization. At the same time, a delayed and phased-in approach may induce other difficulties not considered in the model. Several policy implications are drawn from the model and simulation results; for example, development of an infrastructure to provide for orderly bankruptcy and the development of money and capital markets should be given high priority in the liberalization process.

PB 01-02

### A Cure Worse than the Disease?

### Currency Crises and the Output Costs of IMF-Supported Stabilization Programs

Michael Hutchison, *University of California, Santa Cruz;*

*Visiting Scholar, FRB San Francisco*

This paper investigates the output effects of IMF-supported stabilization programs, especially those introduced at the time of a severe balance of payments/currency crisis. Using a panel data set over the 1975–1997 period and covering 67 developing and emerging market economies (with 461 IMF stabilization programs and 160 currency crises), we find that currency crises—even after controlling for macroeconomic developments and political and regional factors—significantly reduce output growth for one to two years. Output growth is also lower (0.7 percentage point annually) during IMF stabilization programs, but it appears that growth generally slows prior to implementation of the program. Moreover, programs coinciding with recent balance of payments or currency crises do not appear to further damage short-run growth prospects. Countries participating in IMF programs significantly reduce domestic credit growth, but no effect is found on budget policy. Applying this model to the collapse of output in East Asia following the 1997 crisis, we find that the unexpected (forecast error) collapse of output in Malaysia—where an IMF program was not followed—was similar in magnitude to those countries adopting IMF programs (Indonesia, Korea, the Philippines, and Thailand).



PB 01-03

## Financial Liberalization and Banking Crises in Emerging Economies

Betty C. Daniel, *University at Albany-SUNY; Visiting Scholar, FRB San Francisco*

John Bailey Jones, *University at Albany-SUNY*

In this paper, we provide a theoretical explanation of why financial liberalization is likely to generate financial crises in emerging market economies. We first show that under financial repression the aggregate capital stock and bank net worth are both likely to be low. This leads a newly liberalized bank to be highly levered, because the marginal product of capital—and thus loan interest rates—are high. The high returns on capital, however, also make default unlikely, and they encourage the bank to retain all of its earnings. As the bank's net worth grows, aggregate capital rises, the marginal product of capital falls, and a banking crisis becomes more likely. Although the bank faces conflicting incentives toward risk-taking, as net worth continues to grow the bank will become increasingly cautious. Numerical results suggest that the bank will reduce its risk, by reducing its leverage, before issuing dividends. We also find that government bailouts, which allow defaulting banks to continue running, induce significantly more risk-taking than the liability limits associated with standard bankruptcy.

PB 01-04

## Financial Development and Growth: Are the APEC Nations Unique?

Mark M. Spiegel, *FRB San Francisco*

Forthcoming in *Proceedings of the 2001 APEC World Economic Outlook Symposium*.

[See p. 87 for the abstract of this paper.](#)

PB 01-05

## Structural Changes and the Scope of Inflation Targeting in Korea

Gongpil Choi, *Korea Institute of finance; Visiting Scholar, FRB San Francisco*

A small open macroeconomic model that accounts for new financial accelerator effects (the effects of fluctuations in

asset prices on bank credit) is developed to evaluate various policy rules for inflation targeting. Given conditions in asset markets and the fragility of the financial sector, monetary policy responses can potentially accentuate the financial accelerator effect. Simulations are used to compare various forms of inflation targeting using a model that emphasizes long-term inflation expectations, output changes, and the asset price channels. The simulations suggest that a successful outcome can be obtained by adhering to forward-looking simple rules, rather than backward-looking policy rules. Furthermore, inflation targeting can contribute to price stability as well as output stability by helping to keep the financial accelerator from being activated. Inflation targeting in emerging economies can provide an environment conducive to long-term capital market development.

PB 01-06

## Australian Growth: A California Perspective

Ian W. McLean, *University of Adelaide, Australia*

Alan M. Taylor, *University of California, Davis; Visiting Scholar, FRB San Francisco*

Examination of special cases assists understanding of the mechanics of long-run economic growth more generally. Australia and California are two economies having the rare distinction of achieving 150 years of sustained high and rising living standards for rapidly expanding populations. They are suitable comparators since in some respects they are quite similar, especially in their initial conditions in the mid-19th century, their legal and cultural inheritances, and with respect to some long-term performance indicators. However, their growth trajectories have differed markedly in some subperiods and over the longer term with respect to the growth in the size of their economies. Most important, the comparison of an economy that remained a region in a much larger national economy with one that evolved into an independent political unit helps identify the role of several key policies. California had no independent monetary policy, or exchange rate, or controls over immigration or capital movements, or trade policy. Australia did, and after 1900 pursued an increasingly interventionist and inward-oriented development strategy until the 1970s. What difference did this make to long-run growth? And what other factors, exogenous and endogenous, account for the differences that have emerged between two economies that shared such similar initial conditions?

PB 01-07

## The Impact of Japan's Financial Stabilization Laws on Bank Equity Values

Mark M. Spiegel, *FRB San Francisco*

Nobuyoshi Yamori, *Nagoya University, Nagoya, Japan*

In the fall of 1998, two important financial regulatory reform acts were passed in Japan. The first of these acts, the financial Recovery Act, created a bridge bank scheme and provided funds for the resolution of failed banks. The second act, the Rapid Revitalization Act, provided funds for the assistance of troubled banks. While both of these acts provided some government assistance to the banking sector, they also called for reforms aimed at strengthening the regulatory environment. Using an event study framework, this paper examines the evidence in equity markets concerning the anticipated impact of the regulatory reforms. Our evidence suggests that the anticipated regulatory impact of the financial Recovery Act was mixed, while the Rapid Revitalization Act was expected to disproportionately favor weaker Japanese banks. As such, it appears that the market was skeptical about the degree to which the new acts would lead to true banking reform.

PB 01-08

## Factor Analysis of a Model of Stock Market Returns Using Simulation-Based Estimation Techniques

Diana Zhumabekova, *Australian National University; Visiting Scholar, FRB San Francisco*

Mardi Dungey, *Australian National University*

A dynamic latent factor model of stock market returns is estimated using simulation-based techniques. Stock market volatility is decomposed into common and idiosyncratic components, and volatility decompositions are compared between stable and turmoil periods to test for possible shift-contagion in equity markets during Asian financial crisis. Five core Asian emerging stock markets are analyzed—Thailand, Indonesia, Korea, Malaysia and the Philippines. Results identify the existence of shift-contagion during the crisis and indicate that the Thai market was a trigger for contagious shock transmission.

Monte Carlo experiments are conducted to compare simulation method of moments and indirect inference estimation techniques. Consistent with the literature such experiments find that, in the presence of autocorrelation and

time-varying volatility, indirect inference is a better method of conducting variance decomposition analysis for stock market returns than the conventional method of moments.

PB 01-09

## Testing for Contagion Using Correlations: Some Words of Caution

Mardi Dungey, *Australian National University*

Diana Zhumabekova, *Australian National University; Visiting Scholar, FRB San Francisco*

Tests for contagion in financial returns using correlation analysis are seriously affected by the size of the “noncrisis” and “crisis” periods. Typically the crisis period contains relatively few observations, which seriously affects the power of the test.

