Intervention and the Bid–Ask Spread in G-3 Foreign Exchange Rates

by William P. Osterberg

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Introduction

Tests of the efficiency of foreign exchange markets continue to proliferate. Because these markets have become worldwide in scope and nonstop in operation, economists have been able to test many hypotheses about how information becomes incorporated into prices and transferred between markets in different locations. However, the finding that forward rates for foreign exchange are not unbiased predictors of future spot rates remains without a coherent explanation.

It seems reasonable to speculate on the role that central-bank intervention plays in such findings. After all, central banks may possess information not available to other traders. However, since central banks usually have not made available to the public accurate information about their daily foreign exchange activities, it has been difficult to determine if intervention influences foreign exchange market efficiency.

Greater interest in central-bank intervention has also been stimulated by an increase in the frequency of intervention. During the period of ostensibly floating rates, central-bank intervention policy has been, at various times, designed either to influence the level of the exchange rate or to reduce its volatility. Specifically, as discussed by Funabashi (1989) and Dominguez (1990), soon after the Plaza accord in September 1985, the finance ministers of the G-5 (France, Germany, Japan, the United Kingdom, and the United States) agreed to reduce the dollar's exchange value. Then, at the Louvre meeting in 1987, they decided to shift to a regime of stabilization. Thus, there is a clear interest in analyzing the impact of intervention on both the level and volatility of exchange rates.

This paper examines the relationship between G-3 (Germany, Japan, and the United States) central-bank intervention and bid–ask spreads in the German mark/U.S. dollar (DM/$) and yen/U.S. dollar (yen/$) spot and forward foreign exchange markets. Bid–ask spreads may be related to volatility and risk. The examination is stimulated by the speculation of Bossaerts and Hillion (1991), henceforth referred to as B/H, that an intraweekly pattern in intervention explains the intraweekly pattern in bid–ask spreads that they observed for the currencies in the European Monetary System. They determine that bid–ask spreads are higher on Fridays and that taking account of such asymmetry alters conclusions regarding the efficiency of forward markets. B/H surmise that the higher Friday bid–ask spreads are related to market participants' anticipation that decisions about intervention will be undertaken on weekends. Here, I utilize official intervention data to see if G-3 intervention influences G-3 spreads. To the best of my knowledge, this is the first time that such an investigation has been undertaken.

The organization of this paper is as follows. Section I reviews selected literature on forward market efficiency and the impact of central-bank intervention. Section II discusses the data on intervention and the bid–ask spreads. In the third section, I examine 1) intraweekly patterns in bid–ask spreads, 2) holiday effects, 3) intraweekly patterns in intervention, 4) bid–ask spreads over periods of nonintervention versus intervention, and 5) Granger-causality tests for the intervention–spread relations. Section IV concludes and summarizes.

I find that 1) bid–ask spreads are higher on Fridays for both spot and forward G-3 exchange rates, 2) intervention is no more likely to occur on Mondays than on other days, 3) for both currencies, periods of purported intervention are associated with lower, rather than higher, bid–ask spreads, 4) conditional on whether or not intervention occurred, expectations of intervention seem to be associated with lower spreads, and 5) intervention generally does not Granger-cause spreads. Overall, there appears to be little evidence to support the view that spreads widen in anticipation of intervention. A more plausible view is that the expectation of intervention has a negative impact on spreads. A structural model of the relations among intervention, spreads, and volatility would be necessary to address these issues in more detail.

I. Related Literature

Foreign Exchange Bid–Ask Spreads

A small body of literature focuses on the determination of foreign exchange bid–ask spreads. Flood (1991) provides a summary of the theory and points out the difficulties in applying to the foreign exchange market the framework used to analyze securities market spreads.[1] A unique aspect of spread determination in exchange markets is that two trading structures coexist. There are market-makers, who provide both bids and asks upon demand, and brokers, who quote the best bids and asks from their books of orders. Flood suggests that adverse selection costs and inventory holding costs are likely influences on market-maker spreads. Adverse selection influences spreads if market-makers confront traders who have inside information and who are thus able to speculate against the market-maker. Inventory holding costs are influenced by the possibility of unfavorable price changes during the time that currencies are held.

Flood submits that models of brokers' spreads are less applicable to the foreign exchange market, where (unlike in securities markets) brokerage and market-making are separated. One distinction between the two activities is that brokerage maintains the anonymity of the transacting parties. It is worth noting that U.S. intervention operations utilize both market-makers, who generally are commercial and investment banks, and brokers. "Secret" intervention occurs via a broker. Intervention via a market-maker may increase spreads, since a market-maker could view the intervening central bank as having inside information. This is the mechanism to which B/H refer.

Early empirical work by Fieleke (1975) and Overturf (1982) shows that spreads are positively related to foreign–domestic interest differentials and exchange volatility. Allen (1977) provides a theoretical rationale for the volatility–spread relation. Black (1989), Boothe (1988), Glassman (1987), and Wei (1991) find that spreads are positively related to transactions volume. Although a lower rate of transactions could influence the risk component of the spread by increasing the length of time an open position would be held, it is also possible that volatility and volume are determined simultaneously.

Intervention and Risk Premia

Though B/H contend that intervention influences the spread, most investigations have viewed intervention as influencing a risk premium defined in other terms, as discussed below. However, it is not at all clear that a significant risk premium exists (see Hakkio and Sibert [1991]). The existence of a time-varying risk premium is only one of the possible explanations of the finding that the forward rate is not an unbiased and efficient predictor of future spot rates.

The unbiasedness and efficiency of forward rates has been widely tested by analyzing variations on equation (1).[2]

■ 1 George, Kaul, and Nimalendran (1991) provide a recent summary of the findings regarding spreads in equity markets. They conclude that only 8 to 13 percent of the spreads can be explained by adverse selection and claim that the predominant influence on equity spreads is processing costs.

■ 2 Baillie and McMahon (1989) and Hodrick (1987) provide comprehensive reviews of this literature.

(1) $E_t(S_{t+k}) = F_{t,t+k}$,

where the left side is the expectation at time t of the spot exchange rate k periods in the future and the right side is the forward rate at time t for a transaction at time $t+k$. In practice, $E_t(S_{t+k})$ is replaced by S_{t+k}; S and F are often replaced by their logarithms or by $(S_{t+k} - S_t)/S_t$ and $(F_t - S_t)/S_t$; and an equation such as (2) is analyzed.[3]

(2) $$(S_{t+k} - S_t)/S_t = \alpha + \beta(F_{t,t+k} - S_t)/S_t + u_{t+k}.$$

As summarized by Baillie (1989), a consensus against unbiasedness has emerged—the hypothesis that $\alpha = 0$ and that $\beta = 1$ is usually rejected. One possible explanation is the presence of a risk premium. Equation (1) could be expected to hold purely as the outcome of arbitrage among risk-neutral speculators who can take an open position in the forward market based on their expectation of the future spot rate at which positions would have to be covered. On the other hand, the portfolio-balance approach to exchange-rate determination considers risk-averse investors who choose holdings of assets denominated in different currencies. If such assets are imperfect substitutes, then factors such as relative asset supplies will influence exchange rates and imply rejection of the unbiasedness hypothesis.

B/H suggest that the frequent use of the average of the bids and asks in equations (1) and (2) is inappropriate and claim that intervention is responsible for an asymmetry of the true price around the average of bids and asks. Other possible theoretical explanations include the inappropriateness of the rational expectations assumption (Frankel and Froot [1987]), the possibility that policy changes would lead to ex post biasedness even if unbiasedness held ex ante (Lewis [1988]), anticipation of real exchange-rate changes (Levine [1989]), and the existence of liquidity premia (Engel [1990]).[4]

A variety of approaches, summarized by Hodrick (1987), imply a time-varying risk premium. Lucas (1978) relates the risk premium to the conditional covariance between a long position in the forward market and the marginal rate of substitution between future and current consumption. Hodrick (1989) shows how the risk premium in the forward market can be more directly related to the conditional variance of market fundamentals, such as money supply and government spending. Osterberg (1989) modifies Hodrick's paper to show how intervention can influence the risk premium in the forward market. In general, evidence in favor of the existence of a risk premium in the forward market is weak (see Engel and Rodrigues [1989], Kaminsky and Peruga [1990], and Mark [1988]). This may result in part from using data of no higher than monthly frequency in analyzing the relationship between the forward-rate forecast error and either consumption or money.[5] Volatility measures such as conditional variance exhibit less time variation when constructed from data of lower frequency.

Measurement and testing issues are also involved with the controversy over the existence of risk premia in forward rates.[6] B/H determine that the use of the average of bids and asks in tests of forward market efficiency ignores the information contained in the bid–ask spread, biases the test results, and distorts the magnitude of the implied risk premium. In this paper, I focus on the authors' contention that the bid–ask spread widens when the market anticipates intervention, because the possibility of intervention induces an adverse selection problem for market-makers or brokers. B/H conclude that the spreads are wider on Fridays.

Other investigators have found evidence of day-of-the-week effects in foreign exchange markets.[7] Glassman (1987) finds that bid–ask spreads are higher on Fridays and on days before market holidays. So (1987) confirms previous findings that exchange rates on Monday

■ 3 These transformations ameliorate problems introduced by the nonstationarity of exchange rates (see Baillie and McMahon [1989] or Hodrick [1987] for details) and Siegel's paradox. Siegel's paradox states that if equation (1) holds when S and F are expressed as units of currency A per unit of currency B, then it cannot also hold for the inverse rates, because $E(1/X)$ and $1/E(X)$ are not equal.

■ 4 Other possibilities include Siegel's paradox and transactions costs. Research has generally concluded, however, that these are not important empirically. See Baillie and McMahon (1989) for a summary.

■ 5 There are indirect approaches to testing for a risk premium using daily data. One approach is that taken by Levine (1989), who tests the implication of many asset-pricing models that the risk premium embedded in the forward rate is exactly equal to the risk premium in the differential in real interest rates. Giovannini and Jorion (1987) test for the influence of various proxies for a risk premium, such as lagged forward rates and squared interest rates.

■ 6 Bekaert and Hodrick (1991) discuss the impact on the measurement of risk premia of 1) matching forward and spot quotes so as to be consistent with settlement conventions in the foreign exchange markets and 2) the use of averages of bids and asks.

■ 7 Thaler (1987) summarizes the evidence regarding day-of-the-week effects in equity markets, but finds no consistent explanation of the results. Negative returns from Friday to Monday are due to the change from the Friday close to the Monday open. Highest returns are on Wednesday and Friday. Returns also tend to be lower on days before holidays.

and Wednesday tend to be higher than on Thursday and Friday. McFarland, Petit, and Sung (1982) contend that these findings may be related to settlement conventions and to the fact that money supply announcements are made on Thursday. Baillie and Osterberg (1991) examine the forward-rate error with daily data and find that conditional variances are higher on Fridays and before holidays. Baillie and Bollerslev (1989) estimate a generalized autoregressive conditional heteroscedasticity (GARCH) model for daily exchange rates and determine that conditional variances are higher on Mondays and lower on Thursdays. Humpage and Osterberg (1992) estimate a GARCH model for the risk premium implied by the deviation from uncovered interest parity for the G-3 currencies. They find that the risk premium for the DM/$ is lower on Thursdays and that the conditional variance of the deviation for the yen/$ is higher on Fridays and around holidays. Hsieh (1988) concludes that daily exchange-rate distributions are not independently and identically distributed across days and that there are no day-of-the-week effects in the mean of the exchange-rate change. However, he does find that variances are larger when the trading period spans a weekend or holiday.

Channels of Influence for Intervention

The linkage between intervention and bid–ask spreads has not previously been examined. Instead, studies of intervention view it as influencing risk premia or conditional variances. Most analyses have concentrated on sterilized intervention, partly because there is interest in whether it can be viewed as a policy lever in addition to monetary and fiscal policies.[8] Unsterilized intervention is equivalent to monetary policy.

The two major channels through which sterilized intervention can influence exchange rates are the portfolio-balance channel and the signaling channel.[9] Sterilized intervention alters the relative supplies of domestic and foreign bonds and, if investors are risk averse and if domestic and foreign bonds are imperfect substitutes, leads to a readjustment of rates of return via the exchange rate; this is the portfolio-balance mechanism. The impact of intervention operating through the portfolio-balance channel can be mitigated by three conditions: 1) perfect substitutability, 2) Ricardian equivalence, under which consumers perfectly anticipate future taxes associated with the change in government debt, and 3) the slight effect of intervention on asset supplies.

The signaling channel is usually analyzed within the asset-market approach to exchange-rate determination. Exchange rates equal the present discounted value of future economic fundamentals. If monetary authorities have inside information, intervention may signal future monetary policies. For example, a sterilized purchase of marks by the United States may lead to an appreciation in marks (a decrease in the DM/$ rate) if the purchase is believed to signal inside information (more expansionary U.S. monetary policy) that increases the expected future exchange rate.

The question arises as to why intervention is the type of signal chosen. One answer may be that it gives authorities an incentive to follow through with the expected policy. For example, if authorities have just purchased foreign currency, they may wish to see an appreciation in its value. On the other hand, since intervention does not require an immediate change in the monetary base, market participants may be misled. However, if the subsequent monetary policy is not consistent with that implied by the initial action, the effectiveness of future intervention may be reduced. This has led some to suggest that intervention is an effective signal only if followed by consistent monetary policy. If this is true, however, it is not clear that intervention is independent of monetary policy. Humpage (1991) discusses concerns associated with this point.

Empirical evidence suggests that the signaling channel is probably of more significance than the portfolio-balance channel. Early studies of the latter, summarized by Obstfeld (1988), generally find that intervention has little impact or that coefficients' signs are inconsistent with theory. One reason for the small estimated impact is that intervention is minute relative to the outstanding stocks of assets. Another reason may be that calculation of asset supplies precludes the use of high-frequency data.

Studies that utilize relatively high-frequency data have found signaling effects. Dominguez (1988) examines weekly data on money surprises,

■ 8 A country sterilizes its intervention when it negates the initial impact of the intervention on its money supply through an offsetting open-market transaction. For example, when U.S. authorities purchase marks with dollars, the supply of dollars is increased. Selling U.S. government securities in the same amount as the intervention removes dollars and sterilizes the intervention.

■ 9 Some authors have suggested other channels. Humpage (1988) finds that intervention sometimes provides "news" other than about future monetary policy. Dominguez (1988) discusses how intervention can have an influence by misleading exchange market participants. The vast majority of theoretical and empirical research focuses on the portfolio-balance and signaling channels.

exchange rates, and intervention and concludes that the effectiveness of intervention as a signal depends on the credibility of the implied monetary policy. In a later paper, Dominguez (1990) finds the distinction between coordinated and unilateral intervention to be important. If the mechanism was portfolio balance, only the change in relative asset supplies would matter.[10]

Few studies use both daily exchange-rate data and official intervention data, as does this paper. Dominguez (1990), Loopesko (1984), and Humpage and Osterberg (1992) use official data to examine the impact of intervention on the risk premium implied by deviations from uncovered interest parity. All three studies find significant effects of intervention. Baillie and Humpage (1992) estimate a simultaneous system in which intervention either "leans against the wind" or seeks to stabilize volatile markets. They determine that intervention influences the conditional variance of the exchange rate. Baillie and Osterberg (1991) examine intervention's impact on the conditional mean and variance of the daily forward-rate forecast error, finding that U.S. purchases of foreign currency influence the conditional mean. If efficiency is assumed, the mean is interpreted as a risk premium.

B/H and Hung (1991) both view intervention as operating via the market microstructure of heterogeneous traders. In B/H, traders face the possibility that the central bank may decide to push the rate down or up. As a result, traders may find that they have offered to buy too high or to sell too low. In either case, the dealer sets a wider bid–ask spread.

Hung (1991) considers a signaling role for intervention that differs from that discussed by Dominguez. If doubts about credibility make intervention an ineffective signal of monetary policy, and if the market is without a strong direction, public intervention can influence the trading strategies of chartists or other nonfundamental traders. A strong implication of this is that the central bank must know the current market trading strategies. In addition, the ability of intervention to increase or decrease volatility depends on market conditions. For example, if the dollar is acknowledged to be overvalued but is still moving upward, the Fed would prefer to wait until a short-term downward movement began, which it could encourage through secret intervention. Selling dollars with this downward trend would increase volatility. However, if the dollar is on a strong downward trend, the Fed could help it move down and decrease volatility by countering short-term upward movements.

II. Data

The exchange-rate data were provided by the Federal Reserve Bank of New York. At 10:00 a.m. of each day on which the New York market is open, the Bank obtains both bid and ask quotes for the spot and forward rates for the DM/$ and the yen/$. The intervention data were provided by the Board of Governors of the Federal Reserve System.[11] I analyze four series: U.S. purchases of dollars vis-à-vis the mark, German purchases of dollars (sales of marks), U.S. purchases of dollars vis-à-vis the yen, and Japanese purchases of dollars (sales of yen).