PB 01-10

## Foreign Exchange: Macro Puzzles, Micro Tools

Richard K. Lyons, *University of California, Berkeley; Visiting Scholar, FRB San Francisco*

[Please see pp. 51-69 for the full text of this paper.](#)

PB 01-11

## The Political Economy of Foreign Bank Entry and Its Impact: Theory and a Case Study

Gabriella Montinola, *University of California, Davis*  
Ramon Moreno, *FRB San Francisco*

We apply Becker's (1983) model of lobbying to show that liberalization of foreign bank entry may result from political changes and a fall in domestic bank efficiency caused by lack of competition, which raises the costs to domestic banks of restricting foreign bank entry. We also show that in equilibrium, reform may be too limited to improve efficiency. We use this model and data envelopment analysis techniques to interpret the liberalization of foreign bank entry in the Philippines in 1994. Declines in banking efficiency reduced resistance to foreign bank entry, but the effects of liberalization on efficiency were by some measures modest.

PB 01-12

## Is Money Still Useful for Policy in East Asia?

Ramon Moreno, *FRB San Francisco*Reuven Glick, *FRB San Francisco*

Since the East Asian crises of 1997, a number of East Asian economies have allowed greater exchange rate flexibility and abandoned monetary targets in favor of inflation targeting, apparently because the perceived usefulness of money as a predictor of inflation, i.e. the information content of money, has fallen. In this paper, we discuss factors that are likely to have influenced the stability of the relationship between money and inflation, particularly in the 1990s, and then assess this relationship in a set of East Asian economies. We focus on (1) the stability of the behavior of the velocity of money; (2) the ability of money growth to predict inflation as measured by tests of Granger causality, and (3) the contribution of money to the variance of the forecast error of inflation. We find evidence that, with a few exceptions in which capital flows were particularly large, velocity remained generally stable, as did the relationship between money growth and inflation. However, the contribution of money to inflation forecast errors fell considerably in the 1990s, reducing its value as an information variable to monetary authorities.

## Abstracts of Articles Accepted in Journals, Books, and Conference Volumes\*

### United States Disability Policy in a Changing Environment

**Mary C. Daly**, with  
Richard V. Burkhauser,  
*Cornell University*

Published in *Journal  
of Economic Perspectives* 16(1)  
(Winter 2002) pp. 213–224.

In this paper we provide a broader perspective from which to evaluate current disability policy. We begin by reviewing the major aspects of the Disability Insurance and Supplemental Security Income programs. We then examine trends in employment and disability benefit receipt among those with disabilities, paying particular attention to the last 15 years. Within this framework we summarize the primary difficulties in crafting an efficient and equitable assistance program for a heterogeneous population that changes with its environment. Finally, we place disability policy in the context of the broader United States social welfare system and consider how changes in other social welfare programs likely will affect disability program usage in the future.

### How Working-Age People with Disabilities Fared over the 1990s Business Cycle

**Mary C. Daly**, with  
Richard V. Burkhauser,  
*Cornell University*  
Andrew J. Houtenville,  
*Cornell University*

Published in *Ensuring Health  
and Income Security  
for an Aging Workforce*,  
eds. Peter Burdetti, et al., pp. 291–346.  
Kalamazoo, MI: Upjohn Institute for  
Employment, 2001.

Using data from the March Current Population Survey (CPS) we show that while the longest peacetime economic expansion in the United States' history has increased the economic well-being of most Americans, the majority of working-age men and women with disabilities have been left behind. Robust economic growth since the recession of the early 1990s has lifted nearly all percentiles of the income distribution of working-age men and women without disabilities beyond their previous business cycle peak levels of 1989. In contrast, the majority of working-age men and women with disabilities did not share in economic growth over this period. Not only did their employment and labor earnings fall during the recession of the early 1990s, but their employment and earnings continued to fall during the economic expansion that followed.

### Black-White Wage Inequality in the 1990s— A Decade of Progress

**Mary C. Daly**, with  
Kenneth Couch,  
*University of Connecticut*

Published in *Economic Inquiry* 40(1)  
(January 2002) pp. 31–41.

Using Current Population Survey data, we find that the gap between the wages of black and white males declined during the 1990s at a rate of about 0.60 percentage point per year. Wage convergence was most rapid among workers with fewer than 10 years of potential experience, with declines in the gap averaging 1.40 percentage points per year. Using standard decomposition methods, we find that greater occupational diversity and reductions in unobserved or residual differences are important in explaining this trend. General wage inequality tempered the rate of wage convergence between blacks and whites during the 1990s.

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\*The abstracts are arranged alphabetically by FRB San Francisco authors, whose names are in boldface.

## Optimal Indicators of Socioeconomic Status for Health Research

**Mary C. Daly**, with

Greg J. Duncan,

*Northwestern University*

Peggy McDonnough, *York University*

David Williams, *University of Michigan*

Forthcoming in *American Journal  
of Public Health* (July 2002).

This paper examines the relationship between various measures of socioeconomic status (SES) and mortality for a representative sample of individuals. We use data from the Panel Study of Income Dynamics, sampling 3,734 individuals aged 45 and above who participated in the 1984 interview and tracking them between 1984 and 1994 using Cox event-history regression models. We found that wealth has the strongest associations with subsequent mortality, and these associations differ little by age and sex. Other economic measures, especially family size-adjusted household income, have significant associations with mortality, particularly for nonelderly women. By and large, the economic components of SES have associations with mortality that are at least as strong as, and often stronger than, more conventional components (e.g., completed schooling, occupation).

## Population Mobility and Income Inequality in California

**Mary C. Daly**, with

Deborah Reed,

*Public Policy Institute of California*

Heather N. Royer, doctoral student,

*University of California, Berkeley*

Published in *California Counts* 2(4)  
(May 2001). Public Policy Institute  
of California.

We examine trends in family income inequality through 1999, focusing in particular on the relationship between inequality and population movement into and out of California. We find that international immigration explains about one-third of California's growing inequality over the past three decades, while the substantial exodus from the state in the 1990s had little effect, since out-migrants tended to be in families at all levels of the income distribution.

## The Effects of Pensions, Health, and Health Insurance on Retirement: A Comparative Analysis of California and the Nation

**Mary C. Daly**

**Robert G. Valletta**

Published in *Employment and Health  
Policies for Californians Over 50*,  
eds. Dorothy Rice and Edward Yelin,  
pp. 183–200. San Francisco:  
UCSF and the California  
Wellness Foundation, 2001.

Among the factors that affect individual retirement decisions, previous research has identified the timing of social security payments, private pension eligibility, health status, and health insurance coverage as key determinants. In this chapter, we first review existing research on the links between retirement outcomes and these key determinants. We then examine the impact of the first three factors (excluding health insurance) relying primarily on data from the 1998 California Work and Health Survey. We also compare results from the California survey with results based on nationally representative samples from the Current Population Survey and the Health and Retirement Survey. The empirical results indicate substantial effects of social security, private pensions, and poor health on retirement decisions in California and in the nation as a whole.



## Inflation Expectations and the Stability Properties of Nominal GDP Targeting

**Richard Dennis**

Published in *The Economic Journal* 111  
(January 2001) pp. 103–113.

Ball (1999) uses a small closed economy model to show that nominal GDP targeting can lead to instability. This paper extends Ball's model to uncover the role inflation expectations play in generating this instability. Allowing inflation expectations to be formed by the more general mixed expectations process, which encompasses Ball's model, we show that nominal GDP targeting is unlikely to lead to instability. We further show that in Ball's model where exact targeting causes instability, moving to inexact targeting restores stability.

## Fixed or Floating: Is It Still Possible to Manage in the Middle?

**Reuven Glick**

Published in *Financial Markets and Policies in East Asia*, ed. Gordon de Brouwer. New York: Routledge, 2001.

This paper reviews the theoretical and empirical basis for the view that intermediate ("soft") exchange rate regimes have become increasingly less feasible. It shows that the proportion of countries with hard currency pegs or flexible exchange rates has increased over time, and that the countries remaining in the "shrinking middle" typically must restrict capital movements. The paper also assesses the feasibility of alternative exchange rate arrangements for the developing countries of East Asia.