The sample period is from August 6, 1985 to September 6, 1991. However, because not all Japanese and German holidays coincide, the number of observations differs for the two exchange rates under examination. The intervention data are close-of-business (COB) net daily purchases, measured in $1 million units. The following analysis attempts to account for the fact that the foreign exchange quotes are not contemporaneous with the intervention numbers. Unfortunately, the available data do not permit discrimination between interventions that occur via a broker and those that occur via market-makers.

III. Results

Table 1 presents the bid–ask spreads for both the spot and forward rates for the DM/$ and yen/$ for each day of the week. Beneath the spreads are the t-statistics for the hypothesis that each day's spread is equal to the Friday spread. Except for the Tuesday numbers for both the spot and forward spreads for the yen/$, the two-tailed test indicates rejection of the null at the 5 percent level. In all cases, the null is rejected at 10 percent. The Friday versus non–Friday tests are consistent with these results.

Table 2 looks at holiday effects in the spreads. This focus is motivated by three facts: First, markets by definition are closed on holidays as well as on weekends (although markets may be open elsewhere in the world on U.S., German, or

10 Dominguez and Frankel (1991) and Ghosh (1989) attempt to distinguish between portfolio-balance and signaling channels. Using monthly data, Ghosh finds that portfolio-balance variables add a small but significant effect to exchange rates. With weekly data, Dominguez and Frankel determine that the signaling mechanism enhances the portfolio balance effect.

11 The data on U.S. intervention are now publicly available from Publications Services, Board of Governors of the Federal Reserve System.

TABLE 1

Daily Patterns in Bid–Ask Spreads

	Monday	Tuesday	Wednesday	Thursday	Friday	Non-Friday
DM/$						
Spot	6.360E–4	6.534E–4	6.465E–4	6.796E–4	7.774E–4	6.544E–4
T-stat.	5.160[a]	4.405[a]	4.818[a]	3.523[a]		5.985[a]
Forward	7.616E–4	7.754E–4	7.687E–4	8.034E–4	9.065E–4	7.778E–4
T-stat.	4.984[a]	4.410[a]	4.779[a]	3.497[a]		9.660[a]
N	266	311	304	302	304	1,183
Yen/$						
Spot	6.123E–2	6.384E–2	6.222E–2	6.186E–2	6.872	6.233
T-stat.	2.712[a]	1.760[b]	2.468[a]	2.530[a]		3.324[a]
Forward	7.316E–2	7.52E–2	7.370E–2	7.378E–2	8.062E–2	7.407E–2
T-stat.	2.531[a]	1.735[b]	2.465[a]	2.359[a]		3.181[a]
N	263	304	303	298	298	1,168

a. Significant at the 5 percent level for a two-tailed test.
b. Significant at the 10 percent level for a two-tailed test.
NOTE: Entries for "spot" and "forward" are the average bid–ask spreads. The t-tests are for the differences from the Friday spreads. "N" indicates the number of observations.
SOURCE: Author's calculations.

Japanese bank holidays). If spreads are higher on Fridays because markets are going to be closed and prices therefore cannot "reveal" information, spreads may also be higher on days before holidays. Second, an examination of the intervention data shows that intervention does not occur on weekends, although it does sometimes occur on U.S., German, or Japanese holidays in markets that are still open. If market participants are aware of these facts, and if anticipated intervention widens spreads, then spreads will indeed be wider on days before holidays. Third, since more holidays are on Mondays than on any other day, the "Friday effect" could be a "holiday effect." In order to focus on the possible influence of intervention on spreads, I isolate a pure holiday effect by controlling for whether or not the day before a holiday falls on a Friday. I also present the comparisons necessary to detect a pure Friday effect.

The results show that spreads are higher on days before holidays, but there is mixed evidence of a pure holiday effect. First, although spreads are higher on Fridays before holidays than on other Fridays, the difference is not significant for any of the four spreads. Second, for other days before holidays, both spot and forward spreads are wider for the DM/$ rates, but not for the yen/$ rates. There is also mixed evidence for a pure Friday effect. In terms of both currencies and spreads, Fridays not before holidays are higher than non–Fridays not before holidays. However, there are no significant differences between Fridays not before holidays and non–Fridays not before holidays.

These comparisons provide no compelling reason to think that higher spreads on Fridays are due to the fact that many Fridays fall before holidays on which intervention may occur. The last column of table 2 compares spreads on days before single holidays with spreads on days before consecutive holidays. The spreads on days before multiple holidays are lower than, but not significantly different from, days before single holidays.

The remaining tables present information about the relationship between the daily and holiday patterns in spreads and intervention.[12] Ideally, data on expected intervention would be used to test the hypotheses presented by B/H. Newspapers regularly report intervention. Such reports, however, often either mention intervention that did not occur or fail to note actual intervention (see Klein [1992]). Another consideration is that while the foreign exchange quotes are as of 10:00 a.m., the intervention data are as of COB.

■ 12 Intervention rarely occurred on holidays. The United States and Germany intervened five and nine times, respectively, in the DM/$ market. The United States and Japan intervened eight and 13 times, respectively, in the yen/$ market.

TABLE 2

Friday and Day-Before-Holiday Effects in Bid–Ask Spreads

	A	B	C	D	E	F	G	H
	Before	~A	Fri., A	Fri., ~A	~Fri., A	~Fri., ~A	Multiple	Single
DM/$								
Spot	8.015E–4	6.718E–4	8.430E–4	7.664E–4	7.600E–4	6.502E–4	6.250E–4	8.097E–4
T-stat. (H)		3.694[a]		1.290		2.355[a]		–0.868
T-stat. (F)			0.955		5.408[a]			
Forward	9.292E–4	7.961E–4	9.669E–4	8.960	8.916E–4	7.733E–4	7.500E–4	9.376E–4
T-stat. (H)		3.595[a]		1.130		2.406[a]		–0.844
T-stat. (F)			0.820		5.390[a]			
N	90	1,397	45	259	45	1,138	4	86
Yen/$								
Spot	6.943E–2	6.320E–3	7.147E–4	6.815E–4	6.735E–2	6.210E–2	6.423E–2	7.020E–2
T-stat. (H)		2.038[a]		0.570		1.341		–0.672
T-stat. (F)			0.692		2.905[a]			
Forward	8.223E–2	7.489E–2	8.443E–2	7.983E–2	8.007E–2	7.380E–2	7.577E–2	8.323E–2
T-stat. (H)		2.253[a]		0.744		1.488		–0.779
T-stat. (F)			0.678		2.708[a]			
N	101	1,365	51	247	50	1,118	13	88

a. Significant at the 5 percent level for a two-tailed test.

NOTE: Entries for "spot" and "forward" are the average bid–ask spreads. "N" indicates the number of observations.

Explanation of columns:

A: Days before market holidays
B: (~A) Days not before market holidays
C: (Fri., A) Fridays before market holidays
D: (Fri., ~A) Fridays not before market holidays
E: (~Fri., A) Non–Fridays before market holidays
F: (~Fri., ~A) Non–Fridays not before market holidays
G: Days before multiple, consecutive market holidays
H: Days before single market holidays

Explanation of t-statistics:

(H), (F) distinguish tests designed to isolate pure day-before-holiday and Friday effects, respectively.
B: Days before holidays compared to days not before holidays
C: Fridays before holidays compared to non–Fridays before holidays
D: Fridays before holidays compared to Fridays not before holidays
E: Fridays not before holidays compared to non–Fridays not before holidays
F: Non–Fridays before holidays compared to non–Fridays not before holidays
H: Days before multiple holidays compared to days before single holidays

SOURCE: Author's calculations.

Table 3 presents the daily variation in frequency of intervention. B/H suggest that decisions about intervention took place over the weekend for the currencies in the European Monetary System. If this were true for the G-3, we may expect to see more intervention occurring on Mondays. However, there is no significant evidence that this is the case.