This paper was presented to the conference on "Financial Markets and Policies in East Asia" at the Australian National University, Canberra, September 4–5, 2000.

## Banking and Currency Crises: How Common Are Twins?

**Reuven Glick**, with  
Michael M. Hutchison,  
*University of California, Santa Cruz*

Published in *Financial Crises in Emerging Markets*, eds. Reuven Glick, Ramon Moreno, and Mark M. Spiegel, pp. 35–69. New York: Cambridge University Press, 2001.

The coincidence of banking and currency crises associated with the Asian financial crisis has drawn renewed attention to causal and common factors linking the two phenomena. In this paper, we analyze the incidence and underlying causes of banking and currency crises in 90 industrial and developing countries over the 1975–1997 period. We measure the individual and joint ("twin") occurrence of bank and currency crises and assess the extent to which each type of crisis provides information about the likelihood of the other.

We find that the twin crisis phenomenon is most common in financially liberalized emerging markets. The strong contemporaneous correlation between currency and bank crises in emerging markets is robust, even after controlling for a host of macroeconomic and financial structure variables and possible simultaneity bias. We also find that the occurrence of banking crises provides a good leading indicator of currency crises in emerging markets. The converse does not hold, however, as currency crises are not a useful leading indicator of the onset of future banking crises. We conjecture that the openness of emerging markets to international capital flows, combined with a liberalized financial structure, make them particularly vulnerable to twin crises.

## Does a Currency Union Affect Trade? The Time Series Evidence

**Reuven Glick**, with  
Andrew K. Rose,  
*University of California, Berkeley*

Forthcoming in  
*European Economic Review*.

Does leaving a currency union reduce international trade? This paper answers this question using a large annual panel data set covering 217 countries from 1948 through 1997. During this sample a large number of countries left currency unions; they experienced economically and statistically significant declines in bilateral trade, after accounting for other factors. Assuming symmetry, we estimate that a pair of countries that starts to use a common currency experiences a near doubling in bilateral trade.

## Payer Type and the Returns to Bypass Surgery: Evidence from Hospital Entry Behavior

**Gautam Gowrisankaran**, with  
Michael Chernew,  
*University of Michigan*  
A. Mark Fendrick,  
*University of Michigan*

Forthcoming in  
*Journal of Health Economics*.

In this paper we estimate the returns associated with the provision of coronary artery bypass graft (CABG) surgery, by payer type (Medicare, HMO, etc.). Because reliable measures of prices and treatment costs are often unobserved, we seek to infer returns from hospital entry behavior. We estimate a model of patient flows for CABG patients that provides inputs for an entry model. We find that FFS provides a high return throughout the study period. Medicare, which had been generous in the early 1980s, now provides a return that is close to zero. Medicaid appears to reimburse less than average variable costs. HMOs essentially pay at average variable costs, though the return varies inversely with competition.

## A Theory of Liquidity in Residential Real Estate Markets

**John Krainer**

Published in  
*Journal of Urban Economics* 49(1)  
(January 2001), pp. 32–53.

A “hot” real estate market is one where prices are rising, average selling times are short, and the volume of transactions is higher than the norm. “Cold” markets have the opposite characteristics—prices are falling, liquidity is poor, and volume is low. This paper provides a theory to match these observed correlations. I show that liquidity can be good while prices are high because the opportunity cost of failing to complete a transaction is high for both buyers and sellers. I also show how state varying liquidity depends on the absence of smoothly functioning rental markets.

## Equilibrium Valuation of Illiquid Assets

**John Krainer**, with  
Stephen F. LeRoy, *University of  
California, Santa Barbara*

Published in *Economic Theory* 19(2)  
(January 2002), pp. 223–242.

We develop an equilibrium model of illiquid asset valuation based on search and matching. We propose several measures of illiquidity and show how these measures behave. We also show that the equilibrium amount of search may be less than, equal to, or greater than the amount of search that is socially optimal. Finally, we show that excess returns on illiquid assets are fair games if returns are defined to include the appropriate shadow prices.

## Fiscal Policy, Increasing Returns, and Endogenous Fluctuations

**Kevin J. Lansing**, with  
Jang-Ting Guo,  
*University of California, Riverside*

Forthcoming in  
*Macroeconomic Dynamics* 6(5) (2002).

This paper examines the quantitative implications of government fiscal policy in a discrete-time one-sector growth model with a productive externality that generates social increasing returns to scale. Starting from a laissez-faire economy that exhibits local indeterminacy, we show that the introduction of a constant capital tax or subsidy can lead to various forms of endogenous fluctuations, including stable 2-, 4-, 8-, and 10-cycles, quasi-periodic orbits, and chaos. In contrast, a constant labor tax or subsidy has no effect on the qualitative nature of the model's dynamics. We show that the use of local steady-state analysis to detect the presence of multiple equilibria in this class of models can be misleading. For a plausible range of capital tax rates, the log-linearized dynamical system exhibits saddle-point stability, suggesting a unique equilibrium, while the true nonlinear model exhibits global indeterminacy. This result implies that stabilization policies designed to suppress sunspot fluctuations near the steady state may not prevent sunspots, cycles, or chaos in regions away from the steady state. Overall, our results highlight the importance of using a model's nonlinear equilibrium conditions to fully investigate global dynamics.

## Evaluating the Predictive Accuracy of Volatility Models

**Jose A. Lopez**

Published in *Journal of Forecasting*  
20(2) (March 2001) pp. 87–109.

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Standard statistical loss functions, such as mean-squared error, are commonly used for evaluating financial volatility forecasts. In this paper, an alternative evaluation framework, based on probability scoring rules that can be more closely tailored to a forecast user's decision problem, is proposed. According to the decision at hand, the user specifies the economic events to be forecast, the scoring rule with which to evaluate these probability forecasts, and the subsets of the forecasts of particular interest. The volatility forecasts from a model are then transformed into probability forecasts of the relevant events and evaluated using the selected scoring rule and calibration tests. An empirical example using exchange rate data illustrates the framework and confirms that the choice of loss function directly affects the forecast evaluation results.

## Evaluating Covariance Matrix Forecasts in a Value-at-Risk Framework

**Jose A. Lopez**, with  
Christian A. Walter,  
*Credit Suisse Group, Zurich*

Published in *Journal of Risk* 3(3)  
(Spring 2001) pp. 69–98.

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Covariance matrix forecasts of financial asset returns are an important component of current practice in financial risk management. A wide variety of models, ranging from matrices of simple summary measures to covariance matrices implied from option prices, are available for generating such forecasts. In this paper, we evaluate the relative accuracy of different covariance matrix forecasts using standard statistical loss functions and a value-at-risk (VaR) framework. This framework consists of hypothesis tests examining various properties of VaR models based on these forecasts as well as an evaluation using a regulatory loss function.

Using a foreign exchange portfolio, we find that implied covariance matrix forecasts appear to perform best under standard statistical loss functions. However, within the economic context of a VaR framework, the performance of VaR models depends more on their distributional assumptions than on their covariance matrix specification. Of the forecasts examined, simple specifications, such as exponentially weighted moving averages of past observations, perform best with regard to the magnitude of VaR exceptions and regulatory capital requirements. These results provide empirical support for the commonly used VaR models based on simple covariance matrix forecasts and distributional assumptions.

## Bank Credit versus Nonbank Credit, and the Provision of Liquidity by the Central Bank

**Milton H. Marquis**

Published in *Challenges for Central Banking*, eds. Anthony Santomero, Staffan Viotti, and Anders Vredin (Chapter 14) pp. 247–270. Boston: Kluwer, 2001.

When banks tighten their terms and conditions on business lending, bank loan rates rise, and the economy slows, as firms shift their borrowing away from the banks and toward nonbank sources of credit. When tighter lending standards coincide with economic downturns, the contraction of output and the decline in employment are exacerbated. The central bank can offset this decline in bank loans by injecting liquidity into the banking system. However, this action raises inflationary expectations, and nominal interest rates in the credit markets increase, such that the consequent decline in nonbank credit can more than offset the increase in bank credit, and the economy experiences an even sharper decline.

## Bank Intermediation over the Business Cycle

**Milton H. Marquis**, with Tor Einarsson, *University of Iceland*

Published in *Journal of Money, Credit, and Banking* 33(4) (November 2001) pp. 876–899.

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A model is developed in which banks engage in valued asset transformation by converting illiquid assets (working capital loans) into highly liquid demand deposit accounts that households use for transactions purposes. Consumption-smoothing behavior induces countercyclicality in the degree to which firms rely on bank borrowings to finance their working capital expenses, which is consistent with U.S. data. The importance of financial markets that provide alternative sources of short-term funds to firms is also illustrated. Absent these markets, nominal interest rates become nearly perfectly positively correlated with output, which is counterfactual, and monetary shocks induce (perhaps artificially) large aggregate employment responses.

## Fiscal Policy and Human Capital Accumulation in a Home Production Economy

**Milton H. Marquis**, with Tor Einarsson, *University of Iceland*

Published in *Contributions to Macroeconomics* 1(1) (2001), article 2.  
<http://www.bepress.com/bejm/contributions/vol1/iss1/art2/>.

The decision to invest in human capital is introduced into a home production economy with fiscal policy distortions where balanced growth is achieved through Harrod-neutral, labor-augmenting technology spillovers into home production. In comparison with home production economies that abstract from human capital accumulation, the welfare losses from distortionary taxes are quite large due to their adverse effect on growth. However, the transition costs associated with a move to a less distortionary tax system are proportionately much lower. This owes to the fact that growth enhances the adjustment process such that less radical and more empirically plausible swings in employment, investment, and output are required to reach the new balanced growth path.

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## Pegging and Macroeconomic Performance in East Asia

**Ramon Moreno**

Published in *ASEAN Economic Bulletin* 18(1) (April 2001) pp. 48–62.

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<http://www.iseas.edu.sg/pub.html>

This paper assesses the case for pegging in East Asia by briefly surveying the recent literature on the choice of exchange rate regime. Using a new method for classifying exchange rate regimes based on exchange rate volatility, East Asia's experience with pegged exchange rates is examined. In contrast to other areas, inflation in East Asia under pegging is similar to that under floating, as are monetary and fiscal conditions. Growth tends to be higher under pegging, but the channels are not clear since pegging was not associated with greater competitiveness nor with lower exchange rate volatility, and openness was not higher under pegging. Before 1997 pegging was associated with higher cumulative inflation and similar cumulative growth around currency crisis episodes. Thus differences in economic performance across pegged and floating regimes in East Asia are relatively modest. However, the 1997 crises—which were preceded by pegged regimes—were followed by unprecedented contractions in output that suggest that the costs of pegging may have risen.

## Assessing Nominal Income Rules for Monetary Policy with Model and Data Uncertainty

**Glenn D. Rudebusch**

Published in *The Economic Journal* 112 (April 2002), pp. 402–432.

Nominal income rules for monetary policy have long been debated, but two issues are of particular recent interest. First, there are questions about the performance of such rules over a range of plausible empirical models—especially models with and without explicit rational inflation expectations. Second, there are questions about the performance of these rules in real time using the type of data that is actually available contemporaneously to policymakers rather than final revised data. This paper determines optimal monetary policy rules in the presence of such model uncertainty and real-time data uncertainty and finds only a limited role for nominal output growth.

## Is the Fed Too Timid? Monetary Policy in an Uncertain World

**Glenn D. Rudebusch**

Published in *The Review of Economics and Statistics* 83(2) (May 2001) pp. 203–217.

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Estimates of the Taylor rule using historical data from the past decade or two suggest that monetary policy in the U.S. can be characterized as having reacted in a moderate fashion to output and inflation gaps. In contrast, the parameters of optimal Taylor rules derived using empirical models of the economy often recommend much more vigorous policy responses. This paper attempts to match the historical policy rule with an optimal policy rule by incorporating uncertainty into the derivation of the optimal rule and by examining plausible variations in the policymaker's model and preferences.

## Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia

**Glenn D. Rudebusch**

Forthcoming in  
*Journal of Monetary Economics*.

Numerous studies have used quarterly data to estimate monetary policy rules or reaction functions that appear to exhibit a very slow partial adjustment of the policy interest rate. The conventional wisdom asserts that this gradual adjustment reflects a policy inertia or interest rate smoothing behavior by central banks. However, such quarterly monetary policy inertia would imply a large amount of forecastable variation in interest rates at horizons of more than three months, which is contradicted by evidence from the term structure of interest rates. The illusion of monetary policy inertia evident in the estimated policy rules likely reflects the persistent shocks that central banks face.

## Eurosystem Monetary Targeting: Lessons from U.S. Data

**Glenn D. Rudebusch**, with  
Lars E.O. Svensson,  
*Princeton University*

Published in  
*European Economic Review* 46(3)  
(March 2002), pp. 417–442.

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Using a small empirical model of inflation, output, and money estimated on U.S. data, we compare the relative performance of monetary targeting and inflation targeting. The results show monetary targeting to be quite inefficient, yielding both higher inflation and output variability. This is true even with a nonstochastic money demand formulation. Our results are also robust to using a  $P^*$  model of inflation. Therefore, in these popular frameworks, there is no support for the prominent role given to money growth in the Eurosystem's monetary policy strategy.

## Financial Development and Growth: Are the APEC Nations Unique?

**Mark Spiegel**

Forthcoming in  
*Proceedings of the 2001 APEC  
World Economic Outlook Symposium*.

This paper examines panel evidence concerning the role of financial development in economic growth. I decompose the well-documented relationship between financial development and growth to examine whether financial development affects growth solely through its contribution to growth in factor accumulation rates, or whether it also has a positive impact on total factor productivity, in the manner of Benhabib and Spiegel (2000). I also examine whether the growth performances of a subsample of APEC countries are uniquely sensitive to levels of financial development. The results suggest that indicators of financial development are correlated with both total factor productivity growth and investment. However, many of the results are sensitive to the inclusion of country fixed effects, which may indicate that the financial development indicators are proxying for broader country characteristics. Finally, the APEC subsample countries appear to be more sensitive to financial development, both in the determinations of subsequent total factor productivity growth and in rates of factor accumulation, particularly accumulation of physical capital.

## Monetary Union Expansion: The Role of Market Power in Trade

**Mark Spiegel**

Published in *European Monetary  
Union and Capital Markets*,  
Vol. 2 of *International Finance Review*,  
eds. J. Choi and J. Wrase.  
Oxford: Elsevier, 2001.

This paper examines the feasibility of a monetary union expansion which is desirable for both the entering country and the existing union members. The paper concentrates on the fact that the outside country is likely to be small relative to the existing monetary union, and lack the resistance to inflation which comes with market power in trade. Consideration of this market power effect allows for mutually desirable entry if the outside nation central bank is moderately more averse to inflation than the central bank of the existing monetary union.