Rather than define periods of intervention as days on which intervention officially occurred ex post, in table 4, I use two measures of expected intervention. Panel A compares the bid–ask spreads over periods usually thought of as times of intervention as opposed to "nonintervention" periods. Ignored for the moment is the issue of whether intervention actually occurred at these times. The intervention periods are defined as 9/1/85 to 12/31/85, 9/1/86 to 1/1/87, 2/1/87 to 6/1/87, and 10/1/87 to 12/31/87. The most noteworthy dates are 9/22/85 (Plaza accord), 2/23/87 (Louvre accord), and 10/19/87 (the U.S. stock market crash). Dominguez (1990) presents reasons to focus on the wider time frames utilized here. The nonintervention

TABLE 3

Day-of-the-Week Effects in Intervention

	Monday	Tuesday	Wednesday	Thursday	Friday	Non-Monday
DM/$						
U.S.	0.1312	0.1158	0.1118	0.1325	0.1513	0.1278
T-stat.		0.5759	0.7198	–0.0306	–0.6724	0.1684
Germany	0.1917	0.1897	0.1447	0.1523	0.1809	0.1671
T-stat.		0.0614	1.5022	1.245	0.3303	0.9663
N	266	311	304	302	304	1,221
Yen/$						
U.S.	0.1367	0.1151	0.1089	0.1342	0.1174	0.1189
T-stat.		0.7794	1.0135	0.0915	0.6899	0.8079
Japan	0.2358	0.1875	0.1848	0.2114	0.1946	0.1945
T-stat.		1.4067	1.4877	0.6902	1.1843	1.5089
N	263	304	303	298	298	1,203

NOTE: Entries for each country are the proportion of days on which intervention occurred. T-statistics are for the difference between the Monday numbers and other days. "N" indicates the number of observations.
SOURCE: Author's calculations.

TABLE 4

Bid–Ask Spreads: Intervention Periods vs. Nonintervention Periods

	Panel A: Purported Intervention?		Panel B: Two Consecutive Days		Panel C: Expected vs. Unexpected, Realized vs. Unrealized			
	1) Yes	2) No	1) Int.	2) Non.	A:1, B:1	A:1, B:2	A:2, B:1	A:2, B:2
DM/$								
Spot	8.342E–4	8.744E–4	6.670E–4	6.821E–4	7.707E–4	8.323E–4	9.455E–4	8.856E–4
T-stat.	–1.308		–0.472			–1.011	–1.576	–1.973[a]
Forward	9.930E–4	1.030E–3	7.987E–4	8.050E–4	9.361E–4	9.883E–4	1.084E–3	1.042E–3
T-stat.	–5.465[a]		–0.211			–0.832	–1.300	–1.779[b]
N	339	246	111	1,145	41	229	11	222
Yen/$								
Spot	7.799E–2	8.411E–2	7.091E–2	6.176E–2	7.393E–2	7.671E–2	8.182E–2	8.317E–2
T-stat.	–2.099[a]		3.855[a]			–0.667	–1.354	–1.880[b]
Forward	9.290E–2	9.890E–2	8.464E–2	7.309E–2	8.907E–2	9.113E–2	9.655E–2	9.820E–2
T-stat.	–1.975[a]		4.524[a]			–0.465	–1.262	–1.818[b]
N	339	246	147	1,098	61	234	44	161

a. Significant at the 5 percent level for a two-tailed test.
b. Significant at the 10 percent level for a two-tailed test.
NOTE: T-statistics for panels A and B are for the intervention–nonintervention difference. T-statistics for panel C are for the differences from the A:1, B:1 spreads. "N" indicates the number of observations.
Explanation of panel C:
A:1, B:1: Days on which intervention was expected and realized
A:1, B:2: Days on which intervention was expected but not realized
A:2, B:1: Days of "surprise" intervention
A:2, B:2: Days on which intervention was neither expected nor realized
SOURCE: Author's calculations.

period is defined as all other days. For purposes of comparability, the panel A calculations leave out the post–1987 subsample. Both DM/$ and yen/$ spreads are significantly lower during periods of purported intervention.

Panel B of table 4 compares spreads from days within actual intervention periods with days from periods when intervention did not occur. Specifically, if either the United States or Germany was intervening on day $t-1$ and on day t, the 10:00 a.m. day t quote on the DM/$ is said to be from a period of intervention. If both countries were not intervening on either day, the quote is from a nonintervention period. In effect, this indicates that if there was intervention on day $t-1$ (ex post) and intervention as of COB on day t, it is likely that, at 10:00 a.m. on day t, traders perceived that they were in the midst of a period of intervention. Table 4 shows that the yen/$ spreads were significantly higher during these periods, while the DM/$ rates were lower, though not significantly so.

Panel C further refines these measures of expected intervention.[13] The periods of purported intervention analyzed in panel A might be better thought of as periods when intervention was likely to have been anticipated. The "two consecutive days" criterion utilized in panel B may better identify periods of actual intervention. Thus, one possible explanation of the higher spreads for the yen/$ in panel B may be that not all intervention that occurred during two consecutive days was anticipated. Days that fell into the first columns of both panels A and B may more closely identify intervention that was both expected and realized. Days that fell into both of the second columns tell us when intervention neither occurred nor was expected. The in-between cases are when days met only one of the criteria. Panel C provides the results for all four cases.

All four of the t-statistics imply significant differences at the 10 percent level, and the relative magnitudes of the spreads are consistent with my interpretation of panel A. Spreads are lower when actual intervention was expected than when intervention was neither expected nor realized. Spreads when intervention was expected but not realized lie between the "expected intervention" and "neither" cases. In addition, conditional on whether intervention occurred as defined by the panel B criterion, spreads are lower when intervention was anticipated, as defined in panel A. This weakens the qualification that the yen/$ findings in panel B had for concluding that intervention lowers spreads. More important, however, panel C is contrary to the B/H hypothesis that expectations of intervention increase bid–ask spreads.

Causality should not be inferred from correlations such as those presented here. While B/H contend that spreads widen in anticipation of intervention, at times intervention has been intended to counter volatility. Bid–ask spreads may in part reflect volatility, and thus intervention and bid–ask spreads may be correlated because of attempts to counter volatility reflected in spreads.

In the absence of a fully specified model of the determinants of the spreads and of the response of intervention to market movements, I utilize the concept of Granger-causality to learn more about the temporal relations between spreads and intervention. Granger-causality utilizes equations of the form

$$(3) \qquad S_t = \sum_{i=1}^{p} b_{SSi} S_{t-i} + \sum_{j=1}^{q} b_{SIj} I_{t-j} + u_{St},$$

$$(4) \qquad I_t = \sum_{k=1}^{r} b_{ISk} S_{t-k} + \sum_{l=1}^{s} b_{IIl} I_{t-1} + u_{It}.$$

Here, I and S are each regressed on past values of themselves and on lagged values of the other variable. I Granger-causes S if past values of I improve upon the ability of past values of S to predict S. Since the focus is on whether intervention Granger-causes spreads, I test for the significance of the b_{SI}'s.[14] However, before estimating these equations, I test for the presence of unit roots in the spreads. The presence of such effects would imply a type of nonstationarity that would invalidate the results. I consistently reject the null that such an effect existed.[15] In addition, the length of the autoregressions, p, q, r, and s, must be chosen. I arrive at a lag length of 20 by considering successively longer lag lengths (10, 15, 20, and 25) and by testing whether the additional terms are significant.

■ 13 I am grateful to Jacky So for suggesting this further refinement. Because B/H claim that anticipation of intervention widens spreads, theirs is a claim about weak-form market efficiency. Use of actual, confidential intervention data is relevant for tests of strong-form efficiency.

■ 14 Alternative concepts of, and tests for, causality are presented by Granger and Newbold (1986).

■ 15 These tests were performed with both the Dickey–Fuller and Phillips–Perron procedures, both with and without deterministic trends. The number of lagged first differences on the right side was the minimum number to produce residuals that were free of serial correlation as measured by Box–Ljung Q statistics. Baillie and McMahon (1989, pp. 105–107) discuss these test procedures. The results of the unit root tests are available from the author.

TABLE 5

Granger-Causality Tests: Intervention to Spreads, Significance Levels

	Full Sample	9/9/85–12/31/86	1/1/87–12/31/89
U.S.–Germany			
Int.→Spreads	0.4978	0.4260	0.3657
U.S.–Japan			
Int.→Spreads	0.9680	0.0001	0.6717

NOTE: Significance levels are for the likelihood ratio tests of whether the vector of intervention terms Granger-causes the vector of spreads.
SOURCE: Author's calculations.

Table 5 presents the results of the tests for Granger-causality from intervention to spreads.[16] This is done for each currency, so that when DM/$ (yen/$) spreads are on the left side, then lagged DM/$ (yen/$) spreads, lagged German (Japanese), and lagged U.S. intervention are on the right side. For the full sample, there is no evidence of Granger-causality from intervention at conventional levels of significance.

Table 5 also presents the results of the same causality tests when the sample was split at the end of 1985 and the second subperiod ends at the close of 1986. Hung (1991) suggests that the impact of U.S. intervention on unexpected volatility changed over these periods in response to different market conditions, as discussed above. U.S. and Japanese intervention Granger-causes yen/$ spreads for the first subperiod. No such effect is found for the three other tests. It is well known, however, that such tests should not be interpreted in terms of structural models.

IV. Summary

In a recent article, Bossaerts and Hillion (1991) present evidence that tests of forward market efficiency that ignore variation in the bid–ask spread are biased, at least for currencies in the European Monetary System. They observe that spreads are wider on Fridays and speculate that this may be due to anticipation of central-bank intervention. In this paper, I use official data on intervention to see if it can explain intraweekly patterns in G-3 spreads.

The tests confirm the tendency for Friday spreads to be higher than for other days of the week and also find some evidence of holiday effects. However, there is no evidence that intraweekly patterns in intervention are related to the patterns in spreads. In addition, I find no evidence to support the conclusion that anticipation of intervention widened spreads. Last, Granger-causality tests suggest that intervention generally does not lead spreads.

Although I cannot interpret such results in terms of a structural model, previous research has documented that intervention influences risk premia and that conditional variances exhibit intraweekly variation. Intervention policies at times have been explicitly designed to respond to volatility. Further investigation into the relations among intervention, spreads, and volatility would be greatly facilitated by a structural model.

16 Tests of whether spreads Granger-cause intervention would need to be strongly qualified due to the nature of the distribution of the intervention variables (many observations are clustered at zero). This problem, however, does not invalidate the tests for Granger-causality from intervention.

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TABLE 1

The Storage Technology for Three Periods

	$T = 0$	$T = 1$	$T = 2$
Return	−1	1	0
		0	R

SOURCE: Author.

Tastes

Agents are identical, with the following constant elasticity of substitution (CES) utility function:

(1) $U = G(u)$,

where $u(c_1, c_2) = (c_1^{\,1-1/\sigma} + \beta c_2^{\,1-1/\sigma})^{\sigma/(\sigma-1)}$ and $G(u) = 1/(1-\gamma)\, u^{1-\gamma}$.

Three important parameters specify preferences: β, the discount factor; σ, the intertemporal elasticity of substitution; and γ, the rate of relative risk aversion toward variation in lifetime wealth. In the economies studied below, agents face uncertainty about lifetime wealth, so that we can meaningfully separate attitudes about risk aversion from those concerning the time pattern of consumption. Once individuals enter period 1, they face neither uncertain income nor risky assets. Thus, agents formulate consumption plans contingent on the level of lifetime wealth. Lifetime utility, but not the consumption strategy, depends on the risk-aversion parameter γ.

Endowments

Each individual has an endowment of a single good in each period. At periods 0 and 2, all agents have identical endowments Φ and y_2 . At period 1, each individual receives a *privately observable* income level $y_1(\theta) = y_1 + \theta$, where y_1 is the level of per capita income. Consumers know y_1 at $T = 0$, and they learn θ at $T = 1$. The idiosyncratic component of income, θ, is continuously distributed on $(\underline{\theta}, \overline{\theta})$ with density function $f(\theta, x)$ having $E(\theta) = 0$ and $E(\theta \mid x) = 0$ (x is an aggregate shock discussed later). I assume a continuum of traders indexed at period 1 by the realized value of θ. Thus, the analysis proceeds as if each value of the distribution is realized (see Judd [1985]).

Intertemporal Technology

Along with preferences and endowments, the actors in the model have a storage technology, that is, an intertemporal production function that rewards long-term storage. Goods stored in $T = 0$ pay no net interest if removed in period 1, but pay a gross return $R > 1$ if left until $T = 2$, as shown in table 1.

This provides a tractable case in which the time paths of investment projects are somewhat irreversible. An alternative motivation is that individuals (banks) cannot costlessly liquidate assets before their maturity. Economywide movements are captured by introducing randomness into the intertemporal technology.

R, the technological rate of return, varies positively with the aggregate shock x. Individuals observe x costlessly and perfectly at $T = 0$, so that they know $R(x)$ from the beginning. Furthermore, the distribution of θ depends on the aggregate shock. A higher value of x induces a mean-preserving spread on the distribution of θ, $f(\theta)$, subjecting agents to more risk. This assumption is designed to capture the view that progress benefits some individuals more than others. Schumpeter (1939) assigns this view a major role:

> Industrial change is never harmonious advance with all elements of the system actually moving, or tending to move, in step. At any given time, some industries move on, others stay behind; and the discrepancies arising from this are an essential element in the situations that develop. (pp. 101–102)

Thus, I separate the effects of an aggregate shock into two components. One is an increase in the productivity of long-term storage, whereby a positive x increases R. The other is an increase in the dispersion of the random variable θ. Following Rothschild and Stiglitz (1970), I let the shift put more weight in the tails of the distribution.[5] These effects cause $f(\theta, x)$ to become riskier (in the sense of a mean-preserving spread) with increases in x and cause $R(x)$ to increase in x. That is, the shock raises market (or technological) interest rates. Conversely, a negative shock decreases R and reduces the dispersion of θ.

This connection between a macroeconomic variable (R) and a microeconomic variable (the

5 As the authors point out, this sort of mean-preserving spread corresponds to natural economic measures of increasing dispersion. Any risk-averse individual will prefer the old distribution, and the new distribution will equal the old distribution plus a noise term.

TABLE 2

Observation of Shocks for Three Periods

$T = 0$	$T = 1$	$T = 2$
x realized $f(\theta, x)$ known	θ realized	$R(x)$ paid off

SOURCE: Author.

individual's endowment risk) is critical in studying the behavior of optimal bank contracts in this economy. Because individuals can observe x at $T = 0$, knowledge of $R(x)$ and $f(\theta, x)$ simplifies the analysis by reducing the problem to comparative statics on the distribution of θ. Additionally, this specification abstracts from the uncertainty about aggregate shocks and instead emphasizes their distributional consequences. I thus concentrate on the *direct* effects of the aggregate shocks, not on uncertainty about them. To recapitulate, then, agents observe x, and thus $f(\theta, x)$ in period 0, and θ obtains in period 1 (see table 2).

As a benchmark for comparison with later results, consider the macroeconomic effects of an aggregate shock in this economy without contracts. The individual uncertainty about the distribution of income has no effect on aggregate variables, so it makes sense to examine only the average individual. The increased dispersion caused by the impulse has no effect on aggregate variables: The per capita change in consumption and savings is the same as if the distribution of income had been entirely ignored.

The simplicity of this macro model underscores a point generic to models of this class; namely, this simple economy can be understood in an aggregate sense by ignoring individual differences and by focusing on the average agent.

II. Economic Institutions and the Exchange of Risk

When facing diversifiable risk, however, agents in this economy will not accept the market structure imposed above. The ability to write contracts at $T = 0$ means that they can improve upon their initial position by creating a richer institutional structure. In the simple world considered here, banks arise endogenously to meet that demand for insurance. The bank is able to pool agents' diversifiable risk by exploiting the production structure of the economy. This section abstracts from aggregate shocks in order to examine the nature of the emergent institutions more clearly.

Demand for Insurance

Whether the market system produces a bank, an insurance company, or a security market depends on the information structure of the economy. If θ were public information, a regular insurance contract with premiums and payoffs could protect people against the diversifiable income risk. The private character of θ gives rise to adverse selection, however, and rules out such insurance. Still, since I assume that individuals may write contracts on any observable quantity, there may be some other way to trade risk.

In one case, individuals might exchange claims on long-term storage maturing in $T = 2$ after receiving their random income. Unfortunately, this ex post security market provides no improvement over autarky. In equilibrium, arbitrage opportunities between production and securities imply that the price of such securities must be one. If a claim on one unit in storage (R tomorrow) sold for more than one, no one would buy it, preferring instead to place one unit in productive storage. If the price were below one, no one would sell (see Diamond and Dybvig [1983] for a more detailed discussion of this point). Selling these bonds is thus equivalent to taking goods out of production. As we have seen, the ability to draw down storage stocks does not eliminate the possibility of low first-period income.[6] There is still room for an institution that can provide insurance and pool risk even if private income shocks are unobservable.