## The Bootstrap and Multiple Imputations: Harnessing Increased Computing Power for Improved Statistical Tests

**Rob Valletta**, with  
David Brownstone,  
*University of California, Irvine*

Published in  
*Journal of Economic Perspectives* 15(4)  
(Fall 2001) pp. 129–142.

The bootstrap and multiple imputations are two techniques that can enhance the accuracy of estimated confidence bands and critical values. Although they are computationally intensive, relying on repeated sampling from empirical data sets and associated estimates, modern computing power enables their application in a wide and growing number of econometric settings. We provide an intuitive overview of how to apply these techniques, referring to existing theoretical literature and various applied examples to illustrate both their possibilities and their pitfalls.

## A Submerging Labor Market Institution? Unions and the Non-wage Aspects of Work

**Rob Valletta**, with  
Thomas C. Buchmueller,  
*University of California, Irvine*  
John DiNardo,  
*University of California, Berkeley*

Forthcoming in *Emerging Labor Market  
Institutions for the 21<sup>st</sup> Century*,  
NBER and University of Chicago Press.

Using data from a variety of sources, and straightforward econometric methods, we investigate the differences between union and non-union jobs. Despite the substantial decline in the percentage of workers unionized over the last 20 years, union jobs continue to differ from comparable non-union jobs in a large variety of nonwage characteristics. In general union workers work fewer hours per week and fewer weeks per year, spend more time on vacation, and spend more time away from work due to own illness or the illness of a family member. They are also more likely to be offered and to be covered by health insurance, more likely to receive retiree health benefits, more likely to be offered and to be covered by a pension plan, and more likely to receive dental insurance, long-term disability plans, paid sick leave, maternity leave, and paid vacation time.

## Union Effects on Health Insurance Provision and Coverage in the United States

**Rob Valletta**, with  
Thomas C. Buchmueller,  
*University of California, Irvine*  
John DiNardo,  
*University of California, Berkeley*

Forthcoming in  
*Industrial and Labor Relations Review*.

During the past two decades, union density has declined in the United States and employer provision of health benefits has undergone substantial changes in extent and form. Using individual data spanning the years 1983–1997, combined with establishment data for 1993, we update and extend previous analyses of private-sector union effects on employer-provided health benefits. We find that the union effect on health insurance coverage rates has fallen somewhat but remains large, due to an increase over time in the union effect on employee “take-up” of offered insurance, and that declining unionization explains 20 to 35 percent of the decline in employee health coverage. The increasing union take-up effect is linked to union effects on employees’ direct costs for health insurance and the availability of retiree coverage.

## Is Embodied Technology the Result of Upstream R&D? Industry-Level Evidence

**Daniel J. Wilson**

Forthcoming in  
*Review of Economic Dynamics*.

This paper provides an exploratory analysis of whether data on the research and development (R&D) spending directed at particular technological/product fields can be used to measure industry-level capital-embodied technological change. Evidence from the patent literature suggests that the R&D directed at a product, as the main input into the “innovation” production function, is proportional to the value of the innovations in that product. I confirm this hypothesis by showing that the decline in the relative price of a good is positively correlated with the R&D directed at that product. The hypothesis implies that the technological change, or innovation, embodied in an industry’s capital is proportional to the R&D that is done (“upstream”) by the economy as a whole on each of the capital goods that the (“downstream”) industry purchases. Using R&D data from the National Science Foundation, I construct measures of capital-embodied R&D. I find they have a strong effect on conventionally-measured TFP growth, a phenomenon that seems to be due partly to the mismeasurement of quality change in the capital stock and partly to a positive correlation between embodied and disembodied technological change. Finally, I find the cross-industry variation in empirical estimates of embodied technological change accord with the cross-industry variation in embodied R&D.



## Monograph

### Financial Crises in Emerging Markets

Reuven Glick,  
Ramon Moreno, and  
Mark M. Spiegel, editors\*

Published by Cambridge University  
Press, 2001; 467 pages.

The causes of the financial crises in emerging markets during the late 1990s have been the subject of much debate—especially considering that, before the crises, many of the Asian countries involved tended to have balanced budgets and generally sound macroeconomic performances. Some observers argue that the generally favorable macroeconomic conditions indicate that the crises were not caused by incompatibility between fiscal and monetary policies and exchange rate pegs, but rather by the unexpected and self-fulfilling panics of foreign investors. Others, in contrast, attribute the crises to policy mistakes, such as excessive private spending, overvaluation of real exchange rates, and the buildup of bad loans and bank weaknesses. This volume contains 11 papers that investigate the causes and consequences of financial currency crises in emerging markets as well as the options available to policymakers. These papers were prepared originally for a conference sponsored by the Federal Reserve Bank of San Francisco's [Center for Pacific Basin Monetary and Economic Studies](#) in September 1999.

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\* Reuven Glick is Vice President of International Research and Director of the Center for Pacific Basin Monetary and Economic Studies, Ramon Moreno is Research Advisor, and Mark M. Spiegel is Research Advisor, all at the Federal Reserve Bank of San Francisco.

## Conferences

### Asset Prices, Exchange Rates, and Monetary Policy

#### Nominal Rigidities

The San Francisco Fed's Research Department organized two conferences in 2001.

The first, cohosted with the Stanford Institute for Economic Policy, was a two-day conference that provided some first steps in understanding how policymakers at central banks can and should respond to fluctuations in asset prices. Papers covered the role of asset prices in forecasting output and inflation and how asset prices, financial conditions, and exchange rate uncertainty affect monetary policy decisions.

The second conference, cosponsored with the National Bureau of Economic Research and the Central Bank Institute of the Federal Reserve Bank of Cleveland, focused on the effects of policy in economies with "sticky" prices or wages, that is, economies in which wages or prices adjust sluggishly to changes in the environment. The papers analyzed the usefulness of sticky prices and the role they play in propagating business cycles, as well as how optimal policies should be set in a sticky-price environment.

These conferences bring professional economists from the Federal Reserve System and from research institutions together with policymakers from the U.S. and abroad. Many of the papers presented are "works in progress" and therefore represent the latest research on policy-related issues.

Attendance at all of the conferences is by invitation only. In addition, the papers are chosen from submissions by a select group of noted researchers.

This section contains the conference agendas as well as summaries of the two conferences that appeared in our *FRBSF Economic Letter*.

## Asset Prices, Exchange Rates, and Monetary Policy

Stanford University  
March 2–3, 2001

*Cosponsored by the Federal Reserve Bank of San Francisco  
and the Stanford Institute for Economic Policy Research*

Papers presented at this conference can be found on the conference website  
<http://www.frbsf.org/economics/conferences/0103/index.html>

### **Keynote Speaker**

John Lipsky, *Chief Economist, J.P. Morgan and Company*

### **Forecasting Output and Inflation: The Role of Asset Prices**

James H. Stock, *Harvard University*  
Mark W. Watson, *Princeton University*

Discussants: Clive Granger, *University of California, San Diego*  
Christopher Sims, *Princeton University*

### **Simple Monetary Policy Rules and Exchange Rate Uncertainty**

Kai Leitemo, *Norges Bank*  
Ulf Söderström, *Sveriges Riksbank*

Discussants: Pierpaolo Benigno, *New York University*  
Andrew Rose, *University of California, Berkeley*

### **Monetary Policy Rules for an Open Economy**

Nicoletta Batini, *Bank of England*  
Richard Harrison, *Bank of England*  
Stephen P. Millard, *Bank of England*

Discussants: Richard Clarida, *Columbia University*  
Jeffrey Fuhrer, *FRB Boston*

### **Asset Prices, Financial Conditions, and the Transmission of Monetary Policy**

Charles Goodhart, *London School of Economics*  
Boris Hofmann, *University of Bonn*