The Organization of Banking

I define a bank as a coalition of individuals, perhaps brought together by an entrepreneur, that receives a deposit Φ in $T = 0$ and pays interest rates r_0 from $T = 0$ to $T = 1$, and r_1 from $T = 1$ to $T = 2$. Agents can withdraw any fraction of the account in any period. A bank is linear if the

6 I assume that Φ is sufficiently large relative to y_1 and y_2 so that market equilibrium takes place "off the corner" at the aggregate level. That is, individuals will want to store some of Φ. Also, Φ is not so large relative to lifetime wealth that agents wish to deposit in $T = 1$.

interest rate paid is independent of the amount in the account. A bank provides agents with a higher level of expected utility than a situation of autarky because the bank partially insures agents against income risk. The provision of insurance is typically incomplete, because the bank faces a trade-off between risk-pooling and the incentives for saving.

Relative to the technological return (or, equivalently, to ex post security markets), banks offer higher short-term yields ($r_0 > 1$) and lower long-term yields ($r_1 < R$). This is how banks provide insurance. To determine the interest rates that actually occur, take the analysis one step further and consider the *optimal linear* bank.[7] This bank sets r_0 and r_1 to maximize the expected utility of agents given the total resources of the bank and the decision rules of the individuals. The analysis closely follows the optimal income taxation investigations of Mirrlees (1971).

An individual must choose consumption and savings withdrawal given the bank's interest rates r_0 (from $T = 0$ to $T = 1$) and r_1 (from $T = 1$ to $T = 2$). If $r_0 > 1$, the problem for a rational individual begins in period 1:

(2) $$\max \ u(c_1, c_2)$$

subject to

(i) $y_1(\theta) + w = c_1$,

(ii) $y_2 + r_1(r_0\Phi - w) = c_2$.

The solution to this problem provides four functions of the income shock and interest rates: an indirect utility function, $v(\theta, r_0, r_1)$; two consumption functions, $c_1^*(\theta, r_0, r_1)$ and $c_2^*(\theta, r_0, r_1)$; and an optimal withdrawal function $w^*(\theta, r_0, r_1)$. With a CES utility function, indirect utility is linear in wealth, $v = \alpha(r_1)\, a(r_0, r_1\theta)$. Since $w^* = c_1^* - y_1(\theta)$, one can straightforwardly show that

$$\frac{\partial w^*}{\partial r_0} > 0, \ \frac{\partial w^*}{\partial r_1} < 0, \text{ and } \frac{\partial w^*}{\partial \theta} < 0.$$

Recall the assumption (footnote 6) that the initial endowment is large enough so that the withdrawal will be positive for all θ.

The bank, as a coalition of individuals, wishes to maximize the depositors' expected utility $EG[v(\theta, r_0, r_1)]$ subject to a resource constraint. This constraint, written as equation (3), states that the period 0 present value of assets, Φ, must equal the present value of the liabilities both in period 1, $Ew^*(\theta, r_0, r_1)$, and in period 2, $r_1[r_0\Phi - Ew^*(\theta, r_0, r_1)]$.

(3) $$\Phi = Ew^*(\theta, r_0, r_1) + R^{-1}\{ r_1 [r_0\Phi - Ew^*(\theta, r_0, r_1)]\}.$$

In other words, the bank must be able to cover all withdrawals. Notice that the bank views total withdrawals as certain. Thus, Ew^* involves simply "summing" across all depositors. In addition to the resource constraint (3), the bank is constrained by the individuals' decision rules, such as the withdrawal function, which is a function of bank actions r_0 and r_1 as well as θ.

Banking and Insurance

What are the characteristics of an optimal banking structure? First, consider a small increase in r_0 from its initial position of one and a small decrease in r_1. The bank must respect its budget constraint, that is,

(4) $$0 = dr_0[\Phi - (1/r_1 - 1/R)\,E(\partial c_2^*/\partial r_0)] - dr_1\{(y_2 - Ec_2^*) + (1/r_1 - 1/R)\,E[\partial c_2^*/\partial(1/r_1)]\}/r_1^2.$$

When evaluated at $r_1 = R$, expression (4) becomes simply $dr_0\Phi = dr_1(y_2 - Ec_2^*)/r_1^*$. Since $Ec_2^* > y_2$, a small increase in r_0 requires a decrease in r_1.

The effects on expected utility can similarly be calculated by differentiation.

(5) $$dU = E(G'\,\partial v/\partial r_0)\,dr_0 + E(G'\,\partial v/\partial r_1)\,dr_1 = E(G'\alpha)\,\Phi\,dr_0 - E\{G'\alpha[y_2 - c_2^*(\theta)]\}\,dr_1/r_1.$$

■ 7 Haubrich and King (1990) examine such a bank, but with a nonreversible storage technology. Consideration of linear institutions undoubtedly simplifies the analysis, but more important, it prevents the formation of depositor coalitions that could arbitrage across nonlinearities in the rate structure. In other words, an interest-rate structure that is nonlinear in the size of withdrawals would be subject to raiding by coalitions of depositors at $T = 1$. For example, small depositors might combine funds and act as a syndicate to obtain the better rates received by large depositors. This would change the distribution (especially the expected value) of withdrawals and ruin the bank. A budget just balanced, with some individuals obtaining low interest rates, has no room for everyone to receive high rates. A competitive bank simply could not give everyone a higher interest rate.

Expression (5) indicates that increases in r_0 have an identical wealth effect on all consumers. α is the marginal utility of a unit of period 1 wealth. As discussed above, α is invariant to θ under CES utility. By contrast, the wealth effect of an increase in r_1 is greatest for the largest lenders in period 1, for whom $y_2 < c_2^*(\theta)$. Requiring feasibility of dr_0 and dr_1 and rearranging the resulting expression,

$$(6) \qquad dU = \alpha E[G'(c_2^* - Ec_2^*)]\, dr_1 / r_1^2 .$$

With risk aversion, $G'' > 0$, so that the covariance term is unambiguously negative and a small decline in r_1 raises welfare. Intuitively, by raising r_0 and lowering r_1, the bank has shifted wealth from those with high θ's to the average individual. The lucky people with high θ's will attempt to smooth consumption and save the windfall, withdrawing relatively little. The lower r_1 penalizes them. The unlucky people with a low θ withdraw a lot, benefiting from the high r_0. This redistribution provides insurance in $T=0$, when θ is unknown. In effect, in period 0, the bank offers an individual a security that 1) has a certain period 1 expected return (Φdr_0), 2) pays negative returns when high θ's occur, and 3) reduces individual risks.

The Optimal Linear Bank

The economic intuition behind these results (small changes in r_0 and r_1 from the initial position $r_0 = 1$ and $r_1 = R$) extends to interpretation of the optimal banking structure. Again, following Mirrlees (1971) and Atkinson and Stiglitz (1980), I derive the result that for the CES case, the optimal level of r_1 satisfies the following condition:

$$(7) \qquad r_1 = R(\varepsilon_2 + \delta_2 \frac{\partial c_2^*}{\partial a}) / (\varepsilon_2 + \delta_2 \frac{\partial c_2^*}{\partial a} + R\delta_2)$$

$$\equiv R \cdot z(\varepsilon_2, \delta_2, \frac{\partial c_2^*}{\partial a}),$$

where ε_2 is the compensated semi-elasticity of second-period consumption with respect to its price, $p_2 \equiv \frac{1}{r_1}$. ε_2 is a constant because utility is CES, $\varepsilon_2 = (1/c^*)$, and $\frac{\partial c_2}{\partial p_2} > 0$. $\frac{\partial c_2}{\partial p_2}$ is the effect of a wealth increment on second-period consumption, and δ_2 is the risk premium of a private agent for a consumption bet of the form c_2^* / Ec_2^*. Such a bet has expected utility of one but covaries negatively with lifetime marginal utility: $\delta_2 = -\{cov\{G', c_2^*(\theta)\} / EG' Ec_2^*\}$.

Notice that risk aversion implies $r_1 < R$ and thus $r_0 > 1$, both of which preserve the flavor of the local results above.

Banks and Other Structures

It is worth comparing this bank with the other institutions already discussed. In autarky, each individual agent is subject to income risk. Because the technology is reversible, no one benefits from being able to sell shares in an ex post security market, that is, by transferring goods from $T=2$ to $T=1$. A simple ex post equity market, then, does not improve upon autarky, because it cannot remove any of the income risk faced by agents.

However, the optimal linear banking structure provides agents with a higher level of expected utility than an ex post market does, because it partially insures agents against income risks. The provision of such insurance is incomplete because the bank pays for insurance by distorting the intertemporal trade-off facing consumers. Relative to ex post security markets, banks offer higher short-term yields ($r_0 > 1$) and lower long-term yields ($r_1 < R$). Without income uncertainty, or with full insurance from another source, the optimal bank would set $r_0 = 1$ and $r_1 = R$, and would serve no economic purpose.

Notice this classic relation between the bank and asset markets: The bank creates long-term assets from short-term liabilities. Though agents may withdraw money from their account at any time, the bank balances these withdrawals and invests partly in long-term production. A nonclassical restriction is the requirement of a choice of institution. As in other models of this sort (Diamond and Dybvig [1983], Haubrich and King [1990], and Jacklin and Bhattacharya [1988]), a bank and an equity market cannot coexist.

A more detailed analysis of these questions would proceed by initially characterizing Pareto-optimal allocations—subject to resource and incentive constraints—and then asking whether particular market arrangements can effectively decentralize these allocations or yield Pareto-optimal quantities as the outcomes of individual choices in a specified market. Because this paper concentrates on the effects of aggregate shocks, and not on the banking contract per se, it will not formalize the mechanism-theoretic approach to this problem. Additionally, a digression here could not do justice to the many interesting issues that arise, and would be redundant in light of the fuller treatment of the banking contract found in Haubrich (1988) and Haubrich and King (1990). Still, an informal discussion summarizing results from the other papers can clarify several related issues.

A key question is which institutions can support the optimal allocations arising from the planning problem. A bank contract supports such allocations, as do some other institutions. The main difference concerns the possibility of bank runs. Adding a sequential service constraint, as in Diamond and Dybvig (1983), will create panics. However, banks without this feature (and indeed mutual funds issuing derivative securities) can support the optimal allocations and remain immune to panics. I consider only such stable institutions.

An equity market does *not* support the optimal allocation. Once a bank exists, there are individual incentives to create a stock market. This would ruin the bank, however, so the planner does not allow that market to open. This exclusivity seems to be a generic defect of this type of banking model. Haubrich (1988) examines the informational assumptions allowing such exclusion. Jacklin and Bhattacharya (1988) interpret banking regulation as a means of preventing the arbitrage that would destroy banks. Gorton and Haubrich (1987) explore coexistence using a somewhat different model.

Finally, support for the full optimum mentioned above requires a nonlinear bank—one that pays contingent on withdrawal size. The general form of the contract remains the same, and the same techniques can be used to characterize the interest-rate schedule, but comparative statics become intractable. The linear bank results from the arbitrage conditions discussed above, which in the planning problem take the form of "multilateral incentive compatibility constraints" (see Haubrich [1988]). The nonlinearities that exist in the real world may result from the inability to arbitrage the bank—perhaps due to transactions costs or to the inability of group members to monitor one another. Still, the linear bank seems a useful approximation.

III. Banking with Aggregate Shocks

This section reintroduces fluctuations into the economy by integrating the banking sector into the basic macro model. It explores how the aggregate random variable x influences bank interest rates and in turn affects savings and consumption. This section illustrates the importance of contracts in economies with connections between a macroeconomic variable, R, and a microeconomic variable, individuals' endowment risk. Recall that a positive x increases R and induces a mean-preserving spread in $f(\theta)$, while a negative draw lowers R and reduces the dispersion of θ. In the presence of banks, this interaction has important consequences.

Individuals can observe x in $T = 0$, so that knowledge of $R(x)$ and $f(\theta, x)$ allows calculation of the interest rates r_0 and r_1. This reduces the problem to comparative statics on the distribution of θ and suggests that it is not uncertainty about aggregate shocks that drives banks' effects on interest rates, but rather the distributional consequences of such shocks.

It will be easier to examine these effects in three steps. First, I examine how r_1 changes with R if the distribution of θ remains fixed. Next, I keep R fixed and note how r_1 changes with the dispersion of θ. Finally, I put the two together.

Pure Aggregate Shocks

The case of an aggregate shock—with no effect on the uncertainty of income—serves as a benchmark for comparison with more complicated scenarios. With a "pure" aggregate shock, if the underlying technological rate of return R increases, the economy is richer and should be able to support a higher interest rate on bank deposits. This is indeed what happens, since

$$dr_1 / dR = z(\delta_2, \partial c_2^* / \partial a, \varepsilon_2) - r_1 \delta_2(\varepsilon_2 + \delta_2 \partial c / \partial a + R\delta) > 0 .$$

Thus, the direct or "pure" effect of an aggregate shock moves both bank and market interest rates in the same direction. The second term in the equation is model specific: Because the utility function exhibits constant relative risk aversion, the increased income leads consumers to demand less insurance for a given absolute risk. This term would be absent with constant absolute risk aversion. A short calculation reveals that r_0 rises with R; economically, because of a higher payoff to storage, the bank can afford to distribute more goods, and both bank and market interest rates increase.

Pure Distribution Effects

The next determination is how banks' interest rates move when individuals are subject to greater uncertainty. I wish to sign $\partial z/\partial x$; that is, to hold R fixed, but to allow x to change $f(\theta)$. Equation (7) tells us $r_1 = z(\delta_2, dc_2/da, \varepsilon_2)R$.

Notice that the CES specification makes ε_2 constant, and the homotheticity of indifference curves implies that $\partial c_2/\partial a$ is independent of the distribution of θ. This means that the only term changed by a mean-preserving shift in $f(\theta)$ is δ_2. Not surprisingly, the movement in the interest rate depends on the movement of the risk premium on period 2 consumption. Recall that a greater risk premium indicates a greater demand for insurance, which is provided by a lower interest rate. Notice that $\partial r_1/\partial \delta_2 = -\varepsilon_2 R/(\varepsilon_2 + \delta_2 + \partial c_2^*/\partial a)^2 < 0$. Thus, a mean-preserving spread will decrease r_1 if it increases δ_2. Since δ_2 measures the risk premium on c_2^*/Ec_2^*, we expect it to rise with a risker c_2^*, which in turn is a linear function of θ. Intuitively, a positive shock, say a good harvest, will increase the uncertainty of individual incomes. This drives up δ_2, the risk premium on the lifetime consumption gamble, and sends r_1 down. The bank pools some of the increased risk by pushing r_1 and r_0 closer together, hence further redistributing income from the lucky to the unlucky.

The clear intuition on the effects of a mean-preserving spread belies the complexity of the actual calculation. The multiperiod, multiple-choice problem does not fit the one-variable techniques of Rothschild and Stiglitz (1970, 1971). In a closely related problem, calculating the change in the optimal linear income tax with a change in the ability distribution, Stern (1976) resorts to numerical examples even after specifying both utility and distribution functions. With problems in such a simple case, it is not surprising that more general specifications prove intractable.

Calculating the change in δ_2 is straightforward when G takes the form of log utility.[8] This is the only case for which an intertemporal investor facing a changing investment opportunity set will act as if he were a one-period maximizer (Merton [1982]). With log utility, changes in the interest rate alone do not alter consumption or savings decisions, and the result is a one-period problem on which standard comparative static techniques can be used. In this paper, because interest rates differ across periods, individuals face a changing investment opportunity set. With that problem simplified, comparative statics on the bank problem become feasible. The appendix carries out the calculation for log utility and examines the robustness of the result. A mean-preserving spread also increases the risk premium in another tractable case, quadratic utility.

Another way to obtain results is to restrict the distribution function. The appendix shows that for arbitrary utility functions, a two-point distribution yields the required result, as do certain changes related to the martingale measure of risk. Thus, although the general case seems intractable, a number of specific results support the intuitive conclusion.

Micro and Macro Shocks Together

The pure aggregate shock moves the underlying interest rate. The pure distribution effect, on the other hand, increases individual uncertainty and induces people to pool more risk by accepting a lower interest rate. The combination of both effects means that a macroeconomic disturbance will increase bank interest rates, but by less than the underlying rate. In other words, the aggregate shock x moves R directly, increasing both r_1 and r_0. In fact, without changes in individual uncertainty, an efficient bank would raise r_1 proportionately with R. The distribution effect by itself lowers r_1 when x rises. Both effects together imply that r_1 moves by less than R. Further, we expect that the direct effect dominates the distributional (indirect) effect, and both r_1 and R increase (that is, bank rates move less than one-to-one with the underlying interest rates). Similarly, a negative x decreases R, and the distribution effect raises r_1. Again, sluggishness results. Since the two effects of x—an increase in R and a greater dispersion of θ—are mathematically distinct, we must simply assume the dominance of the direct effect. This assumption accords with the macroeconomic evidence and theories mentioned in section I.