Discussants: Ben Bernanke, *Princeton University*  
Andrew Filardo, *FRB Kansas City*

### **External Constraints on Monetary Policy and the Financial Accelerator**

Mark Gertler, *New York University*  
Simon Gilchrist, *Boston University*  
Fabio Natalucci, *New York University*

Discussants: Ricardo Caballero, *Massachusetts Institute of Technology*  
Michael Kumhof, *Stanford University*

### **Inflation Targeting and the Liquidity Trap**

Bennett McCallum, *Carnegie-Mellon University*

Discussants: Lars Svensson, *Stockholm University*  
Carl Walsh, *University of California, Santa Cruz*

## Nominal Rigidities

Federal Reserve Bank of San Francisco  
June 16, 2001

*Cosponsored by the Federal Reserve Bank of San Francisco,  
the National Bureau of Economic Research,  
and the Central Bank Institute  
of the Federal Reserve Bank of Cleveland*

Papers presented at this conference can be found on the conference website  
<http://www.frbsf.org/economics/conferences/0106/index.html>

### **Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy**

Lawrence Christiano, *Northwestern University*  
Martin Eichenbaum, *Northwestern University*  
Charles Evans, *FRB Chicago*

Discussant: Julio Rotemberg, *Harvard University*

### **Sticky Information Versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve**

Greg Mankiw, *Harvard University*  
Ricardo Reis, *Harvard University*

Discussant: William Dupor, *University of Pennsylvania*

### **Closed and Open Economy Models of Business Cycles with Marked-up and Sticky Prices**

Robert Barro, *Harvard University*  
Silvana Tenreyro, *Harvard University*

Discussant: Valerie Ramey, *University of California, San Diego*

### **Predicting the Effects of Fed Policy in a Sticky Price Model**

Ellen McGrattan, *FRB Minneapolis*

Discussant: Andy Levin, *Federal Reserve Board of Governors*

### **Optimal Fiscal and Monetary Policy: Equivalence Results**

Pedro Teles, *Banco de Portugal, U. Catolica Portuguesa, and CEPR*  
Isabel Correia, *Banco de Portugal, U. Catolica Portuguesa, and CEPR*  
Juan Pablo Nicolini, *Universidad Di Tella*

Discussant: V.V. Chari, *University of Minnesota*

### **Optimal Fiscal and Monetary Policy under Sticky Prices**

Martín Uribe, *University of Pennsylvania*  
Stephanie Schmitt-Grohé, *Rutgers University and CEPR*

Discussant: Pedro Teles, *Banco de Portugal, U. Catolica Portuguesa,  
and CEPR*

## Asset Prices, Exchange Rates, and Monetary Policy

Stanford University  
March 2–3, 2001

*Cosponsored by the Federal Reserve Bank of San Francisco and the Stanford Institute for Economic Policy Research*

This *Economic Letter* summarizes the papers presented at the conference “Asset Prices, Exchange Rates, and Monetary Policy” held at Stanford University on March 2–3, 2001, under the joint sponsorship of the Federal Reserve Bank of San Francisco and the Stanford Institute for Economic Policy Research.

During the past decade, asset markets have played an increasingly important role in many economies, and fluctuations in asset prices have become an increasingly important factor for policymakers. Indeed, movements in exchange rates, equity values, and prices for real assets such as housing and real estate, each have been, at various times, the focus of keen interest at central banks. In a variety of situations, central banks have questioned how they should respond to fluctuations in asset prices.

The six papers presented at this conference provide some first steps in understanding what central banks can and should do with regard to asset prices. The papers are listed at the end and are available at <http://www.frbsf.org/economics/conferences/0103/index.html>.

The papers by Stock and Watson and by Goodhart and Hofmann provide analyses of the forecasting ability of asset prices for inflation and output. As a whole, their conclusions are cautionary, even skeptical, regarding the ability of individual asset prices to consistently forecast well. However, both papers are more optimistic about the ability of combinations of asset prices—composite financial indexes or weighted averages—to produce useful forecasts.

The papers by Leitemo and Söderström and by Batini, Harrison, and Millard contribute to the rapidly growing monetary policy rules literature (e.g., Taylor 1999). Both papers consider the appropriate response of central banks to movements in foreign exchange rates. The first paper examines the success of monetary policy rules when there is uncertainty about what determines exchange rates and provides an important contribution to the literature on robust monetary policy rules. The second paper focuses on whether the exchange rate adds information to a policy rule that responds to inflation forecasts. Both papers suggest a fairly limited policy reaction to exchange rate movements.

The paper by Gertler, Gilchrist, and Natalucci explores the interaction between financial distress—weakening

asset prices and tightening financial conditions—and the exchange rate regime. Under fixed exchange rates, this paper shows that the central bank has great difficulty in adjusting interest rates to alleviate the financial distress and stabilize the economy.

Finally, the paper by McCallum considers whether the liquidity trap, in which nominal interest rates have been lowered to their absolute minimum of zero, is a problem of practical importance. The paper emphasizes that even with the interest rate policy instrument immobilized by a liquidity trap, an exchange rate channel still may be available to the central bank to stabilize the economy.

### **Forecasting output and inflation: the role of asset prices**

The Stock and Watson paper assesses the ability of asset prices to predict inflation and output using both in-sample and simulated out-of-sample techniques. To set the stage for this analysis, the authors first provide a survey of 66 previous papers on this subject. Much of this previous research is contradictory, with an initial series of papers identifying a potent predictive relation, which is subsequently found to break down in the same country or not to be present in other countries. Based on this literature review, Stock and Watson argue that many of the purported empirical forecasting relationships are ephemeral. However, the most robust and convincing evidence indicates that the spread between long-term and short-term interest rates usually predicts real economic activity.

The authors go on to conduct their own econometric analysis of the practical value of asset prices as predictors of real economic activity and inflation. Their empirical results are consistent with their review of the literature: Certain individual asset prices have predictive content for output growth in some countries during certain periods. The uncertainty and instability of these informational relationships make it unlikely that they can be exploited. Furthermore, the evidence is even weaker that asset prices can forecast inflation. An exception to these pessimistic results is that Stock and Watson find that combining informa-



tion from a large number of asset prices does seem to result in reliable forecast accuracy improvements. They argue that this is a promising avenue for future research.

### **Asset prices, financial conditions, and the transmission of monetary policy**

Goodhart and Hofmann also examine the amount of information in asset prices for forecasting future economic activity and inflation. These authors, however, focus on creating a “Financial Conditions Index” (FCI) that provides a broad measure of the relative tightness or looseness of financial factors in restraining or promoting economic expansion. As a predecessor, a “Monetary Conditions Index” (MCI) has been constructed by some central banks as a weighted average of a short-term policy interest rate and the foreign exchange rate. Such MCIs have been used as summary measures of the stance of monetary policy because both higher interest rates and higher exchange rates reduce real demand and affect the prospects for future inflation.

Goodhart and Hofmann consider whether an MCI could be usefully broadened to an FCI that also includes the real prices of housing and equities. These additional asset prices are thought to be important determinants of the wealth effect on consumption and so might provide useful information on future aggregate demand. The authors construct FCIs for each of the G7 economies, with component weights chosen to maximize the performance of the indexes in explaining the output gap. This analysis is done with both a small structural model and a nonstructural model. The resulting indexes are then evaluated on how well they predict inflation. The authors find that while the indexes tend to lead inflation, they did not clearly outperform a simple alternative model in an out-of-sample inflation forecasting exercise.