This distribution effect also influences r_0. The bank's budget constraint, (3), implies that a decrease in r_1 requires an increase in r_0. When the dispersion of θ rises, the bank provides more insurance by increasing r_0 and decreasing r_1. This affects consumption and savings in two ways: The higher r_0 augments the wealth of all agents as of $T = 1$, and the lower r_1 makes current consumption more attractive. These distributional

■ 8 The dynamic asset pricing literature often exploits this tractability, which stems from the offsetting income and substitution effects.

consequences counteract the intertemporal effects of the pure gain in R, which induces people to consume more later.

The effect on interest rates is an immediate illustration of how contracts change the qualitative macroeconomic behavior of this economy. As the intertemporal price, the interest rate has additional effects. In general, comparing the path of aggregate disturbances will be complicated, but in the case of log utility, simple results emerge. The sluggish adjustment of interest rates dampens the effect of aggregate shocks on consumption and savings. Some lengthy but straightforward calculations show that

$$(8) \quad 0 > \frac{\partial c_1^*}{\partial x} \text{ (bank)} > \frac{\partial c_1^*}{\partial x} \text{ (no bank), and}$$

$$(9) \quad \frac{\partial c_2^*}{\partial x} \text{ (no bank)} > \frac{\partial c_2^*}{\partial x} \text{ (bank)} > 0 .$$

Thus, though idiosyncratic risk "washes out" across all agents, it affects the economy because agents form institutions and write contracts to protect against that risk. Even if interest rates adjust one-to-one, the deviation of the bank rate from the technological rate alters behavior. More significant, however, is that the bank filters the effect of the shock by changing the underlying risk. Hence, ignoring or simply exogenously imposing institutions on a macro model seriously distorts conclusions. Figures 1 and 2 give a flavor of possible applications of this model and show that there are useful and tractable extensions of the representative-agent framework.

IV. Conclusion

This paper illustrates how institutions play a central role in aggregate phenomena. In this section, I argue that the results hold in a very general context and that the general study of institutions arising from competition is essential for adequate macroeconomics.

The analysis presented above extends beyond bank rates. Other financial institutions play a part in macroeconomic disturbances, and although this paper argues in terms of risk-pooling, the underlying ideas pertain to risk-shifting as well. The institution studied here is termed a bank, but as a pure financial intermediary, its functions may be duplicated by an appropriate derivative security market.

For example, consider dividend payments. When individuals face private risks, dividend payments may set the return on equity to provide insurance. An interaction between macro- and microeconomic shocks leads to dividends that adjust slowly (Copeland and Weston [1979]).

In fact, the analysis is not limited to financial institutions: Some recent work on labor contracts also discusses the role of aggregate shocks as signals about unobservable individual disturbances. Haubrich and King (1991) examine a case in which the money supply signals individual dispersion, leading to the non-neutrality of perceived money. Grossman, Hart, and Maskin (1983) focus on economies where asymmetric information between firms and workers produces cyclical unemployment.

These new markets and institutions attempt to avoid the problems of adverse selection arising from private information. In this sense, derivative security markets or institutions occupy niches similar to other schemes discussed in the literature. In order for the institution to survive, the incentive structures must force agents to reveal themselves at least partially. Markets cannot always completely exploit this information, because to do so would distort the incentives that allowed revelation in the first place.

This paper provides an equilibrium analysis of how endogenously arising financial institutions alter the impact of macroeconomic shocks. It explains the modifications in consumption and investment decisions as reactions to prices that react sluggishly to the underlying economic disturbances. This suggests that income distribution plays a major role in aggregate disturbances, such as business cycles. It also suggests that a relevant business cycle theory eventually must explicitly model why banks exist and why they take their present form. This explanation of bank rate sluggishness illustrates a powerful principle: When aggregate disturbances also have distributional consequences, the pattern of efficient contract-specified prices can change.

Appendix

In this appendix, I calculate the change in the risk premium δ_2 caused by an increase in individual uncertainty. First, recall that indirect utility and optimal second-period consumption are

(A1) $v = \alpha(r)[w(\theta)]$ and

(A2) $c_2^* = r[1 - b(p_2)][w(\theta)] = q(r)[w(\theta)]$.

δ_2 can be written as

(A3) $$\delta_2 = -[E(v^{-\gamma}c_2) - Ec_2 Ev^{-\gamma}]/Ec_2 Ev^{-\gamma}$$
$$= 1 - E(v^{-\gamma}c_2)/Ec_2 Ev^{-\gamma}.$$

Using (A1) and (A2), I rearrange (A3) to obtain

(A4) $$1 - \delta_2 = E[w(\theta)^{1-\gamma}]/E[w(\theta)]E[w(\theta)^{-\gamma}].$$

To discuss how δ_2 changes with increases in the dispersion of θ, I employ the techniques of Sandmo (1970) and Rothschild and Stiglitz (1970, 1971) and stretch the distribution by replacing θ with $x\theta$ in order to sign $\partial\delta_2/\partial x$. First, take the derivative:

$$\partial\delta_2/\partial x =$$
$$-[Ew(x\theta)Ew(x\theta)^{-\gamma}(\partial/\partial x)Ew(x\theta^{1-\gamma})$$
$$- Ew(x\theta)^{1-\gamma}Ew(x\theta)\cdot(\partial/\partial x)Ew(x\theta^{-\gamma})]/$$
$$(EwEw^{-\gamma})^2.$$

Without loss of generality, I evaluate this expression at $x = 1$.

(A5) $$-\{Ew(\theta)Ew(\theta)^{-\gamma}E[(1-\gamma)w(\theta)^{-\gamma}\theta]$$
$$- Ew(\theta)^{-\gamma}Ew(\theta)E[-\gamma w(\theta)^{-\gamma-1}\theta]\}/$$
$$(EwEw^{-\gamma})^2.$$

Notice that the first and second terms of this expression are positive, as are all the terms after the minus sign (fourth, fifth, and sixth terms). The third term is negative when $\gamma < 1$, making the entire derivative unambiguously positive. Thus, an increase in x increases δ_2 and decreases r_1. When $\gamma < 1$, the sign of expression (A4) becomes ambiguous. Without explicitly determining its sign, though, we can gain some idea of its properties. Simple numerical examples involving uniform distributions indicate that in some cases (A4) is positive. Additionally, (A4) is always positive with a discrete, symmetric, two-point distribution. To see this, write the numerator of (A5) as

$$Ew^{-\gamma}Ew^{-\gamma}\theta$$
$$+\gamma(Ew^{1-\gamma}Ew^{-\gamma-1}\theta - Ew^{-\gamma}Eq^{-\gamma}\theta).$$

The first term is always negative. I can use the linearity of wealth to express w as $(a \pm k)$, where the distribution is the two-point discrete distribution with probability 1/2 on k and $-k$. The sign of (A5) is then the opposite of $(a-k)^{1-\gamma}(a+k)^{1-\gamma}(-4a)$, which is always negative. Thus, the risk premium moves positively with x.

When G is quadratic, $G(x) = x - \frac{1}{2}bx^2$, the result also holds. Substitute into (A4) to obtain

(A6) $$1 - \delta_2 =$$
$$\frac{E\big[1 - b\{a[\alpha(a+\theta)]\}\{q(a+\theta)\}\big]}{E[1 - b(\alpha a + \alpha\theta)]E[q(a+\theta)]}.$$

With a mean-preserving spread on θ, only the numerator of (A6) changes, becoming $E[q(1+\theta)] - baq\,E(a^2 + 2a\theta) - baq\,E(\theta^2)$. The MPS on θ increases the variance, proving the result.

For general utility functions, $1 - \delta_2$ can be expressed as a "martingale measure of risk" as in Nachman (1979, section 4.1). Then, if f is the distribution for c_2,

$$f^*(c) = \frac{G'}{EG'},\ f = \frac{G'}{\int G' f(c)\,dc} f(c).$$

Defining $E_f^*(c) - \int c f^*(c)\,dc$, Nachman extends Rothschild and Stiglitz's arguments to show $E_f^*(c) < E(c)$. The assumption on the movement from f to g implies $E_g^*(c) < E(c)$. Similarly, if g is riskier than f^*, it is also risker than f. The new expression for $1 - \delta_2$ is $E_g^*(c) < E_g(c) < E_f^*(c) < E_f(c)$. Again, the desired result follows. Here, the function G is general, but a large shift in dispersion is required.

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