### **Simple monetary policy rules and exchange rate uncertainty**

The Leitemo and Söderström paper examines whether a more stable economy can be achieved when the central bank relies on the exchange rate in setting monetary policy. In an open economy, movements in the exchange rate have several important effects. First, an increase in the real exchange rate boosts the demand for domestic goods as foreign goods become relatively more expensive. Second, the more expensive foreign goods increase consumer prices directly and raise firms’ costs through imported intermediate goods. Therefore, it seems possible that the exchange rate could serve as a useful indicator of policy. (This rea-

soning also underlies some of the popularity of the MCIs described above.)

Unfortunately, movements in the exchange rate are not very well understood in practice. In particular, the main theories of exchange rate determination—namely, the parity conditions that link prices of tradeable goods and interest rates across countries—do not have much empirical support. Thus, there is a high degree of uncertainty about how exchange rates will react to changes in monetary policy or other economic factors.

This paper allows for exchange rate uncertainty by considering four different models of exchange rate determination. The paper examines how a policy rule developed assuming one exchange rate process performs in stabilizing the economy when exchange rates are actually set by another process. The authors find that policy rules that include the exchange rate are less robust to this form of model uncertainty than other rules. In particular, a Taylor rule, which includes a response to the output gap and inflation, stabilizes the economy, in general, better than a Taylor rule augmented with the exchange rate. (See Dennis 2001 for further discussion.)

### **Monetary policy rules for an open economy**

The Batini, Harrison, and Millard paper also examines the properties of various optimal simple rules in an open economy model. Their model is richer than most in the literature as it contains both a tradeable and a nontradeable good. The presence of these two sectors generates asymmetric effects because the traded good is more sensitive to exchange rate movements than the nontraded good. The analysis also considers a larger set of possible monetary policy rules than most research. Among the rules analyzed are some developed for closed economies and some open economy rules with an explicit exchange rate response. The authors favor a rule in which the interest rate is set in response to deviations of expected future inflation from an inflation target. These “inflation-forecast-based” rules perform quite well in their model. Adding a separate exchange rate response to this rule provides only a marginal improvement in performance.

### **External constraints on monetary policy and the financial accelerator**

The Gertler, Gilchrist, and Natalucci paper examines the effect of a “financial accelerator” in a small open economy. The financial accelerator links the condition of a borrower’s balance sheet to the cost of borrowing and hence to the demand for capital. In essence, entrepreneurs borrow-

ing from a bank pay a risk premium that varies inversely with their net worth, so the cost of finance increases as the entrepreneur becomes more leveraged. In the aggregate, a drop in asset prices will reduce net worth, which boosts the financing premium and magnifies the effects of the asset price shock on the economy.

To demonstrate the role of this mechanism in their open economy model, the authors carry out a series of exercises. First they consider an increase in foreign interest rates. When the domestic central bank is enforcing a fixed exchange rate, it is forced to raise domestic (nominal and real) interest rates in response. Higher rates cause domestic asset prices to fall, which raises the leverage ratio and borrowers' financing costs. As a consequence, investment and output both fall. In contrast, when exchange rates are flexible, domestic interest rates do not have to go up as much because the domestic currency is allowed to depreciate, which mitigates the fall in domestic investment and output.

Such a difference in outcomes under fixed and flexible exchange rate regimes would emerge even in a model without a financial accelerator. However, the authors show that the presence of the financial accelerator magnifies the declines in the real economy under fixed exchange rates.

### **Inflation targeting and the liquidity trap**

The McCallum paper considers a variety of theoretical and empirical issues regarding the liquidity trap, which occurs during a persistent deflation when nominal short-term interest rates fall to their zero lower bound. In these circumstances, the central bank is in a liquidity trap because it can no longer ease policy by lowering interest rates (see Hutchison 2000). McCallum argues that a liquidity *trap* is unlikely to be a very common or insurmountable problem.

As a general theoretical issue, he notes that the liquidity trap in many models would not occur if agents were partially (or boundedly) rational and constructed their forecasts of inflation using sensible algorithms. In particular, if the agents learn from past data, they will not encounter a liquidity trap.

However, in the real world, as a practical matter, even if a liquidity trap were encountered, McCallum argues that the central bank would not be powerless to defuse it. Although the usual interest rate channel to stimulate the

economy is immobilized, monetary policy still may be potent because of the existence of a transmission channel involving foreign exchange. Indeed, the author proposes that a central bank could stimulate recovery from the liquidity trap by using base money to purchase foreign currency and thereby depreciate the home currency and raise net exports. This type of policy will not work if the exchange rate is governed by the interest rate parity condition discussed above. However, the author notes that this condition has weak support in the data and in theory.

*Glenn D. Rudebusch*  
*Vice President, Macroeconomic Research*

### **Conference Papers**

Papers are available in pdf format at <http://www.frbsf.org/economics/conferences/0103/index.html>.

Batini, Nicoletta, Richard Harrison, and Stephen P. Millard. "Monetary Policy Rules for an Open Economy." Bank of England.

Gertler, Mark, Simon Gilchrist, and Fabio Natalucci. "External Constraints on Monetary Policy and the Financial Accelerator." New York University and Boston University.

Goodhart, Charles, and Boris Hofmann. "Asset Prices, Financial Conditions, and the Transmission of Monetary Policy." London School of Economics and University of Bonn.

Leitemo, Kai, and Ulf Söderström. 2001. "Simple Monetary Policy Rules and Exchange Rate Uncertainty." Norges Bank and Sveriges Riksbank.

McCallum, Bennett. "Inflation Targeting and the Liquidity Trap." Carnegie-Mellon University.

Stock, James H., and Mark W. Watson. "Forecasting Output and Inflation: The Role of Asset Prices." Harvard University and Princeton University.

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## Nominal Rigidities

Federal Reserve Bank of San Francisco

June 16, 2001

*Reprinted from "Recent Research on Sticky Prices," FRBSF Economic Letter 2001-24, August 24, 2001.*

This *Economic Letter* summarizes the papers presented at the conference "Nominal Rigidities" held in San Francisco on June 16, 2001, under the joint sponsorship of the Federal Reserve Bank of San Francisco, the National Bureau of Economic Research, and the Federal Reserve Bank of Cleveland.

Broadly speaking, the papers at the conference were concerned with modeling the effects of policy in an economy with nominal rigidities—that is, with prices and wages that are relatively inflexible, or “sticky.” One set of papers focused on determining the characteristics that a model economy would require to plausibly reproduce the observed behavior of key macroeconomic variables such as output and inflation, especially in response to a monetary policy shock. Christiano, Eichenbaum, and Evans find that wage rigidity (along with some other requirements) is a must, while McGrattan finds that price rigidity is not particularly useful. Mankiw and Reis argue that it is more useful to think of the rigidities as arising from the costs of acquiring and processing information, rather than the costs of changing wages or prices. The paper by Barro and Tenreyro has a different focus: it assumes sticky prices in only part of the economy and looks at the role played by sticky-ness in propagating business cycles. Their model implies that the more concentrated the industry, the more countercyclical its prices, an implication for which they find some support in the data. The final two papers in the conference, authored by Schmitt-Grohé and Uribe and by Correia, Nicolini, and Teles, discuss how the prescriptions for optimal fiscal and monetary policy that are derived in models with flexible prices get modified when prices are assumed to be sticky. The key finding here is that it may be advisable to pay greater attention to stabilizing prices in an environment with sticky prices than one would in an environment with flexible prices.

### What kind of “sticky-ness” is best?

In recent years, economists have been working with models in which the decision-making problems of firms and households are explicitly specified, as are the environments in which they operate. More recently, within this tra-

dition, some economists have begun to explore the role played by “sticky” wages and prices, that is, by prices and wages that are not free to adjust quickly in response to changes in the environment. A key objective of this research program has been the construction of models that produce plausible descriptions of how a change in monetary policy affects the economy. The first set of papers is part of this program; their analysis can be viewed as trying to determine the best place (in the model) to locate this sticky-ness or nominal rigidity.

Christiano, Eichenbaum, and Evans (CEE) ask what sort of restrictions must be imposed on a model of the economy with optimizing agents and a richly specified environment in order to obtain the same response to a monetary policy shock as observed in a simple description of the actual data. In their model, both prices and wages adjust sluggishly. They find that they can mimic the responses in the data most closely when they allow wage contracts to have an average duration of roughly two quarters while prices are allowed to be reset every three quarters. Wage rigidity turns out to be the more crucial requirement of the two. Assuming that prices are fully flexible in a world with sticky wages does not lead to results that are very different from the case where both prices and wages are assumed to be sticky; by contrast, assuming that prices are sticky while wages are flexible leads to a marked deterioration in the model’s performance.

McGrattan’s goal is similar to CEE. She sets up a model with optimizing households and firms as well; her focus, however, is on the role played by sticky prices. In her model monetary policy is conducted using the well-known Taylor rule, according to which the monetary authority sets interest rates in response to changes in inflation and departures of output from an estimate of its long-run trend.

McGrattan’s model yields some counterfactual implications. For example, she finds that interest rates are negatively serially correlated, in contrast to the positive correlation observed in the data. She also finds that in her model the response of output to a monetary shock is not as persistent as observed in the data. Allowing for nonmonetary shocks does lead to more persistent changes in output;

however, the attempt to make output more persistent makes the amplitude of the business cycles generated by the model too small. Overall, McGrattan concludes that introducing sticky prices into fully articulated models of the economy does not allow these models to replicate the behavior of key economic data and does not help us understand how monetary policy affects the economy.

Mankiw and Reis (MR) focus on a model where price stickiness is associated with the costs of acquiring and processing the information necessary to set prices. In their model, prices are easy to change, but because information is assumed to diffuse only gradually through the economy, these changes end up being based upon old estimates of the state of the economy.

MR show how their model responds to a variety of monetary policy shocks and compare its predictions to those from two versions of the sticky price model which differ in their assumption about how expectations are formed. Consider, for example, what happens when the monetary authority announces that it will engineer a decrease in the growth rate of aggregate demand in the near future. In the (sticky price) model with forward-looking households and firms, the result is an increase in output, because prices start falling when the announcement is made; with the money supply growth rate unchanged, output goes up. By contrast, this announcement has no effect in the (sticky price) model with backward-looking firms and households. However, both prices and output begin to fall sharply after the monetary authority tightens, just as they would if the authority had made no such announcement.

MR argue that, while the predictions of both versions are hard to reconcile with empirical observations, this is not the case for the sticky information model. Although the timing of the responses in the sticky information model is the same as in the backward-looking model, the magnitudes are much smaller and, therefore, closer to what is observed in practice. In particular, because some of the firms have been able to incorporate the relevant information into their plans before the policy change takes effect, output falls less than and inflation falls more quickly than in the backward-looking model (once the monetary authority tightens). Thus, a preannounced reduction in demand leads to a contraction in output that is smaller than it would be if the reduction were a surprise. Note also that this contrasts sharply with the forward-looking model's questionable prediction that output should boom after the announcement.

Barro and Tenreyro (BT) show how the existence of sticky prices in part of the economy can play a role in the propagation of business cycles. Their model contains two sectors: final and intermediate goods. Final goods are assumed to be produced in a competitive environment, while

the intermediate goods sector is imperfectly competitive and produces goods that are differentiated from each other. Assume now that there is an increase in the degree of competition in the intermediate goods sector. This leads to a decrease in the price of intermediate goods relative to final goods, causing final goods firms to increase the use of intermediate goods and thereby increase output. Labor productivity goes up, as do wages. BT show that the same effect can be achieved through monetary policy if intermediate goods prices are assumed to be sticky. An unexpected monetary expansion leads to an increase in the price of final goods and temporarily reduces the relative price of intermediate goods, causing final goods producers to increase output.

BT neither estimate nor test this model directly, but they do test one of its implications, namely, that the relative price of goods produced by less competitive sectors is countercyclical; that is to say, it falls during booms and rises during recessions. Using the growth rate of real output as an indicator of the cycle and price data for the manufacturing sector over the 1958–1997 period, BT find evidence suggesting that the more concentrated the sector, the more countercyclical its relative price.

### **Sticky-ness and optimal policy**

The final two papers address how optimal policies should be set in a sticky price environment. These papers are part of a research program that asks how the government (including the central bank) can finance a given stream of expenditures while minimizing the distortions that any method of raising revenues is likely to impose upon the economy. Using models with flexible prices, some researchers have shown that monetary policy should be conducted according to the Friedman rule, which calls for a zero nominal interest rate, that is, it calls for deflation at a rate equal to the real rate of interest. As Nobel prize-winning economist Milton Friedman originally pointed out, since money is costless to produce, it is optimal to set the cost of holding it (which is the forgone interest) at zero as well. Furthermore, it has been shown that if prices are flexible and the government cannot issue debt whose value varies with the state of the economy, the optimal inflation rate is highly volatile but uncorrelated over time. In this setting, the government uses inflation as a nondistorting tax on financial wealth in order to offset unanticipated changes in the deficit. By contrast, the income tax rate remains relatively stable.

Other researchers have shown how the existence of sticky wages and prices leads to the government's facing a tradeoff in choosing the optimal inflation rate. The benefits of using inflation as a nondistorting tax on financial wealth



must now be balanced against the costs that inflation imposes on firms and households who are unable to adjust prices quickly enough. As Schmitt-Grohé and Uribe (S-GU) point out, these researchers have assumed that the government can freely deploy some rather unusual tools, including production or employment subsidies as well as lump sum taxes. (Since lump sum taxes are, by definition, independent of economic activity, they do not distort the incentives to undertake such activity.) Given these tools, the government is able to keep the inflation rate close to zero, so it can avoid the distortions imposed by nominal rigidities.

S-GU assume that the government does not have access to either lump sum taxes or production subsidies. Even so, they find that optimal policy calls for low inflation volatility. Specifically, in a model in which firms are assumed to adjust prices roughly once every nine months, the volatility (here defined as the standard deviation) of inflation under sticky prices is one-fortieth of what it is under flexible prices. And even if the parameter that governs price stickiness is assumed to be ten times smaller, the volatility of inflation is still a thirteenth of what it is under flexible prices.

Correia, Nicolini, and Teles (CNT) take up the issue of optimal fiscal and monetary policies as well. Their key finding is that, even if prices are sticky, a benevolent government can steer the economy to the same equilibrium as it would if prices were flexible. In a sense, then, the way in which prices are set becomes irrelevant to the final outcome. At first glance, this result seems to contradict the results of the previous authors. It turns out, however, that CNT assume that the government has access to state-contingent debt, that is, it can vary the value of its outstanding obligations depending upon the state of the economy. For instance, in the case of an expensive war, the government could default on some of its debt. It is this extra “instrument” that gives the government the ability to attain the same equilibrium in an economy with sticky prices that it would under flexible prices.

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## Conference Papers

Papers are available in pdf format at <http://www.frbsf.org/economics/conferences/0106/index.html>.

Barro, R.J., and S. Tenreyro. 2001. “Closed and Open Economy Models of Business Cycles with Marked Up and Sticky Prices.”

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McGrattan, E.R. 1999. “Predicting the Effects of Federal Reserve Policy in a Sticky Price Model: An Analytical Approach.”

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